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Integrated Weed Management in *Rabi* Pop Corn (*Zea mays* L. var. *everta*) with New Generation Herbicides

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Abstract

Effect of “Integrated Weed Management in rabi pop corn (Zea mays L. var. everta) under South Gujarat condition” were evaluated in College Farm, Navsari Agricultural University, Navsari (Gujarat) on species wise weed count (per m2), dry weight of weed at harvest (kg ha^{-1}), Weed Control Efficiency (%), Weed Index (%), grain and stover yield (kg ha^{-1}) in rabi pop corn during 2017-18. The experimental soil was clayey in texture, low in available nitrogen (164 kg ha^{-1}), medium in available phosphorus (42 kg ha^{-1}) and high in available potash (315 kg ha^{-1}). Results revealed that the significantly minimum number of monocot (*Cynodon dactylon* L., *Sorghum helepense* L., *Dactyloctenium aegyptium*, *Echinochloa colona* L. and *Brachiaria ramose* L.), dicot (*Euphorbia hirta* L., *Chenopodium album* L., *Digera arvensis Forsk*, *Physalis minima* L., *Phyllanthus niruri* L., *Amaranthus viridis* L., *Alternanthera sessilis* L. and *Portulaca oleracea* L.), sedge weed (*Cyperus rotundus* L.), dry weight (148.52 kg ha^{-1}) of weeds at harvest, weed index (1.57%) and highest weed control efficiency (36.30%) were observed under the weed control through treatment T_6 (Atrazine 0.5 kg ha^{-1} fb Topramezone 0.025 kg ha^{-1} as post-emergence at 20 DAS), fb treatment T_5 (Atrazine 0.5 kg ha^{-1}fb Tembotrione 0.12 kg ha^{-1} as post-emergence at 20 DAS) While, significantly the maximum monocot, dicot, sedge weeds, dry weight (233.17 kg ha^{-1}) of weeds at harvest, weed index (58.17%) and lowest weed control efficiency (0) were recorded under the treatment T_{10} (unweeded control), at 30 DAS, 60 DAS and harvest. Significantly greater grain yield and stover yield (3748 and 7898 kg ha^{-1}, respectively) were registered with treatment T9 (weed-free) but it is statistically at par with treatments of T_6, T_5 and T_4 (Atrazine 0.5 kg ha^{-1} + pendimethalin 0.45 kg ha^{-1} tank- mix as pre-emergence fb HW and IC at 40 DAS.

Key words : Maize, pop corn, herbicide, topramezone, tembotrione, weed control efficiency, weed index, grain yield etc.

Maize (*Zea mays* L.) known as ‘Queen of Cereals’ is one of the important food crops of the world and ranks next only to wheat and rice as the third most important crop in the world as it is grown in more than 130 countries across the world. Maize being a C4 plant is one of the most vibrant food grain crops having wider adaptability under diverse soil and climatic conditions due to this it is cultivated in all seasons viz. Kharif, rabi and spring. Today, it has become one of the leading food grain crops in many parts of the world, not only in tropical and subtropical areas but also in temperate and high hill ecologies (Kumar *et al*., 2015). Among the different types of maize, popcorn (*Zea mays* L. var. *everta*) is one of the major ones; its kernels are composed of hard starch when heated, swell and burst.

Weeds are always associated with human endeavours and cause huge reductions in crop yields, increase the cost of cultivation, reduce input efficiency, interfere with agricultural operations, impair quality, act as alternate hosts for several insect pests, diseases and nematodes, several weed species compete with corn plant reduce yield. As there are limitations of every weed control method, therefore integrated weed management is a good option for sustainable agriculture as it involves the combination of all

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the possible methods to suppress the weeds below the economic threshold level, although some methods are effective against weeds, they prove uneconomical for the farmers or pose environmental hazards. Weeds compete with corn for light, nutrients, and water, especially during the first 3 to 5 weeks following the emergence of the crop. Yield loss due to weed in maize varies from 28 to 93%, depending on the type of weed flora and intensity and duration of the crop-weed competition. Pre-emergence application of herbicides may lead to cost-effective control of the weeds right from the sowing.

Integrated Weed Management (IWM) is the combination of physical, mechanical, biological and chemical management practices to reduce a weed population to an acceptable level while preserving the quality of existing habitat, water, and other natural resources. The field of chemical weed control is practically remained limited up to certain crops because growers are not aware of proper doses of herbicides, time of application and their economics. Practically no systematic research work has so far been done to evaluate the efficacy of new herbicides for weed management in rabi popcorn for this region.

Materials and Methods

An experiment was conducted at College Farm, NAU, Navsari during *rabi* season 2017-18 which is located 12 km away in the east from the Arabian seashore at 20° 57' N latitude, 72° 54' E longitude and 10 m above the mean sea level. The experimental field was "Deep Black" soils as old alluvium of basaltic material by its origin under the great group of Ustochrepts, a sub group of VerticUstochrepts, suborder Ochrepts and order Inceptisols with Jalalpore series. The experimental soil was clayey in texture, slightly alkaline (pH 8.23) with normal electric conductivity (0.30 ds m^{-1}), low in available nitrogen (164 kg ha^{-1}), medium in available phosphorus (42 kg ha^{-1}) and high in available potash (315 kg ha^{-1}). Ten treatments including in weed management practices *viz*., T_1 : Atrazine 0.75 kg ha^{-1} as a pre-emergence, T_2 : Atrazine 0.5 kg ha^{-1} as pre-emergence fb HW and IC at 40 DAS, T_3 : Pendimethalin 0.9 kg ha^{-1} as pre-emergence fb HW and IC at 40 DAS, T_4 : Atrazine 0.5 kg ha^{-1} + Pendimethalin 0.45 kg ha^{-1} tank-mix as pre-emergence fb HW and IC at 40 DAS, T_5 : Atrazine 0.5 kg ha^{-1} fb tembotrione 0.12 kg ha^{-1} as post-emergence at 20 DAS, T_6 : Atrazine 0.5 kg ha^{-1} fb topramezone 0.025 kg ha^{-1} as post-emergence at 20 DAS T_7 : Atrazine 0.5 kg ha^{-1} as a pre-emergence fb 2,4-D (Na salt) 0.5 kg ha^{-1} as post-emergence at 40 DAS, T_8 : HW and IC at 20 and 40 DAS T9: Weed-free and T_{10} : Unweeded control were evaluated with an amber variety of pop corn as a test crop in randomized block design along with three replications.

Popcorn cv. 'Amber' (110-120 days duration) seeds of 15 kg ha^{-1} were sown by hand in rows at 60 cm x 20 cm planting geometry. The crop was subjected to 120:60:00 kg N, P_2O_5 and K_2O ha^{-1}, P_2O_5 was supplied at basal and N was applied with three splits (50% basal, 25% at the four-leaf stage, and 25% at the tasselling stage). The required amount of herbicides were sprayed using 400 l ha^{-1} of water with a knapsack sprayer fitted with a flat fan nozzle.

At sampling time for species wise weed count, an iron quadrate measuring 1.0 m^2 was placed randomly in each net plot at 30 DAS. A periodical count at 60 DAS and harvest was also made from this demarcated area. The number of monocots, dicots and sedges observed within the quadrate was counted and recorded. Weed dry weight (g) was also recorded after completion of crop harvest weeds were uprooted from the net plot and left for sun drying till reached a constant weight and finally, the mean dry weight was recorded for each treatment of all the replications.

Weed control efficiency (%) is defined as the efficiency to control the weed in terms of dry matter accumulation in treated plots compared to unweeded control plots and expressed in per cent. And weed index (%) was calculated based on yield recorded from the weed-free plot compared with yield from the treated plot as per the standard formula. The grain and stover yield was recorded from the net plot area just after picking off the cob and expressed in kg ha^{-1}.

Results and Discussion

Weed flora : The weed flora in the experimental site constituted by monocot weeds *viz*., *Cynodon dactylon* L., *Sorghum helepense* L., *Dactyloctenium aegyptium* L., *Echinochloa colona* L. and *Brachiaria ramose* L. and dicot weeds *viz*., *Euphorbia hirta* L., *Chenopodium album* L., *Digera arvensis Forsk*, *Physalis minima* L., *Phyllanthus niruri* L., *Amaranthus viridis* L., *Alternanthera sessilis* L. and *Portulaca oleracea* L. and sedge weed *Cyperus rotundus* L.

Species wise weed count : The mean data on monocots, dicots and sedges weeds count as influenced by different treatments of weed management recorded at 30 DAS, 60 DAS and harvest of the crop from the net plot area during the experimentation are presented in (Table 2).

Monocot weeds count : The treatments differed significantly from each other. Next to weed-free treatment, the significantly minimum number of monocot weeds per m^2 (2.92, 6.72 and 1.91) were noted under the treatment T6 at 30 DAS, 60 DAS and harvest respectively, which remained statistically at par with the treatments T_5 and T_4 at 30 and 60 DAS, while in case of at harvest it was remaining at par with only T_5. While, significantly the highest monocot weeds count per m^2 (4.80, 6.72 and 6.88) were observed under the treatment T_{10} at 30 DAS, 60 DAS and harvest respectively.

Dicot weeds count : The treatments differed significantly from each other. Next to weed-free treatment, the significantly minimum number of dicot weeds per m^2 (3.02, 2.92 and 2.98) were noted under the treatment T_6 at 30 DAS, 60 DAS and harvest respectively. In which at 30 DAS remained statistically at par with T_5, T_4, T_8 and T_2; at 60 DAS with the T_5, T_4, T_8, T_2, T_3 and T_7 and at harvest remained statistically at par with the treatments T_5 and T_4. While, significantly the highest dicot weeds per

Table 1. Chemical composition of different herbicides

Name of herbicides	Trade names	Formu-lations	Chemical name	Chemical formula
Atrazine	Aatrex, Actinite PK, Akticon, rgezin, Atazinax, Atranex, trataf, Atred,	50% WP Candex	1-Chloro-3-ethylamino-5-isopropylamino-2,4,6-triazine	$C_8H_{14}ClN_5$
Pendimethalin	Prowl, Stomp, Pendilin, Herbadox	30% EC	N-[1-(ethyl-propyl)-3,4-dimethy l-2 dinitrobenzene Amine]	$C_{13}H_{19}N_3O_4$
Tembotrione	Laudis (Bayer)	42% SC (34.4% w/w)	2-{2-Chloro-4-mesyl-3-[(2,2,2 trifluoroethoxy) methyl] benzoyl}cyclohexane-1,3-dione	$C_{17}H_{16}ClF_3O_6S$
Topramezone	Tynzer (BASF)	33.6% a.i.	4-[3-(4,5-dihydro-1,2-oxazol-3-yl)-2-methyl- 4-methylsulfonylbenzoyl]-2-methyl-1H-pyrazol-3-one	$C_{17}H_{16}ClF_3O_6S$
2,4-D (Na salt)	Zura (Atul), Fernoxon, Hedonal and Trinoxol	58% WSC	(2,4-dichlorophenoxy) acetic acid	$C_8H_6Cl_2O_3$

Table 2. Effect of different weed control treatments on weed density of monocot, dicot and sedges weeds periodically

Treatments	Monocot weeds m^{-2}			Dicot weeds m^{-2}			Sedges weeds m^{-2}		
	30 DAS	60 DAS	Har-vest	30 DAS	60 DAS	Har-vest	30 DAS	60 DAS	Har-vest
T_1 - Atrazine 0.75 $kgha^{-1}$ as at pre- emergence	3.80 (14.09)	3.86 (14.47)	3.90 (14.74)	3.77 (13.81)	3.45 (11.43)	3.59 (12.40)	3.98 (15.39)	3.85 (14.39)	3.94 (15.01)
T_2 - Atrazine 0.5 kg ha^{-1} as pre-emergence fb HW and IC at 40 DAS	3.45 (11.48)	2.79 (7.31)	3.05 (8.86)	3.44 (11.49)	3.21 (9.91)	3.34 (10.64)	3.16 (9.51)	3.00 (8.51)	3.10 (9.12)
T_3 - Pendimethalin 0.9 kg ha^{-1} as pre- emergence fb HW and IC at 40 DAS	3.48 (11.65)	2.86 (7.73)	3.08 (9.01)	3.58 (12.33)	3.31 (10.46)	3.35 (10.73)	3.37 (10.91)	3.22 (9.91)	3.31 (10.52)
T_4 - Atrazine 0.5 kg ha^{-1}+ pendimethalin 0.45 kg ha^{-1} tank- mix as pre-emergence fb HW and IC at 40 DAS	3.12 (9.29)	2.19 (4.32)	2.73 (6.97)	3.26 (10.13)	3.08 (9.02)	3.16 (9.53)	2.52 (5.89)	2.31 (4.89)	2.43 (5.48)
T_5 - Atrazine 0.5 kg ha^{-1} fb Tembotrione 0.12 kg ha -1as post-emergence at 20 DAS	3.01 (8.60)	1.92 (3.23)	2.06 (3.75)	3.15 (9.52)	3.01 (8.62)	3.15 (9.47)	2.12 (4.03)	1.87 (3.03)	1.96 (3.38)
T_6 - Atrazine 0.5 kg ha-1 fb Topramezone 0.025 kg ha-1as post emergence at 20 DAS	2.92 (8.03)	1.71 (2.46)	1.91 (3.17)	3.02 (8.68)	2.92 (8.07)	2.98 (8.44)	2.08 (3.88)	1.83 (2.88)	1.90 (3.13)
T_7 - Atrazine 0.5 kg ha^{-1} as a pre- emergence fb 2,4-D (Na salt) 0.5 kg ha^{-1} as post-emergence at 40 DAS	3.57 (12.37)	3.02 (8.71)	3.11 (9.18)	3.67 (13.03)	3.37 (10.92)	3.45 (11.43)	3.50 (11.75)	3.35 (10.75)	3.45 (11.41)
T_8 - HW and IC at 20 and 40 DAS	3.19 (9.71)	2.73 (7.01)	2.95 (8.23)	3.34 (10.76)	3.14 (9.43)	3.32 (10.55)	2.64 (6.50)	2.44 (5.50)	2.64 (6.51)
T_9 - Weed free	0.70 (0.00)	0.70 (0.00)	0.70 (0.00)	0.70 (0.00)	0.70 (0.00)	0.71 (0.00)	0.70 (0.00)	0.70 (0.00)	0.70 (0.00)
T_{10} - Unweeded control	4.80 (22.61)	6.72 (44.74)	6.88 (46.90)	4.99 (24.46)	6.51 (41.86)	6.74 (44.94)	6.24 (38.53)	6.55 (42.50)	6.69 (44.27)
S.Em. ±	0.11 (1.39)	0.09 (1.14)	0.06 (0.86)	0.18 (2.21)	0.15 (1.77)	0.09 (1.41)	0.07 (1.02)	0.07 (0.94)	0.10 (1.04)
C.D at 5%	0.33 (2.93)	0.26 (2.40)	0.18 (1.82)	0.54 (4.64)	0.46 (3.73)	0.27 (2.97)	0.20 (2.15)	0.20 (1.99)	0.31 (2.19)
C.V. %6.01	5.30 (12.92)	3.51 (11.45)	9.62 (7.81)	8.19 (19.34)	4.59 (14.81)	3.75 (11.05)	4.08 (9.64)	5.99 (9.28)	(9.57)

Data presented in parentheses indicate the transformed data $\sqrt{(X+0.5)}$

m^2 count (4.99, 6.51 and 6.74) were observed under the treatment T_{10}.

Sedge weeds count : The treatments differed significantly from each other. Next to weed-free treatment, the significantly minimum number of sedge weeds per m^2 (2.08, 1.83 and 1.90) were noted under the treatment T_6 at 30 DAS, 60 DAS and at harvest respectively, which remained statistically at par with the treatment T_5. While, significantly the highest sedge weeds count per m^2 (6.24, 6.55 and 6.69) were observed under the treatment T_{10} at 30 DAS, 60 DAS and harvest respectively.

This might be due to the effective weed control in respective treatments either manual or effect of herbicides or both which resulted in a remarkable reduction in weed population periodically. T_{10} recorded the highest weed population at 30 DAS, 60 DAS and harvest owing to unrestricted weed growth. These findings are in close conformity with those reported by Joseph *et al*. (2008), Choudhary *et al*. (2013), Madhavi *et al*. (2014) and Mathukia *et al*. (2014).

The dry weight of weeds at harvest : The weed dry weight was significantly influenced by weed control treatments. Data in (Table 3) indicated that next to treatment T_9 significantly lowest dry weight of weeds (148.52 kg ha^{-1}) was recorded under treatment T_6 but remained at par with treatments of T_5, T_4 and T_8. The significantly highest dry weight of weeds (233.17 kg ha^{-1}) was recorded under the treatment T_{10}. This might be due to the periodical removal of weeds at regular intervals through hand weeding accounting for a lower count of weeds. Better weed control efficiency of herbicide along with hand weeding might be

Table 3. Effect of different weed control treatments on grain yield, straw yield, dry weight of weed (kg ha^{-1}), weed control efficiency (%) and weed index (%) as influenced by different weed management treatments in pop corn (*Zea mays* L. var. *everta*)

Treatments	Grain yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Dry weight of weed (kg ha^{-1})	Weed control efficiency (%)	Weed index (%)
T_1 - Atrazine 0.75 kg ha^{-1} as at pre- emergence	1885.20	3896.19	212.69	8.78	49.69
T_2 - Atrazine 0.5 kg ha^{-1} as pre-emergence fb HW and IC at 40 DAS	2612.85	5646.59	184.57	20.84	30.29
T_3 - Pendimethalin 0.9 kg ha^{-1} as pre-emergence fb HW and IC at 40 DAS	2539.40	5070.28	195.39	16.20	32.23
T_4 - Atrazine 0.5 kg ha^{-1}+ pendimethalin 0.45 kg ha^{-1} tank-mix as pre-emergence fb HW and IC at 40 DAS	3019.26	6544.25	166.91	28.41	19.42
T_5 - Atrazine 0.5 kg ha^{-1} fb Tembotrione 0.12 kg ha^{-1} as post-emergence at 20 DAS	3575.20	7205.07	157.79	32.32	4.59
T_6 - Atrazine 0.5 kg ha^{-1} fb Topramezone 0.025 kg ha^{-1} as post emergence at 20 DAS	3688.74	7614.02	148.52	36.30	1.57
T_7 - Atrazine 0.5 kg ha^{-1} as a pre- emergence fb 2,4-D (Na salt) 0.5 kg ha^{-1} as post-emergence at 40 DAS	2359.49	4378.64	203.56	12.69	37.04
T_8 - HW and IC at 20 and 40 DAS	2733.55	6062.60	175.18	24.87	27.06
T_9 - Weed free	3747.63	7897.80	0.00	100	0.00
T_{10} - Unweeded control	1567.37	3325.79	233.17	0	58.17
S.Em. ±	361.58	751.64	24.90	-	-
C.D at 5 %	759.65	1579.14	52.31	-	-
C.V. %	13.04	13.04	14.84	-	-

due to effective weed control obtained under pre-emergence application of herbicides in the initial and early growth stage and then after hand weeding. These treatment's effects are reflected in less number of weeds and ultimately lower weed biomass. In addition to this, a dense crop canopy might have suppressed weed growth and ultimately less biomass. The highest dry weight of weeds in T10 might be due to no effort to suppress weed growth which favoured luxurious weed growth leading to increased dry matter. Similar results were also reported by Kour *et al*. (2014), Madhavi *et al.* (2014), Akhtar *et al*. (2015), Duary *et al.* (2015) and Rana *et al*. (2017).

Weed control efficiency (WCE) and weed index (WI) (%) : The 100% WCE was observed under treatment T_9. Among the rest of the weed management treatments, the highest WCE (36.30%) was registered under treatment T_6, followed by treatments T_5, T_4, T_8, T_2, T_3, T_7 and T_1. And in the case of weed index (WI), the highest WI (58.17%) was recorded under the treatment T_{10} which indicates the unrestricted weed growth reduced the grain yield of pop corn by 58.17%. Among the rest of the treatments, the lowest WI of 1.57% was recorded under treatment T_6, closely followed by treatments T_5, T_4 and T_8. (Table 3), This might be due to effective weed control achieved under these weed management treatments in terms of reduced biomass of weeds and higher weed control efficiency. These findings are in agreement with those of Hatti *et al*. (2015) and Samant *et al*. (2015).

Grain yield and Stover yield (kg ha^{-1}) : Data in (Table 3) indicated that significantly the yield (kg ha^{-1}) of grain (3747.63 kg ha^{-1}) and stover (7897.80 kg ha^{-1}) was recorded with treatment T_9 but remained at par with treatments of T_6, T_5 and T_4. Significantly lowest grain yield (1567.37 kg ha^{-1}) recorded under the treatment T_{10}. This might be due to effective control of weeds as well as higher weed control efficiency observed in respective treatments, besides minimum depletion of nutrients by weeds and better uptake by crop which cumulatively facilitated the crop to utilize more nutrients and water for better growth and development in terms of various yield attributing character. Analogous findings have been reported by Arvadiya *et al*. (2013), Hatti *et al*. (2014), Mathukia *et al*. (2014), Sabiry *et al.*. (2015), Srinivasulu *et al.* (2016).

Conclusion

Based on the results of the field experiment, it can be concluded that effective weed control and potential production in *rabi* pop corn can be achieved by keeping weed-free conditions by hand weeding and inter-culturing during the crop growth period. When labours are not easily available, another alternative is the pre-emergence application of Atrazine 0.5 kg ha^{-1} fb topramezone 0.025 kg ha^{-1} as post-emergence at 20 DAS or tembotrione 0.12 kg ha^{-1} (as post-emergence) also equally effective (for potential and profitable maize production) for weed control in *rabi* pop corn.

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