*J. Agric. Res. Technol., 47 (3) : 316-321 (2022)* https://doi.org/10.56228/JART.2022.47311

# Studies on Sowing Windows for Sustainable Production of *Rabi* Sorghum (*Sorghum bicolour* L.) Under Changing Climatic Condition in Scarcity Zone of Maharashtra.

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## Abstract

The field experiment was conducted at research farm, Zonal Agriculture Research Station, Solapur Mahatma Phule Krishi Vidyapeeth,Rahuri for five years (2016-17 to 2020-21) in *rabi* on sorghum entitled as "Studies on Sowing windows for Sustainable Production of Rabi Sorghum (*Sorghum bicolour* L.) Under Changing Climatic Condition in Scarcity Zone of Maharashtra." to find out most optimum meteorological week for sowing sorghum in *rabi* season, to study the relationship between meteorological parameters and yield by using four different sowing windows. The results were obtained from the experiment; it was found that rabi sorghum sown at MW 40 (01-07 Oct) produced maximum pooled grain yield (808.28 kg ha$^{-1}$), fodder (1494.11 kg ha$^{-1}$) and total monetary returns (Rs. 26633 ha$^{-1}$). Among the varieties, M-35-1 was produced significantly higher grain yield (717.94 kg ha$^{-1}$), fodder yield (1559.03 kg ha$^{-1}$) and total monetary returns (Rs. 24968 ha$^{-1}$) over the other variety. The meteorological studies showed that the mean CUM and MUE recorded by sorghum crop was 240 mm and 2.7 kg ha$^{-1}$ mm. The highest CUM was recorded by $S_1$ sown crop (282 mm) however the MUE was recorded by $S_3$ sown crop (3.5 kg ha$^{-1}$ mm). This indicated that $S_3$ sown crop (*Chitra Nakshtras*) utilized moisture more efficiently than other dates of sowing. Among the variety M-35-1 recorded maximum mean CUM (266 mm) and MUE (3.1 kg ha$^{-1}$ mm) than other varieties. The number of days required to attain physiological maturity and growing degree days were higher in $S_3$ sown crop. Among the varieties it is higher in M 35-1 than Mauli and Yashoda. In case of RUE initially values were low, it increases up to 70 DAS (i.e. up to 50 percent flowering to soft dough stage) further it decreases in all most all the sowing dates.

**Key words : Sowing windows, varieties, yield, GDD, MUE, CUE, RUE.**

Sorghum (*Sorghum bicolor* L.,) plays an important role as grain and fodder crop for both arid and semi-arid regions of the world. This importance is due to its higher water use efficiency, relatively good tolerance to drought and salt stresses and good competitiveness with weeds in advanced growth stages. Sorghum growth, development and yield depend on environmental conditions such as temperature and precipitation. The extent of effect of these environmental parameters may vary depending on planting time. The effect of stress due to environmental factors on final yield may depend upon the growth stage in which it occurs and the genotype. Deciding on early or late planting depends on a farmer's ability to deal with the risk of poor crop establishment with early planting or the effect of water or heat stress at reproductive stages with late planting. Since sorghum is cultivated majorly as a rainfed crop, its productivity is significantly influenced by climatic elements (Srivastava *et al*., 2010). Sorghum yield response to location, time of planting and soil water storage were associated with difference in leaf area development. Sowing time has an impact on sorghum growth stages. Decline in sorghum productivity in future climate change scenarios at different locations of India was primarily attributed to reduction in crop growth period with increase in temperature (Boomiraj *et al*., 2012). Pramod *et al*. (2017) used various adaptation strategies *viz*., change

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in sowing dates to minimize the yield reduction in wheat in India. In India, sorghum is extensively produced and both hybrid and improved varieties are taken on large scale. India is the third largest producer in the world. Among the cereals in India, sorghum ranks third, next to rice and wheat. Sorghum is a rich source of carbohydrates, proteins, minerals and vitamin B1 and B2. By keeping in view, this experiment was conducted to study suitable variety under suitable weather condition for optimum production and to identify the suitable sowing date and variety for better growth and yield of sorghum crop. Planting date affects not only the time from sowing to flowering but time from flowering to physiological maturity of grain sorghum (Clark, 1997).

## Materials and Method

The experiment was carried out for five years during the *rabi* season from 2016-17 to 2020-21 at Dry Farming Research Station, Solapur (17.65° N 75° 90' E and 483.6 m MSL) on medium black soil (60 cm soil depth). The experiment was laid out in split plot design with four replications. Treatments were comprised of four sowing dates i.e. $S_1$: MW 36 (Sept.03-09) *Purva nakshtra*, $S_2$: MW 38 (Sept.17-23) *Uttara nakshtra*, $S_3$: MW 40 (Oct.01-07) *Hasta nakshtra*, $S_4$: MW 40 (Oct.15-21) *Chitra nakshtra*. Three sorghum genotypes i.e. $V_1$: M-35-1, $V_2$: Mauli and $V_3$: Yashoda were sown at spacing 45 cm x 15cm. The sowing of seed was done by dibbling method on respective date of sowing. Recommended packages of practices like thinning, weeding, application of recommended dose of fertilizer and pesticide were uniformly followed. Observations were recorded on five plants randomly selected per treatment. The soil of the experimental site was low in organic carbon (0.35%), medium in phosphorus (18.7 kg $ha^{-1}$) and high in potash content (540 kg $ha^{-1}$) with neutral pH (7.2). The crop was fertilized with 50:25:0 kg NPK $ha^{-1}$.

## Results and Discussion

Growth and development of crop is influenced by environmental conditions such as temperature, radiation and photoperiod. The significant difference was recorded with different

**Table 1.** Pooled grain yield (kg $ha^{-1}$) of *rabi* sorghum as influenced by sowing dates and varieties 2016 to 2020

| Treatment | 2016-17 | 2017-18 | 2018-19 | 2019-20 | 2020-21 | Pooled | SYI |
|---|---|---|---|---|---|---|---|
| **Main = Sowing dates** | | | | | | | |
| $S_1$ = MW 36 (Sept.03-09) *Purva nakshtra* | 793.9 | 508.1 | 516.0 | 579.1 | 846.67 | 648.77 | 0.57 |
| $S_2$ = MW 38 (Sept.17-23) *Uttara nakshtra* | 897.4 | 618.2 | 583.3 | 701.6 | 926.92 | 745.46 | 0.63 |
| $S_3$ = MW 40 (Oct. 01-07) *Hasta nakshtra* | 1042.4 | 844.4 | 677.6 | 503.5 | 973.42 | 808.28 | 0.56 |
| $S_4$ = MW 42 (Oct.15-21) *Chitra nakshtra* | 480.9 | 434.0 | 379.9 | 357.2 | 424.24 | 415.25 | 0.76 |
| Mean | 803.7 | 601.2 | 539.2 | 535.4 | 792.81 | 654.44 | 0.63 |
| **Sub = Varieties** | | | | | | | |
| $V_1$ = Maldandi (M-35-1) | 884.3 | 659.1 | 594.3 | 588.5 | 863.56 | 717.94 | 0.64 |
| $V_2$ = Mauli | 770.2 | 573.2 | 514.8 | 534.3 | 801.44 | 638.79 | 0.62 |
| $V_3$ = Yashoda | 756.4 | 571.2 | 508.6 | 483.3 | 713.43 | 606.59 | 0.64 |
| Mean | 803.7 | 601.2 | 539.2 | 535.4 | 792.81 | 654.44 | 0.63 |
| S.E.± (Sowing dates) | 57.1 | 44.4 | 37.02 | 25.2 | 27.2 | 44.5 | |
| C.D. at 5% | 182.6 | 142.1 | 118.45 | 80.7 | 87.1 | 137.1 | |
| S.E.± (Varieties) | 33.3 | 23.9 | 22.16 | 19.6 | 23.3 | 10.3 | |
| C.D. at 5% | 97.1 | 69.6 | 64.69 | 57.3 | 68.1 | 29.7 | |
| S.E.± (SD X V) | 66.5 | 47.7 | 44.32 | 39.3 | 46.7 | 20.6 | |
| C.D. at 5% | NS | NS | NS | NS | NS | NS | |

interval of sowing in respect of grain yield, monetary returns, CUM, MUE, Tmax, Tmin etc.

**Agronomical studies :** Among all the sowing dates the crop sown at MW 40 (01-07$^{th}$ Oct) was produced maximum grain yield (808.29 kg ha$^{-1}$) and total monetary returns (Rs. 26633 ha$^{-1}$) over rest of the treatment (Table 1 and 3). These results are in concurrence with the findings of Hulihalli *et al* (2016). This indicates the hasta sown sorghum gets sufficient period for its biological development than the

**Table 2.** Pooled fodder yield (kg ha$^{-1}$) of *rabi* sorghum as influenced by sowing dates and varieties 2016 to 20

| Treatment | 2016-17 | 2017-18 | 2018-19 | 2019-20 | 2020-21 | Pooled | SYI |
|---|---|---|---|---|---|---|---|
| **Main = Sowing dates** | | | | | | | |
| $S_1$ = MW 36 (Sept.03-09) *Purva nakshtra* | 1500.3 | 1200.3 | 975.2 | 1125.86 | 1655.26 | 1291.40 | 0.61 |
| $S_2$ = MW 38 (Sept.17-23) *Uttara nakshtra* | 1642.9 | 1363.6 | 1126.0 | 1313.04 | 1894.91 | 1468.10 | 0.61 |
| $S_3$ = MW 40 (Oct. 01-07) *Hasta nakshtra* | 1711.3 | 1540.2 | 1145.1 | 975.35 | 2098.54 | 1494.11 | 0.49 |
| $S_4$ = MW 42 (Oct.15-21) *Chitra nakshtra* | 1116.0 | 1060.2 | 881.7 | 883.95 | 929.61 | 974.29 | 0.77 |
| Mean | 1492.7 | 1291.1 | 1032.0 | 1074.55 | 1644.58 | 1306.97 | 0.62 |
| **Sub=Varieties** | | | | | | | |
| $V_1$ = Maldandi | 1811.9 | 1572.2 | 1298.9 | 1298.71 | 1813.47 | 1559.03 | 0.71 |
| $V_2$ = Mauli | 1471.1 | 1275.1 | 995.2 | 1030.05 | 1634.07 | 1281.11 | 0.61 |
| $V_3$ = Yashoda | 1195.0 | 1026.0 | 801.9 | 894.89 | 1486.20 | 1080.79 | 0.54 |
| Mean | 1492.7 | 1291.1 | 1032.0 | 1074.55 | 1644.58 | 1306.97 | 0.62 |
| S.E.± (Sowing dates) | 106.6 | 94.6 | 61.8 | 46.3 | 68.0 | 83.2 | |
| C.D. at 5% | 341.2 | 302.7 | 197.8 | 148.2 | 217.6 | 256.2 | |
| S.E.± (Varieties) | 69.6 | 61.7 | 44.2 | 45.8 | 58.3 | 27.1 | |
| C.D. at 5% | 203.1 | 180.0 | 128.9 | 133.8 | 170.3 | 78.0 | |
| S.E.± (SD x V) | 139.2 | 123.3 | 88.3 | 91.7 | 116.7 | 54.2 | |
| C.D. at 5% | NS | NS | NS | NS | NS | NS | |

**Table 3.** Pooled total monetary returns (Rs. ha$^{-1}$) of *rabi* sorghum by sowing dates and varieties 2016 to 20

| Treatment | 2016-17 | 2017-18 | 2018-19 | 2019-20 | 2020-21 | Pooled | SYI |
|---|---|---|---|---|---|---|---|
| **Main = Sowing dates** | | | | | | | |
| $S_1$ = MW 36 (Sept.03-09) Purva nakshtra | 27349 | 18704 | 17777 | 23003 | 23706 | 22108 | 0.66 |
| $S_2$ = MW 38 (Sept.17-23) Uttara nakshtra | 30649 | 22273 | 19922 | 27611 | 25953 | 25281 | 0.68 |
| $S_3$ = MW 40 (Oct. 01-07) Hasta nakshtra | 34617 | 28810 | 22501 | 19982 | 27255 | 26633 | 0.60 |
| $S_4$ = MW 42 (Oct.15-21) Chitra nakshtra | 17603 | 16152 | 13906 | 15135 | 11878 | 14935 | 0.72 |
| Mean | 27555 | 21485 | 18527 | 21433 | 22198 | 22239 | 0.68 |
| **Sub = Varieties** | | | | | | | |
| $V_1$ = Maldandi | 31167 | 24338 | 21010 | 24147 | 24179 | 24968 | 0.68 |
| $V_2$ = Mauli | 26611 | 20706 | 17845 | 21179 | 22440 | 21756 | 0.69 |
| $V_3$ = Yashoda | 24886 | 19410 | 16725 | 18973 | 19975 | 19994 | 0.68 |
| Mean | 27555 | 21485 | 18527 | 21433 | 22198 | 22239 | 0.68 |
| S.E.± (Sowing dates) | 1665.7 | 1329.7 | 1084.5 | 937.9 | 7619 | 1352.9 | |
| C.D. at 5% | 5328.9 | 4254.0 | 3469.5 | 3000.5 | 2437.5 | 4168.7 | |
| S.E.± (Varieties) | 914.7 | 667.5 | 599.1 | 762.9 | 653.3 | 248.9 | |
| C.D. at 5% | 2669.7 | 1948.3 | 1748.6 | 2226.8 | 1906.9 | 716.9 | |
| S.E.± (SD x V) | 1829.3 | 1335.0 | 1198.1 | 1525.9 | 1306.6 | 497.7 | |
| C.D. at 5% | NS | NS | NS | NS | NS | NS | |

reproductive development, this might be due to uneven and inadequate distribution of rainfall and moisture during vegetative growth period of crops. It is also seen that as there was delay in sowing increase in consistency in grain yield production than the earlier sowing. This might be due to delayed sown crops were get uniform sufficient moisture for their development.

Among the varieties, M-35-1 was produced significantly higher grain yield (717.94 kg $ha^{-1}$) and total monetary returns (Rs.24968 $ha^{-1}$) over

**Table 4.** CUM and MUE as influenced by sowing time in *rabi* sorghum (2016 to 20)

| Sowing time | CUM (mm) | | | | MUE (kg $ha^{-1}$ mm ) | | | |
|---|---|---|---|---|---|---|---|---|
| | M-35-1 | Mauli | Yashoda | Mean | M-35-1 | Mauli | Yashoda | Mean |
| $S_1$ | 270 | 285 | 290 | 282 | 2.7 | 2.2 | 2.0 | 2.3 |
| $S_2$ | 240 | 268 | 270 | 259 | 3.4 | 2.7 | 2.6 | 2.9 |
| $S_3$ | 210 | 240 | 250 | 233 | 4.1 | 3.3 | 3.1 | 3.5 |
| $S_4$ | 185 | 189 | 192 | 189 | 2.5 | 2.1 | 2.0 | 2.2 |
| Mean | 226 | 245 | 250 | 240 | 3.1 | 2.6 | 2.4 | 2.7 |

**Table 5.** Mean Growing degree days (GDD) required to attain phenological stages as influenced by sowing dates in *rabi* sorghum (2016 to 20)

| Sowing time | Phenological stage | | | | | | |
|---|---|---|---|---|---|---|---|
| | Emer. | 3 leaf | Flag leaf | 50 % flowering | Soft dough | Hard dough | Phy. maturity |
| $S_1V_1$ | 183 | 499 | 753 | 386 | 438 | 344 | 358 |
| Cumulative | 682 | 1252 | 1139 | 824 | 782 | 702 | 2963 |
| $S_1V_2$ | 198 | 496 | 777 | 312 | 416 | 357 | 361 |
| Cumulative | 694 | 1273 | 1089 | 728 | 773 | 718 | 2920 |
| $S_1V_3$ | 151 | 450 | 751 | 350 | 379 | 330 | 467 |
| Cumulative | 601 | 1201 | 1101 | 729 | 709 | 797 | 2893 |
| $S_2V_1$ | 197 | 490 | 830 | 340 | 457 | 385 | 340 |
| Cumulative | 687 | 1320 | 1170 | 797 | 842 | 725 | 3041 |
| $S_2V_2$ | 170 | 469 | 782 | 363 | 393 | 313 | 453 |
| Cumulative | 639 | 1251 | 1145 | 756 | 706 | 1066 | 2944 |
| $S_2V_3$ | 198 | 440 | 730 | 365 | 419 | 335 | 380 |
| Cumulative | 638 | 1170 | 1095 | 784 | 754 | 715 | 2871 |
| $S_3V_1$ | 168 | 463 | 833 | 393 | 433 | 337 | 432 |
| Cumulative | 631 | 1296 | 1226 | 826 | 770 | 769 | 3062 |
| $S_3V_2$ | 197 | 434 | 778 | 395 | 461 | 361 | 367 |
| Cumulative | 631 | 1212 | 1173 | 856 | 822 | 728 | 2996 |
| $S_3V_3$ | 161 | 450 | 751 | 350 | 379 | 330 | 467 |
| Cumulative | 611 | 1201 | 1101 | 729 | 709 | 797 | 2893 |
| $S_4V_1$ | 187 | 477 | 747 | 302 | 402 | 382 | 369 |
| Cumulative | 664 | 1224 | 1049 | 704 | 784 | 751 | 2869 |
| $S_4V_2$ | 187 | 398 | 706 | 358 | 399 | 351 | 392 |
| Cumulative | 585 | 1104 | 1064 | 757 | 750 | 743 | 2793 |
| $S_4V_3$ | 183 | 506 | 799 | 335 | 435 | 367 | 332 |
| Cumulative | 689 | 1305 | 1134 | 770 | 802 | 699 | 2627 |

**Table 6.** Periodical radiation use efficiency (g $MJ^{-1}$) as influenced by varieties and sowing dates in sorghum (2016- to 2020)

| MW | DAS | $S_1$ | | | $S_2$ | | | $S_3$ | | | $S_4$ | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | M.35-1 | MAU | YESH | M.35-1 | MAU | YESH | M.35-1 | MAU | YESH | M.35-1 | MAU | YESH |
| 36 | SO | SOW | SOW | SOW | - | - | - | - | - | - | - | - | - |
| 38 | 14 | 0.42 | 0.34 | 0.28 | - | - | - | - | - | - | - | - | - |
| 40 | 28 | 0.78 | 0.62 | 0.66 | 0.45 | 0.31 | 0.27 | - | - | - | - | - | - |
| 42 | 42 | 1.55 | 1.42 | 1.40 | 0.72 | 0.55 | 0.58 | 0.54 | 0.43 | 0.34 | - | - | - |
| 44 | 56 | 2.41 | 2.33 | 2.11 | 1.38 | 1.25 | 1.26 | 0.95 | 0.88 | 0.88 | 0.39 | 0.18 | 0.15 |
| 46 | 70 | 2.65 | 2.60 | 2.58 | 2.38 | 2.09 | 2.26 | 1.90 | 1.83 | 1.80 | 0.60 | 0.41 | 0.46 |
| 48 | 84 | 2.60 | 2.44 | 2.56 | 2.60 | 2.62 | 2.45 | 2.18 | 2.37 | 2.22 | 1.27 | 1.10 | 1.10 |
| 50 | 98 | 2.16 | 2.04 | 2.05 | 2.70 | 2.60 | 2.50 | 2.72 | 2.61 | 2.60 | 2.32 | 1.86 | 2.08 |
| 51 | 105 | 2.07 | 1.86 | 1.75 | 2.48 | 2.38 | 1.90 | 2.60 | 2.11 | 2.03 | 2.39 | 2.38 | 2.28 |
| 1 | 119 | 1.82 | 1.57 | 1.67 | 2.39 | 2.11 | 1.71 | 2.53 | 1.93 | 1.69 | 2.50 | 2.10 | 2.08 |
| 3 | 133 | 0.42 | - | - | 2.16 | 1.67 | 1.52 | 2.24 | 1.61 | 1.87 | 2.40 | 2.00 | 1.80 |
| 5 | 147 | - | - | - | 1.85 | - | 1.38 | 2.10 | 1.36 | 1.51 | 1.76 | 1.65 | 1.56 |
| 6 | 154 | - | - | - | - | - | - | 1.44 | - | 0.34 | 1.35 | 1.44 | 1.39 |
| 7 | 161 | - | - | - | - | - | - | - | - | - | 1.30 | - | 1.40 |

the other variety. This might be due to M.35-1 was more effective in utilizing available moisture and weather for its growth and development than other varieties. Similar results were reported by Jadhav *et al.* (2010) and Mokashi *et al* (2008). This indicates that M.35-1 was more consistent in production of grain, biomass and total monetary returns than other variety (Table 3).

**Meteorological studies :** Growth and development of crop is influenced by environmental conditions such as temperature, radiation and photoperiod (Friend, 1966). The consumptive use of moisture (CUM) and moisture use efficiency (MUE) were presented in Table 4. Changing planting date could effluence on growth process with changing environment temperature (Dehghan, 2007). The mean CUM and MUE recorded by sorghum crop was 240 mm and 2.7 kg $ha^{-1}$ mm. The highest CUM was recorded by $S_1$ sown crop (258 mm) however the MUE was recorded by $S_3$ sown crop (3.5 kg $ha^{-1}$ mm). This indicated that $S_3$ sown crop (*Hasta Nakshtras*) utilized moisture more efficiently than other dates of sowing.

The number of days required to attain physiological maturity and growing degree days were higher in $S_3$ (2984) sown crop. Among the varieties it is higher in M35-1 (2983) than Mauli and Yashoda. This is due to more duration required by $S_3$ sown crop and M-35-1 variety.

The consumptive use of moisture (CUM) during total growth period of *Rabi* sorghum Fig. 1 showed a polynomial relationship with grain yield ($y=-0.0373\ x^2 +15.477x - 737.45 R^2 = 0.8693$). The CUM of 240 mm was found to be optimum for getting higher grain yield. The RUE studies depicted in Fig. 2 showed linear relationship with grain yield. This indicated that radiation interception is directly related with grain yield ($y=1243.5x-5234.8x+5898.6\ \ R^2 =$

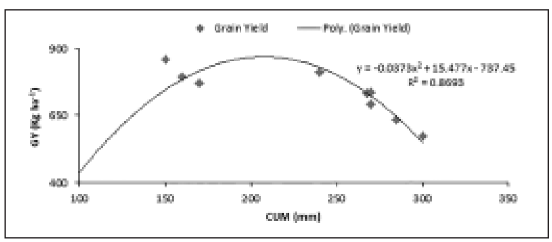


**Fig. 1.** Grain yield with CUM in Sorghum

0.8159). The figure showed that if RUE increases from 2.08 to 2.72 g $mj^{-1}$.

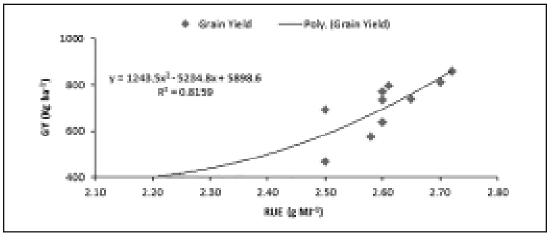


**Fig. 2.** Grain yield with RUE in Sorghum

The GDD was correlated with the grain yield of rabi sorghum and depicted in **Fig. 3.** It showed a linear relationship with grain yield (y=-0.0013 $x^2$ -6.3088 x-7826.8 $R^2$ = 0.7702). This indicated that with increase of GDD there was increase in grain yield upto 3082 GDD. The Tmax was correlated with the grain yield of rabi sorghum and depicted in **Fig. 4.** It showed a polynomial relationship with grain yield (y=31254 $x^2$ -2E+06+3E+07 $R^2$ = 0.8657). This indicated that with increase of $T_{max}$ there was increase in grain yield upto 31.8°C and later on yield decrease with increase in $T_{max}$. The

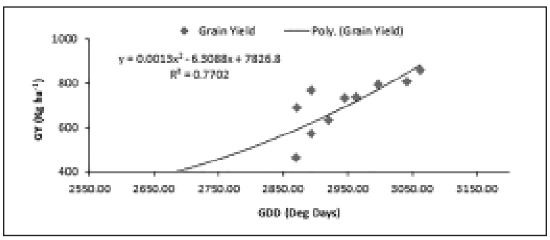


**Fig. 3.** Grain yield with GDD in Sorghum

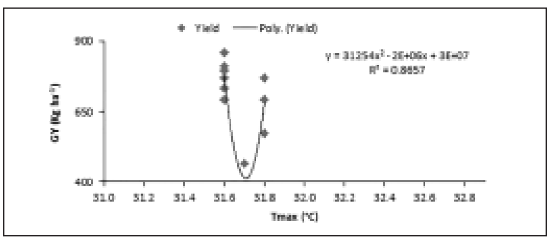


**Fig. 4.** Grain yield with Tmax in Sorghum

$T_{min}$ was correlated with the grain yield of *rabi* sorghum and depicted in **Fig. 5.** It showed a polynomial relationship with grain yield (y=-191.12 $x^2$ + 6612x- 56367 $R^2$ = 0.7686). This indicated that with increase of T min there was increase in grain yield upto 17.5°C later on yield decrease with increase in $T_{min}$.

Initially the RUE values were low it increases

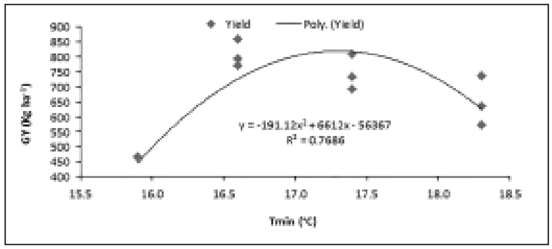


**Fig. 5.** Grain yield with Tmin in Sorghum

up to 70 DAS i.e. up to 50 percent flowering to soft dough stage further it decreases in all most all the sowing dates and varieties.

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