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CONTENTS

Photosynthetic Efficiency and Active Radiation in Relation to Growth and Yield of Sesamum (*Sesamum indicum* L.) Genotypes - Ashvini Bodhale, R. W. Bharud and D. V. Deshmukh 367

Performance of Wheat at Foliar Application of Nutrients Under Different Sowing Conditions - K. P. Deolankar, A. B. Gosavi, R. H. Kolse, S. M. Todmal and P N Rasal 379

Effect of Polyamines on Storability and Quality of Pomegranate Fruit (*Punica granatum* L.) Cv. Bhagawa - D. P. Waskar, V. S. Khandare, B. M. Kalalbandi and P. S. Shelke 385

Phenological Interventions in Groundnut Genotypes as Influenced by Seasonal Variation in Temperature and Sowing Dates - P. M. Nigade, R. S. Wagh, R. W. Bharud and V. L. Amolic 389

Genetic Diversity Studies in Napier Grass (*Pennisetum purpureum* Schum) - S. Y. Kamble, P. P. Surana and G. C. Shinde 395

" Phule Govardhan"- A New Variety of Marvel Grass for Green Forage - P. P. Surana, G. C. Shinde and A. H. Sonone 399

Production Potential and Nutrient Uptake of Castor (*Ricinus communis*) Based Intercropping Systems - S. B. Gangawane, M. K. Arvadia, S. B. Bhagat and N. M. Patel 404

Morpho-Physiological Study of Soybean (*Glycine max* L.) Genotypes under Water Stress Condition - S. M. Pawal, S. N. Mate and D. V. Deshmukh 409

Genetic Diversity in Rice Genotypes Based on Agronomic Characters - S. D. Kumbhar, P. L. Kulwal, J.V. Patil, C. D. Sarawate and A. P. Gaikwad 421

Influence of NPK Fertilizers on Growth and Yield of Heliconia sp. cv. 'Local Yellow' - M. Raja Naik and B. Prasannakumar 428

Evaluation of Germination Properties of Different Durum Wheat (*Triticum aestivum* L.) Genotypes under Osmotic Stress - N. S. More, R. S. Wagh, D. V. Deshmukh, A. A. Ghatage and R. W. Bharud 432

Diversity Analysis of Elite Groundnut (*Arachis hypogaea* L.) Germplasm under Konkan Condition in Maharashtra - B. D. Waghmode, V. C. Navhale, V. V. Sagvekar, S. G. Tambat and S. G. Bhave 439

Influence of Different Nitrogen and Phosphorus Ratios on Productivity of Groundnut (*Arachis hopogaea* L.) during *kharif* Season - V. V. Sagvekar, B. D. Waghmode, A. S. Kamble, V. C. Navhale, S. G. Tambat and U. V. Mahadkar 443

Pollen Viability and Stigma Receptivity Studies in Parental Lines of Sunflower Hybrid-Raviraj - G. J. Talele, V. R. Shelar, D. R. Nagawade and A. P. Karjule 447

Diversification of Groundnut Based Cropping Systems - D. P. Pacharne, A. D. Tumbare and D. W. Thawal 453

Response of Nutrient Management on Yield, Nutrient Uptake and Energy Balance in Groundnut Based Diversified Cropping Systems - D. P. Pacharne, A. D. Tumbare and D. W. Thawal 460

Genetic Divergence for Yield and Yield Attributing Traits in Brinjal (*Solanum melongena* L.) - J. P. Devmore, S. G. Bhave, P. B. Sanap and M. M. Burondkar 467

Management of Aphid Vectors vis-a-vis PRSV-P Incidence in Papaya - V. M. Chavan, K. Chandrashekar, Aarti B. Bhosle and Lakshmi R. Sonke 471

Knowledge and Adoption of Turmeric Growers About Post Harvest Technology - A. M. Chavai, A. S. Yamgar and P. K. Barange 476

Cashew Processing in South Konkan Region - An Economic Analysis - S. S. Wadkar, D. B. Malave, A. D. Hake and S. A. Wagle 481

Agriculture Students Attitude Towards Entrepreneurship - P. R. Deshmukh and R. P. Kadam 490

Rainfall Characterization for Crop Planning in Aurangabad District of Maharashtra State - P. B. Shinde, V. G. Maniyar and P. R. Jaybhaye 497

Storage Studies on Custard Apple (*Annona squamosa* L.) Pulp - V. A. Salve, P. B. Jagtap, C. R. Kshirsagar and S. B. Gurav 504

Hyperspectral Field Reflectance Measurements to Develop Spectral Signatures for Different Crops - S. A. Kadam, S. D. Gorantiwar, S. D. Dahiwalkar and M. G. Shinde 508

Leaf Area Index of Sorghum (*Sorghum bicolor* L.) Crop using Hyperspectral Field Reflectance Measurements - S. A. Kadam, S. D. Gorantiwar, S. D. Dahiwalkar and M. G. Shinde 512

RESEARCH NOTES

Response of Summer Groundnut (*Arachis hypogaea* L.) to Land Configurations, Irrigation Regimes and Potassium Levels - B. T. Sinare, R. P. Andhale and M. B. Dhonde 518

Effect of Summer Sesamum (*Sesamum indicum* L.) Cultivars on Dry Matter Production and Yield under Different Sowing Times - A. A. Shaikh, S. V. Bagade, S. G. Kumbhar and K. D. Gorad 522

Response of Paddy to Silicon in Inceptisols - V. N. Patil, R. B. Pawar and A. L. Pharande 525

Effect of NPK Levels on Linseed (*Linum usitatissimum* L.) under Plain Zone of Maharashtra - V. B. Pohare, P. U. Raundal and T. S. Bhondave 528

Varietal Evaluation to Identify Promising Potato Varieties for Pune Region - M. R. Deshmukh, M. B. Khamkar, S. A. More and S. B. Gurav 532

Effect of Sowing Time and Methods on Wheat Production - K. P. Deolankar, A. B. Gosavi, R. H. Kolse, S. M. Todmal and P. N. Rasal 534

Utilization of Date (*Phoenix dactylifera* L.) in the Manufacturing of Khoa Burfi - Sheetal Patil, Poonam Naik, S. V. Joshi and V. S. Dandekar 537

Effect of Pretreatments on Dehydration of Green Chilli (*Capsicum annum* L.) - D. P. Waskar, V. S. Khandare, B. M. Kalalbandi and T. D. Kadam 541

Index to Authors 545

Table of Contents 548

J. Agric. Res. Technol., 40 (3) : 367-378 (2015)

Photosynthetic Efficiency and Active Radiation in Relation to Growth and Yield of Sesamum (*Sesamum indicum* L.) Genotypes

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(Received : 31-01-2014)

Abstract

The experiment on thirty seven sesamum genotypes was laid out in randomized block design (RBD) with two replications to investigate the photosynthesis, water use efficiency and active radiation and to assess the effect of photosynthetic parameter on growth and yield of sesamum. The genotypes significantly differed in respect of yield plant^{-1}. The highest seed yield (kg ha^{-1}) was recorded by the genotypes JLS-116, JLS-506-3, JLS-613-1-1 and JLT-7, JLSG-05-11 due to higher rate of photosynthesis, transpiration rate, stomatal conductance, water use efficiency, CO_2 concentration and water vapour at atmospheric and intercellular partial pressure, photosynthetically active radiations, yield contributing characters *viz*., number of capsules plant^{-1}, seed yield plant^{-1} (g) and seed yield (Kg) plot^{-1} and harvest index (%). The oil, carbohydrate, protein, oleic acid, linoleic acid and linolenic acid content were higher in the genotype KMK-28, JLS-608-2-1, JLS-301-24, SI-2334-2 JL-Sel-07-11 and JLS-301-24. There were significant differences in the oil content of the genotypes ranging from 41.33 to 59.57 per cent. The genotypes JLT-7, JLS-506-3, JLS-613-1-1, JLSG-05-11 and JLS-116 may be utilized for the yield heterosis, whereas the genotypes KMK-28, JLS-608-2-1, JLS-301-24, SI-2334-2, JL-Sel-07-11 and JLS-301-24 for improving oil, carbohydrate, protein, oleic acid, linoleic acid and linolenic acid content in further breeding programme. Therefore, it can be concluded that, the significant variation in yield could be seen in different genotypes due to their differential behaviour in respect of growth, development, phenology, total dry matter production potential and translocation of photosynthates from source to sink. In high yielding genotypes the photosynthetic rate, transpiration rate, water use efficiency, photosynthetically active radiation, number of capsules, seed weight, harvest index and chlorophyll content were observed to be the major yield contributing characters.

Key words : Sesamum, photosynthetic efficiency, PAR, vegetative growth, yield and yield contributing characters

Sesamum (*Sesamum indicum* L.) is one of the most important oil seed crop, locally known as til, gingelly, sim-sim or gergelim is essentially a crop of tropical and sub-tropical regions. Sesamum stands next to groundnut, soybean and sunflower in importance among *kharif* oil seed crops in total area and production in India. The area under sesamum is 1834.5 ha with 7.5 lakh tones production in the year 2012-2013 (www.indiastat.com). The main reasons for low productivity of sesamum are its cultivation in marginal and sub-marginal lands, non improved varieties and non-availability of improved agro-production techniques. Crop production is dependent on many factors, including availability of moisture, temperature and light intensity. Water is the main factor limiting plant production in several regions of the world, with crop growth and economic yield being severely affected by water availability. The water use and water use efficiency are critical parameters where water is scare. Radiation use efficiency in crop results to increase in biological yield, seed yield, seed oil, seed protein and harvest index. Interception and absorption of PAR in the crop increases the growth, development and yield of the crop (Sarika Jena *et al*., 2010). Periods of high temperature above 40°C during flowering

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reduce capsule and seed development. The literature on research related to sesame crop water relation is relatively small in comparison with other oil seed crops. Thus, the objective of the present work was to investigate the photosynthesis, water use efficiency and active radiation and to assess the effect of photosynthetic parameter on growth and yield of sesamum.

Materials and methods

Thirty seven sesamum genotypes were evaluated in randomized block design (RBD) with two replications to investigate the photosynthesis, water use efficiency and active radiation and to assess the growth and yield variation at PGI Farm, Department of Botany, MPKV, Rahuri, Dist. Ahmednagar (M.S.) during *kharif*, 2012. The gross and net plot size were 4.00 x 2.7 m^2 and 3.2 x 2.5 m^2, respectively with the spacing of 40 x 10 cm. Randomly five plants were sampled for recording the observations on morpho-physiological traits. The observations on morphological traits, dry matter production and it's distribution and physiological parameters were recorded. The photosynthetic rate (Pn), transpiration rate (E; mmol m^{-2} s^{-1}), stomatal conductance (gs; µmol H2O m^{-2} s^{-1}) and CO_2 and water vapour concentrations at atmospheric and intracellular partial pressure were measured using Infra-red Gas Analyser (IRGA; Model Portable Photosynthesis System LI 6400, LI-COR® Inc, Lincoln, Nebraska, USA). The E and Gs were measured continuously by monitoring H_2O of the air entering and existing in the IRGA headspace chamber. Measurements were made at mid day, between 11:30 and 12:00 eastern day time (1400-1800 mmolm^{-2} s $^{-1}$ PPFD), on top fully expanded third leaf blades. The flow rate of air in the sample line was adjusted to 500 µmol m^{-2}s^{-1}. The water use efficiency (WUE) was calculated as the ratio of Pn to E. The photosynthetically active radiations were recorded by using line quantum sensors. The canopy temperature and canopy temperature depression were measured with the help of infra red thermometer. The chlorophyll content was recorded by using SPAD chlorophyll meter. The biochemical parameters from seed samples were estimated on NIR spectrometer (ZEUTEC, Germany Make), is a dual-beam near infrared spectrometer. In the NIR spectrometer, the sample is exposed near infrared light of specific wavelengths, selected from upto 19 high precision interference filters. The light penetrated the sample, interacted with sample molecules and is partly absorbed and partly diffusely reflected. The reflected light is measured by a lead sulfide (PbS) detector mounted in a gold coated integrating sphere located above the sample. The mean data analyzed for analysis of variance described by Panse and Sukhatme (1985).

Results and discussion

The knowledge of crop physiology through growth analysis technique, which involves tracing the history of growth and identifying the growth and yield factors contributing for yield variation, is a vital tool in understanding the crop behavior. This would be vital to the breeder as well as agronomist in tailoring suitable genotype or management technology for boosting up the growth and yield factors of the crop. Therefore, for a complete analysis of biological yield, it is necessary to investigate crop growth through computation of growth indices such as vegetative growth and source, dry matter production and growth analysis. Reproductive growth in grain crops is initiated by flowering and a period of capsule or seed set. Flower production and seed set is a key phase in the yield production process. The significant growth of economically reproductive part becomes relevant with the time requirement for its full development.

The genotypes, JLS-116 (28.0 days), SI-3079-2 (29.0 days), JLS-613-1-1 (29.5 days) and JLT-7 (29.5 days) were early for initiation of flowering. These genotypes required 37.0, 36.0, 36.0 and 37.5 days for 50 per cent flowering and matured within 83.5, 84.0, 84.5 and 83.5 days, respectively (Table 1). Even though, the genotype JL-Sel-05-3 (35.5 days)

Table 1. Crop phenology and morphological characters influenced by sesame genotype

Genotype	Days to initiation of flowering	Days to 50 % flowering	Days to physio-logical maturity	Plant height (cm)	Bran-ches plant-1	Leaves plant-1	Leaf area plant^{-1} (cm)
JLS-110-12	31.5	38.5	85.0	94.00	3.05	45.50	100.74
JLS-116	28.0	37.0	83.5	93.50	3.10	62.00	158.21
JLS-301-24	38.0	38.0	87.5	95.50	3.30	39.50	99.57
JL-Sel-05-3	33.5	35.5	85.5	91.00	3.55	44.00	89.98
JLS-301-7	36.0	44.0	85.5	148.00	4.05	36.00	99.28
JLS-120	34.0	42.0	86.5	143.00	4.30	41.00	118.69
JLS-502-1	33.5	41.5	84.5	153.00	3.75	34.00	87.35
JLS-502-3	36.0	48.0	88.0	147.50	3.45	44.50	91.57
JLS-506-3	30.0	44.0	87.0	153.00	3.90	44.50	136.51
JLS-507-4	33.5	45.5	88.5	148.00	4.20	35.50	128.53
JLS-603-4-1	32.0	45.0	89.5	124.50	2.65	36.50	86.99
JLS-603-4-3	36.0	48.5	90.5	95.00	3.55	32.50	119.40
JLS-603-6-1	34.5	44.0	90.0	123.50	4.15	39.00	98.30
JLS-606-6-4	32.5	45.0	90.0	104.00	2.50	30.00	98.89
JLS-606-7	35.5	45.5	89.5	125.50	3.35	49.00	106.23
JLS-608-2-1	33.5	44.5	86.5	93.50	3.05	41.00	95.80
JLS-613-1-1	29.5	36.0	84.5	130.00	3.55	42.50	144.86
JLS-615-9-1	32.5	45.0	90.5	115.00	2.55	44.50	105.19
PT-1	31.5	39.5	92.0	151.50	3.40	53.50	96.33
JLT-7	29.5	37.5	83.5	121.00	4.15	56.00	146.43
JLT-26	34.0	47.5	85.5	82.50	3.05	60.00	95.20
JLT-408	32.0	42.5	87.5	114.50	3.95	54.00	94.12
IC-4132-53	34.0	43.5	86.5	125.50	3.35	53.00	89.75
JLSG-5-11	36.5	42.5	87.0	114.50	3.10	46.50	121.02
G-47	35.0	45.5	88.5	108.00	2.70	51.50	102.19
SI-2334-2	37.0	48.5	91.0	127.00	2.85	42.50	98. 09
JL-Sel-07-03	36.0	49.0	88.5	126.00	3.05	54.00	99.19
JMLS-07-01	36.0	45.5	87.5	117.50	3.20	55.00	104.13
JLT-27	31.5	45.5	90.0	95.00	2.95	39.50	104.79
KMR-33	31.5	43.5	86.5	97.50	3.45	49.00	89.77
KMK-28	33.5	45.5	90.5	83.50	3.15	52.00	87.20
JLSG-05-06	33.0	44.5	86.5	97.00	3.50	47.50	90.99
JMLS-07-03	31.0	43.0	85.5	94.50	3.05	55.50	89.66
SI-3079-2	29.0	36.0	84.0	88.50	2.65	45.50	86.66
JL-Sel-07-11	31.0	39.5	87.0	107.00	2.75	58.50	92.96
IC-413241	32.0	43.5	88.5	109.00	2.90	61.00	107.00
RT-54	32.5	42.5	86.5	110.50	3.40	62.50	133.10
Mean	33.0	43.0	87.4	114.81	3.31	46.99	105.26
SE ±	1.1	0.9	0.9	0.95	0.07	1.10	1.30
CD at 5%	3.3	2.5	2.7	2.71	0.21	3.16	3.72

was early for 50 per cent flowering and maturity (85.5 days) still required more number of days for initiation of flowering (33.5). Similarly, JLS-502-1 was earlier for days to

Table 2. Photosynthetic characters and water use efficiency influenced by sesame genotype

Genotype	Photosynthetic rate umol m^{-2} sec^{-1}		Transpiration rate mmol m^{-2} sec^{-1}		Stomatal conductance umol m^{-2} sec^{-1}		Water use efficiency		Chlorophyll index (SPAD index)	
	S 1	**S 2**	**S 1**	**S 2**	**S 1**	**S 2**	**S 1**	**S 2**	**S 1**	**S 2**
JLS-110-12	20.53	10.59	3.35	1.88	0.31	0.04	6.12	5.64	37.50	28.5
JLS-116	25.76	12.03	2.91	1.61	0.26	0.04	8.87	7.49	44.00	33.0
JLS-301-24	16.53	7.67	4.19	2.16	0.38	0.05	3.94	3.55	38.00	30.5
JL-Sel-05-3	16.78	9.03	3.61	2.03	0.37	0.04	4.64	4.45	36.00	29.0
JLS-301-7	20.40	10.59	3.33	1.93	0.35	0.05	6.13	5.48	40.00	29.5
JLS-120	19.08	10.22	3.61	1.93	0.33	0.04	5.29	5.30	36.00	28.0
JLS-502-1	15.53	6.13	3.03	1.80	0.22	0.03	5.13	3.40	40.00	26.5
JLS-502-3	23.26	12.50	3.51	1.88	0.52	0.06	6.64	6.66	35.00	32.0
JLS-506-3	25.26	13.92	4.69	2.98	0.52	0.06	5.39	4.67	42.50	33.5
JLS-507-4	17.34	8.85	4.12	2.51	0.48	0.06	4.22	3.53	38.00	31.0
JLS-603-4-1	20.44	10.52	5.93	2.88	0.49	0.06	3.45	3.65	30.50	24.5
JLS-603-4-3	16.54	8.38	4.40	2.28	0.42	0.05	3.77	3.67	33.50	27.5
JLS-603-6-1	21.35	10.78	5.56	2.63	0.52	0.06	3.85	4.10	40.00	25.5
JLS-606-6-4	14.30	6.74	2.85	1.44	0.23	0.03	5.03	4.70	35.50	31.0
JLS-606-7	19.61	9.58	5.35	2.57	0.54	0.07	3.67	3.74	38.00	29.0
JLS-608-2-1	14.54	6.90	3.75	1.72	0.32	0.04	3.87	4.01	39.50	30.5
JLS-613-1-1	24.31	11.80	5.54	2.69	0.57	0.07	4.39	4.39	42.00	31.0
JLS-615-9-1	16.62	9.44	3.92	1.98	0.34	0.04	4.24	4.77	29.52	26.5
PT-1	16.03	5.54	3.29	1.47	0.24	0.04	4.88	3.76	41.00	27.5
JLT-7	22.84	11.08	6.21	3.24	0.60	0.07	3.68	3.42	45.50	32.5
JLT-26	22.09	10.92	5.30	2.26	0.48	0.06	4.17	4.90	36.50	30.5
JLT-408	20.73	10.95	5.51	2.63	0.52	0.06	3.76	4.16	36.50	26.5
IC-4132-53	15.15	7.49	3.17	1.77	0.35	0.04	4.79	4.23	37.50	31.0
JLSG-5-11	19.54	9.76	2.64	1.50	0.29	0.03	7.40	6.51	35.50	28.5
G-47	15.74	7.92	2.92	1.82	0.34	0.04	5.39	4.34	32.50	25.5
SI-2334-2	15.41	7.75	2.98	1.75	0.30	0.04	5.17	4.43	31.00	24.0
JL-Sel-07-03	17.26	8.77	4.61	2.06	0.49	0.06	3.74	4.27	37.00	28.5
JMLS-07-01	15.49	4.76	3.76	2.05	0.36	0.04	4.12	2.31	39.50	26.5
JLT-27	18.59	7.77	3.11	1.72	0.29	0.04	5.97	4.53	41.50	27.5
KMR-33	16.04	7.78	2.81	1.56	0.28	0.04	5.70	5.00	38.50	27.5
KMK-28	17.57	8.89	3.70	1.89	0.34	0.04	4.75	4.71	34.00	28.5
JLSG-05-06	15.13	4.29	2.68	1.44	0.23	0.03	5.65	2.97	40.50	28.5
JMLS-07-03	16.63	9.10	3.10	1.96	0.38	0.05	5.36	4.65	36.50	28.5
SI-3079-2	18.68	9.90	3.85	1.92	0.30	0.04	4.88	5.17	31.50	25.5
JL-Sel-07-11	16.09	8.00	3.78	1.86	0.34	0.04	4.26	4.29	37.00	25.5
IC-413241	15.65	5.69	2.71	1.46	0.29	0.03	5.77	3.91	35.50	27.0
RT-54	22.67	12.36	5.29	2.06	0.33	0.05	4.29	5.99	42.00	32.0
Mean	18.52	9.04	3.92	2.03	0.37	0.05	4.93	4.50	37.43	28.6
SE ±	0.28	0.24	0.07	0.06	0.01	0.00	0.13	0.15	1.34	1.24
CD at 5%	0.81	0.68	0.21	0.18	0.03	0.01	0.36	0.43	3.84	3.57

S 1 : at 50% flowering stage, S 2 : 15 days after 50% flowering stage maturity (84.5 days), required more number of days for initiation of flowering and 50 per cent flowering.

The vegetative phase governs the overall phenotypic expression of the plant and prepares the plant for the further reproductive phase. The root, stem, branches and leaves, all these parts constitutes vegetative phase and perform specific functions. In the present investigations, plant height ranged between 82.5 and 153.0 cm. The genotypes, JLS-506-3 (153.00), JLS-502-1 (153.00 cm), PT-1 (151.50 cm), JLS-301-7 (148.00 cm), JLS-507-4 (148.00 cm) and JLS-502-3 (147.50 cm) recorded the highest plant height. The number of branches plant^{-1} recorded at the time of harvesting ranged between 2.5 and 4.3. The genotypes, JLS-120 (4.30), JLS-507-4 (4.20), JLT-7 (4.15), JLS-603-6-1 (4.15), JLS-301-7 (4.05) and JLT-408 (3.95) recorded higher number of branches plant^{-1}. The number of leaves plant^{-1} ranged between 30.0 and 62.5. The genotypes RT-54 (62.50), JLS-116 (62.00), IC-413241 (61.00), JLT-26 (60.00), JL-Sel-07-11 (58.5), JLT-7 (56.0) and JMLS-07-03 (55.5) recorded the highest number of leaves plant^{-1}. The finding corroborated with those of Yingzhong and Yishour (2002) and Boureima *et al*., (2007). The leaf area plant^{-1} ranged between 86.66 and 158.20 dm^2. The genotypes, JLS-116 (158.21 dm2), JLT-7 (146.43 dm^2) and JLS-613-1-1 (144.86 dm^2) recorded the highest leaf area plant^{-1} (Table 1). Hemalatha *et al*., (1999) observed that the leaf area had significant influence on the seed yield of sesame.

Nautiyal *et al*., (2012) concluded that, the knowledge on physiological understanding in relation to rate of photosynthesis and productivity and wide genetic variability among various traits, as reported in this study, could be utilized in developing new potential germplasm and designing ideotype for making the cultivars more adaptive for different water availability areas in semi-arid tropics. In the present investigation, the genotypes, JLS-116 (25.76 umol m^{-2}sec^{-1}), JLS-506-3 (25.26 umol m^{-2} sec^{-1}), JLS-502-3 (23.26 umol m^{-2} sec^{-1}) and JLS-613-1-1 (24.31 umol m^{-2} sec^{-1}) recorded higher rate of photosynthesis at 50% as well as at 15 day after 50% flowering to the tune of 12.03, 13.92, 12.50 and 11.80 umol m^{-2} sec^{-1}, respectively (Table 2). The genotype, JLT-7 maintained maximum rate of transpiration at 50 per cent flowering (6.21 mmol^{-2} sec^{-1}) and at 15 days after 50% flowering (3.24 mmol^{-2}sec^{-1}) followed by JLS-603-4-1 (5.93 and 2.88 mmol^{-2} sec^{-1}), JLS-603-6-1 (5.56 and 2.63 mmol^{-2} sec^{-1}), JLS-613-1-1 (5.54 and 2.69 mmol^{-2} sec^{-1}) and JLS-606-7 (5.35 and 2.57 mmol^{-2}sec^{-1}), respectively. Similarly, JLT-7 maintained maximum stomatal conductance at 50% flowering (0.60 umol m^{-2} sec^{-1}) and at 15 days after 50% flowering (0.07 umol m^{-2}sec^{-1}) followed by JLS-613-1-1 (0.57 and 0.07 umol m^{-2} sec^{-1}), JLS-606-7 (0.54 and 0.7 umol m^{-2} sec^{-1}), JLS-502-3 (0.52 and 0.06 umol m^{-2} sec^{-1}) and JLS-506-3 (0.52 and 0.06 umol m^{-2} sec^{-1}). The genotypes JLS-116 maintained higher water use efficiency at 50 per cent flowering (8.87) as well as at 15 days after 50 per cent flowering (7.49) followed by JLSG-5-11 (7.40 and 6.51), JLS-502-3 (6.64 and 6.66) and JLS-110-12 (6.12 and 5.64). The genotypes, JLS-116 (44.00 and 33.00), JLS-506-3 (42.5 and 33.5) and JLT-7 (45.5 and 32.5) were promising genotypes at both the stages of growth for chlorophyll content (Table 2).

Metabolic impairment of photosynthesis by evaluating intercellular CO_2 partial pressure, not calculated from gas exchange measurements, but measured directly in the leaves (Lauer and Boyer, 1992). The genotype, JLS-116 maintained higher CO_2R at 50% flowering (345.01 umol $m^{-2}sec^{-1}$) as well as at 15 days after 50% flowering (175.00 umol m^{-2} sec^{-1}). In addition to this, JLS-301-7 (341.52

Table 3. CO_2 and H_2O concentrations and canopy temperature as influenced by sesame genotype

Genotype	CO_2R		CO_2S		H_2OR		H_2OS		CT (°C)		CTD (°C)	
	S 1	S 2	S 1	S 2	S 1	S 2	S 1	S 2	S 1	S 2	S 1	S 2
JLS-110-12	339.87	167.19	325.35	160.32	6.56	3.44	6.94	5.95	29.61	25.06	1.38	3.62
JLS-116	345.01	175.08	323.34	159.66	8.18	4.25	7.89	6.13	33.36	27.77	0.96	2.18
JLS-301-24	338.21	158.94	322.76	158.36	6.22	3.32	8.23	5.75	28.78	24.80	1.75	3.23
JL-Sel-05-3	338.71	167.70	321.58	162.41	4.70	2.47	7.44	5.38	27.72	26.15	2.75	4.66
JLS-301-7	341.52	166.97	321.18	159.43	8.76	4.11	8.24	6.40	30.33	24.07	2.16	4.12
JLS-120	336.72	164.83	322.93	159.58	8.85	3.96	8.07	5.90	31.06	26.17	2.72	3.76
JLS-502-1	335.96	161.82	323.56	158.64	5.15	2.80	6.98	4.89	30.07	26.41	2.65	4.95
JLS-502-3	334.78	161.91	319.85	152.77	4.89	2.96	6.37	4.83	31.13	24.92	1.36	3.36
JLS-506-3	336.17	166.61	317.35	149.57	6.51	3.08	7.39	6.65	33.73	27.82	1.04	2.19
JLS-507-4	337.70	168.28	322.34	154.08	6.72	3.40	7.58	6.30	32.45	26.35	1.22	2.95
JLS-603-4-1	336.22	166.94	320.58	153.68	5.02	3.01	7.53	6.49	31.76	25.17	1.74	3.45
JLS-603-4-3	337.01	165.04	322.72	154.44	6.25	3.22	6.13	5.81	26.33	24.00	2.63	4.38
JLS-603-6-1	337.06	166.72	318.31	152.52	6.37	3.26	7.36	6.32	28.95	26.53	3.11	4.94
JLS-606-6-4	338.66	170.89	325.09	161.02	6.80	3.24	7.31	4.99	28.44	25.38	1.81	2.68
JLS-606-7	338.20	169.35	321.41	155.41	6.86	3.66	8.90	6.70	30.36	25.97	1.24	2.45
JLS-608-2-1	336.82	163.52	323.23	154.72	7.13	3.74	7.84	5.38	31.70	25.31	1.26	2.62
JLS-613-1-1	337.17	169.05	319.15	152.78	7.23	3.85	8.99	6.94	32.57	28.23	1.08	2.09
JLS-615-9-1	334.88	166.70	321.07	154.38	6.36	3.02	7.80	5.56	30.58	24.84	2.28	3.00
PT-1	338.38	168.26	326.95	158.15	6.37	3.40	6.82	5.07	29.82	26.36	2.89	4.16
JLT-7	336.23	167.12	318.98	152.39	6.49	3.43	10.24	7.26	33.17	27.63	1.68	2.01
JLT-26	333.02	161.27	319.87	152.84	6.23	3.20	8.90	6.66	27.57	24.91	2.26	3.51
JLT-408	333.26	162.40	318.87	152.15	6.25	3.23	8.43	6.09	32.12	25.31	1.91	3.32
IC-4132-53	336.32	167.46	323.23	159.76	6.80	3.59	7.92	5.67	29.92	26.00	3.09	5.09
JLSG-5-11	356.55	186.59	338.44	173.00	6.76	3.47	6.24	4.99	28.89	24.99	3.03	3.99
G-47	337.71	164.41	324.14	158.64	6.47	3.26	7.80	5.39	30.21	23.84	2.86	4.13
SI-2334-2	338.31	169.44	324.38	157.66	6.89	3.55	7.99	5.76	27.41	26.70	3.07	4.95
JL-Sel-07-03	356.27	182.52	335.01	169.89	6.74	3.43	7.36	5.24	26.56	25.22	2.36	3.98
JMLS-07-01	338.91	169.13	330.69	163.30	5.13	2.94	7.24	5.23	27.48	24.20	1.85	4.32
JLT-27	336.32	167.59	322.73	154.74	5.07	2.88	7.06	4.94	31.20	26.73	1.69	3.85
KMR-33	339.22	165.83	325.94	159.95	7.23	3.85	7.67	5.85	30.29	24.36	1.75	4.19
KMK-28	333.14	161.86	319.85	153.67	6.58	3.60	8.06	5.72	29.09	24.34	1.87	3.78
JLSG-05-06	332.92	164.73	325.25	157.15	5.20	3.15	6.44	4.81	29.01	25.53	2.16	4.72
JMLS-07-03	338.26	168.43	322.63	157.74	7.41	3.89	8.67	6.29	29.68	26.75	2.03	4.33
SI-3079-2	338.49	169.58	321.44	155.18	6.34	3.31	8.01	5.89	26.97	26.24	2.83	4.35
JL-Sel-07-11	337.92	167.75	325.98	160.17	7.41	3.61	8.08	6.02	28.49	24.39	2.76	4.24
IC-413241	338.07	165.04	326.64	157.11	6.53	3.32	7.05	5.02	29.29	24.95	2.05	3.99
RT-54	340.42	171.09	324.15	151.61	5.62	3.20	7.63	5.50	31.17	28.33	1.29	3.09
Mean	338.39	167.51	323.43	157.26	6.49	3.38	7.69	5.78	29.94	25.72	2.07	3.69
SE ±	0.70	2.07	0.57	1.89	0.09	0.12	0.28	0.11	1.18	0.67	0.05	0.17
CD at 5%	2.02	5.94	1.63	5.43	0.26	0.34	0. 79	0.30	3.38	1.93	0.15	0.49

CO_2R: CO_2 concentration at atmospheric partial pressure, CO_2S: CO_2 concentration at intercellular partial pressure, H_2OR: water vapour at atmospheric partial pressure, H_2OS: water vapour at intercellular partial pressure, CT: Canopy temperature, CTD: Canopy temperature dipression, S 1: at 50% flowering stage, S 2: 15 days after 50% flowering stage umol $m^{-2}sec^{-1}$), JLSG-5-11 (356.55 umol m^{-2} sec^{-1}), JL-Sel-07-3 (356.27 umol m^{-2} sec^{-1}) and RT-54 (340.42 umol m^{-2} sec^{-1}) at 50% flowering and JLSG-05-11 (186.59 umol m^{-2} sec^{-1}) and JL-Sel-07-03 (182.52 umol m^{-2} sec^{-1}) at 15 days after 50 per cent flowering were found superior for maintaining higher CO_2R (Table 3). However, the genotype JLS-5-11 maintained maximum CO_2S at 50 per cent flowering (338.44 umol m^{-2} sec^{-1}) and at 15 days after 50% flowering (173.00 umol m^{-2} sec^{-1}) followed by JL-Sel-07-03 (335.01 and 169.89 umol m^{-2} sec^{-1}) and JLMS-07-01 (330.69 and 163.30 umol m^{-2} sec^{-1}). While considering the water vapour concentration at atmospheric (H_2OR) and inter-cellular level (H_2OS), the genotype, JLS-120 maintained higher H_2OR at 50 per cent flowering (8.85 umol m^{-2} sec^{-1}) as well as at 15 day after 50 per cent flowering (3.96 umol m^{-2} sec^{-1}) followed by JLS-301-7 (8.76 and 4.11 umol m^{-2} sec^{-1}), JLS-116 (8.18 and 4.25 umol m^{-2} sec^{-1}) and JMLS-07-03 (7.41 and 3.89 umol m^{-2} sec^{-1}), respectively. However, the genotype, JLT-7 maintained maximum H_2OS at 50 per cent flowering (10.24 umol m^{-2} sec^{-1}) and at 15 days after 50 per cent flowering (7.27 umol m^{-2} sec^{-1}) followed by JLS-613-1-1 (8.99 and 6.94 umol m^{-2} sec^{-1}), JLS-606-7 (8.90 and 6.70 umol m^{-2} sec^{-1}) and JLT- 26 (8.90 and 6.66 umol m^{-2} sec^{-1}), respectively (Table 3). Similar results obtained by Nikam *et al.*, (1994), Mulholland *et al.*, (2000), Kalpana *et al.*, (2003), Vijay Kumar and Vanaja (2004) and Kawagoe *et al.,* (2005).

Deviation of temperature of plant canopies in comparison to ambient temperature, also known as CTD, has been a good criterion for screening heat stress tolerance (Reynolds *et al.*, 1998). The canopy temperature and canopy temperature depression are the important physiological parameters which constitute to maintain the internal environment by matching with external climatic parameters. The genotypes, JLS-603-4-3 (26.33°C), JL-Sel-07-03 (26.56°C), SI-3079-2 (26.97°C) at 50% flowering, whereas, the genotypes, G-47 (23.84°C), JLS-603-4-3 (23.99°C), JMLS-07-01 (24.20°C), KMK-28 (24.34°C) at 15 days after 50 per cent flowering recorded minimum canopy temperature (Table 3). At 50 per cent flowering, the genotypes, JLS-116 (0.95°C), JLS-506-3 (1.04°C), JLS-613-1-1 (1.08°C) and JLS-507-4 (1.22°C) while at 15 days after 50 per cent flowering, JLT-7 (2.01°C), JLS-613-1-1 (2.09°C), JLS-116 (2.18°C), JLS-506-3 (2.19°C) and JLS-606-7 (2.45°C) recorded maximum canopy temperature depression (CTD). The results were in conformity with Yasar *et al.*, (2008) and Idso *et al.*, (1981).

The photosynthetically active radiation (PAR) is defined in terms of photon (quantum) flux, specifically, the number of moles of photons in the radiant energy between 400 nm and 700 nm. PAR measure of radiant power is important in evaluating the effect of light on plant growth. This is expected because photosynthesis is a photochemical conversion where each molecule is activated by the absorption of one photon in the primary photochemical process. In the present investigation, the genotypes, JLS-506-3 (1559.50 and 817.00), JLT-7 (1558.5 and 808.0), JLS-613-1-1 (1551.0 and 781.0) and JLS-116 (1547.0 and 801.00) for PAR; JLT-7 (396.5 and 271.0), JLS- 506-3 (384.5 and 255.5), RT-54 (382.0 and 252.0) and JLS-613-1-1 (385.0 and 225.0) for IPAR; JLT-7 (447.5 & 316.00), JLS-116 (440.00 and 319.50), RT-54 (443.00 and 290.5) and JLS-613-1-1 (434.00 and 297.00) for APAR maintained higher values at 50 per cent flowering as well as 15 days after 50 per cent flowering (Table 4). However, the genotypes, JLS-120 (827.50), JLT-408 (777), JLS-116

(772), JLS-301-24 (771) and JLS-506-3 (770) at 50 per cent flowering and the genotypes, JL-Sel-07-11 (401.00), JLS-606-7 (351.00), JLS-120 (300) and JLS-506-3 (290) at 15 days after 50 per cent flowering recorded highest fractional PAR. The genotypes, JLT-7, RT-54, JLS-116 and JLS-506-3 were good indicators for the absorbance of photosynthetically active

Table 4. Photosynthetically active radiations (PARs) as influenced by sesame genotype

Genotype	PAR		IPAR		APAR		FPAR	
	S 1	S 2	S 1	S 2	S 1	S 2	S 1	S 2
JLS-110-12	1372.00	646.00	354.00	233.50	400.00	263.00	652.00	172.50
JLS-116	1547.00	801.00	376.50	274.00	444.00	319.50	772.50	236.50
JLS-301-24	1358.50	603.00	287.00	242.00	331.00	204.50	771.50	242.00
JL-Sel-05-3	1295.50	650.00	304.00	192.00	350.50	218.00	674.00	255.00
JLS-301-7	1302.00	641.00	301.50	217.50	337.50	241.00	686.50	198.00
JLS-120	1427.50	666.00	293.00	177.00	334.00	202.50	827.50	300.50
JLS-502-1	1260.50	656.50	345.00	186.50	390.00	208.50	559.00	271.50
JLS-502-3	1424.00	544.00	324.00	222.00	368.50	247.00	761.50	89.00
JLS-506-3	1559.50	817.00	384.50	255.50	425.00	297.50	770.00	290.00
JLS-507-4	1345.50	696.50	367.50	245.00	423.00	276.00	599.00	195.50
JLS-603-4-1	1390.50	618.50	343.50	251.50	392.50	280.00	689.50	108.50
JLS-603-4-3	1266.50	599.00	295.00	232.00	345.00	257.50	660.50	126.50
JLS-603-6-1	1286.50	682.00	371.50	246.00	417.00	272.50	526.50	178.50
JLS-606-6-4	1329.00	630.50	322.50	226.50	357.50	245.00	668.50	169.00
JLS-606-7	1264.00	718.00	378.50	181.00	427.00	200.00	492.50	351.50
JLS-608-2-1	1381.50	661.00	322.50	238.50	366.00	266.50	719.50	173.50
JLS-613-1-1	1551.00	781.00	385.00	255.00	434.00	297.00	761.50	254.00
JLS-615-9-1	1402.50	634.00	340.50	205.00	398.00	239.50	707.50	213.00
PT-1	1349.00	728.50	358.50	224.00	410.50	256.00	615.00	268.00
JLT-7	1558.50	808.00	396.50	271.00	447.50	316.00	743.00	248.00
JLT-26	1440.50	642.50	369.50	219.50	428.00	251.50	690.00	190.00
JLT-408	1454.00	712.50	331.00	236.50	383.50	258.00	777.00	232.50
IC-4132-53	1350.50	548.50	316.00	226.50	356.00	256.00	704.00	83.50
JLSG-5-11	1247.50	649.50	349.50	247.50	392.00	281.50	535.50	142.00
G-47	1291.50	633.00	348.50	233.00	381.50	259.50	579.50	156.00
SI-2334-2	1138.50	528.50	290.00	180.00	328.00	199.50	547.00	158.50
JL-Sel-07-03	1375.00	718.50	384.50	218.00	418.50	254.50	591.50	270.00
JMLS-07-01	1122.50	523.50	267.00	159.50	306.00	176.00	577.50	197.00
JLT-27	1371.00	713.00	361.50	242.00	408.50	274.00	632.50	219.00
KMR-33	1321.50	627.00	344.00	213.50	391.50	245.00	618.00	185.50
KMK-28	1446.00	566.50	374.50	209.00	411.50	238.50	686.00	134.50
JLSG-05-06	1150.50	546.50	303.50	208.50	341.00	231.50	532.50	120.00
JMLS-07-03	1430.00	700.50	324.50	221.50	365.50	256.00	767.00	244.50
SI-3079-2	1140.50	536.50	353.50	218.00	389.00	241.00	420.50	90.50
JL-Sel-07-11	1301.50	724.50	334.50	156.50	383.00	181.00	616.50	401.00
IC-413241	1380.00	678.50	331.00	242.50	381.50	276.00	702.50	180.00
RT-54	1499.50	786.00	382.00	252.00	443.00	290.50	717.50	266.50
Mean	1354.91	659.92	340.97	221.49	386.66	250.74	658.18	205.73
SE ±	2.07	1.83	2.08	1.70	2.23	2.12	3.60	2.20
CD at 5%	5.95	5.25	5.97	4.86	6.40	6.09	10.33	6.30

S 1: at 50% flowering stage, S 2: 15 days after 50% flowering stage radiations. The finding corroborated with those of Muchow (1985) and Ghosh (2000).

The generative growth constitutes the growth and development of reproductive parts. From yield point of view, this phase assumes significance as the sink lies in the reproductive part. The genotypes, JLS-116 (62.00), JLS-603-6-1 (61.50), JLS-507-4 (59.00), JLS-608-2-1 (57.50) and JLT-7 (56.50) recorded the

Table 5. Yield and yield contributing characters as influenced by sesame genotype

Genotype	Capsule plant-1	Seed capsule^{-1}	100 grain weight (g)	Seed yield ha^{-1} (kg)	Total dry matter (gm)	Harvest index (%)
JLS-110-12	48.0	54.00	3.68	550.92	23.30	17.15
JLS-116	62.0	62.00	3.76	800.63	26.60	18.89
JLS-301-24	40.0	56.00	3.50	472.22	21.57	19.32
JL-Sel-05-3	47.0	51.00	3.48	449.07	20.70	21.21
JLS-301-7	51.5	60.00	3.32	453.70	22.55	15.51
JLS-120	47.5	52.50	3.86	444.44	19.81	19.09
JLS-502-1	49.5	56.00	3.30	370.36	22.95	16.28
JLS-502-3	45.0	53.50	3.51	662.03	20.21	22.17
JLS-506-3	54.5	64.00	3.92	703.70	29.02	16.09
JLS-507-4	59.0	61.00	3.55	462.96	26.10	13.15
JLS-603-4-1	54.0	54.50	3.81	273.14	27.90	10.66
JLS-603-4-3	50.5	56.50	3.15	384.25	27.62	17.24
JLS-603-6-1	61.5	48.50	3.37	324.07	27.53	12.72
JLS-606-6-4	38.5	52.50	3.64	597.21	21.76	20.00
JLS-606-7	36.0	55.00	3.08	569.44	20.72	19.23
JLS-608-2-1	57.5	56.00	3.43	379.58	25.56	12.42
JLS-613-1-1	56.5	64.00	3.36	694.44	28.72	17.43
JLS-615-9-1	40.0	53.00	4.01	634.25	26.70	16.41
PT-1	43.5	57.50	3.88	444.44	21.69	16.59
JLT-7	56.5	66.00	3.23	648.14	29.12	11.19
JLT-26	33.5	55.00	3.75	388.88	22.94	15.14
JLT-408	42.0	55.00	3.36	379.62	21.64	14.72
IC-4132-53	43.5	51.00	3.22	421.15	21.19	15.84
JLSG-5-11	39.0	48.00	3.24	601.84	18.66	24.52
G-47	37.5	54.50	3.18	388.88	24.95	12.43
SI-2334-2	45.0	49.50	3.06	333.33	24.76	11.01
JL-Sel-07-03	41.5	50.00	2.90	402.77	23.42	13.84
JMLS-07-01	40.0	53.50	3.58	291.66	21.46	13.15
JLT-27	38.5	53.50	3.19	421.29	21.13	16.15
KMR-33	42.5	58.00	2.98	444.44	18.97	15.95
KMK-28	44.0	51.50	3.19	356.48	21.78	14.87
JLSG-05-06	49.5	49.50	3.56	634.25	23.53	19.27
JMLS-07-03	52.5	53.00	3.40	486.11	20.97	12.59
SI-3079-2	49.0	47.50	2.86	384.25	27.64	9.94
JL-Sel-07-11	54.5	52.00	2.91	361.11	22.77	11.86
IC-413241	48.5	49.00	3.45	574.07	21.82	19.17
RT-54	54.0	60.50	3.59	629.62	28.33	17.72
Mean	47.4	54.72	3.41	481.59	23.68	15.97
SE ±	0.9	1.57	0.08	17.46	0.35	0.26
CD at 5%	2.7	4.50	0.22	50.09	1.00	0.75

highest number of capsule plant^{-1}. The data regarding number of seeds capsule^{-1} revealed that, the genotypes, JLT-7 (66.0), JLS-506-3 (64.0), JLS-613-1-1 (64.0) and JLS-116 (62.0) recorded the highest number of seeds capsule^{-1}. The genotypes, JLS-615-9-1 (4.01 g), JLS-506-3 (3.91 g), PT-1 (3.88 g) and JLS-603-4-1 (3.81 g) recorded the highest 1000

Table 6. Biochemical parameters as influenced by sesame genotype

Genotype	Oil content (%)	Carbo-hydrate content (%)	Protein content (%)	Oleic acid content (%)	Linoleic acid content (%)	Linolenic acid content (%)
JLS-110-12	51.03	13.66	21.04	39.01	46.03	0.35
JLS-116	44.65	13.68	25.32	39.45	46.18	0.46
JLS-301-24	56.67	12.94	29.85	38.00	45.78	0.53
JL-Sel-05-3	51.33	13.44	20.79	39.09	46.00	0.31
JLS-301-7	52.61	13.59	24.94	38.56	45.89	0.48
JLS-120	50.73	13.32	25.02	38.68	45.90	0.37
JLS-502-1	48.44	13.85	20.74	39.57	45.94	0.38
JLS-502-3	52.20	13.50	21.82	39.13	45.84	0.32
JLS-506-3	50.43	13.59	22.43	38.81	46.08	0.36
JLS-507-4	51.13	13.63	21.62	39.17	46.07	0.32
JLS-603-4-1	52.62	13.73	21.27	39.17	45.86	0.31
JLS-603-4-3	51.31	13.55	18.50	39.75	45.79	0.39
JLS-603-6-1	53.68	13.71	20.18	39.00	46.29	0.34
JLS-606-6-4	53.63	13.43	24.98	38.74	46.02	0.41
JLS-606-7	54.25	13.68	20.65	40.33	45.94	0.39
JLS-608-2-1	51.37	13.86	23.31	38.32	46.24	0.40
JLS-613-1-1	55.92	13.81	21.13	39.10	45.91	0.37
JLS-615-9-1	49.63	13.28	18.59	37.96	46.12	0.41
PT-1	50.07	13.64	21.10	38.93	45.81	0.39
JLT-7	51.35	13.58	19.93	39.21	46.03	0.35
JLT-26	54.64	13.65	18.60	39.48	46.08	0.31
JLT-408	50.49	13.55	22.62	39.11	46.15	0.38
IC-4132-53	51.44	13.53	20.83	39.85	45.94	0.41
JLSG-5-11	52.44	13.70	20.49	39.57	45.84	0.36
G-47	52.45	13.74	18.72	38.94	45.87	0.26
SI-2334-2	41.33	12.45	25.67	43.43	44.08	0.02
JL-Sel-07-03	55.03	13.12	26.98	38.38	45.91	0.44
JMLS-07-01	48.63	13.69	24.46	38.82	46.11	0.45
JLT-27	55.20	13.20	26.42	38.32	45.97	0.47
KMR-33	51.15	13.75	21.51	39.59	45.90	0.41
KMK-28	59.57	13.10	26.97	39.18	45.68	0.48
JLSG-05-06	49.86	13.52	22.20	40.10	46.23	0.39
JMLS-07-03	52.88	13.81	22.77	39.49	45.73	0.39
SI-3079-2	50.64	12.80	24.22	37.58	46.31	0.31
JL-Sel-07-11	54.96	13.76	20.99	39.76	54.96	0.35
IC-413241	54.08	13.71	22.30	39.87	54.08	0.37
RT-54	45.47	13.58	15.26	39.38	45.47	0.13
Mean	51.71	13.51	22.27	39.21	51.71	0.36
SE ±	0.10	0.03	0.25	0.03	0.10	0.01
CD at 5%	0.29	0.08	0.71	0.08	0.07	0.02

seed weight. The data regarding yield ha^{-1} revealed that, the genotypes, JLS-116 (800.63 kg), JLS-506-3 (703.70 kg), JLS-613-1-1 (694.44 kg), JLS-502-3 (662.03 kg) and JLT-7 (648.14 kg) recorded the highest yield. The genotypes, JLT-7 (29.12 g), JLS-506-3 (29.02 g), JLS-613-1-1 (28.72 g) and RT-54 (28.33 g) recorded the highest dry matter production $plant^{-1}$. The genotypes, JLSG-05-11 (24.52%), JLS-502-3 (22.17%), JL-Sel-05-3 (21.21%) and JLS-606-6-4 (20.0%) recorded highest harvest index. The seed yield of the genotype JLS-116 was mainly due to favorable yield contributing character like number of capsule per plant, number of seed, 1000 seed weight and harvest index (Table 5). These findings are on the similar lines to those reported by Biswas and Akbar (1995), Hemalatha *et al*., (1999), and Solanki and Gupta (2001).

The comparative performance of the genotypes studies in the biochemical parameters were according to Were *et al*., (2006) and Uzun *et al*., (2007). In the present investigation, the oil, carbohydrate, protein, oleic acid, linoleic acid and linolenic acid content ranged between 41.33 and 59.57, 12.45 and 13.86, 15.25 and 29.85, 37.58 and 43.43, 44.08 and 54.96 and 0.02 and 0.53 per cent, respectively. The genotypes KMK-28 (59.57%), JLS-301-24 (56.67%), JLS-613-1-1 (55.92%), JLT-27 (55.19%) for oil content; JLS 608-2-1 (13.85 %), JLS-502-1 (13.85%) and JLS-613-1-1 (13.81%) for carbohydrate content; JLS-301-24 (29.85%), JL-Sel-07-3 (26.98%), JLT-27 (26.42%) and SI-2334-2 (25.67%) for protein content; SI-2334-2 (43.43 %), JLS-606-7 (40.33%) and JLSG-05-06 (40.10) for oleic acid content; JL-Sel-07-11 (54.96%), IC-413241 (54.08%), SI-3079-2 (46.31%) and JLS-603-6-1 (46.29%) for linoleic acid content and JLS-301-24 (0.53 %), JLS-301-7 (0.48 %) and KMK-28 (0.48 %) for linolenic acid content (Table 6) were better for related chemical properties. These findings are in accordance with the results of Gupta (1990) and Sverup *et al*., (1993).

Phenologically, the genotypes, JLS-116, SI-3079-2, JLS-613-1-1 and JLT-7 were earlier for days to initiation of flowering as well as 50 per cent flowering and maturity. However, JLS-506-3, JLS-502-1, PT-1, JLS-301-7, JLS-507-4 and JLS-502-3 were tall genotypes, JLS-120, JLS-507-4, JLT-7, JLS-603-6-1, JLS-301-7 and JLT-408 had profuse branching and RT-54, JLS-116, IC-413241, JLT-26, JL-Sel-07-11, JLT-7 and JMLS-07-03 were better for number of leaves $plant^{-1}$. On the basis of physiological parameters, JLS-116, JLT-7, JLS-502-3, JLS-506-3 and JLS-613-1-1 were better for maintaining higher rates of photosynthesis, transpiration, stomatal conductance, water use efficiency and chlorophyll content. However, the genotypes, JLS-116, JLT-7, JLSG-5-11, JL-Sel-07-03 and JL-Sel-07-03 were found better for maintaining higher CO_2R, CO_2S, H_2OR and H_2OS, whereas, JLS-603-4-3, JL-Sel-07-03, SI-3079-2 for minimum canopy temperature and JLS-116, JLS-506-3, JLS-613-1-1 and JLS-507-4 for higher CTD. The genotypes, JLT-7, RT-54, JLS-116, JLS-613-1-1 and JLS-506-3 were good indicators for the absorbance of photosynthetically active radiations. The genotypes, JLS-116, JLT-7, JLS-506-3, JLS-613-1-1, JLS-502-3 and JLSG-05-11 recorded the highest seed yield might be due to desirable phenological traits, higher total dry matter accumulation and morpho-physiological traits. The genotypes KMK-28, JLS-608-2-1, JLS-301-24, SI-2334-2 JL-Sel-07-11 and JLS-301-24 were rich in oil, carbohydrate, protein, oleic acid, linoleic acid and linolenic acid content and also on account of total biomass and physiological parameters.

Therefore, the genotypes, JLS-116, JLT-7, JLS-506-3, JLS-613-1-1, JLS-502-3 and

JLSG-05-11 may be utilized in further breeding programme for the yield heterosis, whereas the genotypes KMK-28, JLS-608-2-1, JLS-301-24, SI-2334-2, JL-Sel-07-11 and JLS-301-24 for improving oil, carbohydrate, protein, oleic acid, linoleic acid and linolenic acid content in further breeding programme.

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Performance of Wheat at Foliar Application of Nutrients Under Different Sowing Conditions

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Abstract

A field experiment was conducted to know performance of wheat under different sowing period and to foliar nutrient sprays during 2010-11 to 2012-13. Based on three years of the experimentation, it was observed that sowing of wheat in 45[th] meteorological week significantly gave higher grain yield (45.64 q ha^{-1}, 13.45 % increase over 48[th] meteorological week) and straw yield (63.68 q ha^{-1}, 14.84% increase over 48[th] meteorological week). Similarly, spraying of 19:19:19, $N:P_2O_5:K_2O$ @ 2 per cent produced significantly higher grain yield (46.73 q ha^{-1}, 21.19% increase over water spray) and straw yield (65.55 q ha^{-1}, 22.91% increase over water spray). Improvement in ancillary characters of wheat sown at 45[th] meteorological week, *viz*., 1000 grain weight, number of earheads $square^{-1}$ meter and number of grains $earhead^{-1}$ due to foliar spraying of 19:19:19 $N:P_2O_5:K_2O$ @ 2 per cent was observed. The B:C ratio (1.92 and 1.89 for sowing time and foliar sprays) of the same combination of treatments was also observed higher over other treatments.

Key words : Wheat, sowing conditions, foliar sprays

Wheat (*Triticum aestivum* L.) has a prominent position among the cereals that supplement nearly one-third of the world population's diet by providing half of the dietary protein and more than half of the calories (Dhanda *et al*., 2004). As a result, there is always pressure to harvest higher wheat yields to feed the burgeoning population. Many factors contribute in increasing yield, such as early and timely sowing (Akhtar *et al*., 2006; Sattar *et al*., 2010), seed quality (Farooq *et al*., 2008), availability of high-yielding varieties (Hussain *et al*., 1998) and judicious use of inputs such as fertilizers and irrigation (Mullaa *et al*., 1992; Kibe *et al*., 2006).

Foliar application gives guarantee for the availability of nutrients to crops for obtaining higher yield. (Arif *et al*., 2006). Among major nutrients, nitrogen plays a vital role in increasing the yield of crop. Application of proper amount of nitrogen is considered key to obtain bumper crop of wheat. Foliar application of nitrogen has more effect on yield and yield components of wheat because it is more effective and minimum losses involved in foliar spray. (Sud *et al*., 1990).

Rahman *et al*., (2014) observed that foliar fertilization of urea and potassium caused significant stimulatory effect on growth parameters, however, foliar feeding with urea 2% + K 2% gave the highest significant values for all growth characters at 65, 90 and 115 days after sowing and also for yield and its components i.e. plant height, number of spikes m^{-2}, weight of spikes m^{-2} as well as grain, straw and biological yields.

In many agricultural production systems, phosphorus (P) has been identified as the most deficient essential nutrient after nitrogen (N). Mosali (2006) studied P application to wheat crop and observed that, the best phosphorus (P) fertilizer use efficiency is around 16% when

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Table 1. Nutrient contents of salts used for spraying in the experiment

Fertilizer	N	P_2O_5 (%)	K_2O
Urea	46	0	0
DAP	18	46	0
KNO3	13	0	45
KCL	0	0	60
19:19:19	19	19	19

knifed or applied with the seed in winter wheat. Intuitively, one would expect foliar applied P to have higher use efficiencies than when applied to the soil. Results from this study suggested that low rates of foliar applied P might correct mid-season P deficiency in winter wheat, and that might result in higher P use efficiencies when compared to soil applications. Foliar P appeared to be more beneficial when yield levels were lower, likely due to moisture stress. Harbi *et al.*, (2013) reported that foliar application of P @ 2% at physiological growth stage increased wheat grain yield and P uptake versus no foliar. Results confirmed the beneficial effect of foliar P fertilization especially in the absence of soil P fertilizer application. Soil available P values obtained at the end of growing period increased significantly with increasing rates of added P. Thus, application of P fertilizer by foliar along with medium rates of soil P fertilizer may contribute to improve P fertilizer efficiency and increase wheat grain yield in calcareous soil.

Eman and Mogied, (1998) from their studies revealed that potassium is a "work horse" plant nutrient. Perhaps this is why it is not bound into any specific plant compound. Therefore, potassium is free to travel and to wheel and deal

Table 2. Grain and straw yields of wheat (q ha^{-1}) as influenced due to different treatment (2010-11 to 2012-13)

Treatments	2010-11		2011-12		2012-13		Pooled mean	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
A) Main plot (Sowing time)								
D_1 - Timely sown	55.14	66.62	46.07	70.10	35.70	54.31	45.64	63.68
D_2 - Late sown	47.86	56.17	41.88	63.18	30.95	47.00	40.23	55.45
SE±	0.68	0.38	1.29	2.23	0.43	0.48	0.11	1.80
C.D. at 5%	1.83	1.20	3.84	6.75	1.26	1.41	0.34	5.37
B) Sub plot (Foliar spray at 55 and 70 DAS)								
S_1 - 2% Urea spray	51.90	60.78	44.17	66.95	33.07	50.08	43.05	59.25
S_2 - 2% DAP spray	53.95	64.95	46.60	70.93	35.77	54.43	45.45	63.44
S_3 - 2% KNO_3 spray	51.92	60.30	44.36	67.67	35.30	53.83	43.87	60.62
S_4 - 2% KCL spray	48.82	58.71	41.41	62.34	29.66	44.64	39.96	55.22
S_5 - 2% NPK (19:19:19) mixture spray	56.08	68.15	47.28	71.87	36.81	56.67	46.73	65.55
S_6 - Water spray	46.33	55.49	40.02	60.07	29.35	44.29	38.56	53.33
SE±	0.75	0.96	0.86	1.37	0.65	0.96	0.50	0.69
C.D. at 5%	2.24	2.86	2.54	4.07	1.93	2.84	1.48	2.05
C) Interaction (A x B)								
SE±	0.78	0.51	1.04	1.95	0.47	0.53	0.13	2.01
C.D. at 5%	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

within the plant almost at well. It should not be surprising that a shortage of potassium can result in loss of crop yield, quality and profitability. Foliar spray of potassium in combination with nitrogen and some micro-nutrients like zinc had significant effect on grain yield of wheat. Zareian (2013) observed that net photosynthesis, stomatal conductance, transpiration rate significantly decreased by drought stress. Also these traits showed significant increase by increasing potassium foliar application (1.5 and 3% potassium spray).

Aown *et al.*, (2012) conducted a study to find out the response of wheat (*Triticum aestivum* L.) cultivars (Lasani-2008, Auqab-2000) to foliar application of 1% potassium at different growth stages (tillering, flower initiation and milking) under water limited environment and revealed that foliar application of 1 per cent potassium at all three stages improved the drought tolerance of plants and growth and yield components. Late season foliar N applications before or immediately following flowering may significantly enhance grain N content and, thus, percent protein in winter wheat (Woolfolk, *et al.*, 2002).

Materials and Methods

A field experiment on sowing time and foliar sprays of nutrients for wheat was conducted at Agricultural Research Station, Niphad, Dist. Nasik (Maharashtra State) during 2010-11 to 2012-13. The soil of the experimental site was

Table 3. Pooled grain and straw yields, gross returns, cost of cultivation, net returns and B: C ratio as influenced due to different treatments (2010-11 to 2012-13)

Treatments	Grain yield (q ha^{-1})	Straw yield (q ha^{-1})	Gross returns (Rs. ha^{-1})	Cost of cultivation (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	B:C ratio
A) Main plot (Sowing time)						
D_1 - Timely sown	45.64	63.68	70587	36857	33730	1.92
D_2 - Late sown	40.23	55.45	62106	36857	25248	1.69
SE±	0.11	1.80	-	-	-	-
C.D. at 5%	0.34	5.37	-	-	-	-
B) Sub plot (Foliar spray at 55 and 70 DAS)						
S_1 - 2% Urea spray	43.05	59.25	66402	35967	30435	1.85
S_2 - 2% DAP spray	45.45	63.44	70356	37620	34099	1.87
S_3 - 2% KNO3 spray	43.87	60.62	67899	38455	29444	1.77
S_4 - 2% KCL spray	39.96	55.22	61530	36127	25403	1.72
S_5 - 2%NPK(19:19:19) mixture spray	46.73	65.55	72400	38488	33912	1.89
S_6 - Water spray	38.56	53.33	59493	35855	23638	1.67
SE±	0.50	0.69	-	-	-	-
C.D. at 5%	1.48	2.05	-	-	-	-
C) Interaction (AxB)						
SE±	0.13	2.01	-	-	-	-
C.D. at 5%	N.S.	N.S.	-	-	-	-

Market Price (Rs. q^{-1})

Year	Wheat grain	Wheat straw
2010-11	1180	150
2011-12	1320	150
2012-13	1375	300

clayey in texture having pH 7.92, EC 0.42 dSm^{-1}, medium in organic carbon (0.58%), low in nitrogen (201 kg ha^{-1}), low in phosphorous (13.25 kg ha^{-1}) and high in potassium (574 kg ha^{-1}). The experiment was laid in split plot design with sowing time (45th and 48th meteorological week i.e. From 2 to 8 November and 23 to 29 November) as main treatment and sprays of nutrients @ 2 per cent (urea, DAP, KNO_3, KCL, 19:19:19 $N:P_2O_5:K_2O$ and water spray) at 55 and 70 days after sowing as sub treatment replicated three times. The pH of fertilizer solution used for spray was maintained between 7.0 to 7.3. Recommended dose of fertilizers (90:60:40 $N:P_2O_5:K_2O$ kg ha^{-1}) was applied uniformly to all treatments. NIAW 917 (Tapovan) wheat variety was used for the said experiment. Limiting micronutrients i.e. zinc sulphate and ferrous sulphate @ 20 kg ha^{-1} each incubated separately in FYM for one week before application in soil, were added uniformly to all the treatments. Before sowing of wheat crop, soybean was taken as a general crop in the *kharif* season.

Results and discussions

Sowing time : Sowing time plays vital role in yield potential of wheat production. Varietal selections made by the farmers also contribute to yield differences between farmers. After completion of three years of the experimentation, within main treatments, it was observed that, sowing of wheat in 45th meteorological week gave significantly higher grain (45.64 q ha^{-1}) and straw yields (63.68 q ha^{-1}) over sowing of wheat at 48th meteorological week. The 11.85 per cent loss in the grain yield of wheat was recorded due to the late sowing. This finding is supported by the findings of Refay, (2011) who found that, the delayed sowing was associated with substantial losses in grain yield estimated by 7.98 per cent as compared with early sowing.

The results of the findings showed that, yield contributing characters such as thousand grain weight, number of grains $earhead^{-1}$ and numbers of earheads $square^{-1}$ meter were highly correlated to yield and the yield attributing characters were badly affected under

Table 4. Number of earheads per sq meter, Number of grains per earhead and thousand grain weight of wheat as influenced due to different treatments (2010-11 to 2012-13)

Treat-ments	Number of earheads $sq.^{-1}$ m				Number of grains $earhead^{-1}$				Thousand grain wright			
	2010-11	2011-12	2012-13	Pooled mean	2010-11	2011-12	2012-13	Pooled mean	2010-11	2011-12	2012-13	Pooled mean
A) Main plot (Sowing time)												
D_1	405.91	398.42	392.38	398.90	48.20	45.90	34.62	42.91	39.10	38.39	38.20	38.56
D_2	391.48	389.00	382.14	387.54	44.26	43.81	33.86	40.64	37.64	36.96	37.04	37.21
B) Sub plot (Foliar spray at 55 and 70 DAS)												
S_1	396.67	391.17	397.17	395.00	46.60	46.17	34.01	42.26	38.57	37.69	37.68	37.98
S_2	404.83	394.11	397.50	398.81	46.97	48.00	37.01	43.99	38.55	38.53	38.61	38.56
S_3	404.00	392.73	396.00	397.58	46.20	47.33	36.00	43.18	38.20	38.02	38.13	38.12
S_4	396.50	389.28	390.50	392.09	45.73	45.00	33.68	41.47	37.86	37.18	37.68	37.57
S_5	409.17	396.67	406.67	404.17	48.40	48.33	38.18	44.97	40.03	38.89	39.90	39.61
S_6	394.50	388.15	366.00	382.88	45.67	39.67	31.83	39.06	37.80	36.79	35.92	36.84

D_1 - Timely sown, D_2 - Late sown, S_1 - 2% Urea spray, S_2 - 2% DAP spray, S_3 - 2% KNO_3 spray, S_4 - 2% KCL spray, S_5 - 2%NPK(19:19:19) mixture spray, S_6 - Water spray late sown condition. The results were corroborated with the findings of Refay, (2011).

Nutrient sprays : Feeding of nutrients through foliar application can improve the availability of nutrients to crops for obtaining higher yield. Among the sub treatments, spraying of 19:19:19 $N:P_2O_5:K_2O$ @ 2 per cent produced significantly higher grain (46.73 q ha^{-1}) and straw yields (65.55 q ha^{-1}). Availability of major nutrients through foliar feeding at 55 and 70 days after sowing would have helped for nourishment of the crop to fulfill the hidden hunger of the crop. The yield increased by 21.19 per cent due to spraying of 19:19:19 $N:P_2O_5:K_2O$ @ 2 per cent over water spray treatment. The yield contributing characters such as thousand grain weight, number of grains $earhead^{-1}$ and number of earheads $square^{-1}$ meter also improved due to foliar application of 19:19:19 $N:P_2O_5:K_2O$.

The improvement in plant height, spike length, number of grains, 100 grain weight, biological yield and grain yield of wheat due to spraying of 4 per cent urea at tillering, stem elongation and boot stage was reported by Khan *et al.*, (2009). The increase in grain yield by 32 per cent was noticed by spraying of 4 per cent urea. A significant linear increase in total grain N was observed for post flowering applications using urea ammonium nitrate (UAN) in five of six site-years. A significant linear increase was observed for pre-flowering applications of UAN. No consistent increases or decreases from foliar N applications were observed for grain yield, straw yield, or straw N. Over years and locations, UAN applied pre-flowering and post flowering at 34 kg nitrogen ha^{-1} increased total grain N over that of the check (no foliar N applied) by 2.7 and 2.4 g kg^{-1}, respectively.

Economics

Sowing time : Economics of the wheat cultivation at different time of sowing reveled that sowing of wheat crop at 45^{th} meteorological week gave significantly higher gross monitory returns (Rs. 70587/-), net monitory returns (Rs. 33730/-) and B:C ratio (1.92) as compared to late sowing at 48th meteorological week.

Nutrient sprays : Nutrient sprays to wheat reveled that spraying of 19:19:19% $N:P_2O_5:K_2O$ @ 2 per cent at 50 and 70 days after sowing gave highest gross monitory returns (Rs. 72400/-), net monitory returns (Rs. 33912/-) and B:C ratio (1.89) which was followed by 2% DAP spray over rest of the treatments during three years of the experimentation.

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Effect of Polyamines on Storability and Quality of Pomegranate Fruit (*Punica granatum* L.) Cv. Bhagawa

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Abstract

The present investigation was carried out to study the effect of polyamines on storability and quality of pomegranate fruit. The study revealed that the treatment consisting of 1 mM putrescine resulted in minimum PLW%, CI, and titrable acidity over rest of the treatments under study in different storage conditions and storage periods. Treatment consisting of untreated fruits recorded maximum physiological loss in weight (PLW%), chilling injury (CI) and titrable acidity. Teatment consisting of 1 mM spermidine recorded no CI, and maximum per cent juice recovery over other treatments. Treatment of 2 mM putrescine recorded maximum TSS, while minimum in treatment control at ambient storage conditions. Overall 5°C storage conditions proved to be superior over 8°C and room condition storage at different storage periods.

Key words : Pomegranate, polyamines, storability, quality.

Pomegranates stored below 5°C develop chilling injury (CI). The most common symptoms are surface pitting, husk scald and skin browning (Elyatem and Kader, 1984). To reduce the occurrence of chilling injury in pomegranate, several technologies have been tested (Artes *et al*., 2000). Studies of polyamines such as (Putrescine, Spermidine and spermine) have been reported by Bouchereau *et al*., (1999) in extending shelf life of fruits. Hence, minimizing the incidence of CI and decay during long term storage of pomegranate, the fruits would go a long way in extending the marketing both in domestic as well as export trade. Therefore, research investigation on studies on effect of polyamines on storability and quality of pomegranate fruits Cv. Bhagawa was undertaken.

Materials and Methods

The present investigation was undertaken at Department of Horticulture, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani during year 2011-2012.The experiment was laid out in completely randomized block design with three replications and seven treatments. The experiment consisted of different levels of polyamines stored at room, 50 °C and 80 °C temperature conditions affecting the quality of pomegranate fruits. The treatments consisted of T_1 - 1 mM putrescine, T_2 - 2 mM putrescine, T_3 - 4 mM putrescine, T_4 - 0.5 mM spermidine, T_5 - 1 mM spermidine, T_6 - 1.5 mM spermidine and T_0 - Control room temperature storage, 5°C and 8°C. The observations on physico-chemical changes *viz*., total soluble solids (%), titrable acidity (%), juice recovery (%), chilling injury index (%), physiological loss in weight (PLW) (%) and sensory evaluation of fruits were recorded at 15 days interval upto 45 days of storage at room temperature and 75 days at low temperature. Initial observations were recorded before placing the fruit in corrugated fibre boxes (CFB) boxes. The data generated was subjected for statistical analysis as suggested by Panse and Sukhatme (1995).

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Results and Discussion

The results in respect of physiological loss in weight of pomegranate fruits during storage showed statistically significant differences due to various treatments combinations (Table 1). There was a linear increase in PLW per cent in all storage conditions with increase in storage days from 15 to 75 days of storage periods under each treatment. Significantly, minimum PLW per cent (1.40) was recorded in treatment T_1 stored for a period of 15 days at 8°C. It was followed by the treatment T_5 (1.41) stored at 5°C at 15 days of storage. Treatment T_4 stored at 8°C showed maximum PLW per cent (14.24) at 75 days of storage. Loss of weight in stored pomegranate fruits was mainly due to evaporation of water from the fruit and become apparent as shriveling. Daniel *et al.*, 2007 reported similar results which supports present findings.

Perusal of data presented in Table 2 revealed that chilling injury as influenced by polyamines treatments on pomegranate fruits in different storage conditions and periods differed significantly. Significantly, no CI was recorded in treatment T_1 and T_5 under 5°C

Table 1. Effect of polyamines on PLW (%) of pomegranate fruits at different storage conditions

Treat-ments	Storage period (days)											
	Room temp. (°C)		5°C					8°C				
	15	30	15	30	45	60	75	15	30	45	60	75
T_1	2.18	8.80	1.35	2.22	6.12	9.84	11.00	1.40	2.40	6.19	9.84	11.07
T_2	3.31	11.23	2.22	3.70	9.10	12.16	14.13	2.29	3.82	9.13	12.17	14.21
T_3	2.91	12.23	2.74	3.90	8.90	11.44	13.86	2.91	3.94	8.90	11.49	14.07
T_4	2.87	11.80	2.83	3.98	9.12	12.20	14.16	2.86	4.01	9.16	12.21	14.24
T_5	2.27	9.00	1.41	2.74	7.14	10.04	11.12	1.64	2.80	7.16	10.08	11.26
T_6	2.92	12.00	2.87	4.01	8.89	11.05	13.92	2.90	3.98	9.10	11.85	14.04
T_0	9.34	18.50	4.30	8.90	-	-	-	4.42	9.09	-	-	-
SE±	0.36	0.12	0.02	0.15	0.03	0.06	0.03	0.01	0.08	0.01	0.01	0.04
CD at 5%	1.11	0.38	0.08	0.47	0.09	0.09	0.09	0.03	0.26	0.04	0.03	0.12

Table 2. Effect of polyamines on chilling injury of pomegranate fruits at different storage conditions

Treat-ments	Storage period (days)					
	5°C			8°C		
	15	30	45	15	30	45
T_1	-	14.06 (16.97)*	21.20 (12.23)*	27.20 (15.78)*	29.20 (16.98)*	39.22 (23.08)*
T_2	21.73 (12.55)*	29.20 (8.085)*	39.40 (23.20)*	30.20 (17.75)*	34.06 (19.91)*	45.50 (27.06)*
T_3	19.22 (11.08)*	31.05 (18.08)*	37.06 (21.75)*	30.32 (17.68)*	32.22 (18.79)*	45.30 (26.93)*
T_4	24.66 (14.29)*	32.33 (18.86)*	39.33 (22.86)*	30.22 (17.52)*	32.06 (18.70)*	44.19 (26.22)*
T_5	-	18.30 (18.54)*	26.60 (15.42)*	28.30 (16.44)*	30.10 (17.51)*	41.03 (24.22)*
T_6	17.32 (99.76)*	18.40 (10.60)*	39.06 (22.99)*	-	34.20 (20.00)*	44.07 (26.23)*
T_0	28.30	35.00	40.00	30.25	36.00	46.00
SE±	(0.75)*	(0.01)*	(0.01)*	0.01	0.02	0.37
CD at 5%	(2.28)*	(0.03)*	(0.04)*	0.03	0.08	0.14

*Arc sine value

storage conditions and in treatment T_6 under 8°C storage conditions at 15 days of storage. Significantly, more CI (46%) was noted in control at 45 days of storage period under 8°C storage. Here control pomegranate fruits failed to cold acclimation/adaption and thus CI occurred. Polyamines play a very significant role in alleviating chilling injury symptoms in fruits due to its antioxidant property and its action to prevent lipid per oxidation and thus protect the membrane lipid from being conversion in physical state. The present findings are in agreement with Mirdehghan *et al.*, (2007) work on pomegranate.

Data depicted in Table 3 revealed that the effect of polyamines treatments on pomegranate fruit showed gradual increase in TSS content during storage under all treatments under study. It was observed that TSS increase was more under 8°C storage rather than 5°C and ambient stored fruits from 15 days to 75 days of storage. Significantly, maximum TSS (17.01%) was recorded in control stored at 8°C for 75 days of storage. Significantly, minimum TSS (15.37%) was recorded in treatment T_2 stored at room temperature at 30 days of storage. Overall 5°C storage temperature was superior over 8°C followed by room temperature at the end of

Table 3. Effect of polyamines on TSS (%) of pomegranate fruits at different storage conditions

Treat-ments	Storage period (days)											
	Room temp. (°C)		5°C					8°C				
	15	30	15	30	45	60	75	15	30	45	60	75
T_1	15	15.49	15	15.50	15.76	15.74	16.16	15	15.5	16.21	16.41	16.18
T_2	15	15.37	15	15.42	15.62	15.73	16.14	15	15.42	15.84	15.95	16.16
T_3	15	15.36	15	15.41	15.58	15.72	16.13	15	15.41	15.64	15.90	16.15
T_4	15	15.37	15	15.41	15.68	15.70	16.14	15	15.41	15.54	15.85	16.10
T_5	15	15.47	15	15.46	15.71	15.77	16.16	15	15.46	16.14	16.35	16.17
T_6	15	15.39	15	15.40	15.70	15.70	16.15	15	15.4	16.17	16.20	16.07
T_0	15	15.42	15	15.39	15.56	15.60	16.25	15	15.39	16.23	16.50	17.01
SE±	0	0.007	0	0.005	0.008	0.005	0.005	0	0.005	0.005	0.005	0.005
CD at 5%	0	0.023	0	0.015	0.026	0.015	0.016	0	0.015	0.017	0.17	0.17

Table 4. Effect of polyamines on titrable acidity (%) of pomegranate fruits at different storage conditions

Treat-ments	Storage period (days)											
	Room temp. (°C)		5°C					8°C				
	15	30	15	30	45	60	75	15	30	45	60	75
T_1	0.36	0.36	0.36	0.32	0.31	0.36	0.35	0.36	0.34	0.30	0.30	0.29
T_2	0.36	0.4	0.36	0.37	0.36	0.39	0.38	0.36	0.36	0.35	0.35	0.33
T_3	0.36	0.51	0.36	0.36	0.36	0.50	0.49	0.36	0.70	0.35	0.35	0.34
T_4	0.36	0.56	0.36	0.37	0.40	0.55	0.54	0.36	0.43	0.39	0.39	0.38
T_5	0.36	0.37	0.36	0.36	0.35	0.36	0.35	0.36	0.30	0.34	0.34	0.33
T_6	0.36	0.46	0.36	0.41	0.36	0.45	0.44	0.36	0.36	0.35	0.35	0.35
T_0	0.36	0.61	0.36	0.42	0.41	0.58	0.57	0.36	0.38	0.40	0.40	0.39
SE±	-	0.008	-	0.007	0.006	0.008	0.009	-	0.007	0.007	0.006	0.006
CD at 5%	-	0.027	-	0.02	0.02	0.0027	0.028	-	0.021	0.022	0.02	0.02

Table 5. Effect of polyamines on juice recovery (%) of pomegranate fruits at different storage conditions

Treat-ments	Storage period (days)											
	Room temp. (°C)		5°C					8°C				
	15	30	15	30	45	60	75	15	30	45	60	75
T_1	48.47	45.07	48.47	47.07	46.51	44.01	43.91	48.47	47.08	48.11	43.03	42.02
T_2	48.47	44.02	48.47	46.01	45.71	43.02	43.51	48.47	45.03	47.61	-	-
T_3	48.47	44.56	48.47	43.03	45.91	41.03	41.02	48.47	43.51	46.51	42.02	40.07
T_4	48.47	39.41	48.47	41.02	40.03	39.01	38.81	48.47	41.11	40.68	41.11	-
T_5	48.47	45.51	48.47	47.33	46.31	44.07	43.04	48.47	46.82	47.81	43.01	42.01
T_6	8.47	43.51	48.47	45.02	44.21	45.02	43.02	48.47	44.71	46.02	42.01	41.01
T_0	48.47	40.01	48.47	42.02	41.02	39.07	38.02	48.47	40.61	39.91	35.1	-
SE±	-	0.006	-	0.011	0.006	0.006	0.005	-	0.006	0.253	0.005	0.005
CD at 5%	-	0.019	-	0.036	0.018	0.019	0.017	-	0.02	0.769	0.016	0.015

storage period. Above findings are in agreement with the findings of Waskar and Gaikwad (2003) work on pomegranate. It is evident from Table 4 that significantly more titrable acidity (0.61%) was recorded in treatment control at 30 days of storage under room temperature of storage conditions. Treatment T_1 (1 mM putrescine) stored at 5°C for 75 days of storage period recorded less titrable acidity (0.30%). Present results are in accordance with findings of Mirdehghan *et al.,* (2007).

Results on percentage juice recovery on fruit aril weight basis at 15 days of storage revealed that juice recovery decreased under all treatments (Table 5). However, decline was much higher in control fruits than 1 mM Putrescine and 1 mM Spermidine treated fruits. Regardless of the treatments under study, the juice recovery was found depleting after 45 days of storage. Pomegranate fruits treated with 1 mM Putrescince and 1 mM Spermidine at 5°C showed better juice recovery (%) over control and other treatments of polyamines at 8°C and room temperature storage. Above finding are on lines with Asrey and Barman *et al.,* (2011) work on pomegranate fruit.

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Phenological Interventions in Groundnut Genotypes as Influenced by Seasonal Variation in Temperature and Sowing Dates

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Abstract

Two field trials were conducted during summer 2012 and summer 2013 in order to investigate the effect of varying climatic conditions in terms of sowing dates on phenological attributes of six groundnut genotypes. Sowing dates in terms of fortnights were differentiated into different growth phases of crop (R1 to R7) and accordingly correlation of temperature regime for phenological attributes has been investigated. Study revealed that S_3 was found to be most promising for early phenological development and recorded minimum days for emergence, days to anthesis, days to appearance of first flower bud, days to peg formation, days to 50% flowering and days to physiological maturity due to rise in temperature as compared with other sowing dates. Among genotypes TAG-24(V4) recorded minimum days for aforesaid phenological parameters.

Key words : Groundnut, sowing dates, temperature, phenology

In Maharashtra Groundnut crop is generally grown in summer season and optimum date of sowing is in second fortnight of February. In some cases late sowing may be done due to late harvesting of *rabi* season crop. Hence late sowing of groundnut has to face consequences of early showers of monsoon. Groundnut is also sensitive to temperature, with the optimum temperature for most processes being between 27 and 30 °C (De Beer 1963). Thus in view of this, depending upon environment, sowing date a cultivar may experience sub-optimal or supra-optimal temperature range throughout growing period. Both conditions i.e. low and high temperatures are known to affect the growth and development of groundnut (Leong and Ong, 1983).

Knowledge of crop phenology is important for at least three reasons, first, for optimal crop yield in an environment it is necessary to match the life cycle of the crop to the length of the growing season. Such information is needed to develop better cropping systems so that high stable productivity can be achieved. Second, the introduction of improved genotypes or new crops into new regions is largely determined by temperature and phenology (Aitken, 1974) and finally phenology is an essential component of whole-crop simulation models, which can be used to specify the most appropriate rate and time of specific developmental processes to maximize yield. Hence, study was undertaken to investigate effect of varying temperature conditions in terms of sowing dates on phenological development and also its behaviour at different phases of growth of groundnut crop. It will be more beneficial to select such sowing date that will fetch optimum growth and yield of crop (Ong, 1986).

Materials and Methods

The experiment was conducted during two summer seasons (2012 and 2013) at AICRP farm of Cotton Improvement Project, Mahatma Phule Krishi Vidyapeeth Rahuri, Dist-Ahmednagar (Maharashtra). The soil was light

1. Student, 2. and 4. Associate Professor and 3. Head

Table 1. Climatic factors at different growth stages of groundnut

Fortnight	Sowing dates			Temperature (°C)				Humidity				Sunshine (hrs.)		Evaporation (mm)	
	S1 (6th Feb)	S2 (22nd Feb)	S3 (8th Mar)	Max.		Min.		Mor.		Eve.					
				2012	2013	2012	2013	2012	2013	2012	2013	2012	2013	2012	2013
6 - 20 February	R1			31.80	31.34	11.12	14.30	54.74	56.86	20.60	30.73	9.46	8.61	4.44	5.32
	Range			24.6 - 235.2	26.8 - 34.6	3.0 - 14.9	8.4- 17.5	33.0 - 66.0	45.0- 71.0	16.0- 30.0	11.0- 43.0	7.7- 10.3	7.1- 11.4	0.0- 5.8	3.8- 6.7
21 Feb - 7 March	R2	R1		33.95	34.05	12.50	13.16	46.06	46.20	14.87	19.13	9.75	10.02	6.65	6.82
	Range			30- 36.2	32.2- 36.6	8.9- 14.4	10.2- 17.1	32.0- 69.0	33.0- 69.0	8.0- 23.0	6.0- 28.0	9.1- 10.6	9.4- 10.4	5.8- 7.8	5.7- 8.1
8 - 22 March	R3	R2	R1	34.80	35.79	13.02	16.35	43.06	42.06	15.60	17.33	9.33	8.84	8.32	8.02
	Range			29.0- 38.0	29.4- 37.0	8.4- 16.3	14.9- 18.9	30.0- 63.0	30.0- 54.0	10.0- 25.0	13.0- 33.0	8.3- 9.8	7.7- 9.4	7.4- 9.4	7.4- 8.7
23 March-6 April		R3	R2, R3	38.30	36.82	17.99	17.48	38.53	47.53	13.80	18.60	8.49	8.46	8.68	8.36
	Range			37.4- 39.4	35.5- 39.0	12.4- 24.4	14.7- 20.3	23.0- 56.0	32.0- 59.0	9.0- 19.0	12.0- 25.0	7.3- 9.1	7.0- 10.0	7.4- 10.2	6.8- 9.4
7 - 21 April	R4			38.10	38.26	20.84	18.66	46.06	50.46	19.2	16.53	8.70	9.13	9.40	9.23
	Range			37.0- 40.0	35.0- 40.0	18.9- 25.4	10.5- 22.1	28.0- 68.0	36.0- 65.0	10.0- 30.0	8.0- 28.0	5.5- 10.0	0.9- 11.2	6.6- 10.3	8.6- 10.0
22 April - 6 May	R5	R4	R4	38.06	39.88	19.58	22.17	42.73	47.86	16.26	17.40	10.20	10.52	9.76	10.92
	Range			37.0- 39.0	37.8- 42.0	16.8- 21.6	15.4- 29.9	34.0- 63.0	34.0- 68.0	10.0- 24.0	10.0- 26.0	8.2- 10.9	9.5- 11.3	7.8- 11.0	9.2- 12.4
7- 21 May	R6	R5		38.57	39.75	21.06	23.80	49.86	43.46	19.86	19.76	10.52	7.40	9.94	10.81
	Range			37.0- 40.6	38.8- 41.5	17.0- 23.4	19.9- 26.5	17.0- 73.0	27.0- 73.0	11.0- 33.0	14.0- 27.0	8.4- 11.5	2.1- 10.9	7.8- 11.8	7.6- 11.9
22 May - 5 June		R6	R5	38.82	37.98	22.37	23.27	48.46	59.13	21.40	28.66	10.63	9.30	11.54	11.28
	Range			37.4- 40.2	34.4- 40.0	19.4- 24.3	21.7- 24.9	43.0- 56.0	48.0- 81.0	14.0- 27.0	20.0- 67.0	7.8- 11.3	4.3- 11.4	9.4- 12.2	8.5- 13.2
6 - 20 June	R7		R6	35.40	32.22	24.41	23.13	62.13	79.00	37.93	57.43	6.92	3.68	8.15	6.16
	Range			31.6- 38.4	26.6- 35.0	22.9- 26.4	21.4- 24.4	49.0- 78.0	67.0- 88.0	30.0- 55.0	39.0- 92.0	0.8- 10.6	0.0- 9.5	5.2- 10.2	2.2- 8.6
21 June - 5 July		R7		34.45	30.90	23.42	22.90	67.86	75.80	42.86	64.13	6.46	2.24	7.44	4.79
	Range			29.6- 36.0	26.6- 32.8	22.4- 24.0	21.5- 23.9	56.0- 83.0	59.0- 84.0	30.0- 64.0	51.0- 89.0	1.6- 10.0	0.0- 5.9	5.4- 9.6	2.9- 6.4
6 - 20 July			R7	31.45	28.76	23.50	22.46	73.66	82.00	55.33	73.46	3.11	1.64	5.64	3.96
	Range			27.8- 34.2	24.0- 33.6	22.7- 24.4	21.5- 23.5	69.0- 83.0	69.0- 95.0	43.0- 87.0	48.0- 98.0	0.0- 7.1	0.0- 7.5	4.2- 6.8	0.8- 7.2
	Growing degree days			3050.45 (2012)		3021.45 (2013)									

R1 - Germination + seedling stage, R2 - Vegetative stage, R3 - Vegetative + flower bud initiation stage, R4 - Flowering + pod formation, R5 - Pod development stage, R6 - Pod maturation, R7 - Maturity and harvesting stage and having very low water holding capacity. Six varieties were used in the experiment belonging to Spanish bunch type. Each variety was sown on three sowing dates with 15-days interval i.e. from 6th February, 2012 to 8th March 2012 and from 6th February 2013 to 8th March 2013. Treatments were replicated three times in a split-plot arrangement with sowing dates as main plots and cultivars as sub-plots.

The observations were recorded on days to emergence, days to appearance of first flower bud, days to anthesis, days to peg formation, days to 50 per cent flowering and days to physiological maturity. Sowing dates were divided into different fortnights with respect to different critical growth phases i.e. R1 (Germination + seedling stage), R2 (Vegetative stage), R3 (Vegetative + flower bud initiation stage), R4 (Flowering + pod formation), R5 (Pod development stage), R6 (Pod maturation) and R7 (Maturity and harvesting stage). Temperature variations at different stages of crop growth were observed and accordingly the results in context to phenological development of six cultivars are summarized below.

Results and Discussion

Environment : The weather experienced during the experiments in the two years is presented in Table 1. However, since sowing dates differed so greatly, consideration of the conditions prevailing during various phases of growth is more appropriate. From the Table 1, it is found that, the average maximum/ minimum temperatures during the course of first sowing date sown on 6th February were 31.80/11.12°C and 31.34/14.30°C at R1 (Germination+seedling stage), 33.95/12.50°C and 34.5/13.16°C at R2 (Vegetative stage), 34.80/13.02°C and 35.79/16.35°C at R3 (Vegetative and flower bud initiation), 38.10/ 20.84°C and 38.26/18.66°C at R4 (Flowering + pod formation), 38.06/19.58°C and

Table 2. Field emergence and days to first flower bud as influenced by different sowing dates and varieties

Sowing date	Days to field emergence			Days to first flower bud		
	2012	2013	Pooled	2012	2013	Pooled
S_1	8.94	10.00	9.47	34.78	35.50	35.14
S_2	8.89	10.06	9.47	31.87	32.67	32.27
S_3	6.61	8.28	7.44	30.07	31.56	30.81
S.E.±	0.218	0.695	0.163	0.215	0.424	0.233
C.D. at 5%	0.854	2.729	0.990	0.843	1.666	0.754
Varieties						
V_1	8.33	10.00	9.17	31.67	32.89	32.28
V_2	8.22	9.67	8.94	32.11	33.11	32.61
V_3	8.00	9.78	8.89	32.67	33.56	33.11
V_4	8.56	9.78	9.17	31.93	32.89	32.41
V_5	7.44	8.44	7.94	32.38	33.56	32.97
V_6	8.33	9.00	8.67	32.67	33.44	33.06
S.E.±	0.236	0.390	0.193	0.270	0.438	0.131
C.D. at 5%	0.681	1.127	NS	NS	NS	NS
Interaction						
S_1V_1	9.33	10.67	10.00	34.20	34.67	34.43
S_1V_2	8.33	10.33	9.33	34.27	35.00	34.63
S_1V_3	8.67	10.67	9.67	35.67	36.00	35.83
S_1V_4	9.33	10.33	9.83	34.53	35.33	34.93
S_1V_5	9.00	9.00	9.00	34.93	36.67	35.80
S_1V_6	9.00	9.00	9.00	35.07	35.33	35.20
S_2V_1	9.00	10.33	9.67	31.13	32.00	31.57
S_2V_2	8.67	10.33	9.50	32.33	33.00	32.67
S_2V_3	9.00	10.33	9.67	32.40	33.00	32.70
S_2V_4	9.00	10.00	9.50	31.07	32.00	31.53
S_2V_5	8.00	9.33	8.67	31.93	33.00	32.47
S_2V_6	9.67	10.00	9.83	32.33	33.00	32.67
S_3V_1	6.67	9.00	7.83	29.67	32.00	30.83
S_3V_2	7.67	8.33	8.00	29.73	31.33	30.53
S_3V_3	6.33	8.33	7.33	29.93	31.67	30.80
S_3V_4	7.33	9.00	8.17	30.20	31.33	30.77
S_3V_5	5.33	7.00	6.17	30.27	31.00	30.63
S_3V_6	6.33	8.00	7.17	30.60	32.00	31.30
S.E.±	0.408	0.676	0.334	0.468	0.759	0.228
C.D. at 5%	NS	NS	NS	NS	NS	NS

V1 - RHRG-6021, V2 - RHRG-6083, V3 - JL-501, V4 - TAG-24, V5 - SB-XI, V6 - TPG-41, S1 - 6 February, S2 - 22th February, S3 - 8th March

39.88/22.17°C at R5 (Pod development stage), 38.57/21.06°C and 39.75/23.80°C at R6 (Pod maturation), 35.40/24.41°C and 32.22/23.13°C at R7 (Physiological maturity and harvesting stage) in the year 2012 and 2013, respectively.

Regarding sowing date S2 (06/02) all critical growth stages comes under temperature regime from R1 (33.95/12.50°C, 34.05/13.16°C) to R7 (34.45/23.42°C, 30.90/22.90°C) including maximum and minimum temperature during the year 2012 and 2013. As far as sowing date S3 is concerned critical growth stages i.e. from R1 to R7 comes under temperature regime of (34.80/13.02°C, 35.79/16.35°C) to (31.45/23.50°C, 28.76/22.46°C) including maximum and minimum temperatures during 2012 and 2013. Temperature range was found to be increasing throughout the growth stages up to pod development stage but tends to decrease towards maturity stage during both the years 2012 and 2013. The both the seasons were similar for the temperatures at different growth phases, but year 2013 appreciably cooler than 2012 during the vegetative phase. Late sowing increased the mean temperature during growth phases upto pod development relative to the early sowing dates.

Phenology : Among the sowing dates studied, S3 (08/03) contributed minimum days for emergence (7.44), days to appearance of first flower bud (30.81), days to anthesis (30.84) or it may be related with days to 50% flowering (40.92), days to peg formation (36.79) and days to physiological maturity (126.14). This early phenological development may be due to warm temperature.

The processes of germination and emergence have a minimum threshold value, optimum range and maximum threshold value

Table 3. Days to anthesis and days to 50% flowering as influenced by different sowing dates and varieties

Sowing date	Days to anthesis			Days to 50% flowering		
	2012	2013	Pooled	2012	2013	Pooled
S_1	34.93	35.56	35.24	45.44	48.39	46.92
S_2	32.02	32.67	32.34	41.89	44.56	43.22
S_3	30.13	31.56	30.84	40.33	41.50	40.92
S.E.±	0.228	0.402	0.228	0.157	0.109	0.478
C.D. at 5%	0.895	1.578	1.386	0.617	0.427	2.910
Varieties						
V_1	31.76	32.89	32.32	41.56	44.44	43.00
V_2	32.31	33.11	32.71	44.89	46.89	45.89
V_3	32.84	33.56	33.20	44.33	46.67	45.50
V_4	32.09	32.89	32.49	40.89	43.00	41.94
V_5	32.49	33.67	33.08	40.89	42.78	41.83
V_6	32.69	33.44	33.07	42.78	45.11	43.94
S.E.±	0.263	0.431	0.156	0.264	0.321	0.169
C.D. at 5%	NS	NS	NS	0.762	0.926	0.510
Interaction						
S_1V_1	34.33	34.67	34.50	45.00	49.33	47.17
S_1V_2	34.67	35.00	34.83	47.67	50.00	48.83
S_1V_3	35.93	36.00	35.97	45.33	48.00	46.67
S_1V_4	34.73	35.33	35.03	43.33	46.67	45.00
S_1V_5	34.93	37.00	35.97	43.00	45.67	44.33
S_1V_6	35.00	35.33	35.17	48.33	50.67	49.50
S_2V_1	31.27	32.00	31.63	40.33	43.33	41.83
S_2V_2	32.33	33.00	32.67	44.33	47.00	45.67
S_2V_3	32.67	33.00	32.83	44.67	48.00	46.33
S_2V_4	31.20	32.00	31.60	40.67	42.67	41.67
S_2V_5	32.27	33.00	32.63	40.33	42.67	41.50
S_2V_6	32.40	33.00	32.70	41.00	43.67	42.33
S_3V_1	29.67	32.00	30.83	39.33	40.67	40.00
S_3V_2	29.93	31.33	30.63	42.67	43.67	43.17
S_3V_3	29.93	31.67	30.80	43.00	44.00	43.50
S_3V_4	30.33	31.33	30.83	38.67	39.67	39.17
S_3V_5	30.27	31.00	30.63	39.33	40.00	39.67
S_3V_6	30.67	32.00	31.33	39.00	41.00	40.00
S.E.±	0.456	0.746	0.270	0.457	0.556	0.293
C.D. at 5%	NS	NS	NS	1.319	1.605	0.883

V1 - RHRG-6021, V2 - RHRG-6083, V3 - JL-501, V4 - TAG-24, V5 - SB-XI, V6 - TPG-41, S1 - 6 February, S2 - 22th February, S3 - 8th March for both temperature and soil moisture contents. As S3 sowing date having maximum values of evaporation (8.32/8.02 mm, 8.68/8.36 mm, 9.40/9.23 mm and 9.76/10.92 mm) right from R1 (seedling+ emergence stage to R4 (Flowering + pod formation) stage these values were comparatively more than that of S1 and S2. This might be due to increment in soil temperature. Mohamed *et al.*, (1988) and Kumar (2012) also reported similar findings.

It is also found that, average maximum and minimum temperatures for S1 (06/02) sowing date were 33.95/12.50°C and 34.05/ 13.16°C at R2 (Vegetative and flower bud initiation stage) while temperature regimes for S3, it was 38.30/17.99°C and 36.82/17.48 0C. Regarding days to appearance of first flower bud, S3 took minimum days (30.81-pooled) as compared with S1 (35.14) and S2 (32.27) (Table 3). Similar trend was observed in case of days to anthesis, days to 50 per cent flowering, days to peg formation and days to physiological maturity. i.e. S1 recorded maximum days for anthesis (35.24), peg formation (41.87) (Table 3), days to 50 per cent flowering (46.92) and physiological maturity (129.00 in 2013) (Table 4) as having minimum temperature regimes during early phenological development.

As far years are concerned both years depicted temperature variation. Here GDD (growing degree days) in terms thermal units for both years are calculated which reports that temperature had a significant effect on phenology of groundnut i.e. number of days to emergence and flowering progressively reduced with a rise in temperature. As sowing date S3 required minimum days (124.61) having cumulative growing degree days (GDD) 3050.45 during 2012 while during 2013 same sowing date took 127.67 days for maturity having 3021.45 GDD (Table 1).These results

Table 4. Days to peg formation and days to physiological maturity as influenced by different sowing dates and varieties

Sowing date	Days to peg formation			Days to physiological maturity		
	2012	**2013**	**Pooled**	**2012**	**2013**	**Pooled**
S_1	41.46	42.28	41.87	125.56	129.00	127.28
S_2	38.33	39.50	38.92	125.28	128.94	127.11
S_3	35.92	37.67	36.79	124.61	127.67	126.14
S.E.±	0.242	0.537	0.233	0.165	0.378	0.155
C.D. at 5%	0.951	1.507	0.718	0.648	0.985	NS
Varieties						
V_1	37.93	39.33	38.63	130.33	136.33	133.33
V_2	38.07	39.00	38.53	130.00	132.44	131.22
V_3	38.82	40.22	39.52	120.67	123.78	122.22
V_4	38.27	39.11	38.69	118.44	121.89	120.17
V_5	39.11	40.33	39.72	120.22	123.78	122.00
V_6	39.22	40.89	40.06	131.22	133.00	132.11
S.E.±	0.326	0.452	0.256	0.425	0.651	0.609
C.D. at 5%	0.942	1.306	0.770	1.226	1.881	1.835
Interaction						
S_1V_1	39.93	40.00	39.97	130.00	139.00	134.50
S_1V_2	39.93	40.00	39.97	129.67	131.67	130.67
S_1V_3	43.00	43.67	43.33	122.67	122.67	122.67
S_1V_4	41.73	42.67	42.20	118.67	122.00	120.33
S_1V_5	41.80	44.00	42.90	120.33	124.00	122.17
S_1V_6	42.33	43.33	42.83	132.00	134.67	133.33
S_2V_1	37.67	38.67	38.17	131.00	136.67	133.83
S_2V_2	38.60	39.33	38.97	130.00	133.33	131.67
S_2V_3	38.53	39.67	39.10	120.67	126.33	123.50
S_2V_4	37.20	38.00	37.60	118.33	121.00	119.67
S_2V_5	38.93	40.67	39.80	120.33	123.67	122.00
S_2V_6	39.07	40.67	39.87	131.33	132.67	132.00
S_3V_1	36.20	39.33	37.77	130.00	133.33	131.67
S_3V_2	35.67	37.67	36.67	130.33	132.33	131.33
S_3V_3	34.93	37.33	36.13	118.67	122.33	120.50
S_3V_4	35.87	36.67	36.27	118.33	122.67	120.50
S_3V_5	36.60	36.33	36.47	120.00	123.67	121.83
S_3V_6	36.27	38.67	37.47	130.33	131.67	131.00
S.E.±	0.565	0.783	0.443	0.735	1.128	1.054
C.D. at 5%	1.632	2.262	1.334	NS	3.258	NS

V1 - RHRG-6021, V2 - RHRG-6083, V3 - JL-501, V4 - TAG-24, V5 - SB-XI, V6 - TPG-41, S1 - 6 February, S2 - 22^{th} February, S3 - 8^{th} March are due to increment in temperatures at respective growth stages. Enhancement in early phenological development due to influence of temperature also reported by Begnall and King (1991a) and Kumar (2012).

Among six genotypes of groundnut tested, these genotypes showed significant differences for the days to 50 per cent flowering, days to peg formation and days to physiological maturity. Genotype TAG-24 (V4) recorded minimum days for emergence (7.44 and 8.44) and physiological maturity i.e.118.44 and 121.89 days, respectively during both years 2012 and 2013, while RHRG-6021 (V1) recorded significantly maximum number of days to field emergence (10.00) in 2013 (Table 2) and physiological maturity (133.33 days-pooled) Table 4.

The results of this study indicate that there is significant variation for phenological traits for sowing dates due to seasonal variation in temperature. In context with phenological development (Table 2 to 4) it is clear that, sowing dates significantly affected phenology (time to emergence, flowering and maturity) with groundnut sown in February taking the longest time to reach these phenological stages. That means all the genotypes took progressively less time to flower and to complete reproductive processes as sowing was delayed from February (having minimum temperature) to March (having maximum temperature).Among different sowing dates, S3 resulted into early phenological development in terms of floral bud initiation, early 50 per cent flowering and physiological maturity due to rise in temperature toward reproductive phase.

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Genetic Diversity Studies in Napier Grass (*Pennisetum purpureum* Schum)

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Abstract

The nature of magnitude of genetic diversity was studied in a set of 28 Napier grass (*Pennisetum purpureum* Schum) diverse genotypes. The objective was to select the parents with maximum genetic divergence to use in hybridization programme. The genotypes were grouped into six clusters using Mahalanobis D^2 statistics. Cluster-I was the largest with 21 genotypes followed by cluster-VI with 3 genotypes. The Cluster-II, III, IV and V were monogenotypic. The maximum inter cluster distance was observed between Cluster-V and cluster-VI followed by cluster-I and cluster-VI. The green forage yield contributed maximum (29.89%) followed by plant height (23.02%), leaf width (12.96%), number of leaves (11.38%) and leaf length (10.32) towards genetic divergence.

Key words : Genetic divergence, cluster, variability, Napier grass

Napier grass (*Pennisetum purpureum* Schum.), also known as elephant grass, is an important forage crop in the tropical and subtropical regions. It is distributed in Asia, Africa, Southern Europe and America and dry and semi-arid areas of India, valued for its high biomass production, perennial nature, pest resistance and forage quality (Schank *et al.*, 1993). Because of its rapid growth and degradable biomass characteristics, Napier grass also has potential for bioenergy production and conversion to alcohol or methane (Anderson *et al.*, 2008). Napier grass is an open-pollinated species with low seed production, so its commercial propagation is mostly done vegetatively. Owing to its natural crossing, the genetic diversity within this species is high (Augustin and Tcacenco, 1993). Improvement of existing varieties is a continuous process in plant breeding. The selection of parents with high genetic variability is a basic requirement in any successful hybridization to produce desirable character combinations for selecting high yielding genotypes. Mahalanobis D^2 statistic (1936) is the rational criterion for selecting such parents. A very limited work on this aspect in Napier grass has been done. Therefore, an attempt was made to study the genetic diversity among the genotypes and also to identify the suitable genotypes for hybridization programme on the basis of clustering pattern.

Materials and Methods

Twenty-eight diverse Napier grass genotypes were grown in two replications under randomized block design at Grass Breeding Scheme, Mahatma Phule Krishi Vidyapeeth, Rahuri during *kharif*, 2009-10. Each genotype was represented by two rows of 7.20 m length by keeping 90 cm spacing between rows and 60 cm between plants. All the recommended package of practices for Napier grass was followed to raise a healthy crop. Total three cuts were taken; first cut was at 60 days after planting and subsequent two cuts at an interval of 45 days. Observations

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were recorded on ten randomly selected plants of each genotype from each replication for nine characters *viz.*, for plant height (cm), number of tillers, number of leaves, leaf length (cm), leaf width (cm), leaf : stem ratio, dry matter yield plant^{-1} (kg) and green forage yield plant^{-1} (kg). Mahalanobis D^2 (1936) statistic was used to estimate genetic divergence. The genotypes were grouped into different clusters by following Tocher's method as described by Rao (1952).

Results and Discussion

The analysis of variance showed significant differences among 28 genotypes for nine characters indicating the presence of genetic variability. The simultaneous test of significance based on Wilk's criteria for pooled effect of all the characters also showed significant differences among genotypes for aggregate of all characters.

The minimum and maximum D^2 values were observed between the pair of genotypes GBN-2001-2 and GBN-2001-3 (10.30) and FD-461 and FD-483 (1380.68), respectively. Based on relative magnitude of D^2 values, 28 genotypes were grouped into six clusters (Table 1), indicating the presence of diversity for different traits. The cluster-I (21) had the largest number of genotypes, followed by cluster-VI (3). The cluster-II, cluster-III, Cluster-IV and cluster-V were solitary indicating wide diversity from the rest and also from each other. These finding confirmed the earlier report of Suthamati and Dorairaj (1994) and Sukanya (1995).

It is interesting to note that 19 genotypes of Coimbatore origin were grouped into all six clusters while, all nine genotypes of Rahuri were grouped into single cluster- I along with genotypes of Coimbatore indicating that the geographic diversity is not necessarily related to

Table 1. Grouping of 28 genotypes of Napier grass in different clusters

Cluster no.	No. of genotype	Name of genotype	Origin
I	21	GBN-2001-1, GBN-2001-3, GBN-2001-4, GBN-2001-5, GBN-2001-6, GBN-2001-7, GBN-2001-8, GBN-2001-9, GBN-2001-10	Rahuri
		FD-448, FD-451, FD-444, GBN-2001-2, FD-1890-1, , FD-436, FD-473, FD-432, FD-1890-2, CN-092, FD-472, FD-453	Coimbtore
II	1	FD-468	Coimbtore
III	1	CN-014	Coimbtore
IV	1	CN-011	Coimbtore
V	1	FD-461	Coimbtore
VI	3	FD-483, FD-482, FD-477	Coimbtore

Table 2. Intra (Diagonal) and Inter (above diagonal) cluster 'D' values of Napier grass genotypes

Cluster	I	II	III	IV	V	VI
I	10.121	13.476	14.480	14.348	13.569	31.214
II		0.000	12.710	8.546	14.917	30.861
III			0.000	13.731	19.517	27.031
IV				0.000	13.313	29.830
V					0.000	34.327
VI						12.867

Table 3. Percent contribution of various characters to divergence in Napier grass

Source	Times rank 1st	Contribution (%)
Plant height (cm)	87	23.02
Number of tillers plant^{-1}	20	5.29
Number of leaves plant^{-1}	43	11.38
Number of internodes plant^{-1}	9	2.38
Leaf length (cm)	39	10.32
Leaf width (cm)	49	12.96
Leaf : Stem ratio	15	3.97
Dry matter yield plant^{-1} (kg)	3	0.97
Green forage yield plant^{-1} (kg)	113	29.89

genetic diversity. Similar results were also reported by Suthamati and Dorairaj (1994), Sukanya (1995) and Bramwel *et al*., (2013) in Napier grass and Shanmuganathan *et al*., (2006), Lakshmana *et al*., (2010) and Mukesh Sankar *et al*., (2014) in pearl millet.

The intra and inter cluster D values were worked out from divergence analysis and presented in Table 2. The highest intra cluster distance was observed for cluster VI (12.867) followed by cluster I (D=10.121) suggesting the genotypes present in these cluster might have different genetic architecture. The highest inter-cluster distance was observed between cluster V and VI (D = 34.327) followed by cluster I and VI (D = 31.214), cluster II and VI (D = 30.861) and cluster IV and VI (D = 29.830) suggesting that genetic makeup of genotypes included in these clusters may be entirely different from one another. The lowest inter cluster distance was observed between cluster- II and IV (8.546), indicating that the genetic constitution of these genotypes in one cluster were in close proximity with the genotype in other cluster.

The variance of cluster means provides information on relative importance of different characters towards yield. In order to study the contribution of individual characters towards divergence, among nine characters, green forage yield (29.89%) contributed maximum followed by plant height (23.02%), leaf width (12.96%), number of leaves (11.38%) and leaf length (10.32%) indicating that these characters were responsible for genetic divergence (Table 3). Number of tillers (5.29%), leaf: stem ratio (3.97%), number of internodes (2.38%) and dry matter yield (0.79%) contributed the least to genetic divergence. Lakshmana *et al.,* (2010) also reported highest contribution of plant height to total genetic divergence in pearl millet.

The cluster means for nine characters are presented in Table 4. Cluster II had highest mean for plant height (237.50 cm), Cluster III recorded maximum number of leaves (15.33), number of internodes (10.90) and leaf width (3.58 cm). Cluster V had highest mean for leaf:

Table 4. Cluster mean of various characters in Napier grass

Cluster	Plant height (cm)	No. of tillers plant^{-1}	No. of leaves plant^{-1}	No. of inter-nodes plant^{-1}	Leaf length (cm)	Leaf width (cm)	Leaf: Stem ratio	Dry matter yield plant^{-1} (kg)	Green forage yield plant^{-1} (kg)
I	161.44	10.97	12.18	7.51	74.59	2.37	0.73	0.92	3.75
II	237.50	17.92	14.10	10.28	77.92	1.98	0.52	1.46	5.56
III	220.40	16.70	15.33	10.90	83.53	3.58	0.61	1.98	8.14
IV	235.86	20.00	12.98	10.28	89.90	2.71	0.63	2.14	7.17
V	166.88	22.52	13.10	9.90	63.22	2.06	0.83	1.25	4.65
VI	218.26	26.22	12.98	9.19	91.67	3.31	0.59	3.07	14.42

stem ratio (0.83). Cluster VI recorded the highest mean for number of tillers 26.22 plant^{-1}, leaf length (91.67 cm), dry matter yield (3.07 kg plant^{-1}) and green forage yield (14.42 kg plant^{-1}).

In the present investigation, on the basis of inter-cluster distance, cluster means and *per se* performance observed, the hybridization programme is suggested which involves the genotypes as a parents *viz*., GBN-2001-8, CN-092 (Cluster-I), FD-461 (Cluster-V), FD-468 (Cluster-II), FD-477, FD-483 (Cluster-VI), and CN-011 (Cluster-IV). These genotypes may produce better hybrids and may also result in production of transgessive segregants in advance generation.

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" Phule Govardhan"- A New Variety of Marvel Grass for Green Forage

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Abstract

Phule Govardhan (Marvel-2008-1) is a marvel grass variety developed by the clonal selection from marvel grass collected from Junnar (Pune) area. Based on it's performance under irrigated condition in station and multilocation trials, it recorded 30.37 and 33.07 per cent higher green forage and dry matter yield, respectively than the check Marvel-06-40. It has better IVDMD %, DDM % and brix and low NDF, ADF, ash and ether extract % than Marvel-06-40. It is moderately resistant to leaf spot and resistant to rust disease and found less susceptible to jassids. Considering the high yield potential of Phule Govardhan (Marvel-2008-1), better nutritional qualities and resistance to pest and diseases over Marvel-06-40, it was , therefore, released under the name Phule Govardhan for green forage under irrigated condition of Maharashtra by Joint Agresco-2013.

Key words : Phule Govardhan, marvel grass, green forage yield, dry matter yield, irrigated

India as compared to other countries of the world has large number of livestock. Moreover, there is a continuous increase in both livestock and human population. Only 6.9 million hectare (4.4% of the total cropped area) is under fodder crops and there is practically little scope for area expansion. Available resources in the country can meet only half of the present feed and fodder requirements and that too through the feeding of poor quality forages. One of the problems facing India today is insufficient quantity of feed and fodder to the large livestock population. The traditional forage production system is under great strain, owing to both land and input constraints. Therefore, the only hope to meet this challenge is raise the productivity level of cultivated forage crops through improved varieties and production technology and to harvest more forage from non-traditional sources.

Marvel grass is an excellent and widely used fodder grass much appreciated by all classes of ruminants. Marvel grass can be used in pastures, in cut-and-carry system or for hay-making or silage making if it is cut before flowering (FAO, 2010). It is grown well in saline soils and the in area receiving rainfall from 300 to 1500 mm.

India has eight species of Marvel (*Dichanthium*) distributed in various agro-ecological zones (Arora *et al*., 1975), but only two species, *viz*., *Dichanthium annulatum* (Forsk.) stapf and *D. caricosum* (L.) *A. camus*, are important for their forage attributes. Out of eight species, four are endemic to India (Bor, 1960). Different ploidy levels and morphologically distinct types are reported in the *Dichanthium annulatum* complex (Mehra, 1961).

In Maharashtra, the marvel varieties Marvel-7 and Marvel-8 were identified for pasture under rainfed condition during the year 1973 and Phule Marvel-06-40 during 2012. However, none of the marvel varieties released

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Table 1. Mean performance of Phule Govardhan (Marvel-2008-1) for green forage yield and dry matter yield (q ha^{-1}) in comparison with the Marvel-06-40 in different trials

Trials and years	No. of trials	Green forage yield (q ha^{-1})			Dry matter yield (q ha^{-1})		
		Phule Gover-dhan	Marvel -06-40	% increase over Marvel -06-40	Phule Gover-dhan	Marvel -06-40	% increase over Marvel -06-40
Station trials [2009-2011]	3	487.04	300.99	61.81	148.00	90.19	64.10
Multilocation trials at Rahuri, Dhule, Vadgaon Maval, Kolhapur [2010-2012]	12	609.55	485.69	25.50	173.08	135.33	27.90
Over all Mean performance in Station and Multilocation trials [2009-2012]	15	585.05	448.75	30.37	168.07	126.30	33.07

Table 2. Green forage yield and dry matter yield (q ha^{-1}) of Phule Govardhan (Marvel-2008-1) as influenced by fertilizer levels and plant spacing during the year 2012

	Green forage yield (q ha^{-1})			Dry matter yield (q ha^{-1})		
(a) Variety x fertilizer levels						
Variety			**Fertilizer levels (NPK kg ha^{-1})**			
	40:20:20	60:40:20	Mean (V)	40:20:20	60:40:20	Mean (V)
Phule Govardhan	779.79	952.97	866.38	236.69	278.96	257.83
Marvel-06-40	306.42	353.12	329.77	80.95	104.33	92.64
Mean (F)	543.11	653.05		158.82	191.65	
(b) Variety x spacing						
Variety			**Spacing (cm)**			
	45 x 30	60 x 30	Mean (V)	45 x 30	60 x 30	Mean (V)
Phule Govardhan	952.27	780.50	866.38	297.57	218.08	257.83
Marvel-06-40	378.48	281.06	329.77	102.94	82.33	92.64
Mean (S)	665.37	530.78		200.26	150.21	
(c) Fertilizer levels x spacing						
Fertilizer (NPK kg ha^{-1})			**Spacing (cm)**			
	45 x 30	60 x 30	Mean (F)	45 x 30	60 x 30	Mean (F)
40:20:20	602.90	483.32	543.11	178.36	139.28	158.82
60:40:20	727.87	578.23	653.05	222.15	161.14	191.65
Mean (S)	665.38	304.14		200.26	150.21	

	Green forage yield (q ha^{-1})		Dry matter yield (q ha^{-1})	
	S.E. ±	C.D. at 5%	S.E. ±	C.D. at 5%
Varieties (V)	5.50	16.68	1.62	4.92
Fertilizer level (F)	5.50	16.68	1.62	4.92
Spacings (S)	5.50	16.68	1.62	4.92
V x F	7.78	23.59	2.29	6.96
	7.78	23.59	2.29	6.96
F x S	7.78	NS	2.29	6.96

for irrigated condition in Maharashtra state. Hence, the efforts were made to develop a new marvel variety for green forage under irrigated condition.

Materials and Methods

The variety Phule Govardhan is a clonal selection from local marvel grass collected from Junnar (Puene) area. The selected clones from marvel were tested at Grass Breeding Scheme, MPKV, Rahuri during 2009 to 2011 in station trial and in multilocation trials during 2010 and 2012 under irrigated condition at Rahuri, Dhule, Vadgaon Maval and Kolhapur. The data recorded on green forage yield and dry matter yield (q ha^{-1}) in different trials was analyzed by adopting method suggested by Panse and Sukhatme (1967).

Results and Discussion

Performance of Phule Govardhan in station trials : The data on green forage yield and dry matter yield (q ha^{-1}) of Phule Govardhan in comparison with Marvel-06-40 is presented in Table 1. In three station trials (2009-2011) conducted at Rahuri centre, Phule Govardhan recorded higher green fodder yield (487.04 q ha^{-1}) and dry matter yield (148.00 q

Table 3. Reaction to major diseases and pests

Year	Percent disease intensity by leaf spot (*Helminthosporium* spp.)		Percent disease intensity by rust (*Puccinia* spp.)		No. of jassids averaged^{-1} 10 plants	
	Phule Goverdhan	Marvel-06-40	Phule Goverdhan	Marvel-06-40	Phule Goverdhan	Marvel-06-40
2011	8.30 (16.72)	8.45 (16.84)	6.90 (15.21)	6.75 (15.05)	10.35 (3.29)	10.90 (3.37)
2012	3.63 (10.98)	3.80 (11.23)	2.70 (9.43)	3.00 (9.96)	3.95 (2.11)	3.90 (2.08)
Mean	5.97 (13.85)	6.13 (14.01)	4.80 (12.35)	4.88 (12.51)	7.15 (2.70)	7.40 (2.72)
Reaction	MR	MR	R	R	Less Succeptible	
SE	0.44		0.34		0.07	
CD	NS		0.98		0.22	

Figures in parentheses in case of leaf spot and rust are arcsine while for jassids are Sqr. transformed values.

Table 4. Mean quality parameters of Phule Govardhan in comparison with Marvel-06-40

Characters	Phule Govardhan			Marvel-06-40		
	2011	2012	Mean	2011	2012	Mean
Crude protein (%)	6.12	6.87	6.50	7.00	6.69	6.85
Acid detergent fibre (%)	55.40	52.00	53.70	56.40	52.20	54.30
Neutral detergent fibre (%)	71.40	73.20	72.30	70.20	74.60	72.40
Crude fibre (%)	41.60	37.60	39.60	39.80	37.40	38.60
Hemi-cellulose (%)	16.00	21.20	18.60	13.80	22.40	18.10
IVDMD (%)	58.40	64.20	61.30	56.80	62.80	59.80
Ash (%)	11.40	11.00	11.20	10.90	12.20	11.55
Nitrogen free extract	35.38	37.78	36.58	37.09	37.53	37.31
Ether extract	0.79	0.75	0.77	0.91	0.94	0.93
DDM (%)	45.74	48.39	47.07	44.96	48.24	46.60
Brix	7.62	7.38	7.50	5.45	5.15	5.30

ha^{-1}) over check Marvel-06-40 (300.99 q ha^{-1} GFY and 90.19 q ha^{-1} DMY) which was 61.81 and 64.10 per cent higher for GFY and DMY, respectively over Marvel-06-40.

Performance of Phule Govardhan in multilocation trials : The multilocation trials were conducted at Rahuri, Dhule, Vadgan Maval and Kolhapur for three years from 2010 to 2012. The pooled mean performance of Phule Govardhan in 12 multilocation trials (Table 1) revealed that it had recorded 609.55 q ha^{-1} green forage and 173.08 q ha^{-1} dry matter yield than check Phule Marvel-06-40 (485.69 q ha^{-1} GFY and 135.33 q ha^{-1} DMY) and in percent it was 25.50 and 27.90 per cent higher over Marvel-06-40 for green forage and dry matter yield, respectively.

Overall performance : Considering the overall mean performance in station and multilocation trials (15 trials) conducted from 2009 to 2012, Phule Govardhan recorded higher green forage yield (585.05 q ha^{-1}) and dry matter yield (168.07 q ha^{-1}) than Marvel-06-40 (448.75 q ha-1 GFY and 126.30 q ha^{-1} DMY) which was 30.37 and 33.07 per cent higher for GFY and DMY, respectively over Marvel-06-40. (Anonymous, 2013).

Performance of Phule Govardhan in agronomic trial : The genotype Phule Govardhan recorded significantly higher green forage yield (866.38 q ha^{-1}) and dry matter yield (257.83 q ha^{-1}) over Marvel-06-40 (329.77 q ha^{-1} GFY, 92.64 q ha^{-1} DMY). The green forage and dry matter yield increased with increase in fertilizer dose and closer spacing (45 x 30 cm).

The interaction effects of varieties x spacing and varieties x fertilizer dose were found significant for green forage and dry matter yield while interaction effect of fertilizer x spacing was found to be significant for dry

Table 5. Botanical description of "Phule Govardhan"

Characters		
Plant height (cm)	:	75 to 115
Growth habit	:	Erect
Growth Pattern	:	Linear
No. of inter nodes	:	8 to 11
Inter node length (middle)	:	12 to 18 cm
Pigmentation on nodes	:	Brown
Hairiness at inter node	:	Absent
Hairiness at node	:	Less hairs
Solidness of stem	:	Solid
Stem juicy /pithy	:	Juicy
No. of tillers/tussock	:	High tillering (75-95)
Regeneration Capacity in multicut	:	multicut, perennial
Bloom or Bloomless	:	Bloom (all the year round)
Leaf sheath colour	:	Green
Leaf sheath hairiness	;	Hairy
leaf sheath length	:	6-7 cm
Leaf colour	:	Green
Leaf shape	:	Linear, tapering to the point
No. of leaves/main tiller	:	10 to 15
Length of leaves (cm)	:	24 to 29 cm
Breadth of leaves (cm)	:	0.6 to 0.8 cm
L/ S ratio	:	0.90
Leaf waxiness	:	Absent
Hairy at leaf blade	:	Present
Leaf orientation	:	Straight
Midrib colour	:	Green
Days to 50 % flowering	:	50 to 55 days
No. of spikes	:	4-7
Length of spike	:	6.0 -8.0 cm
Other characteristics	:	Pedicellate, broadly elliptic, laterally compressed & densely combination
Awn or Awnless	:	Awned
1000 seed (Spikelets) wt. (g)	:	Low, < 1.5 g / 1000 seed wt. (Viable seed is not produced)
Seed colour,	:	White grey
Duration of crop (No. of days)	:	Perennial
Marker character of variety	:	Erect growth habit, brown pigment on nodes, less hairs on nodes and green leaves.

matter yield only . From the interaction effects, it was revealed that Phule Govardhan recorded significantly higher green forage yield and dry matter yield at 45 x 30 cm spacing and fertilizer dose of 60:40:20 kg N:P:K ha^{-1} (Table 2).

Performance of Phule Govardhan for disease and pest reaction : The variety Phule Govardhan (Table 3) had shown moderately resistant reaction to leaf spot (5.97%) and resistant to rust disease (4.80%) and found less susceptible to jassids (7.15 jassids $plants^{-1}$).

Quality characters : In forage quality studies over two years (Table 4), Phule Govardhan recorded higher IVDMD (61.30%), DDM (47.07%) and brix (7.50%) and low ADF (53.70%) NDF (72.30%), ash (11.20%) and nitrogen free extract (36.58 %) than Marvel-06-40. It also had crude protein (6.50) is comparable with Marvel-06-40.

It had a medium flowering duration (50-55 days), erect in growth habit, green leaves and high tillering ability. This is the only variety of marvel grass which is multiplied through the stem budded cuttings (Table 5).

Being high yield potential of Phule Govardhan, better nutritional qualities and resistance to pest and diseases, the variety Phule Govardhan has been recommended for commercial cultivation for green forage under irrigated condition of Maharashtra by Joint Agresco, 2013.

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Production Potential and Nutrient Uptake of Castor (*Ricinus communis*) Based Intercropping System

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Abstract

A field experiment was conducted to study the performance of castor+vegetable intercropping systems during 2011-2013. The seed and stalk yield of castor were higher due to closer spacing (120 x 60 cm) than wider spacing (240 x 120 cm).Similarly, these yields were not influenced due to intercropping treatments; however maximum values were recorded with castor + fenugreek intercropping system. Among intercropping systems, castor intercropped with onion recorded higher green biomass yield of onion, castor equivalent yield and net realization. Land equivalent ratio (LER) varied in the order of their performance as fenugreek > spinach > onion >garlic when intercropped with castor. Higher uptake of major plant nutrients N, P and K by castor was noticed under sowing of castor at normal spacing of 120 cm x 60 cm than wider spacing of 240 cm x 120 cm as well as in all intercropping situations.

Key words : Castor, vegetables, intercropping, yield, economics, castor equivalent yield, LER, NPK uptake

Castor oil is considered as versatile industrial raw material and used in manufacturing of dyes, detergents, plaster of paris, soaps, costumes, polishes, greases, rubber, wetting agents, lubricants etc. Recently, use of castor oil has been reported in preparation of carbon paper, ether, synthetic rubber, synthetic fibers and synthetic resins for surface coating. It is used as bactericides, fungicides and castor cake which is excellent manure. In eri-silk producing areas, leaves of castor are fed to eri-worms. Castor stalks are useful in manufacturing paper, card-board and also widely used as fuel in rural area. Besides its higher economic usefulness castor is a hardy crop and grown under wide range of soil and climatic conditions.

The projected demand at the end of 2030 for vegetables is about 151-193 million tonnes. It may not be possible to increase the area under vegetables due to ever increasing pressure of food and commercial crops on cultivated land. One of the potential opportunities to meet the vegetable demand is by inclusion of vegetables in intercropping system. Secondly, there is an increasing trend among the farmers to cultivate the castor crop at wider spacing. The wider spacing helps in better growth and yield per unit area. Long duration, slow growth of castor crop during initial stages and wider spacing offers a scope for introduction of short duration quick growing vegetables as intercrops to improve the total productivity and net returns per unit area and time.

Materials and Methods

A field experiment was conducted at N.M. College of Agriculture Farm, Navsari Agricultural University, Navsari during *rabi* seasons of 2011-12 and 2012-13. During the period of experimentation the mean maximum temperature ranged between 28.0° to 37.6°C and 28.2° to 38.1°C, while minimum

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temperature ranged between 11.5° to 25.7°C and 9.9° to 25.6°C in 2011-12 and 2012-13, respectively. The mean morning relative humidity ranged between 59.5 to 90.4 and 52.4 to 87.7 per cent whereas afternoon relative humidity ranged between 16.5 to 74.8 and 20.1 to 64.3 per cent during this period, respectively. The mean evaporation ranged between 3.0 to 7.1 and 3.1 to 7.4 mm in the corresponding year, respectively. The soil of experimental plot was clayey in texture with slightly alkaline in reaction (pH 7.7), low in organic carbon (0.43 to 0.44%), low in available N (213 to 217 kg ha^{-1}) , medium in P_2O_5 (31.72 to 32.58 kg ha^{-1}) and high in K_2O (362 to 370 kg ha^{-1}). The seed of castor variety GCH-5 was used. Pili Patti and GG-3 varieties of onion and garlic respectively and local varieties of fenugreek and spinach were used for cultivation. The experiment was laid in Randomized Block Design with three replications. The experiment comprised of ten treatments; two treatments comprised of normal (120 x 60 cm) and wider (240 x 120 cm) spaced sole castor, four treatments where in wider spaced castor was intercropped with onion, garlic, fenugreek and spinach and four sole intercrop treatments were tested. The line sowing was done at a depth of 3-4 cm with two seeds of castor as per spacing. Fenugreek and spinach were sown in 18 lines (10 cm row spacing) while, onion and garlic were planted in 12 lines (15 cm row spacing) between two rows of wider spaced castor crop. The intercrops were sown on the same day of castor as an intercrops and as sole crops. The recommended doses of fertilizers i.e. 80:40:0, 100:50:50, 50:50:50, 20:40:0 and 50:50:0 kg $N:P_2O_5:K_2O$ ha^{-1} were applied to castor, onion, garlic, fenugreek and spinach, respectively.

The first irrigation was given immediately after sowing for satisfactory germination of the

Table 1. Yield of castor, green biomass yield of intercrops, LER, Castor Equivalent Yield and economics as influenced by spacing and Vegetable intercropping systems (Pooled mean)

Treatment	Seed yield (kg ha^{-1})	Stalk yield (kg ha^{-1})	Inter-crop yield (kg ha^{-1})	LER	Castor equi-valent yield (kg ha^{-1})	Gross reali-zation (Rs. ha^{-1})	Cost of culti-vation (Rs. ha^{-1})	Net reali-zation (Rs. ha^{-1})	B:C ratio
T_1 : Normal spacing castor (120 x 60 cm)	2641	5674	-	1.00	2641	100358	25780	74578	3.89
T_2 : Wider spacing castor (240 x 120cm)	2339	4322	-	1.00	2339	88882	24623	64259	3.61
T_3 : Wider spacing castor + onion green	2324	4312	10543	1.89	5098	193742	47705	146037	4.06
T_4 : Wider spacing castor + garlic green	2271	4281	5038	1.85	4260	161868	50926	110942	3.18
T_5 : Wider spacing castor + fenugreek green	2349	4330	4861	1.96	3628	137872	34701	103171	3.97
T_6 : Wider spacing castor + spinach green	2296	4304	6786	1.95	3724	141536	35991	105545	3.93
T_7 : Sole onion	-	-	11741	1.00	3090	117410	30563	86847	3.84
T_8 : Sole garlic	-	-	5736	1.00	2264	86040	33623	52417	2.55
T_9 : Sole fenugreek	-	-	5086	1.00	1338	50860	15771	35089	3.22
T_{10} : Sole spinach	-	-	7031	1.00	1480	56248	16976	39272	3.31
S.Em±	52.6	178.7	277.34	-	79.90	3036.07	-	3036.07	-
C.D. (0.05)	155.05	527.2	803.26	-	229.35	8715.77	-	8715.77	-
C.V. %	5.43	9.7	9.56	-	6.55	12.23	-	12.23	-

Selling rates: Castor seed: Rs. 3800/- q^{-1}, Onion green Rs. 1000/-, Garlic green Rs. 1500/- q^{-1}, Fenugreek green Rs. 1000/- q^{-1} and Spinach green Rs. 800/- q^{-1}

crops. Subsequently, irrigations were applied at 15-20 days interval. No serious pests and diseases were observed during the period of experimentation. However, the slight incidence of pests *viz*., castor semilooper and castor capsule borer were noticed and to control them Dichlorovos 75% EC @ 360 ml ha^{-1} (0.036%) and Emamectin Benzoate 5 per cent WG @ 200 g ha^{-1} (0.02%) were applied alternately during both the years. The growth and yield observations were recorded at specific time and economics of castor based intercropping systems were calculated by considering locally available market rates. The recorded data on yield, intercropping indices, economics and nutrient uptake was statistically analyzed by using the method analysis of variance given by Panse and Sukhatme (1967).

Results and Discussion

Yield of castor : The normal spaced castor (120 cm x 60 cm) produced significantly higher seed and stalk yield (kg ha^{-1}) as compared to wider spaced castor (240 cm x 120 cm). The mean seed and stalk yield advantage under normal spacing was 12.91 and 31.28 per cent over wider spacing (Table 1). The higher yields of seed and stalk at normal or closer spacing can be attributed to the higher plant population per unit area and yield being the function of per plant yield and plant population. The results corroborate the early findings of Raghavaiah and Sudhakara Babu (2000a). Fenugreek intercropped in wider sown castor was found to be significantly superior in respect of yield $plant^{-1}$ over narrow spaced sole castor. However, it was found statistically on par with sole castor sown in wider spacing and wider spaced castor in combination with onion, spinach and garlic. Out of various intercrops tested with wider spaced castor, fenugreek was the only intercrop having capacity to fix the atmospheric nitrogen which might have been further available to the crop itself and the neighbouring plants. Moreover, castor itself utilized optimum light, space, available moisture and nutrients that helped in more photosynthesis in the plant which resulted in enhancement in yield attributes and ultimately the crop yields. The results are in conformity with the finding of Porwal *et al*., (2006) and Patel *et al*., (2007).

Green biomass yield of intercrops : The green biomass yield of intercrops was reduced under intercropping system compared to sole crop. The reduction in yield was observed due to reduced growth of intercrop by

Table 2. Plant height, number of branches and number of leaves $plant^{-1}$ of castor as influenced by spacing and vegetable intercropping systems

Treatment	Plant height (cm)			No. of branches $plant^{-1}$			No. of leaves $plant^{-1}$		
	2011-12	2012-13	Pooled	2011-12	2012-13	Pooled	2011 12	2012-13	Pooled
T_1: Normal spacing castor (120 x 60 cm)	74.17	71.06	72.61	14.77	12.33	13.55	61.73	59.77	60.75
T_2: Wider spacing castor (240 x 120cm)	60.93	60.74	60.84	19.10	19.03	19.07	75.10	70.27	72.68
T_3: Wider spacing castor + onion green	63.90	63.03	63.46	18.43	18.33	18.38	73.00	70.10	71.55
T_4: Wider spacing castor + garlic green	63.70	59.67	61.69	17.77	18.13	17.95	71.10	69.53	70.32
T_5: Wider spacing castor + fenugreek green	65.07	63.85	64.46	19.43	19.70	19.57	76.50	72.73	74.62
T_6: Wider spacing castor + spinach green	64.17	61.22	62.69	18.07	18.23	18.15	71.60	69.87	70.73
S.Em±	2.36	2.12	1.59	0.85	1.17	0.72	2.65	2.47	1.81
C.D. (0.05)	7.45	6.67	4.68	2.67	3.70	2.14	8.35	7.77	5.34

competition between vegetables and castor for environmental resources (Table 3). Average reduction in biomass yield was 10.20, 12.16, 4.42 and 3.48 per cent in onion, garlic, fenugreek and spinach, respectively as compared to their corresponding pure stands. Among the intercrops, onion recorded maximum green biomass yield followed by spinach, garlic and fenugreek, indicating their genetic ability of biomass production potentiality. Similar type of results was also observed by Prasad and Verma (1986).

Evaluation indices and economics of the intercropping systems : All intercrops found physiologically efficient with wider spaced castor intercropping as indicated by maximum values of combined LER over pure culture. The highest LER was recorded due to castor + fenugreek (1.96) followed by castor + spinach (1.95), castor + onion (1.89) and castor + garlic (1.85) intercropping systems in descending order (Table 1). Significantly higher

Table 3. Yield attributes, yield of castor and green biomass yield of intercrops as influenced by spacing and vegetable intercropping systems (mean of two years)

Treatment	No. of spikes	Main spike length (cm)	Capsules on main spike (no.)	Test weight (g 100^{-1} seed)	Seed yield (g $plant^{-1}$)	Seed yield (kg ha^{-1})	Stalk yield (kg ha^{-1})	Inter-crop yield
T_1 : Normal spacing castor (120 x 60 cm)	10.90	63.87	72.73	29.50	194.4	2641	5674	-
T_2 : Wider spacing castor (240 x 120cm)	16.18	77.87	86.40	30.08	675.1	2339	4322	-
T_3 : Wider spacing castor + onion green	16.10	77.30	86.50	30.30	667. 2	2324	4312	10543
T_4 : Wider spacing castor + garlic green	15.40	76.30	83.13	29.93	655.4	2271	4281	5038
T_5 : Wider spacing castor + fenugreek green	16.85	78.33	87.33	30.67	692.2	2349	4330	4861
T_6 : Wider spacing castor + spinach green	15.82	76.60	85.35	30.00	661.8	2296	4304	6786
T_7 : Sole onion	-	-	-	-	-	-	-	11741
T_8 : Sole garlic	-	-	-	-	-	-	-	5736
T_9 : Sole fenugreek	-	-	-	-	-	-	-	5086
T_{10} : Sole spinach	-	-	-	-	-	-	-	7031
S.Em±	0.70	1.91	2.08	0.85	28.65	52.6	178.7	277.34
C.D. (0.05)	2.06	5.63	6.15	NS	84.52	155.05	527.2	803.26

Table 4. Nutrient uptake (kg ha^{-1}) by castor as influenced by spacing and vegetable intercropping systems (pooled mean)

Treatment	Nutrient uptake (kh ha^{-1})								
	Nitrogen			Phosphorous			Potassium		
	Seed	Stalk	Total	Seed	Stalk	Total	Seed	Stalk	Total
T_1 : Normal spacing castor (120 x 60 cm)	55.91	17.69	73.60	8.18	7.50	15.68	11.75	57.34	69.09
T_2 : Wider spacing castor (240 x 120cm)	49.27	14.33	63.60	7.23	6.24	13.47	10.07	47.85	57.93
T_3 : Wider spacing castor + onion green	49.28	14.13	63.41	7.13	6.16	13.29	10.11	47.11	57.21
T_4 : Wider spacing castor + garlic green	45.65	13.41	59.06	6.77	5.66	12.43	9.56	45.22	54.78
T_5 : Wider spacing castor + fenugreek green	49.75	14.53	64.28	7.28	6.34	13.61	10.37	48.03	58.40
T_6 : Wider spacing castor + spinach green	47.00	14.02	61.02	7.00	5.83	12.83	10.02	46.77	56.80
S.Em±	1.22	0.50	1.60	0.19	0.22	0.38	0.27	1.58	1.70
C.D. (0.05)	3.60	1.48	4.72	0.55	0.65	1.11	0.81	4.68	5.03
C.V. %	6.04	8.39	6.11	6.32	8.57	6.82	6.52	7.97	7.07

castor equivalent yield (5098 kg ha^{-1}) was recorded with castor + onion intercropping as compared to rest of the treatments. The highest castor equivalent yield with castor + onion might be due to higher intercrop yield obtained with little reduction in main crop yield and higher additional gross gains from intercrop produce. Maximum net realization was obtained due to wider spaced castor in combination with short duration vegetables i.e., onion, garlic, fenugreek and spinach over both wider and narrow spaced sole castor as well as pure culture of respective intercrops. In case of intercropping combinations, castor + onion intercropping recorded comparatively higher values of net realization of Rs. 1,46,037 ha^{-1} and B:C ratio 4.06 (Prasad and Verma 1986).

Nutrient uptake : Irrespective of the treatments, the extent of total uptake of N and P was maximum through seed and that of K was through stalk. In terms of percentage, around 76 per cent N and 52 per cent P was removed by castor seed, while 83 per cent K was removed by castor stalk (Table 4). Sowing of castor at normal spacing of 120 cm x 60 cm resulted into significantly higher total nutrient uptake over wider spacing of 240 cm x 120 cm sole castor as well as all the intercropping treatments. This may be attributed to the closer spacing which recorded higher biomass production per unit area that resulted in to the higher uptake of individual nutrients.

Among intercropping systems, wider spaced castor intercropped with fenugreek recorded significantly higher values of total N and P uptake over treatment castor +garlic on pooled mean basis, however, being equally effective with remaining intercropping treatments and widely spaced sole castor during both the years of experimentation. Fenugreek being leguminous crop was beneficial for castor growth than garlic; vis-a-vis castor growth was more in fenugreek intercropping and resulted in to higher total uptake of N and P as compared to garlic. However, wider spaced castor intercropped with fenugreek recorded numerically higher values of total K uptake and being equally effective with remaining intercropping treatments as well as widely spaced sole castor during both the years of experimentation and in pooled analysis. These findings are in conformity with the results of Giri *et al*., (2006).

Thus, it can be concluded that, short duration vegetables intercropped in wider spaced castor (240 x 120 cm) were more productive and profitable than their sole cultivation. This also helped to improve soil nutrient status which enhances the production of next season crop. Intercropping of onion in wider spaced *rabi* castor (240 x 120 cm) castor crop found to be more remunerative and beneficial with better growth and yield of both the crops.

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Morpho-Physiological Study of Soybean (*Glycine max* L.) Genotypes under Water Stress Condition

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Abstract

The studies revealed that the water stress had a strong influence on the growth, yield and physiology of soybean crop. Significant differences were observed for phenological traits, vegetative growth and source characters, physiological parameters, biochemical and yield contributing characters. The genotypes, KDS 753, KDS-726, KDS-751, JS-335, KDS-344, DS-228, KDS-730 and DSB-21 maintained higher seed yield under stress as well as non-stress condition as a result of higher number of branches plant^{-1}, number of leaves plant^{-1}, leaf area plant^{-1}, higher rate of photosynthesis, high transpiration rate, low canopy temperature and canopy temperature depression, high chlorophyll content, high pod number and high harvest index. Amongst them, KDS-753, KDS-726, KDS-751 and JS-335 maintained higher mean productivity (MP), geometric mean (GMP), stress tolerance index (STI) and harmonic mean (HAM) in conjunction with the tolerance and yield susceptibility index at optimum level. The genotypes, DS-228, JS-335, KDS-344 and DSB-21 maintained higher yield stability index (YSI), least stress susceptibility index (SSI) and minimum tolerance (TOL). These genotypes considered as stable genotypes for stress and non-stress conditions. Therefore, the genotypes, KDS-753, KDS-726, KDS-751 and JS-335 classified into genotypes producing high yield under stress and non-stress conditions, considered for further breeding programme for boosting up the yield heterosis in soybean.

Key words : Drought indices, moisture stress, soybean, physiological parameters, vegetative growth and source

Soybean has become a major oilseed crop in India next to groundnut and Indian mustard. It is a major source of edible vegetable oil and high protein feed. Current soybean cultivars contain approximately 41 per cent proteins and 21 per cent oil in seed on a dry weight basis. Soybean provides approximately 60 per cent of the world's supply of vegetable proteins and 30 per cent of the oil. Besides oil and high quality protein, it fixes atmospheric nitrogen in the soil at the rate of 65 - 100 kg ha^{-1} with the help of *Rhizobium japonicum* bacteria. On the global scale it has come to the top of the list of oil seed crops and contributes a major part of the total supply of the world vegetable oil. Because of all these benefits, it is often designated as "golden bean" and has become the miracle crop of the twentieth century. Drought by general term means a sustained period of significant abnormal water or moisture supply. The effect of drought is generally more pronounced in cells, which are in the state of rapid growth periods classified as critical stages of growth with respect to moisture stress. Plant acquired ability to ensure the maintenance of cellular turgor and metabolic functions, as most of the crop plants are highly sensitive to even a mild dehydration stress. Under such situation the challenge is to establish ways and means for minimizing the crop yield reduction. Therefore, it is imperative to identify the physiological components causing performance difference in stressful condition and to evaluate different genotypes of

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soybean which are more productive and tolerant to stress condition having an ability of utilizing existing resources for better physiological functioning. The systematic characterization of differences in physiological response of plant to drought stress, leads to better understanding of mechanism of drought resistance. The Soybean crop is cultivated in Western Maharashtra in large area that too in drought prone regions where the crop faces moisture stress problem at one stage or the other resulting considerable yield reductions. The moisture stress at reproductive stage causes more damage than at vegetative stage. In the view of this consideration the present investigation was undertaken to study physiological basis of drought tolerance efficiency of soybean genotypes and to assess and identify the morpho-physiological trait for drought tolerance.

Materials and Methods

The populations of fourteen soybean genotypes were evaluated under controlled condition in rainout shelter at Post Graduate Farm, Department of Botany, MPKV, Rahuri, Dist.: Ahmednagar (M.S.), India during *kharif*-2014 in randomized block design in two separate experiments *viz.*, under irrigated and moisture stress conditions with two replications. The plot size was 3.90 x 2.30 m with the spacing of 45 x 10 cm. Total fertilizer dose of 50 kg N and 75 kg P ha^{-1} was given at the time of sowing. The irrigation was given to moisture stress plot at the time of sowing for better germination, whereas, under non-stress plots the crop was irrigated regularly so as to keep the soil moisture close to field capacity. The soil moisture status was monitored at four places randomly in moisture stress and irrigated plots with the help of soil moisture console during sowing, 20 DAS (branching), 40 DAS (flowering), 60 DAS (pod development and grain filling), 80 DAS (seed development) and 100 DAS (pre- maturity). The averages were considered as soil moisture content (SMC). The plant protection measures were adopted as per the recommendations. The observations were recorded on phenological characters during crop growth period while, number of leaves, leaf area and physiological parameters were recorded at the time of 50 per cent flowering by using leaf area meter, IRGA, SPAD meter and infra-red thermometer. The observations on dry matter production and it's distribution in component parts of plant and yield and yield contributing characters were recorded at the time of harvest. Oil content in seeds was estimated by using NIR spectrometer. The harvest index and indices for drought tolerance were estimated by using the following formulae.

Harvest index (HI) calculated by using the formula (Donald, 1962)

$$HI = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

Mean productivity (MP), the genotypes with low values of this index are more stable in two different conditions (Rosielle and Hamblin, 1981).

$$MP = \frac{Y_s + Y_p}{2}$$

Y_s, Yield of genotype under stress, Y_p, Yield of genotype under non-stress

Yield stability index (YSI), the genotypes with high YSI values can be regarded as stable genotypes under stress and non-stress conditions.

$$YSI = \frac{Y_s}{Y_p}$$

Y_s, Yield of genotype under stress, Y_p, Yield of genotype under non-stress

Stress susceptibility index (SSI), measurement of yield stability that apprehended the changes in both potential and actual yields in variable environments (Fischer and Maurer, 1978). SSI more and less than 1 indicate above and below-average susceptibility to drought stress, respectively [Guttieri *et al.*, 2001].

$$SSI = \frac{1-(Y_s/Y_p)}{SI}$$

$$SI = 1 - \bar{Y_s} / \bar{Y_p}$$

Y_s, Yield of genotype under stress, Y_p, Yield of genotype under non-stress, $\bar{Y_s}$ Average yield of population under stress, $\bar{Y_p}$ Average yield of population under non-stress, SI= Stress intensity

Tolerance (TOL), differences in yield between the stress and irrigated environments and mean productivity (MP) as the average yield of genotypes under stress and non-stress conditions (Rosielle and Hamblin, 1981).

$$TOL = Y_p - Y_s$$

Geometric mean productivity (GMP), use by breeders interested in relative performance, since drought stress can vary in severity in field environments over years (Ramirez and Kelly, 1998). The genotypes with high GMP value will be more desirable.

$$GMP = (Y_s) \times (Y_p) \text{ (Fernandez, G.C.J., 1992)}$$

Stress tolerance index (STI), which can be used to identify genotypes that produce high yield under both stressed and non-stressed conditions [Fernandez, 1992]. The genotypes with high STI values will be tolerant to drought stress (Fernandez, 1992).

$$STI = (Y_p/\bar{Y_p})(Y_s/\bar{Y_s})(\bar{Y_s}/\bar{Y_p}) = (Y_p \times Y_s)/(\bar{Y_p})^2$$

Y_s, Yield of genotype under stress, Y_p, Yield of genotype under non-stress, $\bar{Y_s}$- Average yield of population under stress, $\bar{Y_p}$- Average yield of population under non-stress

Harmonic mean (HAM), the genotypes with high value of this index will be more desirable.

$$HAM = \frac{2(Y_p \times Y_s)}{(Y_p + Y_s)}$$

Y_s, Yield of genotype under stress, Y_p, Yield of genotype under non-stress

The mean data analyzed by as per Panse and Sukhatme (1985).

Results and Discussion

Soil moisture status : The data on soil moisture status during crop growth stages are presented in Table 1. The soil moisture status was monitored separately in moisture stress and non-stress plots at four places with the help of soil moisture console. At the time of sowing there was sufficient moisture in the soil and the germination and initial growth was satisfactory. Under moisture stress there was considerable depletion of available soil moisture from flowering onwards and the crop was exposed to the terminal drought. As the plant roots were mostly concentrated in upper 0-30 cm layer. The soil moisture content was just near to the permanent wilting point at pod development stage, and crop really experienced severe drought. Under irrigated condition, the scheduling of irrigation was at critical growth stages and therefore the crop did not experienced moisture stress throughout the growth period. Under irrigated condition the soil moisture content upto 40 days was 26.80 per cent in 0-15 and 26.40 in 15-30 cm depth of soil. Thereafter, it declined to 21.30 per cent in 0-15 cm and 23.80 in 15-30 cm. In further course of time the soil moisture went down rapidly and recorded 19.80 in 0-15 cm and 21.90 in 15-30 cm depth of soil at 100 DAS. Thus, crop under stress plot experiment had shortage of water right from 40 DAS till harvesting. At the time of sowing there was sufficient available moisture present. At sowing available soil moisture was ranged between 9.56 and 15.56 per cent at 0-15 cm and 11.46 and 16.86 at 15-30 cm depth under irrigated condition, while, under moisture stress condition available moisture at 40 days 08.96 in 0-15 cm depth and 08.56 in 15-30 cm depth. Then it declined upto 1.96 in 0-15 cm and 4.06 to 15-30 cm depth of soil. The SDF value is lower in irrigated condition and it ranged between 0.200 to 0.344 in 0-15 cm depth and 0.169 to 0.368 in 15-30 cm depth of soil. In moisture stress condition the SDF value is highest and ranged between 0.270 and 0.526 under 0-15 cm and 0.227 and 0.475 in 15 to 30 cm depth soil, respectively.

Phenological studies : The data on days to initiation of flowering, 50 per cent flowering and physiological maturity influenced by moisture stress and irrigated conditions on soybean genotypes are presented in Table 2. The genotypic differences were statistically significant under both the conditions indicated the wider range of variation amongst the genotypes. The genotype JS-335 required minimum number of days for initiation of flower bud under moisture stress (32.50) and irrigated (33.00) condition followed by KDS-726 (33.50 and 32.50) and KDS-751 (34.00 and 32.00). The genotype KDS-378 required maximum number of days for initiation of flower bud under irrigated (39.50) and moisture stress (38.50) conditions followed by genotypes Bragg and KDS 739 (38.00) under irrigated and moisture stress (35.5 and 34.5) conditions, respectively. The genotype KDS-726 required minimum number of days for 50% flowering under irrigated (42.00) and moisture stress (40.50) condition followed by genotype KDS-

Table 1. The soil moisture status under water stress and non-stress condition during crop growth period

Stage	DAS	Soil moisture content (SMC)		Available moisture (%)		Severity duration frequency (SDF)	
		I_1	I_0	I_1	I_0	I_1	I_0
0-15 cm depth							
1	0	33.40	30.50	15.56	12.66	0.200	0.270
2	20	32.30	29.10	14.46	11.26	0.227	0.303
3	40	34.40	26.80	16.56	8.96	0.176	0.358
4	60	29.20	21.30	11.36	3.46	0.301	0.490
5	80	28.80	20.90	10.96	3.09	0.310	0.499
6	100	27.40	19.80	9.56	1.96	0.344	0.526
15-30 cm depth							
1	0	34.70	32.30	16.86	14.46	0.169	0.227
2	20	33.60	30.70	15.76	12.86	0.195	0.265
3	40	29.30	26.40	11.46	8.56	0.368	0.368
4	60	29.90	23.80	12.06	5.96	0.284	0.43
5	80	30.40	24.40	12.56	6.56	0.272	0.416
6	100	30.60	21.90	12.76	4.06	0.267	0.475

I_1: non-stress, I_0: moisture stress

753 (42.50 and 41.00) and JS-335 (43.50 & 41.00). The genotype KDS-378 required maximum number of days for days to 50 per cent flowering under irrigated (49.00) as well as moisture stress (46.50) conditions. The genotypes KDS-751 (100), JS-335 (100.50), KDS-726 and KDS-753 (101) under irrigated, whereas, KDS-726 (93.50), KDS-753 (93.50) and JS-335 (94.00) under moisture stress conditions required minimum number of days to maturity. The genotype KDS-378 (108.00), KDS-739 (106.00) and JS-9305 (106.00) under irrigated and KDS-739 (101.50) under moisture stress were late for physiological maturity. Jungale *et al*., (1995) recorded high heritability for days from anthesis to maturity, days to 50 per cent flowering and days to initiation of flowering.

Vegetative growth and source : The data on influence of moisture stress and irrigated conditions on vegetative growth and source parameters of soybean genotypes are presented in Table 3. The differences amongst the genotypes were statistically significant indicated that, there was a wide range of variability for all the traits. The genotype KDS-753 maintained higher plant height under irrigated (69.00 cm) as well as moisture stress (52.50 cm) condition. In addition to this, JS-335 (64.50 cm), KDS-741(64.50 cm) and KDS-751 (64.50 and) under irrigated while KDS-751 (49.00 cm), JS 335 (47.00 cm) and KDS-344 (46.50 cm) under moisture stress recorded maximum plant height. However, KDS-344 (52.00cm) under irrigated condition while KDS-378 (35.50) under moisture stress condition recorded minimum plant height. Feroud *et al*., (1993) reported that water stress at beginning of seed stage caused significant reduction (7%) in plant height of soybean.

The genotype, KDS-753 recorded maximum number of primary branches under irrigated (7.00) and moisture stress (4.50) condition. JS-335 is another promising genotype for profuse branching under irrigated (6.50) as well as moisture stress condition (4.25). The genotypes KDS-378 and KDS-741 (3.50) recorded minimum number of primary branches under irrigated, while KDS-739 and Bragg (2.00) recorded minimum number of primary branches under moisture stress condition. The genotypes KDS-753 (45.50) and KDS-726 (45.00) under irrigated while KDS-344 (38.50) and JS-335 (37.50) under moisture stress condition recorded maximum number of leaves plant^{-1}. The genotype KDS-739 and JS-9305 recorded minimum number of leaves plant^{-1} under irrigated (32.50 and 33.50) and moisture stress (29.50 and 28.00) condition. The genotypes KDS-753 (32.80 dm^2) and JS-335 (31.75 dm^2) under irrigated condition while under moisture stress condition

Table 2. Influence of moisture stress and irrigation on phenology of different soybean genotypes

Genotype	Days to initiation of flowering		Days to 50% flowering		Days to maturity	
	I_1	I_0	I_1	I_0	I_1	I_0
JS-335	33.0	32.5	43.5	41.0	100.5	94.0
MAUS-61	37.0	34.5	48.0	45.5	105.0	98.0
Bragg	38.0	35.5	47.0	42.0	103.5	99.5
KDS-741	36.5	34.0	46.5	44.0	105.5	100.5
KDS-730	35.5	37.5	46.0	42.5	105.5	100.5
KDS-344	34.5	32.5	45.0	43.5	102.0	98.5
KDS-739	38.0	34.5	48.0	44.0	106.0	101.5
KDS-753	35.0	33.0	42.5	41.0	101.0	93.5
DSB-21	34.5	34.0	45.5	43.5	103.0	98.0
KDS-751	34.0	32.0	44.5	42.5	100.0	94.5
DS-228	35.5	33.0	47.5	45.5	102.0	97.5
JS-9305	37.5	36.0	47.5	44.5	106.0	99.0
KDS-378	39.5	38.5	49.0	46.5	108.0	101.0
KDS-726	33.5	32.5	42.0	40.5	101.0	93.5
GM	35.9	34.3	45.9	43.3	103.5	97.8
SE(+)	1.13	0.92	0.92	0.61	1.23	0.74
CD at 5%	3.18	2.57	2.54	1.74	3.52	2.12

I_1: non-stress, I_0: stress

genotypes KDS-753 (30.45 dm^2) and JS-335 (29.50 dm^2) recorded highest leaf area. The genotypes KDS-730 (24.15 dm^2) and JS-9305 (25.20) recorded minimum leaf area under irrigated condition, whereas, genotypes KDS-730 (20.75 dm^2) and JS-9305 (22.05 dm^2) recorded minimum leaf area under moisture stress condition.

Dry matter study : The data on dry matter production and it's distribution in component parts of plant under stress and non-stress conditions are presented in Table 4. The differences among the genotypes were statistically significant under both the conditions. The genotypes, KDS-751 (6.05 g), DSB-21 (5.85 g) and JS-335 (5.80 g) under irrigated, whereas, KDS-344 (4.2 g) and DS-228 (4.05 g) under moisture stress condition recorded maximum dry weight of stem $plant^{-1}$. The genotype KDS-751 (7.30 g) and JS-335 (7.05 g) were at par and recorded maximum dry weight of leaves $plant^{-1}$ under irrigated condition, whereas, the genotype DS-228 (5.00 g) recorded maximum dry weight of leaves per plant followed by JS-9305 (4.4 g) under moisture stress condition. The KDS-344 (18.60 g) and JS-335 (17.75 g) were at par and recorded highest dry matter in pods $plant^{-1}$ under irrigated, while, DS-228 (15.85 g) and KDS-344 (14.40 g) were at par and recorded highest dry matter in pods under moisture stress condition. The genotypes JS-335 (30.60 g), KDS-344 (28.75 g) and DSB-21 (28.20 g) recorded maximum total dry matter production under irrigated, while, DS-228 (24.90 g), DSB-21 (21.95 g) and KDS-344 (21.80 g) attained maximum total dry matter $plant^{-1}$ under moisture stress conditions.

Table 3. Influence of moisture stress and irrigation on morphological characters of different soybean genotypes

Genotype	Plant height (cm)		Primary branches $plant^{-1}$		Leaves $plant^{-1}$		Leaf area $plant^{-1}$ (dm^2)	
	I_1	I_0	I_1	I_0	I_1	I_0	I_1	I_0
JS-335	64.50	47.00	6.50	4.25	43.00	37.50	31.75	29.50
MAUS-61	53.00	41.00	4.00	2.25	36.00	31.50	26.85	25.40
Bragg	60.50	38.50	4.00	2.00	35.00	33.00	25.95	25.70
KDS-741	64.50	36.50	3.50	2.50	36.50	29.50	25.25	22.75
KDS-730	58.00	40.50	4.00	2.50	40.50	36.00	24.15	20.75
KDS-344	52.00	46.50	5.50	4.20	40.00	38.50	27.85	26.60
KDS-739	56.50	40.00	4.50	2.00	32.50	29.50	26.75	24.25
KDS-753	69.00	52.50	7.00	4.50	45.50	36.00	32.80	30.45
DSB-21	60.00	38.00	5.50	4.00	39.50	36.50	29.80	26.80
KDS-751	64.50	49.00	5.50	3.75	43.50	30.50	29.65	27.45
DS-228	57.00	44.50	4.50	3.50	37.50	36.00	27.85	25.55
JS-9305	54.50	41.00	4.00	2.50	33.50	28.00	25.20	22.05
KDS-378	54.00	35.50	3.50	2.25	38.50	33.50	26.20	23.00
KDS-726	59.50	42.50	5.50	3.50	45.00	36.50	32.10	29.30
GM	59.11	42.36	4.82	3.12	39.03	33.75	28.00	25.00
SE(+)	0.90	1.17	0.60	0.35	1.10	1.07	0.50	0.44
CD @5%	2.76	3.57	1.90	1.07	3.60	3.20	1.78	1.30

I_1: non-stress, I_0: stress

Physiological parameters : The data on the physiological parameters recorded at 50 percent flowering stage are presented in Table 5. The genotypic differences were statistically significant at moisture stress as well as irrigated conditions except stomatal conductance under moisture stress condition. The rate of photosynthesis was more in irrigated condition than that of moisture stress condition. Fisher and Maurer (1978) found that during grain filling, yield reduction occurred largely because of reduced assimilates supply earned by reduced rate of photosynthesis but especially by induced foliar senescence. The genotype KDS-753 (23.50 µmol $m^{-2}s^{-1}$), KDS-726 (16.3 µmol $m^{-2}s^{-1}$), KDS-751 (23.25 µmol $m^{-2}s^{-1}$), DSB-21 (22.45 µmol $m^{-2}s^{-1}$) and JS 335 (21.35 µmol $m^{-2}s^{-1}$) were at par and recorded significantly the highest photosynthetic rate under non stress condition, whereas, KDS-726 (18.20 µmol $m^{-2}s^{-1}$) recorded significantly the highest photosynthetic rate followed by KDS-751 (16.30 µmol $m^{-2}s^{-1}$) which were at par with KDS-753 (16.00 µmol $m^{-2}s^{-1}$) under moisture stress condition. The rate of transpiration was more in irrigated condition than that of moisture stress condition except genotype KDS-753. The genotypes, KDS-739 (3.92 mmol $m^{-2}s^{-1}$), KDS-726 (3.9 mmol $m^{-2}s^{-1}$), KDS-730 (3.85 m/mol $m^{-2}s^{-1}$), DSB-21 (3.73 mmol $m^{-2}s^{-1}$) and KDS-344 (3.70 mmol $m^{-2}s^{-1}$) recorded the highest transpiration rate under non stress condition, whereas, genotypes, KDS-739 (3.75 mmol $m^{-2}s^{-1}$), KDS-726 (3.55 mmol $m^{-2}s^{-1}$), DSB-21 (3.50 mmol $m^{-2}s^{-1}$), KDS-730 (3.45 mmol $m^{-2}s^{-1}$) and KDS-753 (3.43 mmol $m^{-2}s^{-1}$) recorded the highest transpiration rate under moisture stress condition. The stomatal conductance was more in irrigated condition than that of moisture

Table 4. Influence of moisture stress and irrigation on dry matter production and it's distribution in component parts of plant in soybean genotypes

Genotype	Stem (g $plant^{-1}$)		Leaves (g $plant^{-1}$)		Pod (g $plant^{-1}$)		Total (g $plant^{-1}$)	
	I_1	I_0	I_1	I_0	I_1	I_0	I_1	I_0
JS-335	5.80	3.65	7.05	3.80	17.75	13.75	30.60	21.20
MAUS-61	3.70	2.65	6.20	3.25	14.55	10.40	24.45	16.30
Bragg	3.15	3.15	4.70	3.85	14.40	13.30	22.25	20.30
KDS-741	3.89	2.75	5.05	3.45	13.50	12.50	22.44	18.70
KDS-730	3.50	3.15	3.70	3.75	13.20	13.20	20.40	20.10
KDS-344	4.90	4.20	5.25	3.20	18.60	14.40	28.75	21.80
KDS-739	4.00	2.80	4.95	3.55	15.15	10.55	24.10	16.90
KDS-753	4.40	3.00	5.35	3.90	14.35	10.20	24.10	17.10
DSB-21	5.85	3.85	6.35	4.20	16.00	13.90	28.20	21.95
KDS-751	6.05	3.35	7.30	3.15	13.35	12.80	26.70	19.30
DS-228	4.95	4.05	5.50	5.00	15.85	15.85	26.30	24.90
JS-9305	4.70	3.15	5.95	4.40	11.80	9.80	22.45	17.35
KDS-378	3.70	3.45	4.85	3.40	12.15	11.55	20.70	18.40
KDS-726	4.50	3.35	6.80	3.50	16.75	12.85	28.05	19.70
GM	4.51	3.30	5.60	3.74	14.81	12.50	25.00	19.00
SE(+)	0.31	0.14	0.30	0.11	0.87	0.71	1.07	0.70
CD @5%	0.95	0.43	0.91	0.35	2.70	2.10	3.20	2.10

I_1: non-stress, I_0: stress

stress condition. The genotype JS-335 (0.09 molm^{-2}sec^{-1}) maintained significantly the highest stomatal conductance under non stress as well as stress condition (0.07 molm^{-2}sec^{-1}). Lee *et al.*, (1994) reported that the transpiration rate and stomatal conductance rapidly decreased in soybean with decreasing soil moisture.

The genotype, DS-228 maintained higher water use efficiency under irrigated (8.90) as well as moisture stress condition (7.60). In addition to this, KDS-753 (6.80) and KDS-751 (6.40) under irrigated and JS-9305 (6.50) and MAUS-61 (5.90) under moisture stress also maintained higher water use efficiency. The genotype JS-9305 (32.35°C) and KDS-741 (32.15°C) recorded significantly the highest canopy temperature under non stress condition, whereas, KDS-739 (34.25°C), JS-9305 (33.75°C) and Bragg (33.50°C) recorded significantly the highest canopy temperature under moisture stress condition. The canopy temperature depression was more in irrigated than that of moisture stress condition. The genotype Bragg recorded significantly the highest canopy temperature depression among all genotypes under irrigated (-5.50°C) and moisture stress (-5.75°C) condition. The genotypes, KDS-753 (-0.55°C) and KDS-344 (-0.65°C) were at par and recorded significantly the lowest canopy temperature depression under non stress condition, whereas, KDS-751 (-1.00°C) and KDS-753 (-1.30°C), DS-228 (-1.30°C) recorded significantly the lowest canopy temperature depression under moisture stress condition.

Biochemical and yield contributing character : The data on biochemical and yield

Table 5. Influence of moisture stress and irrigation on physiological parameters of soybean genotypes

Genotype	Pn		E		gs		WUE		CT		CTD	
	I_1	I_0	I_1	I_0	I_1	I_0	I_1	I_0	I_1	I_0	I_1	I_0
JS-335	21.35	15.90	3.60	3.16	0.09	0.07	5.90	5.00	31.95	32.15	-0.90	-1.75
MAUS-61	14.50	12.75	2.45	2.15	0.07	0.07	5.90	5.90	30.55	33.25	-3.50	-4.50
Bragg	13.05	10.50	2.85	2.35	0.06	0.05	4.60	4.50	30.85	33.50	5.50	-5.75
KDS-741	15.10	11.25	2.75	2.45	0.06	0.05	5.50	4.60	32.15	32.75	-4.50	-5.00
KDS-730	15.45	10.25	3.85	3.45	0.08	0.04	4.00	3.00	31.70	32.50	-4.25	-5.50
KDS-344	16.95	13.60	3.70	3.61	0.06	0.05	4.60	3.80	31.85	32.00	-0.65	-1.45
KDS-739	17.85	12.90	3.92	3.75	0.08	0.05	4.60	3.40	31.45	34.25	-3.50	-4.25
KDS-753	23.50	16.00	3.42	3.43	0.09	0.06	6.80	4.70	31.55	31.85	-0.55	-1.30
DSB-21	22.45	14.80	3.73	3.50	0.08	0.05	6.00	4.20	31.50	33.25	-1.10	-1.90
KDS-751	23.25	16.30	3.65	3.00	0.09	0.05	6.40	5.40	30.50	31.50	-0.70	-1.00
DS-228	19.40	15.60	2.20	2.05	0.07	0.04	8.90	7.60	29.75	30.40	-1.20	-1.30
JS-9305	15.20	12.75	2.58	1.95	0.06	0.03	5.90	6.50	32.35	33.75	-4.00	-5.50
KDS-378	16.60	11.65	3.05	2.45	0.05	0.05	5.40	4.80	31.75	32.45	-4.25	-4.50
KDS-726	23.25	18.20	3.90	3.55	0.07	0.05	6.00	5.10	30.75	31.25	-0.75	-1.50
GM	18.42	13.75	3.25	2.90	0.07	0.05	5.80	4.90	31.3	32.4	-1.69	-3.23
SE(+)	0.98	0.41	0.15	0.07	0.01	0.01	0.60	0.20	0.42	0.35	0.46	0.39
CD @5%	3.00	1.25	0.47	0.21	0.02	NS	1.70	0.50	1.30	1.07	1.40	1.20

I_1: non-stress, I_0: stress, Pn: Photosynthetic rate (µmolm^{-2}s^{-1}), E: Transpiration rate (molm^{-2}s^{-1}), gs: Stomatal conductance (molm^{-2}s^{-1}), WUE: Water use efficiency, CT: Canopy Temperature (0C), CTD: Canopy temperature depression contributing characters under irrigated and moisture stress are presented in Table 6. The differences amongst the genotypes were statistically significant for all the characters. The chlorophyll content was more in irrigated condition than that of moisture stress condition. The genotypes, KDS-726 (46.65), KDS-753 (46.55) and KDS-751 (46.15) recorded highest chlorophyll content under non stress, whereas, DS-228 (34.00), KDS-344 (33.45) and KDS-751 (33.00) recorded the highest chlorophyll content under moisture stress condition. Park *et al.,* (1998) stated that leaf chlorophyll content in soybean was highest at flowering and decreased by water stress. The genotype JS-335 maintained higher oil content under irrigated (21.30 µ moles g^{-1}) as well as moisture stress (21.00 µ moles g^{-1}) condition, whereas, KDS-741 recorded minimum oil content under irrigated (17.50 µ moles g^{-1}) and moisture stress (16.80 µ moles g^{-1}) conditions.

Kpoghmoc *et al.,* (1990) reported that stress at flowering and pod filling stage reduced the number of pods $plant^{-1}$, seeds pod^{-1} and 100-seed weight than stress at vegetative stage. In the present investigation, the genotypes, KDS-753 (50.50) and KDS-726 (49.50) under irrigated conditions, while, JS-335 (38.50) and KDS-753 (38.00) under moisture stress condition recorded significantly higher numbers of pod $plant^{-1}$. The genotypes, JS-9305 (33.00) and KDS- 378 (35.50) under irrigated condition, whereas, KDS- 378 (27.00) and JS-9305 (29.50) under moisture stress condition recorded minimum number of pods $plant^{-1}$. The genotypes, KDS-726 (14.8 g) and JS-335, KDS-753 and DS-228 (13.5 g) under irrigated,

Table 6. Influence of moisture stress and irrigation on biochemical and yield contributing characters on soybean genotypes

Genotype	Choropgyll content (SPAD)		Oil content (%)		Pod $plant^{-1}$		100 seed weight (g)		Yield ha^{-1} (q)		Harvest index (%)	
	I_1	I_0	I_1	I_0	I_1	I_0	I_1	I_0	I_1	I_0	I_1	I_0
JS-335	43.15	32.30	21.30	21.00	43.0	38.5	13.5	13.0	24.30	21.50	48.78	43.30
MAUS-61	44.65	31.45	19.50	17.50	42.0	34.8	10.7	9.3	17.25	12.00	41.02	33.80
Bragg	41.20	27.50	17.50	19.90	38.0	34.0	11.6	9.5	16.20	11.70	39.58	31.80
KDS-741	42.85	32.75	17.50	16.80	36.0	34.5	11.4	10.3	19.00	14.00	46.90	33.30
KDS-730	42.75	25.50	18.95	18.05	37.0	35.4	10.5	10.3	21.75	11.70	42.63	36.20
KDS-344	43.15	33.65	20.75	20.60	46.0	37.5	12.0	12.8	22.75	19.80	47.33	45.70
KDS-739	44.85	28.25	18.75	18.90	40.0	32.0	10.8	10.3	19.00	14.50	36.59	30.80
KDS-753	46.55	32.50	20.20	19.75	50.5	38.0	13.5	11.6	28.00	23.00	53.32	46.60
DSB-21	44.10	26.80	20.05	19.40	44.0	37.0	12.8	12.7	21.50	18.50	38.42	34.40
KDS-751	46.15	33.00	21.10	19.75	46.5	33.5	13.0	11.6	25.20	21.00	45.25	41.20
DS-228	45.55	34.00	20.70	20.40	39.5	35.5	13.5	12.3	21.95	20.20	52.59	50.10
JS-9305	42.50	25.50	21.05	20.60	33.0	29.5	9.5	9.6	17.50	11.90	42.68	28.40
KDS-378	43.75	26.50	19.50	18.50	35.5	27.0	10.0	8.5	18.00	13.50	43.18	38.00
KDS-726	46.65	31.50	20.75	19.50	49.5	36.5	14.8	12.5	26.50	22.00	54.66	50.60
GM	44.1	30.09	19.8	19.3	41.0	35.0	12.0	11.0	21.35	16.80	45.21	38.90
SE(+)	0.45	1.6	0.33	0.37	1.20	1.49	0.64	0.35	1.09	1.0	3.07	2.5
CD @5%	1.39	5.02	1.03	1.15	3.67	4.56	1.96	1.08	3.34	3.1	9.3	7.5

I_1: non-stress, I_0: stress

while, JS-335 (13.0 g), KDS-344 (12.8 g), DSB-21 (12.7 g), KDS-726 (12.5 g) and DS-228 (12.3 g) recorded higher 100 seed weight under moisture stress conditions including bold seed size. The genotypes, JS-9305 (9.5 g) and KDS-378 (10.0 g) under irrigated, whereas, KDS-378 (8.5 g) and MAUS-61 (9.3 g 100) recorded least 100 seed weight under moisture stress condition.

The genotypes, KDS-753 (28.00 q ha^{-1}) and KDS-726 (26.50 q ha^{-1}) under irrigated condition as well as KDS-753 (23.00 q ha^{-1}) and KDS-726 (22.00 q ha^{-1}) under moisture stress condition recorded maximum seed yield. The genotypes, Bragg (16.20 q ha^{-1}) and JS-9305 (17.50 q ha^{-1}) under irrigated condition while, KDS-730, Bragg (11.70 q ha^{-1}) and JS-9305 (11.90 q ha^{-1}) under moisture stress condition had minimum seed yield. According to Fernandez [1992] theory, KDS-753, KDS-726, KDS-751 and JS-335 classified into genotypes producing high yield under both stress and non-stress conditions, whereas, genotypes Bragg, KDS-730, MAUS-61and JS-9305 with poor performance under both stress and non-stress conditions. The genotypes, KDS-726 (54.66% and 50.60%), KDS-753 (53.32 and 46.60%) and DS-228 (52.59% and 50.10%) recorded maximum harvest index under irrigated and moisture stress condition, respectively. The genotype, KDS-739 (36.59%) under irrigated conditions, while, JS-9305 (28.40%) under moisture stress showed minimum harvest index. Similar results were also obtained by Sapra and Beyl (1990).

Indices for drought tolerance : Drought indices which provide a measure of drought based on loss of yield under drought conditions in comparison to normal conditions have been used for screening drought tolerant genotype (Mitra, 2001). These indices are either based on drought resistance or susceptibility of genotypes (Fernandez, 1992). Drought susceptibility of a genotype is often measured

Table 7. Indices for drought tolerance influenced by soybean genotypes

Genotype	MP	YSI	SSI	TOL	GMP	STI	HAM
JS-335	22.90	0.88	0.75	2.80	522.45	38.47	22.81
MAUS-61	14.63	0.70	1.98	5.25	207.00	15.24	14.15
Bragg	13.95	0.72	1.81	4.50	189.54	13.96	13.59
KDS-741	16.50	0.74	1.72	5.00	266.00	19.59	16.12
KDS-730	16.73	0.54	3.01	10.05	254.48	18.74	15.22
KDS-344	21.28	0.87	0.85	2.95	450.45	33.17	21.17
KDS-739	16.75	0.76	1.54	4.50	275.50	20.29	16.45
KDS-753	25.50	0.82	1.16	5.00	644.00	47.42	25.25
DSB-21	20.00	0.86	0.91	3.00	397.75	29.29	19.89
KDS-751	23.10	0.83	1.09	4.20	529.20	38.97	22.91
DS-228	21.08	0.92	0.52	1.75	443.39	32.65	21.04
JS-9305	14.70	0.68	2.09	5.60	208.25	15.34	14.17
KDS-378	15.75	0.75	1.63	4.50	243.00	17.89	15.43
KDS-726	24.25	0.83	1.11	4.50	583.00	42.93	24.04
Mean	19.08	0.79	1.39	4.54	358.83	26.42	18.81

MP: Mean productivity (q ha^{-1}), YSI: Yield stability index, SSI: Stress susceptibility index, TOL: Stress tolerance, GMP: Geometric mean productivity, STI: Stress tolerance index, HAM: Harmonic mean.

as a function of the reduction in yield under drought stress (Blum, 1996). Mean productivity (MP) as the average yield of genotypes under stress and non-stress conditions. The stress tolerance index (STI) was defined by Fernandez (1992), which can be used to identify genotypes that produce high yield under both stressed and non-stressed conditions. The geometric mean productivity (GMP) is often used by breeders interested in relative performance, since drought stress can vary in severity in field environments over years (Ramirez, and Kelly, 1998). The optimal selection criterion should distinguish genotypes that express uniform superiority in both stressed and non-stressed environments than favorable only in one environment. The genotypes with high value of harmonic mean (HAM) is more desirable for stress tolerance.

In the present investigation, the high yielding genotype KDS-753 maintained higher mean productivity (25.50 q ha^{-1}), geometric mean (644.00 q ha^{-1}), stress tolerance index (47.42) and harmonic mean (25.25 q ha^{-1}) in conjuction with the tolerance (5.00) and yield susceptibility index (0.82) at optimum level. In addition to this, KDS-726 (24.25 q ha^{-1}), KDS-751 (23.10 q ha^{-1}) and JS-335 (22.90 q ha^{-1}) maintained high magnitude of mean productivity alongwith geometric mean (583.00, 529.20 and 522.45 q ha^{-1}), stress tolerance index (42.93, 38.97 and 38.47) and harmonic mean (24.04, 22.91 and 22.81 q ha^{-1}), respectively.

The yield stability index (YSI) is the other yield-based estimates which evaluate the stability of genotypes in the both stress and non-stress conditions (Bouslama and Schapaugh, 1984). The stress susceptibility index (SSI) suggested by Fischer and Maurer (1978) for measurement of yield stability that apprehended the changes in both potential and actual yields in variable environments. Guttieri *et al.*, (2001) suggested that SSI more and less than 1 indicates above and below-average susceptibility to drought stress, respectively. The stress tolerance (TOL) was defined by Rosielle and Hamblin (1981) as the differences in yield between the stress and irrigated environments. In the present investigation, the genotypes, DS-228 maintained higher yield stability index (0.92), least stress susceptibility index (0.52) and minimum tolerance (1.75) followed by JS-335 (0.88, 0.75 and 2.80), KDS-344 (0.87, 0.85 and 2.95) and DSB-21 (0.86, 0.91 and 3.00). These genotypes considered as stable genotypes for stress and non-stress conditions.

The genotypes, KDS 753, KDS-726, KDS-751, JS-335, KDS-344, DS-228 KDS-730 and DSB-21 maintained higher seed yield under stress as well as non stress condition as a result of higher number of branches $plant^{-1}$, number of leaves $plant^{-1}$, leaf area $plant^{-1}$, higher rate of photosynthesis, high transpiration rate, low canopy temperature and canopy temperature depression, high pod number and high harvest index. Amongst them, KDS-753, KDS-726, KDS-751 and JS-335 maintained higher mean productivity (MP), geometric mean (GMP), stress tolerance index (STI) and harmonic mean (HAM) in conjunction with the tolerance and yield susceptibility index at optimum level. The genotypes, DS-228, JS-335, KDS-344 and DSB-21 maintained higher yield stability index (YSI), least stress susceptibility index (SSI) and minimum tolerance (TOL). These genotypes considered as stable genotypes for stress and non-stress conditions. On the basis of relative ranking, the genotypes, KDS-753, KDS-726, KDS-751 and JS-335 classified into genotypes producing high yield under both stress and non-stress conditions and better performance for drought indices considered for further breeding programme for boosting up the yield heterosis.

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Genetic Diversity in Rice Genotypes Based on Agronomic Characters

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Abstract

A set of sixty-five rice (*Oryza sativa* L.) accessions including 25 landraces and 8 local selections were screened for twelve morphological characters to study the nature and magnitude of genetic divergence using Mahalanobis D^2 statistics. The genotypes studied showed wide variation for all the characters under study. Grain length: breadth ratio, test weight, plant height and number of spikelets panicle^{-1} had high values of genetic coefficient of variation and phenotypic coefficient of variation. High heritability coupled with genetic advance was observed for spikelets panicle^{-1} and plant height. Based on genetic distances, sixty-five genotypes were classified into ten clusters. The maximum inter-cluster distance was recorded between the cluster VIII and IX. The clustering pattern of the genotypes was quite random indicating that the geographical origin and genetic diversity were not related. The character test weight had major contribution towards total divergence.

Key words : Rice, Genetic diversity, agronomic traits

Rice is the most important food crop in the world and feeds over half of the global population. Rice has played a central role in human nutrition and culture for the past 10000 years. However, increase in global population, projected to be 9.2 billion by 2050 will pose greater challenges for the rice breeders and agricultural scientist to fulfill the food demand. Being staple food, improving productivity and quality of rice always remains crucial. To accomplish this, crop improvement programmes should necessarily aim at broadening the genetic base of the breeding stock (Vanaja and Babu 2004). Success of crop improvement generally depends on the magnitude of genetic variability and extent to which the desirable characters are heritable (Singh *et al*., 2011). India has tremendous biodiversity for rice. The number of landraces cultivated locally is rapidly replaced by improved varieties, which cause narrowing the genetic base (Guei 2000). Thus, reduced genetic variability underscores the need to collect landraces for *ex-situ* conservation and to characterize them for future rice breeding programme.

Germplasm constitute the foundation of any genetic improvement programme of crop. The pace and magnitude of genetic improvement generally depends on the amount of genetic variability present in the population. The systematic breeding programme involves the steps like creating genetic variability, practicing selection and utilization of selected genotypes to evolve promising varieties. The large spectrum of genetic variability and genetic advance among combining genotypes offers a better scope for selection. Estimates of heritability and genetic advance will play an important role in designing future research programme of rice improvement. Murthy and Arunachalam (1966) stated that multivariate

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analysis with "Mahalanobis D^2 statistics" is a powerful tool to know the clustering pattern to recognize genetic divergence and to determine the role of different quantitative characters towards the maximum divergence.

In view of this, the present study was conducted to evaluate the extent of genetic variability and diversity among 65 rice genotypes based on important morphological traits. The results will enable maximized selection of diverse parents and assist in broadening the germplasm base of future rice breeding programme in order to develop high yielding desirable genotypes in rice.

Material and Methods

Sixty five diverse genotypes of rice including 25 landraces, 8 local selections, and 32 improved varieties maintained at Agricultural Research Station, Radhanagari, District Kolhapur, MS, India were grown at two locations *viz*., ARS, Radhanagari and ARS, Lonavala, MS, India during rainy season of 2010. The seeds of the genotypes were sown on raised beds in second week of June and seedlings were transplanted in second week of July at both the locations in randomized block design with two replications. Each entry was represented by four rows of 3 m length with spacing of 20 cm between rows and 15 cm between plants. All the recommended agronomic practices were followed to grow the crop successfully. Observations were recorded on five randomly selected plants of each replication for twelve yield and yield contributing characters *viz*., days to 50 per cent flowering, days to maturity, plant height, panicle length, spikelets panicle^{-1}, spikelet fertility, tillers plant^{-1}, test weight, grain length, grain breadth, length: breadth ratio and seed yield plant^{-1}.

The data was analyzed following Panse and Sukhatme (1985). Genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) were calculated following the method suggested by Burton (1952), whereas heritability was calculated following Burton and DeVane (1953) and the genetic advance was estimated as per Johnson *et al*., (1955) using Windostat Genetic analysis software. The genetic divergence was estimated using D^2 statistics of Mahalanobis (1936) as described by Rao (1952). The D^2 values were used to make clustering pattern by Tocher's method.

Table 1. Variability parameters of rice genotypes

Character	Range	Mean	G.C.V.	P.C.V.	Heritability % (BS)	Genetic advance	G.A. as % of mean
Days to 50% flowering (number)	62.25 - 124.75	105.115	9.805	10.224	92.00	20.362	19.371
Days to maturity (number)	86.00 - 155.25	135.108	9.105	9.604	89.90	23.748	17.784
Plant height (cm)	65.03 - 152.48	107.237	20.932	21.591	94.00	44.829	41.804
Panicle length (cm)	17.00 - 27.55	23.033	11.014	11.885	85.90	4.843	21.027
Spikelets panicle^{-1} (number)	76.70 - 239.10	153.115	20.094	21.027	91.30	60.571	39.559
Spikelet fertility (%)	87.61 - 96.43	94.249	1.423	1.749	66.10	2.246	2.383
Tillers plant^{-1} (number)	5.45 - 9.45	7.393	11.342	13.123	74.70	1.493	20.193
Test weight (g)	9.46 - 33.70	21.624	24.605	24.612	99.90	10.957	50.671
Grain length (mm)	3.88 - 8.05	6.088	16.148	16.197	99.40	2.019	33.163
Grain breadth (mm)	1.60 - 2.92	2.139	14.128	17.169	67.70	0.512	23.947
L:B ratio	1.44 - 5.05	2.959	26.123	26.437	97.60	1.573	53.175
Seed yield plant^{-1} (g)	6.69 - 21.38	16.073	17.445	19.515	79.90	5.164	32.126

Results and Discussion

The genetic variability present in the material is the basis for improvement in crop plants. The utility of the germplasm could be judged on the basis of extent of variability available in the material. The analysis of variance were highly significant for all the morphological traits under study, designating considerable variation among the genotypes for all the characters under study. The present material therefore could serve a pool for selection of suitable material in breeding programme. This was in agreement with the findings of Gahalain (2006) and Naik *et al*., (2002), who reported significant differences for all the characters in their studies. The material was assessed for the genetic and environmental components of variability to estimate the true breeding value of the genotype. Among the characters studied, grain length: breadth ratio exhibited highest GCV and PCV (26.12 and 26.44, respectively), followed by test weight (24.61 and 24.61) whereas, spikelet fertility exhibited the lowest GCV (1.42) as well as PCV (1.75) (Table 1). The results are in confirmation with the studies of Singh and Choudhary (1996) who reported higher PCV and GCV for number of panicles plant^{-1} and test weight,

Table 2. Distribution of rice genotypes into different clusters based on agronomic characters

Cluster	No. of genotypes	Genotype	Characters
I	22	Phule Samruddhi, RDN 99-12, KJT 2, Indrayani, RDN 99-14, Haryana Basmati, Kasturi, RDN 01-2-10-9, Ratna, Improved Pusa Basmati 1, Taroari Basmati, Karnal Local, RTN purple, SD 7, Basmati 370, Bhogavati, Sugandhamati, EK 70, RDN 99-18, Sonsali, Antersal, Juhibengal.	Dwarf plant type, long-slender grain, medium test weight.
II	7	Ghansal, Ajara Local 1, Ambemohar 157, Ajara Local 3, Badshabhog, BPT 5204, Phule Radha.	Short grains, low L:B ratio, long panicle, more number of spikelets per panicle, low to medium test weight.
III	14	Halvi Sal 17, RDN 185-2, Pomendi Local, Jaya, Pinjarwadi Local, LK 248, Nalabhat, RTN1, Heera, Kunchi, Mahisugandha, IGT 13857, MC 4, Pawana	Early flowering and maturity, coarse grain type, low to medium L:B ratio, high test weight.
IV	12	Velkat, Tulshi tall, RDN 98-2-3-5-14, RDN 97-2, Vikram, Ambemohar 102, Basmati 386, RDN 02-80, Kalajirga, Jagatpuri, Kothimbire, Champakali.	Mixed performing group, intermediate in characters. Contains short- slender and long -slender grain type, early & midlate maturity, dwarf and tall plant type.
V	1	Pusa Basmati 1.	Extra long-slender grain, high L:B ratio.
VI	1	Pavsal.	Very late maturity, tall plant type, high no. of tillers, coarse grain type, high yield.
VII	1	SD 17	Extra long-slender grain, high L:B ratio.
VIII	4	Vivek Dhan 82, Siddhagiri, Phule Maval, Patni.	Long-bold grain, high test weight.
IX	2	Diwani, Shyamjeer.	Short-slender grain, very low test wt. (< 10 gm), tall plant type, late maturity.
X	1	Khalibagh.	Dwarf plant type, long-slender grain, high L:B ratio, low test weight.

whereas Marekar and Siddique (1997) reported higher GCV and PCV for grain length: breadth ratio in the study. The difference between magnitude of GCV and PCV was very low for all the characters studied, indicating good correspondence between genotypic and phenotypic expression of trait with low level of environmental factors operating on the trait.

The proportion of genetic variability which is transmitted from parent to progeny is reflected by heritability. In the present investigation, all the characters showed high broad sense heritability ranging from 66 per cent for spikelet fertility to 99 per cent for test weight and grain length (Table 1). Naik *et al*., (2002) and Raut *et al*., (2009) also reported high heritability for all the traits studied by them. As heritability in broad sense includes both additive and non-additive gene effects, heritability estimates should be considered in combination with genetic advance (Johnson *et al*., 1955). Based on this consideration, in the present investigation, high heritability coupled with high genetic advance were observed for spikelets per panicle followed by plant height, days to maturity and days to 50 per cent flowering. Direct selection based on these traits would be effective as heritability and genetic advance might be due to additive gene interaction. Genetic advance for grain yield plant^{-1} was low indicating the predominance of non-additive gene interaction. However, when expressed as percentage of mean, it was fairly high. Raut *et al*., (2009) also reported high heritability and high genetic advance for grains panicle^{-1}, plant height, days to maturity and 1000 grain weight highlighting the importance of these characters in direct selection.

The important objective in obtaining biometrical measurements is to understand the possibilities of classifying individual genotypes into different groups. With this view, the genetic divergence in 65 genotypes of rice was measured following Mahalanobis's (1936) D^2 statistics. The D^2 values corresponding to the pair of genotypes studied ranged from 4.21 to 24015.45 indicating the presence of great amount of genetic diversity in the material. Wide variation for agro-morphological traits of rice was observed indicating the presence of great amount of genetic diversity in the material. Wide variation for agro-morphological traits of rice was observed by many workers (Naik *et al*., 2002; Gahalain, 2006; Raut *et al*., 2009). The landraces reported higher D values indicating the presence of great amount of genetic diversity in the material.

The classification by Tocher's method grouped the rice genotypes into 10 clusters

Table 3. Average intra and inter cluster D^2 values of clusters

Cluster number	I	II	III	IV	V	VI	VII	VIII	IX	X
I	191.55	3940.07	1188.18	1128.96	377.53	509.41	820.25	3516.49	6947.22	724.69
II		256.64	8277.36	1296.00	4563.00	5095.10	7638.76	13656.26	641.61	3666.30
III			282.58	3642.12	1612.83	638.07	668.74	998.56	12624.77	2770.97
IV				350.06	1627.32	1710.65	3306.25	7394.28	3090.24	1428.84
V					0.00	1168.96	554.60	3976.56	7572.48	184.69
VI						0.00	1087.68	2328.06	8602.56	1944.81
VII							0.00	1832.70	11664.00	1285.22
VIII								457.10	19165.63	5776.00
IX									111.94	6144.99
X										0.00

Table 4. Mean performance of 10 clusters for agronomic characters in rice

Character	Cluster number									
	I	II	III	IV	V	VI	VII	VIII	IX	X
Days to 50% flowering (number)	107.36	109.00	98.82	105.50	98.25	121.25	106.50	101.38	109.75	107.00
Days to maturity (number)	136.55	138.00	125.91	133.90	123.75	151.00	136.25	128.25	140.00	136.50
Plant height (cm)	99.59	123.43	104.78	108.03	98.28	138.55	104.18	124.06	115.94	83.03
Panicle length (cm)	22.85	24.32	22.75	21.67	25.13	23.90	25.65	24.64	23.91	24.60
Spikelets panicle^{-1} (number)	143.80	206.27	134.44	159.68	131.45	141.50	166.65	141.44	196.53	148.20
Spikelet fertility (%)	93.76	95.26	93.99	94.52	93.52	94.80	94.10	94.93	95.41	93.68
Tillers plant^{-1} (number)	7.73	6.91	6.88	7.79	7.35	9.10	6.90	6.61	7.10	8.40
Test weight (g)	22.05	13.17	26.97	17.98	21.75	24.35	25.27	31.13	9.65	19.83
Grain length (mm)	6.65	4.69	6.27	5.41	7.75	5.23	7.95	6.39	4.68	8.05
Grain breadth (mm)	2.01	2.05	2.34	2.11	1.67	2.37	1.75	2.52	2.49	1.60
L :B ratio	3.40	2.35	2.75	2.62	4.65	2.21	4.56	2.63	2.08	5.05
Seed yield plant^{-1} (g)	16.07	15.35	15.69	16.04	15.39	16.54	16.54	18.73	16.50	15.27

(Table 2). Cluster I was the largest including 22 genotypes followed by cluster III (14 genotypes), cluster IV (12 genotypes), cluster II (7 genotypes), cluster VIII (4 genotypes) and cluster IX (2 genotypes). The clusters V, VI, VII and X had single genotypes.

Cluster I included largest number of genotypes, mainly comprised of improved varieties having dwarf plant type with long-slender grain type and medium test weight. The group is of interest because of prevailing cultivated scented basmati (Basmati 370, Taraori Basmati) and non-basmati (Indrayani, Bhogavati, Phule Samruddhi) varieties. Whereas, cluster II consisting of seven genotypes was characterized by short-slender or short-bold grained genotypes with long panicle length and higher number of spikelets. The widely cultivated fine grained BPT 5204 and Phule Radha were grouped in this cluster. Cluster III represents medium-slender or long-bold genotypes with medium grain length, broader grain width and high test weight, whereas the four genotypes (Vivek Dhan 82, Siddhagiri, Phule Maval, Patni) with very bold grains with low length-breadth ratio and high grain yield per plant were grouped in the cluster VIII.

The cluster IX comprised of two landraces, one each from Uttar Pradesh (Diwani) and Bihar (Shyamjeer). These genotypes have short-slender grain with very low test weight (9.65 g) grouping them separately from other

Table 5. Percent contribution of agronomic characters for divergence in rice

Character	No. of times appearing Ist in ranking	Per cent contri-bution
Days to 50% flowering (number)	10	0.48
Days to maturity (number)	0	0.00
Plant height (cm)	24	1.15
Panicle length (cm)	0	0.00
Spikelets panicle^{-1} (number)	2	0.10
Spikelet fertility (%)	2	0.10
Tillers plant^{-1} (number)	1	0.05
Test weight (g)	1644	79.04
Grain length (mm)	269	12.93
Grain breadth (mm)	4	0.19
L :B ratio	123	5.91
Seed yield plant^{-1} (g)	1	0.05
Total	2080	100.00

genotypes. These landraces can be used for breeding very fine grained varieties. The clusters V, VI, VII and X with single genotypes represents the unique genotypic constitution in these genotypes. The extra-long, fine grained genotypes Pusa Basmati 1, SD 17 and Khalibagh were grouped separately in cluster V, VII and X, respectively and were separated mainly based on their distinct expression for plant type, duration and test weight. Whereas, the genotype Pavsal grouped in cluster VI represents a tall plant type with very late maturity, short bold grains. These clusters with single genotypes represent unique allelic combinations with independent evolutionary history that distinguishes them from most other varieties and can be used as diverse sources in future breeding programme. It indicates that grouping of rice genotypes based on agronomic traits largely reflects the phenotypic similarities between them. The grouping was more or less character specific (i.e. plant stature, maturity, grain type etc.) than that to ancestry, geographical or evolutionary terms.

The intra and inter cluster D^2 and D values worked out from divergence analysis (Table 3) showed maximum intra cluster distance between the cluster VIII (D^2 = 457.10), followed by cluster IV (350.06) and cluster III (D^2 = 282.58), indicating that the genotypes in these clusters might have different genetic architecture. The minimum intra-cluster distance was found in cluster IX (D^2 = 111.94), followed by cluster I (D^2 = 191.55) and cluster II (D^2 = 256.64). The cluster V, VI, VII and X being monogenotypic, had intra-cluster distance 0.00.

The maximum inter-cluster distance was observed between cluster VIII and IX (D^2 = 19165.63), followed by cluster II and VIII (D^2 = 13656.26) indicating a wide range of divergence among these clusters, whereas, the cluster V and X (D^2 = 184.69) reported

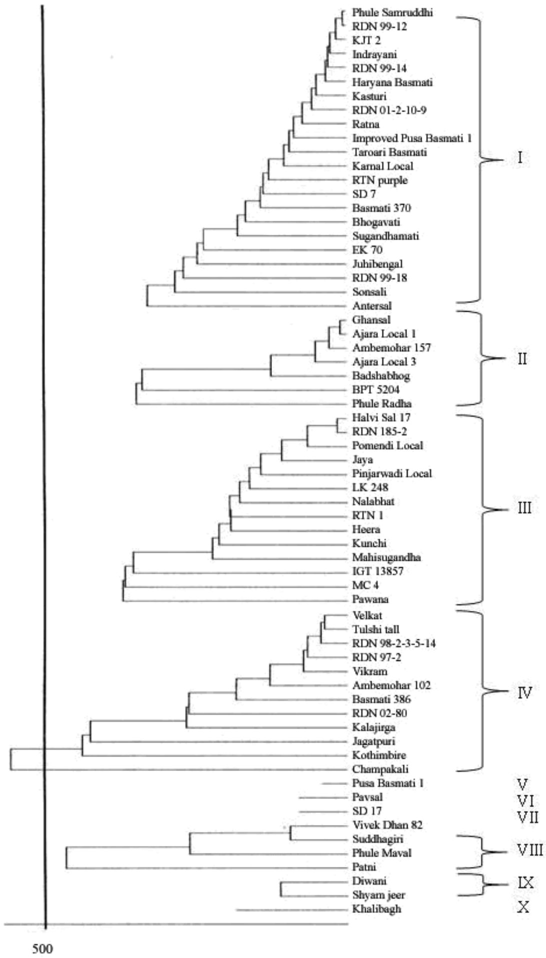

Fig. 1. Clustering of rice genotypes by Tocher's method

minimum inter-cluster distance followed by cluster I and V (D^2 = 377.53) suggesting minimum genetic relatedness among the genotypes of the concern clusters. Genotypes of distinct clusters separated by high genetic distances would be utilized in breeding programme for obtaining a wide range of variability in the segregating generation. Results of present investigation suggest a possibility for obtaining greater variation in the segregating generations derived from hybridization between genotypes of cluster II, VIII, IX and X. Cluster means for twelve characters presented in Table

4 revealed wide range of variability among the clusters for the characters plant height, days to 50 per cent flowering, days to maturity, spikelets panicle^{-1}, tillers plant^{-1}, test weight, grain length, grain breadth and L:B ratio. Gahalain (2006) also reported wide variation in the mean performance among twelve clusters of 55 rice genotypes, whereas Raut *et al.*, (2009) reported wide variation in the performance of three clusters formed from 40 rice genotypes for all the characters under study.

The per cent contribution of the twelve characters studied towards total divergence (Table 5), indicated that the test weight has contributed major part of divergence (79.04%), followed by grain length (12.93%) and length: breadth ratio (5.91%). The contribution of other characters is least. This suggested that test weight, grain length and length: breadth ratio should deserve the consideration while choosing parents for breeding programme. Higher contribution of test weight and length: breadth ratio was also reported by Bharadwaj *et al.*, (2001) and Rather *et al.*, (2001).

Based on the diversity study, the genotypes from genetically diverse clusters can be selected to exploit maximum heterosis and to get best transgressive segregants in advance generations. The crosses between the genotypes from clusters II, III, VIII and IX may give high heterotic performance. Genotypes from these clusters with higher grain yield and/or specific traits can be used in further breeding programme.

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Influence of NPK Fertilizers on Growth and Yield of Heliconia sp. cv. 'Local Yellow'

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Abstract

An investigation was carried out to study the effect of inorganic fertilizers on growth, flowering and yield in heliconia (*Heliconia* sp.) cv. 'Local Yellow'. The treatment combination of 20:20:10 g NPK plant^{-1} (T_6) recorded significantly higher plant height (175.73 cm), number of leaves (182.51), shoot girth (7.85 cm), leaf length (64.84 cm), leaf breadth (20.93 cm), number of shoots (47.00) and time required for reproductive phase (141.8 days). Longer spike (156.97 cm), number of bracts (91.54), spikes (22.67), flowers (57.53 m^{-2}) and vase life (11.04 days) were obtained in plants which were nourished with 20:20:20 g NPK plant^{-1} (T_8).

Key words : Growth, yield, NPK fertilizers, heliconia

Heliconia (*Heliconia* sp.) is tropical plant of princely dimensions grown for attractive foliage and brilliant flower spikes. It is native to Central and South America. Recently, it is shifted to the family Heliconiaceae. Heliconia is mostly grown for flowers and beautifying the garden. The inflorescence is a cluster of bracts. The showy part of the spikes is the colorful bracts subtending the flowers. They are gaining popularity among the flower growers of India owing to the fact that they can be successfully grown with little care and attention and they do fairly well under partial shade also. Bracts are the main floral parts contributing to the attractiveness of the spikes (Sheela *et al*., 2005). It is necessary to develop suitable agrotechniques to enhance production of high quality spikes. Nutrition is one of the most important aspects in increasing the flower yield of heliconia. Growth and flower yield could be optimized with appropriate fertilizer application, provided attention is paid to the N: K ratio so that the size of the plants and their flowers. The probability of shoots flowering declined markedly with order of shoot emergence, although this could be increased with appropriate mineral nutrition. The maximum number of leaves subtending the inflorescence was obtained at high N and P rates (Rajeevan *et al*., 2003). The present investigation was, therefore, undertaken in order to determine the most suitable form of nutrient combination and its application in heliconia under coconut plantation.

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Materials and Methods

The experiment was laid out on heliconia (*Heliconia* sp.) cv. 'Local Yellow' in randomized block design with nine treatments and three replications during 2013-2014 at Horticultural Research Station, Vijayarai, West Godavari Dt. Andhra Pradesh. The treatments consisted combination of different source of inorganic nutrients *viz*., T_1-10:10:10 g NPK plant^{-1}, T_2-10:20:10 g NPK plant^{-1}, T_3-10:10:20 g NPK plant^{-1}, T_4-10:20:20 g NPK plant^{-1}, T_5-20:10:10 g NPK plant^{-1}, T_6-20:20:10 g NPK plant^{-1}, T_7- 20:10:20 g NPK plant^{-1}, T_8-

20:20:20 g NPK plant^{-1} and T_9 - Control (farmyard manure @ 2.5 kg m^{-2}).

Healthy rooted rhizomes were planted in raised bed at the spacing of 60 x 60 cm. The beds were incorporated with well decomposed FYM @ 2.5 kg m^{-2}. Drip irrigation system was installed under the coconut for heliconia and depending on the soil condition, the beds were irrigated with drip method. The inorganic nutrients, half dose of N and full dose of P and K was applied as a basal at the time of planting and remaining half dose of N was applied at 60 days after planting to respective treatments. All the cultural operations were carried out uniformly. The data was recorded for different growth and yield parameters from five tagged plants and was statistically analyzed.

Results and Discussion

The different nutrient combinations significantly influenced the plant height (Table 1). Plants which received the treatment 20:20:10 g NPK plant^{-1} (T_6) recorded significantly highest plant height (175.73 cm). Shortest plant height of 136.45 cm was recorded in plants which were nourished with organic manures (T_9). Increase in plant height due to nutrient combination could be attributed to the role of major essential nutrients (N, P and K) in plant metabolism, particularly in the cell elongation and multiplication and also wider spacing attributing to reduced competition for space, light, soil moisture and nutrients. This is in close conformity with the results of several earlier reports in heliconia (Girish, 2006; Clemens and Morton, 1999; Ferreira and Oliveira, 2003) and in banana (Dinesh *et al*., 2008).

Plants applied with treatment T_6 showed significantly higher number of leaves plant^{-1} (182.51), whereas minimum leaf number was recorded in only organic source of application (60.10). Plants nourished with 20:20:10 g NPK plant^{-1} recorded significantly highest shoot girth (7.85 cm), longer leaves (64.84 cm), more leaf breadth (20.93 cm) and more number of shoots plant^{-1} (47.00).

The nutrient combination consisted of higher ratio of nitrogen and phosphorous mediated increased root geometry, might had further contributed to improved growth resulting in increased photosynthesis, source sink relationship, besides excellent chemical

Table 1. Effect of NPK fertilizers on vegetative parameters of *Heliconia* cv. 'Local Yellow'

Treatment	Plant height (cm)	No. of leaves	Shoot girth (cm)	Leaf length (cm)	Leaf breadth (cm)	No. of shoots clump^{-1}
T_1	145.03	129.67	7.13	60.50	15.06	41.20
T_2	175.23	110.40	7.43	57.20	13.68	38.27
T_3	165.16	124.40	7.38	64.57	14.69	37.60
T_4	170.15	126.88	6.83	53.20	14.59	43.60
T_5	170.31	120.02	6.75	58.22	14.61	25.53
T_6	175.73	182.51	7.85	64.84	20.93	47.00
T_7	152.22	93.38	6.48	56.57	16.38	28.87
T_8	159.62	101.84	6.75	55.47	13.75	33.93
Control (T_9)	136.45	60.10	4.69	29.18	13.23	22.45
CD (P=0.05)	17.46	2.47	1.65	15.34	1.63	14.37
S.EM ±	5.78	0.81	0.54	5.07	0.54	4.75
CV (%)	6.21	1.21	13.84	15.82	6.14	23.26

activities (Bhalla *et al*., 2006). The early and increased sprouting percentage leading to rapid development of root system is critical to the successful establishment of heliconia in the field. Similar results of increased vegetative growth were also reported by Sushma *et al*., (2012) in heliconia.

Table 2 indicates that, there was significant influence of treatments on flower parameters and yield of heliconia. Plants took minimum days (141.80 days) to reach reproductive stage when they were treated with 20:20:10 g NPK plant^{-1}. The treatment (T_8) developed significantly longer spike (156.97 cm), bract count (91.54), number of spikes (22.67), number of flowers (57.53) and vase life in distilled water (11.04 days). This could be attributed to the input combination comprised higher ratio of phosphorus, particularly potassium could have contributed excellent biochemical functions which could resulted in better flower and yield. Increase in yield and improvement in quality due to nitrogen and phosphorous levels could be related to the corresponding increase in growth parameters like plant height, number of leaves, stem girth and number of tillers which ultimately might have resulted in higher photosynthesis and yield per plant. Similar results with respect to yield and yield components had been reported earlier in heliconia by Bankar (1990).

The effect of inorganic nutrients on number of flowers statistically varied. It can also be attributed to the fact that there will be higher translocation of carbohydrates from other parts to reproductive parts during development. The source to sink translocation can be more effective only when the rate of photosynthesis is high (Johnson, 1984). Further, the photosynthetic capacity of a plant depends upon chlorophyll content in leaves (Mathur and Vyas, 1995). A similar trend of findings in heliconia was reported by Sudhakar and Ramesh Kumar (2012).

Hence, it can be concluded from the investigation that the plants nourished with inorganic nutrient combination using 20:20:10 NPK plant^{-1} (T_6) and 20:20:20 NPK plant^{-1} (T_8) showed good result to all growth, flower and yield parameters, respectively.

Table 2. Effect of NPK fertilizers on flower and yield parameters of Heliconia cv. 'Local Yellow'

Treatments	Time required to reach reproductive stage	Spike length (cm)	No. of bracts	No. of spikes	Vase life (days)	No. of flowers m^{-2} (yield)
T_1	195.22	156.38	57.77	16.27	6.88	51.87
T_2	166.00	142.71	55.83	17.00	7.96	50.88
T_3	194.07	152.80	75.49	19.20	6.32	51.40
T_4	195.20	152.73	80.54	18.47	8.93	52.16
T_5	205.85	151.07	64.15	11.30	7.40	41.49
T_6	141.80	139.21	76.46	22.40	6.80	49.42
T_7	168.08	137.93	71.09	18.13	5.93	40.38
T_8	168.74	156.97	91.54	22.67	11.04	57.53
Control (T_9)	225.33	122.23	51.85	14.04	5.17	42.86
CD (P=0.05)	6.26	11.96	4.63	2.69	0.67	5.11
S. EM ±	2.07	3.96	1.53	0.89	0.22	1.73
CV (%)	1.94	4.70	3.82	8.69	5.17	5.86

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Evaluation of Germination Properties of Different Durum Wheat (*Triticum aestivum* L.) Genotypes under Osmotic Stress

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Abstract

Drought stress, play an important role in reduction of the plant growth stage, specifically during germination in arid and semi arid regions in India. Result indicated significant difference among wheat (*Triticum aestivum*) genotypes with respect to drought stress levels. In all the traits studied a significant reduction was observed with increase in stress, but highest reduction was observed in -5 and -7 bar osmotic stress. Drought stress reduced the shoot and root length at more than -3 bar. The genotype NI-5439 and K-227 exhibited better germination percentage, shoot length and seed vigour at all higher osmotic stress levels. The genotype HD-2932 and K-227 showed better performance for root length. According to dry weight basis NIAW-1161 and NI-5439 were found promising to drought.

Key words : Osmotic stress, wheat, PEG-6000, root, shoot, vigour

Water deficit can be defined as the absence of adequate moisture necessary for normal plant growth and to complete the life cycle (Zhu, 2002). Water stress is a problem in 45% of the world's geographical area and is a major limitation to the productivity of agricultural systems and food production worldwide (Boyer, 1982). Drought stress significantly reduced the yield of some genotypes and some of them revealed tolerance to drought, which suggested the genetic variability for drought tolerance (Talebi *et al.,* 2009). Evaluation of crop tolerance to environmental stresses during seed germination and seedling emergence is a main measure to choose them for cropping in different circumstances since common investigations in field conditions are time consuming and influenced by many companion variables of climate, soil and agricultural practices, so fast and precise evaluation of crop response to stress would be achieved using an experiment in controlled environment conditions (Khalesro and Aghaalikhani, 2006). The capacity for osmotic adjustment was the main physiological attribute associated with wheat resistance under cyclic water stress which enabled plants to recover from water deficit (Izanloo *et al*., 2008). Seedling and early growth vigour in wheat and barley might be important for plant water status under drought stress since faster ground cover reduces soil surface evaporation and increases the amount of soil moisture available for transpiration (Rebetzke and Richards, 1999).

Water stress at different growth stages causes various morpho-physiological alters in the plant to acclimatize under such conditions. For example, water stress at seedling stage might lead to higher germination rate, higher dry root weights, longer roots and coleoptiles which could be exploited as selection criteria for stress tolerance in crop plants at very early stages of growth (Dhanda *et al*., 2004). Various methods are used to screen genotypes for water stress in stress physiology studies out of which screening genotypes based on polyethylene glycols or PEG is a neutral osmotically active

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polymers with a certain molecular weight PEG 6000 (the number signifying molecular mass) is most frequently used to induce dehydration by decreasing the water potential of the nutrient solution. Polyethylene solutions are commonly used to control water potential in seed germination (Young *et al.*, 1983). PEG solutions are used because higher molecular weight cannot pass through plant cell wall (Carpita *et al.*, 1979) and a solution water potential control and eliminate the confounding hydraulic conductivity effect solution seed in contact the seed germination medium. Many experiment have been done and the results have showed plumule is more likely to be affected by water stress than other traits. Hence the purpose of this study was to screen wheat genotypes under different levels of osmotic stress conditions and detect drought tolerant and susceptible genotype. As seed germination is considered to be the most critical growth stage especially, under water stress conditions for the successful stand establishment of crop plants it was used and determined in this study.

Materials and Methods

In order to study drought stress, an experiment was carried out in a completely randomized design with two replications and five level of PEG-6000 (0, -1, -3, -5 and -7 Bar). The seeds of twenty five wheat genotypes were obtained from Agriculture Research Station, Niphad, Maharashtra. The experiment was carried out in seed germination chamber, Seed Technology Research Unit, Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra.

Osmotic potentials were produced using different concentrations of polyethylene glycol 6000 (PEG) at 20°C according to the method of Michel and Kaufmann (1973). PEG-6000 (0, 78.49, 151.020, 202.130 and 243.485 g) was dissolved in 1 L of nutrient solution separately to create water stress treatments of control, -1, -3, -5 and -7 bar, respectively. Twenty seeds were placed in two layers of Whatman No. 2 filter paper in 20 x 40 mm glass petridish and 25 ml of 0, -1, -3, -5 and -7 bar O. P. solutions were added. Number of seeds germinated was counted at 2^{nd}, 4^{th}, 6^{th} and 8^{th} days. A seed was considered germinated when radicle had emerged up to 3 mm. Total germination was expressed in per cent and data were analyzed statistically. Shoot length and root length, dry weights of seedling were recorded after 8th days from start of the experiment.

Seedling vigour was calculated at 2^{nd}, 4^{th}, 6^{th} and 8^{th} days. Numbers of seedling emerged were counted from day of sowing the seeds in the medium till the time of germination is complete. Thereafter a germination index (G.I.) was computed by using the following formula;

$$\text{G.I.} = \frac{\text{Number of seedlings emerging on day}}{\text{Day after counting } (2^{nd}, 4^{th}, 6^{th} \text{ and } 8^{th})} \times 100$$

Greater the G.I. showed vigorous seedling than laser ones.

Results and Discussion

Per cent germination at 4^{th}, 6^{th}, and 8^{th} days : The per cent germination at 0 osmotic potential (non stress) MPa to -1.2 MPa condition, it was observed that increased drought levels had deleterious effect on germination. Ahmadi *et al.*, (2012) observed per cent germination, root length, root dry weight and vigour index of all species were decreased with increas in PEG concentration. Germination begin with water uptake by the seed (imbibitions) and end with the emergence of the embryonic axis, usually the radical.

From 4^{th} to 8^{th} day the observed per cent germinations were, at 0 bar 22.50-100%, -1 bar 17.50-100%, -3 bar 15-100% (NI-5439, 100%), -5 bar 02.50-97.50% (NI-5439, 97.50%) and -7 bar 0-90% (NI-5439, 75% and RAJ-3765, 0%) (Table 1). NI-5439 exhibited better germination per centage at all levels of stress followed by K-227, whereas overall minimum germination was recorded in RAJ-3765 and NIAW-2313. Germination is adversely affected by moisture stress. Maximum germination per centage (97.50 and 90.00%) was recorded in NI-5439 followed by K-227 (92.50 and 82.50%) at osmotic potential of -5 and -7 bars at 6th and 8th day.

The genotypes responded differently to various osmotic stress levels. Drought (moisture) stress can contribute to improved germination rate and seedling emergence in different plant species by increasing the expression of aquaporins (Gao *et al.*, 1999), ATPase activity enhancement, RNA and phosphatase acid synthesis (Fu *et al.*, 1988) and also by increasing proteases or lipases activity analysis

Table 1. PEG 6000 induced osmotic stress influenced on per cent germination of wheat genotypes at 4th, 6th and 8th days

Genotypes	% Germination at 4th day					% Germination at 6th day					% Germination at 8th day				
	0 bar	-1 bar	-3 bar	-5 bar	-7 bar	0 bar	-1 bar	-3 bar	-5 bar	-7 bar	0 bar	-1 bar	-3 bar	-5 bar	-7 bar
HD-2781	27.50	27.50	25.00	12.50	7.50	90.00	82.50	67.50	60.00	42.50	95.50	92.50	92.50	63.00	55.00
HD-2987	37.50	35.00	32.50	17.50	5.00	85.00	72.50	60.00	60.00	47.50	100.0	97.50	75.00	70.00	55.00
HD-2932	45.00	40.00	32.50	22.50	12.50	95.00	92.50	85.00	72.50	47.50	100.0	100.0	92.50	91.50	67.50
HI-977	40.00	37.50	35.00	22.50	12.50	90.00	77.50	62.50	72.50	52.50	100.0	97.50	95.00	91.50	80.00
K-227	35.00	35.00	27.50	17.50	15.00	92.50	82.50	77.50	72.50	55.00	97.50	92.50	92.50	92.50	82.50
MP-4080	37.50	35.00	30.00	12.50	05.00	77.50	72.50	67.50	60.00	45.00	97.50	97.50	92.50	87.50	75.00
RAJ-4037	35.00	22.50	20.00	12.50	10.00	87.50	82.50	70.00	67.50	52.50	95.00	95.00	92.50	87.50	80.00
SONALIKA	52.00	45.00	37.50	12.50	00.00	92.50	87.50	67.50	57.50	22.50	100.0	95.00	92.50	65.00	32.50
AKAW-4627	47.50	42.50	32.50	20.00	05.00	87.50	77.50	70.00	52.50	40.00	100.0	97.50	95.00	92.50	57.50
DBW-14	50.00	47.00	32.50	15.00	02.50	77.50	87.50	67.50	60.00	20.00	97.50	92.50	90.00	62.50	27.50
NIAW-9947	42.50	42.50	37.50	15.00	12.50	90.00	87.50	72.50	73.00	42.50	95.00	92.50	95.00	92.50	52.50
NIAW-1121	45.00	47.50	40.00	27.50	02.50	97.50	87.50	77.50	62.50	22.50	97.50	97.50	97.50	67.50	25.00
NIAW-1161	42.50	35.00	27.50	05.50	00.00	92.50	90.00	67.50	55.00	17.50	100.0	97.50	90.00	82.50	27.50
NIAW-1188	37.50	35.00	27.50	20.00	07.50	87.50	87.50	70.00	62.50	37.50	95.00	95.00	92.50	85.00	42.50
NIAW-34	35.00	30.00	25.00	15.00	07.50	95.50	93.00	72.50	67.50	47.50	100.0	92.50	87.50	87.50	60.00
NI-5439	52.50	50.00	32.50	30.00	12.50	92.50	92.50	87.50	72.50	72.50	100.0	100.0	100.0	97.50	90.00
NIAW-1415	30.00	25.00	22.50	20.00	05.00	95.00	92.50	82.50	70.00	22.50	97.50	92.50	92.50	75.00	27.50
NIAW-2030	47.50	32.50	25.00	12.50	02.50	75.00	77.50	62.50	55.00	35.00	95.00	92.50	92.50	87.50	45.00
NIAW-1885	40.00	35.00	20.00	10.00	05.00	80.00	72.50	65.00	55.00	12.50	97.50	97.50	95.00	85.00	45.00
NIAW-1994	45.00	40.00	32.50	15.00	10.00	92.50	87.50	75.00	62.50	42.50	97.50	92.50	92.50	87.50	52.50
NIAW-301	27.50	25.00	22.50	17.50	02.50	85.00	80.00	70.00	62.50	30.00	97.50	95.00	92.50	80.00	40.00
MACS-6222	30.00	22.50	17.50	15.00	02.50	70.00	65.00	60.00	55.00	20.00	97.50	95.00	92.50	90.00	22.50
NIAW-2313	35.00	30.00	15.00	05.00	00.00	72.50	67.50	62.50	52.45	07.50	100.0	92.50	92.50	70.00	12.50
RAJ-3765	22.50	17.50	15.00	02.50	00.00	65.00	57.50	60.00	42.50	07.50	97.50	90.00	92.50	72.50	07.50
HD-2285	40.00	32.50	20.00	07.50	07.50	87.50	77.50	67.50	52.50	20.00	97.50	92.50	87.50	62.50	22.50
Mean	39.18	34.68	27.40	15.32	06.10	86.12	81.22	69.90	61.42	34.50	97.92	94.90	92.10	81.04	47.40
S.E.±	2.18	1.96	1.74	1.15	0.41	2.06	2.74	3.43	2.89	1.94	2.18	2.29	2.87	2.65	2.29
CD@1%	6.36	5.70	5.06	3.36	1.20	6.00	7.98	9.98	8.42	5.66	NS	NS	8.65	7.71	6.68

Table 2. PEG 6000 induced osmotic stress influenced on shoot length, root length, dry weight and seed vigour of wheat genotypes at 8th day

Genotypes	Shoot length (cm)					Root length (cm)					Dry weight (g)					Seedling vigour				
	0 bar	**-1 bar**	**-3 bar**	**-5 bar**	**-7 bar**	**0 bar**	**-1 bar**	**-3 bar**	**-5 bar**	**-7 bar**	**0 bar**	**-1 bar**	**-3 bar**	**-5 bar**	**-7 bar**	**0 bar**	**-1 bar**	**-3 bar**	**-5 bar**	**-7 bar**
HD-2781	14.20	17.30	10.85	02.30	2.20	18.05	19.83	18.56	13.81	12.70	0.036	0.031	0.032	0.034	0.030	3.59	3.46	3.30	2.29	1.86
HD-2987	14.46	12.60	05.00	04.30	2.85	22.88	22.60	18.75	15.24	15.70	0.050	0.040	0.034	0.032	0.031	3.84	3.63	2.92	2.54	1.86
HD-2932	16.88	15.45	08.40	10.02	1.45	20.51	19.03	15.90	18.80	10.35	0.042	0.036	0.034	0.032	0.031	4.04	3.94	3.57	3.29	2.23
HI-977	17.76	16.70	09.95	08.64	3.40	20.66	21.40	18.60	17.86	12.15	0.033	0.035	0.031	0.031	0.030	3.92	3.71	3.48	3.25	2.65
K-227	19.08	17.20	13.65	10.70	4.35	19.81	19.10	19.85	17.84	17.55	0.042	0.037	0.035	0.031	0.026	3.79	3.52	3.42	3.11	2.77
MP-4080	20.44	21.80	15.00	08.80	3.58	19.39	18.95	15.65	14.65	11.75	0.035	0.030	0.029	0.029	0.028	3.71	3.63	3.38	2.90	2.34
RAJ-4037	16.52	17.13	11.85	05.70	2.55	19.65	23.74	21.78	16.75	13.50	0.052	0.048	0.042	0.039	0.027	3.69	3.44	3.23	2.96	2.61
SONALIKA	15.58	15.75	10.50	03.40	0.85	17.92	21.34	21.40	16.33	09.30	0.042	0.046	0.042	0.038	0.038	4.15	3.86	3.50	2.32	1.00
AKAW-4627	16.58	12.49	10.65	04.70	1.50	21.59	19.97	17.91	16.97	12.40	0.049	0.048	0.043	0.040	0.029	4.02	3.79	3.50	3.09	1.86
DBW-14	14.39	11.80	09.80	03.55	0.35	19.40	17.70	19.70	15.70	10.15	0.042	0.039	0.036	0.030	0.029	3.92	3.84	3.36	2.31	0.90
NIAW-9947	18.29	15.45	09.25	05.95	1.90	18.69	19.72	16.55	16.85	13.65	0.037	0.040	0.033	0.031	0.030	3.84	3.75	3.61	3.18	1.88
NIAW-1121	21.15	15.39	09.86	03.95	0.25	19.18	21.32	16.29	14.07	09.70	0.043	0.032	0.039	0.035	0.028	4.00	3.96	3.75	2.68	0.86
NIAW-1161	14.85	17.06	11.55	06.85	0.35	20.67	23.66	22.55	17.70	09.75	0.056	0.047	0.047	0.044	0.041	3.98	3.77	3.27	2.61	0.84
NIAW-1188	15.88	12.45	09.83	05.60	1.35	16.89	22.75	14.40	15.99	13.35	0.035	0.036	0.035	0.030	0.028	3.73	3.69	3.36	2.94	1.51
NIAW-34	15.77	13.85	09.65	04.75	1.65	20.28	21.90	17.56	14.65	11.20	0.047	0.036	0.037	0.034	0.029	3.88	3.59	3.21	3.00	2.03
NI-5439	21.90	19.85	12.54	08.75	4.83	19.34	18.47	19.61	16.55	15.05	0.046	0.046	0.043	0.041	0.040	4.15	4.11	3.77	3.54	3.07
NIAW-1415	12.74	14.05	08.50	04.75	0.30	20.73	20.71	21.80	16.95	08.20	0.035	0.036	0.034	0.030	0.025	3.73	3.50	3.38	2.79	0.96
NIAW-2030	23.84	20.15	13.50	07.55	1.75	19.95	21.75	20.45	13.97	11.20	0.056	0.046	0.047	0.044	0.033	3.79	3.50	3.25	2.86	1.46
NIAW-1885	16.87	16.78	12.34	05.95	0.35	19.79	19.65	20.93	15.45	09.25	0.039	0.036	0.037	0.033	0.032	3.77	3.63	3.25	2.75	1.31
NIAW-1994	14.88	13.60	08.05	03.85	0.45	20.20	20.98	18.74	15.35	10.00	0.043	0.039	0.037	0.035	0.029	3.96	3.71	3.48	2.96	1.84
NIAW-301	16.07	15.95	11.90	04.90	3.30	21.39	20.91	16.25	17.80	15.70	0.039	0.034	0.031	0.030	0.029	3.61	3.46	3.28	2.82	1.29
MACS-6222	16.48	16.01	10.30	05.05	2.65	21.95	25.23	20.09	14.50	15.10	0.048	0.035	0.033	0.032	0.027	3.52	3.29	3.11	2.96	0.77
NIAW-2313	18.56	16.83	13.10	03.05	0.30	22.63	21.25	18.50	14.25	12.00	0.035	0.031	0.028	0.027	0.024	3.69	3.38	3.09	2.27	0.38
RAJ-3765	17.47	16.95	12.37	02.80	0.25	21.32	21.63	20.61	13.60	11.00	0.044	0.038	0.037	0.028	0.026	3.36	3.08	3.07	2.21	0.25
HD-2285	18.98	15.59	14.50	05.40	1.90	20.62	17.90	17.60	14.25	12.85	0.043	0.042	0.039	0.031	0.029	3.84	3.50	3.09	2.13	0.86
Mean	17.18	15.93	10.92	5.65	1.79	20.14	20.86	18.80	15.84	12.14	0.043	0.039	0.037	0.034	0.030	3.82	3.63	3.34	2.79	1.57
S.E.±	0.75	0.85	0.63	0.32	0.15	0.88	1.178	0.88	0.60	0.60	0.001	0.001	0.001	0.002	0.002	0.13	0.10	0.08	0.13	0.06
CD@1%	2.19	2.47	1.85	0.93	0.44	NS	3.431	2.58	1.80	1.74	0.004	0.004	0.004	0.005	0.005	NS	0.30	0.23	0.38	0.18

(Ashraf and Foolad, 2005). According to Ayaz *et al*., (2000), seed germination reduction under stress conditions is due to occurrence of some metabolic disorders. It seems that, decrease in germination per centage and germination rate is related to reduction in water absorption into the seeds at imbibition and seed turgescence stages (Hadas, 1977). Diverse genetic differences were found among the genotypes with respect to germination and there was a substantial decline in germination in all wheat genotypes. These findings are in agreement with the outcomes of Jotoi *et al*., (2014) in wheat cultivars.

Shoot length at 8th day : The mean shoot length was 17.18, 15.93, 10.92, 5.65 and 1.79 cm under 0, -1, -3, -5 and -7 bar osmotic potential of moisture stress, respectively (Table 2). Slight increases in shoot length associate with the -1 bar treatment, it was observed in HD-2781, MP-4080, RAJ-4037 and NIAW-1161 genotypes. The genotype NI-5439 (at -5 bar, 08.75 and -7 bar, 4.83 cm) and K-227 (at -5 bar, 10.70 and -7 bar, 4.35 cm) were found superior in respect of shoot length. Lowest values of shoot length (02.80 and 0.25 cm) recorded in RAJ-3765 at osmotic potential of -5 and -7 bars.

Root length at 8th day : In general, root length was not much affected as compared to shoot length and they showed genotype to genotype variation. The mean root length was 20.14, 20.86, 18.80, 15.84 and 12.14 cm under 0, -1, -3, -5 and -7 bar osmotic potential of moisture stress condition, respectively (Table 2). Slight increases in root length associate with the -1 bar treatment, it was observed in HD-2781, HI-977, SONALIKA, NIAW-9947, NIAW-1188, MACS-6222, RAJ-4037 and NIAW-1161 genotypes. Similar result also reported by Jatoi *et al*., (2014) in wheat cultivars.

The genotype HD-2932 (18.80 cm) and HI-977 (17.86 cm) recorded highest root length at -5 bar, whereas, K-227 (17.55 cm) and NIAW-301 (15.70 cm) reported highest root length at -7 bar and were found superior in respect of shoot length. Minimum values of root length (13.60 cm and 08.20 cm) recorded in RAJ-3765 and NIAW-1415 at osmotic potential of -5 and -7 bars, respectively.

PEG concentration (drought stress) affects seed germination via limitation of water absorption by seeds (Dodd and Donovan, 1999), excessive use of nutrient pool (Bouaziz and Hicks, 1990) and creation of disorders in protein synthesis. PEG concentrations resulted in a decline of seedling length. The reduction in the shoot and root length may be due to an impediment of cell division and elongation, leading to a kind of tuberization. This tuberization and lignifications of the root system allow the water stress plant to enter a slow-down state, while waiting for the conditions to become favourable (Fraser *et al*., 1990). Badiane *et al*., (2004) concluded that the expression of certain genes controlling root formation is stimulated by drought conditions which indicated a promising role of some dominant drought tolerance genes in wheat varieties which developed a decent root system under water deficit condition.

Radhouane (2007) showed that, genotypes with longer root length under water stress conditions are able to access deeper water in the soil. He suggested that the increase in root length was an adaptive response. In present study, K-277 and NI-5439 had the highest root length at severe stress condition and there was positive correlation between shoot length and root length. The reason may be that root is the first organ emerged from the seed, therefore its growth is faster than shoot and also shoot have no any direct contact with water resources because of its lately emergence and its location on the seed (Matsou *et al*.,1995). These findings are in agreement with the outcomes of Dhanda *et al*., (2004) and Jotoi *et al.,* (2014) reported that with the increase in water stress, root and shoot length decreases.

Dry weight at 8th day : Seedling survival in drought prone environments may depend upon the species ability to compensate for the negative effect of low water potentials in the soil and atmosphere by adjusting root and shoot morphological and physiological patterns. The mean dry weight was 0.043, 0.039, 0.037, 0.034 and 0.030 g under 0, -1, -3, -5 and -7 bar osmotic potential of moisture stress, respectively (Table 2). The genotype NIAW-1161 (at -5 bar, 0.044 g and -7 bar, 0.041 g) and NI-5439 (-7 bar, 0.040 g) were found superior in respect of dry weight. Minimum values of dry weight (0.027 g and 0.024 g) recorded in NIAW-2313 at osmotic potential of -5 and -7 bars.

Genetic variations were recorded among the genotypes with respect to growth subjected to osmotic stress conditions. Dry weight has been utilized as a selection criterion for drought tolerance by many plant breeders. Water uptake by the root is a complex parameter that depends on root structure, root anatomy, and the pattern by which different parts of the root contribute to overall water transport (Cruz *et al*., 1992). The present outcomes are in agreement with the results of Ahmadi *et al*., (2012) in wheat, they reported that there was significant decrease in dry weight as per increase in osmotic potential.

Seedling vigour : The mean seedling vigour was 3.82, 3.63, 3.34, 2.79 and 1.57 under 0, -1, -3, -5 and -7 bar osmotic potential of moisture stress respectively (Table 2). Seedling vigour was not much affected at -1 and -3 bar osmotic potential, but drastically decreased at -5 and -7 bar. The genotypes NI-5439 (at -5 bar, 3.54 and -7 bar, 3.07), HD-2932 (3.29, at -5 bar) and K-227 (at -7 bar, 2.77) were found superior in respect of seedling vigour. Least values for seed vigour recorded in NIAW-2313 (2.27 and 0.38) and RAJ-3765 (2.21 and 0.25) at osmotic potential of -5 and -7 bars.

Germination is a critical stage of plant life and resistance against moisture stress during the germination makes a plant more stable. The degree and percentage of seed establishment are enormously key factors in deciding yield and period of maturity (Rauf *et al*., 2007). Speed of germination is more sensitive than germination under osmotic stress (Khayatnezhad *et al*., 2010). Water stress significantly reduces the seedling vigour, thus reducing the resistance of young plants to withstand other unfavourable field conditions. Germination is delayed by moderate stress intensities only while greater stress concentrations had an effect on final germination percentages and these results associated with the outcomes of Almansouri *et al*., (2001).

The genotypes NI-5439 and K-227 was found most tolerant and RAJ-3565 is most sensitive genotype to drought while considering per cent germination, shoot length and seed vigor. HD-2932 and K-227 reported most tolerant genotype while considering root length. According to dry weight basis NIAW-1161 and NI-5439 were most drought tolerant genotype.

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Diversity Analysis of Elite Groundnut (*Arachis hypogaea* L.) Germplasm under Konkan Condition in Maharashtra

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Abstract

Diversity analysis was carried out on eighty groundnut germplasm with twelve yield and yield contributing traits was carried out by Manalanobis"s D^2 Statistics. The D^2 values ranged between 1.6 to 15.6 suggesting the presence of considerable amount of genetic diversity. All the eighty genotypes were grouped into 12 clusters in which cluster I had maximum genotypes (44) followed by cluster VIII (11). The maximum intra cluster distance was exhibited by cluster VIII (243.2) followed by cluster XI (230.4) and X (159.9) while as maximum inter cluster distance was recorded between cluster X and XI (26.6), followed by cluster IX and XI (24.9), cluster VII and XI (23.7), indicating wide divergence between these clusters. Variance of cluster means revealed that dry pod yield plant^{-1}, haulm yield plant^{-1}, shelling percentage, 100 kernel weight and number of pods plant^{-1} were the main characteristics contributing to divergence. On the basis of intra and inter cluster distance, cluster mean and *per se* performance of genotypes *viz.*, IC 383, IC 568, ICG5539, ICG5571, IC832 and IC851 can be used for future breeding programme.

Key words : D^2 statistics, divergence, intra and inter cluster, groundnut etc.

Groundnut (*Arachis hypogaea* L.) is an important oilseed crop of India. It is widely used as cooking oil, digestible protein, minerals and vitamins in many countries and contributes significantly to food security and alleviating poverty. The percentage of oil and protein are extracted from the seed are approximately 48-50 per cent and 25-28 per cent respectively.

The Groundnut crop occupied 5.3 million hectare (*Kharif* and *rabi* summer) in the year 2011-12 with a production of 6.9 million tonnes and productivity of 1323 kg ha^{-1}. Groundnut accounts for 22 per cent of the cropped area under the oilseeds, 24 per cent to the total production and 30 per cent of domestic edible- oil supply. Most of the groundnut production in India is concentrated in six states *viz*., Gujrat, Andhra Pradesh, Tamil Nadu, Kanataka, Maharashtra and Rajasthan. The remaining groundnut producing areas are scattered in the states of Madhya Pradesh, Chhattisgarh, Uttar Pradesh, Punjab, Orissa and West Bengal. The Groundnut crop is cultivated on 1.91 lakh hectare in *kharif* and 0.33 lakh hectare with average productivity of 2.24 t ha^{-1} during rabi summer in Maharashtra during 2012-13 (Anonymous, 2013a).

The Konkan region of Maharashtra is one of the high potential areas for groundnut production. It was cultivated on 2200 ha area with 2300 tonnes production and 1045 kg ha^{-1} productivity during *kharif* while as groundnut is cultivated on 4850 ha area with 8600 tonnes production and 2150 kg ha^{-1} productivity during *rabi* 2011-12 (Anonymous, 2013b).

Success of plant breeding programme depends on the choice of appropriate parents. It is expected that the utilization of divergent parent in hybridization result in promising

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recombinants. Hence, the present investigation was undertaken to study the genetic divergence in groundnut germplasm to identify potential genotypes for yield contributing characters which could be utilized in further groundnut improvement programme.

Materials and Methods

The experimental material comparised of 80 genotypes of groundnut obtained from Directorate of Groundnut Research, Junagadh. The experimental materials were evaluated during three succeeding seasons from *rabi* 2011-12 to 2013-14 at Agricultural Research Station, Shirgaon dist: Ratnagiri (MS). The genotypes were grown in two rows of 2 m length with 30 x 10 cm spacing during each season.

All the recommended cultural practices were adapted. The observations were recorded on five randomly selected plants in each genotype for 12 quantitative traits *viz*., days to first flowering, days to 50 per cent flowering, number of primary branches plant^{-1}, plant height (cm), number of pods plant^{-1}, number of kernels pod^{-1}, dry pod yield plant^{-1} (g), haulm yield plant^{-1} (g), 100 pod weight (g), 100 kernel weight (g), shelling percentage and days to maturity. The analysis of genetic diversity was carried out by using Mahalanobis's (1936) D2 statistics. The grouping of genotypes was done as per Tocher's method.

Results and Discussion

The analysis of variance exhibited significant differences among 80 genotypes of groundnut for all the twelve characters. The 80 genotypes were grouped into 12 clusters (Table 1). The cluster I had maximum genotypes (44) followed by cluster VIII (11). The maximum intra cluster distance was exhibited by cluster VIII (243.2) followed by cluster XI (230.4) and X (159.9). The maximum inter cluster distance was recorded between cluster X and XI (26.6), followed by cluster IX and XI (24.9), cluster VII and XI (23.7), indicating wide divergence between these clusters.

Table 1. Composition of D^2 clusters on pooled basis

Cluster no.	No. of genotypes included	Genotypes
I	44	ICG1750, ICG 1760, ICG 1767, ICG 1768, ICG1769, ICG1774, ICG1785, ICG1844, ICG1859, ICG1873, ICG2570, ICG2598, ICG2609, ICG2630, ICG2674, ICG2711, ICG2729, ICG2732, ICG 2774, ICG2777, ICG2826, ICG2850, ICG2870, ICG2874, ICG2964, ICG3147, ICG3189, ICG3196, ICG3442, ICG 3476, ICG4337, ICG4349, ICG4372, ICG4489, ICG4700, ICG4793, ICG4797, ICG4822, ICG4841, ICG4865, ICG4876, ICG4909, ICG4917, ICG5530.
II	2	ICG5536,ICG5559
III	2	ICG5537, ICG5582
IV	2	ICG5539, ICG5571
V	2	ICG5505, ICG5518
VI	2	ICG5500, ICG5548
VII	2	IC374,IC 335915
VIII	11	ICG 4923, ICG4932, ICG5001, ICG5504, ICG5642, IC335914, IC102, IC 343136, IC653, IC 342813, IC588
IX	2	IC832, IC851
X	8	IC 66, IC852, IC564, IC860, IC884, IC611, IC 338555, IC378
XI	2	IC 383, IC568
XII	1	IC376

The cluster I was the largest, involving forty-four genotypes followed by cluster-VIII with eleven genotypes, cluster X with 8 genotype and cluster XII with one genotype. The remaining clusters included two genotypes each. Based on divergence existed among groundnut population Katule *et al*., (1992) grouped groundnut genotypes in 8 cluster. Golakiya and Makne (1991) grouped 24 groundnut genotypes in 6 clusters, Vankatramana *et al*., (2001) grouped 144 genotypes in 6 clusters, Awatade (2007) grouped 40 genotypes in 7 cluster and Nikam and Thaware (2010), grouped 39 genotypes in 9 clusters in their groundnut crop studies.

In the present investigation the D^2 values (Table 2) between all possible pairs of 80

Table 2. Intra and Inter cluster distance D^2 (above the diagonal) and D value (below the diagonal) on pooled basis

Clusters	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Intra cluster
I		98.6	88.9	105.2	93.2	92.2	109.3	258.0	154.7	239.3	482.9	95.0	147.8
II	9.9		6.2	7.7	10.6	6.0	18.4	275.1	127.7	232.2	534.2	30.5	2.5
III	9.4	2.5		13.5	10.4	6.1	14.4	251.5	103.3	194.5	510.3	18.2	3.9
IV	10.3	2.8	3.7		21.6	13.3	30.9	286.6	125.2	257.3	536.3	46.0	5.7
V	9.7	3.2	3.2	4.7		10.3	19.3	262.7	109.2	186.8	538.3	20.7	6.3
VI	9.6	2.5	2.5	3.6	3.2		18.1	250.2	119.0	215.0	488.8	24.8	6.5
VII	10.5	4.3	3.8	5.6	4.4	4.3		281.5	144.0	199.4	560.2	17.1	8.1
VIII	16.1	16.6	15.9	16.9	16.2	15.8	16.8		332.3	378.8	300.2	250.6	243.2
IX	12.4	11.3	10.2	11.2	10.5	10.9	12.0	18.2		141.3	621.0	101.8	11.8
X	15.5	15.2	13.9	16.0	13.7	14.7	14.1	19.5	11.9		709.5	144.0	159.9
XI	22.0	23.1	22.6	23.2	23.2	22.1	23.7	17.3	24.9	26.6		539.3	230.4
XII	9.7	5.5	4.3	6.8	4.6	5.0	4.1	15.8	10.1	12.0	23.2		0.0
Intra cluster	12.2	1.6	2.0	2.4	2.5	2.5	2.9	15.6	3.4	12.6	15.2	0.0	

Table 3. Intra cluster means for different characters and contribution of character towards genetic divergence of groundnut on pooled environment basis

Character	Cluster means												Contri-bution (%)
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
Days to first flowering	32.1	30.8	32.3	30.5	30.7	30.0	31.0	30.5	38.7	38.4	24.7	32.0	1.14
Days to 50% flowering	37.2	35.7	37.0	34.8	35.2	36.0	37.3	36.2	43.2	42.9	34.0	36.3	0.13
Number of primary branches plant^{-1}	2.6	2.4	2.2	2.3	2.3	2.4	2.4	2.7	2.5	2.7	2.6	2.7	0.38
Plant height (cm)	41.0	41.9	39.7	39.0	46.4	45.2	37.0	42.6	37.2	38.0	43.4	37.9	0.44
Number of pods plant^{-1}	10.1	9.8	9.9	7.9	7.8	10.9	9.9	16.5	5.8	6.2	26.6	10.3	0.51
Number of kernels pod^{-1}	1.9	1.8	2.0	2.0	1.8	2.0	1.9	1.9	1.9	2.0	2.0	2.1	0.19
Dry pod yield plant^{-1} (g)	0.50	0.40	0.40	0.30	0.30	0.40	0.30	1.00	0.20	0.20	1.30	0.20	10.16
Haulm yield plant^{-1} (g)	0.70	0.20	0.30	0.30	0.30	0.30	0.20	1.60	0.30	0.30	2.30	0.20	3.92
100 Pod weight (g)	128.0	109.1	114.1	110.3	114.8	113.7	99.3	140.2	163.5	148.4	155.8	116.5	15.41
100 Kernel weight (g)	51.3	46.0	49.2	49.7	47.7	48.2	51.1	53.2	70.5	62.0	63.0	48.1	0.54
Shelling %	76.6	79.1	77.7	81.4	76.2	78.1	75.3	73.5	77.7	67.5	76.4	73.3	37.09
Days to maturity	106.2	102.8	104.2	103.3	104.7	103.7	103.8	100.3	113.8	110.9	80.7	110.0	30.09

genotypes ranged between 1.6 to 15.6 suggesting the presence of considerable amount of genetic diversity. Among the clusters maximum intra cluster distance was recorded within Cluster VIII (15.6) followed by cluster XI (15.2) and cluster X (12.6). The maximum inter cluster distance was observed between cluster X and XI (26.6), followed by cluster IX and XI (24.9), cluster VII and XI (23.7), indicating wide divergence between these clusters. The criteria use for hybridization using D^2 analysis is the inter cluster distance. Those genotypes included in cluster with maximum inter cluster distance are obviously genetically more divergent. Hence, it would be logical to choose genotypes from these clusters in the future breeding programme. Mahalaxmi *et al*., (2005) observed maximum inter cluster divergence between cluster IV and VII. Maximum inter cluster D^2 valued observed between cluster II and IV in both the environment by Venkatramana *et al*., (2001). Nikam and Thaware (2010) reported maximum inter cluster distance between clusters VI and VII (23.70) in their 38 groundnut genotype studies.

The cluster means for different characters (Table 3) showed that cluster-III exhibited highest mean value for the character dry pod yield plant^{-1} (1.30 g). The genotypes, IC383 and IC568 were the members of this cluster. The cluster XI had less number of days to 50 per cent flowering (34.0), and plant height (37.0cm). While, cluster IV had maximum shelling per cent (81.4) and least days to maturity (80.7) and cluster IX exhibited maximum 100 kernel weight (70.5 g). The two genotypes *viz*., IC832 and IC851 were the member of this cluster. The cluster XI recorded maximum number of pods plant^{-1} (26.6) and maximum haulm yield plant^{-1} (2.30 g).

Golakia and Makne (1992) observed highest mean for the character kernels yield plant^{-1}, biomass yield plant^{-1} and recovery percentage in cluster III. They reported that genotype for important characters like pod yield, 100-kernal weight and recovery percentage recorded maximum mean performance were grouped into cluster II, III and IV. Nikam and Thaware (2010) recorded that cluster II exhibited highest mean value for the characters oil percentage and cluster III had maximum number of pods plant^{-1}.

Table 4. Genotypes identified for specific characters

Genotypes identified	Specific character
IC 383, IC568	Dry pod yield plant^{-1}
IC 383, IC568	Haulm yield plant^{-1}
ICG5539, ICG5571	Shelling percentage
IC832, IC851	100 Kernel weight

Maximum contribution towards the genetic divergence was in days to maturity (41.6) followed by shelling per cent (22.7), 100 kernel weight (g) (16.5) and Haulm yield plant^{-1} (5.9). Nikam and Thaware (2010) observed maximum genetic divergence days to maturity (113.49) followed by shelling per cent (80.07) and oil percentage (45.33)

Based on cluster mean and genetic diversity studies genotypes *viz*., IC383 , IC 568 for dry pod and haulm yield plant^{-1}, ICG5539 and ICG5571 for shelling percentage and for number of kernels pod^{-1}, IC832, IC851 were consider as potential parents for breeding programme (Table 4).

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Influence of Different Nitrogen and Phosphorus Ratios on Productivity of Groundnut (*Arachis hopogaea* L.) during *kharif* Season

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Abstract

The experiments were carried out to persuade impact of different nitrogen and phosphorus ratios on groundnut productivity under konkan condition during *kharif* season. The pooled results revealed that, application of 30:75:00 NPK kg ha^{-1} (0.40 NP ratio) i.e. T_4 noticed higher dry pod (3397 kg ha^{-1}) and kernel yield (2538 kg ha^{-1}) over rest of treatments. Increment in pod and kernel yield due to 0.40 NP ratio over control were 40.74 and 44.28 per cent, respectively. However, significantly higher haulm yield (3852 kg ha^{-1}) was recorded with the treatment application of 30:60:0 NPK kg ha^{-1} (0.50 NP ratio) over control. The plant height and number of branches plant^{-1} not influenced due to use of different nitrogen and phosphorus ratios. Moreover, application of 0.40 NP ratio perceived significantly more number of pods plant^{-1} and dry pod weight over all other treatments. Economic study revealed that higher net returns of Rs. 43216/- was observed with application of 30:75:0 NPK kg ha^{-1} (0.40 NP ratio) and B:C ratio of 1:1.60.

Keywords: Groundnut, nitrogen, phosphorus, yield and economics

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Groundnut (*Arachis hypogaea* L.) is known as poor man's almond in India. It is widely used as cooking oil, rich in digestible protein, minerals and vitamins in many countries and contributes significantly to food security and alleviating poverty. It also has some industrial uses like in paint, varnish, lubricating oil, soap, furniture polish. It has important role in animal feed (cake) left after oil extraction and groundnut haulms constitute nutritious fodder for livestock. It contains about 50 per cent oil,

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25-30 per cent protein, 20 per cent carbohydrate and 5 per cent fiber and ash which make a substantial contribution to human nutrition (Fageria *et al*., 1997). It is the richest plant source of thiamine and also rich in niacin, which is low in cereals. Area under groundnut cultivation in Maharashtra was 23.80 M ha with total production of 23.62 M tonnes and average productivity was 993 kg ha^{-1} during *kharif* 2012. While in konkan, region area under cultivation was 2200 ha and production of 2600 tonnes with average productivity of 1196 kg ha^{-1} (Anonymous, 2013).

Nitrogen and phosphorus are important elements for effective production of groundnuts. Nitrogen is essential component of many compounds of plant, such as chlorophyll, nucleotides, proteins, alkaloids, enzymes, hormones and vitamins (Marschner, 1995). Phosphorus is essentially required for healthy growth and efficient root system and profuse nodulation which in turn can affect the N_2-fixation potential. Since, phosphorus is considered as a limiting factor in plant nutrition due to the deficiency of available soluble phosphate in the soil (Maheswar and Sathiyavani, 2012).

Intense rainfall in konkan during *kharif* season leading to removal of bases and nutrients from soil. Accurately quantifying the optimum fertilizer rate is essential to maximize profitability and to minimize the potential environmental impact in konkan. Also, enough information on different proportions of nitrogen and phosphorus has not been generated under such circumstances. This situation warrants the need to find appropriate nutrient management practice to exploit production and productivity of groundnut in konkan region during *kharif* season. Hence, present investigation was undertaken to study the impact of different nitrogen and phosphorus ratios on groundnut productivity during *kharif* season.

Materials and methods

Field experiments were conducted on lateritic soil of konkan at Agricultural Research Station, Shirgaon during two consecutive *kharif* seasons of 2012 and 2013 to ascertain effect of different nitrogen and phosphorus

Table 1. Performance of different characters of groundnut at harvest as influenced by different treatments (pooled basis)

Treatments	Total no. of pods plant^{-1}	Dry pod weight (g plant^{-1})	Dry pod yield (kg ha^{-1})	Kernel yield (kg ha^{-1})	Haulm yield (kg ha^{-1})	Harvest index (%)
T_1 : 0:0:0 NPK kg ha^{-1}, NP ratio: 0.00	15.0	18.6	2013	1414	2676	0.30
T_2 : 25:75:0 NPK kg ha^{-1}, NP ratio: 0.33	29.3	33.7	3224	2298	3737	0.33
T_3 : 18:46:0 NPK kg ha^{-1}, NP ratio: 0.39	23.1	30.4	2756	1972	3564	0.31
T_4 : 30:75:0 NPK kg ha^{-1}, NP ratio: 0.40	30.9	35.1	3397	2538	3774	0.35
T_5 : 25:60:0 NPK kg ha^{-1}, NP ratio: 0.42	26.0	31.2	3102	2282	3772	0.33
T_6 : 25:50:0 NPK kg ha^{-1}, NP ratio: 0.50	23.5	28.4	2973	2109	3640	0.32
T_7 : 30:60:0 NPK kg ha^{-1}, NP ratio: 0.50	27.6	32.8	3133	2235	3852	0.32
T_8 : 25:45:0 NPK kg ha^{-1}, NP ratio: 0.56	21.3	27.0	2960	2130	3486	0.33
T_9 : 30:45:0 NPK kg ha^{-1}, NP ratio: 0.67	23.4	28.8	2647	1924	3302	0.32
T_{10} : 25:30:0 NPK kg ha^{-1}, NP ratio: 0.83	16.9	20.3	2726	1925	3370	0.32
T_{11} : 30:30:0 NPK kg ha^{-1}, NP ratio: 1.0	18.5	22.7	2770	2044	3562	0.32
S.E.±	1.4	1.6	190	133	210	1.6
CD (0.05)	4.0	4.5	541	379	599	4.5

ratios on groundnut productivity. The experimental site was high in organic matter content, medium in nitrogen and phosphorus while high in potassium content. The experiment was conducted using randomized block design consisting of 11 treatments *viz*., T_1: 0:0:0 NPK kg ha^{-1} (NP ratio: 0.00), T_2: 25:75:0 NPK kg ha^{-1} (NP ratio: 0.33), T_3: 18:46:0 NPK kg ha^{-1} (NP ratio: 0.39), T_4: 30:75:0 NPK kg ha^{-1} (NP ratio: 0.40), T_5: 25:60:0 NPK kg ha^{-1} (NP ratio: 0.42), T_6: 25:50:0 NPK kg ha^{-1} (NP ratio: 0.50), T_7: 30:60:0 NPK kg ha^{-1} (NP ratio: 0.50), T_8: 25:45:0 NPK kg ha^{-1} (NP ratio: 0.56), T_9: 30:45:0 NPK kg ha^{-1} (NP ratio: 0.67), T_{10}: 25:30:0 NPK kg ha^{-1} (NP ratio: 0.83) and T11: 30:30:0 NPK kg ha^{-1} (NP ratio: 1.00). Groundnut cultivar TKG Bold was sown with spacing of 30 x 15 cm. All the recommended packages of practices were adopted as per need of crop. At harvest, a random sample of five plants were taken from each plot to determine averages of plant height (cm), number of pods plant^{-1}, number of kernels pod^{-1}, dry pod yield plant^{-1}, 100-seed weight (g), shelling percentage and sound mature kernels. Agronomic yield were determined on plot basis and then converted into per hectare yield basis.

Results and Discussion

Pooled data presented in Table 1 revealed that, different nitrogen and phosphorus ratios failed to exhibit any significant effect on height of plant and number of branches plant^{-1}. Moreover, total number of pods plant^{-1} and dry pod weight were found be significant due to application of different nitrogen and phosphorus ratios and recorded significantly higher when nitrogen and phosphorus were applied in the proportion of 30:75:0 NPK kg ha^{-1} (NP ratio: 0.40) (T_4) over all the treatments

Table 2. Dry pod yield, kernel yield, haulm yield and harvest index of groundnut at harvest as influenced by different treatments

Treat-ment	Gross returns (Rs. ha^{-1})			Cost of cultivation (Rs. ha^{-1})			Net returns (Rs. ha^{-1})			B:C ratio		
	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled	2012	2013	Pooled
T_1	66526	70355	68440	59530	60793	60162	6995	9562	8279	1.12	1.16	1.14
T_2	101863	116726	109294	68548	73074	70811	33315	43652	38484	1.49	1.60	1.54
T_3	77374	112229	94802	63669	70975	67322	13705	41254	27480	1.22	1.58	1.40
T_4	106469	123645	115057	69384	74297	71841	37085	49347	43216	1.53	1.66	1.60
T_5	92238	119508	105873	66581	72890	69736	25657	46617	36137	1.39	1.64	1.51
T_6	91245	111373	101309	66174	71103	68639	25071	40270	32670	1.38	1.57	1.47
T_7	96204	117329	106767	67311	72598	69955	28893	44731	36812	1.43	1.62	1.52
T_8	82950	119853	101401	64671	72301	68486	18279	47552	32915	1.28	1.66	1.47
T_9	72945	109056	91001	63073	70572	66822	9873	38484	24179	1.16	1.55	1.35
T_{10}	80006	106544	93275	63818	69436	66627	16188	37108	26648	1.25	1.53	1.39
T_{11}	81550	108293	94922	64145	69798	66971	17406	38495	27950	1.27	1.55	1.41
Mean	86306	110446	98376	65173	70713	67943	21133	39734	30434	1.32	1.56	1.44

T_1 : 0:0:0 NPK kg ha^{-1}, NP ratio: 0.00, T_2 : 25:75:0 NPK kg ha^{-1}, NP ratio: 0.33, T_3 : 18:46:0 NPK kg ha^{-1}, NP ratio: 0.39, T_4 : 30:75:0 NPK kg ha^{-1}, NP ratio: 0.40, T_5 : 25:60:0 NPK kg ha^{-1}, NP ratio: 0.42, T_6 : 25:50:0 NPK kg ha^{-1}, NP ratio: 0.50, T_7 : 30:60:0 NPK kg ha^{-1}, NP ratio: 0.50, T_8 : 25:45:0 NPK kg ha^{-1}, NP ratio: 0.56, T_9 : 30:45:0 NPK kg ha^{-1}, NP ratio: 0.67, T_{10} : 25:30:0 NPK kg ha^{-1}, NP ratio: 0.83, T_{11} : 30:30:0 NPK kg ha^{-1}, NP ratio: 1.0

except treatment T_2 (25:75:0 NPK kg ha^{-1} i.e. NP ratio: 0.33) and T_7 (30:60:0 NPK kg ha^{-1} i.e. NP ratio: 0.50). Treatment T_1 (0:0:0 NPK kg ha^{-1} i.e. N:P ratio 0.00) recorded the lowest number of pods $plant^{-1}$ and dry pod weight than rest of the treatments. Similar kinds of results were reported by Tomar *et al*., 1996 and Hemalatha *et al*., 2013.

Data from the Table 1 insinuate that, application of 30:75:0 NPK kg ha^{-1} (NP ratio: 0.40) i.e. T_4 recorded significantly higher pod yield (3397 kg ha^{-1}) but it was at par with treatments T_2, T_5, T_6, T_7 and T_8 in that descending order of significance. Similarly, kernel yield (2538 kg ha^{-1}) was significantly higher with the treatment T_4 which was on par with treatments T_2, T_5 and T_7. However, for haulm yield treatment T_7 (30:60:0 NPK kg ha^{-1}, NP ratio: 0.50) recorded significantly higher value of (3852 kg ha^{-1}) over control i.e. T_1 but was remained at par with rest of all the treatments. The increase in dry pod and kernel yield (3397 kg and 2538 kg ha^{-1}, respectively) by treatment T_4 over control (2013 kg and 1414 kg ha^{-1}, respectively) was to the tune of 40.74 per cent and 44.28 per cent, respectively while that of treatment T_7 (3852 kg ha^{-1}) over control (2676 kg ha^{-1}) was to the tune of 30.53 per cent in respect of haulm yield. The higher value of harvest index (0.35%) was recorded for the treatment T_4. As the soil was medium in N and P its response was higher when 30 kg N and 75 kg P ha^{-1} was added. The yield advantage increased from N 30 and P 60 kg ha^{-1} to N 30 and P 75 kg ha^{-1} fertilizer application was due to higher root growth. These results are in same line with those reported by Bhatol *et al*., (1994) and Hossain and Hamid, (2007). The shelling per cent, sound mature kernels (%) and 100 kernel weight were did not reach to the level of significance due to application of different ratios of nitrogen and phosphorus during both the years of experimentation as well as in pooled analysis.

Data furnished in Table 2 indicated that, higher net returns of Rs. 43216/- was observed with application of 30:75:0 NPK kg ha^{-1} (NP ratio: 0.40) i.e. T_4 during both the years of experimentation and in pooled data.

The results conclude that, application of N and P offers large scope for obtaining higher yield of groundnut under konkan conditions. As application of 30:75:0 NPK kg ha^{-1} (NP ratio 0.40) is most suitable to obtain higher productivity and profitability of groundnut during *kharif* season in konkan region.

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Pollen Viability and Stigma Receptivity Studies in Parental Lines of Sunflower Hybrid- Raviraj

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Abstract

The investigation was undertaken to study stigma receptivity and pollen viability of parental lines of sunflower hybrid. Seed setting percentage, number of seeds capitulum^{-1}, seed weight capitulum^{-1} (g), 100 seed weight (g), germination percentage and seedling vigour index were observed for stigma receptivity and pollen viability. Pollen viability was determined by using acetocarmine test. The stigma receptivity of male sterile line (17A) showed highest seed setting percentage (83.15 %), highest number of seeds capitulum^{-1} (720.75), seed weight capitulum^{-1} (33.62 g), 100 seed weight (5.81 g) and seed qualities *viz*., germination percentage (92.00 %) and vigour index (2695.73) at zero day of starvation period. However these parameters were found to be decreased at each successive starvation period. Pollen viability of male sterile (MS) line showed highest seed setting percentage (81.97 %), highest number of seeds capitulum^{-1} (649.75), seed weight capitulum^{-1} (35.73 g) and seed quality parameters *viz*., germination percentage (91.00 %) and vigour index (2688.90) at zero hour of pollination period followed by 4 hrs of pollination period (76.16%) and 8 hrs of pollination period (73.56%). However these parameters were found to be decreased at each successive pollination period. Study revealed that stigmas of MS line remained receptive for 3 days and pollens of the restorer line (R-437) remained viable for 24 hours as determined by using both field test and acetocarmine test.

Key words : Acetocarmine test, pollen viability, stigma receptivity, sunflower

Sunflower is highly cross pollinated crop. Pollination and synchronization of flowering is most important in hybrid seed production. Staggered sowing of male and female parent is necessary to maintain synchrony in flowering period. The knowledge regarding stigma receptivity of male sterile line (A) and pollen viability of B and R line is essential in hybrid seed production. This information is more useful when artificial hand pollination is needed for highest seed setting percentage in hybrid seed production. Keeping in view the above facts, the present investigation was undertaken to study the stigma receptivity of male sterile line and pollen viability of restorer line.

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Materials and methods

The study involved sunflower hybrid-Raviraj and its parental lines *viz*., male sterile line (A line: 17A) and restorer line (R line: R-437), seeds of which were obtained from Agricultural Research Station, Savalivihar, Tal. Rahata, Dist. Ahmednagar and was carried out at Seed Technology Research Unit, Mahatma Phule Krishi Vidyapeeth, Rahuri during *rabi*, 2010.

The experiment was conducted with 4 replications in a Randomized Block Design (RBD) with 6 treatments each for stigma receptivity and pollen viability. Two seeds of male sterile line (17A) and restorer line (R-437) were dibbled per hill at 30 cm plant to plant and 60 cm row-to-row distance in 4 x 5 m^2 plot. For stigma receptivity and pollen viability studies, the male sterile line and restorer line were sown in separate plot.

Method for stigma receptivity studies : Male sterile line (A line: 17A) and restorer line (R line: R437) were sown in separate plots to study the stigma receptivity period in male sterile line. Twenty four plants per replication from male sterile line flowering on the same day were selfed with the help of muslin cloth bag just a day before the start of anthesis. The total numbers of disc florets opened in a day in all twenty four capitulum of male sterile line were marked early in the morning and four capitulum from male sterile line were pollinated with the fresh pollen of R line collected on muslin cloth bag at 8.00 hours with the help of camel hair brush. The pollinated capitulums were again covered with muslin cloth bags and they were labeled. On next day (one day of starvation) another four capitulum from male sterile line were pollinated with fresh pollens from R line and the capitulums were again covered with muslin cloth bags and this process was continued for 6 days. Stigma receptivity study contains treatments *viz*., T_1: Pollination at 0 day starvation period, T_2: Pollination at 1 day starvation period, T_3: Pollination at 2 day starvation period, T_4: Pollination at 3 day starvation period, T_5: Pollination at 4 day starvation period, T_6: Pollination at 5 day starvation period.

Method for pollen viability studies : Male sterile line (A line: 17A) and restorer line (R line: R437) were sown in separate plots to study the pollen viability of pollen parent. The twenty four capitulums per replication from male sterile line flowering on same day were selfed with the help of muslin cloth bag just a day before the start of anthesis. The total numbers of disc florets opened on a day in all capitulum of male sterile line were marked. The sufficient pollen from R line was collected on muslin cloth bag kept in petridishes in the morning at 8.00 hours with the help of camel hair brush. The pollination was continued for total period of 32 hours starvation at 0, 4, 8, 24, 28 and 32 hours interval. The six pollinated capitulum per replication were covered again with muslin cloth bag to avoid out crossing. Pollen viability study contains treatments *viz*., T_1: Pollination immediately after anthesis (0 hour), T_2: Pollination 4 hours after anthesis, T_3: Pollination 8 hours after anthesis, T_4: Pollination 24 hours after anthesis, T_5: Pollination 28 hours after anthesis, T_6: Pollination 32 hours after anthesis.

Pollen viability study under laboratory condition : The pollen viability was studied under laboratory conditions by using acetocarmine method. The pollens were collected from the field early in the morning in petridishes from restorer line. The extent of viability was judged by differentiating perfect and plume pollen grains which were stained. Empty and imperfect which appeared unstained under microscope. Three slides for each observation were made. The whole process was repeated at every two hours interval (Singhal, 1998).

$$\text{Pollen viability (\%)} = \frac{X}{X + Y} \times 100$$

Where, X = Number of stained pollen, Y = Number of unstained pollen

The field data obtained from all parameters was analyzed by Randomized Block Design (RBD) and laboratory data was analyzed by Completely Randomized Design (CRD) method as described by Panse and Sukhatme, 1989.

Results and discussion

Stigma receptivity

Days to 50 per cent flowering and maturity : The female parental line 17 A took 69 days for 50 per cent flowering and 106 days for maturity (Table 1), result is in accordance with Bhattacharya *et al*., (1975), Chhabra *et al*., (1982), and Virupakshappa (1992).

Seed setting percentage: Significant differences in seed setting percentage of male sterile line 17 A were found in all treatments (Table 1). Pollination made after zero days of starvation period (T_1) was found to be significantly superior over all other treatments for seed setting percentage. Highest seed setting (83.15%) was observed when the pollination was done immediately after the protrusion of stigma i. e. at zero days (T_1) followed by one day of starvation (79.38%) and thereafter it was found to be decreased significantly at each successive starvation period. The stigmas of male sterile line 17 A remained receptive for 3 days during *rabi* season. As seed setting is more than 70 per cent when pollinated within three days of starvation period. Borikar *et al*., (1993) reported similar results that stigma receptivity in sunflower was observed for 3 days in 338 A and 207 A in *rabi* season at Parbhani conditions. Similar results were are also reported by Jawale *et al*., (1998), Yadava *et al*., (2004) and Singh *et al*., (2010).

Number of seeds capitulum^{-1} at different starvation periods : Pollination made after zero days of starvation period (T_1) treatment was found to be significantly superior over all other treatments for number of seed capitulum^{-1} (Table 2). Highest number of seed capitulum^{-1} (720.25) was observed when the pollination was effected immediately after the protrusion of stigma i.e. at zero days (T_1) followed by one day of starvation (684) and thereafter it was found to be decreased with successive starvation period. The fresh stigmas produced maximum number of seeds capitulum^{-1} than that of older stigmas. Maximum number of seeds capitulum^{-1} obtained might be due to pollination made immediately after protrusion of stigma at zero days of starvation period. Similar results were reported by Singh *et al*., (2010).

Seed weight capitulum^{-1} (g) at different starvation periods : The highest number of seed weight capitulum^{-1} (33.62 g) was observed when the pollination was effected immediately after the protrusion of stigma i. e. at zero days (T_1) followed by one day of starvation (28.99 g) (Table 1). The weight of seeds capitulum^{-1} was decreased with increased starvation period. Similar results were reported by Singh *et al*., (2010).

100 seed weight (g) at different starvation periods : The data shows that

Table 1. Effect of different stigma starvation period on seed setting and seed quality parameter

Treatment stigma starvation period	Seed setting percentage	No. of seeds capitulum^{-1}	Seed weight capitulum^{-1} (g)	100 seed weight (g)	Germination percentage	Vigour index
0 day (T_1)	83.15 (65.77)	720.75	33.62	5.81	92.00 (73.63)	2695.73
1 day (T_2)	79.38 (62.99)	684.00	28.99	5.62	90.00 (71.61)	2484.98
2 day (T_3)	75.39 (60.27)	661.50	25.42	5.56	87.00 (68.94)	2154.40
3 day (T_4)	52.53 (46.45)	491.50	17.34	5.02	83.00 (65.70)	1818.90
4 day (T_5)	39.64 (39.01)	331.50	13.95	4.35	79.00 (62.76)	1589.10
5 day (T_6)	29.89 (33.14)	230.25	9.81	3.67	70.00 (56.85)	1407.10
S.E.±	0.808	5.19	0.792	0.149	1.471	36.706
CD at 5%	2.436	15.65	2.386	0.448	4.371	124.58

Figures in parentheses are arc sin values there were significant differences in 100 seed weight in all treatments (Table 1). The highest 100 seed weight (5.81 g) was observed at zero days of starvation which was at par with that of T_2 (5.62 g) and T_3 (5.56 g). Thereafter 100 seed weight found to be decreased significantly at each successive starvation period. The fresh stigmas produced heavier and healthy seeds and older stigmas produced lighter seeds and 100 seed weight was decreased with increased starvation period. These results are in conformity with result reported by Shete *et al.*, (1994) and Patil *et al.*, (1993) in sunflower.

Germination percentage and vigour index at different starvation periods : Pollination made after zero day starvation periods (T_1) treatment was observed superior over T_3, T_4, T_5, and T_6 however at par with T_2 treatments for germination percentage. The highest germination (92%) and vigour index (2695.73) was observed in the seed harvested from zero day of starvation i. e. T_1 which was at par with that of one day of starvation period (90%) for germination. The poor receptivity of stigma reduced the germination percentage of seed and seedling vigour index considerably and thereafter it was decreased with increased starvation period. Maximum germination percentage of seed obtained might be due to pollination made immediately after protrusion of stigma at zero days of starvation period. Similar results was reported by Singh *et al.*, (2010) in Bhendi.

Pollen viability at different pollination period

Days to initiation of anthesis, 50 per cent anthesis and complete anthesis : Restorer line (R-437) took 62 days for initiation, 66 days for 50 per cent anthesis and 69 days for complete anthesis.

Seed setting percentage : The data with significant differences on seed setting percentage of male sterile line obtained from pollination made after different hours of collection of pollens from restorer line are presented in Table 3. Pollination made immediately after collection of pollens (T_1) was found to be superior over all other treatments for seed setting percentage. The highest seed setting percentage (81.97%) was observed when pollination made immediately after collection of pollens at zero hour of pollination period i.e. T_1 followed by 4 hrs of pollination period i.e. T_2 (76.16%). It is revealed that, pollens of restorer line R-437 remained viable for 24 hours. Maximum seed setting percentage was obtained might be due to pollination was made immediately after

Table 2. Effect of different pollen starvation period on seed setting and seed quality parameter

Treatment (Period of pollen storage)	Seed setting percentage	No. of seeds capitulum^{-1}	Seed weight capitulum^{-1} (g)	Germination percentage	Vigour index
0 hrs (T_1)	81.97 (64.76)	649.75	35.73	91.00 (72.67)	2688.90
4 hrs (T_2)	76.16 (60.81)	620.00	33.46	89.00 (70.78)	2458.55
8 hrs (T_3)	73.56 (59.07)	570.00	29.51	87.00 (69.11)	2280.07
24 hrs (T_4)	70.51 (57.11)	529.75	25.82	82.50 (65.29)	2008.80
28 hrs (T_5)	35.58 (36.60)	273.50	13.49	76.50 (61.05)	1552.37
32 hrs (T_6)	26.93 (31.25)	213.75	9.17	69.50 (56.52)	1433.35
S.E.±	1.108	4.853	1.141	1.783	37.45
CD at 5%	3.39	14.623	3.439	5.296	112.84

Figures in parentheses are arcsine values collection of pollens at zero hour of pollination period. Similar results were reported by Borikar *et al*., (1993), Shete *et al*., (1994), Jawale *et al*., (1998), Patil *et al*., (1993) and Hujare (1995) in sunflower hybrids.

Number of seeds capitulum^{-1} : Pollination made immediately after collection of pollens (T_1) was found to be superior (Table 4) over all other treatments for number of seeds per capitulum having maximum number of seeds per capitulum (649.75) observed when pollination made immediately after collection of pollens i.e. T_1 treatment followed by 4 hrs of pollination period i.e. T_2 (620). More viable pollens produced maximum number of seeds capitulum^{-1} than that of low viable pollens. Number of seeds capitulum^{-1} decreased significantly with increased pollination period. Maximum number of seed per capitulum was obtained might be due to pollination was made immediately after collection of pollens at zero hour of pollination period as reported by Hujare (1995) in sunflower.

Seed weight capitulum^{-1} (g) : Pollination made immediately after collection of pollens (T_1) was found to be significantly superior over T_3, T_4, T_5 and T_6 treatment however at par with T_2 treatment. Maximum seed weight capitulum^{-1} (35.73 g) was observed when pollination made immediately after collection of pollens i.e. T_1 which was at par with that of 4 hrs. pollination period (33.46 g) i.e. T_2. Higher viable pollens produced high weight of seeds capitulum^{-1} than that of low viable pollens. The seed weight capitulum^{-1} was decreased due to decrease in number of filled seeds and increase in number of unfilled seeds.

Germination percentage of seed : T_1 treatment was found to be significantly superior over T_4, T_5 and T_6 treatment however at par with T_2 and T_3 treatment, showing maximum seed germination (91%) was observed which was at par with that of 4 hrs. pollination period i.e. T_2 (89%) and 8 hrs. pollination period i.e. T_3 (87%). It is revealed from above study that, viable pollens produced significantly higher germinated seeds, especially when pollination was made immediately after pollen collection. Germination percentage of seed was decreased with increased pollination period. Similar results were reported by Hujare (1995) in sunflower.

Vigour index of seed obtained from different pollination periods : Maximum vigour index (2688.90) was observed when pollination made immediately after collection of pollens i.e. T_1 (Table 4) which is in conformity with result reported by Hujare (1995), followed by 4 hrs of pollination period i.e. T_2 (2458.55) and thereafter it was found to be decreased significantly at each successive pollination period. The lowest vigour index (1433.35) was obtained when pollination made 32 hrs. after collection of pollens i.e. T_6.

Table 3. Viable pollens per cent of restorer line (R-437) tested by using acetocarmine solution at different hours of storage after collection

Restorer line	Period of pollen storage (hrs)										Mean
	0	2	4	6	8	24	26	28	30	32	
R-437	94.66 (77.08)	93.33 (75.67)	92.0 (73.65)	86.66 (68.83)	84.0 (66.45)	76.66 (61.15)	72.66 (58.50)	54.0 (47.31)	39.33 (38.83)	28.0 (31.94)	71.46 (59.94)
S.E.±	1.822										
C. D. at 5 %	5.376										

Figures in parentheses are arcsin transformed values

Pollen viability by using acetocarmine solution : The pollens were collected from restorer line immediately after anthesis in petri dishes. The percentage of pollen viability was recorded at every 2 hrs. of interval under laboratory condition by using acetocarmine solution (Table 5).The highest pollens were found viable when it was tested immediately after collection (94.66 per cent) which was at par with 2 hr. and 4 hr. period of pollen storage. The pollen viability was more than 70 per cent up to 26 hr. of period of pollen storage and thereafter, as the period of pollen storage increased the pollen viability decreased significantly. It is concluded that, more pollens were remained viable for 24-26 hrs. of pollen storage. Similar results were reported by Zebrowska (1995) in strawberry genotypes, Bhat *et al*., (1995) in *Myristica fatua* var. Magnifica and Hujare (1995) in sunflower hybrid.

The stigma receptivity of male sterile line (17A) showed highest seed setting percentage at zero day of starvation period i.e. pollination was effected immediately after protrusion of stigma. The highest number of seeds capitulum^{-1}, seed weight capitulum^{-1}, 100 seed weight and seed quality parameters *viz*., germination percentage and vigour index were observed at zero days of starvation period. However these parameters were found to be decreased at each successive starvation period. Seed setting percentage was found satisfactory up to 3 days of starvation period (75.39%) hence it is concluded that stigmas of male sterile line 17A remained receptive for 3 days as seed setting is more than 70.00 per cent up to 3 days.

Significantly highest number of seed capitulum^{-1}, seed weight capitulum^{-1} and seed quality parameters *viz*., germination percentage and vigour index obtained at zero hour of pollination period and it decreased at each successive pollination period i.e. as the period of pollen storage increased. From above points it is concluded that, pollens of restorer line (R-437) remained viable for 24 hours. Acetocarmine test leads to conclude that pollens of restore line (R-437) remained viable for 24-26 hours as pollen viability is more than 70 per cent up to 26 hours period of pollen storage.

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Diversification of Groundnut Based Cropping Systems

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Abstract

A field experiment was carried out to evaluate the groundnut based cropping systems (groundnut-onion, groundnut-wheat and groundnut-chickpea) under different nutrient management treatments. The yield target of 25 q ha^{-1} was achieved in *kharif* groundnut by application of fertilizer as per STCR (23.55 q ha^{-1}) equation with less than 10 per cent variation (-5.8 %) on pooled basis. Among the cropping systems, groundnut-onion cropping system recorded significantly maximum total system productivity (67.21, 89.17 and 78.19 q ha^{-1}), production efficiency (30.16, 39.96 and 35.06 kg ha^{-1} day^{-1}) and economic efficiency (Rs. 620.66, 1064.26 and 842.46 ha^{-1} day^{-1}) than groundnut-chickpea and groundnut-wheat cropping systems. Similarly, groundnut- onion cropping system obtained significantly maximum gross monetary returns (Rs. 2,31,903, Rs. 3,34,409 and Rs. 2,83,156 ha^{-1}), net monetary returns (Rs. 1,38,207, Rs. 2,37,982 and1,88,095 ha^{-1}) and B:C ratio (2.84, 3.47 and 2.98) than groundnut-chickpea and groundnut-wheat cropping systems.

Key words : Cropping systems, nutrient management, productivity, gross and net monetary returns

Crop diversification has been recognized as an effective strategy for achieving the objectives of food security, nutritional security, income growth, poverty alleviation and employment generation, judicious use of natural resources like land and water for sustainable agricultural development and environmental improvement. Crop diversification is intended to give a wide choice in the production of a variety of crops in a given area so as to expand production related activities on various crops and also to lesser risk. The shift of crop also takes place due to governmental policies and thrust on some crops over a stipulated time, e.g. establishment of the technology mission on oilseeds to give

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thrust on higher production as a national need for the less dependency on import (Reddy and Suresh, 2009). Targeted yield approach has been an unique one in the sense that this method not only indicates soil test based fertilizer dose, but also the levels of yield, the farmers can hope to achieve if good agronomy is followed in raising the crop. It also provides the scientific basis for balanced fertilization not only between the soil and fertilizer nutrients, but also between the soil available nutrients themselves and strike a balance between fertilizing the crop and fertilizing the soil, leading to realization of desired yields and maintenance of soil fertility (Velayutham, 1977). To increase the production and profitability of legume based cropping system on effort was made to carry out an experiment for two consecutive years with "Diversification of groundnut based cropping systems".

Materials and Methods

A field experiment was carried out during 2011-12 and 2012-13 at MPKV, Rahuri (M.S.) on sandy clay loam soil with low in available nitrogen (172.11 kg ha^{-1}) was determined by Alkaline permanganate method (Subbiah and Asija (1956), medium in available phosphorus (18.02 kg ha^{-1}) was determined by 0.5 M $NaHCO_3$ method (Olsen *et al.*,1954) and high in available potassium (427.0 kg ha^{-1}) was determined by 1N NH_4OA_C method (Hanway and Heidal, 1967) and the soil was moderately alkaline in reaction (pH 8.2) determined by Potentimetric (Jackson, 1973). The electrical conductivity, organic carbon and $CaCO_3$ were 0.29 dSm^{-1}, 0.54 and 4.50 per cent were determined by Conductometric (Jackson 1973), Wet oxidation (Nelson and Sommer, 1982) and Acid neutralization (Piper 1966), respectively.

The treatment consist of three cropping systems *viz.*, C_1-groundnut-onion, C_2-groundnut-wheat and C_3- groundnut-chickpea with four nutrient management treatments *viz.*, T_1- recommended dose of fertilizer, T_2-fertilizer dose as per soil test, T_3- fertilizer dose as per STCR equations and control as main plot treatment whereas three fertilizer levels *viz.*, F_1-100 % RDF, F_2-75% RDF and F_3- 50 % RDF as sub plot treatments. The experiment was laid out in randomized block design in *kharif* season in nine replications and strip plot design in *rabi* season with three replications. Groundnut JL- 501, onion N 2-4-1, wheat-Trimbak and chickpea-Digvijay these cultivators were used during *kharif* and *rabi* seasons, respectively. Both the years crop seasons were favourable to grow the *kharif* and *rabi* crops. The recommended package of practices were adopted to grow the crops and fertilizers were applied as per treatments.

Results and Discussion

Productivity of *kharif* crop : Application of fertilizer as per STCR equation to *kharif* groundnut recorded maximum and significantly higher dry pod yield (23.08, 24.49 and 23.55 q ha^{-1}) than fertilizer dose as per soil test, recommended dose of fertilizer and control treatment during first year, second year and pooled basis. The yield target of 25 q ha^{-1} was achieved by STCR equation with less than 10 per cent variation (-5.8 %). The fertilizer dose as per soil test was found second rank (18.91, 19.59 and 19.26 q ha^{-1}) during both years and on pooled mean (Table 1). This is because of balanced nutrition through yield target approach increases the photosynthetic rate and translocation of photosynthates towards reproductive parts (pods). Similarly, the groundnut being a legume crop having more nitrate reductase activities in root which is beneficial for peg formation and pod development stage. These results are in confirmity with the results obtained by

Dudhatra *et al*., (2002) and Srinivas and Srinivasa Raju (2000)

Productivity of *rabi* crops

Onion : Data presented in Table 1. indicated that, application of fertilizer as per STCR equation to preceeding crop *kharif* groundnut registered maximum and significantly higher yield of onion bulb (58.85, 60.67 and 59.76 t ha^{-1}) and it was 10.26, 8.90 and 9.75 per cent higher over recommended dose of fertilizer during first year, second year and on pooled mean. Application of fertilizer as per soil test was found in second rank (54.86, 56.52 and 55.69 t ha^{-1}).

Application of higher level of fertilizer (100% RDF) to succeeding onion crop preceded by *kharif* groundnut registered significantly higher bulb yield (48.03, 49.75 and 48.89 t ha^{-1}) and it was 4.52, 4.38 and 4.46 per cent higher over 75 per cent recommended dose of fertilizer and 15.45, 17.80 and 16.65 per cent higher over 50 per cent recommended dose of fertilizer during first year, second year and on pooled mean (Table 2). This might be because of the residual effect of preceding crop maintaining soil organic matter, major and micronutrients, which increases the uptake of these nutrients and accelerating the physiological activities in crop for improving growth attributes. Similarly, it also increased the translocation of photosynthates towards onion bulb resulted in increasing the size (polar and equatorial diameter) and weight of bulb. These results are in confirmity with those reported by Konde (2002), Reddy and Suresh (2009) and Jat *et al*., (2011).

Wheat : Application of fertilizer as per STCR equation to preceding crop *kharif* groundnut recorded significantly higher grain yield (42.13, 43.11 and 42.62 q ha^{-1}) of wheat

Table 1. Yield of component crops in different cropping systems as influenced by different treatments

Treatment	Groundnut pod yield (q ha^{-1})			Onion bulb yield (t ha^{-1})			Wheat grain yield (q ha^{-1})			Chickpea grain yield (q ha^{-1})		
	2011-12	2012-13	Pooled mean	2011-12	2012-13	Pooled mean	2011-12	2012-13	Pooled mean	2011-12	2012-13	Pooled mean
Nutrient management												
T_1	16.43	17.61	17.11	53.37	55.71	54.54	39.04	39.68	39.36	25.64	26.34	25.99
T_2	18.91	19.59	19.26	54.86	56.52	55.69	40.15	41.49	40.82	26.37	27.43	26.90
T_3	23.08	24.49	23.55	58.85	60.67	59.76	42.13	43.11	42.62	28.62	29.28	28.95
T_4	7.96	6.63	7.30	13.68	13.28	13.48	13.47	12.66	13.07	14.01	13.06	13.53
SEm±	0.59	0.52	0.49	0.76	0.82	0.60	0.26	0.38	0.41	0.27	0.59	0.45
C.D. at 5%	1.71	1.54	1.44	2.64	2.83	2.72	0.91	1.33	1.44	0.95	2.05	2.03
Fertilizer levels												
F_1	-	-	-	48.03	49.75	48.89	35.98	36.82	36.40	26.41	26.49	26.45
F_2	-	-	-	45.95	47.66	46.80	34.21	35.41	34.81	24.15	24.46	24.30
F_3	-	-	-	41.60	42.23	41.91	30.91	32.49	31.69	20.43	21.14	20.78
SEm±	-	-	-	0.52	0.68	0.46	0.39	0.46	0.74	0.37	0.36	0.43
C.D. at 5%	-	-	-	2.05	2.65	2.79	1.54	1.79	2.36	1.46	1.42	2.61
General mean	16.59	17.08	16.80	45.19	46.54	45.87	33.71	34.24	33.97	23.66	24.03	23.84

T_1 - Recommended dose of fertilizer, T_2 - Fertilizer dose as per soil test, T_3 - Fertilizer dose as per STCR eq^n (25 q ha^{-1}), T_4 - Control (No fertilizer), F_1 - 100% of RDF, F_2 - 75% of RDF, F_3 - 50% of RDF and it was 8.28 per cent higher over recommended dose of fertilizer on pooled mean basis (Table1).

Application of 100 per cent recommended dose of fertilizer to wheat crop during *rabi* season recorded significantly maximum grain yield (35.98, 36.82 and 36.40 q ha^{-1}) and it was 14.86 per cent higher in pooled mean than reduced level of fertilizer i.e. 50 per cent recommended dose of fertilizer but at par with 75 per cent recommended dose of fertilizer during both year. This indicate that growing of wheat crop after *kharif* groundnut saves 25 per cent recommended dose of fertilizer because of balance nutrition to *kharif* groundnut through STCR equation creates favourable environment in the root rhizosphere of wheat crop to absorb more nutrients and moisture by improving the production efficiency. These results are in corroborated with Verma *et al*., (2005) and Mubarak and Singh (2011).

Chickpea : Application of fertilizer as per STCR equation to preceding crop *kharif* groundnut recorded significantly maximum grain yield of chickpea (28.62, 29.28 and 28.95 q ha^{-1}) than recommended dose of fertilizer and control treatment during the period of investigation, however it was at par with fertilizer dose as per soil test during second year of experimentation.

Application of 100 per cent recommended dose of fertilizer to chickpea during *rabi* season recorded significantly maximum grain yield

Table 2. The productivity of different cropping systems as influenced by different treatments

Treatment	Total system productivity (q ha^{-1})			Production efficiency (kg ha^{-1} day^{-1})			Economic efficiency (Rs. ha^{-1} day^{-1})		
	2011-12	2012-13	Pooled mean	2011-12	2012-13	Pooled mean	2011-12	2012-13	Pooled mean
A. Cropping system									
C_1 - Groundnut-onion	67.21	89.17	78.19	30.16	39.96	35.06	620.66	1064.26	842.46
C_2 - Groundnut-wheat	31.19	34.28	32.73	14.34	15.67	15.01	166.09	252.63	209.36
C_3 - Groundnut-chickpea	39.96	41.20	40.58	18.94	19.61	19.27	327.32	399.66	363.49
SEm±	0.39	0.56	0.64	0.18	0.26	0.15	6.68	9.66	5.95
CD at 5%	1.14	1.66	1.91	0.53	0.75	0.45	20.13	28.35	17.45
B. Nutrient management									
T_1 - Recommended dose of fertilizer	50.32	61.85	56.09	23.17	28.45	25.81	422.98	681.73	552.35
T_2 - Fertilizer dose as per soil test	53.74	64.92	59.33	24.60	29.56	27.08	474.61	721.74	598.16
T_3 - Fertilizer dose as per STCR eq^n (25 q ha^{-1})	60.91	72.86	66.89	27.63	32.87	30.25	578.11	848.56	713.34
T_4 - Control (No Fertilizers)	19.53	19.91	19.72	9.18	9.44	9.31	9.74	36.72	23.24
SEm±	0.45	0.65	0.81	0.21	0.29	0.18	7.92	11.15	6.87
C.D. at 5%	1.32	1.92	2.41	0.61	0.87	0.53	23.25	32.73	20.15
C. Fertilizer levels									
F_1 - 100% of RDF	47.68	57.18	52.43	21.84	26.40	24.12	391.75	607.80	499.77
F_2 - 75% of RDF	47.12	56.40	51.76	21.61	25.49	23.55	386.92	597.72	492.32
F_3 - 50% of RDF	43.58	51.07	47.32	19.99	23.34	21.67	335.41	511.04	423.22
SEm±	0.44	0.33	0.46	0.20	0.32	0.21	6.94	5.65	3.76
C.D. at 5%	1.25	0.94	1.36	0.57	0.95	0.60	19.76	16.08	10.69
General mean	46.13	54.88	50.51	21.15	25.08	23.12	371.36	572.18	471.77

(26.41, 26.49 and 26.45 q ha^{-1}) during first year, second year and on pooled mean, however, it was at par with 75 per cent recommended dose of fertilizer in respect of grain yield on pooled mean. (Table 1). This might be because of beneficial residual effect of *kharif* groundnut by fixing the atmospheric nitrogen through biological means and which may be available to mineralization of plant residues there by increases the yield of succeeding crop. These results are in accordance with with Reddy and Suresh (2009), Singh *et al*., (2010) and Jat *et al*., (2011)

Total system productivity : The total system productivity of cropping systems was assessed based on groundnut equivalent yield in groundnut-onion, groundnut-wheat and groundnut-chickpea cropping systems. Among the cropping systems, groundnut-onion cropping system recorded significantly maximum total system productivity of 67.21, 89.17 and 78.19 q ha^{-1} and it was 115.48, 160.12 and 138.89 per cent higher than groundnut-wheat and 68.19, 116.43 and 92.68 per cent higher than groundnut-chickpea during both years and on pooled mean (Table 2).

Table 3. Economics of different cropping systems as influenced by different treatments

Treatment	Gross monetary returns (Rs. ha^{-1})			Net monetary returns (Rs. ha^{-1})			B:C ratio		
	2011-12	2012-13	Pooled mean	2011-12	2012-13	Pooled mean	2011-12	2012-13	Avg. of two years
Cropping system									
C_1 - Groundnut-onion	231903	334409	283156	138207	237982	188095	2.48	3.47	2.98
C_2 - Groundnut-wheat	107622	128550	118086	36465	55557	46011	1.51	1.76	1.64
C_3 - Groundnut-chickpea	137887	154535	146211	70118	84282	77200	2.05	2.16	2.11
SEm±	1349	2130	1253	1349	2129	1253	-	-	-
CD at 5%	3960	6248	3675	3958	6247	3677	-	-	-
Nutrient management									
T_1 - Recommended dose of fertilizer	173601	231969	202785	92490	148599	120544	2.14	2.78	2.47
T_2 - Fertilizer dose as per soil test	185431	243449	214440	104208	158959	131584	2.29	2.88	2.59
T_3 - Fertilizer dose as per STCR eq^n (25 q ha^{-1})	210156	273232	241694	127665	188477	158071	2.58	3.22	2.90
T_4 - Control (No Fertilizers)	67361	74675	71018	2024	7727	4875	1.03	1.11	1.07
SEm±	1558	2459	1446	1558	2458	1447	-	-	-
C.D. at 5%	4573	7215	4244	4570	7213	4246	-	-	-
Fertilizer levels									
F_1 - 100% of RDF	164493	214458	189476	86092	133688	109891	2.10	2.65	2.38
F_2 - 75% of RDF	162564	211504	187034	85023	131614	108319	2.09	2.64	2.37
F_3 - 50% of RDF	150355	191531	170943	73674	112519	93097	1.96	2.42	2.20
SEm±	1519	1241	911	1519	2198	1283	-	-	-
C.D. at 5%	4322	3530	2603	4322	6594	3851	-	-	-
General mean	159137	205831	182484	81597	125940	103768	2.05	2.57	2.31

Market price: 2011-12: Groundnut 3450 Rs. q^{-1}, Onion 360 Rs. q^{-1}, Wheat 1400 Rs. q-1, Chickpea 3300 Rs. q^{-1}.
2012-13: Groundnut 3750 Rs. q^{-1}, Onion 600 Rs. q^{-1}, Wheat 1800 Rs. q-1, Chickpea 3600 Rs. q^{-1}.

The nutrient management as per STCR equation proved it's superiority by recording maximum total system productivity of 60.91, 72.86 and 66.89 q ha^{-1} and it was followed by nutrient management as per soil test during first year, second year and on pooled mean.

The total system productivity was significantly higher with 100 per cent recommended dose of fertilizer to succeeding crop during *rabi* season and at par with 75 per cent recommended dose of fertilizer during both the years and pooled mean. These results are in accordance with Walia *et al*., (2009), Jat *et al*., (2011) and Mukundam *et al*., (2012).

Production efficiency : Among the cropping systems, groundnut-onion cropping system gave significantly higher production efficiency (30.16, 39.96 and 35.06 kg ha^{-1} day^{-1}) over groundnut-wheat and groundnut-chickpea cropping systems in both the years of experimentation. The groundnut-wheat cropping system gave significantly lowest production efficiency (14.34, 15.67 and 15.01 kg ha^{-1} day^{-1}) in both the years and on pooled mean.

The nutrient management treatments as per STCR equation registered significantly higher production efficiency of 27.63, 32.87 and 30.25 kg ha^{-1} day^{-1} and it was 19.24, 15.53 and 17.20 per cent higher over recommended dose of fertilizer during first year, second year and on pooled mean.

Application of 100 per cent recommended dose of fertilizer to succeeding crop during *rabi* season gave significantly higher production efficiency (21.84, 26.40 and 24.12 kg ha^{-1} day^{-1}) over 50 per cent recommended dose of fertilizer and at par with 75 per cent recommended dose of fertilizer during both the years and on pooled mean. (Table 2). This is because of inclusion of legume crop in rotation improve the soil fertility by reducing pH, EC and increasing organic carbon content, soil available nitrogen, phosphorus and potassium, This indicates that, growing of *kharif* groundnut with balanced nutrition reduces 25 per cent recommended dose of fertilizer to succeeding crops. Similar findings were reported by Srinivas and Srinivasa (2000), Walia *et al*., (2009) and Jat *et al*., (2011).

Economic efficiency : The groundnut-onion cropping system recorded significantly higher economic efficiency (Rs. 620.66, 1064.26 and 842.46 ha^{-1} day^{-1}) over groundnut-wheat (Rs. 166.09, 252.63 and 209.36 ha^{-1} day^{-1}) and groundnut-chickpea (Rs. 327.32 and 399.66, 363.49 ha^{-1} day^{-1}) cropping systems in both the years and on pooled mean.

Application of fertilizer as per STCR equation to *kharif* groundnut recorded significantly higher economic efficiency (Rs. 578.11, 848.56 and 713.34 ha^{-1} day^{-1}) than rest of the nutrient management and control treatment in both the years. The control treatment gave significantly lowest economic efficiency (Rs. 9.74, 36.72 and 23.24 ha^{-1} day^{-1}) because yield obtained was minimum as both the crops were grown without addition of fertilizers during both the years and on pooled mean.

The economic efficiency of different cropping systems was also influenced by different fertilizer levels. Application of 100 per cent recommended dose of fertilizer to succeeding crop in *rabi* season recorded significantly higher economic efficiency (Rs. 391.75, 607.80 and 499.77 ha^{-1} day^{-1}) over 50 per cent recommended dose of fertilizer level (Rs. 335.41, 511.04 and 423.22 ha^{-1} day^{-1}) and it was at par with 75 per cent recommended dose of fertilizer (Rs. 386.92, 597.72 and 492.32 ha^{-1} day^{-1}) in both years and pooled mean (Table 2). This is because of higher yield and biomass production with higher level of fertilizer. These results are in agreement with Reddy and Suresh (2009), Walia *et al*., (2009) and Singh *et al*., (2010)

Economics : Among the cropping systems, groundnut- onion cropping system gave significantly maximum gross monetary returns (Rs. 2,31,903, Rs. 3,34,409 and Rs. 2,83,156 ha^{-1}), net monetary returns (Rs. 1,38,207, Rs. 2,37,982 and Rs. 1,88,095 ha^{-1}) and B:C ratio (2.48, 3.47 and 2.98) than groundnut-wheat and groundnut-chickpea cropping systems during both the years and on pooled mean.

The groundnut-chickpea cropping system was found second rank in respect of gross and net monetary returns during both the years and on pooled mean. Application of fertilizer as per STCR equation to *kharif* groundnut obtained significantly maximum gross monetary returns (Rs. 2,10,156, Rs. 2,73,232 and Rs. 2,41,694 ha^{-1}), net monetary returns (Rs. 1,27,665, Rs. 1,88,477 and Rs. 1,58,071 ha^{-1}) and B:C ratio (2.58, 3.22 and 2.90) over rest of the nutrient management treatments during both the years and on pooled mean.

Application of 100 per cent recommended dose of fertilizer to succeeding crop in *rabi* season obtained significantly maximum gross monetary returns (Rs. 1,64,493, Rs. 2,14,458 and Rs. 1,89,476 ha^{-1}), net monetary returns (Rs. 86,092, Rs. 1,33,688 and Rs. 1,09,891 ha^{-1}) and B:C ratio (2.10, 2.65 and 2.38) over 50 per cent recommended dose of fertilizer. However, it was at par with 75 per cent recommended dose of fertilizer in respect of gross monetary returns, net monetary returns and B: C ratio during both the years and on pooled mean (Table 3). These results are in confirmity with those reported by Walia *et al*., (2009), Jat *et al*., (2011) and Mukundam *et al*., (2012).

On the basis of two years of experiment, it could be concluded that, application of fertilizer as per soil test crop response equation (25 q ha^{-1}) to *kharif* groundnut followed by 75 per cent recommended dose of fertilizer (75:37.5:37.5 N, P_2O_5, K_2O kg ha^{-1}) to onion during *rabi* season found most remunerative proposition to achieve maximum productivity and profitability in groundnut- onion cropping system.

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Response of Nutrient Management on Yield, Nutrient Uptake and Energy Balance in Groundnut Based Diversified Cropping Systems

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Abstract

Among the cropping systems, groundnut-onion cropping system recorded significantly maximum total system productivity of 67.21 and 89.17 q ha^{-1} and it was 115.48 and 160.12 per cent higher than groundnut-wheat and 68.19 and 116.43 per cent higher than groundnut-chickpea during first and second year. Whereas significantly higher energy output-input ratio (9.31 and 9.54) and energy balance per unit input (8.31 and 8.54) was observed in groundnut-chickpea cropping system during both the years. Among the cropping systems, nitrogen uptake was higher in groundnut-chickpea cropping system it means that higher nitrogen was removed by groundnut- chickpea cropping system (-300.94 kg ha^{-1}).

Key words : Cropping systems, nutrient management, uptake, productivity, energy balance, nutrient balance

In the changing agricultural scenario, It is abundantly clearly that, the farmers are facing growing stress from climate change and that the greater implementation of diversified agricultural systems may be productive way to build resilience into agricultural systems. The challenges to increasing adoption of diversified agricultural management strategies are both scientific and policy based.

Crop diversification is intended to give a wide choice in the production of a variety of

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crops in a given area so as to expand production related activities on various crops and also to lesser risk. In cropping system, if legume is a component crop which contributes considerable mineralizable nitrogen in soil (Singh and Sahu, 1981). Inclusion of legume in a crop sequence not only takes care of soil health but also gives higher yield and helps to increase soil organic carbon, available N, P and K fertilizer in 0-15 cm soil layer. However, soil fertility build-up through biological sources is considered more beneficial than organic sources. In the present study efforts were made to assess the effect of different nutrient management practices on yield potential of *kharif* groundnut and its residual effect on succeeding crops (onion, wheat and chickpea) in *rabi* season under different fertilizer levels in order to increase and sustain the yield potential of groundnut based cropping systems and improvement in soil health.

Materials and Methods

A field experiment was carried out during 2011-12 and 2012-13 at MPKV, Rahuri (M.S.) on sandy clay loam soil with low in available nitrogen (172.11 kg ha^{-1}), medium in available phosphorus (18.02 kg ha^{-1}) and high in available potassium (427.0 kg ha^{-1}) and moderate in Fe (6.89 µg g^{-1} soil), Mn (9.51 µg g^{-1} soil), Zn (0.62 µg g^{-1} soil) and Cu (3.41 µg g^{-1}soil). The soil was moderately alkaline in reaction (pH 8.2). The electrical conductivity, organic carbon and $CaCO_3$ were 0.29 dS m^{-1}, 0.54 and 4.50 per cent, respectively.

The treatment consist of three cropping systems *viz*., C_1-groundnut-onion, C_2-groundnut-wheat and C3-groundnut-chickpea with four nutrient management treatments *viz*., T_1- recommended dose of fertilizer (RDF), T_2-fertilizer dose as per soil test, T_3- fertilizer dose as per STCR equations and T_4- control as main plot treatment whereas three fertilizer levels *viz*., F_1-100 % RDF, F_2-75% RDF and F_3- 50 % RDF as sub plot treatments. The experiment was laid out in a strip plot design with three replications. Groundnut JL- 501, onion N 2-4-1, wheat-Trimbak and chickpea-Digvijay these cultivars were used during *kharif* and *rabi* seasons, respectively. Both the year's crop seasons were favourable to grow the *kharif* and *rabi* crops. The recommended package of practices were adopted to grow the crops and fertilizers were applied as per treatments. The energy studies were calculated as per formula given by Gopalan *et al*., (1978).

Results and Discussion

Yield of *kharif* groundnut : The dry pod yield of groundnut as influenced by different treatments are presented in Table 1. Application of fertilizer as per STCR equation recorded maximum and significantly higher dry pod yield of 23.08, 24.49 and 23.55 q ha^{-1} than rest of treatments during both years and pooled mean. The yield target of 25 q ha^{-1} was achieved by STCR equation with less than 10 per cent variation (-5.8%). This might be because of balanced nutrition, the uptake of essential nutrients increased and which accelerates the activites of cell elongation and cell multiplication as well as metabolic activities resulted in increasing growth and yield. These results are in confirmity with the results obtained by Gill *et al*., (2009), Aulakh (2010) and Jat *et al*., (2011).

Yield of *rabi* crops : The yield of crop is the function of growth, yield attributes and nutrient uptake by crop, hence the nutrient management as per STCR equation exhibited significantly higher yield of onion bulb (58.85, 60.67 and 59.76 t ha^{-1}), wheat grain (42.13, 43.11 and 42.62 q ha^{-1}) and chickpea grain (28.62, 29.28 and 28.95 q ha^{-1}) than rest of the treatments during both the years and pooled mean (Table 1). Though the residual effect of *kharif* groundnut was observed in all treatments, application of fertilizer as per STCR equation found to better distribution of nutrients to all the parts (root, shoot and grains) and reflect their efficiency. Similarly, it also influenced photosynthetic rate and dry matter partitioning between roots and shoots. These results are in confirmity with those reported by Kathmale *et al*., (2000), Dudhatra *et al*., (2002) and Ghosh *et al*., (2003).

Application of 100 per cent recommended dose of fertilizer to succeeding crop preceded by *kharif* groundnut registered significantly maximum higher onion bulb yield (48.03, 49.75 and 48.89 t ha^{-1}), grain yield of wheat (35.98, 36.82 and 36.40 q ha^{-1}) and chickpea (26.41, 26.49 and 26.45 q ha^{-1}) was achieved than reduced level of fertilizer i.e. 50 per cent recommended dose of fertilizer but at par with 75 per cent recommended dose of fertilizer during first, second year and pooled mean, respectively (Table 1). This indicate that growing of onion, wheat and chickpea crop after *kharif* groundnut saves 25 per cent recommended dose of fertilizer, because of balance nutrition to *kharif* groundnut through STCR equation creates favourable environment in the root rhizosphere of *rabi* crop to absorb more nutrients and moisture by improving the soil porosity, moisture holding capacity and nutrient use efficiency, which leads to increase the growth and yield of *rabi* crops. These results are in corroborated with Dudhatra *et al*., (2002), Ghosh *et al*., (2003) and Ramesh *et al*., (2009).

Table 1. Yield of different crops as influenced by different treatments

Treat-ment	Gr. nut pod yield (q ha^{-1})		Pooled mean	Onion bulb yield (t ha^{-1})		Pooled mean	Wheat grain yield (q ha^{-1})		Pooled mean	Chickpea grain yield (q ha^{-1})		Pooled mean
	Ist year	IInd year		Ist year	IInd year		Ist year	IInd year		Ist year	IInd year	
Nutrient management (T)												
T_1	16.43	17.61	17.11	53.37	55.71	54.54	39.04	39.68	39.36	25.64	26.34	25.99
T_2	18.91	19.59	19.26	54.86	56.52	55.69	40.15	41.49	40.82	26.37	27.43	26.90
T_3	23.08	24.49	23.55	58.85	60.67	59.76	42.13	43.11	42.62	28.62	29.28	28.95
T_4	7.96	6.63	7.30	13.68	13.28	13.48	13.47	12.66	13.07	14.01	13.06	13.53
SEm±	0.59	0.52	0.49	0.76	0.82	0.60	0.26	0.38	0.41	0.27	0.59	0.45
C.D. at 5%	1.71	1.54	1.44	2.64	2.83	2.72	0.91	1.33	1.44	0.95	2.05	2.03
Fertilizer levels (F)												
F_1	-	-	-	48.03	49.75	48.89	35.98	36.82	36.40	26.41	26.49	26.45
F_2	-	-	-	45.95	47.66	46.80	34.21	35.41	34.81	24.15	24.46	24.30
F_3	-	-	-	41.60	42.23	41.91	30.91	32.49	30.69	20.43	21.14	20.78
SEm±	-	-	-	0.52	0.68	0.46	0.39	0.46	0.74	0.37	0.36	0.43
C.D. at 5%	-	-	-	2.05	2.65	2.79	1.54	1.79	2.36	1.46	1.42	2.61
Interaction (T x F)	-	-	-	Sig	Sig	Sig	Sig	Sig	Sig	Sig	Sig	Sig
C.V. (%)	4.31	3.79	4.05	5.12	5.03	2.82	4.03	4.61	3.24	5.39	5.22	5.08
General mean	16.59	17.08	16.80	45.19	46.54	45.87	33.71	34.24	33.97	23.66	24.03	23.84

T_1 - Recommended dose of fertilizer, T_2 - Fertilizer dose as per soil test, T_3 - Fertilizer dose as per STCR eq^n (25 q ha^{-1}), T_4 - Control (No fertilizer), F_1 - 100% of RDF, F_2 - 75% of RDF, F_3 - 50% of RDF.

Total system productivity : The total system productivity of cropping systems was assessed based on groundnut equivalent yield in groundnut-onion, groundnut-wheat and groundnut-chickpea cropping systems. Among the cropping systems, groundnut-onion cropping system recorded significantly maximum total system productivity of 67.21 and 89.17 q ha^{-1} and it was 115.48 and 160.12 per cent higher than groundnut-wheat and groundnut-chickpea during first and second year (Table 2). The similar findings were also reported by Tomar *et al*., (1996), Gill *et al*., (2009) and Singh *et al*., (2012).

The nutrient management as per STCR equation proved it's superiority by recording maximum total system productivity of 60.91 and 72.86 q ha^{-1} and it was followed by nutrient management as per soil test during both years. Similar findings were reported by Walia *et al*., (2010), Narkhede *et al*., (2011) and Vidyavathi *et al*., (2011).

The total system productivity was significantly higher with 100 per cent recommended dose of fertilizer to succeeding crop during *rabi* season and at par with 75 per cent recommended dose of fertilizer during

Table 2. Total system productivity and energy balance of different cropping systems as influenced by different treatments

Treatment	Total system productivity		Input energy (x 10^3 MJ ha^{-1})		Output energy (x 10^3 MJ ha^{-1})		Energy balance (x 10^3 MJ ha^{-1})		Energy output-input ratio		Energy balance unit^{-1} input	
	Ist year	IInd year	Ist year	IInd year	Ist year	IInd year	Ist year	IInd year	Ist year	IInd year	Ist year	IInd year
Cropping system												
C_1	67.21	89.17	23.14	23.57	154.21	158.49	131.07	134.91	6.39	6.42	5.39	5.42
C_2	31.19	34.28	20.07	20.97	172.92	183.28	152.84	162.31	8.37	8.44	7.37	7.44
C_3	39.96	41.20	17.57	18.18	168.09	179.24	150.52	161.06	9.31	9.54	8.31	8.54
SEm±	0.39	0.56	0.01	0.12	0.77	1.09	0.77	1.09	0.04	0.05	0.04	0.05
CD at 5%	1.14	1.66	0.03	0.36	2.27	3.21	2.27	3.22	0.12	0.16	0.12	0.16
Nutrient management												
T_1	50.32	61.85	20.85	21.01	180.19	185.06	159.33	164.05	8.83	8.98	7.83	7.98
T_2	53.74	64.92	21.22	22.31	186.83	202.34	165.61	180.03	8.96	9.21	7.96	8.20
T_3	60.91	72.86	24.45	25.71	218.57	233.86	194.13	208.14	9.03	9.22	8.04	8.21
T_4	19.53	19.91	14.53	14.59	74.70	73.42	60.17	58.83	5.27	5.15	4.26	4.15
SEm±	0.45	0.65	0.01	0.14	0.89	1.26	0.89	1.26	0.05	0.06	0.05	0.06
C.D. at 5%	1.32	1.92	0.03	0.42	2.62	3.71	2.62	3.71	0.14	0.18	0.14	0.18
Fertilizer levels												
F_1	47.68	57.18	21.33	21.97	179.49	186.84	158.16	166.03	8.34	8.44	7.32	7.39
F_2	47.12	56.40	20.26	20.91	167.85	172.32	147.59	154.83	8.11	8.23	7.14	7.22
F_3	43.58	51.07	19.20	19.84	147.88	153.68	128.68	137.42	7.61	7.80	6.62	6.80
SEm±	0.44	0.33	0.001	0.08	0.79	1.09	0.79	1.09	0.04	0.06	0.04	0.06
C.D. at 5%	1.25	0.94	0.003	0.22	2.24	3.11	2.25	3.12	0.12	0.17	0. 12	0.17
General mean	46.13	54.88	20.26	20.91	165.07	170.95	144.81	152.76	8.02	8.13	7.02	7.14

C_1 - Groundnut-onion, C_2 - Groundnut-wheat, C_3 - Groundnut-chickpea, T_1 - Recommended dose of fertilizer, T_2 - Fertilizer dose as per soil test, T_3 - Fertilizer dose as per STCR eq^n (25 q ha^{-1}), T_4 - Control (No fertilizer), F_1 - 100% of RDF, F_2 - 75% of RDF, F_3 - 50% of RDF.

both the years (Table 1). This indicates that, there was saving of 25 per cent recommended dose of fertilizer to succeeding crop, when grown after *kharif* groundnut. These results are in accordance with Ramesh *et al*., (2009), Jat *et al*., (2011) and Mukundam *et al*., (2012).

Energy studies : The cropping systems were evaluated on the basis of input energy, output energy, energy balance, energy output - input ratio and energy balance per unit input during both the years and presented in Table 2.

The groundnut-onion cropping system registered significantly higher energy input (23.14 and 23.57 x 10^3 MJ ha^{-1}), while groundnut - wheat cropping system recorded significantly higher output energy (172.92, 183.28 x 10^3 MJ ha^{-1}). Whereas significantly higher energy output-input ratio (9.31 and 9.54) and energy balance per unit input (8.31 and 8.54) was observed in groundnut-chickpea cropping system during both the years. These results are in agreement with those reported by Dudhatra *et al*., (2002), Jat *et al*., (2011) Singh *et al*., (2012).

Application of fertilizer as per STCR equation to *kharif* groundnut registered significantly higher input energy (24.45 and 25.71 X103 MJ ha^{-1}), output energy (218.57 and 233.86 X103 MJ ha^{-1}), energy balance (194.13 and 208.14 X103 MJ ha^{-1}), energy output-input ratio (9.03 and 9.22) and energy balance per input (8.04 and 8.21) and it was at par with fertilizer dose as per soil test in respect of energy output-input ratio and energy balance per unit input during both the years. Similar results reported by Tomar *et al*., (2007), Walia *et al*., (2010) and Jat *et al*., (2011).

Application of 100 per cent recommended dose of fertilizer to succeeding crop during *rabi* season registered significantly higher input

Table 3. Nutrient balance sheet of different cropping systems as influenced by different treatments

Treatment	Nutrient added (kg ha^{-1})			Nutrient uptake (kg ha^{-1})			Nutrient after harvest of crops (kg ha^{-1})			Nutrient balance (kg ha^{-1})		
	N	P	K	N	P	K	N	P	K	N	P	K
Cropping system												
C_1	268.74	104.53	147.09	288.52	65.80	192.55	186.93	17.88	309.75	-34.60	38.87	72.03
C_2	298.75	110.53	134.64	350.35	70.91	338.39	185.39	17.70	262.05	-64.88	39.94	-38.80
C_3	156.24	104.08	84.84	437.28	64.84	248.30	192.01	18.03	270.27	-300.94	39.23	-6.73
Nutrient management												
T_1	229.58	111.88	110.84	384.51	70.40	281.90	204.88	19.86	302.77	-187.70	39.64	-46.83
T_2	242.01	100.79	100.84	421.50	78.67	301.82	194.48	19.74	285.11	-201.86	20.40	-59.09
T_3	252.16	117.14	157.22	480.39	93.44	338.47	186.42	18.98	279.92	-242.54	22.74	-34.17
T_4	0.00	0.00	0.00	148.88	26.20	116.79	166.43	12.89	268.81	-143.20	-21.07	41.40
Fertilizer levels												
F_1	282.08	118.13	134.64	386.09	73.45	276.68	195.77	19.18	291.30	-127.67	43.52	-6.30
F_2	241.24	106.66	122.18	368.73	68.19	264.89	186.95	18.03	281.97	-142.33	38.46	2.32
F_3	200.41	95.20	109.74	321.65	59.80	237.66	181.61	16.39	272.64	-130.74	37.03	26.44
General mean	241.24	107.66	122.44	358.79	67.13	259.74	188.09	17.87	282.45	-157.64	29.91	-4.97
Initial soil status (kg ha^{-1})	172.11	18.02	427.0									

C_1 - Groundnut-onion, C_2 - Groundnut-wheat, C_3 - Groundnut-chickpea, T_1 - RDF, T_2 - AST, T_3 - STCR eq^n (25 q ha^{-1}), T_4 - Control, F_1 - 100% of RDF, F_2 - 75% of RDF, F_3 - 50% of RDF.

energy (21.33 and 21.97 x 10^3 MJ ha^{-1}), output energy (179.49 and 186.84 x 10^3 MJ ha^{-1}), energy balance (158.16 and 166.03 x 10^3 MJ ha^{-1}), energy output-input ratio (8.34 and 8.44) and energy balance per unit input (7.32 and 7.39) than 75 and 50 per cent recommended dose of fertilizer during both the years. These results are in accordance with Tomar *et al.*, (2007), Walia *et al.*, (2010) and Singh *et al.*, (2012).

Nutrient balance : The nutrient balance was assessed on the basis of initial nutrient status, nutrient added, uptake of nutrients by crop and available nutrients after harvest of each crop and cropping system during both the years and presented in Table 3.

Among the cropping systems, the higher uptake of nitrogen was recorded by groundnut-chickpea cropping system (437.28 kg ha^{-1}) and its nutrient balance was negatively recorded by same cropping system (-300.94 kg ha^{-1}). The groundnut and chickpea both the crops are legumes which requires higher amount of nitrogen for their metabolic activities. As a result, there was higher uptake of nitrogen from soil. Similar results recorded by Ramesh *et al.*, (2009) and Jat *et al.*, (2011)

In nutrient management studies, the application of fertilizer as per STCR yield target equations recorded higher uptake of nutrients (480.39 kg ha^{-1}) and ultimately it resulted more deficit in their soil available nitrogen (-242.54 kg ha^{-1}) and less deficit in potash (-34.17 kg ha^{-1}) balance except control treatment in potash. This might be because of addition fertilizer dose of nitrogen and potassium to groundnut as per STCR equation are sufficient for (25 q ha^{-1}) yield target. Similar results recorded by Walia *et al.*, (2010), Narkhede *et al.*, (2011) and Prasad *et al.*, (2011).

The fertilizer levels *viz.*, 100, 75 and 50 per cent of recommended dose of fertilizer did not showed numerically considerable difference in soil nutrient uptake and balance at the end of cropping systems. Whereas, it was found that the depletion of nitrogen (-142.33 kg ha^{-1}) was more in 75 per cent recommended dose of fertilizer but gain of phosphorus (43.52 kg ha^{-1}) and depletion of potash(-6.30 kg ha^{-1}) was maximum in application of 100 per cent recommended dose of fertilizer. Similar findings were reported by Narkhede *et al.*, (2011) and Prasad *et al.*, (2011).

Interaction : The interaction effect between nutrient management and fertilizer levels were found significant in respect of onion, wheat and chickpea yield during both years and pooled mean.

On the basis of two years of experiment, it could be concluded that, application of fertilizer as per soil test crop response (STCR) equation (25 q ha^{-1}) to *kharif* groundnut followed by 75 per cent recommended dose of fertilizer (75:37.5:37.5 N, P_2O_5, K_2O kg ha^{-1}) to groundnut-onion cropping system to found most remunerative in total system productivity but groundnut-chickpea cropping system recorded maximum energy output - input ratio and energy balance per unit input.

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Genetic Divergence for Yield and Yield Attributing Traits in Brinjal (*Solanum melongena* L.)

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Abstract

In the present investigation, an attempt has been made to evaluate the genetic diversity for yield and yield attributing traits in twenty nine genotypes of brinjal. On the basis of D^2 analysis, these genotypes were grouped into six clusters, irrespective of geographic divergence, indicating no parallelism between diversity and geographical divergence. Cluster I had highest number of genotypes (13) followed by cluster II and cluster IV, which had seven and six genotypes respectively. Cluster III, V and VI were solitary. The maximum genetic divergence was observed between cluster IV and VI (76.72), followed by cluster IV and V (69.68) and cluster III and IV (62.47). The character fruit weight had highest (28.31 %) contribution towards total genetic divergence followed by fruit yield per plant (16.73 %), fruit length (15.01 %), fruit breadth (14.53 %) and number of branches per plant (12.49 %). Hence, the genotypes belonging to divergent clusters, IV and VI, IV and V, III and IV may be selected for hybridization so as to generate desirable variability.

Key words : Genetic diversity, brinjal

Brinjal (*Solanum melongena* L.) is one of the most common, popular and principle vegetable crop grown throughout the country except at higher altitude. It is a valuable member of the human diet in Asia, especially in India, which is a primary diversity centre of the species. It (*S. Melongena* L.) belongs to Solanaceae family, is an important and versatile crop adapted to different agro-climatic regions. It has more regional preferences for specificity of fruit traits ranging from round to long fruit with green, purple, pink, white and stripped multicolours. Considering the potentiality of this crop, there was a prime need to develop varieties suited to specific agro-ecological conditions for specific use. The average yield of this crop is very low in India, and year to year variation in yield is also remarkably high, therefore, there is an urgent need to design breeding programme that can enhance productivity and stabilize the yield. Information on genetic divergence among the available germplasm is vital to a plant breeder for an efficient choice of parents for hybridization. It is an established fact that genetically diverse parents are likely to contribute desirable segregants. It is also believed that, the more diverse the parents, greater would be the chances of obtaining high heterotic F_1's and broad spectrum of variability in the segregating generation.The wide range in genetic diversity available in India has not been fully exploited to improve the yield of brinjal. Mahalanobis's D^2 statistic as a tool for estimating genetic divergence in crop plants can be used to choose the parents without making crosses before the initiation of hybridization programme. Therefore, the present investigation was undertaken to study the genetic divergence in twenty nine genotypes of brinjal.

Materials and Methods

Twenty nine brinjal genotypes procured from different regions of the country *viz*., IIVR,

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Varanasi, IIHR, Bengaluru, Vellanikkara, Ranchi, Bhubaneshwar, Nirmal Seeds, and some local cultivars were maintained at Vegetable Improvement Scheme, Wakawali and evaluated during *rabi* 2010-11 in a randomized block design with three replications at the research farm, Department of Agril. Botany, Dapoli, Dist. Ratnagiri MS, India. Each genotype was represented by three rows of three meter length with a spacing of 60 x 60 cm between rows and plant to plant respectively. Scrupulously, all the recommended package of practices and plant protection measures were followed to raise the healthy crop. The data was subjected to estimate the genetic divergence as per Mahalanobis (1936) D^2 statistics as described by Rao (1952).

Results and Discussion

Analysis of variance for twenty nine brinjal genotypes revealed significant differences for all the characters indicating presence of genetic variability for all the characters under study.The present material therefore, could serve as a pool for selection of suitable genotypes in breeding programmes. As per Tocher's method, twenty nine genotypes were grouped into six clusters (Table 1). Among the six clusters, I clusterwas found to be a largest, containing thirteen genotypes followed by cluster II and cluster IV with 7 and 6 genotypes, respectively. Rest of the three genotypes formed independent cluster for themselves. The solitary clusters indicating their independent identity and importance due to the unique characters possessed by those genotypes. These genotypes may serve as potential parents for breeding programme.Thus composition of clusters revealed that, the grouping pattern of genotypes was not directly associated with geographic diversity. These results are in close agreement with the findings of Muniappan *et al.*, (2010). There are forces other than geographical separation such as natural and artificial selection, exchange of breeding material, genetic drift, environmental variation, etc., which are responsible for diversity in brinjal. This emphasise that, choice of the parents for hybridization should be decided on the basis of genetic diversity rather than geographic diversity.

Besides cluster means for particular character, intra cluster distance is another parameter which indicates the extent of diversity existed in the genotypes of a particular

Table 1. Grouping of brinjal genotypes into different clusters

Cluster no.	No. of genotype included in cluster	Name of genotype
I	13	N-1008, N-1009, NB-746, D-79-19, Sadave Local, BB-46-13, Bholanath, DPL-B-4, BG-TP-2, Vengurla Local , IIHR-3, DPL-B-5, Majal Local
II	7	Utsav Utkal, BG-TP-1, Vetore Local , VNR-218, Asond Local, Manjari Gota(N), SM-6-6
III	1	Lanja Local
IV	6	RCM-BL-3, NB-1067, Navashi Local, N-1007, BB-64, CHES-309
V	1	Bandhtiware Local
VI	1	Singnath

Table 2. Average Intra and inter-cluster distance (D2) among 29 brinjal genotypes

Cluster	I	II	III	IV	V	VI
I	**18.32**	36.28	30.63	42.58	51.58	46.57
II		**30.77**	40.39	55.23	42.59	57.39
III			**0.000**	62.47	30.92	19.85
IV				**43.08**	69.68	76.72
V					**0.000**	21.03
VI						**0.000**

Bold and diagonal values indicate intra-cluster distances and remaining values indicate inter-cluster distances.

cluster. The perusal of intra and intercluster distances (Table 2) revealed that values of inter-cluster distance were greater than intra-cluster distance values. Intracluster D^2 values ranged from 0 to 43.08. The maximum intracluster distance was observed for cluster IV (43.08), followed by cluster II (30.77) and cluster I (18.32). The high intra-cluster distance in cluster IV indicated the presence of wide genetic diversity among the genotypes in this cluster, *viz.*, RCM-BL-3, NB-1067, Navashi Local, N-1007, BB-64, and CHES-309.

The nearest intercluster distance was found between cluster III and VI (19.85), followed by cluster V and VI (21.03); indicating the close relationship and similarity for most of the characters of the genotypes. The widest inter cluster distance was found between cluster IV and VI (76.72), followed by cluster IV and V (69.68), cluster III and IV (62.47) and cluster II and VI (57.39). Based on these results i.e genotypes those are grouped into above clusters had more divergence and may be selected for hybridization programme for getting better segregants in brinjal. This could form the material for selection of genetically diverse parents which is an important prerequisite so as to obtain better and desirable recombinants. These findings were in conformity with the results of Singh *et al.*, (2006).

Similarly, the cluster means for twelve quantitative characters under study (Table 3) revealed considerable differences between clusters for all the characters. The cluster I comprised of thirteen genotypes which exhibited better average for the characters *viz.*, days to first picking (73.67), days to last picking (132.22), and fruit weight (84.93). The cluster II comprises seven genotypes and exhibited maximum average values for plant height (60.80) and fruit length (11.41). The cluster III comprised of only one genotype and showed maximum average value for the characters *viz.*, number of branches plant^{-1} (6.56), days to initiation of flowering (36.75), days to fifty per cent flowering (45.25), fruit breadth (4.29), number of fruits plant^{-1} (13.44) and fruit yield plant^{-1} (949.37). The cluster IV had six genotypes with maximum seeds fruit^{-1} while cluster V and VI each had one genotype and exhibited considerably but minimum average values for all the characters.

Table 3. Cluster means for various characters in brinjal

Characters	**Clusters**					
	I	**II**	**III**	**IV**	**V**	**VI**
Plant height (cm)	58.46	60.80	50.48	56.74	56.63	57.88
Branches plant^{-1}	3.33	3.32	6.56	5.79	4.22	3.78
Days to 1st of flowering	36.33	31.78	36.75	30.56	29.30	29.52
Days to 50% flowering	41.78	40.00	45.25	37.56	36.26	37.05
Days to 1st picking	73.67	67.22	66.25	66.33	66.33	65.38
Days to last picking	132.22	128.00	129.67	127.56	129.11	129.29
Fruit length (cm)	8.28	11.41	8.36	7.83	7.93	7.76
Fruit breadth (cm)	3.38	4.19	4.29	3.34	3.50	3.72
Fruit weight (g)	84.93	68.17	63.84	64.11	59.03	56.20
Fruits plant^{-1}	11.26	11.66	13.44	12.36	11.74	10.31
Seeds fruit^{-1}	466.00	355.78	550.42	1159.4	553.04	883.95
Fruit yield plant^{-1} (g)	824.96	823.51	949.37	896.44	783.98	689.49

The per cent contribution of an individual character towards total divergence helps in identifying the diversity in different proportion which ultimately aids in deciding the utilization of genetic material for the improvement of specific character. The character fruit weight contributed maximum towards total divergence (28.31%) followed by yield plant^{-1} (16.73%), fruit length (15.01%), fruit breadth (14.53%) and branches plant^{-1} (12.49%). Higher contribution of these characters towards total divergence were also reported by Mohanty and Prusti (2001), Babu and Patil (2002), Sharma and Maurya (2004), Naik (2005) and Sherly and Shanthi (2009). Hence, the importance of selection for divergent parents based on these characters would be useful for heterosis breeding in brinjal.

From present studies it is concluded that, the brinjal genotypes differed significantly, for all the characters studied and were grouped into six clusters. Considerable diversity within and between the clusters were observed. It is further evident that, genotypes from divergent clusters IV and VI, IV and V, III and IV would serve as potential parental lines for hybridization to exploit heterosis and transgressive segregants.

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Management of Aphid Vectors *vis-a-vis* PRSV-P Incidence in Papaya

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Abstract

PRSV-P disease management through vector control using chemical pesticides and border cropping of maize was evaluated in the field on popular papaya variety Taiwan 786 (Red Lady) (2010-11) and PSRV-P tolerant line Pune Selection -3 (PS-3) (2012). The number of aphids collected on traps in different treatments was significantly less compared to control plots during all the three years. In case of Taiwan 786 (Red Lady), higher PRSV-P disease incidence was observed in 2011 compared to 2010. Lowest disease incidence in 2010 was observed in the treatment consisting of maize as border crop with fortnightly alternate sprays of dimethoate 30 EC (0.05%) and azadirachtin 0.03 EC (4 ml l^{-1}) followed by sprays of thiamethoxam 25 WG (0.005%) and buprofenzin 25% SC (0.025%). All the treatments with maize as border crop produced significantly higher yields of papaya compared to control plots which showed higher disease incidence, produced lesser number of fruits and resulted in lower yields. Disease incidence in experiment with PS-3 was relatively less compared to incidence in Taiwan 786 (Red Lady). Maximum disease incidence in control treatment of PS-3 was only 20 percent compared to 34-49 percent incidence observed in control plots of Taiwan 786 (Red Lady). Similarly higher control yield was observed in experiment with papaya line PS-3 (25.17 kg $plant^{-1}$) compared toTaiwan 786 (Red Lady) (16-17 kg $plant^{-1}$).

Key words : Papaya, aphid, PRSV-P, disease management, chemical pesticides, border crop, Pune Selction-3

Production of papaya which is an important fruit crop suffers up to 85-90% losses due to severe attack of papaya ringspot virus-papaya (PRSV-P) (Lokhande *et al*., 1992; Hussain and Verma, 1994). PRSV-P is transmitted by more than 20 species of aphids in non-persistent manner (Khurana and Bhargava,1971; Krishan Kumar *et al*., 2010; Kalleshwaraswamy and Krishnakumar, 2008). Hence management of aphid vector is very essential for preventing virus attack and it's further spread to healthy plants. Most of the aphid species does not colonize on papaya,however, PRSV-P is spread mostly by alate forms of aphids in non-persistent manner from infected host plants weeds^{-1} (Chavan *et al*., 2010).

Present study evaluated different chemical pesticides and border cropping with maize for reducing incidence of PRSV-P through management of aphid vectors in commercial papaya variety Taiwan 786 (Red Lady) and PRSV-P tolerant line Pune Selection-3 (PS-3).

Materials and Methods

Experiments were conducted at Indian Agriculture Research Institute, Regional Station Pune for three years from 2010-2012. During 2010 and 2011, trials were performed using the popular commercial papaya variety Taiwan 786 known as Red Lady, whereas during 2012, PRSV-P tolerant line PS-3 (developed atthe Station) was used.

Experiments conducted in Randomized Block Design with 10 treatments in three

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replications.The treatments consisted of spray of chemicals *viz*., Thiamethoxam 25 WG (0.005%), Imidacloprid 17.8% SL (0.01%), Acetamaprid 20% SP (0.005%), Buprofenzin 25% SC (0.025%), Dimethoate 30 EC (0.05%), Azadirachtin 0.03 EC (12 ppm); Border crop of maize + alternate spray of Dimethoate 30 EC and Azadirachtin 0.03 EC, Border crop of maize + Dimethoate 30 EC, Border crop of maize + Azadirachtin 0.03 EC and Control (No spray). Chemical pesticides were sprayed at 15 days intervals starting from 15 days after transplanting of papaya seedlings (raised under insect proof net and 50 days old) till fruit setting stage. Maize (African Tall, 3 rows) as border crop was sown 20 days prior to transplanting of papaya seedlings. Each plot consisted of two rows of papaya planted at a distance of 2.5 x 2.5 meter with 10 plants row^{-1}. All other cultivation practices were followed as per recommendations.

Observation were recorded on 3rd, 7th and 14th days after each spray application on total number of PRSV-P infected plants in each plot from which percent disease incidence was calculated. The data was pooled, analyzed after arc-sin transformation and presented as percentage PRSV-P incidence per treatment. The yield data was recorded in terms of number of fruits and total weight of fruits plant^{-1}.

Yellow sticky taps (three numbers) were

Table 1. Management of aphid vectors *vis-à-vis* PRSV incidence in commercial Papaya variety Taiwan 786 (Red Lady)

Treatments	No. of alate aphids sq.$^{-1}$ inch Av. (2010-11)	PRSC incidence (%)		Av. no. of fruits plant^{-1}		Yield (kg pl^{-1})	
		2010	2011	2010	2011	2010	2011
Thiamethoxam 25 WG(0.005%)	0.78±0.18	15.02±1.06	34.33±2.35	14.40±1.31	10.67±0.89	28.94±0.78	18.52±0.50
Imidacloprid 17.8% SL (0.01%)	0.53±0.27	31.35±0.72	39.94±4.15	13.67±0.89	13.17±1.49	23.90±2.23	18.72±2.01
Acetamaprid 20% SP (0.005%)	0.66±0.39	21.19±1.84	41.70±3.41	14.82±1.49	12.92±1.05	24.53±0.77	21.14±0.66
Buprofenzin 25% SC (0.025%)	0.83±0.37	20.85±4.65	43.99±1.94	14.20±1.47	12.26±1.02	27.36±0.94	20.12± 0.48
Dimethoate 30 EC (0.05%)	0.09±0.05	24.46±2.10	36.44±1.83	12.33±1.57	12.49±4.86	23.12±1.63	19.32± 0.99
Azadirachtin 0.03 EC (4 ml l^{-1})	0.59±0.10	21.94±1.51	44.22± 2.44	11.11±1.44	13.97±0.37	23.23±3.50	20.97±0.28
Border crop of maize + Alternate spray of Dimethoate 30 EC (0.05%) & Azadirachtin 0.03 EC(4 ml l^{-1})	0.10±0.06	13.56±4.65	21.21±3.41	14.83±1.14	16.27±1.66	29.74±0.84	24.60±0.58
Border crop of maize + Dimethoate 30 EC (0.05%)	0.11±0.11	20.60±1.89	26.60±0.89	14.40±1.28	13.40±0.80	25.42±1.27	21.41±0.71
Border crop of maize + Azadirachtin 0.03 EC (4 ml l^{-1})	0.54±0.26	20.47±1.30	30.47±2.32	14.67±1.20	13.67±1.10	25.07±1.02	20.07±0.97
Control	3.03±0.18	34.69±2.63	49..55±2.37	8.65±1.17	10.24±0.18	17.07±1.49	16.11±0.72
CD @5%	0.70	6.27	7.76	4.32	2.00	7.79	2.68

installed in each treatment to record population of alighting winged aphids.. Aphids collected in each trap were counted in 10 randomly selected squares at weekly interval and expressed as average number/week/square inch.

Results and Discussion

Disease management technique through vector control using chemical pesticides in combination with border cropping of maize was evaluated in the field against incidence of PRSV-P on popular papaya variety Red Lady (2010 and 2011) and PSRV-P tolerant line PS-3 (2012).

In case of Red Lady, percent disease incidence of PRSV-P in 2010 was least (13.56%) in the treatment consisting of maize as border crop with alternate spray of dimethoate 30 EC (0.05%) and azadirachtin 0.03 EC (4 ml l^{-1}) followed by sprays of thiamethoxam 25 WG (0.005%) and buprofenzin 25% SC (0.025%) recorded 15.02 and 20.85 percent disease incidence, respectively. All the treatments with maize as border crop produced significantly higher yields of papaya compared to control. The maximum yield (29.74 kg pl^{-1}) was observed in treatment consisting of maize as border crop followed by alternate sprays of dimethoate 30 EC (0.05%) and azadirachtin 0.03 EC (4 ml l^{-1}). Among chemicals sprays, thiamethoxam 25 WG (0.005%) produced the maximum yield in 2010 followed by buprofenzin 25% SC (0.025%) (Table 1). Disease incidence was higher in the year 2011 compared to 2010 in all the treatments and hence has produced relatively lesser yield of papaya. However all the treatments with maize as a border crop showed significantly lower disease incidence and produced higher yields of papaya during both the years (2010 and 2011). Control plots which showed higher disease incidence have produced lesser number of fruits and lower yields. Number of aphids collected in the traps in different chemical treatment plots was significantly less compared to control plots; however their number did not show significant variations among treatments except treatment of buprofenzin (0.025%) (Table 1).

All the management practices were also evaluated against PSRV-P tolerant papaya line

Table 2. Management of aphid vectors vis-à-vis PRSV incidence in PSRV (P) tolerant line of papaya Pune Selection -3 (PS-3)

Treatments	No. of alate aphids sq^{-1} inch	PRSV incidence (%)	Av. no. of fruits $plant^{-1}$	Yield (kg pl^{-1})
Thiamethoxam 25 WG(0.005%)	0.59±0.24	17.35±1.42	20.90±1.68	25.56±2.07
Imidacloprid 17.8% SL (0.01%)	0.60±0.29	21.25±0.40	23.25±1.27	30.14±0.59
Acetamaprid 20 % SP (0.005%)	0.54±0.28	16.69±1.38	28.46±2.28	35.98±2.06
Buprofenzin 25% SC (0.025%)	0.54±0.25	18.61±0.43	25.14±1.41	33.13±1.50
Dimethoate 30 EC (0.05%)	0.32±0.01	18.28±0.49	22.46±3.34	31.15±4.09
Azadirachtin 0.03 EC (4 ml l^{-1})	0.38±0.02	17.48±0.99	20.40±2.21	25.94±3.60
Border crop of maize + Alternate spray of Dimethoate 30 EC (0.05%) & Azadirachtin 0.03 EC (4 ml l^{-1})	0.30±0.04	15.180.75	27.38±0.62	34.83±1.72
Border crop of maize + Dimethoate 30 EC (0.05%)	0.11±0.13	15.14±1.19	22.47±1.39	32.57±1.39
Border crop of maize + Azadirachtin0.03 EC (4 ml l^{-1})	0.54±0.26	16.07±0.50	24.86±0.90	35.73±1.02
Control	1.80±0.17	20.76±2.37	20.32±1.85	25.17±3.45
CD @5%	0.53	3.18	5.74	7.06

PS-3 during year 2012. Disease incidence (%) in PS-3 was relatively less compared to incidence in Taiwan 786 (Red Lady) observed in previous years. As in case of Taiwan 786 (Red Lady), all the treatments with maize as border crop also showed significantly lower PSRV-P incidence compared to control in PS-3. However, among chemical pesticide sprays, only acetamaprid showed significant reduction in vector infestation resulted into less disease incidence over control (Table 2). As observed in Taiwan 786 (Red Lady), in case of PS-3 also the number of aphids in treatments was significantly less compared to control plots (Table.2).

The maximum disease incidence in control treatment plots of PS-3 was only 20 percent compared to 34-49 percent incidence observed in control plots of Taiwan 786 (Red Lady) (Table 1 and 2). Similarly higher control yield was observed in experiment with papaya line PS-3 (25.17 kg plant^{-1}) compared to the control yield (16-17 kg plant^{-1}) in the experiments with commercial variety Taiwan 786 (Red Lady).

Most of the chemical sprays reported to be ineffective in preventing PRSV-P incidence in papaya which is not a preferred host for aphid colonization. Aphids can acquire and transmit virus within seconds to few minutes through their probing activity before insecticides could kill them (Gonsalves *et al.*, 2010). In the present study, significant reduction in disease incidence was observed due to sprays of thiamethoxam and buprofenzin in case of Red Lady and acetamapridin PS-3. Thiamethoxam and acetamiprid foliar sprays are reported to be very effective against aphids (John *et al.*, 2001).

Chemicals which prevent landing of aphids on papaya due to repellent action are expected to provide protection against PRSV-P however azadirachtin application which is known insect repellent mostly (excluding 2010) did not provide any protection. The azadirachtin products were significantly less effective against aphids in head lettuce largely due to their inability to contact the insects (John *et al.*, 2001). Krishan Kumar *et al.*, (2010) did not observe any significant protection from PRSV-P in papaya due to different treatments including neem oil, mineral oil used alone or in combination with banana barrier cropping during the months of August to December. They also recorded high aphid population during these months. However, there was significant protection of papaya plants from PRSV-P incidence in treatments with maize as border crop. The difference may be due to the fact that in the present experiments papaya was planted in the month of March during which minimum population of aphid vector prevails in the region (Chavan *et al.*, 2010).

Aphid population observed in traps installed in plots with maize as borderand alternate sprays of chemicals was significantly less compared to control plots, but not significant compared to other chemical treatments. This suggests that low aphid population in border cropped plots may be due to effect of chemical sprays rather than due to maize acting as barrier. Low incidence of PSRV-P in bordered cropped plots may be due to removal of virus inoculum from aphids which might have landed initially on maize plants bordering papaya plants. Thus the maize might have served as virus sink (Bradley, 1959; Nault and Styler 1972; Sharma and Varma, 1984, Dhanju *et al.*, 1995 and Fereres 2000).

The study suggests growing of maize as border crop and alternate sprays of dimethoate30EC (0.05%) and azadirachtin 0.03 EC (4 ml l^{-1}) at fortnightly interval for reducing incidence of PRSV-Pin papaya. Use of PRSV-P tolerant line PS-3 can be incorporated in the integrated disease management approach for PRSV-P in papaya crop.

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Knowledge and Adoption of Turmeric Growers About Post Harvest Technology

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Abstract

The study revealed that, the 43.64 per cent of the turmeric growers belonged to age group 35 to 45 years, had educated up to college level (41.81%), land holding 1.01 to 2.00 ha (54.55%), with family size of 6 to 7 members (57.27%). The annual income of Rs.2,08,001 to Rs.3,53,300/- (63.64%), medium sources of information (61.82%) and medium level risk during cultivation (66.36%). Regarding knowledge level, the almost all growers had complete knowledge of drying of turmeric by spreading in single layer after two to three days, storage in gunny bags (99.09%), use of cold storage (58.18%) . Regarding adoption, almost all growers adopted drying of turmeric (100 %), storage in gunny bags (95.45%). The 90.00 per cent of the turmeric growers expressed their main constraints was more fluctuation in market prices, non availability of labours at the time of harvesting (81.81%), in non availability of Agricultural Research Station for turmeric crop (47.27%), timely credit facility (47.27%) and market oriented improved turmeric varieties and farm mechanization technologies (40.90%). The 97.27 per cent of them suggested, the government should declare the minimum support price, to reforms in the rules and regulations of Market Committee (91.82%), storage facility should made available (84.55%), the State Agricultural Universities, KVKs and State Department of Agriculture should made available the training facilities (81.82 54 %), the financial institutes should provide sufficient and timely credit facilities (74.55%), the ICAR, New Delhi should provide separate Agricultural Research Station for turmeric growing bowl of Maharashtra (72.72%),the State Agricultural University should provide research priority on market oriented new variety and farm mechanization (65.45 %) and the turmeric sale counter should be nearer to sample area for minimizing transport cost (54.54%).

Key words : Knowledge, adoption, constraints, suggestion, post harvest technology of turmeric

Turmeric is produced in various states of India but due to lack of post harvest technology, losses in terms of quality and quantity occur promptly. In Maharashtra, area and production of turmeric during 2010-11 was 9000 ha and 45300 million MT, respectively. Price fluctuations and weather phenomenon directly affect the production of turmeric. Mahatma Phule Krishi Vidyapeeth, Rahuri has recommended the post harvest technology of turmeric for value addition to make high profit to farmers. But it is observed that there is low level of knowledge and adoption of these recommended technology to the turmeric growers. In view of this the present study was conducted in the year 2013 with the objectives to study the socio-economic profile of turmeric growers, to assess the knowledge and adoption of post harvest technology and to study the relationship between socio economic profile with their knowledge and adoption, constraints in adoption and suggestions to overcome it.

Materials and Methods

The present study was undertaken in the tahsils having maximum area under turmeric crop *viz*., Miraj (14,476.37 ha) and Walwa (18201.96 ha) tahsils of Sangli district of Maharashtra. The three villages from each

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tahsil and 16-18 farmers from each selected village's were selected on the basis of turmeric production and area of growers. Thus, final sample consisted of 6 villages and 110 farmers from Sangli district. Primary data were collected with the help of pretested interview scheduled specially designed in local language for the purpose. Simple statistical tools like percentage, mean standard deviation and Karl pearson's correlation co-efficient were used for the analysis of data.

Results and Discussion

Socio-economic profile : It is revealed from Table 1 that, 43.64 per cent of the turmeric growers belonged to age group 36 to 45 years and 41.81 per cent had college level education. The 54.55 per cent of them had land holding 1.01 to 2.00 hectares and 57.27 per cent had medium family size of 6 to 7 members. The 63.64 per cent of the farmers had received annual income of Rs. 2,08,001 to 3,53,300/- from agriculture, while 79.09 per cent of them had medium social participation, 61.82 per cent had used medium sources of information and the 66.36 per cent turmeric growers take medium level of risk during cultivation and production of turmeric. Similar, results were also reported by Walke (2008) and Tayade (2010).

Knowledge and adoption of turmeric growers about post harvest technology : It is seen from Table 2 that, regarding knowledge the most of the turmeric growers had complete knowledge of drying of turmeric (100%), storage in gunny bags (99.09%), polishing by using drum (92.72%) and testing of boiled turmeric by hand pressing (92.72%). However, the 58.18 per cent of them had complete knowledge in storage of turmeric in cold storage, while 67.27 per cent of them had partial knowledge about scientific method of boiling. While, regarding the adoption the turmeric growers had high adoption in harvesting of the turmeric at 8-9 months (83.64%), traditional method of boiling (90.00%), drying (100%), polishing of turmeric by using drum (98.18%), grading of the turmeric (100%) and storage of turmeric in

Table 1. Socio-economic profile of turmeric growers

Characters (N= 110)	Frequency	Percentage
Age		
Young (upto to 35 years)	22	20.00
Middle (36 to 45 years)	48	43.64
Old (46 and above years)	40	36.36
Education		
Illiterate	05	04.50
Primary (up to IVth std)	01	00.99
Secondary (8th to Xth std)	22	20.00
Higher (XIth to XIIth std)	36	32.70
College (Above XIIth std)	46	41.81
Land holding		
Upto 1.00 ha	16	14.55
1.01 to 2.00ha	60	54.55
2.01 to 4.00 ha	21	19.09
4.01 and above	13	11.81
Family size		
Upto 5 member	02	1.82
6 to 7 member	63	57.27
8 and above member	45	40.91
Annual income		
Upto Rs 2,08000/-	20	18.18
Rs.2,08001 to 3,53,300 /-	70	63.64
Rs.3,53,301 and above	20	18.18
Social participation		
Low (upto 2)	08	07.27
Medium (3 to 5)	87	79.09
High (6 and above)	15	13.64
Sources of information		
Low (upto 17)	19	17.27
Medium (18 to 37)	66	61.82
High (38 and above)	23	20.91
Risk orientation		
Low (upto 7)	25	22.73
Medium (8 to 11)	73	66.36
High (12 and above)	12	10.91

gunny bags (95.25%). Adoption to the medium extent in testing of boiled turmeric by use of sticks (41.82%) and use of ware houses for storage (24.55%). Turmeric grower had low adoption in scientific method of boiling (07.27%) and use of cold storage for storage of turmeric (04.55%). The findings of present study are similar to those of Singh and Kaur 2004, Kolte (2002) and Kubade *et al.,* (1999).

Relationship between the socio-economic profile of turmeric growers with their knowledge and adoption : It was revealed from Table 3 that, the non-significant relationship between age and family size of the turmeric growers with their knowledge and adoption . A highly significant relationship was observed between education, land holding, annual income, social participation, sources of information and risk orientation with their knowledge and adoption about post harvest technology followed by turmeric growers. Similar results were reported by Kadam (2008).

Constraints faced by turmeric growers in adoption of post harvest technology : It is revealed from Table 4 that, the 90.00 per cent of the turmeric growers expressed their main constraints was more fluctuation in market prices, while 81.81 per cent of them expressed non availability of labours at the time of harvesting, the less technical knowledge about seed treatment (76.36%), lack of complete knowledge about diseases

Table 2. Distribution of turmeric growers according to their knowledge and adoption of post harvest technology

Recommended post harvest technology	Knowledge and adoption of turmeric growers (N=110)					
	Complete knowledge	Partial knowledge	No knowledge	High adoption	Medium adoption	Low adoption
Harvesting						
Harvesting at 8-9 months	107 (97.27)	03 (02.73)	00 (00.00)	92 (83.64)	15 (13.63)	03 (02.73)
Yield of dried turmeric (60-75 q ha-1)	104 (94.55)	04 (03.64)	02 (01.81)	83 (75.45)	20 (18.18)	07 (06.36)
Post harvest technology						
A. Boiling						
Traditional method	110 (100.00)	00 (00.00)	00 (00.00)	99 (90.00)	11 (10.00)	00 (00.00)
Scientific method	10 (09.09)	74 (67.27)	26 (23.63)	08 (07.27)	55 (50.00)	47 (42.73)
B. Testing						
Sticks (piercing)	98 (89.09)	07 (06.36)	05 (04.54)	46 (41.82)	52 (47.27)	12 (10.90)
Hand pressing	102 (92.72)	08 (07.27)	00 (00.00)	99 (90.00)	09 (08.18)	02 (01.82)
C. Drying						
Spreading in single layer (2-3 days)	110 (100.00)	00 (00.00)	00 (00.00)	110 (100.00)	00 (00.00)	00 (00.00)
Collection of dried turmeric (9-10 days)	107 (97.27)	03 (02.73)	00 (00.00)	108 (98.18)	02 (01.82)	00 (00.00)
D. Polishing						
1. Using drum	102 (92.72)	07 (06.36)	01 (00.90)	105 (95.45)	04 (03.64)	01 (00.91)
2. Using turmeric powder or solution	75 (68.18)	27 (24.54)	08 (07.27)	04 (03.64)	97 (88.18)	09 (08.18)
E. Grading						
According to size	107 (97.27)	01 (00.90)	02 (01.81)	110 (100.00)	00 (00.00)	00 (00.00)
Separating mother rhizomes	87 (79.09)	23 (20.90)	00 (00.00)	82 (75.55)	15 (13.64)	13 (11.82)
F. Storage						
Gunny bags	109 (99.09)	01 (00.90)	00 (00.00)	105 (95.45)	05 (04.55)	00 (00.00)
Iron pev's	105 (95.45)	04 (03.63)	01 (00.90)	15 (13.64)	70 (63.64)	25 (22.73)
Ware houses	98 (89.09)	08 (07.27)	04 (03.63)	27 (24.55)	65 (59.02)	18 (16.37)
Cold storage	64 (58.18)	42 (38.18)	04 (03.63)	05 (04.55)	73 (66.36)	32 (29.09)
G. Plant protection measures	89 (80.90)	17 (15.45)	04 (03.63)	71 (64.55)	24 (21.82)	15 (13.64

Table 3. Relationship between the socio-economic profile of turmeric growers with their knowledge and adoption

Socio-economic profile	r' value knowledge	r' value adoption
Age	-0.113 NS	0.035 NS
Education	0.189 *	0.188 *
Land holding	0.485**	0.414 **
Family size	0.087 NS	0.054 NS
Annual income	0.525**	0.331**
Social Participation	0.571**	0.268**
Information sources	0.660**	0.423**
Risk orientation	0.643**	0.491**

D.F. = 110, NS = Non-Significant, * = Significant at 5%, ** = Significant at 1%

management (72.72%), higher charges by market commission agents (70.00%), lack of complete knowledge about pest management (69.09%), non availability of Agricultural Research Station for Turmeric crop (47.27%), non availability of timely credit facility (47.27%) and non availability of market oriented improved turmeric varieties and farm mechanization technologies (40.90%).

Suggestions made by the turmeric growers to overcome the constraints : It is observed from Table 5 that, the 97.27 per cent of the turmeric growers suggested the Government should declare the minimum support price for turmeric to minimize the price fluctuation. While, the 91.82 per cent of them suggested to reforms in the rules and regulations of market committee to control the market middlemen and commission agents, storage facility should made available to the turmeric growers by the Government (84.55 54%), the State Agricultural Universities, KVKs and State Department of Agriculture should made available the training facilities to the turmeric growers (81.82 54%), the financial institutes should provide sufficient and timely credit facilities to the turmeric growers (74.55 54%), the ICAR, New Delhi should provide separate Agricultural Research Station for turmeric growing bowl of Maharashtra (72.72%), the State Agricultural University should provide research priority on market oriented new variety and farm mechanization (65.45 54%) and the turmeric sale counter should be nearer to sample area for minimizing transport cost (54.54%).

The study concluded that, maximum turmeric growers were directly made any processing product. Also there is constraints in various agencies which were not directly related to turmeric growers. The concern line departments like State Department of

Table 4. Constraints faced in adoption of post harvest technology

Constraints	Turmeric growers (N=110)	
	Freq-uency	Percen-tage
More fluctuation in market prices	99	90.00
Non availability of labours at the time of harvesting	90	81.81
Less technical knowledge about seed treatment	84	76.36
Lack of complete knowledge about diseases management	80	72.72
Higher charges by market commission agents	77	70.00
Lack of complete knowledge about pest management	76	69.09
Non availability of Agricultural Research Station for turmeric crop	52	47.27
Non availability of timely credit facility	52	47.27
Non availability of market oriented improved turmeric varieties and farm mechanization technologies	45	40.90

Table 5. Suggestions made by the turmeric growers to overcome the constraints

Suggestions	Turmeric growers (N=110)	
	Frequency	Percentage
Government should declare the minimum support price for turmeric	107	97.27
Reforms in the rules and regulations of market committee to control the market middlemen and commission agents	101	91.82
Storage facility should made available to the turmeric growers by the Government.	93	84.55
The State Agricultural Universities, KVKs and State Department of Agriculture should made available the training facilities to the turmeric growers	90	81.82
The financial institutes should provide sufficient and timely credit facilities to the turmeric growers	82	74.55
The ICAR, New Delhi should provide separate Agricultural Research Station for turmeric growing bowl of Maharashtra	80	72.72
The State Agricultural University should provide research priority on market oriented new variety and farm mechanization	72	65.45
The turmeric sale counter should be nearer to sample area for minimizing transport cost	60	54.54

Agriculture, Maharashtra State Agricultural Marketing Federation etc. should provide knowledge through trainings to the turmeric growers about package of practices for processing which encourage the stability in prices. The Agricultural Universities, various agricultural research stations and agricultural department of state government should provide information and knowledge to the turmeric growers about proper time of harvesting, proper post harvest technologies, pest control etc. which will help to prevent losses and also to obtain higher market prices. The Agricultural Universities should give emphasis on practical training of turmeric growers on post harvest technology *viz.*, boiling process, grading and processing of turmeric into different products. The extension workers should use advanced communication medias for diffusion of innovations in the field of horticulture, especially about turmeric growers for convincing them about the adoption of post harvest technology of turmeric. This should necessarily include the organization of demonstrations, rallies and exhibitions. The federation as well as the government should look into development of processing unit for producing processed product of turmeric *viz.*, turmeric powder, medicine, cosmetics. This will help the turmeric growers to tide over the market glut conditions and also the helpful to consumers. The government should provide subsidy and encouragement to the entrepreneurs for establishing such processing units in the turmeric growing area.

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Cashew Processing in South Konkan Region - An Economic Analysis

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Abstract

A total of 50 unit were selected randomly from Ratnagiri and Sindhudurg district of South Konkan region (M.S.). Selected unit were categories into Home scale-26 (HSU), small and medium-14 (SMSU) and large units-10 (LSU). Most of the units were found to be processed cashew on steam roasting method. The proportion of fixed capital was comparatively quite lower than the working capital requirement. Out of total working capital investment share of raw material was the highest in all cashew processing units. The per factory total cost incurred by processing units was varied directly with size of unit. In all the units, B:C. ratio was more than one and net added value was varied between 38 per cent to 62 per cent. The capacity utilization in all units was less than installed capacity. The capital efficiency was highest in LSU followed by HSU and SMSU. This indicated that large scale units were most profitable.

Key words : Processing, net added value, home scale unit, cost and returns, LSU, HSU, SMSU

Agro-processing units help to increase agricultural prosperity, agricultural production, agricultural income and absorb surplus labour force in the rural area. The wonder nut 'Cashew means cash you!' is the slogan of cashew. It is a dollar-earning crop of our country as Indian cashew is highly preferred in the export market. Cashewnut is one of the agricultural produces of commercial importance. Processing is an important marketing function in the present market of agricultural produces. A little more than a century ago, it was relatively unimportant function. Large proportion of farm produce was sold in an unprocessed form and great deal of the processing was done by consumers themselves. Processing converts the raw material into the form in which it can easily be consumed by the consumers. Essentially processing is concerned with value addition to product by changing its form mainly for horticultural products coming from the field. Thus, apart from its economical significance, the cashewnut has potential to play a leading role in the social and financial upliftment of rural poor.

The area under cashew plantation is increased significantly from implementation of EGS (Employment Generation Scheme) linked with 'Horticulture Plantation Scheme' (1990-91 onwards). Now a days most of the plantation is more than 10 years old and cashewnut graph of production is showing increasing trend.

Materials and Methods

South Konkan region was purposively selected for the present investigation because most of the cashew processing units were situated in this region. A list of cashew processing unit operating at household level was obtained from sub-divisional office and D.I.C. A total of 50 units were selected randomly from the region. 25 units each from the Sindhudurg district and Ratnagiri district

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were selected and they were categories into home scale (26), small and medium (14) and large units (10). The data were collected by survey method through personal interviews with the processors involved in the study. The information was collected regarding investment pattern and capacity utilization in processing unit, cost and returns etc. The constraints in the processing of cashew kernels were also studied.The collected data were analyzed for arriving of useful conclusions. The data were analyzed by tabular method. Simple statistical tools such as arithmetic averages, frequency distribution, percentages and ratios were used.

To know the performance of business, cost of processing and break-even point of production analysis was also carried out.

Break even point of production

The formula used for estimation of break-even point of production is given below.

$$Q = \frac{FC}{P - VC}$$

Where,

Q = Quantity of break-even point production in qtls, FC = Total annual fixed cost of processing units in Rs., P = Selling price per unit of cashew kernel in Rs., VC = Variable cost per unit of cashew kernel in Rs.

Capital efficiency

1) Rate of capital turnover:

Rate of capital turnover = (Gross income / Average capital investment) x 100

2) Rate of return on capital investment:

Rate of return on capital investment = (Returns on investment/Average capital investment) x 100

Where, Returns on investment = Gross income minus total cost except interest on capital

3) Capital investment per hundred rupees of gross income:

Capital investment per hundred rupees of gross income = (Total capital investment/ Gross income) x 100

4) Capital per worker :

Capital per worker = Total capital investment/Number of workers

5) Input output ratio:

Input out ratio = Gross income/Total expenses

6) Per unit cost of processing:

Per unit cost of processing = Total cost of processing/Total quantity processed

Table 1. Classification of cashew processing units

Group	Capacity of boiler (Q day^{-1})	No. of units (N=50)	Average working season (day)	Quantity processed per season (Q.)	Quantity of nuts processed per unit per day (Q.)
Home scale (HSU)	up to 1	26 (52.00)	163	101.34	0.62
Small/Medium Scale (SMSU)	1.01 to 6.0	14 (28.00)	224	1021.44	4.56
Large Scale (LSU)	6.01 and above	10 (20.00)	310	4206.7	13.57

Figures in the parentheses indicate percentage to total sample

Results and Discussion

The success of any enterprise in the business of agriculture can be judged on the basis of economic benefits accrued to the entrepreneur from that particular enterprise. With the technical improvement in processing and open market situation the processors are experiencing the impact of interplay of various economic forces. It has now become necessary for them to look upon business as a commercial proposition. This can not be achieved unless the processors are conscious about various aspects of processing and marketing such as capacity utilization, investment pattern, cost, returns, working efficiency, marketing cost, market margin, price spread etc.

Accordingly, 50 cashew processing units at different level were selected. The quantity processed, employment created and capital invested in the units were the different aspects of measuring the size of factory. Similarly, the size of units also depends on working season. In the present study, capacity of boiler per day was taken as basis for classification of selected cashew processing units. The selected cashew processing units were classified on the basis of capacity of boiler per day and are presented in Table 1. They were categorized as Home scale (up to 1q.), small (1.01 to 6.00 q.) and large (6.01 q and above.). In HSU group 26 cashew processing units. 14 units were in SMSU group and 10 units were in LSU. The average working season was 163 days, 224 days and 310 days in HSU, SMSU and LSU group, respectively. Per season quantity of nuts processed varied from 101.34 q in HSU to 4206.7 q in LSU group, SMSU group processed 1021.44 q. The per day quantity of nuts processed by the unit in HSU, SMSU and LSU groups was 0.62 q, 4.56 q, and 13.57 q, respectively. Obviously, per season and per day quantity of nuts processed was more in large group.

Table 2. General information of cashew processing unit

Particulars	Size of the processing unit		
	HSU (N=26)	SMSU (N=14)	LSU (N=10)
Av. establishment period (years)	7.43	9.21	9.98
Ownership			
a) Individual	26 (100.00)	9 (64.26)	6 (60.00)
b) Partnership	-	3 (21.43)	3 (30.00)
c) Co-operative	-	1 (7.14)	1 (10.00)
d) Bachat Gat	-	1 (7.14)	-
Method of processing			
a) Drum roasting	3 (11.54)	1 (7.14)	-
b) Steam roasting	23 (88.46)	14 (100.00)	10 (100.00)
c) Both		1 (7.14)	
Training in processing			
i) Yes	24 (92.31)	12 (85.71)	10 (100.00)
ii) No	02 (7.69)	2 (14.29)	-
b) Training period Av. (days)	6.32	8.15	15.86
Sponsoring agency			
1) Own	2 (7.69)	2 (14.29)	2 (20.00)
2) Government	20 (76.92)	7 (50.00)	5 (50.00)
3) NGO	4 (15.38)	4 (28.57)	2 (20.00)
4) Other	-	1 (7.14)	1 (10.00)

Figures in the parentheses indicates percentage to total sample units

Average establishment period was found to be vary with 7.43 years in HSU to 9.98 years in LSU. Majority of processors (82%) had owned the unit individually whereas 12.00 per cent factories were in partnerships, 4 per cent units were in co-operative while 2 per cent unit were run by the Self Help Group (SHG).

Drum roasting and steam roasting are the two methods of processing. Except six, all the unit were processing by the steam roasting (92.00 per cent). Monthly of the respondent were taken training of cashew nut processing. The agencies were found to be Government NGO and others. Out of the total sample respondents 46 processors has undergone processing training while 14 processors were untrained. In HSU group 92 per cent processors were trained and 7.69 per cent were untrained. In SMSU 15 (85.71%) respondents had undergone training and 2

Table 3. Working season, employment and wage rates in cashew processing units

Particulars	Size of the processing unit		
	HSU (N=26)	**SMSU (N=14)**	**LSU (N=10)**
Average working days per CPU	163	224	310
Total quantity processed per year per CPU (Qtls.)	101.34	1021.44	4206.7
Per day average quantity processed (Kg.)	62.17	456.00	1357.00
Per day per unit employment			
I) Male a) Skilled	0.67 (25.09)	1.53 (12.08)	4.61(9.69)
b) Unskilled	0.86 (32.21)	2.69 (21.25)	6.23 (13.09)
II) Female a) Skilled	0.21(7.86)	2.28 (18.01)	8.39 (17.63)
b) Unskilled	0.93 (34.84)	6.16 (48.66)	28.36 (59.59)
Total	2.67 (100.00)	12.66 (100.00)	47.59 (100.00)
Wage rate day^{-1} (Rs.)			
I) Male a) Skilled	145.17	148.12	147.82
b) Unskilled	120.68	124.16	122.33
II) Female a) Skilled	122.74	138.56	135.86
b) Unskilled	100.80	116.38	120.06

Figures in the parentheses indicate percentage to sample units

Table 4. Capital investment pattern in cashew processing units (Figures in Lakhs)

Particulars of investment	Size of the processing unit		
	HSU (N=26)	**SMSU (N=14)**	**LSU (N=10)**
Fixed capital			
1. Land	1.58 (12.14)	5.44 (5.52)	26.50 (6.47)
2. Building	1.53 (11.76)	6.25 (6.34)	20.34 (4.96)
3. Machinery and equipment	1.17 (8.99)	4.97 (5.04)	21.02 (5.13)
4. Infrastructural facilities	0.14 (1.08)	1.42 (1.44)	3.60 (0.88)
5. Other fixtures	0.40 (3.07)	1.85 (1.88)	2.45 (0.60)
Sub Total (A)	4.82 (37.06)	19.93 (20.21)	73.91(18.04)
Working capital			
1. Raw nuts	7.31(56.19)	74.21(75.25)	311.97 (76.15)
2. Labour charges	0.52 (3.99)	3.57 (3.62)	18.56 (4.53)
3. Packaging material	0.28 (2.15)	0.60 (0.61)	3.29 (0.80)
4. Rent/Taxes	0.012 (0.09)	0.06 (0.06)	0.32 (0.08)
5. Fuel/Electricity/Telephone charges	0.054 (0.41)	0.20 (0.20)	1.45 (0.35)
6. Other	0.012 (0.09)	0.04 (0.04)	0.15 (0.04)
Sub Total (B)	8.188 (62.94)	78.68 (79.79)	335.74 (81.96)
Total (A+B)	13.01 (100.00)	98.61 (100.00)	409.65(100.00)

Figures in the parentheses indicate percentages to total

(14.25%) respondents were not trained. In large group all the respondents were trained.

Providing employment opportunities to rural people is one of the objectives of starting agro-based industries. Therefore, employment created by cashew processing units and the wage rates paid to the workers were studied and the information regarding employment, wage rates and working season is presented in Table 3.

On an average, working season ranged between 163 days to 310 days, in HSU and LSU, respectively. The per day per unit employment worked out to 2.67 persons in HSU group, Which consisted of 0.67 skilled and 0.86 unskilled male, 0.21 skilled and 0.93 unskilled female. In SMSU group, employment per day per unit worked out to 12.66 persons, which consisted of 1.53 skilled and 2.69 unskilled male, 2.28 skilled and 6.16 unskilled female. Per day per unit employment in large group was observed to be 47.59 persons, which consisted of 4.61 skilled and 6.23 unskilled male, 8.39 skilled and 28.36 unskilled female. Among different groups, per day per unit employment was found to be maximum in large group. This is because of the fact that in large group quantity of cashewnut processed was more and hence utilization of laborers was higher than other groups. This indicated that out of total labour employment, nearly 73.68 per cent was female labour.

Table 5. Per quintal cost and returns from cashew processing units (Figures in Rs.)

Item of cost	**Size of processing unit**		
	HSU (N=26)	**SMSU (N=14)**	**LSU (N=10)**
A. Raw nuts	7016 (77.75)	7165 (81.29)	7216 (81.78)
Processing cost Wages	529.20 (5.86)	349.44 (3.96)	441.29 (5.00)
Packing materials	65.75 (0.73)	102.35 (1.16)	101.90 (1.15)
Fuel charges	181.50 (2.01)	98.15 (1.11)	80.65 (0.91)
Electricity charges	101.06 (1.12)	120.86 (1.37)	102.65 (1.16)
Telephone charges	3.80 (0.04)	3.89 (0.04)	2.05 (0.02)
Depreciation			
a) Building	46.05 (0.51)	23.37 (0.26)	33.51 (0.38)
b) Machinery and equipment's	114.65 (1.27)	67.12 (0.76)	40.16 (0.45)
Interest on			
a) Fixed capital	196.80 (2.18)	103.24 (1.17)	78.48 (0.89)
b) Working capital	768.39 (8.51)	780.72 (8.86)	727.10 (8.24)
Sub Total	2007.2 (22.25)	1649.18 (18.71)	1607.79 (18.22)
Total	9023.20 (100.00)	8814.18 (100.00)	8823.27 (100.00)
B) Returns Quantity of kernels received (q.) *Recovery (%)	24.34	24.96	25.00
Returns from			
a) Main product	11634.52 (99.72)	13054.08 (99.71)	13200.00 (99.52)
b) By-product	32.80 (0.28)	38.32 (0.29)	63.30 (0.48)
Total	11667.32 (100.00)	13092.4 (100.00)	13263.3 (100.00)
Net Returns	2644.12	4278.22	4440.03
Cost Benefit ratio	1.29	1.48	1.50
BEP (q.)	59.39	239.79	888.18

Figures in the parentheses indicate percentages to total

The wage rates paid to skilled and unskilled male and female laborers are different. Average wage rates paid to skilled male laborers in all the categories were almost same with small fluctuations (Rs. 145 to Rs. 148). In HSU wages paid to unskilled male laborers was Rs. 121 per day, wage rates paid to skilled female labourers was 123 and for unskilled female labourers was Rs. 100. In SMSU group wages paid to unskilled male labourers was Rs. 124.00 per day, wage rate paid to skilled and unskilled female labourers was Rs. 139 and Rs. 116 per day, respectively. In large group Rs. 122 per day paid to unskilled male labourers, wage rate paid to skilled and unskilled female laborers was Rs. 136 and Rs. 120 per day, respectively.

To start any business certain amount of capital is required to be invested. The amount invested in processing units is classified into two categories a) Fixed capital includes investment in land, buildings, machinery and equipments, infrastructure facilities and other fixtures and b) Working capital includes expenses on purchase of raw material, labour and other miscellaneous items. The information about capital investment by different categories of cashew processing units is given in Table 4.

In HSU, SMSU and LSU group total capital investment was Rs. 13.01 lakhs, Rs. 98.61 lakhs, Rs. 409.65 lakhs, respectively, out of which total fixed capital investment was Rs. 4.82 lakhs, Rs. 19.93 lakhs Rs. 73.92 lakhs respectively and Rs. 8.19 lakhs, Rs. 78.68 lakhs, Rs. 335.74 lakhs was working capital, respectively. In HSU, out of total investment, share of raw nuts was the highest 7.31 lakh (56.19%), followed by Land (12.14%) and building (11.76%), Machinery and equipment and labour cost other fixture labour by 0.52 lakh. Similar trend was observed in SMSU and LSU.

This indicated that in cashew processing, proportion of fixed capital was comparatively lower than the working capital. Among the different categories of units, total capital investment was highest Rs. 409.65 lakhs in large group and the lowest Rs. 13.01 lakhs in HSU group. Same trend was observed both in fixed and working capital investment. Out of total working capital investment, share of raw material was the highest in all the groups of unit. This has influenced economics of scale.

Cost of processing : The cost of processing is the most important factor on which the success or failure of the unit depends. More the cost of processing, lesser is the margin to the unit and vice-versa. Per quintal cost of processing incurred by the units is presented in Table 5. Wages, packing material, fuel charges, electricity charges, telephone charges, depreciation on building, machinery

Table 6. Proportion of kernels and by product from cashew processing units

Items of cost	Size of the processing unit		
	HSU (N=26)	SMSU (N=14)	LSU (N=10)
Main product Kernels	24.34	24.96	25.00
By productShells	70.00	69.99	70.01
Testa (Husk)	1.99	2.94	2.99
Rejection	3.67	2.10	2.00
Total	100.00	100	100

Table 7. Cost and return structure of cashew processing units (Rs. in lakhs)

Particulars	Size of the processing unit		
	HSU (N=26)	SMSU (N=14)	LSU (N=10)
Sale realization	12.90	133.33	555.28
Cost of Processing	10.04	90.03	371.11
Net returns	2.86	43.30	184.17
Benefit cost ratio	1.29	1.48	1.50

and equipment, interest on fixed and operating capital are the items of cost of processing. It is observed from the Table 5 that, the cost of processing per quintal of cashewnut was Rs. 2007.2 in HSU group, Rs. 1649.18 in SMSU group and Rs. 1607.79 in large group. This revealed that, processing was costly in the units of smaller capacities. The major cost was on raw nuts and wages. Per quintal quantity of kernels received was near about same in all sizes of processing units 0.25 qtls. The value received for per quintal kernels was Rs. 11635, Rs. 13054, and Rs. 13200, respectively. Returns from by-product at HSU, SMSU and LSU units were Rs. 32.80, Rs. 38.32, and Rs. 63.30, respectively. The quintal^{-1} gross returns worked out to be Rs. 11667 in HSU group and Rs. 13092 in SMSU group and Rs. 13263 in LSU group. The net returns worked out to Rs. 2644 in HSU group, Rs. 4278 in SMSU group and Rs. 4440 in large group, respectively.

Profitability in processing of cashew nut is presented in Table 6. The per factory total cost incurred by the processing units was varied directly with size of unit was more in LSU units (Rs. 371.11) SMSU (Rs. 90.03 lakh) and HSU processing units (Rs. 10.04). It was more in large units (Rs. 184 lakhs) than SMSU (Rs. 43.30 lakh) and HSU units (Rs. 2.86 lakhs). It was observed that cashewnut processing units realized the profit to the tune of benefit cost ratio various from 1.29 to 1.50, large processing unit realized higher profit, benefit cost ratio (Rs 1.50) as compared to SMSU benefit cost ratio (Rs.1.48) and HSU processing units benefit cost ratio (Rs.1.29). Dalvi *et al*., (1992) in Maharashtra and Amita Naik (2001) in Goa estimated similar cost and returns for cashew processing units. This is attributed to the scale of economics more favourably in large units.

Processed product : The Kernel is the main product while cashewnut shell; testa and rejection are the by-products in cashewnut processing. The details of group wise processed products from per quintal of cashewnut processing given in Table 6. Out turn of main product was 24.35 to 25.00 per cent in all the sizes of processing units. In HSU, SMSU, LSU processing units rejection was 3.67, 2.10, 2.00 kg, respectively. However the rejections were high in HSU processing units that were 3.67 kg and low in LSU processing units, that was 2.00 kg.

Cost and return from processing of cashew nut is presented in Table 7. It was more in LSU units (Rs. 555.28 lakhs) than SMSU (Rs. 133.33 lakhs) and HSU processing units (Rs. 12.90 lakhs). Net return was more in LSU units

Table 8. Capacity utilization of cashew processing units

Size of the processing unit	Installed capacity day^{-1} (q)	Quantity processed day^{-1} (q)	Capacity utili-zation (%)
Home Scale (HSU)	1.00	0.62	62.00
Small/Medium Scale (SMSU)	6.00	4.56	76.00
Large Scale (LSU)	15.87	13.57	85.50

Table 9. Value addition quintal^{-1} of cashewnut processed (Figures in Rs.)

Particulars	Size of the processing units		
	HSU (N=26)	SMSU (N=14)	LSU (N=10)
Sale value of kernels	11667.32	13092.40	13263.30
Purchase value of cashewnuts	7016	7165	7216
Gross value added	4651.32	5927.40	6047.3
Per quintal processing cost	2007.20	1649.18	1607.79
Net value added	2644.12	4278.22	4439.51
Added value (%)			
a) Gross	66.29	82.73	83.80
b) Net	37.69	59.71	61.52

(Rs. 184.17 lakhs) than SMSU (43.30 lakhs) and HSU processing units (Rs. 2.86 lakhs). It was observed that cashewnut processing units realized the profit to the tune of Rs. 184 lakhs in large unit. At an overall level large processing unit realized higher profit. This is attributed to the scale of economics.

The information on capacity utilization of cashew processing units is presented in Table 8. The installed capacity was lower in HSU processing units, which are 1.00 q day^{-1} as compared to other size groups of processing units. It was higher in large processing units that are 15.87 q. per day. Whereas the number of working days were minimum in HSU processing units, that is 163 days per year and maximum in large processing units with 310 days per year.

This lead to a maximum amount of annual installed capacity (4919 q) in large processing units, as compared to 1344.00 q and 163.45 q in SMSU and HSU processing units, respectively. Similarly, the annual quantity of raw nut processed was the highest in large size units that are 4206 q as compared to 1021.44 q in SMSU units and 101.34 q in small units. However, the proportion of capacity utilization by percentage was higher in larger processing units, accounting for 85.50 per cent of the installed capacity as compared to HSU and SMSU processing units, that is 76.00 per cent and 62.00 per cent, respectively. This revealed that capacity utilization was good in large size processing units. The installed capacity was high in large processing units and low in small processing units, which was directly related to the amount of fixed capital invested.

The added value in cashew processing is worked out and shown in Table 9. The per quintal gross added value is worked out by deducting cost of raw material charges from the gross value received and net value added is worked out by deducting processing cost from gross added value received. The gross added value and net added value are given in percentage terms. It is seen from the table, that the gross added value in cashewnut processing was 66.29, 82.73 and 83.80 per cent in HSU, SMSU and LSU group, respectively. Whereas, net added value in cashew processing was 37.69, 59.71 and 61.52 per cent, respectively. When the percentage of value addition by processing activity in different sizes of processing unit was considered it was found to be higher in LSU and SMSU units 83.80 per cent and 82.73 per cent, respectively. This may be because of higher sale value of cashew kernel and low purchase value of cashewnuts obtained by big unit than HSU. Balsubramanium (2002) in Dakshin Karnataka for cashew and Anantram Verma for Gur in Indore (MP) observed similar result.

It is seen from the capital investment analysis that lakhs of rupees are required to be invested to start the business of cashew processing. To keep the business in profit, available capital should be utilized efficiently. In view of this, capital efficiency in cashew processing was studied (Table 10). The measures of capital efficiency studied were rate of capital turnover, returns on investment,

Table 10. Measures of capital efficiency in cashew processing

Measure of efficiency	Size of processing units		
	HSU (N=26)	**SMSU (N=14)**	**LSU (N=10)**
Rate of capital turnover (%)	109.68	110.37	145.70
Return on capital investment (%)	30.00	26.71	51.70
Capital per hundred rupee of gross income (Rs.)	91.18	90.61	68.63
Capital per worker (Rs. in lakhs)	0.79	0.96	0.99
Input output ratio	1:1.29	1:1.48	1:1.50

capital per hundred rupees of gross income, capital per worker and input output ratio. The data presented in Table 10 indicated that the rate of capital turnover and returns on capital investment were the highest in large units and in medium units, as compared to small units. The rate of capital turnover in LSU units was 145.70 per cent, 110.37 per cent in SMSU, 109.68 per cent in HSU. This indicated that invested capital was most efficiently used in large units, followed by medium units, least being in small units. Capital per hundred rupees of gross income was maximum in HSU units Rs. 91.18 and minimum in LSU units (Rs. 68.63). It was Rs. 90.61 in SMSU units. This is again a sign of low capital efficiency in HSU units. As regards the capital per worker it was Rs. 0.79 in HSU Rs. 0.96 in SMSU units, Rs. 0.99 in LSU units. The input output ratio, it was more than unity in units. Capital efficiency was the highest in LSU unit followed by HSU and SMSU units. This indicated that large unit is most profitable followed by medium. Decreasing trend of input out put ratios in these units also supports the same. Balsubramanium (2003) for Cashew in Karnataka and Jain (1989) for arhar pulse in Madhya Pradesh concluded similar result.

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Agriculture Students Attitude Towards Entrepreneurship

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Abstract

Entrepreneurship which can be understood as the mind set and process to create and develop economic activities. In today's economic entrepreneurship is seen as vital source for economic growth and competitiveness, job creation as well as wealth creation and providing societal interest. The present study was an attempt to assess the attitude of B.Sc. (Agri.) VIIIth semester agricultural students towards entrepreneurship at College of Agriculture in Parbhani. The study was conducted with a surveying methodology by using questionnaire. Statistical population of the study consisted of 20 students of each Experiential Learning Module i) Groundnut Production Technology-Agronomy, ii) Milk and Milk Products- Dairy, iii) Mushroom Production Technology- Plant Pathology, iv) Commercial Vegetable Production-Horticulture, v) Soil Water Plant & Fertilizer Analysis Laboratory- Soil Science vi) Commercial Sericulture, thus 120 agricultural graduating students samples were selected randomly. A five point Likert scale questions was used. More than half of the respondents (51.66%) was having medium annual family income (Rs. 60001 to 2,00,000), maximum number of respondents (57.50%) had medium level social participation, with regards to gender, it was observed that more than two third (76.67%), of the respondents were male. Majority of the respondents (62.50%) had living in joint type of family. Near about thirty per cent (29.17%) of the respondent had semi medium land holding, majority of respondents (82.50%) belong to rural back ground, majority respondents (61.67%) had medium family size, (5 to 7 members), academic performance i.e. CGPA of majority (64.17%) of the respondents possessed second class. Scholarship holding by the respondent is concerned majority (55.83%) respondents got GOI scholarship. It was noticed that majority of the respondents (64.16%) were agreed that they know the techniques for findings out what the market wants. As far as the sensitization of respondents towards entrepreneurship is concern, it is observed that more than forty percent of the respondents (41.67%) have agreed and 31.66 per cent strongly agreed that they clearly followed or assisted friends who have started entrepreneur. It was delineated that majority (65.00%) and (49.17%) of the respondents strongly agreed that entrepreneurship improves individual and social growth and entrepreneurship results in employability and income generation respectively. It is observed that majority (72.50%) of the respondents had favourable attitude towards the entrepreneurship

Key words : Entrepreneurship, attitude, students, sensitization, tendencies

The role of education has been conformed as a important component in the creation and continuing development of entrepreneurial attitude. In this context students are seen as the primary resource of future entrepreneur. However there is a need to understand how to develop and nurture potential entrepreneur further while continuing to grow in entrepreneurship education, our understanding of students in respect to entrepreneurial education is still lacking.

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There are numerous interconnections between attitudes and various interrelated objects. Attitudes would measure the extent of individual values positively or negatively. Generally, the behaviour of an individual is greatly determined by his/her attitude.

Further attitude has been defined as a feeling or evaluative reaction to an idea, object or situation. It depicts how positive or negative, favourable or unfavourable a person feels towards that particular idea, object, or situation in question. Accordingly, the positive or negative attitude of the students towards entrepreneurial activities is a function of his / her held beliefs on those attributes associated with entrepreneurship. In other words for entrepreneurship program to be implemented successfully, there is a need to determine the attributes associated with entrepreneurship and the attitude towards them.

Materials and Methods

The present study was an attempt to assess the attitude of B.Sc. (Agri.) IVth year agricultural students towards entrepreneurship at College of Agriculture, Parbhani. The study was conducted by surveying method by using questionnaire. Statistical population of the study consisted of 20 students of each Experiential Learning Module i) Ground nut Production Technology-Agronomy, ii) Milk and Milk Products- Dairy, iii) Mushroom Production Technology- Plant Pathology, iv) Commercial Vegetable Production-Horticulture, v) Soil Water Plant and Fertilizer Analysis Laboratory-Soil Science vi) Commercial Sericulture, thus 120 agricultural graduating students samples were selected randomly.

Data gathering tool was a questionnaire a paper based survey was used in order to allow the survey to achieve high coverage as the questionnaires could be given directly to students and collected at the same time, which was structured in two parts. The first part was related to personal characteristics such as gender, annual family income, social participation, family type, land holding, family size, family background, academic performance and scholarship. In the second part, as the most important section of the questionnaire. In particular, the research question for this study included *viz.*, i) Personal entrepreneurship capability, ii) Sensitization of respondents

Table 1. The profile of the respondents

Characteristics	**Respondents (N=120)**	
	Frequ-ency	**Per cent**
Annual family income (Rs.)		
Low (up to Rs. 60,000)	32	26.67
Medium (60,001 to 2,00,000)	62	51.66
High (above 2,00,000)	26	21.67
Social participation (Score)		
Low (up to 2)	38	31.67
Medium (3 to 5)	69	57.50
High (6 & above)	13	10.83
Gender		
Male	92	76.67
Female	28	23.33
Family type		
Joint	75	62.50
Nuclear	45	37.50
Land holding (ha.)		
Landless	16	13.33
Marginal(up to 01 ha.)	08	6.67
Small (1.01 to 02 ha.)	25	20.83
Semi-medium (2.01 to 4 ha.)	35	29.17
Medium (4.01 to 6 ha.)	17	14.17
Big (above 6.1 ha.)	19	15.83
Family background		
Rural	99	82.50
Urban	21	17.50
Family size		
Small (up to 4 members)	26	21.67
Medium (5 to 7 members)	74	61.67
Big (7 and above members)	20	16.66
Academic Performance (CGPA)		
First with distinction (Above 8.50)	00	00.00
First (7.50 to 8.49)	43	35.83
Second (6.00 to 7.49)	77	64.17
Pass (5.50 to 5.99)	00	00.00
Scholarship		
GOI	67	55.83
Free ship	06	5.00
Other (NTS)	11	9.17

towards Entrepreneurship, iii) Interest in studying Entrepreneurial concepts and iv) Tendencies for becoming self employed v/s being an employee.

A five point Likert scale questions (Strongly Agree (SA), Agree (A), Undecided (UD), Disagree (DA), and Strongly Disagree (SDA)) was used by above four sub head questions. Finally, with regard to positive response coding was done like Strongly Agree-5, Agree-4, Undecided-3, Disagree-2, and Strongly Disagree-1 or for negative questions reverse coded. The data were subjected to statistical analysis with the help of frequency, percentage, mean, and standard deviation and co-efficient of correlation.

Results and Discussion

The data with regards to profile of the respondents are presented in Table 1. More than half of the respondents (51.66%) was medium (Rs. 60001 to 2,00,000) annual family income, while 26.67 per cent and 21.67 per cent respondents were found in low (Up to Rs. 60,000) and high (above Rs. 2,00,000) annual family income category respectively.

Table 2. Personal entrepreneurship capability

Statements	Response				
	SA	A	UD	DA	SDA
I know techniques for finding out what the market Demands	27 (22.5)	77 (64.16)	08 (06.66)	05 (04.16)	03 (02.50)
I understand the type of issues that confront (face to face) an entrepreneur in taking an idea to market	30 (25.00)	70 (58.34)	14 (11.67)	06 (05.00)	-
I can create a business plan and a business concept	41 (34.17)	58 (40.33)	14 (11.67)	07 (05.83)	-
I know how to legally finance a new business concept	11 (09.17)	66 (55.00)	29 (24.17)	09 (07.50)	05 (04.16)

Table 3. Sensitizations of respondents towards entrepreneurship

Statements	Response				
	SA	A	UD	DA	SDA
I regularly read books / articles about entrepreneurship.	31 (25.83)	59 (49.16)	23 (19.16)	07 (05.83)	-
I participate regularly in conferences / lectures/ workshops on entrepreneurship	33 (27.50)	50 (41.67)	18 (15.00)	15 (12.50)	04 (03.33)
I have been a freelancer or self employed	38 31.67	46 38.33	17 14.17	09 07.50	10 08.33
I have closely followed or assisted family members who have started enterprise.	30 (25.00)	53 (44.16)	19 (15.84)	14 (11.66)	04 (03.34)
I have closely followed or assisted friends or acquaintances who have started enterprise.	32 (26.66)	50 (41.67)	22 (18.33)	11 (09.17)	05 (04.17)
One should not start a business when there is a risk it might fail.	19 (15.84)	36 (30.00)	16 (13.33)	31 (25.83)	18 (15.00)
Entrepreneurship has no scope in India	05 (04.16)	02 (01.66)	05 (04.16)	30 (25.00)	78 (65.00)

Maximum number of respondents (57.50%) had medium level social participation, while 31.67 per cent and 10.83 per cent respondents had low and high social participation, respectively. With regards to gender, it was observed that more than two third (76.67%), of the respondents were male and (23.33%) respondents were female.

Majority of the respondents (62.50%) was living in joint type of family while 37.50 per cent of them belongs to nuclear family.

Near about thirty per cent (29.17%) of the respondent had semi medium land holding, followed by small land holding (20.83%), big land holding (15.83%) while 14.17 per cent were medium and 13.33 per cent landless, whereas 6.67 per cent of the respondents were marginal land holder.

Large majority of respondents (82.50%) had belonged to rural back ground, while 17.50 per cent of them had urban background. Majority respondents (61.67%) had medium family size, (5 to 7 members) while 21.67 per cent and 16.66 per cent of the respondents had small (Upto 4 members) and big family size (more than 7 members), respectively. Academic performance (CGPA) of majority (64.17%) of the respondents possessed second class while 35.83 per cent respondents had first class, whereas none of the respondents was found pass class and first class with distinction.

As far as scholarship holding by the respondent is concerned majority (55.83%) respondents reported that they got GOI scholarship, while 9.17 per cent and 5.00 per cent respondents holding other (NTS) and freeship respectively.

The data regarding entrepreneurship capability of the respondents were collected under four sub areas, which are presented in Table 2. It was noticed from Table 2 that majority of the respondents (64.16%) were agreed that they know the techniques for findings out what the market demands and more than fifty per cent of the respondents (58.34%) understand the types of issues that confront an entrepreneur in taking an idea to market, while 34.17 per cent of respondents were strongly agreed that they can create a business plan and business concept. However, 55.00 per cent respondents agreed that they

Table 4. Interest in studying entrepreneurial concepts

Statements	Response				
	SA	A	UD	DA	SDA
Starting a new enterprise from an idea	52 (43.33)	60 (50.00)	04 (03.33)	01 (00.84)	03 (02.50)
Entrepreneurship using research	33 (27.50)	67 (55.83)	10 (08.34)	09 (07.50)	01 (00.83)
Entrepreneurship within an existing enterprise.	19 (15.84)	53 (44.16)	32 (26.67)	12 (10.00)	04 (03.33)
Entrepreneurship result in economic growth	56 (46.66)	48 (40.00)	09 (07.50)	04 (03.33)	03 (02.50)
Entrepreneurship results in employability and income generation	59 (49.17)	49 (46.83)	08 (06.67)	01 (00.83)	03 (02.50)
Entrepreneurship improves individual and social growth	78 (65.00)	41 (34.16)	-	-	01 (00.83)
Entrepreneurs are rich as compare to other	39 (32.50	49 (40.83)	15 (12.50)	13 (10.83)	04 (03.33)

know how to legally finance a new business concept, 25.00 per cent respondents were strongly agreed that they understood the type of issues that confront an entrepreneur in taking an idea to market, 40.33 per cent respondents agreed that they can create a business plan and a business concept.

Over and above 24.17 per cent of respondents were undecided to know how to legally finance a new business, followed by equal percentage i.e. 11.67 per cent respondents were undecided that they can create a business plan and business concept and understand the type of issues that confront an entrepreneur in taking an idea to market.

As a as the sensitization of respondents towards entrepreneurship is concern, it is observed from Table 3 that more than forty percent of the respondents (41.67%) have agreed and 31.66 per cent strongly agreed that they clearly followed or assisted friends who have started entrepreneur. Near about half of (49.00%) respondents agreed that they regularly read books/articles about entrepreneurship. While 44.16 per cent respondents were agreed that they were closely followed or assisted family members who have started enterprise and 41.67 per cent respondents have agreed that they participate regularly in conference / lectures / workshop on entrepreneurship. However, 38.33 per cent respondents agreed that they have been a freelancer or self employed, followed by 30.00 per cent respondents agreed that one should not start a business when there is risk it might fail and meagre per cent that is 1.66 per cent

Table 5. Tendencies for becoming self employed v/s being an employee

Statements	Response				
	SA	A	UD	DA	SDA
Personal independence / Managing own time	62 (51.66)	49 (40.83)	08 (06.67)	01 (00.84)	-
Family / friends are self-employed	22 (18.34)	69 (57.50)	15 (12.50)	11 (09.16)	03 (02.50)
I have an idea that can be a business opportunity	35 (29.16)	65 (54.16)	10 (08.34)	05 (04.17)	05 (04.17)
It is a 'normal thing to do'	15 (12.50)	54 (45.00)	13 (10.84)	33 (27.50)	05 (04.16)
No need to adapt to a business environment	10 (08.33)	29 (24.17)	28 (23.33)	39 (32.50)	14 (11.67)
More interesting work	45 (37.50)	63 (52.50)	08 (06.67)	04 (03.33)	-
Possibilities for self-fulfilment	39 (32.50)	64 (53.33)	09 (07.50)	04 (03.33)	04 (03.33)
More prestigious than being an employee	37 (30.83)	56 (46.67)	14 (11.67)	09 (07.50)	04 (03.34)
Better income prospects and good family life.	47 (39.16)	57 (47.50)	08 (06.67)	05 (04.16)	03 (02.50)
Lack of attractive employment opportunities	25 (20.83)	42 (35.00)	09 (07.50)	31 (25.84)	13 (10.83)
To avoid uncertainties related to employment (e.g. being unemployed)	26 (21.66)	62 (51.66)	15 (12.50)	16 (13.33)	01 (00.83)
Having own business is the most suitable option for me	66 (55.00)	33 (27.50)	10 (08.33)	08 (06.67)	03 (02.50)

respondents agreed that entrepreneurship has no scope in India.

Moreover, 27.50 per cent respondents were strongly agreed about participation in conference / lecture / workshop on entrepreneurship followed by 25.84 per cent respondents strongly agreed that they regularly read books / articles about entrepreneurship and 25.00 per cent respondents have strongly agreed that they have closely followed or assisted friends who have started entrepreneurship while, 15.84 per cent and 4.16 per cent respondents strongly agreed that one should not start a business when there is risk it might fail and entrepreneurship has no scope in India, respectively.

While 19.16 per cent respondents undecided regarding regularly reading books / articles about entrepreneurship, followed by 18.33 per cent and 15.84 per cent respondents were undecided about having closely followed or assisted friends who have started enterprise and having closely followed or assisted family members who have started enterprise, respectively.

Regarding disagreement of respondents to the statement was concern 25.83 and 25.00 per cent respondents disagreed that one should not start a business when there is a risk it might fail and entrepreneurship has no scope in India, respectively.

It was delineated from Table 4 that majority (65.00%) and (49.17%) of the respondents were strongly agreed that entrepreneurship improves individual and social growth and entrepreneurship results in employability and income generation respectively. Where as 55.83 and 50.00 per cent respondents were agreed that entrepreneurship using research and starting a new enterprise from an idea respectively. However, 46.66 per cent of respondents were strongly agreed that entrepreneurship result in economic growth. Followed by 44.16 per cent respondents were agreed that entrepreneurship within existing enterprise. While 40.83 per cent respondents were agreed that entrepreneurs are rich as compare to other.

Moreover, 26.67 per cent respondents were undecided and 10.00 per cent respondents were disagreed that entrepreneurship within an existing enterprise. Followed by 12.50 per cent respondents were undecided and 10.83 per cent were disagreed that entrepreneur are rich as compared to other.

The data presented in Table 5 indicates that more than half of (57.50%) the respondents agreed that family / friends are self employed, followed by 55.00 per cent respondents strongly agreed that having own business is the most suitable option for them. While, 54.16 and 53.33 per cent respondents agreed that they have an idea that can be business opportunity and have possibilities for self fulfilment.

However, 52.50 per cent respondents were agreed that becoming self employed is more interesting work. While equal percentage i.e. 51.66 respondents were agreed that becoming self employed mean to avoid uncertainties related to employment and strongly agreed with becoming self-employed mean a personal independence / managing own time, followed by 47.50 and 46.67 per cent respondents agreed that becoming self employed lead better

Table 6. Overall attitude of the respondents towards entrepreneurship

Attitude	Frequency	Percentage
Unfavourable (Upto 102)	07	05.83
Favourable (103 to 127)	87	72.50
Highly favourable (128 and above)	26	21.67

Mean = 115, SD: 12

income prospects and good family life and more prestigious than being employee, respectively.

It was further observed that 32.50 and 27.50 per cent of the respondents disagreed that for becoming self employed there is no need to adopt to business environment and it is normal thing to do, respectively. 25.84 per cent respondents also disagreed that lack of attractive employment opportunities. While, 23.33 per cent respondents were undecided on there is no need to adopt two adopted to a business environment. Equal percentage of respondents 12.50 per cent was undecided about family / friends are self employed and avoid uncertainties related to employment.

The data with regard to respondent's overall attitude towards entrepreneurship are presented in Table 6. It is observed from table 6 that majority (72.50%) of the respondents had favourable attitude towards the entrepreneurship, while 21.67 and 5.83 per cent respondents had highly favourable and unfavourable attitude towards entrepreneurship respectively. It means majority of the respondents were having favourable attitude regarding entrepreneurship in future.

The respondents had predominantly the profile as they were male, having rural background, medium annual family income, social participation, semi medium land holding belonging to joint and medium size family, sought GOI scholarship and possessed second class in academic performance.

Results revealed that agricultural students have a considerable high intention to entrepreneurship; this positive attitude can assist to formation new business for agricultural students as the potential entrepreneurs.

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Rainfall Characterization for Crop Planning in Aurangabad District of Maharashtra State

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Abstract

The study was carried out at Department of Agricultural Meteorology, V.N.M.K.V., Parbhani during 2008-2009 to analyze rainfall pattern and to suggest crop and cropping pattern in different types of soil at taluka level on the basis of rainfall. The daily rainfall data for the period 30 years were collected from Collectorate, Aurangabad and Water and Land Management Institute (WALMI), Aurangabad. The annual mean rainfall (661.13 mm) was distributed as SW monsoon 86.27 percent, NE monsoon 12.92 per cent, winter season 0.38 per cent and in summer 0.43 per cent. Annual rainfall recorded lowest at Vaijapur and highest in Soygaon in Aurangabad district and it ranged from 527.5 to 777.0 mm quantitatively. Season wise distribution was observed in monsoon season 447.6 mm (Vaijapur) to 690.6 mm (Soygaon), in NE monsoon 73.4 mm (Kannad) to 101.1 mm (Gangapur), in winter 1.5 mm (Gangapur) to 4.5 mm (Soygaon). The highest rainfall observed in the month of September in most of the taluka. This special feature of rainfall distribution is observed most beneficial for *rabi* crop. Hence, taluka wise crops and cropping pattern according to soil type is suggested for Aurangabad district.

Key words : Rainfall, variability and cropping pattern

The agricultural production in India is mainly dependent on the vagaries of monsoon and would remain so in near future also. The variation in yield and unstability of production per unit area regionally is due to the rainfall observed during growth period of the crops. For crop planning, a detailed study on rainfall behavior and characterization is important. Rainfall variability, both in time and space affect the agricultural productivity and sustainability of a region. Aurangabad district is located mainly in Godavari basin and its some part towards north-west of Tapi river basin. Geographically Aurangabad district lies between 19° to 20°N latitude and 74° to 76° longitudes in the Deccan Plateau Zone. The geographical area of the district is 10, 10,700 ha. (10,107 sq. km.) and it comprising of nine (9) tahsils *viz*., Aurangabad, Khultabad, Gangapur, Kannad, Sillod, Soygaon, Paithan, Vaijapur and Phulambri having 1368 villages. The south-west monsoon is the predominant monsoon in this district. The agricultural crop productivity largely depends on the rainfall distribution and its intensity during the rainy season. The changes in cropping pattern at some extent already has made by farming community. However, it is not sufficient to mitigate the future demand of food. For this purpose the increase in productivity of Agricultural products is essential.

Materials and Methods

The historical daily 30 years (1979-2008) rainfall data of each taluka of Aurangabad district were collected from Collectorate, Aurangabad and Water and Land Management Institute (WALMI), Aurangabad for the years 1979-2008, except Phulambri taluka. The 8 years (2000-2008) rainfall data was available

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for Phulambri taluka and hence it was not undertaken for study. The data were summed up on annual, seasonal, monthly and weekly basis and subjected to statistical analysis as described by the computerized programs (software) developed by CRIDA, Hyderabad by using Markov and Marshall chain probability model.

Results and Discussion

Annual rainfall : The data revealed that rainfall was more or less stable over the years. The mean rainfall and coefficient of variation of annual rainfall in Aurangabad district is given in Table 1. The average annual rainfall of Aurangabad district is 661.13 mm. The annual rainfall recorded in all taluka of Aurangabad district ranged from 527.5 to 777.0 mm. The highest mean annual rainfall 777.0 mm with C.V. 23.7 per cent was recorded at Soygaon followed by Khultabad 769.9 mm with C.V. 28.4 per cent. The lowest mean annual rainfall was recorded 527.5 mm with C.V. 33.2 per cent at Vaijapur. Among the 30 years annual rainfall data the highest annual rainfall 1249.0 mm (1990) was recorded at Gangapur and lowest 159.0 mm (2003) was also at Gangapur. The highest C.V. of annual rainfall was 33.2 per cent in Vaijapur followed by 31.2 per cent in Gangapur. The statistical analysis for annual rainfall variability indicates that C.V. ranged from 23.7 to 33.2 per cent.

Seasonal rainfall : The mean seasonal rainfall and its variability during the seasons South-West monsoon (June to September), North-East monsoon (October to December) and Winter (January to February) are presented in Table 2. In Aurangabad district the highest average rainfall was received during SW monsoon season (570.30 mm) followed by NE monsoon season (85.42 mm). The major per cent contribution to total rainfall was 86.27 per cent by SW monsoon season and 12.92 per cent by NE monsoon season with lowest C.V. in SW monsoon season followed by NE monsoon season. As Aurangabad district is highly benefited through SW monsoon rainfall, the C.V. of the rainfall during *kharif* season is lowest. In case of SW monsoon season the highest rainfall was recorded in Soygaon (690.6 mm) and lowest in Vaijapur (447.6 mm). In case of NE monsoon season the highest rainfall was recorded in Gangapur (101.1 mm) and lowest in Kannad (73.4 mm). The highest C.V. of SW monsoon rainfall was recorded in Vaijapur (35.8%) and of NE monsoon rainfall is also in Vaijapur (117.0%). The data revealed that growing season of *kharif* crops may be extended even up to end of October month and there will be additional benefits of NE monsoon rainfall for establishment and growth of *rabi* crops. The rainfall received during winter season was very less as compared to other season. There will be slight benefit of winter season rainfall for *rabi* crop.

Monthly rainfall : The monthly mean rainfall and coefficient of variation in Aurangabad district is presented in Table 3. The data indicated that major part of the annual rainfall was concentrated during June to September i.e. South West monsoon season.

Table 1. Talukawise annual mean rainfall and variability in Aurangabad district

Taluka	Mean rainfall (mm)	C.V. (%)
Aurangabad	733.7	24.6
Khultabad	769.9	28.4
Gangapur	640.7	31.2
Kannad	590.9	30.4
Sillod	621.8	24.6
Soygaon	777.0	23.7
Paithan	627.7	28.2
Vaijapur	527.5	33.2
Average	661.13	28.03

However a good quantum of rainfall was also recorded during October. During January to May the amount of rainfall receipt was very less. The statistics presented in Table 3 indicated that variation in rainfall receipts was lower during rainy season June to September as compared to other season. The highest and lowest monthly coefficient of variation was recorded in month from January to May and June to December, respectively. The highest monthly mean rainfall was recorded in the month of August-September in major talukas of Aurangabad district. The monthly mean rainfall revealed that the rainfall in later season suggesting a tool for proper inter cropping with base crop of short duration and intercrop of long duration for making the optimal use of available rainfall.

Weekly rainfall : The average weekly rainfall in Aurangabad district at each taluka is presented in Table 4. From the agricultural management point of view a week is to be considered as an ideal period. Bhatia *et al*., (1975) also reported that data on weekly rainfall are more important than data on monthly and yearly rainfall for selection of suitable crops and their cultivars in the monsoon season under rainfed condition. The data indicated that the rainfall were concentrated during MW 22 to 43. The statistics of the weekly total rainfall indicated that low coefficient of variation was noticed during MW 23 to 43 indicating the surety of good rainfall during this period. However, coefficient of variation in remaining weeks was higher because of low rainfall. Generally higher rainfall variability found in MW 28 to 31 and 34 to 36 indicating that need for contingency crop planning. The highest rainfall was recorded in 32 MW in major talukas of Aurangabad district. The data further indicated that the rainfall receipt started from MW 23 and persists up to MW 43. The receipt of about 70 to 100 mm rainfall is supposed to be sufficient for undertaking the sowing operations. This amount of rainfall was recorded in MW 24 to 26. It is therefore advisable to prepare the land prior to this period so that sowing operation can be implemented in time. These results are in corroborate with, Sharma *et al*., (1996) who analyzed the daily rainfall data from (1969-1993) recorded at regional agriculture station, Assam for annual, seasonal, monthly and weekly periods and suggested suitable rainfed cropping system for the hill zone of Assam. However, Ramesh Kumar (2008) concluded characterization and probability of rainfall for

Table 2. Talukawise seasonal mean rainfall and its variability in Aurangabad district

Taluka	SW		NE		Winter		Total rainfall
	Mean	C.V.	Mean	C.V.	Mean	C.V.	
Aurangabad	640.8	23.3	87.8	103.5	1.9	262.8	733.7
Khultabad	681.5	32.3	84.1	108.1	1.7	332.0	769.9
Gangapur	536.3	29.7	101.1	155.2	1.5	305.6	640.7
Kannad	511.6	29.5	73.4	122.2	3.3	321.5	590.9
Sillod	529.5	28.4	84.8	92.2	3.8	270.9	621.8
Soygaon	690.6	25.7	78.7	102.8	4.5	251.5	777.0
Paithan	524.5	34.1	96.6	100.0	1.7	293.4	627.6
Vaijapur	447.6	35.8	76.9	117.0	2.0	250.0	527.5
Average rainfall (mm)	570.30	29.85	85.42	112.62	2.55	285.96	661.13
Per cent of total average rainfall (%)	86.27		12.92		0.38	100	

SW-South West monsoon, NE- North East monsoon crop planning in Chotanagpur plateau. Thereafter, Gaikwad *et al*., (1996) worked on rainfall variability analysis at Solapur using rainfall data of 29 years (1963-1992) and suggested dry seeding in early June for *kharif* crops.

Proposed cropping pattern : As the Aurangabad district comes under rainfed condition, generally only two seasons are suitable for crop production i.e. *kharif* and *rabi*. It is because of the most of the rainfall are receiving in the district during the month of August and September and especially the highest rainfall was observed during August except in Aurangabad, Paithan and Vaijapur which was in September. Where irrigation facilities are available summer crops can be taken in isolated pockets. The cropping pattern suggested for Aurangabad district mainly on the basis of rainfall and soil types is given below.

The crops and cropping pattern for Vaijapur, Gangapur, Kannad, Khultabad, Sillod taluka in Shallow soil type Bajara, Sorghum, Black gram, Green gram and Sunflower should be grown . In medium type of soil, Cotton, Bajara, Hybrid jowar, Maize and *rabi* Jowar and in deep soil type Soybean-gram, Soybean-Wheat, Soybean-*rabi* Sorghum, Maize-Wheat cropping pattern and sugarcane, tur etc. crop should be taken.

The crops and cropping pattern for Paithan, Aurangabad, Soygaon taluka are recommended as Soybean-Wheat, Bajra-Gram, Soybean-Gram, Soybean- *rabi* Sorghum, Bajra-Wheat etc. in shallow soil. Whereas, in medium type of soil Maize-Gram, Maize-Safflower, Maize-Wheat cropping pattern should be followed and deep soil cotton-wheat, cotton-gram cropping pattern as well as Sugarcane, Tur etc. crops are profitable. The peculiar observation was recorded that the most of the rainfall was received in the month of September

Table 3. Talukawise monthly mean rainfall and its variability in Aurangabad district (Data-1979-2008)

Month	Aurangabad		Khultabad		Gangapur		Kannad		Sillod		Soygaon		Paithan		Vaijapur		Mean	
	RF (mm)	C.V (%)	RF (mm)	C.V (%)	RF (mm)	C.V (%)	RF (mm)	C.V (%)	RF (mm)	C.V (%)	RF (mm)	C.V (%)	RF (mm)	C.V (%)	RF (mm)	C.V (%)	RF (mm)	C.V (%)
Jan.	1.3	318.8	1.7	329.4	0.8	359.4	3.3	324.3	3.4	296.6	2.9	269.2	1.2	369.3	1.8	255.5	2.05	315.31
Feb.	0.6	396.6	0.0	547.7	0.6	382.2	0.0	547.7	0.3	547.7	1.5	313.4	0.5	514.3	0.2	547.7	0.46	474.66
Mar.	0.6	393.8	1.0	351.0	1.5	325.2	2.4	343.7	1.9	528.5	3.1	358.8	2.1	342.7	0.3	547.7	1.61	398.92
April	0.1	547.7	0.0	0.0	0.1	547.7	0.0	0.0	0.0	0.0	0.1	547.7	0.5	547.7	0.2	547.7	0.12	342.31
May	2.4	320.8	1.6	415.3	0.3	465.2	.2	393.1	1.8	342.7	0.0	547.7	2.2	412.2	0.4	449.5	1.11	414.31
June	131.5	69.3	152.9	84.7	120.5	75.3	122.1	66.4	116.3	62.6	138.7	55.0	114.7	69.6	107.1	58.7	125.4	67.7
July	146.8	43.0	171.1	43.5	107.6	62.8	121.0	47.2	140.8	44.8	194.8	49.8	117.8	65.1	103.5	57.0	137.9	51.65
Aug.	173.9	51.4	196.9	51.2	128.5	68.5	137.3	50.6	158.0	56.3	201.8	51.0	120.8	65.4	93.2	65.6	151.3	57.5
Sept.	188.7	67.4	160.6	69.8	179.7	74.5	131.2	70.9	114.5	66.3	155.3	65.7	171.2	74.5	143.9	73.1	155.6	70.27
Oct.	67.1	113.6	57.5	127.7	74.0	143.3	49.3	121.3	63.0	91.7	58.0	100.3	69.2	111.6	54.8	129.4	61.6	117.36
Nov.	13.2	269.0	19.7	249.4	18.3	248.5	15.4	313.2	14.0	225.9	14.7	288.9	16.5	231.6	14.2	272.2	15.75	262.33
Dec.	7.6	235.1	6.9	207.0	8.9	249.8	8.7	201.7	7.8	232.2	6.0	232.8	11.0	209.2	7.9	260.0	8.1	228.47
Total	733.7		769.9		640.7		590.9		621.8		777.0		627.6		527.5		661.00	

Table 4. Talukawise weekly mean rainfall (RF) and its variability in Aurangabad district (Data-1979-2008)

Wk. no.	Aurangabad		Khultabad		Gangapur		Kannad		Sillod		Soygaon		Paithan		Vaijapur		Total RF (mm)
	RF (mm)	C.V (%)	RF (mm)	C.V (%)	RF (mm)	C.V (%)	RF (mm)	C.V (%)	RF (mm)	C.V (%)	RF (mm)	C.V (%)	RF (mm)	C.V (%)	RF (mm)	C.V (%)	
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	547.7	0.0	0.0	0.2	547.7	0.3
2	0.2	547.7	0.2	547.7	0.0	0.0	0.0	0.0	0.7	382.8	0.9	395.1	0.1	547.7	0.6	547.7	2.7
3	0.6	547.7	0.4	547.7	0.5	547.7	0.4	547.7	1.2	384.7	0.6	498.7	0.0	0.0	0.3	547.7	4
4	0.0	0.0	0.3	547.7	0.0	0.0	1.7	547.7	0.5	547.7	0.4	547.7	0.8	547.7	0.0	0.0	3.7
5	1.1	375.7	0.9	547.7	0.6	357.3	1.2	441.7	1.0	534.7	1.6	475.3	0.3	437.2	0.8	392.7	7.5
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	547.7	0.3	547.7	0.0	0.0	0.0	0.0	0.6
7	0.1	547.7	0.0	0.0	0.2	547.7	0.0	0.0	0.0	0.0	0.5	416.3	0.5	547.7	0.0	0.0	1.3
8	0.0	0.0	0.0	0.0	0.2	547.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	547.7	0.4
9	0.0	0.0	0.5	547.7	0.6	547.7	0.0	0.0	0.3	547.7	0.8	442.8	1.2	532.5	0.0	0.0	3.4
10	0.6	393.8	0.5	464.8	0.7	536.7	1.2	441.4	1.6	525.1	2.0	478.8	0.7	416.3	0.3	547.7	7.6
11	0.0	0.0	0.0	0.0	0.2	547.7	1.2	447.7	0.0	0.0	0.0	0.0	0.1	547.7	0.0	0.0	1.5
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	547.7	0.0	0.0	0.0	0.0	0.3
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	547.7	0.0	0.0	0.1
18	0.1	547.7	0.0	0.0	0.1	547.7	0.0	0.0	1.0	547.7	0.1	547.7	0.3	547.7	0.2	547.7	1.8
19	0.0	0.0	0.3	547.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	547.7	0.4
20	0.7	464.3	0.7	547.7	0.1	547.7	0.1	547.7	0.2	547.7	0.0	0.0	0.8	478.1	0.0	0.0	2.6
21	0.9	323.9	0.1	547.7	0.0	0.0	0.1	547.7	0.1	547.7	0.0	0.0	0.2	547.7	0.0	0.0	1.4
22	5.5	247.8	6.1	206.3	5.7	253.3	6.9	243.3	7.1	307.9	3.0	309.9	9.1	276.9	3.1	262.0	46.5
23	32.3	199.0	37.9	238.7	35.8	210.9	27.5	184.8	23.6	216.3	23.7	201.8	30.8	182.9	26.3	162.5	237.9
24	38.4	85.4	37.4	99.8	29.9	92.0	32.0	105.2	31.6	89.1	41.7	90.5	34.1	109.0	27.4	98.4	272.5
25	30.6	126.0	35.6	150.6	26.2	138.8	26.7	148.4	24.2	133.8	33.4	132.2	21.5	150.9	31.7	140.4	229.9
26	28.2	129.9	39.2	144.1	26.3	127.0	30.6	133.5	33.5	105.0	42.1	99.7	23.5	149.8	20.0	131.2	243.4
27	24.5	94.7	27.6	122.0	21.4	125.2	31.3	111.5	27.6	121.7	36.8	104.7	24.6	111.1	25.6	147.4	219.4
28	30.6	124.5	36.8	142.6	19.7	133.8	22.3	91.8	24.4	100.1	39.7	100.3	26.1	139.8	19.8	124.3	219.4
29	33.6	83.3	38.7	95.3	28.8	132.1	24.7	115.6	34.7	82.5	49.6	129.2	22.7	122.4	16.5	81.1	249.3
30	44.6	78.2	52.0	83.7	32.3	120.7	30.4	108.1	42.7	75.5	55.6	69.8	35.9	127.4	35.4	136.0	328.9
31	39.5	106.7	41.0	95.0	14.2	104.7	27.7	90.1	32.8	98.5	39.6	78.7	20.3	119.4	18.3	105.2	233.4
32	53.0	89.1	63.1	107.6	37.1	133.0	48.7	119.1	48.9	110.4	68.0	102.9	34.3	118.7	25.6	137.7	378.7
33	34.6	113.3	37.5	122.2	21.9	137.9	22.6	114.9	24.4	102.9	33.1	90.5	18.5	134.5	15.1	144.0	207.7
34	35.9	104.9	43.0	104.8	35.4	150.0	31.8	125.5	40.8	117.2	49.4	127.7	32.9	120.8	21.9	168.6	291.1
35	39.9	157.9	38.1	142.3	31.1	156.0	24.5	140.8	25.2	113.1	28.4	129.9	26.1	134.6	22.3	161.2	235.6
36	42.6	124.7	37.9	121.2	27.3	127.0	32.5	126.0	28.1	95.2	40.3	109.7	25.8	111.6	25.0	134.4	259.5
37	42.3	143.8	39.3	131.2	45.4	130.4	25.4	149.0	26.0	153.2	34.0	140.4	48.0	123.6	48.4	126.8	308.8
38	43.3	101.2	43.6	105.7	44.8	109.9	34.0	124.2	31.2	114.9	38.1	100.7	45.3	114.1	36.4	94.5	316.7

Table 4. Contd.

Wk. no.	Aurangabad RF (mm)	Aurangabad C.V (%)	Khultabad RF (mm)	Khultabad C.V (%)	Gangapur RF (mm)	Gangapur C.V (%)	Kannad RF (mm)	Kannad C.V (%)	Sillod RF (mm)	Sillod C.V (%)	Soygaon RF (mm)	Soygaon C.V (%)	Paithan RF (mm)	Paithan C.V (%)	Vaijapur RF (mm)	Vaijapur C.V (%)	Total RF (mm)
39	42.2	85.5	27.2	100.2	53.1	98.6	31.8	109.4	23.3	144.2	34.1	147.1	46.3	107.4	29.2	97.3	287.2
40	24.8	155.2	17.7	186.6	20.8	140.4	22.2	133.0	16.7	157.1	22.5	149.6	29.9	155.4	18.7	147.1	173.3
41	16.6	313.4	15.6	291.7	28.5	319.0	14.6	276.5	20.7	201.3	16.1	206.5	14.1	204.7	15.8	283.7	142
42	13.8	212.2	13.8	273.7	13.4	219.0	5.6	283.2	12.4	198.6	8.1	194.0	14.7	216.1	9.1	188.1	90.9
43	9.0	212.4	7.4	214.8	8.7	253.4	5.9	250.3	8.1	278.3	8.7	306.9	7.4	220.7	10.0	202.8	65.2
44	3.3	301.6	3.6	329.1	2.5	305.9	1.5	450.5	5.5	371.2	2.9	316.4	4.4	231.7	1.4	389.7	25.1
45	2.6	277.8	4.7	274.8	3.1	231.2	3.0	287.9	4.6	320.6	1.1	344.7	4.0	352.3	3.5	273.3	26.6
46	3.0	247.0	3.3	319.6	6.2	318.6	3.2	317.3	1.1	281.9	1.3	431.6	4.8	304.7	5.2	358.9	28.1
47	0.8	520.3	1.2	490.1	1.3	289.8	3.2	524.6	1.3	361.2	4.6	357.6	2.5	408.3	1.2	232.3	16.1
48	6.5	418.1	9.8	399.5	7.9	400.5	6.0	387.8	7.0	385.0	7.6	421.2	4.1	389.2	4.3	404.5	53.2
49	4.4	362.9	4.0	318.4	4.6	384.1	4.1	331.6	3.9	356.1	3.2	391.1	4.1	380.8	4.3	404.6	32.6
50	0.8	501.9	0.4	547.7	0.8	547.7	0.8	543.0	0.5	463.0	0.6	547.7	2.7	547.7	1.2	435.2	7.8
51	1.2	488.4	0.7	547.7	0.3	547.7	0.8	547.7	1.2	547.7	1.3	438.9	1.3	518.8	0.6	407.3	7.4
52	1.1	452.6	1.8	381.0	3.0	431.3	2.6	381.6	1.8	488.9	0.9	331.1	2.7	317.5	1.7	383.7	15.6
Total	733.7		769.9		640.7		590.9		621.8		777.0		627.6		527.5		5289.1

and which are found beneficial to *rabi* crops in all talukas of Aurangabad district during the study period. Similar results were also observed by Dixit *et al*., (2005) observed the variability of rainfall and suggested cropping pattern for cultivation in Kokan region for a period 32 years (1972-2003). Further, Kulkarni (2008) studied the rainfall characterization of Osmanabad district of Marathwada region for suggesting crop planning.

Therefore, on the basis of withdrawal of monsoon and post monsoon, it is recommended for all talukas of Aurangabad district for shallow to medium soil crops like Linseed, Safflower, Sunflower, Sorghum, Gram, Mustard etc. may be grown; while in medium to deep soil type, crops like *rabi* Sorghum, Gram, Safflower, Sunflower, Pea and Wheat etc can be planed depending on availability of moisture and soil type.

However, the rainfed plantation with some species *viz*., Anola (*Phyllanthus emblica*), Woodapple (*Carriso Spinarum*), Ber (*Ziziphus mauritiana*), Jamoon (*Syzygium Cumini*), Karwanda (*Carissa Carandas*), Bibwa (*Semecarpus anacardium*) etc. may be beneficial for off season production and it helps for forage purpose, as well as shelter belt and wind breaks to the field.

Where as, protective irrigation availability horticultural fruit crops *viz*., Ber, Mango, Custard apple, Anola, Tamarind and some medicinal crops *viz*., Tikhadi, Ritha etc. can be taken. The horticultural crops like Guava, Sapota, Pomogranate, Fig, Kagzi lime and Sweet orange and floriculture crops like Rose, Marigold, Chrysanthemum, Astar, as well as some vegetables crops *viz*., Capsicum, Ladies finger, Pea, Tomato, Brinjal, Cucumber, Bitter guard, Fenugreek, Spinach, Radish, Onion, Garlic, Indian bean, Cluster bean, French bean, Carrot etc. may be taken. Similar results were obtained with the findings of Maniyar *et al*., (2008) suggested, crop and cropping pattern on the basis of rainfall for Marathwada region of Maharashtra state such as, Cotton, Arhar, short to medium *kharif*- Green gram, Black gram, Soybean, Sorghum, *rabi*-Sorghum, Safflower, Bengal gram under rainfed condition. Similar results were also noted by (Singh, 2005 and Ugale, 2007) who characterize rainfall of Parbhani district from crop planning and suggested vegetable crop (Tomato, Onion, Methi, Pea) pulses crop, floriculture crop. However, the suggested crops and cropping pattern may be useful to cope up the climatic variability as well as mitigating drought up to some extent.

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Storage Studies on Custard Apple (*Annona squamosa* L.) Pulp

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Abstract

Custard apple (*Annona squamosa* L.) is one of the important Annona species due to its wider adaptability, high yield and high nutritive value. Fruit pulp is being used as flavor enhancing ingredient in various food products *viz*., ice-cream, 'rabdi' and milkshake because of its taste and flavor. However, pulp has limited shelf life due to polyphenol oxidase activity which causes its discoloration leading to underutilization of this high value dry land fruit. Therefore, present investigation were undertake to increase the shelf life of pulp upto 90 days at -20°C temperature by adding potassium metabisulphite (KMS) as a preservative in blast freezed pulp. KMS 600 ppm was found significantly superior to restrict discoloration of pulp up to 90 days storage period at -20°C temperature.

Key words : Custard apple pulp, discoloration, potassium metabisulphite (KMS), blast freezing, orgonoleptic evaluation

Custard apple is being cultivated as a commercial fruit crop in tropical and sub tropical regions of India because of its wider adaptability, high yield and nutritive value. The crop is grown on an area of 45,000 ha with the production of 2, 31,550 MT (Shete *et al*., 2009) in Maharashtra.

The fruit yields about 40% pulp having 26.40 °B (TSS), 5.5 pH and 0.5% tannins (Nanjundaswamy and Mahadeviah, 1990). The fruit consists moisture 73.50%, carbohydrate 23.90 %, proteins 1.6 %, fats 0.30%, minerals 0.9%, with good source of vitamin A and C (Gopalan *et al*., 1991). The pulp is utilized for preparation of delicious products like ice-cream, 'rabdi' and milk shake (Chikhalikar *et al*., 2000).

However, custard apple pulp has very limited shelf life due to polyphenol oxidase activity which causes its discoloration and reduces its market value. Prospero (1993) observed discoloration of frozen custard apple pulp within two hours at ambient temperature if additives were not added. Pardede *et al*., (1994) reported loss of quality and value of pulp due to discoloration during frozen state. Sravanthi *et al*., (2014) stored the pulp for six months by adding KMS 1500 ppm. Mysore *et al*., (2008) blast freezed the pulp (-20 °C) and stored the pulp in deep freezer (-25 °C) for 12 months.

Therefore, the present investigation were undertaken to overcome the discoloration and to increase the shelf life of custard apple pulp during storage.

Materials and Methods

The storage study on custard apple pulp was carried out at the National Agricultural Research Project, Ganeshkhind, Pune for three years (2011- 2014). Fruits of Custard apple cv. Phule Purander Selection were procured from All India Coordinated Research Project on Arid

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Zone Fruits (Fig and Custard apple), Jadhavwadi Dist. Pune. Ripened fruits of uniform size and shape were selected. Pulp was extracted manually and 200 g pulp was immediately packed in each polyethylene bag of 200 gauge after giving following treatments. Sealed bags containing pulp were blast freezed in blast freezer (make- Blue Star) at -40 °C for 15 minutes and stored in deep freezer at -20 °C temperature for 90 days. Experiment was conducted in CRD with four replications and five treatments *viz*., T_1 - Potassium metabisulphite (KMS) 300 ppm, T_2 - Potassium metabisulphite (KMS) 450 ppm, T_3 - Potassium metabisulphite (KMS) 600 ppm, T_4 - Potassium metabisulphite (KMS) 750 ppm and T_5 - Control (without KMS).

The physico - chemical parameters like TSS, acidity, total sugar, reducing sugar, moisture content, microbial count and orgonoleptic evaluation was recorded at an interval of every 30 days. The organoleptic evaluation of pulp was done as per the nine point hedonic scale Amerine *et al*., (1965). Pooled data were analyzed and results are discussed below.

Results and Discussion

Initial average values of fresh pulp recovery was 46 per cent, TSS 22.30 °B, acidity 0.24 per cent, total sugar 16.10 per cent and moisture content 73.00 per cent. Beerh *et al*., (1983) reported range of TSS 20.6 to 28 °B, acidity 0.3 to 0.4 per cent, and total sugar 15 to 22 per cent in different cultivars of custard apple while Khader *et al*., (1977) reported proportion of pulp in custard apple 42.40 per cent.

Total soluble solids : Treatments differences were significant in respect of TSS of pulp at 90 days storage period (Table 1). TSS at 90 days of storage period was highest (24.13 °B) in T_5 (control) treatment and was least (22.98 °B) in T4 (KMS 750 ppm). TSS was found to be increased in all the treatments at 90 days compared with the initial TSS. Results are in agreement with the findings of Kolekar (2002) and Mohite (2002).

Table 1. Effect of storage period on chemical composition of custard apple pulp

Treatments	0 day	30 days	60 days	90 days
TSS (°B)				
T_1 KMS 300 ppm	22.31	22.90	23.23	23.41
T_2 KMS 450 ppm	22.31	22.89	23.18	23.30
T_3 KMS 600 ppm	22.26	22.75	22.97	23.08
T_4 KMS 750 ppm	22.29	22.70	22.89	22.98
T_5 Control	22.29	23.1	23.71	24.13
S.E. ±	0.04	0.03	0.04	0.04
C.D. at 5 %	NS	0.09	0.11	0.10
Acidity (%)				
T_1 KMS 300 ppm	0.24	0.29	0.31	0.33
T_2 KMS 450 ppm	0.24	0.27	0.30	0.31
T_3 KMS 600 ppm	0.24	0.27	0.28	0.30
T_4 KMS 750 ppm	0.24	0.26	0.29	0.29
T_5 Control	0.24	0.29	0.33	0.36
S.E. ±	0.002	0.002	0.002	0.003
C.D. at 5 %	NS	0.007	0.007	0.009
Total sugar (%)				
T_1 KMS 300 ppm	16.18	16.53	16.77	16.96
T_2 KMS 450 ppm	16.13	16.46	16.68	16.88
T_3 KMS 600 ppm	16.06	16.26	16.42	16.55
T_4 KMS 750 ppm	16.03	16.22	16.35	16.46
T_5 Control	16.11	16.68	17.19	17.56
S.E. ±	0.03	0.03	0.04	0.05
C.D. at 5 %	NS	0.09	0.12	0.15
Reducing Sugar (%)				
T_1 KMS 300 ppm	13.13	13.69	13.92	14.13
T_2 KMS 450 ppm	13.15	13.60	13.81	13.95
T_3 KMS 600 ppm	13.08	13.39	13.49	13.62
T_4 KMS 750 ppm	13.06	13.36	13.44	13.55
T_5 Control	13.13	13.76	14.18	14.45
S.E. ±	0.03	0.03	0.04	0.04
C.D. at 5 %	NS	0.09	0.11	0.12
Moisture Content (%)				
T_1 KMS 300 ppm	72.99	72.83	72.60	72.36
T_2 KMS 450 ppm	72.86	72.69	72.52	72.34
T_3 KMS 600 ppm	73.10	73.00	72.87	72.70
T_4 KMS 750 ppm	73.25	73.18	73.08	72.84
T_5 Control	73.06	72.76	72.48	72.23
S.E. ±	0.08	0.08	0.09	0.08
C.D. at 5 %	NS	0.23	0.25	0.24

Acidity : Treatment differences were significant in respect of acidity of pulp at 90 days storage period (Table 1). The acidity at 90 days storage period was comparatively low in the treatment, KMS 750 ppm (0.29%) followed by KMS 600 ppm (0.30%) and were at par with each other. Acidity was also found to be increased in all the treatments than the initial acidity. The acidity of custard apple pulp was found increased during storage period by Jadhav (2007) and Baravkar (2008), with whom results are in agreement.

Total sugar : Treatments differences were also significant in respect of total sugar of pulp at 90 days storage period (Table 1). Total sugar at 90 days storage period was comparatively low in the treatment, KMS 750 ppm (16.46%) but was higher in control (17.56%). However, overall increase in total sugar in all the treatments was observed at 90 days than initial total sugar. These findings are supported with the research findings by Mohite (2002).

Reducing sugar : Treatments differences were also significant in respect of reducing sugar of pulp at 90 days storage period (Table 1). Reducing sugar at 90 days storage period was comparatively higher in the treatment, control (14.45%) and was least in the treatment, KMS 750 ppm (13.55%). Reducing sugar was observed to be increased than initial content in all the treatments at 90 days storage period at -20°C. Jadhav (2007) and Baravkar (2008) also reported increase in reducing sugar during storage period.

Moisture content : It was observed (Table 1) that treatment, KMS 750 ppm was significantly superior in retaining higher moisture content (72.84%) while it was least in control (72.23%) after 90 days of storage under -20 °C temperature. Mohite (2002) also reported that there was decrease in moisture content during storage period.

Microbial count : Initial fungal and bacterial count was same i.e. 0.1×10^4 cfu g^{-1} pulp. After 90 days of storage of pulp, the treatment T_2 (KMS 450 ppm), T_3 (KMS 600 ppm) and T_4 (KMS 750 ppm) showed no growth of fungi and bacteria indicating inhibitory action of KMS and blast freezing on microbes. The fungal and bacterial count in the treatment T_1 (KMS 300 ppm) and T_5 (control) was same as that of initial count i.e. 0.1×10^4 cfu g^{-1} pulp after 90 days of storage of pulp. Kolekar (2002) reported that microbial count in

Table 2. Organoleptic evaluation of custard apple pulp

Treatments	0 day	30 days	60 days	90 days
Color and Appearance				
T_1 KMS 300 ppm	8.33	7.47	7.00	6.70
T_2 KMS 450 ppm	8.50	7.47	7.10	6.80
T_3 KMS 600 ppm	8.50	8.00	7.50	7.40
T_4 KMS 750 ppm	8.50	7.93	7.30	7.20
T_5 Control	8.50	7.00	6.70	6.00
Taste				
T_1 KMS 300 ppm	8.00	7.40	7.20	7.00
T_2 KMS 450 ppm	8.50	7.50	7.30	7.10
T_3 KMS 600 ppm	8.50	7.80	7.50	7.50
T_4 KMS 750 ppm	8.50	7.60	7.40	7.33
T_5 Control	8.50	6.70	6.30	6.00
Texture				
T_1 KMS 300 ppm	8.50	7.60	7.40	7.30
T_2 KMS 450 ppm	8.50	7.70	7.40	7.40
T_3 KMS 600 ppm	8.50	7.90	7.80	7.70
T_4 KMS 750 ppm	8.50	7.80	7.60	7.50
T_5 Control	8.50	7.10	6.80	6.30
Flavor				
T_1 KMS 300 ppm	8.5	7.60	7.40	7.00
T_2 KMS 450 ppm	8.50	7.80	7.50	7.20
T_3 KMS 600 ppm	8.50	8.00	7.80	7.50
T_4 KMS 750 ppm	8.50	7.80	7.60	7.30
T_5 Control	8.50	7.30	6.50	6.10
Overall acceptability				
T_1 KMS 300 ppm	8.33	7.52	7.25	7.00
T_2 KMS 450 ppm	8.50	7.55	7.33	7.13
T_3 KMS 600 ppm	8.50	7.93	7.65	7.53
T_4 KMS 750 ppm	8.50	7.78	7.48	7.33
T_5 Control	8.50	7.03	6.55	6.10

By using 9-point hedonic scale

custard apple pulp was low at refrigerated temperature. Baravkar (2008) also found that microbial count of custard apple pulp was minimum at deep freezer (-20°C) during 90 days storage period, with whom results of this experiment are in conformity.

Organoleptic evaluation : The treatment T_3 (KMS 600 ppm) was found superior for all organoleptic parameters like colour, taste, texture, flavor and overall acceptability (Table 2). The overall acceptability was superior for the treatment T_3 (KMS 600 ppm, 7.53), followed by T_4 (KMS 750 ppm, 7.33), T_2 (KMS 450 ppm, 7.13), T_1 (KMS 300 ppm, 7.00) and T_5 (control, 6.10) after 90 days of storage period at -20°C storage temperature. Maclae *et al*., (1993) reported that custard apple pulp treated with KMS 500 ppm can be stored for 120 days with minimal loss of flavor and retention of bright fresh colour. Jadhav (2007) and Baravkar (2008) reported that custard apple pulp preserved with KMS and stored at -20°C has better acceptability even after 90 days of storage period.

Studies carried out in the present investigation clearly demonstrated that blast freezed custard apple pulp (cv. Phule Purander Selection) can be stored in good condition upto 90 days at -20°C by adding KMS 600 ppm. This treatment (KMS 600 ppm) was found superior over rest of the treatments in retention of higher moisture, TSS, acidity, total sugar and reducing sugar at 90 days of storage. This treatment also found superior in organoleptic parameters and overall acceptability. Besides, microbial population was also inhibited by this treatment.

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Hyperspectral Field Reflectance Measurements to Develop Spectral Signatures for Different Crops

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Abstract

Hyperspectral crop reflectance data are useful for several remote sensing applications in agriculture, but there is still a need for studies to define optimal wavebands to estimate crop biophysical parameters and spectral response of crops. The objective of this work is to analyze the hyperspectral field reflectance to develop the spectral signatures for *rabi* season crops viz. Sorghum, chickpea and wheat. A field study was conducted during the *rabi* season of 2012-2013 at Central Farm of the Mahatma Phule Krishi Vidyapeeth, Rahuri. The canopy spectral reflectance was measured using SVC (Spectra Vista Corporation) HR-1024 Spectroradiometer with spectral range from 350 to 2500 nm (1 nm interval) during the crop growth periods. The spectral signatures were developed by plotting the graphs of reflectance (%) as a function of wavelength (nm). The spectral signatures of sorghum, chickpea and wheat crop show low reflectance in visible and red region and the high reflectance in near infrared region and spectral variations among spectral signatures are mainly due to differences in crop growth stages. The spectral signatures obtained can be used in classification and mapping of vegetation and in the detection of plant stress for water resource operations and management.

Key words : Field spectroscopy, spectroradiometer, spectral signatures

Hyperspectral field reflectance measurement is a technique of fundamental importance in remote sensing, both at the level of primary research and in operational applications. (Milton, 1987). Hyper spectral reflectance measurement is the quantitative measurement of radiance, irradiance, reflectance or transmission in the field (Hadjimitsis *et al.*, 2009; Milton *et al.*, 2009 and Agapiou *et al.*, 2010). It involves the study of the interrelationship between the spectral characteristics of the object and their biophysical attributes in the field environment (Milton, 1987). It acts as a bridge between laboratory measurements of spectral reflectance and the field situation and is thus useful in the calibration of airborne and satellite sensors. It is useful in predicting the optimum spectral bands, viewing configuration and time to perform a particular remote sensing task. It provides a tool for the development, refinement and testing of models or functions relating biophysical attributes to remote sensing.

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Hyperspectral field reflectance measurement is used for variety of studies including those that require the collection of field data for ground targets for the more precise image analysis and investigation regarding irrigation water management (Agapiou *et al.*, 2010). The most widely used methodology in the hyperspectral field reflectance measurement is the measurement of the reflectance of composite surface in situ (Milton *et al.*, 2009). The field spectroradiometer is essential and contributed significantly to research by providing a number of direct comparisons between satellite data and ground truth spectral data. It provides the spectral signatures of different crops following the crop growth cycle of each crop so as to create the vegetation indices from the red (IR) and near infrared (NIR) reflectance data corresponding to the bands of different satellite sensors and correlate them to LAI, crop height, crop coefficients and crop yields. Therefore, in this study, the technique of the hyperspectral field reflectance measurement is used in view to develop the spectral signatures for sorghum, chickpea and wheat crops.

The spectral signature is the plot of the variation of reflectance or absorbed electromagnetic radiation as a function of wavelengths. The graph of the spectral reflectance of an object as a function of wavelength is termed the spectral reflectance curve (Lillesand and Kiefer, 1999). Vegetation has a unique spectral signature which enables it to be distinguished readily from other types of land cover in an optical/near-infrared image. Several studies have derived band ratios or spectral indices from spectral reflectance data which are useful for emphasizing certain physiological features, and can be used to distinguish between different vegetation within a mosaic of other land uses (McGwire *et al*., 2000; Underwood *et al*., 2003; Yamano *et al*., 2003 and Galvao *et al*., 2005). Commonly used indices include normalized difference vegetation index (NDVI), soil-adjusted vegetation index (SAVI), and modified soil-adjusted vegetation index (MSAVI) (McGwire *et al*., 2000). Vegetation indices are also used to mask out vegetated areas from remote sensed imagery which are then used in the classification process (Underwood *et al*., 2003; Yamano *et al*., 2003 and Koch *et al*., 2005). This narrates the importance of the spectral signatures of the crops in the application of remote sensing technique in water resource management. Therefore, in this study, the spectral signatures of the different crops were developed with the spectroradiometer data. This spectral data can further be used to create vegetation indices and for modeling the vegetation indices derived from the spectral data to leaf area index, crop height and crop coefficients of crops.

Materials and Methods

Experimental site : The data required for study were collected from sorghum, chickpea and wheat fields. The details of the study area, sowing date, harvesting date are given in Table 1.

Climatically the study area falls under the semi-arid and sub tropical zone with average annual rainfall of 566.5 mm. The average maximum and minimum temperature was 31.68°C and 15.48°C respectively. The average maximum and minimum relative humidity was 61.13 and 34.63 %, respectively. The sunshine hours are in-between 4.40 to 9.10 hrs with average value of 7.81 hrs with average wind speed of 1.91 km hr^{-1} during the crop growth period. The total rainfall during the crop growth periods was 260.40 mm. The pan evaporation varied from 4.40 to 9.10 mm. The average elevation of study area is 657m above the mean sea level. The prominent soil type is clay. The seed plot was selected for the study because all the standard cultivation practices were adopted during the crop growth period and the crop was maintained in unstressed

Table 1. Location details and crop calendar for selected crops

Crop	Latitude	Longitude	Sowing date	Harvesting date
Sorghum (*Sorghum bicolor* L.)	19°21'55.163"N	74°38'43.842"E	7^{th} Sept. 2012	14^{th} Jan. 2013
Chickpea (*Cicer arietinum* L.)	19°19'19.494"N	74°39'16.873"E	29^{th} Sept. 2012	4^{th} Feb. 2013
Wheat (*Triticum astvium* L.)	19°19'58.779"N	74°40'23.348"E	27^{th} Nov. 2012	26^{th} March 2013

condition. The sorghum, chickpea and wheat fields were border-irrigated.

Reflectance measurements : Spectro-radiometers were widely used to collect spectral data and were designed to match the wavebands of different satellites' sensors (Agapiou *et al.*, 2010). Field reflectance measurements were performed over sorghum, chickpea and wheat fields with the SVC HR-1024 spectroradiometer (http://www.spectravista.com) during the crop growth periods at an interval of seven days. The radiometric measurements were collected under clear-sky conditions between 12:00 hrs and 14:00 hrs, at 60 to 80 cm above crop canopy, with the 25° field-of-view (FOV) optic fiber allowing 0.13 to 0.18 m spatial resolutions for each spectral measurement and all the measurements were taken from nadir view. Five spectral reflectance measurements from the most central part of each plot were taken with the spectroradiometer over the spectral range 350-2500 nm at an interval of 1 nm. A reference calibrated spectralon panel with 100% reflectance was used to measure the incoming solar radiation as a reference one, while the measurement over the crops as a target. The reflectance was calculated using the equation, Reflectance = (Target Radiance / Panel Radiance) x Calibration Factor of the panel. In order to avoid any errors due to significant changes in the prevailing atmospheric conditions, the measurements over the spectralon panel and the target were taken with the shortest time lag. The reflection of the spectralon panel was recorded for every measurement to ensure reliable data collection. The same point was visited each time for taking observations over the crop growth period. These measurements were then used to develop the spectral signatures for sorghum, chickpea and wheat crops. The spectral signatures for the respective crops were developed by plotting the graphs of reflectance (%) as a function of wavelength (nm). The average spectral signatures for each crop growth stage are developed as spectral response of a crop canopy in the visible and near infrared regions. The crop growth stages considered for all the crops are: initial stage, crop development stage, mid-season stage and late season stage.

Results and Discussion

The spectral signatures were developed by plotting the per cent spectral reflectance against the wavelength in nm from the spectral reflectance data recorded on weekly basis over the crop growth periods for sorghum, chickpea and wheat crops. The spectral signatures developed for sorghum, chickpea and wheat crops as a plot of variation of reflectance as a function of wavelengths during the crop growth period are presented in Figures 1, 2 and 3.

Fig. 1, 2 and 3 shows the average spectral reflectance behavior at each growth stage for sorghum, chickpea and wheat, respectively. Spectral variations among curves are mainly due to differences in crop growth stages. Lowest reflectance values in near infrared wavelengths (NIR 700-1300 nm) were observed for the initial stage, where biomass is low and reflectance is influenced mainly by soil. Maximum reflectance in the NIR was observed for the mid-season stage for sorghum and

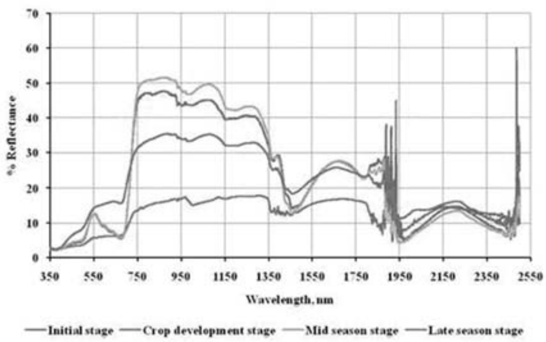

Fig. 1. Spectral signatures of sorghum at distinct growth stages

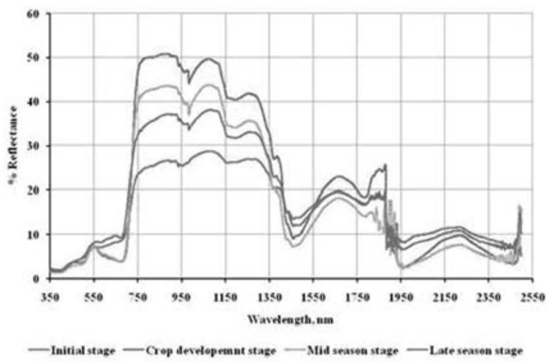

Fig. 2. Spectral signatures of chickpea at distinct growth stages

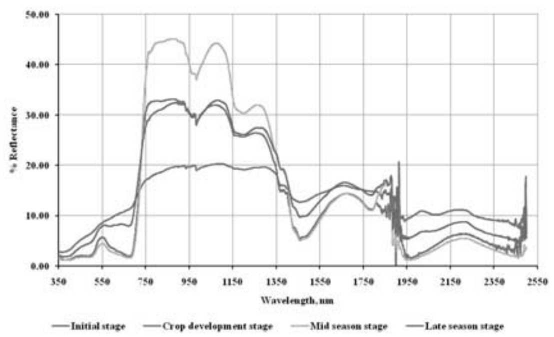

Fig. 3. Spectral signatures of wheat at distinct growth stages

wheat crops, whereas maximum reflectance in NIR was observed for crop development stage for chickpea. The maximum reflectance values are coincident with highest values of green leaf area index and consequently low reflectance of solar radiation in red wavelengths and high scattering of solar radiation in NIR (Moreira *et al*., 1999). At late-season stage, reflectance in visible (VIS: 350 - 700 nm) and NIR regions increase and decrease, respectively, when compared to the previous growth stages, which is mainly caused by the increase of senescent leaves. The visible region shows maximum reflectance at approximately 550 nm and lower reflectance in the blue region at 450 nm and red region at 680 nm. The reflectance reduces at 1400 nm, because of the presence of water in the leaves and strong absorption by the leaves.

The reflectance in the near infrared region increases from initial stage up to mid- season stage while in late season it decreases and in red portion it decreases from mid- season to initial stage and again increases at late season stage for sorghum and wheat crops. Whereas for chickpea crop the reflectance in the near infrared region increases from initial stage up to crop development stage and it is found decreasing from crop development stage to late season stage. In red portion it decreases from mid-season to initial stage and again increases at late season stage.

In general the spectral signatures of sorghum, chickpea and wheat crops show low reflectance in visible and red region and the high reflectance in near infrared region and spectral variations among spectral signatures are mainly due to differences in crop growth stages. The spectral signatures obtained can be used in classification and mapping of vegetation, mapping of crop productivity, crop type or yield mapping, and in the detection of plant stress for water resource operations and management.

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Leaf Area Index of Sorghum (*Sorghum bicolor* L.) Crop using Hyperspectral Field Reflectance Measurements

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Abstract

Recently high spectral resolution sensors have been developed, which allow new and more advanced applications in agriculture. Motivated by the increasing importance of hyperspectral remote sensing data, the need for research is important to define optimal wavebands to estimate biophysical parameters of crop. The use of narrow band vegetation index: Normalized Difference Vegetation Index (NDVI) derived from hyperspectral measurements acquired by a field spectroradiometer was evaluated to estimate sorghum (*Sorghum bicolor* L.) leaf area index (LAI). A field study was conducted during the *rabi* season of 2012-2013 at Water Management Project of the Mahatma Phule Krishi Vidyapeeth, Rahuri. The canopy spectral reflectance was measured using Spectroradiometer with spectral range from 350-2500 nm (1 nm interval) during the crop growth period. Plant Canopy Imager was used to measure leaf area index (LAI) using gap-fraction inversion procedure. The regression analysis was carried out for NDVI with LAI for sorghum using linear, exponential, logarithmic and power relationships over crop growth period considering growth and decline phases of LAI independently. Exponential relationships were found significant with LAI when growth (R^2=0.980) and decline (R^2=0.938) phases were analysed independently.

Key words: Hyperspectral reflectance, spectroradiometer, NDVI, LAI, sorghum

Hyperspectral crop reflectance data are useful for several remote sensing applications in agriculture, but there is still a need for studies to define optimal wavebands to estimate crop

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biophysical parameters and spectral response of crops. The monitoring of agricultural crops during the development cycle is important to food security. Monitoring can be done observing the biophysical variables. One of these biophysical variables that deserve attention is the leaf area index (LAI), that is related with crop evapotranspiration and crop yield (Sellers *et al*., 1997; Xavier *et al*., 2006). One way to estimate these biophysical parameters is by vegetation indices (VI). VI's are mathematical functions of reflected radiant flux in different spectral bands of remote sensing data (Jensen, 2007).

Spectral vegetation behavior usually shows that plants absorb more solar energy in the visible region with increasing biomass. The most frequently used VI are broad bands in red and near-infrared regions, because of the absorption of energy in the red region by leaves and reflectance and transmission of multiple energy scattering that occur on individual leaves and on plant canopy in near-infrared region (Goel, 1988). Therefore, vegetation indices such as normalized vegetation index (NDVI), the most frequently used vegetation index, are usually correlated with LAI and crop yield (Aparicio *et al*., 2000; Eitel *et al*., 2008; Elwadie et 2005; Galvao *et al*., 2009; Raun *et al*., 2008; Serrano *et al*., 2000; Thenkabail *et al*., 2000).

Hyperspectral remote sensing data has the potential to detect more variations on vegetation than multispectral data, because it uses narrow spectral channels of less than 10 nm (Stagakis *et al*., 2010; Thenkabail *et al*., 2000). These narrow channels allow the detection of detailed features, which could otherwise be disguised by broadband (Schmidt and Skidmore, 2003). Advances in the hyperspectral remote sensing technology are driving the development of new methods to analyze spectral reflectance data. Therefore, sorghum spectral reflectance measurements were analyzed in terms of NDVI to estimate LAI during crop growth cycle for sorghum crop.

Materials and Methods

The study area : The data required for this study were collected from Sorghum (*Sorghum bicolor* L.) field located at 19°21 155.163"N latitude and 74°38 143.842"E longitude during *rabi* season of 2012-2013. Climatically the study area falls under the semi-arid and sub tropical zone with average annual rainfall of 566.5 mm. The average maximum and minimum temperature was 31.68°C and 15.48°C respectively. The average maximum and minimum relative humidity was 61.13 and 34.63%, respectively. The sunshine hours are in-between 4.40 to 9.10 hrs with average value of 7.81 hrs with average wind speed of 1.91 km hr^{-1} during the crop growth period. The total rainfall during the crop growth periods was 260.40 mm. The pan evaporation varied from 4.40 to 9.10 mm. The average elevation of study area is 657m above the mean sea level. The prominent soil type is clay. The seed plot was selected for the study because all the standard cultivation practices were adopted during the crop growth period and the crop is maintained in unstressed condition. The sorghum field was border-irrigated. The crop was sown in 7 September, 2012 and harvested on 14 January, 2013 and the data were recorded during this period.

Hyperspectral reflectance measurements : Spectroradiometers are widely used to collect spectral data and are designed to match the wavebands of different satellites' sensors (Agapiou *et al*., 2010). Field reflectance measurements were performed over sorghum field with the SVC HR-1024 spectroradiometer during the crop growth periods at an interval of seven days. The radiometric measurements were collected under clear-sky conditions between 12:00 hrs and 14:00 hrs, at 60 to 80 cm above crop canopy, with the 25° field-of-view (FOV) optic fiber allowing 0.13 to 0.18 m spatial resolutions for each spectral measurement and all the measurements were taken from nadir view. Five spectral reflectance measurements from the most central part of sorghum field were taken with the spectroradiometer over the spectral range 350-2500 nm. A reference calibrated spectralon panel with 100% reflectance was used to measure the incoming solar radiation as a reference one, while the measurement over the crops as a target. The reflectance was calculated using the equation, Reflectance = (Target Radiance / Panel Radiance) x Calibration Factor of the panel. In order to avoid any errors due to significant changes in the prevailing atmospheric conditions, the measurements over the spectralon panel and the target were taken with the shortest time lag. The reflection of the spectralon panel was recorded for every measurement to ensure reliable data collection. The same point was visited each time for taking observations over the crop growth period. These measurements were then used to simulate the narrow-bands and broad-bands from the spectral bands. Due to atmospheric radiation absorption, some bands in the spectral ranges 1350-1440 nm; 1790-1990 nm; and 2360-2500 nm were disconsidered.

Leaf area index (LAI) measurements : LAI is commonly used for monitoring crop growth. Instead of the traditional, direct and labor-consuming method of physically measuring the plant with a ruler (direct method), an optical instrument, Plant Canopy Imager CI-110 (CID Bio- Science Inc., USA) was used (indirect method). The CI-110 uses a fish eye camera, ceptometer and proprietary software to capture and analyze images of canopy data, PAR levels and GPS information. The gap-fraction inversion procedure (Norman and Campbell, 1989) was used to estimate LAI, canopy transmission coefficient and mean leaf angles. The software calculates the solar beam transmission coefficient using a user defined number of zenith and azimuth divisions. The output data is then displayed on the computer screen and can be saved into a file for further analysis. The LAI was estimated by analyzing the image with 5 zenith and azimuth divisions. The threshold contrast level was kept 95 with fish eye camera angle of 180°.

Normalized difference vegetation index and regression models : The reflectance measurements were re-sampled to 1nm wavelength and converted into in-band reflectance of the corresponding IRS LISS-III bands. After transforming the data into 'in band' reflectance of IRS LISS-III (B3: 620-680nm and B4: 770-860nm), the NDVI was calculated by using the equation proposed by Rouse *et al.*, (1974).

$$NDVI = \frac{(B4 - B3)}{(B4 + B3)}$$

Table 1. Results of regression analysis of LAI with NDVI for sorghum over (a) growth phase and (b) decline phase of LAI

Regression Relationship	R^2	RMSE	χ^2	PEM
(a) Growth Phase				
$LAI=5.459(NDVI)-1.851$	0.813	2.998	0.051	2.409
$LAI=0.059e^{4.662(NDVI)}$	0.980	1.112	0.047	0.594
$LAI=2.78\ln(NDVI)+3.055$	0.723	2.828	0.371	2.359
$LAI=4.164(NDVI^{2.490})$	0.958	1.120	0.947	10.06
$LAI=14.37(NDVI)^2 -11.35 (NDVI) +2.483$	0.928	2.266	0.652	0.621
(b) Decline Phase				
$LAI=3.765(NDVI)+0.793$	0.938	2.324	0.111	0.005
$LAI=1.258e^{1.415(NDVI)}$	0.938	0.379	0.020	0.002
$LAI=1.789\ln(NDVI)+4.089$	0.922	2.303	0.193	0.048
$LAI=4.365(NDVI^{0.680})$	0.943	0.380	0.026	0.047
$LAI=-2.0(NDVI)^2+5.903 (NDVI) +0.308$	0.945	1.648	0.117	0.017

The regression relationships used were:

LAI=a (NDVI) + b (Linear)

LAI=a $e^{b(NDVI)}$ (Exponential)

LAI=a ln(NDVI) + b (Logarithmic)

LAI=a $(NDVI)^b$ (Power)

LAI= a $(NDVI)^2$ + b(NDVI) + c

where, 'a', 'b' and 'c' are the coefficients of the regression relationships.

The best fit regression relationship was found out based on the coefficient of determination (R^2), Root Mean Square Error (RMSE), Chi-square (χ^2) and Percent Error Modulus (PEM) values.

Results and Discussion

Spectral reflectance of sorghum : The stagewise spectral reflectances of sorghum crop between the wavelengths of 350 to 2500 nm are shown in Fig.1. Fig. 1 shows the average spectral reflectance behavior at each growth stage for sorghum. Spectral variations among curves are mainly due to differences in crop growth stages. Lowest reflectance values in near infrared wavelengths (NIR: 700-1300 nm) were observed for the initial stage, where biomass is low and reflectance is influenced mainly by soil. Maximum reflectance in the NIR was observed for the crop development stage followed by mid-season stage, which is coincident with highest values of green leaf area index, consequently low reflectance of solar radiation in red wavelengths and high scattering of solar radiation in NIR (Moreira *et al.*, 1999). At late-season stage, reflectance in visible (VIS:350-700 nm) and NIR regions increase and decrease, respectively, when compared to the previous growth stages, which is mainly caused by the increase of senescent leaves. The visible region shows maximum reflectance at approximately 550 nm and lower reflectance in the blue region at 450 nm and red region at 680 nm. In general the spectral signatures of sorghum crop shows low reflectance in visible and red region and the high reflectance in near infrared region.

NDVI and LAI for sorghum : Fig. 2 shows the profile of variation of NDVI and LAI during the crop growth period of sorghum.

Relationships between NDVI and LAI : The regression analysis between leaf area index (LAI) and Normalized Difference Vegetation Index (NDVI) was carried out over the crop growth period (CGC) for sorghum to develop the relationship between LAI and NDVI. The LAI-NDVI relationships developed are presented in Table 1. The part 'a' and 'b' of Table 1 gives the results of regression analysis

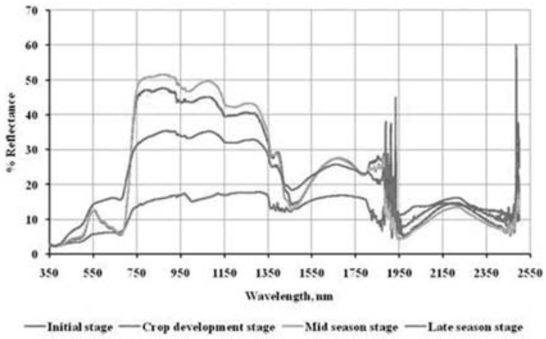

Fig. 1. Spectral reflectance of sorghum at distinct growth stages

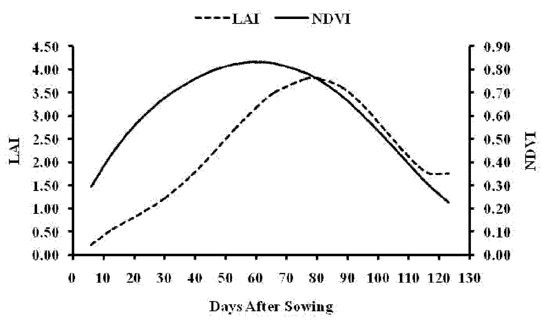

Fig. 2. LAI and NDVI profile for sorghum during crop growth period

for growth and decline phases, respectively. The R^2 values were in 0.723-0.980 range and 0.922-0.945 range for growth and decline phase respectively. It is observed from Table 1 that, the exponential relationships developed for sorghum crop during growth phase indicated the goodness of fit as per the lower value of χ^2 (0.047). It is observed that the value of coefficient of determination (R^2 = 0.980) is maximum, RMSE (1.112) and PEM (0.594) are minimum for exponential relationship. The exponential relationship developed for sorghum crop during decline phase indicated the goodness of fit as per the lower value of χ^2 (0.020). It is observed that the value of coefficient of determination (R^2 = 0.938) was maximum, RMSE (0.379) and PEM (0.002) is minimum for the exponential relationship.

Thus exponential relationships were found best suitable for the estimation of the LAI from NDVI during growth ($LAI=0.059e^{4.662(NDVI)}$) and decline ($LAI=1.258e^{1.415(NDVI)}$) phases for sorghum. The developed exponential relationships could be used for the assessment of sorghum LAI based on NDVI and in the crop evapotranspiration estimation algorithms applying remotely sensed observations.

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RESEARCH NOTES

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Response of Summer Groundnut (*Arachis hypogaea* L.) to Land Configurations, Irrigation Regimes and Potassium Levels

Groundnut (*Arachis hypogaea* L.) is premier among all oilseed crops and one of the most important money minting legume-cum oilseed crop. Among the crop production factors, one of the most important input requirements is irrigation water which is a scarce and expensive input. Mulching is useful for moderating soil temperature, conserving soil moisture and for controlling weed growth. Solar heating of the soil by mulching the bare soil with thin transparent polythene films during hot summer months, immediately before planting of the crop can effect excellent control of weeds, nematodes and soil borne pathogens. Application of mulch not only helps in realizing higher yields, but also contributes in reducing water requirement by 40 per cent eliminating crop weed competition, minimizes incidence of sucking pests and reducing crop duration (7-10 days) (Basu, 2008)

The fertilizer application is the most important factor contributing to the agricultural production. The medium black soils in the intensive cropping area started depleting in potassium on long run from high to medium and to low levels. In such conditions groundnut crop may respond to potassium application (Patil *et al*., 2003). In view of these, the experiment to study the effect of land configurations, irrigation regimes and potassium levels on summer groundnut was conducted during summer season of 2011 and 2012.

The field experiment was conducted during the year 2011 and 2012 at Post Graduate Institute Farm, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar (M.S.). The experiment was laid out in split - split plot design with three replications. There were 27 treatment combinations comprising of three main plot treatments of land configurations *viz*., Flat Bed, Broad Bed Furrow (BBF) and Broad Bed Furrow (BBF) + Polythene mulch (black), three subplot treatments of irrigation regimes *viz*., 0.6, 0.8 and 1.0 IW/CPE ratios and three sub-sub plot treatments of potassium levels *viz*., 20, 40 and 60 kg K_2O ha^{-1}. The gross plot size was 5.10 x 3.60 m and net plot size was 4.50 x 3.00 m for flat bed and 4.50 x 2.40 m for BBF and BBF + polythene mulch. The soil of experimental field was clay loam in texture, slightly alkaline in reaction (pH 8.12), low in available nitrogen (240.0 kg ha^{-1}), medium in available phosphorus (17.5 kg ha^{-1}) and high in potassium (308.0 kg ha^{-1}), Recommended dose of fertilizer (25:50 NP kg ha^{-1}) was applied to all the treatments and K as per treatment. The polythene mulch used was of 7 micron. The variety used for experimentation was 'RHRG 6083'.

Growth and yield of groundnut as influenced by land configurations : The growth contributing characters were recorded significantly higher in the treatment of broad bed furrow + polythene mulch than rest of the land configuration treatments. The growth contributing characters *viz*., plant height (36.4 cm), number of branches (12.0), numbers of composite leaves (134.7), leaf area $plant^{-1}$ (26.8 dm^2), spread $plant^{-1}$ (42.7 cm), dry matter $plant^{-1}$ (96.4 g $plant^{-1}$) were recorded significantly higher on pooled mean basis at harvest in the Broad bed furrow + polythene mulch. (Table. 1).

As regards yield contributing characters, shelling percentage was not influenced significantly due to land configurations. The test weight (43.9 g) and dry pod yield plant^{-1} (28.7 g plant^{-1}) were recorded significantly higher in pooled data of two years due to Broad bed furrow + polythene mulch. The BBF + polythene mulch recorded significantly higher dry pod yield (4915 kg ha^{-1}) and haulm yield (9189 kg ha^{-1}) on pooled mean basis (Table 1). This might be because of higher moisture retention through out the growth period in BBF + polythene mulch enhances the moisture and nutrient availability, rapid germination and early establishment of seedlings, which results in vigorous growth of the crop. It increases the soil temperature and efficacy of microorganisms. It also prevents weed seed to germinate hence no weed competition. The polythene mulch shows glittering effect by reflecting the sunlight, hence sucking pests attack on the crop is minimized (Basu *et al.*, 2008). BBF + polythene mulch increases porosity of soil which increases the root mass. All these together produced higher growth contributing parameters through out growth period and resulted into higher dry pod yield. The results are in conformity with

Table 1. Effect of land configurations, irrigation regimes and potassium levels on growth and yield contributing characters at harvest and yield of summer groundnut

Treatment	Plant height (cm)	No. of branches plant^{-1}	No. of composite leaves plant^{-1}	Leaf area plant^{-1} (dm2)	Spread plant-1 (cm)	Dry matter plant^{-1} (g)	Shelling (%)	Test (100 kernel) weight (g)	Dry pod yield plant^{-1} (g)	Dry pod yield (kg ha^{-1})	Haulm yield (kg ha^{-1})
Land configurations (P)											
Flat Bed	27.6	9.1	104.1	20.1	35.2	75.7	69.9	38.5	24.7	3355	7537
Broad Bed Furrow (BBF)	30.6	10.1	118.6	23.5	39.1	80.5	70.0	40.2	25.3	3809	7958
BBF + Poly mulch	36.4	12.0	134.7	26.8	42.7	96.4	70.8	43.9	28.7	4915	9189
SE (m)	0.79	0.49	2.03	0.39	0.68	0.31	0.12	0.56	0.24	17	34
CD at 5%	4.81	1.40	12.33	2.39	2.73	1.86	NS	3.39	1.47	106	212
Irrigation regimes (I)											
0.6 IW/CPE	28.7	9.5	102.4	19.9	36.2	75.5	69.6	38.8	24.6	3559	7510
0.8 IW/CPE	32.3	10.7	125.4	24.8	40.1	86.6	70.3	41.6	26.8	4243	8497
1.0 IW/CPE	33.5	11.0	129.6	25.8	40.7	90.6	70.8	42.2	27.3	4278	8676
SE (m)	0.22	0.34	2.15	0.42	0.51	1.30	0.56	0.18	0.19	16	38
CD at 5%	0.74	1.06	7.43	1.44	1.77	4.02	NS	0.61	0.64	56	134
Potassium (K2O) levels (F)											
20 kg ha^{-1}	30.0	9.7	109.5	21.0	37.2	80.5	69.9	39.4	25.6	3842	7945
40 kg ha^{-1}	31.6	10.5	121.6	24.2	39.2	84.2	69.8	41.2	26.2	4115	8297
60 kg ha^{-1}	32.9	10.9	126.2	25.3	40.6	87.9	71.0	42.1	26.9	4123	8441
SE (m)	0.45	0.15	2.20	0.43	0.54	1.28	0.54	0.16	0.07	15	26
CD at 5%	1.35	0.45	6.43	1.27	1.58	3.80	NS	0.45	0.21	45	75
Interaction											
P x I	Sig.	NS	NS	NS	NS	Sig.	NS	Sig.	Sig.	Sig	Sig.
P x F	NS	NS	NS	NS	NS	NS	NS	Sig.	NS	NS	NS
I x F	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
P x I x F	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
General mean	31.5	10.4	119.1	23.5	39.0	84.2	70.2	40.9	26.2	4027	8228

Subrahmaniyan *et al*., (2008), Zagade and Chavan (2010) and Bure *et al*., (2011).

Growth and yield of groundnut as influenced by irrigation regimes : The growth contributing characters *viz*., plant height (33.5 cm), numbers of branches plant^{-1} (11.0), number of composite leaves (129.6), leaf area plant^{-1} (25.8 dm^2), spread plant^{-1} (40.7 cm) and dry matter plant^{-1} (90.6 g) were recorded significantly higher at harvest on pooled mean basis in the application of irrigation at 1.0 IW/CPE ratio. However, it was at par with irrigation at 0.8 IW/CPE ratio (Table.1).

In respect of yield contributing characters, shelling percentage did not differed significantly due to irrigation regimes. The test weight (42.2 g) and dry pod yield plant^{-1} (27.3 g) recorded significantly higher at application of irrigation at 1.0 IW/CPE ratio on pooled mean basis. However, it was at par with application of irrigation at 0.8 IW/CPE ratio.

The dry pod yield (4278 kg ha^{-1}) and haulm yield (8676 kg ha^{-1}) on pooled mean basis were obtained in the application of irrigation at 1.0 IW/CPE ratio. However, it was at par with 0.8 IW/CPE ratio (Table 1). This might be due to optimum moisture status with the application of irrigation at 0.8 and 1.0 IW/CPE ratio resulting in to enhanced nutrient availability to the crop favouring the growth and yield contributing parameters. The overall combined effect resulted into higher dry pod yield. The results are in accordance with Zagade and Chavan (2010) and Bure *et al*., (2011).

Growth and yield of groundnut as influenced by potassium levels : The growth contributing characters *viz*., plant height (32.9 cm), number of branches (10.9), composite leaves (126.2) were recorded significantly higher due to the application of 60 kg K_2O ha^{-1} on pooled mean basis. Similar trend was observed in leaf area as it is dependent on composite leaves. Significantly higher leaf area (25.3 dm^2) was recorded on pooled mean basis with the application of potassium @ 60 kg K_2O ha^{-1} at harvest. The plant spread was significantly higher at the time of harvest to the tune of 40.6 cm in pooled mean due to application of 60 kg K_2O ha^{-1}. The dry matter at harvest of crop recorded the highest values of 87.9 g on pooled mean basis with the application of 60 kg K_2O ha^{-1}. However, all these growth attributes were at par with application of 40 kg K_2O ha^{-1} (Table 1).

As regards, yield contributing characters, shelling percentage did not differed significantly due to potassium levels. The test weight (42.1 g) and dry pod yield plant^{-1} (26.9 g) were significantly higher under

Table 2. Interaction effect between land configurations and irrigation regimes on dry pod and haulm yield of groundnut in pooled mean

Land configuration (P) Irrigation regimes (I)	Dry pod yield (kg ha^{-1})			Haulm yield (kg ha^{-1})		
	Flat bed	BBF	BBF + Polymulch	Flat bed	BBF	BBF + Polymulch
0.6 IW/CPE	2835	2963	4878	6590	6824	9118
0.8 IW/CPE	3599	4214	4915	7822	8458	9210
1.0 IW/CPE	3631	4251	4953	8198	8591	9238
		SE (m) ±	CD at 5%		SE (m) ±	CD at 5%
Between I means at same level of P means		28	98		67	232
Between P means at same level of I means		29	114		65	255

application of 60 kg K_2O ha^{-1} on pooled mean basis.

The dry pod yield (4123 kg ha^{-1}) and haulm yield (8441 kg ha^{-1}) on pooled mean basis were obtained significantly higher with potassium application @ 60 kg K_2O ha^{-1}. However, dry pod yield was at par with application of 40 kg K_2O ha^{-1} (Table 1). This might be due to the involvement of potassium in physiological and biochemical functions of plant growth i.e. enzyme activation, water balance, protein synthesis, starch synthesis etc. Its application in legumes improves nitrogen fixation capacity of plants and availability of all nutrients. These favorable effects might have resulted in increased growth and yield contributing attributes. Altogether, combined effect of these factors resulted into higher dry pod yield and haulm yield. The results are in conformity with the Hadvani *et al*., (2007), Singh (2007) and Salve *et al*., (2010).

Interaction effect : The irrigation at 1.0 IW/ CPE ratio with broad bed furrow + polythene mulch recorded significantly higher dry pod yield (4953 kg ha^{-1}) and haulm yield (9238 kg ha^{-1}) on pooled mean basis. However, it was at par with treatment combination of Broad bed furrow + polythene mulch with irrigation at 0.8 IW/ CPE and Broad bed furrow + polythene mulch with 0.6 IW/CPE ratio.

The summer groundnut var. 'RHRG-6083' be cultivated on BBF + polythene mulch with irrigation at 0.6 IW/CPE ratio and application of 40 kg K_2O ha^{-1} for achieving higher yield and net realization.

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Effect of Summer Sesamum (*Sesamum indicum* L.) Cultivars on Dry Matter Production and Yield under Different Sowing Times

Sesamum seeds are rich source of food, nutrition, edible oil, health care and biomedicine. Sesamum though cultivated in small scale, it is of immense importance in industry and commerce. It is also used as a component for the manufacture of soap and paints. Out to synergistic effect, it is used in the preparation of tonic for the hair. They enrich the blood and are useful in the snake bites , bleeding piles etc. Sesamum oil is useful for dry cough, asthma disease of lungs, burning sensation, diseases of the ear and eyes. Recently, omega-6 fatty acid desaturase also got from sesamum which is helpful for heart patients (Jin *et al*., 2001).

The experiment was conducted at Agronomy Farm, College of Agriculture, Pune during summer, 2011.The topography of the experimental field was uniform, leveled and uniform in depth up to 60 cm. The experiment was laid out in a split plot design with three replications. Twelve treatment combinations were formed considering different sowing times and varieties. Main plot treatment consists of four varieties *viz*., Phule til-1, AKT-101, JLT-7 and Padma while sub plot treatments comprised three sowing times *viz*., 4^{th} MW (22^{nd} Jan. - 28^{th} Jan.), 6^{th} MW (5^{th} Feb.-11^{th} Feb.) and 8^{th} MW (19^{th} Jan. - 28^{th} Feb.). The

Table 1. Mean dry matter plant^{-1} (g) and yields as influenced periodically by different treatments

Treatment	Days after sowing				At harvest	Yield (q ha^{-1})	
	30	45	60	75		Seed	Straw
Varieties (V)							
V_1 : Phule til-1	1.50	4.66	6.95	10.21	10.43	9.11	19.89
V_2 : AKT-101	1.57	5.22	7.58	11.02	11.14	10.10	21.84
V_3 : JLT-7	1.42	4.54	6.75	9.56	9.69	8.70	18.30
V_4 : Padma	1.29	4.49	6.61	9.40	9.49	8.51	17.85
SE(m)±	0.023	0.078	1.106	0.132	1.132	0.13	0.19
C.D. at 5%	0.069	0.253	0.319	0.398	1.598	0.41	0.59
Sowing times (S)							
S_1 : 4^{th} Met.week	1.44	4.58	6.84	9.91	10.04	8.79	18.53
S_2 : 6^{th} Met.week	1.50	4.84	7.24	10.45	10.57	9.63	20.93
S_3 : 8^{th} Met.week	1.40	4.76	6.84	9.79	9.95	8.90	19.02
SE(m)±	0.022	0.069	0.109	0.152	0.152	0.08	0.08
C.D. at 5%	0.067	0.208	0.327	0.457	0.457	0.24	0.24
Interaction							
V at same level of S							
SE(m)±	0.045	0.139	0.218	0.0305	0.305	0.16	0.16
C.D. at 5%	N.S.	0.417	N.S.	N.S.	N.S.	0.49	0.48
S at same level of V							
SE(m)±	0.061	0.195	0.293	0.399	0.399		
C.D. at 5%	N.S.	0.434	N.S.	N.S.	N.S.		
Mean	1.44	4.72	6.97	10.04	10.18		

crop was fertilized with 60:40:20 kg NPK ha^{-1}. Full dose of phosphorus and potash was applied at the time of sowing while 50 per cent nitrogen was applied both at sowing and 30 DAS. N, P, K was applied through urea, super phosphate and muriate of potash, respectively. The seeds were sown by dibbling as 2-3 seeds hill^{-1}, the inter row spacing was 45 cm and intra-row spacing was 10 cm. The plants were cut at the ground level and kept for air drying and then in an oven at 60°C temperature till constant weight were obtained. The first sample was collected on the 30th day after sowing and subsequent were collected at an interval of 15 days. The crop was harvested at physiological maturity. After threshing and cleaning, plot^{-1} yield was calculated and reported on hectare basis.

The dry matter accumulation plant^{-1} (Table 1) increased with advancement in crop age. The rate of increment in mean dry matter accumulation plant^{-1} was rapid up to 75 days of crop age and thereafter it was substantially declined. This might be associated with the translocation of assimilated organic constituents towards grain formation.

Effect of varieties : The data presented in Table 1 revealed that dry matter accumulation plant^{-1} was significantly affected by different varieties at all the stages of crop growth i.e. at 30,45,60 and 75 days after sowing and at harvest.The variety AKT-101 reported significantly higher values for dry matter accumulation plant^{-1} (11.14 g) as compared to the variety Padma (9.49 g). AKT-101 has more number of branches as compared to Padma. This might have resulted in increased dry matter production. The similar results were also reported by Kadam (2001), Korhale (2010) and Gade (2012). A variety AKT-101 recorded significantly more seed yield (10.10 q ha^{-1}) as compared to other varieties. Next in order was Phule til-1.This was due to less flower drop, more fruit setting and more number of branches plant^{-1} that helped in production of more number of matured or productive capsules (Table 3). Similar results were reported by Anonymous (1997), Kadam (2001) and Korhale (2010).

Effect of sowing times : The mean dry matter accumulation plant^{-1} increased significantly due to different sowing times. The dry matter accumulation was the highest (10.57 g plant^{-1}) at all the crop growth stages due to more number of branches and leaves when

Table 2. Mean dry matter plant^{-1} (g) as influenced by interaction between varieties and sowing times at 45 days after sowing

Varieties	Sowing times			
	4th MW	6th MW	8th MW	Mean
V_1 : Phule til-1	4.58	4.87	4.53	4.66
V_2 : AKT-101	4.76	5.25	5.64	5.22
V_3 : JLT-7	4.51	4.66	4.46	4.54
V_4 : Padma	4.47	4.58	4.41	4.49
Mean	4.58	4.84	4.76	4.73
	SE(m)±		C.D. at 5%	
V at same level of S	0.139		0.117	
S at same level of V	0.195		0.434	

Table 3. Mean seed yield as influenced by interaction between varieties and sowing times

Sowing times	Seed yield (q ha^{-1})			
	4th MW	6th MW	8th MW	Mean
Varieties				
V_1 : Phule til-1	8.80	9.55	8.97	9.11
V_2 : AKT-101	9.78	10.94	9.57	10.10
V_3 : JLT-7	8.34	8.93	8.84	8.70
V_4 : Padma	8.22	9.12	8.20	8.51
Mean	8.79	9.63	8.90	9.11
Interaction				
SE(m)±	0.16			
C.D. at 5%	0.49			

sesamum was sown during 6th meteorological week. The values were 1.50, 4.84, 7.24, 10.45 and 10.57 g plant^{-1}) at 30, 45, 60, 75 days of crop growth and at harvest, respectively. This finding corroborate the findings of Kadam (2001), Korhale (2010) and Gade (2012). Sowing of summer sesamum at 6th meteorological week recorded significantly maximum seed yield (9.63 q ha^{-1}) over other sowing times (Table 1). This was due to higher fruit setting. Rajib Nath and Chakraborty (2000) also reported the favourable effect of sowing time on seed yield of sesame.

Effect of interaction : The mean dry matter accumulation was not significantly influenced by interaction between varieties and sowing times except at 45 days after sowing (Table 1 and 2). AKT-101 variety produced maximum dry matter plant^{-1} (5.25 g) when it was sown during 6th meteorological week. It was revealed that variety AKT-101 when sown at 6th meteorological week (5th Feb. - 11th Feb.) has maintained its superiority in producing maximum dry matter which is appropriate for sowing summer sesamum. This finding confirms with the findings of Kadam (2001), Korhale (2010) and Gade (2012). The effect of interaction between varieties and sowing times was found significant in respect of seed yield and the relevant data are presented in Table 3. The seed yield of variety AKT-101 was found maximum when sown during 6th meteorological week (10.94 q ha^{-1}) as compared to rest of the sowing times (Table 3). Net in order was similar variety sown in 4th MW. Similar result was observed by Kadam (2001).

Based on the present study it can be concluded that the mean dry matter accumulation plant^{-1} was significantly affected by different varieties and sowing times at all the growth stages. It was revealed that the higher seed and straw yields were recorded with AKT-101 variety when sown during 6th MW (5th Feb. - 11th Feb.) .

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Response of Paddy to Silicon in Inceptisols

Rice is known as silicon accumulator plant and benefits much from silicon nutrition (Takahashi, 1995). Consequently, there is a definite need to consider silicon as an agronomically essential element for increasing and sustaining rice production (Takahashi and Miyake, 1977). Silica is required for healthy and productive development of the rice plant (Lewin and Reimann, 1969). This element is absorbed by rice from the soil in large amounts that are several fold greater than those of other macro-nutrients. On an average, it is estimated that a rice crop producing a total grain yield of about 5 t ha^{-1} will normally remove 230 to 470 kg Si ha^{-1} from soil (Amarasai and Perera, 1975). Rice is having the ability to absorb and accumulate silicon metabolically while many upland crop plants seem to lack such ability.

The field experiment was conducted during *kharif* season of the year 2012 in an Inceptisol at the Agronomy Farm, College of Agriculture Kolhapur by adopting Randomized Block Design. The treatments consisted of four levels of silicon *viz*., 0, 250, 500 and 750 kg Si ha^{-1} which was supplied through Rice Husk Ash (34.2%Si) and Bagasse Ash (27.9%Si) and were replicated four times. The site was selected on the basis of suitability of soil for raising direct seeded rice and having low available silicon (94 ppm). The soil of experimental plot has pH 7.50, EC 0.20 dS m^{-1}, organic carbon 0.80%, available N, P, K and Si and DTP A extractable micronutrients Fe, Mn, Zn and Cu were 272, 20.82, 212.41 and 210.56 kg ha^{-1} and 4.62,1.46,1.62 and 1.48 ppm, respectively. Paddy (Cv. Indrayani) was cultivated by adopting recommended package of practices.

The plant height, total number of productive tillers $plot^{-1}$ and diy matter $hill^{-1}$ of paddy were increased significantly due to silicon application through different sources, however the differences between different sources and levels of silicon were not significant (Table 1). The results revealed that the treatment T_7 recorded significantly highest plant height (76.82 cm) but it was at par with T_4, T_5 and T_6.

The treatment Bagasse ash 750 kg Si ha^{-1} (T_7) recorded significantly highest total number

Table 1. Effect of sources and levels of silicon on growth, yield attributing characters and yield and B:C ratio of paddy

Treatment	Plant height (cm)	Total no. of tillers $hill^{-1}$	Thousand grains wt. (g)	Dry matter $hill^{-1}$ (g)	Grain yield (q ha^{-1})	Straw yield (q ha^{-1})	B:C ratio
T_1 (Control)	68.14	10.96	20.50	22.01	41.21	46.25	1.40
T_2 (RHA250)	73.12	11.82	21.21	23.68	47.43	51.50	1.49
T_3 (RHA500)	73.24	12.27	22.15	23.52	48.66	52.50	1.46
T_4 (RHA750)	75.23	12.30	22.50	23.59	49.12	53.60	1.48
T_5 (BA250)	75.39	11.86	22.20	23.91	49.66	53.84	1.52
T_6 (BA500)	75.84	12.23	22.47	24.53	49.56	53.60	1.50
T_7 (BA750)	76.82	12.35	22.60	24.68	49.82	54.20	1.51
S.E.±	0.90	0.32	0.40	0.25	1.42	1.68	-
C.D.(P=0.05)	2.60	0.98	1.28	0.75	4.23	5.04	-

Table 2. Effect of sources and levels of silicon on silicon uptake by paddy (kg ha^{-1})

Treatment	Uptake of silicon by paddy at different growth stages (kg ha^{-1})			
	Tillers (65 DAS)	Panicle initiation (95 DAS)	Flowering (115 DAS)	At harvest (145 DAS)
T_1 (Control)	51.53	94.34	160.77	179.42
T_2 (RHA 250)	63.87	104.49	176.17	198.74
T_3 (RHA 500)	71.85	111.96	196.77	210.38
T_4 (RHA 750)	74.31	128.76	216.69	224.00
T_5 (BA 250)	77.40	119.65	214.45	227.62
T_6 (BA 500)	75.18	136.52	225.12	251.20
T_7 (BA 750)	81.14	145.73	231.71	262.40
S.E.±	1.32	3.24	3.81	3.86
C.D.(P=0.05)	3.92	9.62	11.34	11.48

of tillers hill^{-1} (12.35) over control (T_1) but it was at par with all other treatments. The dry matter accumulation hill^{-1} at harvest was increased significantly with application of silicon. The dry matter hill^{-1} at harvest significantly highest with treatment T_7 (24.68 g) but it was at par with all other treatments except control (T_1). The grain and straw yields of paddy increased significantly with silicon application. However, the differences between different sources and levels were not significant.

The application of silicon @ 750 kg ha^{-1} through baggase ash recorded significantly highest grain yield (49.82 q ha^{-1}), and straw yield (54.20 q ha^{-1}) and it was at par with all other treatments except control (T_1). These results were in confirmative with those reported by Singh *et al*., (2005), Singh *et al*., (2007), Sawant and Patil (1994) and Patil and Patil (2011), Wader (2013) and Aarekar (2013) also reported increase in growth and dry matter of paddy due to silicon application in the field and pot culture experiment at Kolhapur, respectively.

The silicon uptake of paddy at critical growth stages increased significantly due to silicon application through both the sources of silicon (Table 2). At tillering stage, treatment T_7 recorded highest silicon uptake (81.14 kg ha^{-1}) which was at par with T_5. At panicle initiation stage, significantly the highest silicon uptake was recorded in treatment T_7 (145.73 kg ha^{-1}), however it was at par with treatment T_6. Similar trend of silicon uptake was observed at flowering stage of paddy. The total uptake of silicon at harvest increased significantly with increase in levels of silicon however, significant differences were not observed amongst the different sources at same level of silicon application. The highest total uptake of silicon was recorded in treatment T_7 (262.40 kg ha^{-1})

Table 3. Effect of silicon sources and levels on total uptake of N, P, K, Fe, Mn, Zn and Cu by paddy

Treatment	Total uptake of nutrients (kg ha^{-1})						
	N	P	K	Fe	Mn	Zn	Cu
T_1 (Control)	60.53	13.20	68.80	1.32	0.80	0.72	0.074
T_2 (RHA 250)	73.10	16.55	77.68	1.48	0.88	0.82	0.091
T_3 (RHA 500)	76.54	18.48	81.97	1.50	0.89	0.79	0.100
T_4 (RHA 750)	78.97	19.29	82.77	1.52	0.96	0.78	0.142
T_5 (BA 250)	78.33	18.10	83.29	1.50	0.98	0.88	0.097
T_6 (BA 500)	81.34	19.77	83.46	1.53	0.97	0.84	0.011
T_7 (BA 750)	83.75	20.83	83.49	1.55	0.99	0.82	0.126
S.E.±	1.46	0.43	2.3	0.11	0.19	0.12	0.007
C.D.(P=0.05)	4.34	1.28	6.9	NS	NS	NS	NS

and it was at par with treatments T_6. The increase in uptake of silicon might be due to increased availability of silicon with supply of silicon through both the sources of silicon and its luxury consumption.

The increased total uptake of silicon with increase in levels of silicon were also reported by Dhamapurkar (1999), Similar higher uptake of silicon, than other macronutrient in paddy were reported by Wader (2013) and Aarekar (2013).

The total uptake of nitrogen increased significantly due to the application of silicon in both the sources of silicon *viz*., Rice husk ash and bagasse ash (Table 3). The significantly highest total uptake of nitrogen was recorded in treatment T_7 (83.75 kg ha^{-1}) and it was at par with treatment T_6. The total uptake of P increased significantly due to silicon application. The significantly highest total uptake of P was found with treatment T_7 (20.83 kg ha^{-1}) and it was at par with treatment T6 The highest total uptake of K was found in T7 (83.49 kg ha^{-1}), however it was at par with other treatments except control. The uptake of micronutrients (Fe, Mn, Zn and Cu) was not significantly affected due to different treatments. The increase in uptake of N, P and K due to application of silicon were reported by Talashilkar *et al.,* (2000), Patil and Patil (2011), Wader (2013) and Aarekar (2013).The uptake of micronutrients (Fe, Mn, Zn and Cu) was not significantly affected due to different treatments. Similar beneficial role of silicon in lowering the accumulation of micronutrients like Fe and Mn in paddy were reported by Ma and Takahashi (1990) and Singh *et al*., (2005).

The results of the present investigation indicated that application of silicon @ 250 kg ha^{-1} either through Rice Husk Ash or Bagasse Ash was found to be optimum for increasing growth, yield attributing characters uptake of silicon and macronutrients (N, P, K) by upland paddy in an Inceptisol. However, considering the availability and cost, bagasse ash can be used as good source of silicon for increasing the growth and yield of upland paddy in an Inceptisol of Kolhapur region for upland paddy.

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Effect of NPK Levels on Linseed (*Linum usitatissimum* L.) under Plain Zone of Maharashtra

Linseed (*Linum usitatissimum* L.) is one of the oldest oilseed crop cultivated for its seed and fiber. Linseed is an important *rabi* oilseed crop of India. It is an industrial crop cultivated for its seeds, fibers and oil. All parts of the plant have extensive and varied uses. Fibers obtained from the stem are known for their length, strength and beauty. The oil content of seed varies from 32 to 46 per cent. Linseed oil is found to be comprised of 5 major fatty acids, viz., palmitic, stearic, oleic, linoleic and linolenic.

The productivity of linseed in our country is low compared to world's productivity though there is ample scope for its increased production through optimum use of fertilizer. Linseed responds to N, P and K nutrients very well. The beneficial effect of N, P and K in increasing growth attributes of linseed was reported by several workers (Jain *et al*., 1989). Keeping the above in view the present experiment was conducted.

An experiment was conducted at Agronomy farm, College of Agriculture, Pune during the year of 2011-12 in *rabi* season. The soil of experiment field was clay loam in texture, normal in reaction (pH 7.7) with low available nitrogen (175.4 kg ha^{-1}), medium available phosphorus (29.46 kg ha^{-1}) and high available potassium (460.00 kg ha^{-1}).The experiment was laid out in randomized block design (Factorial) with three level each of nitrogen (N_1 :40, N_2 :60, N3 :80 kg ha $^{-1}$)), phosphorus (P_1: 15, P_2: 30, P3: 45 kg ha $^{-1}$) and potassium (K_1: 0, K_2: 15, K_3: 30 kg ha $^{-1}$) replicated twice. The gross and net plot sizes were 4.00 x 3.00 m^2 and 3.50 x 2.40 m^2, respectively. The linseed variety PKVNL 260 was sown on 3rd December, 2012 with spacing of 30 x 5 cm^2.

The mean plant height of linseed was influenced significantly due to nitrogen levels at all growth phases of crop. The highest plant height was observed in the application of 80 kg N ha^{-1} which was significantly superior over rest of N levels at all the crop growth stages. The increased plant height might be due to more N availability at higher N levels. Similar results were also observed by Dutta (1995), Saumi *et al*., (1995) and Dubey (2001). Effect of nitrogen levels on number of branches $plant^{-1}$ and plant spread of linseed was non significant. The significantly higher dry matter of linseed was registered in 80 kg N ha^{-1} which was significantly superior to rest of N levels. Similar results were also observed by Mishra and Singh (1996) and Singh *et al*., (1999).

The significantly maximum and minimum capsules $plant^{-1}$ and number of seeds capsule^{-1} were recorded with 80 and 40 kg N ha^{-1}, respectively. The difference might be due to N being the component of proteins and protoplast could stimulate the growth and fruiting of linseed crop, adequate application increased availability of N in soil and N uptake by crop. Similar results were also observed by Dutta *et al*., (1995), Saumi *et al*., (1995) and Dubey *et al*., (1997).

The mean seed weight plant^{-1} of linseed was significantly higher in 80 kg N ha^{-1} than 40 kg N ha^{-1}, 60 kg N ha^{-1} being statistically at par with the former. The increase in seed weight plant^{-1} might be due increased availability of N in soil and N uptake by crop. The mean test weight of linseed was significantly higher in 80 kg N ha^{-1} over 40 kg N ha^{-1} but was at par with 60 kg N ha^{-1} level. The increase in test weight might be due to increase availability of N in soil and N uptake by crop. Similar results were also observed by Rajput and Gautam (1993), Reddaih *et al*., (1993), Dutta *et al*., (1995) and Saumi *et al*., (1995).

The mean plant height of linseed was influenced significantly due to phosphorus levels at all growth phases of the crop. The tallest plant, were observed with 45 kg P_2O_5 ha^{-1} which was at par with 30kg P_2O_5 ha^{-1} and significantly superior over 15 kg P_2O_5 ha^{-1} .This may attributed to more P availability at higher P levels. Similar result were also observed by Rajput and Gautam (1993) and Pali and Tripathi (2000). Effect of phosphorus levels on number of branches plant^{-1} and plant spread of linseed was non significant.

The dry matter plant^{-1} of linseed was

Table 1. Growth and yield attributes of linseed as influenced by different N, P and K levels

Treatment	Plant height (cm)	Plant spead (cm)	No. of bran-ches plant^{-1}	Dry matter plant^{-1}	No. of capsules plant^{-1}	No. of seeds capsule^{-1}	Seed weight plant^{-1} (g)	Test weight (g)
Nitrogen levels (kg ha^{-1})								
N_1 : 40	49.96	15.12	2.62	5.57	32.33	8.42	1.52	7.82
N_2 : 60	54.75	16.70	2.74	6.31	40.61	8.84	2.21	8.18
N_3 : 80	61.66	17.41	2.93	6.91	45.81	10.0	2.67	8.42
S.E. m ±	0.71	0.42	0.08	0.18	1.20	0.24	0.20	0.10
C.D. at 5%	2.13	NS	NS	0.53	3.60	0.73	0.60	0.30
Phosphorus levels (kg ha^{-1})								
P_1 : 15	54.00	15.61	2.70	5.93	37.48	8.37	1.53	7.86
P_2 : 30	55.50	15.97	2.77	6.32	39.77	8.77	2.17	8.17
P_3 : 45	56.81	16.49	2.82	6.50	41.51	9.32	2.39	8.25
S.E. m ±	0.71	0.42	0.08	0.18	1.20	0.24	0.20	0.10
C.D. at 5%	2.13	NS	NS	0.53	3.60	0.73	0.60	0.30
Potassium levels (kg ha^{-1})								
K_1 : 0	52.56	15.61	2.74	5.84	37.58	8.62	1.68	7.92
K_2 : 15	55.48	15.95	2.76	6.26	39.76	8.88	2.14	8.15
K_3 : 30	55.77	16.00	2.78	6.51	41.32	9.50	2.40	8.40
S.E. m ±	0.71	0.42	0.08	0.18	1.20	0.24	0.20	0.10
C.D. at 5%	2.13	NS	NS	0.53	3.60	0.73	0.60	0.30
Interaction	NS	NS	NS	Sig.	Sig.	NS	NS	NS
General Mean	55.16	16.09	2.76	6.26	39.58	8.96	2.07	8.13

influenced significantly due to various P_2O_5 levels. The significantly higher dry matter of linseed was registered in 45 kg P_2O_5 ha^{-1} which was at par with 30 kg P_2O_5 ha^{-1} but significantly superior to rest P levels. The dry matter accumulation is the result of all growth and yield attributes *viz*., plant height, number of branches plant^{-1}, plant spread and yield attributes.

The mean number of capsules plant^{-1} and number of seeds capsule^{-1} were significantly higher in 45 kg P_2O_5 ha^{-1} than in 15 kg P_2O_5 ha^{-1} but the former was at par with 30 kg P_2O_5 ha^{-1} level. The difference in the increased in number of capsules plant^{-1} and number of seeds capsule^{-1} in linseed might be due to increased availability of P in soil and P uptake. Similar results were also observed by, Rajput and Gautam (1993), Dubey *et al*., (1997) and Singh and Verma (1997). The mean seed weight plant^{-1} and test weight were significantly higher in 45 kg P_2O_5 ha^{-1} than 15 kg P_2O_5 ha^{-1}, 30 kg P_2O_5 ha^{-1}was statistically at par with the former. The increased seed weight plant^{-1} and test weight in linseed might be due to increased availability of P in soil and P uptake in the plant. Similar results were also observed by Rajput and Gautam (1993) and Pali and Tripathi (2000).

The highest plant height and dry matter were observed with the application of 30 kg K_2O ha^{-1} which was significantly superior over 0 kg K_2O ha^{-1} and at par with 15 kg K_2O ha^{-1} at all the crop growth stages. This may be attributed to more K availability at higher K level. Rajput and Gautam (1993), Pali and

Table 2. Yield , oil content and economics of linseed as influenced by different N, P and K levels

Treatment	**Seed yield**	**Straw yield**	**Oil content in seed**	**Gross monetary returns (Rs. ha^{-1})**	**Cost of cultivation (Rs. ha^{-1})**	**Net monetary returns (Rs. ha^{-1})**	**B:C ratio**
Nitrogen levels (kg ha^{-1})							
N_1 : 40	11.03	23.75	38.77	49635	26994	20101	1.83
N_2 : 60	15.23	27.91	39.35	67594	27107	38149	2.49
N_3 : 80	17.23	30.62	39.59	75419	27220	45729	2.77
S.E. m ±	0.75	1.10	0.03	294.79	-	294.79	-
C.D. at 5%	2.25	3.30	NS	860.31	-	860.31	-
Phosphorus levels (kg ha^{-1})							
P_1 : 15	12.68	25.04	39.16	60766	26889	32071	2.25
P_2 : 30	14.43	27.63	39.25	64069	27009	34623	2.32
P_3 : 45	16.38	29.60	39.31	67814	27129	37285	2.49
S.E. m ±	0.75	1.10	0.03	294.79	-	294.79	-
C.D. at 5%	2.25	3.30	NS	860.31	-	860.31	-
Potassium levels (kg ha^{-1})							
K_1 : 0	12.30	24.00	39.21	63195	26769	34080	2.36
K_2 : 15	14.35	28.00	39.23	63997	27033	34415	2.36
K_3 : 30	16.76	29.20	39.27	65482	27298	35484	2.39
S.E. m ±	0.75	1.10	0.03	294.79	-	294.79	-
C.D. at 5%	2.25	3.30	NS	860.31	-	860.31	-
Interaction	Sig.	Sig.	NS	NS	-	NS	-
General Mean	14.49	27.42	39.24	64216	27049	34659	2.36

Tripathi (2000) observed similarly. Effect of potassium levels on the number of branches plant^{-1} and plant spread of linseed were non significant.

The mean number of capsules plant^{-1}, number of seed capsule^{-1} , seed weight plant^{-1} and test weight of linseed at 30 kg K_2O ha^{-1} were found to be significantly superior over 0 kg K_2O ha^{-1} but was at par with 15 kg K_2O ha^{-1} level. Rajput and Gautam (1993) and Pali and Tripathi (2000) and Dubey (2001) also similarly observed .The seed yield of linseed was influenced significantly due to N levels. The maximum seed yield was recorded with 80 kg N ha^{-1} (17.23 q ha^{-1}) which was at par with 60 kg N ha^{-1} (15.23 q ha^{-1}) but significantly superior over 40 kg N ha^{-1}. The N level 40 kg ha^{-1} recorded the significantly lowest seed yield (11.03 q ha^{-1}). The increase in seed yield might be due to significant increase in growth and yield attributes as discussed above. Similar results were also observed by Dutta *et al*., (1995), Saumi *et al*., (1995), Dubey *et al*., (1997).

The straw yield of linseed was influenced significantly due to N levels. The straw yield was maximum in 80 kg N ha^{-1} (30.62 q ha^{-1}) which was at par with 60 kg N ha^{-1} (27.91 q ha^{-1}) but significantly superior over 40 kg N ha^{-1}. The N level 40 kg ha^{-1} recorded the significantly lowest straw yield (23.75 q ha^{-1}). The increased straw yield might be due to significant increase in vegetative growth of plants ultimately reflects in dry matter. Similar results were also reported by Dutta *et al*., (1995), Saumi *et al*., (1995), Dubey *et al*., (1997).

Effect of nitrogen levels on oil content in seed was not significant. The maximum of gross and net monetary returns were observed in N level of 80 kg ha^{-1}. This level gave higher yield which ultimately increased the gross and net monetary returns and B:C ratio. Similar results were also reported by Agrawal *et al*., (1997) Singh and Verma, (1997).

The seed yield of linseed influenced significantly due to P levels. The seed yield was significantly higher in 45 kg P_2O_5 ha^{-1} (16.38 q ha^{-1}) over 15 kg P_2O_5 ha^{-1} and was at par with 30 kg P_2O_5 ha^{-1} (14.43 q ha^{-1}). The straw yield showed similar trend . The P level 15 kg ha^{-1} recorded significantly lower straw yield (25.04 q ha^{-1}). The increase in seed and straw yield might be due to significant increased in growth and yield attributes owing to more availability of phosphorus. Dubey *et al*., (1997), Singh and Verma (1997) observed similarly. Difference in oil content of linseed was not significant due to different levels of P. The maximum and minimum gross and net monetary returns were observed with 45 and 15 kg ha^{-1}. This level gave higher yield which ultimately increased the gross and net monetary returns and B:C ratio. Similar results were also reported by Agrawal *et al*., (1997) Singh and Verma, (1997). The seed yield of linseed was influenced significantly due to K levels. The seed yield was significantly higher in 30 kg K_2O ha^{-1} (16.76 q ha^{-1}) superior than rest of the levels. The lowest seed yield (12.30 q ha^{-1}) of linseed was recorded with application of 0 kg K_2O ha^{-1}. The straw yield was higher in 30 kg K_2O ha^{-1} (29.20 q ha^{-1}) which was statistically at par with 15 kg K_2O ha^{-1} (28.00 q ha^{-1}) and significantly superior over 0 kg K_2O ha^{-1} which recorded lower straw yield (24 q ha^{-1}). The increase in seed and straw yield might be due to significant increased in growth and yield attributes owing to more availability of potassium. Similar result was also recorded by Singh and Verma (1997). Effect of potassium levels on seed oil content was not significant. The gross and net monetary returns were significantly influenced by K levels. The significantly highest gross and net monetary returns were observed in 30 kg K ha^{-1}. Similar results were also reported by Agrawal *et al.*, (1997) Singh and Verma, (1997).

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Varietal Evaluation to Identify Promising Potato Varieties for Pune Region

Potato is one of the world's most important non- cereal horticultural food crop. India has taken a giant leap in increasing potato area and production since independence. Compared to 1949-50 the establishment of CPRI, when the total production was 1.54 million tons from an area of 0.234 million ha. We now (2011-12) produce 41.328 million tons of potato from 1.89 million ha area. Currently the national average productivity of 29.68 t ha^{-1} in Gujarat followed by West Bengal. Potato being largely a vegetatively propagated crop it is susceptible to large number of seed borne diseases responsible for degeneration of seed stocks over the year. It is imperative to use promising potato varieties for economic production.

The present investigation on varietal evaluation to identify promising potato varieties for Pune region was initiated in October 2013 at AICRP on Potato, NARP, Ganeshkhind Pune. Potato tubers of *Kufri* Lauvkar, Badshah, Pukhraj were planted at 60 x 20 cm distance on ridges and furrows on 20th Oct 2013.

Fertilizers @ 150 kg N in the form of urea, 60 kg P_2O_5 in the form of Single super phosphate and 120 kg K_2O in the form of murate of potash ha^{-1} were applied. The other cultural operations such as weeding, irrigation, spray of insecticide, earthing up etc. were carried out as and when required for all the treatments uniformly.

Observation on growth characters such as plant emergence, plant vigour, mean canopy and foliage senescence were recorded for six randomly selected plants from each net plot at regular intervals from planting. The data in respect of yield such as total yield, marketable yield, weight of rotten tubers, dry matter (%) was recorded and is presented in Table-1.

The result presented in Table-1 revealed that growth, in respect of per cent plant emergence was found to be the maximum in *Kufri* Surya (95.56 %) followed by *Kufri* Jyoti (94.07) and *Kufri* Pushkar (93.33%) which were at par with each other. However the result related with per cent foliage senescence were found to be non significant. The growth in respect of yield, depicted that *Kufri* Surya recorded the maximum marketable yield (22.33 t ha^{-1}) as well as total tuber yield (23.02 t ha^{-1}) followed by *Kufri* Pukharaj with marketable yield of 20.24 t ha^{-1} and total yield of 20.69 t ha^{-1}. These results are in agreement with those of Basawaraja *et al.,* (2009).

The variety *Kufri* Lauvkar produced lowest yield (17.83 t ha^{-1}) and total tuber yield (18.19 t ha^{-1}). The result in respect of tuber rottage and tuber dry matter were non significant. Incidence of early blight (3.18%) and late blight (3.42%) was significantly lowest in *Kufri* Surya. All the varieties under study were free from viral diseases. These result are in agreement with those reported by Benargi and Naik (2009).

Table 1. Plant emergence, yield of potato tubers, tuber dry matter and disease reactions of promising varieties (Rabi, 2012)

Treatment	Plant emergence (%)	Foliage senescence (%)	Marketable tuber yield		Unmarketable tuber yield		Tuber rottage		Total tuber yield		Tuber dry matter (%)	Disease reaction PDI		
			kg $plot^{-1}$	t ha^{-1}	kg $plot^{-1}$	t ha^{-1}	kg $plot^{-1}$	t ha^{-1}	kg $plot^{-1}$	t ha^{-1}		Late blight	Rarly blight	Viral diseases
K. Lauvkar	89.63	86.00 (69.66)	16.05	17.83	0.17	0.19	0.15	0.17	16.37	18.19	17.31	16.79 (4.16)	16.67 (4.14)	0
K. Badshah	84.07	82.67 (66.09)	17.43	19.37	0.31	0.34	0.23	0.26	17.97	19.97	17.89	12.72 (3.63)	11.11 (3.41)	0
K. Pushkar	93.33	81.33 (64.60)	16.32	18.13	0.34	0.38	0.25	0.28	16.91	18.79	18.00	18.40 (4.34)	16.17 (4.08)	0
K. Surya	95.56	80.67 (64.20)	20.10	22.33	0.38	0.43	0.23	0.26	20.72	23.02	18.27	11.23 (3.42)	9.63 (3.18)	0
K. Khyati	85.19	81.67 (64.90)	17.05	18.94	0.14	0.15	0.23	0.26	17.42	19.36	17.83	15.56 (4.00)	14.07 (3.82)	0
K. Ashoka	89.26	76.67 (61.23)	17.15	19.06	0.21	0.24	0.18	0.19	17.54	19.49	17.84	17.16 (4.18)	15.06 (3.94)	0
K. Jyoti	94.07	77.33 (61.94)	16.17	17.96	0.24	0.27	0.23	0.26	16.64	18.49	17.39	21.23 (4.62)	22.10 (4.75)	0
K. Pukhraj	85.93	77.00 (61.80)	18.22	20.24	0.25	0.28	0.15	0.17	18.62	20.69	18.59	20.86 (4.66)	19.75 (4.50)	0
SE±	2.60	4.39	0.59	0.66	0.02	0.02	0.4	0.4	0.60	0.67	1.50	0.15	0.11	-
CD at 5%	7.88	N.S.	1.80	2.00	0.06	0.07	N.S.	N.S.	1.82	2.02	N.S.	0.44	0.33	-

Keeping in view the marketable tuber yield, total tuber yield and the disease reaction towards early and late blight, it can be recommended that *Kufri* Surya is a promising variety for Pune region.

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Effect of Sowing Time and Methods on Wheat Production

It is believed that Wheat originated in south western Asia from where it spread to other parts of Asia, Europe, Africa and America (Yongqing, 2005). It is one of the important staple cereal crops of India. Low grain yield could be obtained due to the inappropriate planting method, seed rate and crop management. In India, wheat is planted through broadcasting on a large area after harvesting of rice and cotton. Broadcasting not only requires higher seed rate but also results in lower plant population due to improper placement of seed in soil, where as drill sowing method is recommended because of its uniform seed distribution and sowing at desired depth, which usually results in higher germination and uniform stand. A key factor in the highest wheat production is the understanding of early crop establishment. Beside other agronomic factors seed rate and sowing method are major factors which determines the crop vigor and ultimate crop yield (Korres and Williams, 2002). Usually low yields are obtained by conventional methods of wheat planting. For a rapidly growing population of the country, the food security seems under threat by yield stagnations. Wheat production systems are already at risk due to other problems *viz*., ground water depletion, water logging and salinity, deteriorating soil physical conditions and declining soil organic matter content etc. (Hafiz *et al*., 2010).

Agriculture sector, whether in developing or developed countries, depends on climate and climatic resources (Watson *et al*., 1995) leading to the development of special consideration for this sector to study the impacts of climate change. The Intergovernmental Panel on Climate Change (IPCC) and other researchers have stressed the need to study the impacts on agricultural production at local, regional, national and on global scales to capture the local conditions (Freckleton *et al*., 1999). Projecting future crop yields has significant uncertainty due to changed fertilizer and water application strategies, occurrence of extreme climatic events, changes in pest and disease occurrence (Ewert, 2002, Fuhrer, 2003). Considering the above facts a experiment was concluded with the main intention to find out suitable sowing method and sowing period under changing climate situations.

A field experiment on sowing time and sowing methods for wheat was conducted at Agricultural Research Station, Niphad, Dist. Nasik (MS) during 2010-11 to 2012-13. The experiment was laid out in split plot design with 3 replications. Main treatment comprised of sowing periods which was D_1 - 15th November, D_2 - 01st December, D_3 - 15th December, D_4 - 01st January and D_5 - 15th January. The sub treatment was sowing methods which included S_1 - sowing at 22.5 cm, S_2 - sowing at 18.0 cm, S_3 - Cross sowing at 22.5 cm, S_4 - Cross sowing at 18 cm and S_5 - Broadcasting. Recommended dose of fertilizers (90:60:40 $N:P_2O_5:K_2O$ kg ha^{-1}) was applied uniformly to all treatments. NIAW 34 wheat variety was used for the said experiment. As a preceding crop in the *kharif* season, soybean was taken as a general crop. The soil of the experimental site was clayey in texture having pH 8.81, EC 0.53 dSm^{-1}, medium in organic carbon (0.52 per cent), low in nitrogen (257 kg ha^{-1}), medium in phosphorous (22 kg ha^{-1}) and very high in potassium (651 kg ha^{-1}).

Table 1. Pooled grain, straw yields and ancillary data of wheat as influenced by sowing time and method

Treatment	Pooled yield (q ha^{-1})		% reduction in grain yield over timely sowing	No. of earhesds per sq meter	No. of grains $earhead^{-1}$	Thousand grain weight (g)
	Grain	Straw				
A) Main plot (Sowing periods)						
D_1 - 15th Nov.	44.59	65.47	-	396.13	45.31	38.65
D_2 - 1st Dec.	44.88	66.35	-	400.53	45.55	39.50
D_3 - 15th Dec.	42.16	61.17	6.06	389.03	45.02	38.88
D_4 - 1st Jan.	36.96	52.95	17.65	379.14	43.53	37.39
D_5 - 15th Jan.	30.13	44.12	32.87	372.95	42.00	37.19
SE±	1.04	1.90	-	-	-	-
C.D. at 5%	2.43	4.44	-	-	-	-
B) Sub plot (Sowing methods)						
S_1 - 22.5 cm row spacing	47.17	68.66	-	400.18	44.32	40.78
S_2 - 18 cm row spacing	43.70	64.06	-	395.34	45.93	40.08
S_3 - Cross Sowing (22.5 cm)	38.37	55.16	-	388.16	44.16	37.10
S_4 - Cross Sowing(18 cm)	37.76	54.48	-	380.20	43.71	36.37
S_5 - Broadcasting	31.72	47.70	-	373.90	43.33	37.28
SE±	0.70	1.23	-	-	-	-
C.D. at 5%	1.43	3.50	-	-	-	-
C) Interaction (A x B)						
SE±	1.57	2.75	-	-	-	-
C.D. at 5%	NS	NS	-	-	-	-

Sowing of wheat at appropriate time is the key factor in grain production. In this experiment, sowing of wheat at 1st December produced significantly higher grain yield (44.88 q ha^{-1}) and straw yield (66.35 q ha^{-1}) which was at par with 15th November sowing over rest of the treatments (Table 1). The number of earheads per square meter (400.53), number of grains $earhead^{-1}$ (45.55) and thousand grain weight (39.50) were higher for the sowing of 1st December over other treatments (Table 2). Soomro (2009) reported that all growth and yield parameters were significantly affected by the sowing methods and seed rates. The interaction of sowing methods and seed rates significantly effected on spikes per plant and grains per spike, while other characters showed non significant interactions. Wheat sown by drilling method at the seed rate of 150 kg ha^{-1} significantly increased the plant vigor and yield. Idnani and Kumar (2013) revealed that the FIRBS planting and irrigation at CRI stage + 100 mm CPE registered significantly highest grain yield, straw yield, harvest index, net return, benefit: cost ratio, cumulative infiltration, N, P and K uptake. Rath *et al*., (2000) conducted the experiment on methods of wheat cultivation and observed that conventionally sown wheat produced 10-13 per cent and 28-35 per cent higher grain yield than raised bed and zero tillage-sown wheat, respectively.

As regards sowing method, wheat sown at 22.5 cm row spacing produced significantly higher grain yield (47.17 q ha^{-1}) and straw yield (68.66 q ha^{-1}) over other treatments of spacing (Table 1). As regards ancillary data, number of earheads per square meter (400.18) and thousand grain weight (40.78) were higher at 22.5 cm spacing. While number of grains $earhead^{-1}$ (45.93) were higher for the sowing of 1st December (Table 2). Mohammad, 2001 reported significantly higher grain yield of wheat due to line sowing method of cultivation over broadcasting and other methods. Naresh *et al*., 2014 reported the results over the years of the study that, the germination were statistically at par in drill sowing at 17.5 cm apart rows and broadcasting. Better plant height was noted in drill planting with 17.5, 20 cm rows and 15:25 cm paired rows. However, number of spikelets $spike^{-1}$ and number of grains $spike^{-1}$ were statistically similar in drilling at 17.5, 20, and 15:25 cm paired apart rows. Similarly, 1000 grain weight was recorded in drill sowing at 20 cm and 15:25 cm paired rows. The maximum grain yield was obtained through 15:25 cm paired rows drill planting method and it was statistically at par with drill planting method where row spacing was 20 cm.

After three years of the experimentation, it was observed that, sowing of wheat upto 1st December had no yield reduction as compared with timely sowing (15th November). However, as the sowing of wheat delayed upto 15th January, 32.87 per cent losses in the grain yield were observed. It means that under changed climatic situations, sowing of wheat can be done upto 1st December. In case of sowing methods, sowing of wheat at 22.5 cm produced significantly higher grain yield over rest of the methods.

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Utilization of Date (*Phoenix dactylifera* L.) in the Manufacturing of Khoa Burfi

Milk has been recognized as a complete food by nutritionists all over the world. The milk production is growing at an appreciable rate of 4.5-6 per cent against world average of about one per cent (Dairy India Yearbook, 2007). Globally; India with its 132.4 million metric tones milk production enjoys numero uno position in terms of milk production. However, it lags behind when it comes to processing milk for tradable products. At the same time, the world is eyeing India as their future market.

Among the heat dessicated milk products, *khoa*- a versatile intermediate concentrate that is base material for wider range of sweetmeats like peda, burfi, gulabjamun etc. The unique adaptability of khoa in its flavour, body and texture blend with a wide range of food adjust provides an impressive array of burfi varieties.

Herbal sweet preparation is a new concept in dairy industry. Similar to milk, honey and grapes, date (*Phoenix dactylifera* L.) are considered, a good source of nutrients. Date are widely used in bakery and confectionery. They are made into jams and preserves or added in cakes and in dishes with milk, butter, meat etc.

Utilization of date in burfi as an additive can be considered as a novelty product and a nutritious sweetmeat.

The research work was carried out at the Department of Animal Husbandry and Dairy Science, College of Agriculture, Dapoli, Dist-Ratnagiri during the year 2011-2012. Fresh buffalo milk was procured from the Dairy unit of this college. Ingredients like sugar, dates were purchased from the local market. Khoa was prepared as per the standard procedure given by De (2008).

Preparation of date paste : The fresh dates (black) were washed and cleaned. The fruits were deseeded and cut into small pieces. The paste was prepared by using electrically operated mixer cum grinder using small quantity of milk. For 250 gm of deseeded dates, 375ml of milk was found sufficient to obtain fine quality date paste.

Preparation of date khoa burfi : After receiving of milk, it was filtered and kept for continuous heating at 55° to 60°C. and then boiling with continuous stirring/scrapping. When viscous product with paste/semisolid consistency was obtained heat was reduced and recommended amount of sugar and date paste as per treatments were added and properly stirred and noticed to obtain khoa burfi mass. Burfi mass was then well spread in greasy tray and kept for cooling/setting for 6 to 8hrs. The burfi was cut into desirable size and shapes of pieces and stored as per recommended packaging material.

The date khoa burfi was prepared with treatments *viz*., T_0 - control (No date paste) as well T_1 T_2, T_3 and T_4 with 5, 10, 15 and 20 per cent date paste of milk, respectively. The sugar was used @ 5 per cent of milk for all the treatments. The trial was conducted with six replications.

The product was analyzed for chemical constituents like total solids, fat, protein, ash and titratable acidity by adopting ISI procedures. The burfi samples were judged for sensory attribute such as colour and appearance, body and texture and flavour. Sensory evaluation was done with nine point hedonic score card by number of ten semi trained judges and then compared statistically to taste the significance difference by "Friedman's" taste of significance by adopting ISI procedures.

Cost economics was worked out by taking into account the prevailing market or prices of the ingredients only. The data was statically analyzed adopting randomized block design with five treatments and six replications.

Total solids content of burfi increased with the increase in the level of date (Table 2). The maximum total solids content (88.72%) was noticed in burfi sample with 20 per cent date (T_4), whereas the lowest (78.44%) was recorded in burfi without date (T_0).

Table 1. Chemical quality of buffalo milk and date

Contributes	Buffalo milk (%)	Date (%)
Total solids	15.43	73.56
Fat	6.14	0.57
Protein	3.70	2.90
Ash	0.87	1.87
Acidity	0.14	-

Table 2. Chemical quality of date burfi

Treat-ments	Total soilds (%)	Fat (%)	Protein (%)	Ash (%)	Acidity (%)
T_0	78.44	23.83	16.11	3.52	0.383
T_1	81.78	23.88	16.32	3.73	0.386
T_2	83.92	23.92	16.53	3.83	0.395
T_3	86.12	23.97	16.79	3.90	0.406
T_4	88.72	24.02	16.95	4.02	0.411
SEI	0.156	0.028	0.079	0.075	0.005
CD	0.460	0.082	0.233	0.220	0.014

The simultaneous increase from T_0 to T_4 may be due to high amount of total solids content of date than khoa. The per cent total solids values of present investigation are well comparable with the value reported by Sakate (2000), Kolhe (2003) and Kumbhar (2011) as 80.30 to 85.29, 85.86 to 89.88 and 85.23 to 89.39 per cent total solids, respectively.

The mean value of fat increased gradually from to T_0 to T_4. The highest fat content (24.02%) was observed in burfi prepared with 20 per cent date (T_4), whereas the lowest (23.83%) in case of burfi without date (T_0).

Incorporation of date increased the fat content of burfi. The increasing trend of fat content can be attributed to the fact that the milk taken for khoa was in the same quantity for all treatments and date paste added as over and above as per treatment at pat formation stage. Due to very low amount of fat in date (0.57%) there may be slight increased trend in fat content of burfi.

The result are in accordance with those of Ghodekar and Dudhani (1982), Rajorhia and Sen (1987) and Reddy and Rajorhia (1992) who observed 27.10, 8.80 to 27.00 and 4.10 to 26.80 per cent fat in burfi samples.

There was increase in protein content of burfi with the increase in the level of date. The highest protein content (16.95%) was observed in burfi with 20 per cent date (T_4), whereas the lowest protein content (16.11%) in case of burfi without addition of date (T_0).

The data revealed that addition of date gradually increases the protein content of burfi. Mandokhot and Garg (1985) studied market quality of burfi and peda samples and observed 14.00 to 20.30 per cent protein in burfi. Reddy and Rajorhia (1990) studied on equilibrium relative humidity of khoa based sweets (Peda and Burfi) and recorded protein content varied from 14.00 to 20.30 per cent.

The increase in the level of date resulted in significant increase in ash content of burfi. The highest ash content (4.02%) was observed in burfi samples prepared using 20 per cent date, whereas the lowest (3.52%) in case of control burfi (T_0) i.e. without addition of date.

The increase in the titratable acidity of burfi was observed to be within a range which varied from 0.44 to 0.46 per cent. Higher acidity (0.46%) was recorded in burfi prepared with 20 per cent date whereas lowest (0.44%) was in case of control burfi i.e. without addition of date (T_0).

The values of titratable acidity of present investigation are with the values mentioned by Sakate (2000), Solanki *et al.,* (2002) and Gargade (2004) who reported 0.28 to 1.20, 0.41 and 0.40 per cent acidity for burfi.

Table 3. Sensory quality of date burfi

Treatments	**Colour and appearance**	**Body and texture**	**Flavour**	**Overall acceptability**
T_0	7.34	6.81	7.20	7.11
T_1	7.86	7.39	7.43	7.56
T_2	7.88	7.49	7.55	7.64
T_3	7.53	7.32	7.26	7.37
T_4	7.34	7.23	7.21	7.26
$T_{Tsb.}$	9.49	9.49	9.49	9.49
$T_{cal.}$	7.005	11.955	10.14	10.536

Table 4. Production cost of date burfi

Treatments	**Production cost (Rs. kg^{-1})**
T_0	125
T_1	130.87
T_2	133.62
T_3	136.02
T_4	138.20

Sensory Evaluation : The highest score for colour and appearance (7.88), body texture (7.49) and flavour (7.55) was recorded in T_2 i.e. burfi blended with 10 per cent date.

The most acceptable product in the present study was observed to be the burfi prepared by addition of 10 per cent date (T_2) with overall acceptable score of 7.64 followed by burfi with 5 per cent date (T_1) scoring 7.56, while the significantly lowest score (7.11) was obtained by burfi without addition of date i.e. control treatment (T_0). The overall acceptability score indicates that burfi samples incorporated with 10 per cent date is superior over rest of treatments. However, date @ 5 per cent can also produce good quality burfi. Higher level of date i.e. 15 and 20 per cent showed reduction in sensory quality score for burfi.

Cost of production : The cost of ingredients only was taken to indicate the cost of burfi production. Increase in the level of date was observed to be increased in the production cost of burfi. The cost of burfi production at T_0, T_1, T_2, T_3 and T_4 was Rs. 125.00, 130.87, 133.62, 136.02 and 138.20 kg^{-1}, respectively. The cost of burfi production of most acceptable level (T_2) was 133.62 kg^{-1}.

From the results of the present investigation, it may be concluded that date fruit could be successfully utilized for the manufacturing of burfi. The most acceptable quality burfi can be prepared by using 10 per cent date. Such replacement did not affect appreciably the composition of burfi. Date had a positive effect on sensory attributes of burfi on its acceptability and consumption. Besides typical flavour, it also adds nutritional properties to the product.

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J. Agric. Res. Technol., 40 (3) : 541-544 (2015)

Effect of Pretreatments on Dehydration of Green Chilli (*Capsicum annum* L.)

The increasing demand of processed ready to eat and ready to cook products has resulted in growing industry of Indian spices. Dehydrated and chemically pretreated green chilli powder has extended shelf life and can easily be incorporated in various homemade recipes like red chilli powder. Chilli is used to impart a peculiar taste, flavour and colour in addition to providing pungency to the cooked vegetable into different product such as dried chilli, pickle, powder, paste, sauce can be prepared for higher returns to almost all chilli growers. Dried chilli products are used as component for various vegetable and spicy dishes. There are no much reports on preparation of green chilli powder with reduced browning. Therefore the present study was undertaken with the objective to study the effect of pretreatments on drying of green chill.

The present study was conducted in the Department of Horticulture, VNMKV, Parbhani during 2011. The freshly harvested green chillies of Pusa Jwala variety were purchased from a local farmer of Nanded. The selected chillies were fresh, uniform, sound and mature. Fresh fruits were washed with running tap water to remove any adhering dust particles, dirt etc. The fruits were destalked manually. The selected chillies were cut into 1.5 cm, 3 cm and as a whole with the help of sharp knife. Seven treatment combinations of pretreatment i.e. whole chilli and chilli pieces by T_1 - Whole fruit + Hot water treatment at 100°C for 3 min, T_2 - Whole fruit + Hot water + 0.25% $MgCO_3$ at 100°C for 3 min, T_3 - Piece of 1.5 cm of Chilli + Hot water treatment at 100°C for 3 min, T_4 - Piece of 1.5 cm of Chilli + Hot water + 0.25% $MgCO_3$ at 100°C for 3 min, T_5 - Piece of 3 cm of Chilli + Hot water treatment at 100°C for 3 min, T_6 - Piece of 3 cm of Chilli + Hot water + 0.25% $MgCO_3$ at 100°C for 3 min. and T_7 - Control were undertaken. The chillies were blanched in hot water at 100°C for 3 min. in 0.25% $MgCO_3$ and 0.1% KMS were used as preservative which were dissolved in hot water and 1 liter of solution of each chemical was prepared for each treatment. One of the samples was pretreated with hot water, second was treated with 0.25% $MgCO_3$ at 100°C for three minutes. Pretreated chillies were then surface dried and transferred to the drying in the hot air oven at temperatures 60°C for each treatment. The sample was placed in a single layer on the trays and drying trays were rotated from time to time to get the uniform drying. The prepared sample was packed in 100 gauge HDPE polythene bags, then sealed and stored for 90 days. The dried product was kept for further analysis.

The physiochemical parameters *viz*., pH, moisture (%), total ash (%), titratable acidity (%) and rehydration ratio of dried chilli were studied while sensory evaluation was done based on colour, taste and overall acceptability of dried chilli. The data obtained in the present investigation were analyzed as suggested by Panse and Sukhatme (1995). The critical difference C.D. at 5 per cent level of probability was used for comparing difference between treatments.

The data pertaining to the pH content of chilli as influenced by various pretreatments (Table1) revealed that pH of chilli varied significantly during 90 days of storage with different pretreatments under study. The pH values differed significantly with various pretreatments and it was in the range of 4.97

to 5.45 with the mean of 5.23. Significantly, more pH (5.45) was recorded in treatment T_4 (Piece of 1.5cm of Chilli + Hot water + 0.25% $MgCO_3$ at 100°C for 3 min) followed by T_2. Significantly, less pH was recorded in treatment T_3 (4.97), while observing pH of dried chilli, it was increased after processing but in storage it was decreasing. One of the major reasons was increased acidity due to drying and in storage it was decreasing. However, during 90 days of storage, increasing trend of pH was observed. Similar result was noticed by Giridhar *et al.*, (1996) in garlic and ginger.

Titrable acidity (%) of dried chilli significantly varied due to different pretreatments, storage and their interaction (Table1). Further, decreasing trend of acid content was observed during the storage among all the treatment combinations. The highest acidity (1.80%) was noticed in treatment of piece of 1.5cm of Chilli + Hot water treatment at 100°C for 3 min. The lowest titrable acidity (1.36 %) was found in the samples of Whole fruit + Hot water + 0.25% $MgCO_3$ at 100°C for 3 min. A decline in titrable acidity during storage might be due to reaction of acids with minerals present in the dried chilli product or might be due to other biochemical interactions resulting in binding of acids with other components. Similar results were reported by Patil (2010) in tomato and Sagar and Suresh Kumar (2009) in mango.

The total ash content of chilli differed significantly among various pretreatments and the highest was found in T_7 (1.71), while it was the lowest in treatment T_3 (1.62). The ash content of chilli dried pieces significantly varied and decreased considerably during storage. Significant reduction in ash content was also reported that by Masalkar (1998) and Sangale (2010) in onion which confirms the present findings.

Moisture content (%) of chilli varied significantly as influenced by the pretreatments and value ranged from 0.16 to 0.35 per cent with mean of 0.26 per cent. The moisture content decreased during storage. Treatment T_7 recorded significantly more moisture per

Table 1. Effect of pretreatments on physiochemical composition of dried chilli

Treat-ments	pH			Titrable acidity (%)			Total ash (%)			Moisture (%)			Rehydration ratio		
	S_1	S_2	Mean	S_1	S_2	Mean	S_1	S_2	Mean	S_1	S_2	Mean	S_1	S_2	Mean
T_1	5.11	5.16	5.13	1.60	1.79	1.69	1.65	1.63	1.64	0.34	0.31	0.32	3.98	4.02	4.00
T_2	5.36	5.41	5.38	1.33	1.39	1.36	1.66	1.67	1.66	0.17	0.34	0.25	3.91	3.96	3.93
T_3	4.96	4.99	4.97	1.60	1.80	1.80	1.62	1.63	1.62	0.19	0.18	0.18	3.98	3.99	3.98
T_4	5.45	5.46	5.45	1.36	1.59	1.59	1.67	1.70	1.69	0.17	0.15	0.16	3.92	3.96	3.94
T_5	5.12	5.17	5.14	1.60	1.79	1.79	1.63	1.65	1.64	0.18	0.49	0.33	3.97	3.98	3.97
T_6	5.39	5.45	5.42	1.35	1.52	1.52	1.66	1.69	1.67	0.17	0.34	0.25	3.91	3.96	3.93
T_7	5.11	5.16	5.13	1.73	1.78	1.74	1.70	1.72	1.71	0.27	0.44	0.35	3.85	3.91	3.88
Mean	5.21	5.25	5.23	1.53	1.70	1.61	1.64	1.65	1.64	0.21	0.32	0.26	3.93	3.96	3.95
SE±(T)	0.01			0.017			0.01			0.002			0.01		
CD at 5%	0.03			0.051			0.03			0.006			0.03		
SEs±(S)	0.02			0.01			0.01			0.004			0.02		
CD at 5%	0.06			0.03			0.03			0.014			0.07		
SEs± (SXT)	0.03			0.017			0.003			0.005			0.03		
CD at 5%	0.09			0.051			0.01			0.016			0.1		

S_1 - Low temperature storage, S_2 - Room temperature storage cent (0.35) followed by T_5 (0.33) while less moisture per cent was recorded in treatment T_4 (0.16) followed by T_3 (0.18). Similar result was noticed by Sangale (2010) in onion.

It was found that rehydration ratio of dried chilli varied significantly immediately after drying and 90 days of storage only with different pretreatments (Table 1). The rehydration ratio significantly differed with the range of 3.93 to 4.0 with mean of 3.95 among various pretreatments. Treatment T_1 recorded significantly more rehydration ratio (4.00) followed by T_3, while less rehydration ratio was recorded in treatment T_6 (3.9). Similar results were reported by Jayraman *et al*., (1991) in green peas and carrot, Kulkarni *et al*., (2005) in okra, and Kumar *et al*., (1991) in dried chilli.

Perusal of data presented in Table 2 revealed that the organoleptic score for colour, taste and overall acceptability differed significantly under different treatment under study. Treatment consisting of piece of 1.5cm of Chilli + Hot water + 0.25% $MgCO_3$ at 100°C for 3 min. recorded significantly superior colour (8.2), taste (8.0), and overall acceptability (7.4) over rest of the treatments under study at 90 days of storage at low temperature. Similar results were reported by Sangale (2010) in onion.

Thus experimental results revealed that the treatment consisting of piece of 1.5 cm of chilli + Hot water + 0.25% $MgCO_3$ at 100°C for 3 min. showed significantly higher pH and low titrable acidity and moisture content. Treatment of Whole fruit + Hot water treatment at 100°C for 3 min. resulted into higher rehydration ratio while control T_7 recorded higher total ash content. Organoleptic score of dried chilli with different pretreatments revealed that colour score, taste and overall acceptability were significantly more in treatment comprised of piece of 1.5 cm of chilli + Hot water + 0.25% $MgCO_3$ at 100°C for 3 min than rest of the treatments under study.

Table 2. Effect of pretreatments on organoleptic score of dried chilli

Treatments	Colour			Taste			Overall acceptability		
	S_1	S_2	Mean	S_1	S_2	Mean	S_1	S_2	Mean
T_1	6.2	6.1	6.1	6.4	6.3	6.3	6.4	6.3	6.3
T_2	7.3	7.1	7.2	7.0	6.9	7.0	7.0	6.8	6.9
T_3	6.2	6.0	6.1	6.6	6.4	6.5	6.6	6.4	6.5
T_4	8.2	8.0	8.0	7.5	7.3	7.3	7.4	7.2	7.3
T_5	6.2	6.1	6.1	6.7	6.6	6.7	6.7	6.6	6.6
T_6	7.8	7.6	7.7	7.2	7.1	7.2	7.2	7.1	7.2
T_7	6.2	6.1	6.1	6.3	6.1	6.2	6.2	6.1	6.1
Mean	6.83	6.67	6.75	6.81	6.64	6.70	6.7	6.6	6.7
SE±(T)	0.03			0.03			0.06		
CD at 5%	0.12			0.10			0.18		
SEs±(S)	0.07			0.06			0.2		
CD at 5%	0.21			0.20			0.6		
SEs± (SXT)	0.06			0.09			0.03		
CD at 5%	0.19			0.28			0.09		

S_1 - Low temperature storage, S_2 - Room temperature storage

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J. Agric. Res. Technol., 40 (3) : 545-547 (2015)

INDEX TO AUTHORS

Volume 40, 2015

	Page
A	
Akashe, V. B.	258
Alse, U. N.	195, 198
Ambad, S. N.	020
Ambadkar, C. V.	262
Amolic, V. L.	389
Andhale, R. P.	169, 518
Andhale, R. R.	129
Arade, Sandesh V.	056
Arvadia, M. K.	404
Asewar, B. V.	314
Aundhekar, R. L.	195, 198
B	
Babu G. Suresh	144
Babu, C.	013
Badwaik, K. A.	147
Bagade, S. R.	077
Bagade, S. V.	332, 522
Bama, K. Sathiya	013
Barange, P. K.	094, 476
Bera, B.	025
Bhagat, D. J.	135
Bhagat, S. B.	404
Bhalekar, M. N.	065, 247
Bhalerao, V. K.	072
Bharad, S. G.	045
Bharambe, P. R.	005
Bharambe, V. Y.	124, 149, 179
Bharud, R. W.	032, 037, 367, 389, 432
Bhave, S. G.	439, 467
Bhingardive, Kanchan	124
Bhondave, T. S.	051, 152, 528
Bhopale, A. A.	277, 286
Bhosale, S. S.	077
Bhosle, Aarti B.	471
Bhuse, A. A.	247
Bidwe, K. U.	354
Birari, D. R.	109, 129
Bodhale, Ashvini	367
Boyal, Vanpal Kumar	309
Burark, S. S.	098, 299, 309
Burli, A. V.	061, 158
Burondkar, M. M.	467
Burte, R. G.	124, 135
C	
Chandrashekar, K.	471
Channabasavanna, A. S.	351
Chaudhary, S. B.	203
Chavai, A. M.	094, 271, 476
Chavan, K. D.	322
Chavan, S. R.	020
Chavan, V. M.	471
Chopade, M. B.	152
Chopade, S. S.	318
Choudhary, J. L.	299
D	
Dahiwalkar, S. D.	508, 512
Damane, P. T.	318
Dandekar, V. S.	537
Dawane, P. T.	020
Deokar, D. K.	109, 113
Deolankar, K. P.	379, 534
Deorukhakar, A. C.	077, 083, 266
Desale, R. J.	109, 322
Deshmukh, A. R.	113
Deshmukh, D. V.	032, 037, 367, 409, 432
Deshmukh, K. V.	176, 305
Deshmukh, M. R.	020, 532
Deshmukh, P. R.	490
Devmore, J. P.	467
Dhage, S. A.	117
Dhakal, U. J.	277
Dharanguttikar, V. M.	037
Dhawan, A. S.	262
Dhonde, M. B.	518
E	
Ekal, A. P.	271
G	
Gaikwad, A. P.	357, 421
Gaikwad, B. G.	207
Gangawane, S. B.	404
Ganvir, B. N.	277, 286
Gare, B. N.	061
Gurav, S. B.	504
Gawande, V. L.	214
Ghatage, A. A.	432
Ghawade, S. M.	163
Ghosh, S. N.	025
Ghotekar, Pallavi	163
Ghube, N. B.	336
Gilande, H. G.	233
Gite, V. K.	339
Gokhale, D. N.	343
Gokhale, N. B.	233
Gorad, K. D.	332, 522
Gorantiwar, S. D.	508, 512
Gore, B. N.	158
Gosavi, A. B.	379, 534
Gud, M. A.	258
Gurav, S. B.	532

	Page
H	
Hake, A. D.	481
Harer, P. N.	032
I	
Iyanar, K.	013
J	
Jadhav, A. B.	336
Jadhav, A. C.	072
Jadhav, A. S.	160
Jadhav, H. A.	198
Jadhav, M. G.	314
Jadhav, S. D.	214
Jadhav, S. S.	109
Jagtap, P. B.	504
Jain, H. K.	104, 299
Jaybhay, S. A.	167
Jaybhaye, P. R.	314, 497
Joshi, R. M.	077
Joshi, S. V.	124, 537
K	
Kadam, B. S.	207
Kadam, J. R.	258
Kadam, R. P.	490
Kadam, S. A.	508, 512
Kadam, S. R.	343
Kadam, T. D.	541
Kalalbandi, B. M.	239, 244, 385, 541
Kalamani, A.	013
Kale, S. T.	343
Kamble, A. S.	443
Kamble, S. Y.	395
Karanjikar, P. N.	343
Karjule, A. P.	447
Katkar, R. N.	005, 163
Katre, S. R.	354
Katwate, S. M.	020
Kerutagi, M. G.	028
Khamkar, M. B.	532
Khandare, V. S.	239, 244, 385, 541
Khandave, Swati	348
Kharche, V. K.	005, 163
Khedkar, H. P.	332
Khirari, P. B.	124
Khole, A. S.	244
Khutal, B. B.	113
Kiran, P.	144
Kolambkar, R. A.	176, 305
Kolse, R. H.	379, 534
Kshirsagar, A. B.	056, 141
Kshirsagar, C. R.	504
Kudtarkar, U. S.	207
Kukanoor, Laxman	028
Kulkarni, S. R.	155
Kulwal, P. L.	421
Kumbhar, S. D.	254, 421
Kumbhar, S. G.	522
Kute, N. S.	203
L	
Lagare, M. G.	083, 266
Laharia, G. S.	163
Lakhe, S. R.	005, 163
Lavanya, Roopa G.	144, 147, 330, 345
Laxmi Narayan,	098
Lingaraja, L.	144
M	
Mahadkar, U. V.	149, 179, 443
Makar, H. B.	094
Malave, D. B.	481
Mandakmale, S. D.	109, 129
Mane, S. H.	117
Maniyar, V. G.	497
Mate, S. N.	409
Meena, G. L.	098
Mehra, Jay	309
Moka, Sunanda	314
More, N. S.	432
More, S. A.	532
Mundhe, A. G.	195, 198
Mundhe, R. P.	169
N	
Nagawade, D. R.	223, 447
Nagre, P. K.	045
Naik, M. Raja	428
Naik, Poonam	537
Nale, V. N.	187
Naresh, L.	345
Narute, T. K.	173
Navhale, V. C.	229, 439, 443
Navsare, N. M.	239
Nevkar, G. S.	207
Nigade, P. M.	389
Nikam, M. B.	088
Nikam, R. P.	051
Nikam, S. P.	104
P	
Pacharne, D. P.	460
Pachpute, S. T.	117
Pande, A. K.	141
Pant, D. C.	299, 309
Paradhi, P. S.	322
Patel, N. M.	404
Patil, B. T.	065, 247
Patil, D. K.	339
Patil, D. M.	233
Patil, D. S.	207

Page

Patil, J. V. 421
Patil, K. B. 207
Patil, S. K. 155
Patil, S. R. 187
Patil, Sheetal 537
Patil, V. N. 525
Pawal, S. M. 409
Pawar, H. D. 339
Pawar, K. B. 173
Pawar, P. K. 065
Pawar, R. B. 525
Pawar, S. V. 160
Pharande, A. L. 525
Pohare, V. B. 528
Pol, K. E. 113
Prasannakumar, B. 428
Praveen, J. 028
Purohit, R. C. 104

R

Rajakumar, H. 351
Rajput, Raghvendra Singh 147
Rasal, P. N. 379, 534
Rathod, N. D. 336
Raundal, P. U. 051, 061, 152, 158, 528
Raut, G. B. 262
Raut, R. S. 336
Rekha, E. 028
Roy, S. 025

S

Sagvekar, V. V. 229, 439, 443
Sakhare, P. S. 129
Salve, V. A. 504
Sanap, P. B. 467
Sarawate, C. D. 254, 421
Sarnobat, D. H. 173
Sarwade, D. D. 117
Satale, S. S. 135
Satpute, Pravina 045
Sawant, P. H. 061, 158
Sawant, S. B. 155
Sawardekar, S. V. 233
Shaikh, A. A. 332, 522
Shekhawat, Ravindra Singh 309
Shelar, V. R. 223, 447
Shelke, P. S. 385
Shende, R. S. 286
Shihare, N. D. 330
Shinde, A. A. 088
Shinde, A. K. 149, 179
Shinde, A. N. 330

Page

Shinde, D. B. 072
Shinde, G. C. 395, 399
Shinde, K. G. 065, 247
Shinde, M. G. 104, 508, 512
Shinde, P. B. 497
Shinde, S. B. 271
Shinde, S. K. 258
Sinare, B. T. 169, 518
Singh, Hari 299
Singh, P. K. 104
Sonke, Lakshmi R. 471
Sonone, A. H. 399
Sonone, N. G. 229
Sonune, B. A. 005
Surana, P. P. 395, 399
Suresh Babu, G. 147, 345
Suryawanshi, Pallavi 348
Suryawanshi, R. R. 305
Swami, S. S. 203

T

Talathi, J. M. 077, 083, 266
Talele, G. J. 223, 447
Tambat, S. G. 229, 439, 443
Tambe, S. I. 032
Tamil Vendon, K. 351
Taware, S. P. 167
Thakare, C. S. 357
Thawal, D. W. 453, 460
Tirmali, A. M. 072
Todmal, S. M. 379, 534
Torane, S. R. 088
Tumbare, A. D. 453, 460

V

Varghese, Philips 167
Veer, D. M. 207
Velayudham, K. 013

W

Wadkar, S. S. 481
Wagh, R. S. 032, 389, 432
Waghmode, B. D. 229, 439, 443
Waghmode, R. R. 176
Wagle, S. A. 481
Wakle, P. K. 354
Warkad, D. P. 345
Waskar, D. P. 239, 244, 385, 541

Y

Yamgar, A. S. 476

J. Agric. Res. Technol., 40 (3) : 548-549 (2015)

TABLE OF CONTENTS

Volume 40, 2015

	Page
Ber	
Nutrient spray	25
Bottle gourd	
Fusarium roseum	357
Brinjal	
NPK	247
Broiler	
Growth performance	135
Cabbage	
Shade net	169
Capsicum	
Dehydration	541
Integrated weed management	61
Plant Spacing	45
Castor	
Nutrient uptake	404
Cattle	
Housing practice	117
Milk production	354
Muzzle printometry	318
Chickpea	
Heterosis	214
Nutrient Uptake	335
Sowing date	51
Cotton	
Fusarium wilt	173
Micronutrient uptake	5
Custard apple	
Pulp storability	504
Economics	
Cashew processing	481
Farming system	99
Growth and instability in Cumin production	309
Production and marketing of Lathyrus	286
Finger Millet	
Economic impact technologies	77
Lassi	322
Variability	233
Fodder grasses	
Marvel Phule Govardhan	399

	Page
Napier -Fodder yield and quality	13
Napier -Genetic diversity	395
Goat	
Morphometric trait	129
Sex and body weight	109
Green gram	
Selection criteria	330
Sulphetic microbial culture	72
Groundnut	
Cropping system	453
Genetic diversity	229, 439
Irrigation and K level	518
N and P ratio	443
Nutrient uptake	460
Pheneological interventions	389
Physiological trait	37
Karonda	
Beverages	239
Linseed	
NPK Level	528
Maize	
Weed control	351
Mango	
Impact of technologies	88
Marrigold	
Economic analysis	305
Growth, yield and quality	20
Milk	
Economic analysis	98
Gulabjamun blended with date	124
Khoa burfi	537
Yield of Phule triveni	113
Onion	
Economics, storage structure	28
Shelf life	244
Sulphur application	65, 163
Ornamental plant	
Business profitability	83
Heliconia -NPK fertilizer	428
Marketing	266
Rose -nodal cutting	56

Page

Papaya
PRSV - P 471

Physical Science
Geomorphic modeling 104
Hyperspectral field reflectance measurement 508
Rainfall characterization and cropping pattern 497

Pigeonpea
Acerage response 277
Pigeonpea + Soybean intercropping 339

Pomogranate
Bacterial blight 262
Storability and quality 385
Sucking pest 155

Potato
Adoption of production technology 94
Varietal evaluation 532

Rice
Effect of silicon 521
Genetic diversity 421
Genetic evaluation 345
Phule RDN -6 254
Seed dormancy 149
Seed storage 179
Yield and quality 147

Safflower
Aphids 141, 258
Drought tolerance 32
Resource use status and yield gap 447

Sesamum
Dry matter and yield 522
Photosynthetic efficiency 367

Page

Topping management 332

Social Science
Adarsh gaon yojna- perception and participation 271
Entrepreneurship attitude 490
NHM impact 348

Sorghum
Genetic diversity 203
Leaf area index 512

Soybean
Integrated phosphorous management 187
Leaf miner 314
Sowing date 167
Water stress 409

Sugarcane
Nutrient management 207
Resource use efficiency 176

Sunflower
Pollen viability and stigma receptivity 447
Seed setting 223

Tobacco
Relay cropping system 158

Turmeric
Post harvest technology adoption 476
Weed management 160

Wheat
Fertilizer 198, 343
Foliar application of nutrient 379
Irrigation 195
Osmotic stress 432
Sowing dates 152, 534

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