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# IMPACT OF SOWING TIME AND FOLIAR SPRAY OF OSMOPROTECTANTS ON GROWTH, YIELD ATTRIBUTES AND YIELD OF WHEAT (*TRITICUM AESTIVUM* L.) AGAINST HEAT STRESS

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**ABSTRACT**

A field experiment was conducted on medium black calcareous soil during *rabi* seasons of 2020-21 and 2021-22 at the Instructional Farm, Department of Agronomy, College of Agriculture, Junagadh Agricultural University, Junagadh to evaluate the impact of sowing time and foliar spray of osmoprotectants on growth, yield attributes and yield of wheat (*Triticum aestivum* L.) against heat stress. The experiment was laid out in split plot design with three replications. The experiment consisting of sixteen treatment combinations, comprising four levels of sowing time ($4^{th}$ week of October, $3^{rd}$ week of November, $1^{st}$ week of December and $3^{rd}$ week of December) were assigned to main plots and four levels of foliar spray of osmoprotectants (water spray, salicylic acid (SA) @ 100 ppm, sodium nitroprusside (SNP) @ 400 µg/ml and $KNO_3$ @ 2.0%) were assigned to sub plots. The results of experiment on pooled data based indicated that among sowing dates, the wheat sown on $3^{rd}$ week of November recorded significantly higher initial (31.06) and final (29.64) plant population per meter row length, growth parameters *viz*., plant height at harvest (96.52 cm), dry matter accumulation at harvest (20.91 g/plant) and number of tillers per plant (4.02), yield attributes *viz*., number of spikes per plant (3.30), number of spikelets per spike (19.198), number of grains per spike (51.31), length of spike (9.59 cm) and test weight (44.86 g), grain yield (5445 kg/ha), straw yield (7433 kg/ha) and biological yield (12878 kg/ha) as compared to rest of the sowing times. The foliar spray of salicylic acid @ 100 ppm at 50 and 75 days after sowing (DAS) significantly increased plant height at harvest, dry matter accumulation at harvest, number of spikes per plant, number of spikelets per spike, number of grains per spike, length of spike, test weight, grain yield, straw yield and biological yield compared to water spray but it remained at par with foliar spray of $KNO_3$ @ 2.0 %. Based on the results of two-year field study, it can be concluded that wheat crop sown during $3^{rd}$ week of November along with foliar spray of salicylic acid @100 ppm or $KNO_3$ @ 2.0% at 50 and 75 DAS was found effective for mitigating of heat stress by improving growth and yield attributes as well as achieving higher yield of wheat under South Saurashtra region of Gujarat.
***Keywords* :** Sowing time, Osmoprotectants, Heat stress, Salicylic acid, Sodium nitroprusside and $KNO_3$

## Introduction

Wheat (*Triticum aestivum* L.) is the world's leading cereal crop in terms of area harvested. It is the third most-produced cereal after maize and rice in the world. Over the past four decades, India has made significant progress in wheat production and is now the second-largest producer in the world. It is grown in India under sub-tropical environment during *rabi* season and occupies an area of 31.82 million hectares with the production of 112.74 million tonnes and productivity of 3543 kg/ha. Gujarat is the $7^{th}$ largest wheat producing state in the country. In Gujarat wheat occupies an area of 1.15 million hectares with production of 3.65 million tonnes and productivity of 3172 kg/ha (Anonymous, 2024). The advent of terminal heat stress (sudden rise in temperature during grain filling period) adversely affects wheat grown on approximately 36 million ha area, comprising 40% of the temperate environment (Hays *et al*., 2007), there is an urgent need to find the mitigation strategies. Studies suggested that optimal temperature for grain set and grain filling in wheat is between 19°C and 22°C (Porter and Gawith, 1999). Lobell *et al*. (2005) reported that wheat yield in Mexico decreased by 10% for every 1°C increase in night time temperature and grain yield showed a strong negative correlation with increasing minimum temperature. In the Saurashtra region, terminal heat stress is a common problem in wheat cultivation, which may be due to short winter season or high temperature at maturity. Shorter growing period available for wheat growth concomitant with delayed sowing exposes the wheat crop to high temperature during the grain filling stage (terminal heat stress) which leads to a drastic loss in yield. This situation necessitates the mitigation of terminal heat stress in wheat through adopting various strategies like selection of appropriate variety, optimum planting time and foliar spray of osmoprotectants.

Sowing time is one of the non-monetary inputs for getting optimum growth and yield in wheat crop according to prevailing agro climatic conditions and genotype. In general, late sowing wheat varieties faces severe temperature stress, shortens the heading and maturity duration, ultimately affecting final yield and grain quality (Hakim *et al.,* 2012). Hence, the early sowing along with selecting genotypes with early maturity and a relatively long time to heading are advocated to evade terminal heat stress and accelerate grain filling (Al-Karaki, 2012). Therefore, maintaining appropriate sowing time is one of the most important agronomic practice for getting optimum plant growth and yield of wheat under heat-stressed environment (Kajla *et al.,* 2015).

Stress mitigating chemicals play an important role in mitigating stress. Exogenous application of osmoprotectants has been reported to improve the yield and nutrient status of various crops. Osmoprotectants serve to raise osmotic pressure in the cytoplasm and can also stabilize proteins and membranes when salt levels or temperatures are unfavourable (Yancey, 1994). Certain chemicals like salicylic acid, sodium nitroprusside and potassium nitrate can be used as osmoprotectants. Salicylic acid (SA) is a phenolic compound involved in the regulation of growth and development of plants and their responses to biotic and abiotic stress factors. It is also involved in the regulates important plant physiological processes such as photosynthesis, nitrogen metabolism, proline (Pro) metabolism, production of glycine betaine (GB), antioxidant defence system and plant water relations under stress conditions and, thereby provides protection in plants against abiotic stresses. Salicylic acid pre-treatment induces thermo-tolerance and definitely plays a role in initiating various mechanisms involved in overcoming high temperature limitations (Khan *et al*., 2013). Sodium nitroprusside (a donor of NO), helps in enhancing the synthesis of antioxidant enzymes, thereby ameliorates high temperature stress (Bavita *et al*., 2012). Potassium nitrate may also play an important role in adaptation of cells to high temperature stress through its effect on water uptake, root growth, carbohydrate redistribution and starch synthesis in storage organs (Bardhan *et al*., 2007). Therefore, generation data on the aspect of sowing time and impact of osmoprotectants on growth, yield attributes and yield of wheat crop in Saurashtra region may helpful for yield stability of wheat.

## Materials and Methods

Field experiment was conducted at Instructional Farm, Department of Agronomy, College of Agriculture, Junagadh Agricultural University, Junagadh during *rabi* seasons of 2020-21 and 2021-22. The soil of the experimental plot was shallow medium black calcareous, clayey in texture with medium in organic carbon, slightly alkaline in reaction with normal electrical conductivity, medium in available nitrogen, phosphorus and potassium. The experiment was laid out in split plot design with three replications. Four levels of sowing time ($D_1$: 4$^{th}$ week of October, $D_2$: 3$^{rd}$ week of November, $D_3$: 1$^{st}$ week of December and $D_4$: 3$^{rd}$ week of December) were assigned to main plot and four levels of foliar spray of osmoprotectants ($F_1$: Control, $F_2$: Salicylic acid @ 100 ppm, $F_3$: Sodium nitroprusside @ 400 µg/ml and $F_4$: $KNO_3$ @ 2.0%) were assigned to sub plot treatments having sixteen treatment combinations.

Foliar spray of osmoprotectants was done at booting (50 DAS) and grain filling (75 DAS) stages using a spray volume of 600 litre/ha. Wheat crop was sown as per sowing treatment. The wheat variety "GJW 463" was used and sown in field plots at a depth of 4-5cm keeping inter row spacing of 22.5cm using recommended seed rate 120 kg/ha. Recommended dose of nitrogen, phosphorus and potassium (120-60-60 N, $P_2O_5$, $K_2O$ kg/ha) were applied in the form of urea, di-ammonium phosphate (DAP) and muriate of potash (MOP) in each plot. The first irrigation was given immediately after sowing. Subsequent irrigations were applied at critical stages and as per need for successful wheat production. Other agronomic practices, pest and disease management were followed as per the recommendations. Observations were recorded on plant population, growth parameters, yield attributes and yield of wheat crop.

Statistical analysis of data was carried out for each character as described by Gomez and Gomez (1984). Critical difference (CD) values at P=0.05 were used for determine the significance of differences between mean values of treatments.

## Results and Discussion

### Plant population

The plant population of wheat at initial (20 DAS) and final stage (at harvest) were significantly influenced by different sowing time treatments (Table 1). Significantly maximum initial (31.06 plants/m row) and final (29.64 plants/m row) plant population was recorded in sowing during 3rd week of November as compared to very late sowing (3rd week of December) and remained at par with early sowing (4th week of October) and late sowing (1st week of December) in pooled analysis, which could be attributed to an unfavourable temperature regime. The optimum temperature for germination of wheat is from 12 °C to 25 °C, while under very late sowing (3rd week of December), the prevalence of low temperature below 12 °C at the early stage of the crop adversely affected the plant population of wheat crop. These findings are closely associated with the study in wheat carried out by Madhu *et al.* (2018), Prajapat *et al.* (2018), Chauhan *et al.* (2020). Foliar spray of osmoprotectants at 50 and 75 DAS did not show any significant effect on plant population initially (20 DAS) and at harvest of wheat.

### Growth parameters

Growth parameters *viz.,* plant height at harvest, dry matter accumulation at harvest and number of tillers per plant were significantly influenced by different sowing treatments and foliar spray of osmoprotectants (Table 1). Significantly, the maximum plant height at harvest (96.50 cm), dry matter accumulation at harvest (20.91 g/plant) and number of tillers per plant (4.02) were found in 3rd week of November sown crop, while the minimum number of tillers per plant were found in 3rd week of December sown wheat. Under favorable temperature, genotypes that were relatively late in heading possessed better vegetative growth, as reflected by increased plant height, a higher number of internodes and number of tillers per plant, but when growth resources are limited by heat stress, the size of plant organs such as leaves, tillers and spikes are reported to be reduced (Stone and Nicolas, 1994). Further, vegetative growth and dry matter production were lower with extended sowing dates. This was mainly because of the rise in temperature during February and March, which forced the late sown wheat to mature earlier and this enforced maturity resulted in shorted growing period. This decreased growth period might have reduced dry matter production with late sowing These findings are in conformity with those of Madhu *et al.* (2018), Prajapat *et al.* (2018), Chauhan *et al.* (2020), Singh *et al.* (2022) and Kumar *et al.* (2023).

Significantly higher values of plant height at harvest (88.22 cm) and dry matter accumulation at harvest (18.84 g/plant) were observed with the foliar application of salicylic acid @ 100 ppm as closely followed by foliar spray of sodium nitroprusside (400 µg/ml) and $KNO_3$ (2.0%). The lowest values of plant height and dry matter accumulation were recorded under water spray (control). The increase in dry matter accumulation with the foliar spray of osmoprotectants could be attributed to an increase in plant height as a result of cell elongation and cell enlargement, consequently, plant might have produced longer and thicker stems ultimately hardiness of plant and hence, the dry matter accumulation might have increased. Thus, overall improvement in growth parameters under application of salicylic acid @ 100 ppm, sodium nitroprusside @ 400 µg/ml and $KNO_3$ @ 2.0% appears to be on account of photosynthetic efficiency by virtue of improvement in total chlorophyll content, greater developed assimilating apparatus (flag leaf area), ultimately resulting in increased dry matter accumulation at every growth stage and also a taller plant These results are in accordance with the earlier findings of Kumawat *et al.* (2013) in barley and Suryavanshi *et al.* (2016), Singh (2021) and Zhang *et al.* (2023) in wheat.

### Yield attributes and yield

Data presented in Table 2 and 3 revealed that yield parameters *viz.,* number of spikes per plant, number of spikelets per spike, number of grains per spike, length of spike and test weight and grain yield, straw yield and biological yield significantly influenced by different sowing treatments and foliar spray of osmoprotectants.

Significantly the highest number of spikes per plant (3.30), number of spikelets per spike (19.19), number of grains per spike (51.31), length of spike (9.59 cm), test weight (44.86 g), grain yield (5445 kg/ha), straw yield (7433 kg/ha) and biological yield (12878 kg/ha) was recorded with 3rd week of November sowing as compared to other sowing times in pooled analysis. The lowest values of yield attributes and yield were found under very late sown wheat (3rd week of December). Delayed emergence of seedlings owing to lower temperature at sowing time and forced early maturity of crop due to terminal heat stress caused by high temperature at reproductive phase might have reduced the growth period of crop and thus resulted in lower yield attributes and yield in 3rd week of December sowing. Higher temperature during germination and the early vegetative phase and the lower temperature during the reproductive phase, as simulated by early sowing on 4th week of October, adversely affected growth parameters as well as yield attributes, which ultimately resulted into lower yield of wheat as compared to sowing under favourable temperature regimes. Similarly, higher temperature at grain filling as stimulated by late and very late sowing, lead to forced maturity, thereby reducing yield of wheat. The increased yield under 3rd week of November sowing might be explained as favourable climatic conditions available during the timely sown crop might have resulted in profuse growth, which consequently reflected into more accumulation of dry matter. The grain yield of a crop is the cumulative effect of growth and yield attributes such as number of spikes per plant, number of spikelets per spike, number of grains per spike, length of spike, test weight etc. Enhanced crop growth in terms of plant height and dry matter accumulation increased straw yield. Further, increased grain and straw yield under timely sown wheat resulted in increased biological yield. Early sowing when temperature was above the optimum produces poor plants and even higher seeding rate cannot compensate low yield. Under late sown conditions, wheat faces low temperature during vegetative growth shortened duration of various phases of crop development and high temperature in the later stages of the growing season cause heat stress which leads a reduction in yield. At optimum temperature, early sowing with an optimum plant population enhances the growth and nutrient uptake of wheat, resulting in higher crop production (Fazily, 2021). The results are in conformity with those reported by Meena *et al.* (2015), Chouhan *et al.* (2017), Patel *et al.* (2018), Praveen *et al.* (2018), Reddy *et al.* (2020) and Kumar *et al.* (2023) in wheat.

On a pooled basis, foliar spray of salicylic acid @ 100 ppm at 50 and 75 DAS significantly improved yield attributes and yield *viz.,* number of spikes per plant (2.63), number of spikelets per spike (17.50), number of grains per spike (45.65), length of spike (8.94 cm), test weight (42.36 g), grain yield (4972 kg/ha), straw yield (6882 kg/ha) and biological yield (11855 kg/ha) followed by foliar spray of $KNO_3$ @ 2.0%. Although, it remained at par with foliar spray of sodium nitroprusside @ 400 µg/ml in case of number of spikelets per spike, length of spike and test weight. Plant under the influence of these osmoprotectants might have maintained greater photosynthetic efficiency, which provided adequate metabolites to reproductive sinks for greater growth and development. Significant improvement in these parameters seems to be due to vigorous vegetative growth of plants, which ultimately resulted in more leaf area and increased photosynthesis, thereby resulting in the formation of a higher number of spikes per plant, number of spikelets per spike, number of grains per spike, length of spike and test weight The significant increased grain yield with the application of salicylic acid and $KNO_3$ might be attributed to the increased number of spikes per plant, number of spikelets per spike, number of grains per spike, length of spike and test weight. The increase in straw yield due to the application of salicylic acid and $KNO_3$ could be attributed to the increased plant height and dry matter accumulation and possibly as a result of higher chlorophyll content (SPAD value) in leaf, increase photosynthesis and higher uptake of nutrients. Thus, an increase in grain yield and straw yield ultimately increased biological yield. Overall, foliar spray of osmoprotectants (salicylic acid, sodium nitroprusside and $KNO_3$) play an offensive role which might have helpful for elevating the adverse effect of heat stress by osmoregulation through balancing water status, dry matter accumulation by photosynthesis and ultimately improvement of yield and yield attributes in wheat. Similar results were also observed by Suryavanshi *et al.* (2016), Chaurasiya *et al.* (2018), Chowdhury *et al.* (2020), Lakhran *et al.* (2021) and Monga and Kumar (2022) in wheat crop who reported higher values of yield attributes and yield due to foliar application of osmoprotectants

## Conclusion

Based on the results obtained from two years of field experimentation, it can be concluded that wheat crop sown during 3rd week of November along with foliar spray of salicylic acid @100 ppm or $KNO_3$ @ 2.0% applied twice at 50 and 75 days after sowing was found effective in combined way for mitigating of heat stress by improving initial and final plant population, growth parameters *viz.,* plant height at harvest, dry matter accumulation at harvest and number of tillers per plant, yield attributes *viz.*, number of spikes per plant, number of spikelets per spike, number of grains per spike, length of spike and test weight as well as grain yield, straw yield and biological yield of wheat under South Saurashtra region of Gujarat.

**Table 1:** Effect of sowing time and foliar spray of osmoprotectants on plant population and growth parameters of wheat (pooled data of two years)

| Treatments | Plant population at 20 DAS (plants/m row length) | Plant population at harvest (plants/m row length) | Plant height at harvest (cm) | Dry matter accumulation at harvest (g/plant) | Number of tillers per plant at harvest |
|---|---|---|---|---|---|
| **Sowing time** | | | | | |
| $S_1$: 4th week of October | 30.08 | 28.51 | 89.93 | 19.59 | 3.43 |
| $S_2$: 3rd week of November | 31.06 | 29.64 | 96.52 | 20.91 | 4.02 |
| $S_3$: 1st week of December | 29.83 | 28.20 | 84.29 | 17.46 | 3.15 |
| $S_4$: 3rd week of December | 28.05 | 25.82 | 73.33 | 13.11 | 2.60 |
| SEm ± | 0.40 | 0.47 | 1.31 | 0.25 | 0.07 |
| CD (P = 0.05) | 1.24 | 1.44 | 4.04 | 0.76 | 0.21 |
| CV (%) | 6.64 | 8.14 | 7.47 | 6.79 | 10.36 |
| **Foliar spray of osmoprotectants** | | | | | |
| $F_1$: Water spray (control) | 29.77 | 27.58 | 81.86 | 15.52 | 3.22 |
| $F_2$: Salicylic acid @ 100 ppm | 29.82 | 28.32 | 88.22 | 18.84 | 3.37 |
| $F_3$: Sodium nitroprusside @ 400 µg/ml | 29.66 | 28.07 | 86.65 | 18.20 | 3.29 |
| $F_4$: $KNO_3$ @ 2.0% | 29.78 | 28.20 | 87.34 | 18.50 | 3.32 |
| SEm ± | 0.28 | 0.32 | 0.93 | 0.16 | 0.05 |
| CD (P = 0.05) | NS | NS | 2.64 | 0.45 | NS |
| CV (%) | 4.68 | 5.55 | 5.29 | 4.33 | 7.71 |
| **Interactions** | | | | | |
| S x F | NS | NS | NS | Sig. | NS |

**Table 2:** Effect of sowing time and foliar spray of osmoprotectants on yield attributes of wheat (pooled data of two years)

| Treatments | Number of spikes per plant | Number of spikelets per spike | Number of grains per spike | Length of spike (cm) | Test weight (g) |
|---|---|---|---|---|---|
| **Sowing time** | | | | | |
| $S_1$: 4th week of October | 2.62 | 16.98 | 47.10 | 8.63 | 43.49 |
| $S_2$: 3rd week of November | 3.30 | 19.19 | 51.31 | 9.59 | 44.86 |
| $S_3$: 1st week of December | 2.34 | 17.59 | 44.76 | 9.07 | 39.80 |
| $S_4$: 3rd week of December | 1.66 | 14.62 | 36.86 | 7.41 | 35.83 |
| SEm ± | 0.05 | 0.25 | 0.71 | 0.11 | 0.58 |
| CD (P = 0.05) | 0.16 | 0.77 | 2.18 | 0.33 | 1.79 |
| CV (%) | 9.97 | 7.17 | 7.69 | 5.96 | 6.96 |
| **Foliar spray of osmoprotectants** | | | | | |
| $F_1$: Water spray (control) | 2.23 | 16.44 | 42.40 | 8.26 | 38.40 |
| $F_2$: Salicylic acid @ 100 ppm | 2.63 | 17.50 | 46.80 | 8.94 | 42.36 |
| $F_3$: Sodium nitroprusside @ 400 µg/ml | 2.51 | 17.16 | 45.00 | 8.71 | 41.48 |
| $F_4$: $KNO_3$ @ 2.0% | 2.55 | 17.28 | 45.82 | 8.80 | 41.76 |
| SEm ± | 0.04 | 0.15 | 0.48 | 0.08 | 0.35 |
| CD (P = 0.05) | 0.11 | 0.43 | 1.36 | 0.23 | 0.99 |
| CV (%) | 7.47 | 4.38 | 5.21 | 4.58 | 4.16 |
| **Interactions** | | | | | |
| S x F | NS | NS | NS | NS | Sig. |

**Table 3:** Effect of sowing time and foliar spray of osmoprotectants on yield of wheat (pooled data of two years)

| Treatments | Grain yield (kg/ha) | Straw yield (kg/ha) | Biological yield (kg/ha) |
|---|---|---|---|
| **Sowing time** | | | |
| $S_1$: 4th week of October | 4817 | 6684 | 11501 |
| $S_2$: 3rd week of November | 5445 | 7433 | 12878 |
| $S_3$: 1st week of December | 4643 | 6490 | 11133 |
| $S_4$: 3rd week of December | 3808 | 5442 | 9250 |
| SEm ± | 102 | 164 | 263 |
| CD (P = 0.05) | 315 | 506 | 810 |
| CV (%) | 10.71 | 12.35 | 11.51 |
| **Foliar spray of osmoprotectants** | | | |
| $F_1$: Water spray (control) | 4219 | 5911 | 10130 |
| $F_2$: Salicylic acid @ 100 ppm | 4972 | 6882 | 11855 |
| $F_3$: Sodium nitroprusside @ 400 µg/ml | 4722 | 6582 | 11304 |
| $F_4$: $KNO_3$ @ 2.0% | 4800 | 6673 | 11473 |
| SEm ± | 70 | 96 | 156 |
| CD (P = 0.05) | 198 | 274 | 445 |
| CV (%) | 7.31 | 7.24 | 6.84 |
| **Interactions** | | | |
| S x F | Sig. | Sig. | Sig. |

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