Research Article

# Effect of Sowing Dates and Genotypes on Yield and Yield Contributing Traits of Upland Cotton (*Gossypium hirsutum* L.)

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**Abstract** | Cotton is an important cash crop that generates a large amount of revenue in Pakistan. Cotton production was decreased due to climate change, biotic and abiotic factors, unpredictable rain patterns, high temperatures. Therefore, it needs to identify cultivars with suitable sowing time in a specific environment. The objective of this experiment was to evaluate the yield potential of different cotton genotypes under different sowing dates (early to late). In 2019 and 2020, a field experiment was conducted at Cotton Research Station, Sahiwal, Pakistan. The experiment was conducted using a split-plot arrangement in a randomized complete block design with three replicates. The main plot comprised six sowing dates with an interval of 15 days starting from 16$^{th}$ March, and the subplot consisted of four varieties: SLH-8, FH-Lalazar, CIM-622 and FH-142.It was observed that maximum seed cotton yield was recorded for sowing date 16$^{th}$ March during both years, i.e., 2019 (1583.63 kgha$^{-1}$) and 2020 (1741.96 kgha$^{-1}$). SLH-8 was the best performing variety among all studied genotypes for plant height, boll weight, and seed cotton yield. The mean seed cotton yield during both years ranged 1434.58 to 1983.77 kg ha$^{-1}$. Maximum seed cotton yield during both years was showed by SLH-8 that was 1726.82 and 2240.71 kg ha$^{-1}$. Correlation analysis showed that seed cotton yield was positively correlated with the boll weight (0.738**) and number of bolls per plant (0.53**). Sowing dates in March, April, and May were grouped together in cluster no. 2, whereas sowing dates in June were grouped together in group 1. This study helps to optimize the sowing date to meet the climate changes and enhance the seed cotton yield.

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## Introduction

Cotton (*Gossypium hirsutum* L.) is an important cash crop that generates a large amount of revenue in Pakistanthrough export of textile products (Ahmad *et al*., 2009; Abro *et al*., 2015). In addition to fiber, it also gives usseed cake and oil. In Pakistan, agriculture is the backbone of the economy and cotton shares 0.8 in GDP during 2019-20 (Economic survey of Pakistan, 2020). The cotton area was increased during 2019-20 from 2.373 to 2.527 million hectares (about 6.5 percent). However, the seed cotton yield was declined from 9.861 to 9.178 million bales (about a 6.9 percent decrease), and an average seed cotton yield was 618 kgha$^{-1}$. The decline in cotton production was due to climate change, biotic and abiotic factors, including harsh weather conditions, higher insect pest infestation, unpredictable rain patterns, high temperature during the reproductive phase and accessibility of water (Economic survey of Pakistan, 2020).

Globally, Climate changes have a negative effect on agriculture production due to the increase in average temperature, precipitation, and humidity (Lobell and Field 2007; Abbas, 2020). The usage of land increases to produce feed and fiber (Solomon *et al*., 2007). Climate change significantly affects fiber production. The cotton crop grows in a hot and tropical environment, but when the temperature goes above 32°C, it affects the developmental stages of plants. In Pakistan, cotton faces a temperature of 40 to 45 °C during the growth development stages, which significantly affects the yield contributing traits and seed cotton yield (Abbas, 2020). Cotton crop is sensitive to change in temperature during flowering and boll development (Ali *et al*., 2020). The metrological data showed that an unexpected rain pattern was observed (Figure 1a). Relative humidity was increase as compared to the precipitation (Figure 1b). The mean temperature data of the previous ten years showed that temperature ranged from 25.05 to 39.05°C (Figure 1c and d).

Globally, cotton faces high temperatures greater than 35°C during a growing period, significantly affecting plants development, growth, and seed cotton yield (Abro *et al*., 2015). Cotton is usually cultivated in hot areas of Pakistan (Riaz *et al*., 2013). The cultivars recommended for cotton-growing areas face high temperatures(50°C) during May and June. The seed cotton yield, fiber, shoot growth, and development were significantly reduced due to adverse environmental conditions (Khan *et al*., 2014; Farooq *et al*., 2018).

Predictable components for sustainable cotton production include many factors, the time of sowing is one of them. The seed cotton yield and yield contributing traits are mainly affected by the sowing time (Gecgel *et al*., 2007). Cultivars interaction with sowing dates is an essential method to assess the crop quality and seed cotton yieldin a specific environment (Campbell and Jones, 2005). As we mentioned earlier, cotton production was significantly decreased in recent years due to climate change, biotic, abiotic stresses, and inappropriate selection of cultivars for specific agro-ecological regions (Arshad *et al*., 2001; Zia-ul-Hassan *et al*., 2014). In this scenario, there is a need to optimize the sowing date of cotton because it plays a significant role in the seed cotton yield of the crop (Deho *et al*., 2012). Potential cultivars for better quality and seed cotton yield would be evaluated by sowing at different dates (early, normal, and late sowing). Early and late sowing of cultivars adversely affects the seed cotton yield contributing traits and seed cotton yield (Usman and Ayatullah, 2016). Early sowing of cotton cultivars leads to more vegetative growth instead of

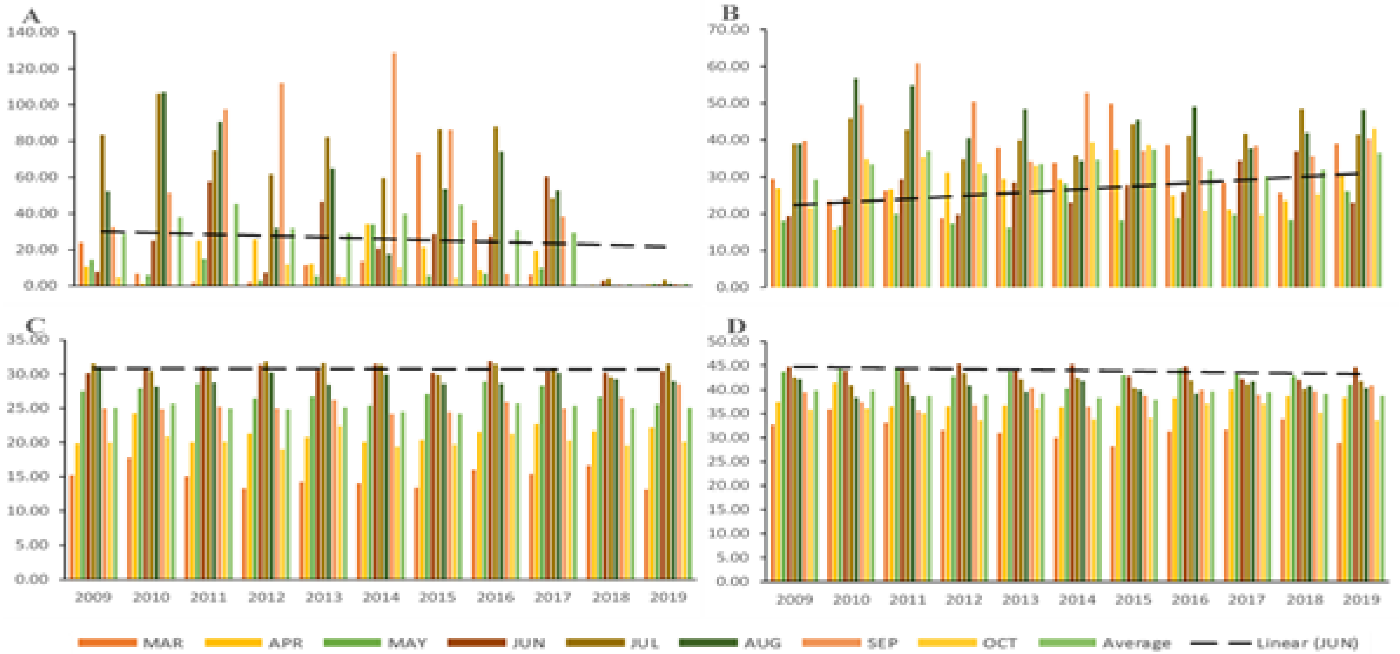


**Figure 1:** *Metrological data of previous ten years of Cotton research station Sahiwal.*
**A:** *Precipitation (mm day$^{-1}$),* **B:** *Relative Humidity,* **C:** *Maximum temperature,* **D:** *Minimum temperature. Data source:* (https://power.larc.nasa.gov/data-access-viewer/).

seed cotton yield (Iqbal *et al*., 2012) and plants face an adverse environment (high temperature) during the reproductive phase that will cause the significant seed cotton yield reduction (Rahman *et al*., 2007). Its worth mentioning that that cotton plants with relatively shorter growing period are also low yielders (Elayan *et al*., 2015).

Optimum sowing date for cotton cultivars is an important yield determining factor because it can not only improve seed cotton yield but also improves insect pest management (Karavina *et al*., 2012). Suitable sowing time increased the seed cotton yield due to prolong period of flowering before onset of any biotic and abiotic stress that leads to healthy plant, that enhanced the efficiency of moisture and nutrient uptake which was helpful in boll formation and maturation (Tahir *et al*., 2009). Likewise, early sowing in May increases seed cotton yield by 45% compared to late sowing in June, with improved yield traits (Farid *et al*., 2017). Moreover, the development and growth of cotton are affected by management practices and environmental conditions. The maturity is influenced by the date of plantation and the population of plants (Edmisten, 2007; Faircloth, 2007). Therefore, there is need to optimize the sowing dates of cotton plants which would give enough time to plant to complete its vegetative and reproductive phases timely and help in the management of insect and diseases of cotton (Ali *et al*., 2005), specifically cotton leaf curl virus. At the reproductive stage of the cotton plant, the yield was reduced by about 80 percent due to the high insect infestation (Pedigo *et al*., 2004). Cotton plant boll retention and fiber quality were significantly reduced above 40°C and 30°C, respectively. Boll size and maturity are negatively associated with the high temperature (Abbas, 2020). Late sowing caused the decrease offiber strength, maturity, and length (Arshad *et al*., 2001). The cultivars response toward the sowing dates were differential. Therefore, there cotton cultivars should be evaluated for an appropriate sowing time to obtain maximum possible yield. Keeping in view the above narrated facts, the purpose of this experiment was to identify suitable genotypes and suitable planting date and their interactions with seed cotton yield and yield contributing traits of upland cotton production.

## Materials and Methods

*Experimental site*

This experiment was conducted at Cotton Research Station, Sahiwal, Pakistan during 2019 and 2020. The longitude and latitude were 72.680°, 32.119° respectively.

*Planting material*

The planting material consist of four varieties, SLH-8, FH-Lalazar, CIM-622 and FH-142. Out of four varieties, two varieties (FH-Lalazar and FH-142) was developed by Ayoub Agriculture Research Institute Faisalabad, CIM-622 developed by Central Cotton Institute Multan and SLH-8 was developed by Cotton research Station, Sahiwal.

*Meteorologic data*

The average temperature was 31.98, minimum and maximum temperature was 25.04 and 38.92, respectively during cotton growing season of both years. The precipitation and relative humidity was 1.14 and 34.20, respectively during cotton growing season of both years (Figure 2).

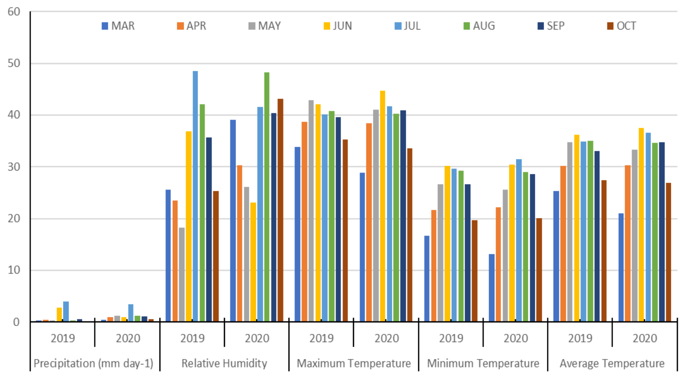


**Figure 2:** *Metrological data of 2019-20 of Cotton research station Sahiwal.*

*Experimental design*

Plant material was grown using a split-plot arrangement in a randomized complete block design with three replications. The main plot comprised six sowing dates with an interval of 15 days starting from $16^{th}$ March, *i.e.* ($16^{th}$March, $1^{st}$ and $16^{th}$ April, $1^{st}$ and $16^{th}$ May, and $1^{st}$ June). Furthermore, the subplot consisted of four varieties, SLH-8, FH-Lalazar, CIM-622, FH-142, and the plot size was 18580.60 x 6967.73cm$^2$.

*Cultural practices*

Seeds of these varieties were delinted using sulfuric acid (1kg sulfuric acid per 10kg seed). All agronomic practices were uniformly applied to all plots except the sowing date. Thinning was done 30 days after sowing.

**Table 1:** *Analysis of variance (mean squares) seed cotton yield and yield contributing traits as influenced by sowing date and different genotypes during 2019 and 2020.*

| Source | DF | PH | NBP | BW | SCYP |
|---|---|---|---|---|---|
| **2019** | | | | | |
| Replication | 2 | 213.69 | 10.43 | 0.11 | 510257 |
| Variety | 3 | 1859.49** | 799.43** | 0.65 | 737444* |
| Error a | 6 | 18.12 | 30.52 | 0.25 | 113093 |
| Sowing | 5 | 6831.85** | 1001.52** | 2.09** | 4420515** |
| Variety* Sowing | 15 | 83.92** | 42.67 | 0.11 | 500537** |
| Error b | 40 | 20.76 | 23.07 | 0.13 | 133023 |
| **2020** | | | | | |
| Replication | 2 | 40.89 | 12.02 | 0.07 | 106557 |
| Variety | 3 | 921.87** | 436.39** | 0.24 | 2287383** |
| Error a | 6 | 43.14 | 24.67 | 0.14 | 190938 |
| Sowing | 5 | 6081.54** | 316.67** | 3.77** | 5879484** |
| Variety* Sowing | 15 | 92.14** | 40.87 | 0.09 | 523913** |
| Error b | 40 | 35.43 | 23.13 | 0.11 | 99032 |
| **2019-2020** | | | | | |
| Replication | 2 | 220.7 | 18.91 | 0.18 | 496606 |
| Variety | 3 | 2673.6** | 1200.42** | 0.81 | 2496679** |
| Error a | 6 | 44.5 | 21.72 | 0.36 | 274008 |
| Sowing | 5 | 12744.3** | 1191.14** | 5.65** | 10190000** |
| Variety* Sowing | 15 | 128.1** | 74.22 | 0.15 | 900913** |
| Error b | 40 | 39.1 | 61.64 | 0.11 | 130017 |

*** significance at 1%, * significance at 5%;* **Df:** *Degree of Freedom,* **PH:** *Plant height (cm),* **NBP:** *Number of bolls plant-1,* **BW:** *Boll weight,* **SCYP:** *Seed cotton yield plant-1(kg ha-1).*

*Data observation*

On maturity, data were collected for plant height (PH) in centimeter, number of bolls per plant ($NBP^{-1}$), boll weight (BW) in grams, and seed cotton yield (SCY) in kg $ha^{-1}$.

*Statistical analysis*

Data were analyzed using the split-plot design using the method given by Steel and Torrie (1980). Correlation analysis was performed using the method given by Peterson *et al*. (2018). Heat map was developed using the complex heat map package (Gu *et al*., 2016) Analysis was performed using the R studio version 1.4.1717.

## Results and Discussion

Analysis of variance revealed that, genotypes had highly significant variation for plant height and number of bolls per plant in both years 2019 and 2020. Seed cotton yield was found significant, and boll weight was non-significant in both years. Variation due to sowing dates was also highly significant for plant height, NB/P, BW, SCY in 2019 and 2020. However, the interaction of sowing dates and genotypes was significant for PH and SCY in both years. Both year data were polled and analyzed and observed that variation due to genotypes and interaction between sowing dates and genotypes was highly significant for PH, NB/P, and SCY. Variation due to genotypes was found significant for all studied traits (Table 1).

The mean data showed that PH was approximately the same in both years with minor differences, given in Table 2. PH ranged between 84.29 to 144.16 cm, and the maximum PH was observed at the sowing date of 16 March in both years. Furthermore, the lowest PH value was observed during the sowing of 01- June, as shown in given in Table 2. The mean performance of PH showed that in 2020, PH was increased compared to 2019 with a minor difference. The maximum average PH value was shown by SLH-8 that was 138.99 cm, and the minimum average value was observed in CIM-622, which was 119.20 cm. CIM-622 showed an increase in PH in 2020 (121.70 cm) compared to 2019 (116.70 cm). Similarly, FH-142 PH was also increased during 2020 (127.12 cm) compared to 2019 (123.37 cm). FH-Lalzar showed a reduction in PH during 2020 (131.49 cm) compared to 2019 (133.69 cm), as given in Table 2. $NBP^{-1}$ was 31.86 during 2019 and reduced to 21.36 in 2020. $NBP^{-1}$ was ranged between 14 to 32.21. The highest $NBP^{-1}$ was observed at the sowing date of 16-March 2019 was 38.75. The lowest value of $NBP^{-1}$ was observed during 01-June-2020, which was 14.166, as given in Table 2. The maximum value of $NBP^{-1}$ showed by SLH-8 (34.94) as compared to the other genotypes. $NBP^{-1}$ was reduced in 2020 as compared to 2019 in all studied varieties. Maximum $NBP^{-1}$ was observed in SLH-8 during 2019 (41.61) compared to the 2020 (28.28) with an average of 34.94, as given in table 2. BW was increased in 2020 as compared to 2019 from 3.27 to 3.34 g. Seed cotton yield was also increased from 1741.96to 1583.63 kg $ha^{-1}$, as given in Table 2. BW was ranged between 2.38 to 3.75 g. The highest BW was observed during the sowing date of 16-March 2020 was 3.80 g. In contrast, the 01 June sowing date showed the lowest boll weight

**Table 2:** *Descriptive Statistics of Yield contributing and Seed cotton yield by sowing dates of Cotton.*

| Sowing dates | Boll weight | | Number of bolls plant$^{-1}$ | | Plant height | | Seed cotton yield (kgha$^{-1}$) | |
|---|---|---|---|---|---|---|---|---|
| | 2019 | 2020 | 2019 | 2020 | 2019 | 2020 | 2019 | 2020 |
| | Mean | | | | | | | |
| 16-Mar | 3.710 | 3.803 | 38.750 | 25.000 | 147.740 | 140.600 | 2194.900 | 2278.200 |
| 01-Apr | 3.448 | 3.578 | 38.332 | 26.100 | 140.620 | 145.620 | 2021.200 | 2379.600 |
| 16-Apr | 3.485 | 3.685 | 36.915 | 24.835 | 141.940 | 139.740 | 2037.000 | 2287.000 |
| 01-May | 3.203 | 3.480 | 34.750 | 22.333 | 133.370 | 140.940 | 1500.600 | 1692.200 |
| 16-May | 3.270 | 3.208 | 26.998 | 15.750 | 123.320 | 125.640 | 1043.100 | 1084.800 |
| 01-Jun | 2.503 | 2.273 | 15.415 | 14.168 | 82.685 | 85.903 | 704.930 | 729.930 |
| **Standard Deviation** | | | | | | | | |
| 16-Mar | 0.235 | 0.146 | 9.763 | 6.196 | 16.937 | 7.533 | 413.460 | 547.720 |
| 01-Apr | 0.398 | 0.314 | 10.629 | 9.343 | 13.048 | 13.048 | 307.980 | 351.440 |
| 16-Apr | 0.097 | 0.097 | 8.376 | 4.881 | 9.287 | 3.669 | 839.420 | 1020.600 |
| 01-May | 0.187 | 0.274 | 5.152 | 6.310 | 9.883 | 12.440 | 229.370 | 330.320 |
| 16-May | 0.187 | 0.153 | 5.184 | 4.534 | 6.897 | 6.029 | 50.490 | 83.742 |
| 01-Jun | 0.319 | 0.090 | 2.392 | 1.937 | 8.419 | 5.403 | 233.370 | 233.370 |
| **Standard Error of Mean** | | | | | | | | |
| 16-Mar | 0.117 | 0.073 | 4.882 | 3.098 | 8.469 | 3.767 | 206.730 | 273.860 |
| 01-Apr | 0.199 | 0.157 | 5.315 | 4.672 | 6.524 | 6.524 | 153.990 | 175.720 |
| 16-Apr | 0.048 | 0.048 | 4.188 | 2.440 | 4.643 | 1.834 | 419.710 | 510.280 |
| 01-May | 0.093 | 0.137 | 2.576 | 3.155 | 4.941 | 6.220 | 114.680 | 165.160 |
| 16-May | 0.094 | 0.077 | 2.592 | 2.267 | 3.449 | 3.014 | 25.245 | 41.871 |
| 01-Jun | 0.160 | 0.045 | 1.196 | 0.968 | 4.210 | 2.701 | 116.690 | 116.690 |
| **Minimum Value** | | | | | | | | |
| 16-Mar | 3.480 | 3.680 | 31.330 | 19.330 | 126.870 | 131.870 | 1741.400 | 1766.400 |
| 01-Apr | 2.910 | 3.110 | 30.330 | 18.330 | 127.870 | 132.870 | 1712.200 | 2070.600 |
| 16-Apr | 3.400 | 3.600 | 31.000 | 21.000 | 130.870 | 135.870 | 1167.200 | 1192.200 |
| 01-May | 3.040 | 3.240 | 30.000 | 16.670 | 120.870 | 125.870 | 1288.900 | 1313.900 |
| 16-May | 3.080 | 2.990 | 21.000 | 11.330 | 113.870 | 118.870 | 1011.500 | 1036.500 |
| 01-Jun | 2.220 | 2.200 | 13.000 | 12.330 | 75.870 | 80.870 | 388.630 | 413.630 |
| **Maximum Value** | | | | | | | | |
| 16-Mar | 4.020 | 4.010 | 52.670 | 32.670 | 167.330 | 150.130 | 2656.300 | 2981.300 |
| 01-Apr | 3.870 | 3.790 | 54.000 | 39.670 | 155.870 | 160.870 | 2393.500 | 2858.900 |
| 16-Apr | 3.600 | 3.800 | 49.330 | 31.670 | 151.130 | 142.870 | 3138.000 | 3423.100 |
| 01-May | 3.430 | 3.790 | 42.000 | 31.330 | 143.870 | 153.130 | 1760.900 | 2119.200 |
| 16-May | 3.450 | 3.340 | 33.330 | 22.000 | 129.730 | 132.800 | 1118.600 | 1210.200 |
| 01-Jun | 2.900 | 2.400 | 18.330 | 16.670 | 94.130 | 92.000 | 923.910 | 948.910 |
| **Coefficient of Variation** | | | | | | | | |
| 16-Mar | 6.321 | 3.825 | 25.196 | 24.782 | 11.465 | 5.358 | 18.837 | 24.041 |
| 01-Apr | 11.531 | 8.784 | 27.729 | 35.799 | 9.279 | 8.960 | 15.237 | 14.769 |
| 16-Apr | 2.777 | 2.626 | 22.690 | 19.653 | 6.543 | 2.626 | 41.208 | 44.624 |
| 01-May | 5.827 | 7.863 | 14.826 | 28.257 | 7.410 | 8.827 | 15.285 | 19.520 |
| 16-May | 5.721 | 4.772 | 19.202 | 28.786 | 5.593 | 4.799 | 4.840 | 7.720 |
| 01-Jun | 12.755 | 3.958 | 15.519 | 13.671 | 10.182 | 6.290 | 33.106 | 31.972 |

**Table 3:** *Performance of varieties on different sowing dates.*

| Variety | Sowing date | Plant height | | Number of bolls plant$^{-1}$ | | Boll weight | | Seed cotton yield per plant (kg ha$^{-1}$) | |
|---|---|---|---|---|---|---|---|---|---|
| | | 2019 | 2020 | 2019 | 2020 | 2019 | 2020 | 2019 | 2020 |
| CIM 622 | 16-Mar | 126.87 | 131.87 | 38.33 | 27.33 | 3.48 | 3.68 | 1741.42 | 1766.42 |
| | 01-Apr | 131.87 | 136.87 | 34.67 | 22.67 | 3.51 | 3.71 | 1712.23 | 2070.56 |
| | 16-Apr | 130.87 | 135.87 | 31.00 | 21.67 | 3.41 | 3.61 | 1678.16 | 1703.16 |
| | 01-May | 120.87 | 125.87 | 32.67 | 20.00 | 3.04 | 3.24 | 1288.87 | 1313.87 |
| | 16-May | 113.87 | 118.87 | 28.33 | 15.67 | 3.08 | 3.28 | 1021.23 | 1046.23 |
| | 01-Jun | 75.87 | 80.87 | 16.33 | 14.67 | 2.22 | 2.22 | 923.91 | 948.91 |
| SLH 8 | 16-Mar | 167.33 | 150.13 | 52.67 | 32.67 | 4.02 | 4.01 | 2656.27 | 2981.27 |
| | 01-Apr | 155.87 | 160.87 | 54.00 | 39.67 | 3.87 | 3.79 | 1833.88 | 2858.88 |
| | 16-Apr | 151.13 | 142.87 | 49.33 | 31.67 | 3.60 | 3.80 | 2164.78 | 3423.11 |
| | 01-May | 137.87 | 153.13 | 42.00 | 31.33 | 3.43 | 3.63 | 1760.89 | 2119.22 |
| | 16-May | 129.73 | 132.80 | 33.33 | 22.00 | 3.41 | 3.22 | 1118.55 | 1210.22 |
| | 01-Jun | 94.13 | 92.00 | 18.33 | 12.33 | 2.90 | 2.40 | 826.58 | 851.58 |
| FH Lalazar | 16-Mar | 152.87 | 139.00 | 32.67 | 20.67 | 3.75 | 3.73 | 1973.78 | 1932.12 |
| | 01-Apr | 146.87 | 151.87 | 34.33 | 23.73 | 2.91 | 3.11 | 2393.49 | 2418.49 |
| | 16-Apr | 147.87 | 137.33 | 34.00 | 25.00 | 3.40 | 3.60 | 1167.21 | 1192.21 |
| | 01-May | 143.87 | 148.87 | 34.33 | 21.33 | 3.06 | 3.26 | 1327.80 | 1686.13 |
| | 16-May | 126.80 | 123.00 | 25.33 | 14.00 | 3.14 | 3.34 | 1011.50 | 1036.50 |
| | 01-Jun | 83.87 | 88.87 | 13.00 | 16.67 | 2.62 | 2.20 | 680.60 | 705.60 |
| FH 142 | 16-Mar | 143.87 | 141.40 | 31.33 | 19.33 | 3.59 | 3.79 | 2408.09 | 2433.09 |
| | 01-Apr | 127.87 | 132.87 | 30.33 | 18.33 | 3.50 | 3.70 | 2145.32 | 2170.32 |
| | 16-Apr | 137.87 | 142.87 | 33.33 | 21.00 | 3.53 | 3.73 | 3138.02 | 2829.68 |
| | 01-May | 130.87 | 135.87 | 30.00 | 16.67 | 3.28 | 3.79 | 1624.64 | 1649.64 |
| | 16-May | 122.87 | 127.87 | 21.00 | 11.33 | 3.45 | 2.99 | 1021.23 | 1046.23 |
| | 01-Jun | 76.87 | 81.87 | 14.00 | 13.00 | 2.27 | 2.27 | 388.63 | 413.63 |

value, 2.27 g, during 2020, as shown in given in Table 2. In both years, the maximum value of BW showed by SLH-8 was 3.54 and 3.48 g compared to the other genotypes. In both years, the average BW was ranged between 3.18 to 3.51 g. However, the highest BW was observed in SLH-8 (3.51 g), as given in Table 3. SCY was ranged between 717.42 to 2236 kg ha$^{-1}$. Maximum SCY was 2278.22 kg ha$^{-1}$ during the sowing of 16 March 2021, and the minimum value was 704.92 kg ha$^{-1}$ during the sowing date of 01-June 201, as given in Table 3.

The SCY rangedfrom 1434.58 to 1983.77 kg ha-1, and maximum value showed by SLH-8 was 1726.82 and 2240.71 kg ha$^{-1}$ during 2019 and 2020, as given in Table 3. During the sowing of 01-April 2019, CIM-622 showed the SCY of 1741.42 kg ha-1. While SLH-8 was best performed in both years during the sowing date of 16 April, SCY was 2164.78 and 3423 kg ha$^{-1}$. FH-Lalazarwas best performed in both years during the sowing of 01-April, and SCY was 2393.49 and 2418 kgha$^{-1}$. FH-142 was also best performed on sowing of 16 April in both years; SCY was 3138.02 and 2829 kgha$^{-1,}$ respectively, as given in Table 3.

The results of correlation analysis showed that PH was positively and highly significantly correlated with NBP$^{-1}$ (0.67), BW (0.86), and SCY (0.75). SCY was also positively and highly significantly correlated with the BW (0.73) and NBP$^{-1}$ (0.53), as given in Table 4.

**Table 4:** *Correlation (Pearson) between yield contributing and seed cotton yield of both years.*

| | PH | NBP | BW | SCYP |
|---|---|---|---|---|
| PH | 1.00 | | | |
| NBP | 0.67** | 1.00 | | |
| BW | 0.86** | 0.55** | 1.00 | |
| SCYP | 0.75** | 0.53** | 0.73** | 1.00 |

The heat map clustered the sowing dates of March, April, and May into cluster 2, and sowing during 01

June was clustered into cluster 1. BW, PH, NBP were clustered into group 1 and SCY into the 2nd cluster during 2019. While heat map of 2020, PH and BW were grouped into 1st group and $NBP^{-1}$ and SCY into 2nd group. The heat map also revealed that cotton sowing during 01-June significantly affected the SCY and yield contributing traits. Cotton sowing during 16 March, 01 April, and 16 April showed a significant increase in the seed cotton yield and yield contributing traits of both years. May sowing of cotton somehow affects the seed cotton yield, as shown in Figure 3.

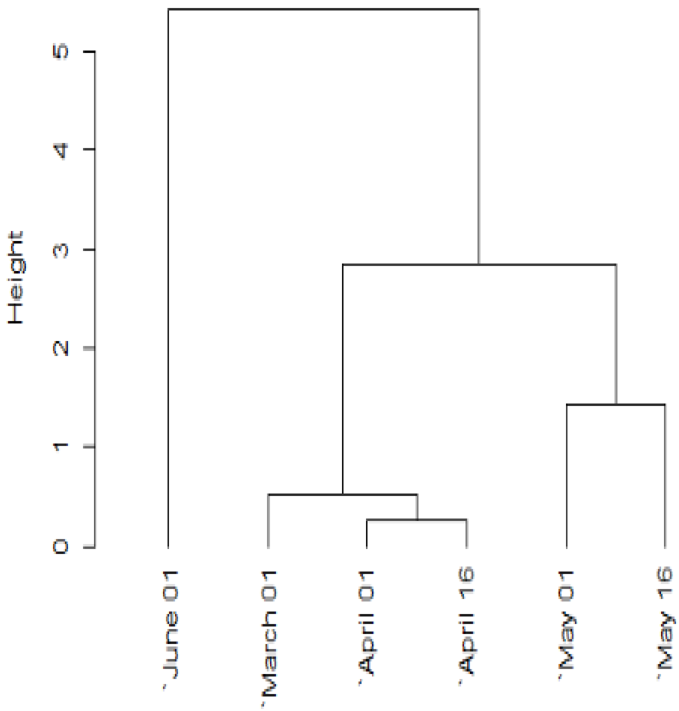


**Figure 3:** *Hierarchical clustering for yield contributing traits and seed cotton yield during 2019 and 2020.*

For breeding purposes, the selection of plant material plays a vital role in the relationship between traits. An ideal structure for the cotton plant is essential for achieving a higher seed cotton yield. Furthermore, temperature also impacted crop emergence and early standing growth (Hussain *et al*., 2012). But cotton growers always focused on the time of plantation for agronomic concerns to get maximum production. This experiment shows that early sowing of cotton on March 16th produced more seed cotton yield than late sowing of the cotton crop (Figure 3). In Pakistan, early sowing of cotton provides favorable weather conditions for flowering and fruit development (Ali *et al*., 2009).

The temperature of colder nights might be harmful for the retention of bolls and plant growth reported by (Yeates *et al*., 2013). Furthermore, the reduced productivity in seed cotton yield and yield-related traits was due to the later dates of sowing in the field and might be due to the poor weather conditions, which mainly affected the reproductive stage because of falling temperature (Lakkineni *et al*., 1994; Kaur *et al*.,2019).

The date of sowing affects the PH and SCY, and had significant variation was observed. SLH-8 shows maximum height in 2019 and shows maximum seed cotton yield in 2020 as compared with other varieties. Furthermore, the interaction between genotypes and sowing dates was significant only for PH and SCY in both years, and this interaction also created a crucial role in both years. In our study, it was observed that PH and SCY were reduced due to late sowing. The reduction in PH and SCY was mainly due to high temperature and insect infestation (Qamar *et al*., 2016).

The temperature at 30 °C provides a favorable environment for boll development at maximum capacity. Maximum $NBP^{-1}$ was attained in optimum temperature because of mean temperature during the boll and flowering period with higher photosynthesis that was mainly dependent on sowing date (Reddy, 1992). Furthermore, cotton crop faces the minimum temperature in late sowing, but this will not be supportive in proper boll development. However, it will increase the population of insects (Ali *et al*., 2004).

Cotton plants require a different quantity of water uptake for better growth. Young ones usually tolerate the drier weather conditions and trying to produce flowers in stress water conditions. However, when the flowers come out from their buds, the requirement for water uptake significantly increases. For the first fourteen days after flowering, water scarcity causes the boll to fall off from the plant (Cotton Foundation, 2018).

Sowing dates played an essential role in obtaining a higher seed cotton yield. Higher temperature significantly affects the production of SCY (Saeed *et al*.,2014; Ahmed *et al*., 2014). Our findings showed that cotton BW showed maximum difference related to sowing dates. The BW was significantly affected by sowing dates, and it showed that it might be due to genotype and environment interaction (Zeng *et al*., 2014).

As compared to vegetative growth, the growth of boll was temperature sensitive. The increase in $NBP^{-1}$ also increases the SCY. NBP-1 contribute in the SCY, these traits was significantly correlated with each and other (Copur, 1999; Baran, 2013; Copur and Yuka, 2016).

The correlation between four traits in different sowing dates showed significant differences. As the PH was positively and significantly correlated with $NBP^{-1}$, BW, and SCY. These results were also similar to the findings of Khalid *et al*. (2018) and Salahuddin *et al*. (2010). SCY was positively and significantly correlated with $NBP^{-1}$ and BW (Arshad *et al*., 2007). Therefore, the plants with these traits will simplify the selection process for desired plants in SCY improvement. Sowing date have a big impact on cotton cultivars. The growth and developmental characteristics of late-sown cotton were significantly reduced (Ali *et al*., 2021).

## Conclusions and Recommendations

It was observed that maximum seed cotton yield has been obtained on the sowing date of 16th March during both years. In genotypes, SLH-8 was the best performing variety among all studied genotypes. The seed cotton yield in both years was ranged between 1434.58 and 1983.77 $kgha^{-1}$, and maximum seed cotton yield was observed for SLH-8 in 2019 and 2020 (1726.82 and 2240.71 $kgha^{-1}$, respectively). Correlation analysis showed that plant heigh was positively and highly significantly correlated with number of bolls $plant^{-1}$, boll weight, and seed cotton yield. Seed cotton yield was also positively and highly significantly correlated with the boll weight and number of bolls $plant^{-1}$.

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## Novelty Statement

This study highlights that under the environmental conditions (high temperature and unpredicted rain pattern) of Sahiwal, sowing of cotton after 1st June will affect drastically the reduce of seed cotton yield. Therefore, according to current weather conditions, the best time for cotton sowing in the Sahiwal zone is 16th March.

## Author's Contribution

**Muhammad Zubair Ishaq**: Designed the experiments and wrote the first draft.
**Umar Farooq**: Measured the observations.
**Muhammad Asim Bhutta**: Conducted this research.
**Saghir Ahmad, Amna Bibi, Hafeez UR Rehman and Umar Farooq**: Assisted in preparation of the draft of this paper.
**Javaria Ashraf and Samaria Nisar**: Proofread the article and finalized the draft.

*Conflict of interest*

The authors have declared no conflict of interest.

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