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# EFFECTS OF PLANT GROWTH REGULATORS AND DATES PLANTING ON SPRING MAIZE PRODUCTION UNDER AGRO-CLIMATIC CONDITIONS OF FAISALABAD, PAKISTAN

M. Qandeel[1], A. Jabbar[1], F. U. Haider[1,2*], A. L. Virk[3] and N. U. Ain[4]

[1]Department of Agronomy, University of Agriculture Faisalabad, Pakistan
[2]College of Resource and Environmental Sciences, Gansu Agricultural Univrersity Lanzhou China
[3]College of Agronomy and Biotechnology, China Agricultural University, Beijing, China
[4]Centre of genomics and Biotechnology, Fuijian Agriculture and Forestry University, Jinshan, Fuzhou, Fujian, China

## ABSTRACT

Maize is a widely grown cereal crop worldwide, butthe heat stress and delayed sowing of maize are major constraints that result in declining the maize productivity.Therefore, the current study was designed to investigate the growth promoting effect of different growth regulators i.e., salicylic acid, methyl jasmonate, and humic acid at multiple sowing times in spring maize. Experiment was laid out in randomized complete block design having split-plot arrangement with three replications having plot size of 6m × 2.25m.The yield contributing agronomic parameters were recorded and analyzed statistically by using Fisher's analysis of variance technique and treatment means were contrasted by Least significance difference having 5% probability test. Results revealed that early and delayed sowing of maize tended to decline the maize productivity and grain yield. Maximum yield and yield contributing traits were observed in $S_1$ (recommended sowing, i.e., 20-02-2017). The plant growth regulators significantly influenced the productivity of maize and minimized heat stress. The interaction between sowing dates and plant growth regulators were also significant. Among plant growth regulators, the foliar application of methyl jasmonate resulted to produce maximum biological, grain yield, 1000-grain weight, and harvest index, which were 23.04, 36.12, 14.06 and 7.87%, respectively higher than the control.The study reported that delayed sowing of maize declined the production of maize due to the gradual rise of temperature in March and plant growth regulators had the potential to minimize the heat stress and productivity of maize.

**Keyword:** heat stress, maize, plant growth regulators, sowing dates

## INTRODUCTION

Maize is cultivated as an important cereal crop after rice and wheat in Pakistan, China, Brazil, India, USA, and many other countries globally (Waqas *et al.,* 2019). In Pakistan, maize is grown primarily in Punjab and Khyber Pahtunkhwa provinces, with a maximum cultivated region being 1334 thousand hectares. Annual production of 6900 thousand tones adds 2.6% value addition in agriculture and 0.5% in country GDP (Rehman *et al.,* 2020). The yield contributing agronomic traits and grain yield of maize are affected by numerous factors i.e., inappropriate time of sowing (Moosavi *et al.,* 2012), delay sowing (Ali *et al.,* 2018), weeds infestation (Haider *et al.,* 2019), utilization of un-approved and non-certified seeds, shortage of water (Golbashy *et al.,* 2010), salts stress and extreme heat stress (Fink, 2017), in particular during the maize reproductive and vegetative phase (Nagar *et al.,* 2015).

Deviations from the normal metabolic activities carried out withinplants are regarded as stress that ultimately restrict the cell growth and leads to cell necrosis (Fink, 2017). During the entire life cycle, plants are subjected to numerous abiotic and biotic stresses, that results to reduce crop production (Golbashy *et al.,* 2010; Waqas *et al.,* 2019). Abiotic stresses consists of extreme climate conditions, accumulation of salts, and water shortage that minimize the yield of cereals, i.e., rice, barley, oat, wheat, and maize (Wahid *et al.,* 2007;

*Corresponding author: fasihullahhaider281@gmail.com

Baum *et al.,* 2019). Among all above abiotic stresses, heat stress, is considered as a critical constrain due to the steady increase in greenhouse gases i.e., chloro-floro carbon, methane, nitrous oxide, and carbondioxide, that decline the production of cereals and legumes (Wahid *et al.,* 2007; Ding *et al.,* 2016). Heat stress trends to produce reactive oxygen species such as $OH^-$, $H_2O_2$, and $O_2^{--}$that eventually decline the enzymatic activity of chloroplast and mitochondria, and eventually minimize the protein synthesis in plants, tissues and necrosis of cells, and minimize grain yield in cereals i.e. rice, wheat, and maize (Casini, 2012; Buriro *et al.,* 2015).

The gradual enhancement in the trapping of gases i.e., oxides of nitrogen, sulfur and chloro-fluoro carbon in the atmosphere (Fink, 2017), produces global warming that increases the mean temperature of the earth from 0.89 $^0$C-2$^0$C (Cao *et al.,* 2016). With reference to model calibrations, it is assumed that in 2100, the earth's temperature will be increased upto 4.8$^0$C (Fink, 2017). The addition of synthetic fertilizers i.e. nitrogen, burning of fossil fuels, and the production of oxides of nitrogen sulfur and chloro-fluoro carbon, boost global warming in the global atmosphere and Pakistan as well (Abdelrahman *et al.,* 2017). These gases cause depletion of ozone that increases the concentration of UV (Ultraviolent) radiations on the earth and cause various skin diseases in human beings and had adverse effects on the development and growth of root, shoot, and leaf plants (Schwarz *et al.,* 2010; Tsimba *et al.,* 2013).

The yield and yield contributing traits of plants are influenced by plant metabolic, physiological activities (Wahid *et al.,* 2007; Rehman *et al.,* 2020). To overcome the adverse consequences of biotic and abiotic stress in crop, plant secretes certain hormones i.e. auxins, salicylic acid, cytokinins, gibberellins, and brassinosteriods that minimize the stress. Maize is cultivated as an important cash crop in Pakistan, exposed to extreme stresses during spring plantation that minimizes the grain yield of maize (Cao *et al.,* 2016; Abdelrahman *et al.,* 2017). To minimize the adverse effects of heat stress i.e., adjustment in planting time, nutrient management, incorporation of stubbles, moderate tillage, genetic modification and hormone application are used (Ding *et al.,* 2016). Moreover, the application of plant hormones significantly enhances the development and growth of maize especially at extreme temperature stress (Ali *et al.,* 2018). Humic acid can significantly minimize the heat stress and improve the enzymatic and metabolic activity in cereals and is an essential component of water and water bodies i.e., rivers, ponds, lakes and oceans (Mohamed, 2012). Humic acid application in soil enhanced the nutrient uptake i.e. potassium, iron, nitrogen, zinc, and phosphorous in plant and positively influenced the agronomic traits of maize. A part from humicacid, the salicylic acid application played an essential rolein mitigating abiotic strains in saline soil, and enhanced the enzymatic activities in maize (Hayat *et al.,* 2010; Tufail *et al.,* 2013). The foliar application of salicylic acid significantly improved the maize production in saline soil by stimulating salt tolerance mechanism (Javaheri *et al.,* 2012; Kumar, 2014). Methyl jasmonate also helps to mitigate the abiotic stress in plants when used as a growth stimulator and influenced the mechanism of antioxidants within plants in horticulture fruits i.e. tomatoes (Norastehnia and Asghari, 2006; Rohwer and Erwin, 2008; Kazemi, 2014).

Besides the heat stress, delayed sowing of maize is also the main reason that declines the productivity (Buriro *et al.,* 2015). Delay sowing of maize enhances the moisture contents and fresh biomass, minimising the net assimilation in cob yield. The sowing date of maize varies based onhybrids or maize cultivars due to relative crop maturity and the duration of the growing season in which crop accumulates radiation, which significantly correlated with crop grain yield (Kharazmshahi *et al.,* 2015; Baum *et al.,* 2019). Ecological, environment and climate variations are linked with planting time of maize that brings changes in the reproductive and vegetative phase of crop (Dahmardeh, 2012; Kharazmshahi *et al.,* 2015). The delay sowing of maize has low yield than early sowing of maize (Casini, 2012). Average day temperature is considered the main environmental factor that influences plant productivity and metabolic activities, and delay sowing of maize trends to minimize leaf area, stem diameter, and maize (Casini, 2012; Kharazmshahi *et al.,* 2015). In Pakistan, to the best of our knowledge, no comprehensive studies have been done to evaluate the impact of plant growth regulators and planting dates on the plant metabolic processes and crop production in maize under high temperatures. So, the current trial was proposed to assess the potential impact of foliar application of methyl jasmonate, salicylic acid, and humic acid against heat stress for various sowing dates on maize growth and productivity in the agro-ecological zone of Faisalabad district, Pakistan. This study assumes that the foliar application of plant growth regulators and sowing dates can significantly influence the agronomic traits and grain yield of maize.

## MATERIALS AND METHODS

The field study was conducted at the post-graduate agricultural research station (PARS), University of Agriculture Faisalabad, Pakistan. This experiment comprises of two factors mentioned in Table 1. The field study was designed in RCBD (Randomized Complete Block Design) with split plot arrangement so that sowing dates were allocated in the main plot and plant growth regulators were placed in sub-plots. The length from the neighbouring row to line was 75 cm and 25 cm from the adjacent field to the crop. The experiment with a net plot size 6m × 2.25m was replicated three times.

**Table 1.** Treatment of current experiment

| **Sowing** | **Factor 1 (sowing dates) main plot** | **Treatment** | **Factor 2 (plant growth hormones) subplots** |
|---|---|---|---|
| $S_1$ | 05-02-2017 (Early sowing) | $T_0$ | Control |
| $S_2$ | 20-02-2017 (Recommended sowing) | $T_1$ | Water spray |
| $S_3$ | 07-03-2017 (Late sowing) | $T_2$ | HA (Humic acid) |
| | | $T_3$ | SA (Salicylic acid) |
| | | $T_4$ | MJ (Methyl Jasmonate) |

### Crop management

The maize crop was sown on various sowing times from the mid-week of February to mid-week of March. The hybrid Monsan to cultivar named DK-6142 was drilled with a suggested seed rate of 25 kg ha$^{-1}$ using rabi drill. The recommended rate of fertilizers i.e. nitrogen100 kg ha$^{-1}$ and phosphorous 65 kg ha$^{-1}$ was appliedby using urea, di-ammonium phosphate, and sulfate of potash as a fertilizer source. The full dosage of phosphorous and 1/3 of total urea was added in preparation of seedbeds. The remaining urea was applied in the first and second irrigation splits. The crop was irrigated with seven irrigations from the sowing upto the maturity of the crop. After first irrigation, Atrazine + Acetochlor at the rate of 908.75 g ha$^{-1}$ were sprayed as herbicide, followed by two manual weedings. During the conduction of the experiment, no severe pest attack was noticed. Methyl jasmonate (MJ), humic acid (HA), and salicylic acid (SA) were collected from Agro-biological Labaratory, Agronomy department, University of Agriculture Faisalabad, Pakistan. The foliar application of water, methyl jasmonate, humic acid, and salicylic acid were applied after 45 days of sowing of maize via using knap sack sprayer at the rate of 600 mg L$^{-1}$. The crop was harvested during the mid week of May, at harvest maturity of the crop. After harvesting, the maize crop was tied in piles, and threshing was done with maize thresher.

### Observations and data collection

The maize plant height was quantified using a meter bar by randomly selecting 10 plants from each replication from the ground to the maize plant head and calculating the mean value (Baum *et al.,* 2019). The leaf area of maize is the totalleaf dimension and can be recorded by multiplying maximum leaf length and maximum leaf width with correction factor (0.631). Already selected maize plants were further used to determine the number of grains cob$^{-1}$, cob diameter, and cobs plant$^{-1}$ (Cao *et al.,* 2016). Maize 1000-grain weight from each replication was collected and weighed on weight balance (Dahmardeh, 2012).The biological yield was determined before the maize threshing. Biological biomass includes the total biomass of the above ground plant parts of the crop. After threshing grains were collected and corn grain yield was measured (Ali *et al.,* 2018). The ratio of grain yield to biological yield is expressed as harvest index (Cao *et al.,* 2016).

$$\text{Harvest index\%} = (\text{Grain yield}/\ \text{Biological yield}) * 100$$

### Economic analysis

Economic analysis was recorded following CIMMYT (1988). The input and output cost individual treatments were changed into rupees ha$^{-1}$. Gross field benefits were calculated from the income obtained from the crop yield.

**Gross field yield** = grain yield value + straw yield value (in rupees)

Gross investment was determined in rupees per hectare by calculating the cost of every treatment of production. For calculating net field benefits rupees per hectare, the gross investment was subtracted from the gross field benefits.

**Net field benefit** = Gross field benefits-Gross investment

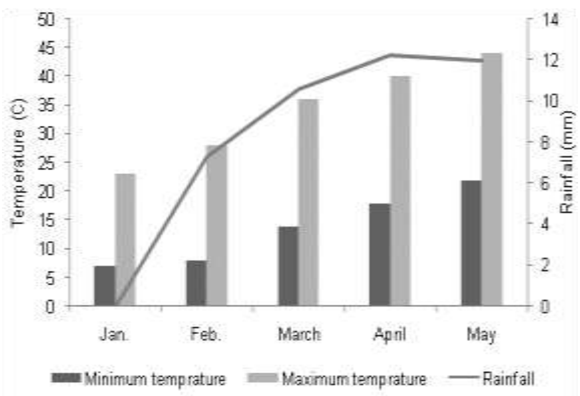
**Benefit- cost ratio**

It is a ratio of net income to the total cost of production.

**Benefit cost ratio** = Gross field benefit/ Gross investment.

**Statistical analysis**

The observed data were analyzed statistically using Fisher's analysis of variance and treatment means compared using Least Significant Difference test having 5% probability (Steel *et al.,* 1997).



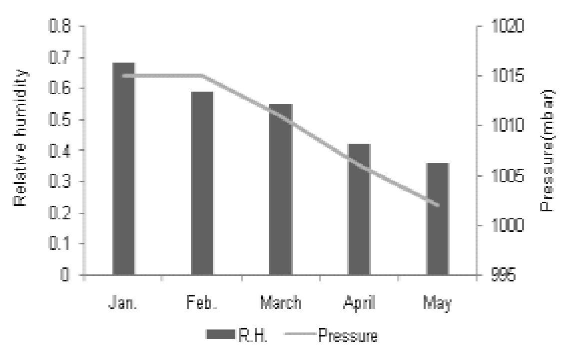




**Figure 1.** Weather data for agro-climatic zone of Faisalabad, Pakistan (2017)

## RESULTS

### Maize plant height and crop leaf area

Foliar application of various growth regulators and different sowing dates of maize significantly influenced the maize plant height and crop leaf area, as mentioned in Tables 2 and 3. Data related to plant height, maximum maize plant height was documented in $S_1$ (recommended sowing) which was 6.18% and 13.20% higher than $S_0$ (early sowing) and $S_2$ (late sowing), respectively. With respect to plant growth regulators, the highest plant height of maize was recorded in $T_4$ (methyl jasmoante), which was 8.33% higher than control. From the results, it can be stated that there were significant differences among interaction between plant growth regulators with sowing dates, on plant height of maize. Among interaction, maximum plant height was recorded in $S_1$ (recommended sowing) with $T_3$ (salicylic acid) having a mean value of 205.87 cm, and the minimum plant height was recorded in $S_2$ (late sowing) and $T_1$ (water spray) with a mean value of 169.60 cm.Similarly, the highest leaf area, was documented in $S_1$ (recommended sowing), which was 5.09% and 20.89% higher than $S_0$ (early sowing) and $S_2$ (late sowing) respectively. Among plant growth regulators, maximum leaf area was recorded in $T_4$ (methyl jasmonate) which was 13.62% higher than control (Table 3). Correspondingly, there were significant differences on leaf area in combined interaction of plant growth regulators with sowing dates. Concerning interaction, maximum leaf area was observed in $S_1$ (recommended sowing) and $T_4$ (methyl jasmonate) with a mean value of 265.05 $cm^2$ and the minimum leaf area was recorded in $S_2$ (late sowing) and $T_1$ (water spray) with a mean value of 169.60 $cm^2$.

### Cob quality parameters

Results revealed that foliar application of various growth regulators and different sowing dates of maize considerably influenced maize cob quality parameters i.e. number of cob $plant^{-1}$, cob diameter, number of grains $cob^{-1}$ (Table 2 and 3). From the experiment, it was observed that maximum no. of cob $plant^{-1}$ was recorded in $S_1$ (recommended sowing) which was 3.97% and 7.37% higher than $S_0$ (early sowing) and $S_2$ (late sowing), respectively. For plant growth regulators, the highest no. of cob $plant^{-1}$ was observed in $T_4$ (methyl jasmoante), which was 5.64% higher than control. There were significant differences among interaction between plant growth regulators with sowing dates, on no. of cob $plant^{-1}$ of maize. Among interaction maximum no. of cob $plant^{-1}$was recorded in $S_1$ (recommended sowing) and $T_4$ (methyl jasmonate) with a mean value of 1.38 and the minimum number of cob $plant^{-1}$ was recorded in $S_2$ (late sowing) and $T_1$ (water spray) with a mean value of 1.12. The highest cob diameter was recorded in $S_1$ (recommended sowing) which was 6.06% and 2.94% higher than $S_0$ (early sowing) and $S_2$ (late sowing), respectively. Among plant growth regulators, maximum cob diameter was documented in $T_4$ (methyl jasmonate) that was 6.34% higher than control. Similarly, among interaction between plant growth regulators with sowing dates, maximum cob diameter was recorded in $S_1$ (recommended sowing) and $T_4$ (methyl jasmonate) with a mean value of 3.96 cm and the minimum cob diameter was recorded in $S_0$ (early sowing) and $T_0$ (control) with a mean value of 3.53 cm. Maximum number of grains cob$^{-1}$ was recorded in $S_1$ (recommended sowing) which was 10.99% and 18.18% higher than $S_0$ (early sowing) and $S_2$ (late sowing), respectively. With respect to plant growth regulators highest number of grain cob$^{-1}$ was documented in $T_4$ (methyl jasmonate) that was 25.23% higher than control. However, from the results it was observed that the interaction between plant growth regulators and sowing dates on number of grain cob$^{-1}$ was non-significant (Table 3).

**Table 2.** Effect of humic acid (HA), salicylic acid (SA), and methyl jasmonate (MJ), and numerous planting time on agronomic traits, biological and grain yield of maize

| Treatments | $T_o$ control | $T_1$ water spray | $T_2$ Humic acid | $T_3$ salicylic acid | $T_4$ methyl jasmonate | Mean | $T_o$ control | $T_1$ water spray | $T_2$ Humic acid | $T_3$ salicylic acid | $T_4$ methyl jasmonate | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sowing date | Plant height (cm) | | | | | | Leaf area (cm$^2$) | | | | | |
| $S_o$ | 175.53cd | 180.27bcd | 189.67b | 189.13 b | 190.00 b | 184.92 B | 214.52 h | 220.51g | 237.36d | 231.05e | 241.39 c | 228.97B |
| $S_1$ | 180.47bcd | 185.60bc | 204.47a | 205.87 a | 205.33 a | 196.35 A | 216.38gh | 226.51 f | 243.66c | 251.51b | 265.05 a | 240.62A |
| $S_2$ | 171.47 d | 169.60 d | 175.87 cd | 174.27 d | 176.07cd | 173.45 C | 192.72m | 195.20 l | 206.46 i | 198.71k | 202.12 j | 199.04C |
| Mean | 175.82 B | 178.49 B | 190.00 A | 189.76A | 190.47A | | 207.87E | 214.07D | 229.16B | 227.09C | 236.19A | |
| LSD value | Sowing (3.21), plant growth regulators (5.01), S×T (11.06) | | | | | | Sowing (4.00), plant growth regulators (1.07), S×T (1.85) | | | | | |
| | No. of cob plant$^{-1}$ | | | | | | Cob diameter (cm) | | | | | |
| $S_o$ | 1.17 f | 1.22 e | 1.28 d | 1.33 b | 1.27 d | 1.26 B | 3.53 l | 3.58 k | 3.62 j | 3.68 h | 3.77 f | 3.64 C |
| $S_1$ | 1.22 e | 1.28 d | 1.31 c | 1.33 b | 1.38 a | 1.31 A | 3.73 g | 3.77 f | 3.91 c | 3.92 b | 3.96 a | 3.86 A |
| $S_2$ | 1.33 b | 1.12 g | 1.17 f | 1.22 e | 1.27 d | 1.22 C | 3.64 i | 3.68 h | 3.72 g | 3.79 e | 3.87 d | 3.74 B |
| Mean | 1.24 D | 1.21 E | 1.25 C | 1.29 B | 1.31 A | | 3.64 E | 3.67 D | 3.75 C | 3.80 B | 3.86 A | |
| LSD value | Sowing (0.056), plant growth regulators (0.041), S×T (0.071) | | | | | | Sowing (0.056), plant growth regulators (0.041), S×T (0.071) | | | | | |
| | No. of grain cob$^{-1}$ | | | | | | 1000 grain weight (g) | | | | | |
| $S_o$ | 496.38 | 504.15 | 539.11 | 574.07 | 608.62 | 544.47AB | 246.27g | 250.13 f | 270.13c | 264.1 d | 259.5 e | 258.01B |
| $S_1$ | 607.86 | 638.67 | 674.26 | 705.86 | 694.87 | 604.31 A | 241.55 h | 251.27 f | 272.17c | 291.2 b | 310.77a | 273.38A |
| $S_2$ | 427.12 | 443.03 | 505.24 | 567.04 | 614.33 | 511.35 B | 200.47 l | 212.03k | 243.0gh | 219.9 j | 230.67 i | 221.21C |
| Mean | 510.46 D | 528.6CD | 572.87B | 615.66 A | 639.27A | | 229.43 E | 237.7 D | 261.75B | 258.40C | 266.97A | |
| LSD value | Sowing (28.86), plant growth regulators (33.79), S×T (58.53) | | | | | | Sowing (2.91), plant growth regulators (2.17), S×T (3.76) | | | | | |
| | Grain yield (kg/plot) | | | | | | Biological yield (kg/plot) | | | | | |
| $S_o$ | 1.77 hi | 2.00 g | 2.37 e | 2.49 e | 2.69 d | 2.27 B | 7.76 ef | 8.57 e | 9.93 d | 10.73cd | 11.25 c | 9.65 B |
| $S_1$ | 1.89 gh | 2.21 f | 3.07 c | 3.24 b | 3.51 a | 2.78 A | 7.57 ef | 9.87 d | 12.91 c | 12.42 b | 15.04 a | 11.56 A |
| $S_2$ | 1.37 l | 1.48 kl | 1.63 jk | 1.56 jk | 1.69 ij | 1.55 C | 6.16 g | 6.87 fg | 7.27 fg | 6.79 fg | 6.67 fg | 6.76 C |
| Mean | 1.68 D | 1.90 C | 2.36 B | 2.43 B | 2.63 A | | 7.16 D | 8.45 C | 10.04 B | 10.00 B | 10.98 A | |
| LSD value | Sowing (0.049), plant growth regulators (0.085), S×T (0.15) | | | | | | Sowing (0.12), plant growth regulators (0.21), S×T (0.37) | | | | | |
| | Harvest index (%) | | | | | | | | | | | |
| $S_o$ | 23.43 bc | 23.90 bc | 24.51abc | 23.70 bc | 24.73abc | 24.05 AB | | | | | | |
| $S_1$ | 25.90 ab | 22.95 c | 24.61abc | 26.89 a | 23.89 bc | 24.85 A | | | | | | |
| $S_2$ | 22.81 c | 22.04 c | 22.93 c | 23.59 bc | 26.14 ab | 23.50 B | | | | | | |
| Mean | 24.05 AB | 22.96 B | 24.02AB | 24.73 A | 24.92 A | | | | | | | |
| LSD value | Sowing (1.26), plant growth regulators (1.58), S×T (2.73) | | | | | | | | | | | |

Sharing a table with the same case letter is not significantly different at *P*<0.05%

$S_o$= (05-02-2017) early sowing; $S_2$= (20-02-2017) recommended Sowing; $S_3$= (07-03-2017) late sowing

$T_o$= control; $T_1$= water spray; $T_2$= HA (humicacid); $T_3$= SA (salicylic acid); $T_4$= MJ (methyl jasmonate).

**Table 3.** Analysis of variance (ANOVA) for agronomic traits, biological and grain yield as affected by humic acid (HA), salicylic acid (SA), methyl jasmonate (MJ) and numerous planting time

| Sources | d.f | Plant height | Leaf area | Number of cob plant$^{-1}$ | Cob diameter | No. of grain cob$^{-1}$ | 1000-grain weight | Grain yield | Biological yield | Harvest index |
|---|---|---|---|---|---|---|---|---|---|---|
| Replications | 2 | 26.45 | 5047.50 | 0.08904 | 0.57184 | 8136 | 196.8 | 0.00452 | 0.2708 | 0.52214 |
| Sowing dates (A) | 2 | 1965.39** | 6900.99** | 0.02493* | 0.18779 * | 169509 ** | 10780.4** | 5.79257 * | 87.6301** | 6.85917* |
| Error 1 | 4 | 6.07 | 15.58 | 0.00003 | 0.00017 | 810 | 8.2 | 0.00233 | 0.1569 | 1.53862 |
| Foliar spray of plant regulators (B) | 4 | 459.19** | 1208.28** | 0.01637* | 0.07641* | 133435** | 2397.7** | 1.40670* | 20.6214** | 5.30623 * |
| Interaction (A*B) | 8 | 75.26 | 198.38 | 0.01330 | 0.00208 | 4959 | 558.8 | 0.25324 | 5.7581 | 5.21706 |
| Error 2 | 24 | 12.99 | 1.21 | 0.00002 | 0.00002 | 1206 | 5.0 | 0.00759 | 0.5469 | 2.63346 |
| Total | 44 | | | | | | | | | |

* and ** represents data significant probability level of 0.05% and 0.01%, respectively

**Table 4.** Calculation of cost-benefit ratio of each treatment

| Treatment | Permanent cost (PC) PKR | Variable cost (VC) PKR | Total cost (PC+VC) PKR | Grain Yield kg/hac | Grain Yield value (kg/hac)/40*1600) PKR | Net Benefit PKR | Cost benefit ratio (Net benefit/total cost) |
|---|---|---|---|---|---|---|---|
| $S_o$ $T_o$ | 25,918.50 | 55,142.50 | 81,061.00 | 5069.28 | 202771.2 | 202771.2 | 2.50 |
| $S_o$ $T_1$ | 25,918.50 | 55,142.50 | 81,061.00 | 5728 | 229120 | 229120 | 2.83 |
| $S_o$ $T_2$ | 25,918.50 | 56,642 | 82,560.50 | 6787.68 | 271507.2 | 271507.2 | 3.29 |
| $S_o$ $T_3$ | 25,918.50 | 56,642 | 82,560.50 | 7131.36 | 285254.4 | 285254.4 | 3.46 |
| $S_o$ $T_4$ | 25,918.50 | 56,642 | 82,560.50 | 7704.16 | 308166.4 | 308166.4 | 3.73 |
| **$S_1$ $T_o$** | 25,918.50 | 55,142.50 | 81,061.00 | 5412.96 | 216518.4 | 216518.4 | 2.67 |
| **$S_1$ $T_1$** | 25,918.50 | 55,142.50 | 81,061.00 | 6329.44 | 253177.6 | 253177.6 | 3.12 |
| **$S_1$ $T_2$** | 25,918.50 | 56,642 | 82,560.50 | 8792.48 | 351699.2 | 351699.2 | 4.26 |
| **$S_1$ $T_3$** | 25,918.50 | 56,642 | 82,560.50 | 9279.36 | 371174.4 | 371174.4 | 4.50 |
| **$S_1$ $T_4$** | 25,918.50 | 56,642 | 82,560.50 | 10052.64 | 402105.6 | 402105.6 | 4.87 |
| **$S_2$ $T_o$** | 25,918.50 | 55,142.50 | 81,061.00 | 3923.68 | 156947.2 | 156947.2 | 1.94 |
| **$S_2$ $T_1$** | 25,918.50 | 55,142.50 | 81,061.00 | 4238.72 | 169548.8 | 169548.8 | 2.09 |
| **$S_2$ $T_2$** | 25,918.50 | 56,642 | 82,560.50 | 4668.32 | 186732.8 | 186732.8 | 2.26 |
| **$S_2$ $T_3$** | 25,918.50 | 56,642 | 82,560.50 | 4467.84 | 178713.6 | 178713.6 | 2.16 |
| **$S_2$ $T_4$** | 25,918.50 | 56,642 | 82,560.50 | 4840.16 | 193606.4 | 193606.4 | 2.35 |
| Price of 40 kg maize grain is Rs 1600 | | | | | | | |

$S_o$= (05-02-2017) early sowing; $S_1$= (20-02-2017) recommended sowing; $S_2$= (07-03-2017) late sowing
$T_o$= control; $T_1$= water spray; $T_2$= HA (humic acid); $T_3$= SA (salicylic acid); $T_4$= MJ (methyl jasmonate).

## Grain yield and biological yield

The experiment results documented that growth regulators foliar spray and different sowing dates of maize significantly influenced the maize grain and biological yield. Maize grain yield was highly recorded in $S_1$ (recommended sowing) which was 22.47% and 79.36% higher than $S_o$ (early sowing) and $S_2$ (late sowing), respectively. Among plant growth regulators highest grain yield was documented in $T_4$ (Methyl jasmonate) which was 56.55% higher than control. Maximum biological yield of maize was observed in $S_1$ (recommended sowing) which was 21.07% and 71.11% higher than $S_o$ (early sowing) and $S_2$ (late sowing) respectively. With respect to plant growth regulators, highest biological yield was calculated in $T_4$ (methyl jasmoante) which was 53.56% higher than control (Table 3). Similarly, from the results, it was observed that there were significant differences among interaction between plant growth regulators with sowing dates, on grain yield and biological yield of maize. Among interaction maximum grain and biological yield were recorded in $S_1$ (recommended sowing) and $T_4$ (methyl jasmonate) with a mean value of 3.51 and 15.04 kg plot$^{-1}$, respectively and the minimum grain and biological yield were recorded in $S_2$ (late sowing) and $T_1$ (water spray) with a mean value of 1.37 and 6.16 kg plot$^{-1}$ respectively (Table 3).

## 1000-grain weight and harvest index of maize

1000-grain weight and maize harvest index were significantly influenced with foliar application of growth regulators and different sowing dates of maize (Table 2 and 3). Data related to 1000-grain weight highest maize 1000-weight was documented in $S_1$ (recommended sowing) that was 5.96% and 23.58% higher than $S_o$ (early sowing) and $S_2$ (late sowing) respectively. Among plant growth regulators maximum maize 1000-grain weight was calculated in $T_4$ (methyl jasmonate) which was 16.36% higher than control. Maximum harvest index was recorded in $S_1$ (recommended sowing) which was 3.28% and 5.70% higher than $S_o$ (early sowing) and $S_2$ (late sowing) respectively. With respect to plant growth regulators, maximum harvest index was documented in $T_4$ (methyl jasmoante) that was 3.66% higher than control (Table 3).

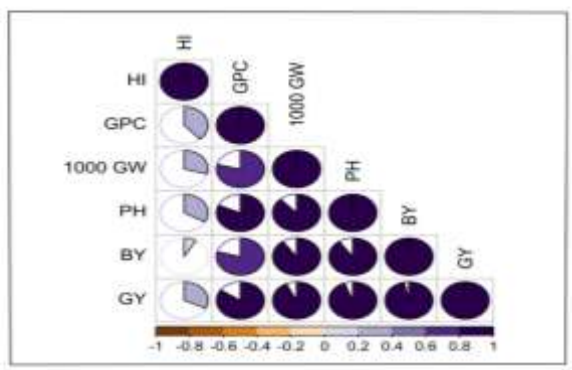



**Figure 2.** Pearson's correlation between different traits under various plant growth regulators and different sowing dates in maize

Correspondingly, from the results, it was observed that there were significant differences among interaction between plant growth regulators with sowing dates, on 1000-grain weight and harvest index of maize. Among interaction, maximum 1000-grain weight was recorded in $S_1$ (recommended sowing) and $T_4$ (methyl jasmonate) with a mean value of

310.77g and the minimum 1000-grain weight was recorded in $S_2$ (late sowing) and $T_o$ (control) with a mean value of 200.47g. Similarly, with respect to interaction, maximum harvest index % was recorded in $S_1$ (recommended sowing) and $T_3$ (salicylic acid) with a mean value of 26.89% and the minimum harvest index % was recorded in $S_2$ (late sowing) and $T_1$ (water spray) with mean value of 22.04% (Table 3). Correlation rank coefficient analysis showed a strong correlation among all variables. While weak correlation resulted between the harvest index and biological yield, as mentioned in Figure 2.

**Economic analysis**

The highest benefit-cost ratio i.e. 4.87 was recorded in $S_1$ (recommended sowing i.e. 20-02-2017) and $T_4$ MJ (methyl jasmonate), which was 45.17% higher than control ($S_1T_o$) (Table 4). In contrast, the minimum benefit-cost ratio i.e., 1.94 was recorded in $S_2$ (late sowing, i.e., 07-03-2017) and $T_o$ (control) (Table 4).

## DISCUSSION

In current study, it was observed that the foliar application of plant growth regulators and sowing dates significantly influenced the agronomic traits and grain yield of maize. To increase maize production, active and uniform plant growth with optimal expansion of the leaves is considered essential (Waqas *et al.,* 2017). Temperature is an essential key environmental factor that influences plants' growth and development (Ali *et al.,* 2018). Significant difference in sowing dates of hybrid maize explained that different sowing time showed variation in maturation periods. Availability of optimum temperature for the development of seed and maturation affected the corn component of yield (Casini, 2012). Crop development is greatly influenced by environmental cues eventually affecting grain yield (Buriro *et al.,* 2015; Cao *et al.,* 2016). For instance, the level of intercepted photosynthetic active radiation around the plant is low at flowering, resulting in a decline in maize grain productivity (Tsimba *et al.,* 2013). Under suitable growing conditions, leaf photosynthetic rate and intercepted photosynthetic active radiation enhances the net assimilation rate of maize (Golbashy *et al.,* 2010). The interception of solar radiation is determined by leaf area and leaf area index that is greatly influenced on photoperiod and temperature (Baum *et al.,* 2019). The sowing date i.e. 20-02-2017 gives the higher crop yield because it depends mostly on photoperiod. The findings are consistent with the findings from Ali *et al.* (2018), which reported that early and late maize sowing decreased plant height and biological yield due to adverse weather and climate conditions. Differences in sowing dates of maize bring changes in grain yield, which might be due to climatic conditions differences that varied due to temperature in whole plant life span (Norastehnia *et al.,* 2007). The decreased biological weight and 1000-grain weight was observed in late sowing due to less assimilate accumulation (Waqas *et al.,* 2017). The consequences are in agreement with the outcomes of Darmardeh (2012) that delayed sowing of maize results in to decline in biological and grain yield of maize crop.

Plant growth regulators significantly minimized the heat stress by bringing changes in metabolic pathways, strengths and gene expression that enhance the resistance to heat stress (Norastehnia *et al.,* 2007; Fink, 2017). Plant growth regulators/ hormones activate the enzymatic activity of superoxide dismutase (SOD) and minimize the activity of catalase (CAT), which increases the resistance in crop against environmental stresses (Kazemi, 2014). Methyl jasmonate enhances the plant resistance against heat stress by taking part in regulation of plant secondary metabolic processes by inhibiting and activating the transcription factor and expressing the activity of key enzymes (Zheljazkov, 2013). Correspondingly, salicylic acid and humic acid induces systematic acquired resistance in the plant through signal transfer against heat stress (Hayat *et al.,* 2010). Furthermore, salicylic acid and humic acid induces plant resistance by closing of stomata, minimize electrolyte leak, un-saturation increase of membrane lipids and decrease the transpiration rate. The findings are identical with the outcomes of Ali *et al.* (2018) and Tufail *et al.* (2013), in which they concluded that plant growth regulators foliar spary i.e., methyl jasmonate and salicylic acid results to improve biological and grain yield of maize.

Sunlight is a significant energy source for plants to fulfil their function especially the photosynthetic activity takes place in the presence of light energy and also plays and important role in growth and development (Rehman *et al.,* 2020). From the experiment it is clearly observed that the plant height, leaf area, and cob quality parameters in late sowing maize plants as compared to the plants cultivated in early and recommended sowing dates. This is due to reduction in photosynthesis activity, relative crop maturity, and the duration of growing season in which crop accumulates radiation, which significantly minimized the plant growth and yield in maize plant (Baum *et al.,* 2019). Thus, plant growth improvement is directly correlated with the better accumulation of dry matter under stress in maize (Waqas *et al.,* 2017). The primary function of plant growth regulator is to increase the efficiency of net assimilates of plants by reducing the stress for the accumulation of dry matter which is critical for the improving stress tolerance in the plant (Cao *et al.,* 2016). Furthermore, application of plant growth regulators under stress improves the root development that helps to enhance the plant nutrients uptake to improve the metabolic activities in plant under stress (Tsimba *et al.,* 2013; Waqas *et al.,* 2017). A similar type of findings were also observed in other cereals i.e., wheat, barley, sorghum, rice, and hybrid and cultivars of maize cultivated under stress (Kharazmshahi *et al.,* 2015). Hence, as reported by other researchers (Moosavi *et al.,* 2012; Nagar *et al.,* 2015) and from this study, it was concluded that the plant growth regulator foliar application (particularly methyl jasmonate) improves the maize agronomic traits significantly improved the grain yield under high temperatures stress and extreme weather conditions.

## CONCLUSION

The findings conclude that recommended sowing dates,i.e. 20-02-2017, and foliar spray of methyl jasmonate, significantly enhanced the yield contributing agronomic traits i.e., 1000-grain weight, ear length, biological yield, and grain yield of maize. So, the current study exhibited that the foliar application of plant growth regulators and optimum sowing dates are therefore considered as important adoptive strategy for enhancing the production and grain yield of maize in the agro-climatic zone of Faisalabad (Punjab), Pakistan. Still, plant growth regulators requires rigorous research or policy analyses to evaluate potential effects of plant growth regulators on maize growth under extreme weather condition on Pakistan on sustainable basis.

## AUTHOR'S CONTRIBUTION

**M. Qandeel:** Performed the experiment

**A. Jabbar:** Write the article and supervise the whole experiment

**F. U. Haider:** Write the article

**A. L. Virk:** Article editing and proof reading

**N. U. Ain:** Article editing and proof reading

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