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Content

1 Comparative Efficacy of Different Insecticides Against Dusky Cotton Bug (Oxycarenus Spp.) Under Field Conditions
Muhammad Hasnain, Muhammad Hussnain Babar, Muhammad Asif, Kahunsa Khakwani, Ghulam Sarwar, Muhammad Akram, and Muhammad Rafiq Shahid

11 Unlocking Agricultural Potential: Early Sowing of Triple Gene Cotton Variety Improves Morphological Traits and Seed Cotton Yield
Zaib-Un-Nisa, Muhammad Ihsan Ullah, Ghulam Sarwar, Saeed Ahmad, Muhammad Rafiq Shahid, Muhammad Anas Rasool, and Sadia Kanwal

19 Effect of Sowing Date, Plant Density and Potassium Fertilization Rate on Productivity and Quality of The Egyptian Cotton Cultivar Giza 96
Ahmed M. S. Solieman, Mohsen A. Omar, Sami Sh. El-Tabakh and Ali I. N. Nawar

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Comparative efficacy of different insecticides against dusky cotton bug (*Oxycarenus Spp.*) under field conditions

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Abstract

Dusky cotton bug (*Oxycarenus* spp.) has become a major insect pest of cotton crop in Pakistan. During ginning process, they are crushed on valuable cotton lint and stained lint fetch low price in the market. The present study was designed to evaluate the efficacy of different insecticides against the dusky cotton bug (DCB) under field conditions. Five insecticides viz. Fiprox 5SC (Fipronil), adder plus 360 EC (Deltamethrin + Triazophos), nurelle-D 505EC (Cypermethrin + Chlorpyriphos), goldstar 200EC (Bifenthrin + Pyridaben) and delegate 25WG (Spintoram) were sprayed in order to determine the reduction in the pest population. The experiment was conducted under Randomized Complete Block Design (RCBD) with three replications. The results revealed that most effective insecticide against dusky cotton bug was nurelle-D with a reduction of 96.73% in the pest population followed by adder plus (85.66%) after 7 days of first spray, respectively. Similarly, after second spray, nurelle-D lowered population up to 84.87% followed by delegate and adder plus giving maximum reduction of *73.55% and 72.46%*, respectively *after* 7 days as compared with 22.54 the pest population in control treatment.

Keywords: cotton, dusky cotton bug, efficacy, insecticides

Introduction

Pakistan has a diverse cropping pattern, in which cotton (*Gossypium hirsutum* L.) being the most valuable golden cash crop, contributes significantly to food, oil, feed and textile sector merchandise (Tausif et al. 2018). Cotton plant's components are each highly beneficial in our daily lives (Evode et al. 2021). Cotton seed and fiber or lint are the most essential elements of the cotton plant (Sarwar et al. 2013). In terms of area, it is the second most planted crop after wheat, with 2764 thousand hectares (projected) under cultivation and a yield of 12.77 million bales (reference for data year). Pakistan is the fifth largest cotton producer (Khalid et al. 2022), as well as per hectare production is significantly lower than in other nations (Jans et al. 2021). There are several causes for low cotton production in Pakistan, including farmer ignorance, a lack of modern technology, a greater prevalence of insect and pest assault, expensive pesticide prices, and chemical contamination (Ali et al. 2013). Insect pest infestation is the most significant limiting factor, lowering output by 5-10%, and even up to 40-50% in certain cases (Kannan et al. 2004). Cotton output in the country can be boosted if insect pests are successfully managed and suggested agronomic practices are followed (Wilson et al. 2018). Cotton is attacked by both sucking pests (whitefly, jassid, aphid, thrips and dusky cotton bug) and bollworms including pink bollworm, american bollworm and spotted bollworm (Rajendran et al. 2018). The most damaging sucking pest is the dusky cotton bug (DCB), which is polyphagous and feeds on the seeds of a variety of plants in the Malvaceae family (Rajendran et al. 2018). The issue of dusky cotton bug (DCB) occurred as a result of reduced application of organophosphate and pyrethroid insecticides on Bt cotton, which were previously employed to combat bollworms (Ullah et al. 2016). Dusky Cotton Bug is also known as the Egyptian cotton stainer (Shah et al. 2016), and it is a pest of cotton, okra, persimmon, fig, dates, and avocado, as well as sunflower seeds and other crops in southern Asia. Iraq, Pakistan, India, Myanmar, Malaysia, Cambodia, Vietnam, and Laos all have it. Except for North America, all cotton-growing regions in the globe have a similar niche (Coppens d'Eeckenbrugge and Lacape 2014).

The population of DCB is at its highest level during the hotter months from March to July, and at the lowest between November and January. This pest seem to do best when the temperature is high and the humidity is low (Iqbal et al. 2022). Dusky cotton bug can also be found on Hibiscus sabdariffa (roselle), Hibiscus vitifolius (tropical rose mallow), and Hibiscus esculentus (okra) (Magdalita and San Pascual 2022). The dusky cotton bug feeds on a variety of plants and weeds, including Deccan hemp, Dombeya burgessiae, Grewia asiatica, Melochia corchorifolia, Malva pusilla, Malva spp., Malvastrum spp., and Malvascus spp. (Schaefer and Panizzi 2000). In half-opened cotton bolls, the female Oxycarenus laetus deposits a batch of cigar-shaped eggs between the lint and the calyx. The eggs hatch in six to ten days, and the young pass through six nymphal stages until reaching full maturity in thirty to forty days (Gaur and Mogalapu 2018).

Previously considered a minor pest, DCB has now been elevated to the category of serious pest. Cotton seed insect and cotton stainer are some names for it (Rippon and Evans 2020). The pest's adult and immature life stages are both capable of causing crop harm by lowering yield, seed weight, and oil content by sucking cell sap (Rajendran et al. 2018).

It is estimated that DCB can lower cotton yield by up to 6.8%, seed weight by 32%, and oil content by 6% (Khan et al. 2014). This insect spends the winter in unginned cotton in factories and holes in the barks of various plants (Khan et al. 2014). It is often crushed with cotton, colouring the lint, resulting in bad quality and a lower market value (Negm and Sanad 2020). It also reduces the viability of seeds by causing huge damage to the seed embryo (Ahmed et al. 2015). Plant protection is critical to the effective production of cotton crops and protecting them from insect assault. Chemical pesticides are widely used in Pakistan, and their use is expanding year after year since they give a rapid knockdown effect when compared to other approaches (Basit 2018). Pesticides costing worth more than ten billion rupees are imported, with about 70-80% being utilized to combat cotton pests (Malinga 2022).

It is a critical need to adopt new-chemistry pesticides that are not only selective to the targeted pest but also safer for beneficial insects and humans. Chemical management is an essential component of crop protection in contemporary agriculture, but over-reliance on pesticides has resulted in resistance issues, ecological instability, and greater producer costs. Extensive research has been carried out in order to evaluate new insecticides with unique modes of action against DCB. The current study aimed to examine the efficacy of novel chemical insecticides against DCB in cotton field settings.

Materials and Methods

The current research trials are being done at the Cotton Research Institute, Multan, Pakistan.

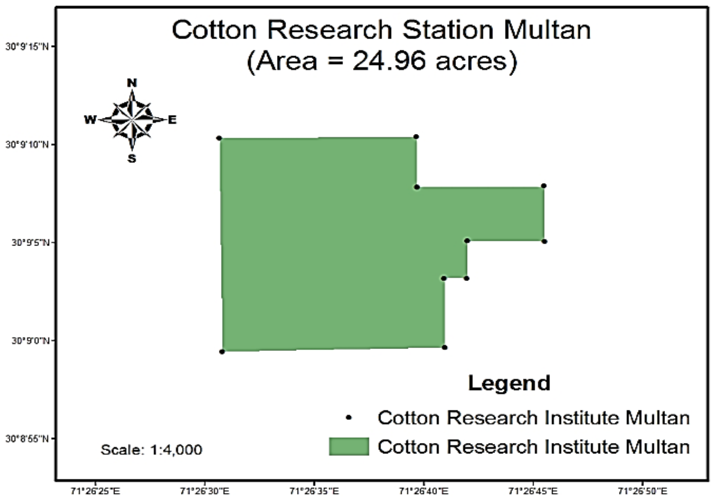

Figure: Geographical location of Cotton Research Institute Multan

The research studies were carried out to investigate the effectiveness of different insecticides against dusky cotton bug using a randomized complete block design (RCBD). There were six treatments in all, including the control. The experiment was repeated two times. Cotton variety MNH-1050 was planted on June 30, 2023. The net plot size was maintained at 5.50 m × 3.50 m. The space between plants and rows was fixed at 30 and 70 cm, respectively. All the standard agronomic practices (hoeing, irrigation and fertilizer application) were adopted in the treated plots including control. A pre-emergence weedicide, Dualgold (S-metolachlor), at 1.0 liter/acre, was used to suppress weeds. When necessary, the crop was irrigated. For the crop, all other recommended agronomic practices were followed until harvesting. All of the pesticides were acquired from the market and used at the authorized doses. When the population of pest reached nymph or adults at economic threshold level (ETL) i.e., 15/ open bolls, insecticides were applied using a hand-operated knapsack sprayer with a hollow cone nozzle. Data were collected from each plot early in the morning, at 24 hours before the spray, and then at 1-, 2-, 3-, and 7-days intervals after the spray. After 15 days, the test pesticides were repeated, and the second spray was applied. Five different insecticides viz. fipronil, Deltamethrin + Triazophos, Cypermethrin + Chlorpyriphos, Bifenthrin + Pyridaben, and Spintoram were tested against dusky cotton bug under field conditions and compared with untreated control (Table 1). Data were analyzed by ANOVA and means were separated through LSD test at 5% level of significance by using Statistix software 8.1. The percent reduction in population at each interval was calculated by using the following formula;

$$Percent\ reduction\ in\ population = \frac{A-B}{A} x100$$

Where,

A= Pre-treatment population

B= Post treatment population

Table 1: Details of insecticides used in the experiment.

Sr. No	Trade Name	Common Name	Dose/Acre
1	Fiprox 5SC	Fipronil	500 ml
2	Adder Plus 360EC	Deltamethrin + Triazophos	500 ml
3	Nurelle-D 505EC	Cypermethrin + Chlorpyriphos	500 ml
4	Goldstar 200EC	Bifenthrin + Pyridaben	250 ml
5	Delegate 25WG	Spintoram	80 ml

Results and Discussion

Reduction of Dusky Cotton Bug at different time intervals after 1st spray

The results of the field efficacy test of different insecticides are presented in the Table 2. After 1st spray, all insecticides showed a highly significant difference among the treatments. After first days of insecticides application, the highest percent reduction of dusky cotton bug was observed in plots treated with (86.77%) followed by (74.87%) and Adder Plus (73.73%), respectively. The least reduction in DCB population was observed by treatments of Fiprox (47.45%) and Goldstar (32.77%), respectively. The least reduction in DCB population per boll was observed in control plots (21.34%). Similarly, highly significant difference was found among treatments for the control of DCB after 2 days of spray. In percentage of DCB population reduction, the insecticides followed the order Nurelle-D (91.47%) > Adder Plus (81.28%) > Delegate (78.23%) > Fiprox (52.55%) > and Goldstar (37.55%). The DCB population per boll was also observed lower in control plots (16.02%). After 3 days performance varied significantly from other tested insecticides, the plots treated with Nurelle-D exhibited the highest percentage of reduction at 94.81%. Conversely, the lowest population reduction was observed in plots treated with Adder Plus (83.97%), Delegate (82.24%), and Fiprox (60.50%).. The least percentage of reduction was recorded Goldstar (45.41%). The control treatments recorded lowest population reduction (8.92%).

After 7 days of spraying, the highest percentage of reduction was also observed in the plots treated with Nurelle-D (96.73 %) and having lowest population was recorded followed by Delegate (86.19%), Adder Plus (85.66%), respectively both was statistically similar and Fiprox (66.01%) was recorded in treated plots. The minimum percentage of reduction was recorded Goldstar (54.13%). The control treatments recorded lowest population of DCB (7.45%). It was observed that all the tested insecticides gave more or less satisfactory percent reduction of mite population Nurelle-D being recorded the highest percentage of reduction.

Table 2: Percent reduction of DCB population after 1, 2, 3 and 7 days after First Spray

Treatments/ Insecticides	Pre-treatment	Post treatment observation/Boll after				% age Reduction			
		1-Day	2-Day	3-Day	7-Day	1-Day	2-Day	3-Day	7-Day
Fiprox 5SC	16.86	8.86^{bc}	8.0^{bc}	6.66^{bc}	5.73^{b}	47.45	52.55	60.50	66.01
Adder Plus 360EC	19.53	5.13^{de}	3.66^{de}	3.13^{d}	2.80^{c}	73.73	81.26	83.97	85.66
Nurelle-D 505EC	14.06	1.86^{e}	1.20^{e}	0.73^{d}	0.46^{d}	86.77	91.47	94.81	96.73
Goldstar 200EC	15.26	10.26^{b}	9.53^{b}	8.33^{b}	7.0^{b}	32.77	37.55	45.41	54.13
Delegate 25WG	21.73	5.46^{cd}	4.73^{cd}	3.86^{cd}	3.0^{c}	74.87	78.23	82.24	86.19
Control	22.54	17.73^{a}	18.93^{a}	20.53^{a}	20.86^{a}	21.34	16.02	8.92	7.45

Means sharing similar letters are not significantly different by Tukey's Test at P = 0.05
HSD =

Reduction pattern of Dusky Cotton Bug Population after 2nd spray

The results of the field efficacy test of different insecticides are presented in the Table 3. The data from these results showed effectiveness of various insecticides for the control of DCB after 2nd spray revealed a highly significant difference among the treatments. After 1 day, the highest reduction of DCB population by the application of insecticides was observed in plots treated with Nurelle-D (70.11%) followed by Delegate (60.38%) and Adder Plus (59.09%), respectively. The least percent reduction was observed in plot treated with Fiprox (38.85%) and Goldstar (17.38%), respectively. Control plots (5.99%) showed significantly lowest DCB population reduction percentage among all of the insecticides tested. Similarly, highly significant difference was found among treatments for the control of DCB after 2 days of spray. The insecticides Delegate (74.88%) and Nurelle-D (74.17%) recorded maximum percent reduction which was statistically similar to each other followed by Adder Plus (67.53%), The least percent reduction was recorded in Fiprox (43.81%) and Goldstar (27.40%) respectively. The DCB population reduction per boll was the lowest in control plots (14.08%). After 3 days of spray, the highest DCB reduction was against observed in the plots treated with Nurelle-D (77.06%) followed by Adder Plus (70.57%), Delegate (68.88%) and Fiprox (51.24%). The least DCB reduction was recorded in treatment where Goldstar (34.36%) was used. The control treatments recorded the lowest DCB population (16.24%). It was observed that all the tested insecticides gave more or less satisfactory control of DCB population but Nurelle-D was recorded as the most effective with the highest DCB control.

After 7 days of spraying, the highest DCB control was observed in the plots treated with Nurelle-D (84.87%) followed by Delegate (73.55%) Adder Plus (72.46%), and Fiprox (56.48%) while the least reduction in DCB population was recorded in treatment where Goldstar (46.12%) was used. The control treatment showed the lowest DCB population reduction (9.06%). It was observed that all the tested insecticides gave variable reduction in population of DCB but Nurelle-D was recorded as the most effective with the highest DCB population control.

Table 3: Table 2: Percent reduction of DCB population after 1, 2, 3 and 7 days after Second Spray

Treatments/ Insecticides	Pre-treatment	Mean DCB Population Per Opened Boll				Percent reduction of DCB Population			
		1-Day	2-Day	3-Day	7-Day	1-Day	2-Day	3-Day	7-Day
Fiprox 5SC	17.76	10.86 bc	9.98 bc	8.66 bc	7.73 b	38.85	43.81	51.24	56.48
Adder Plus 360EC	17.43	7.13 de	5.66 de	5.13 d	4.80 c	59.09	67.53	70.57	72.46
Nurelle-D 505EC	16.26	4.86 e	4.20 e	3.73 d	2.46 d	70.11	74.17	77.06	84.87
Goldstar 200EC	17.26	14.26 b	12.53 b	11.33 b	9.30 b	17.38	27.40	34.36	46.12
Delegate 25WG	18.83	7.46 cd	4.73 cd	5.86 cd	4.98 c	60.38	74.88	68.88	73.55
Control	18.54	17.43 a	15.93 a	15.53 a	16.86 a	5.99	14.08	16.24	9.06

Means sharing similar letters are not significantly different by Tukey's Test at P = 0.05
HSD = ??

The effectiveness of the insecticides against the dusky cotton bug on cotton during the first and second sprays revealed that each pesticide under test was found to be significantly effective in decreasing the dusky cotton bug population. The mean DCB population 1 day before and after 1, 2, 3 and 7 days of spray are represented in Table 2 and 3. After 1 day of spray, there were notable differences in the DCB population decrease between the treated and control plots. Minimum population of 1.86/boll was recorded in Nurelle-D treated plots with percent reduction of 86.77%, while goldstar was found least effective with a mean population of 10.26/boll and a reduction of 32.77%. After 2 days of spray, DCB population per opened boll in plots treated with nurelle-D, adder Plus and deligate was 1.20, 3.66 and 473/boll with a percent reduction of 91.47, 81.26 and 78.23%, respectively. After 3 and 7 days of spray, mean DCB population decreased to 0.73 and 0.46/boll in nurelle-D treated plots with the reduction 94.81% and 96.73%, respectively (Table 2). Nurelle-D also reduced maximum DCB population with percent reduction of 70.11 ,74.17, 77.06, and 84.87 after 1, 2, 3 and 7 days of application of insecticides, respectively (Table 3).

Our findings agree with many of the previous researches (Akram et al. 2013, Abbas et al. 2014). They reported that, by eliminating 94.5% population, chlorpyriphos are the most destructive to DCB. It has been reported that the superior contact action of the organochlorine and organophosphate group make them more effective than other pesticides at controlling Dusky Cotton Bug (Nasir et al. 2019). Chlorpyriphos+?? (Not used alone) was also shown to be highly effective, as evidenced by an 80-95% decrease in the number of dusky cotton bugs when compared to other tested insecticides. The current findings shown that the DCB population was significantly reduced by the pesticide nurelle-D, which is a member of the new chemistry insecticides.

These findings completely concur with the previously conducted research (Rezk et al. 2019). They revealed that new chemical pesticides, by stopping the pests' ability to feed and travel, resulted in the highest possible death rate following a 24-hour treatment (Noureen et al. 2016). Our research showed that a variety of pyrethroid, organophosphate, and other insecticide mixtures, such as Adder Plus (a blend of Deltamethrin + Triazophos), Nurelle-D (a blend of Cypermethrin + Chlorpyriphos), and a mixture of Bifenthrin + Pyridaben, were successful in lowering the population of DCB in field settings. A combination of several pesticides with both systemic and contact activity can be used to effectively control the dusky cotton bug (Smith and Brambila 2008). Under field conditions, we suggest that the following treatments can successfully reduce the population of the dusky cotton bug: Nurelle-D, Adder Plus, and a combination of Lancer & triazophos. In order to control this pest below the economic threshold under field settings, it is thus proposed that producers be advised to use these pesticides.

Conclusions and Recommendations

From the present study it is concluded that Nurelle-D a mixture of Cypermethrin + Chlorpyriphos was highly effective as compared to the other insecticides and can be recommended to growers for the management of dusky cotton bug population in cotton.

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Unlocking Agricultural Potential: Early Sowing of Triple Gene Cotton Variety Improves Morphological Traits and Seed Cotton Yield

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Abstract

Early sowing and short-duration varieties play a critical vital role in improving the overall plant growth and yield. However, there is limited information on cultivating triple-gene cotton varieties during the early sowing season, especially in South Punjab, Pakistan. For this purpose, a triple gene cotton variety *CKC-6 was used to evaluate the effect of different sowing dates on morphological traits and seed cotton yield. The results showed that different sowing dates significantly affected morphological traits of cotton. Early sown cotton had plant height (147 cm), average number of nodes per plant (44.20), average number of bolls per plant (30), and average boll weight (2.85) that were significantly higher as compared to other sowing dates. Moreover, the average seed cotton yield was also significantly higher (2457.6 kg/ha) under early sowing (S1). These results showed that triple gene cotton variety significantly improved the plant height, nodes per plant, bolls per plant, boll weight, and seed cotton yield by about 12%, 15%, 34%, 41%, and 48%, respectively, under S1 compared to S4 (late sowing). Correlation analysis showed* strong positive correlation coefficients between *seed cotton yield* and several morphological traits. We found that yield was significantly positively correlated with plant height (0.98*), number of nodes (0.96*), and number of bolls (0.93*), while non-significant and positively correlated with boll weight (0.93). These findings suggested that early sown triple gene cotton variety positively influenced cotton plants' morphological traits and yield. These findings will contribute valuable insights for cotton growers and researchers, offering a basis for targeted interventions to optimize morphological traits and enhance crop yield in future.

Keywords: Early sowing, morphological traits, triple gene cotton, yield

Introduction

Cotton (*Gossypium hirsutum* L.) is one of Pakistan's most important fiber-producing crop and a major cash crop. It is grown on over 2.6 million hectares in Pakistan, providing economic opportunities for a substantial portion of the population. Among the top five cotton producers, Pakistan ranks fifth after China, India, the United States, and Brazil. The cotton crop accounts for 0.8% of the country's GDP and contributes 4.1% to agricultural value addition. Numerous biotic and abiotic factors contribute to cotton production challenges. The biotic stresses are mostly caused by chewing insects such as cotton bollworms, spotted bollworms, armyworms, pink bollworms, as well as sucking insects like aphids, whitefly, and thrips. Various abiotic factors, such as drought, salinity, high temperatures, etc., significantly reduce cotton yields. However, it has been reported that the insect pest complex, cotton leaf curl disease (CLCuD), and the weeds are mainly responsible for the low productivity of cotton in Pakistan (Aslam, Razaq et al. 2004, Siddiqui, Asad et al. 2022). Hence, it is a matter of great interest to find a possible outstanding solution to this serious issue, e.g., Bt cotton and early maturing/short-duration cotton varieties.

Chemicals like pesticides are often used to manage insect pests. This approach, however, may lead to adverse health and environmental effects, and insects may become resistant to these pesticides (Damalas and Eleftherohorinos 2011). Thus, Bt cotton was first introduced in 1996, that greatly enhanced cotton production (Briefs 2017). However, with time, the resistance of insects has developed against Bt cotton expressing Cry1Ac and Cry2Ab. Until 2012, only five insect species were reportedly resistant to Bt toxins (Tabashnik, Brévault et al. 2013). However, most Bt cotton types grown in Pakistan had little Bt toxin. Interestingly, the main cotton-growing areas in Punjab and Sindh provinces showed that Bt cotton with both Cry1Ac and Cry2Ab genes remains effective and resistant, protecting against various chewing insect pests (Siddiqui, Asad et al. 2022).

Weed control using biotechnology is more advanced than traditional methods due to its advanced technology. A widely used and cost-effective herbicide is glyphosate, commonly known as "Roundup." It is a powerful herbicide that can inhibit various weeds and crop growth. Glyphosate disrupts the shikimate metabolic pathway, inhibiting EPSPS (5-enolpyruvyl-3-phosphoshikimate) synthesis. This disruption prevents the subsequent synthesis of three essential aromatic amino acids—phenylalanine, tryptophan, and tyrosine—and proves lethal to plants. Hence, it is imperative to introduce the glyphosate-resistant gene to control the weeds without damaging the plant health (Naqvi, Asif et al. 2017).

Nevertheless, cotton's early maturation helps mitigate late-season risks from insects/pests, especially bollworms, diseases, and unfavorable weather conditions and reduces input costs to increase economic returns. (Ahmad, Ahmad et al. 2008). Hence, the present study assessed the potential of triple gene (*Cry1Ac*, *Cry2Ab*, and *EPSPS)* cotton variety for earliness. We hypothesized that the presence of these three genes may lead to insect resistance, herbicide tolerance and could improve the yield potential in early sown cotton.

Materials and Methods

The experiment was conducted at Cotton Research Institute, Multan, Punjab, Pakistan, in 2023. The experimental material used in this experiment was the triple gene variety CKC-6. To evaluate the effect of early sowing, four different sowing dates were selected, i.e., 08/03/23 (S1), 24/03/23 (S2), 10/04/23 (S3), and 26/04/23 (S4), each with three replicates. The plot size was 30×100 feet, while plant-to-plant and row-to-row distances were maintained at 1 and 2.5 feet, respectively. To assess the impact of different sowing dates, different morphological traits were recorded, such as plant height (cm), number of nodes per plant, number of bolls per plant, boll weight (g), and seed cotton yield (Monds/ha). All agronomic practices were conducted during the whole experiment. Finally, the experiment was harvested on 24/10/23.

One-way analysis of variance (ANOVA) was performed to analyze the effect of different sowing dates on different traits. We accomplished the LSD (least significant difference) test at $\alpha = 0.05$ to analyze the difference between different treatments of sowing dates using Statistix 8, version 8.1. correlation graph was made by using R-Analysis Soft ware. OriginPro 2023b was used to draw the figure and analyze the correlation.

Results and Discussion

Effect of Early Sowing on Morphological Traits and Yield

The effect of different sowing dates was investigated on various morphological traits and yield was explored and found that early sowing dates had relatively positive effect in cotton plant improvement and yield (Fig. 1). Results showed that maximum plant height (147 cm) was recorded under early sowing date of S1 (08/03/23). While plant height gradually decreased with delay in sowing (Fig. 1A). Likewise, average no. of nodes per plant were also recoded high under early sowing S1 (44.20), while its number decreased with delay in sowing dates to 42.1, 41.8, and 37.8, for S2, S3, S4, respectively (Fig. 1B). For average number of bolls per plants, the effect of sowing dates was significant and early sowing at S1 showed 34% more number of bolls as compared to S4. The minimum number of bolls was recorded in S4 (19.8) (Fig. 1C). Similarly, the boll weight also showed the same trend which was recorded as 2.85, 2.42, 2.30, and 1.69 g at S1, S2, S3, and S4, respectively. Hence, S1 showed maximum boll weight, while, S4 showed the minimum boll weight (Fig. 1D). Similarly, the improvement in morphological traits at early sowing dates led the yield improvement in the same manner also. The average seed cotton yield was recorded at 61.44, 51.13, 43.50, 31.84 Monds/ha at S1, S2, S3, S4, respectively. The average increase in seed cotton yield at early sowing S1 was 48% higher than late sowing of S4 (Fig. 1E). These results imply that early sowing could play a key role in improving the overall plant health in terms of morphological traits and could lead to increase the yield.

So far, an investigation into the effects of different sowing dates on cotton plant morphological traits as well as the yield revealed interesting results and it was found that sowing dates are correlated with various cotton morphological parameters, providing insight into the possible advantages of early sowing. According to the observed trends in plant height, early sowing resulted in the maximum plant height at 147 cm for S1 (08/03/23). This suggests that an early start to the planting season positively affects cotton plant vertical growth. Similar patterns emerged regarding the number of nodes per plant, with S1 exhibiting the highest average number (44.20). Thus, cotton plants are more likely to develop extensive branching structures as they are established early through early sowing. Delay in sowing dates (S2, S3, and S4) further highlights the crucial role of timing in shaping cotton's morphological architecture. It was found that the number of bolls per plant were also significantly affected by sowing dates. As a result of this observation, we can conclude that early sowing leads to more boll production. In addition to boll numbers, sowing dates also affected boll weight. Based on these consistent trends, early sowing affects not only boll quantity, but also their weight, which in turn affects cotton quality and yield. Lastly, the study highlights the importance of early sowing for improved seed cotton yield. These findings are supported by the previous *findings* (Ahmad, Ahmad et al. 2008, Zhao, Chen et al. 2023). There could be further possible explanations for these interesting results. Firstly, the use of triple genes (*Cry1Ac*, *Cry2Ab*, and *EPSPS)* which invigorate the resistance again insects pests and weed controls that results in improvement of overall plant health which ultimately resulted in higher yield (Naqvi, Asif et al. 2017). Secondly, the early sown cotton plant escapes from the critical period of high temperatures and harsh environment, and is also saved from the early season insect pest attack. Due to these reasons, boll retention is maximum which ultimately improve the seed cotton yield (Pettigrew 2002, Tabashnik, Brévault et al. 2013).

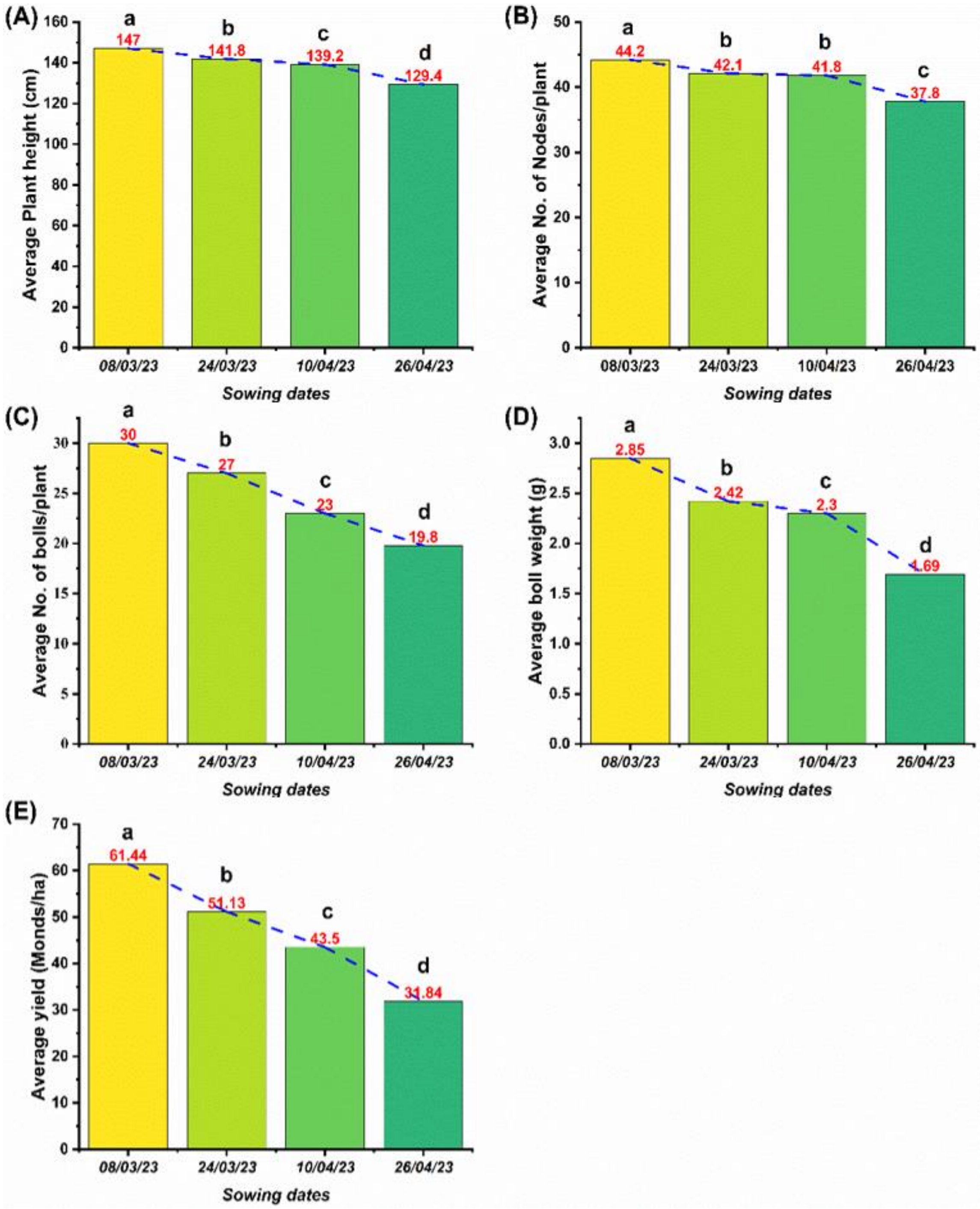

Fig.1. Effect of different sowing dates on cotton plant height (A), number of nodes/plant (B), number of bolls/plant (C), boll weight (D) and yield (E). The different sowing dates 08/03/23, 24/03/23, 10/04/23, and 26/04/23 denotes the S1, S2, S3, and S4, respectively. Blue dotted line showing the trend, while different alphabetic letters showing significant differences at *P<=0.05*.

Correlation among Yield and Morphological Traits

The correlation analysis was performed to check the relationship among different morphological traits and especially relationship of yield with different morphological traits. The results showed that all morphological traits were positively correlated with each other (Fig. 2). For example, with increased plant height, the other traits like number of nodes, bolls, boll weight and yield also increased. We found that *seed cotton yield* was significantly positively correlated with plant height (0.98*), number of nodes (0.96*), number of bolls (0.99*), while non-significantly but positively correlated with boll weight (0.93). These results suggest that changes in one trait lead to changes in others. For example, an increase in plant height will result in more nodes, bolls, boll weight, and, ultimately, more yield. The positive correlation between these traits illustrates how these traits are interconnected in cotton plant growth and development. Specifically, the strong positive correlation coefficients between yield and several morphological traits indicate a robust relationship. Plant height, with a correlation coefficient of 0.98, emerges as a particularly influential factor positively affecting yield. This implies that taller plants are associated with higher yield, reinforcing the importance of vertical growth in achieving optimal cotton crop productivity (Ahmad, Ahmad et al. 2008, Zhao, Chen et al. 2023). Hence, these results imply improvement in morphological traits could lead to improvement in yield.

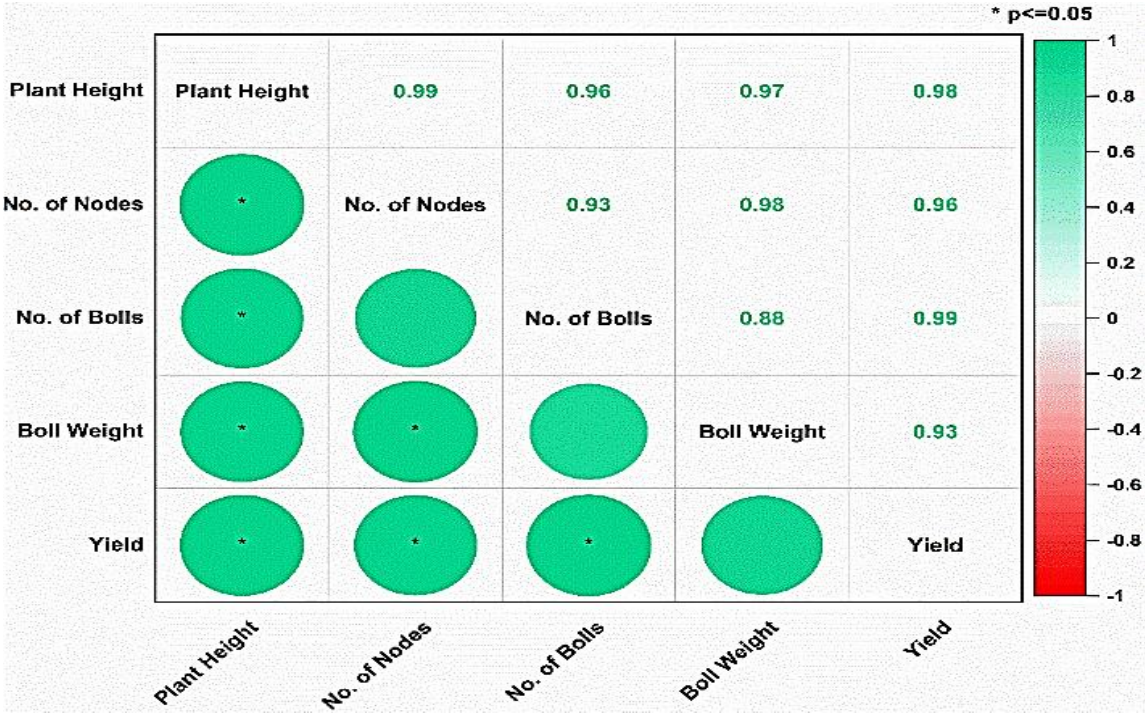

Fig.2. Correlation analysis among the yield and various morphological traits. * represents the significance (*P*<=0.05).

Conclusion

It is concluded from the results of this study that early sowing of cotton crop positively influence morphological traits and *seed cotton yield*. In cotton cultivation, the observed trends in plant height, node numbers, boll quantity, and boll weight support early sowing practices as a strategy to optimize yield and crop performance. Moreover, the correlation analysis reveals a consistent positive relationship among various morphological traits in cotton plants. The strong positive correlations between seed cotton yield and plant height, number of nodes, and number of bolls underscore the importance of these traits in determining cotton yield. These findings contribute valuable insights for cotton growers and researchers, offering a basis for targeted interventions to optimize morphological traits and enhance crop yield.

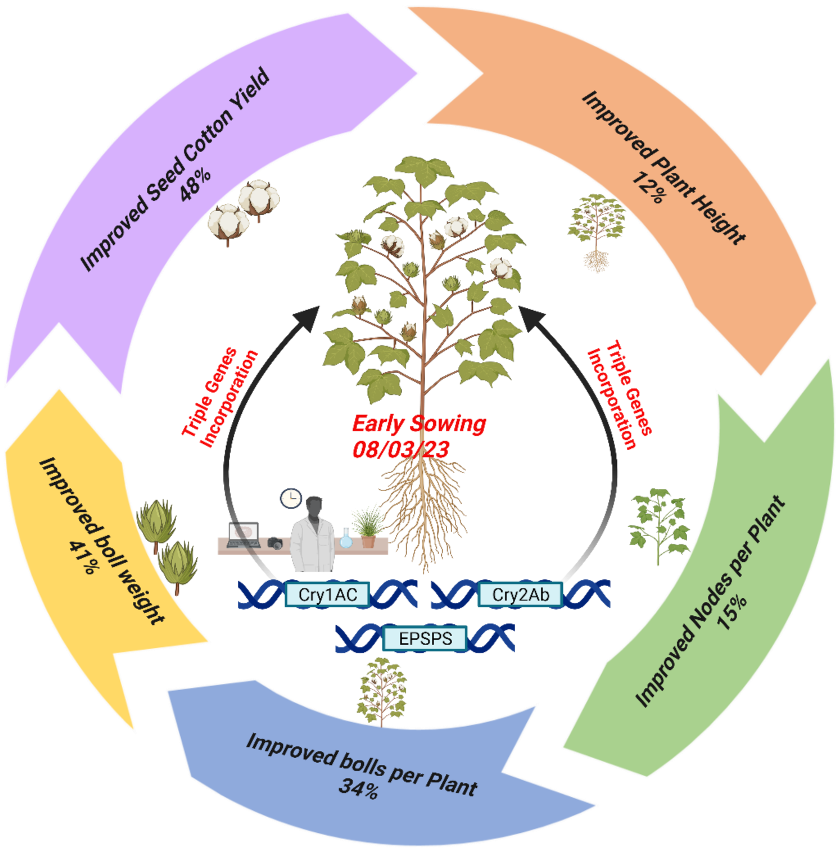

Fig.3. Summary of the study showing improved traits and seed cotton yield with early sowing of triple gene cotton variety.

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Effect of Sowing Date, Plant Density and Potassium Fertilization Rate on Productivity and Quality of The Egyptian Cotton Cultivar Giza 96

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Abstract

The present study was carried out at the Agricultural Experiment Station, Faculty of Agriculture, Alexandria University, Alexandria - Egypt, during the two summer seasons of 2019 and 2020. The aim of the present investigation was to elucidate the importance of sowing date, plant density and potassium application level, and their interactions, on agronomic and quality characters of Egyptian cotton cultivar Super Giza 96. The experiment in both seasons was carried out in a rotatable central composite design. The results revealed that the three factors, and their linear interactions, had significant effect on vegetative characters, such as plant height and number of fruiting branches, and seed cotton yield and yield components such as number of bolls per plant, bolls weight and infestation percentage. With regard to fiber quality characters, UHML and fiber bundle strength, on sowing date had a significant effect on those characters. Nep count was significantly affected by the three factors, where's their linear interactions showed insignificant effect. The study indicated that sowing cotton between 10 to 20 April at plant density of 168000 plants/ha and application of 125 - 145 kg K_2O/ha gave highest seed cotton yield and improved quality characters and nep count.

Key words: Egyptian cotton; Sowing date; Plant density; Potassium fertilization; Cotton yield and yield components

INTRODUCTION

Egyptian cotton holds a prominent position in the global textile industry due to its superior fiber quality. The favorable climate and rich agricultural heritage of Egypt have made it an ideal region for cotton. Cotton crop has an imperative role in Egyptian economy. It faces several environmental situations which check its growth and production. Climate changes bring ahead new pressure for cotton cultivation **(Nada *et al.*, 2018).** The sowing date is a critical decision for cotton farmers as it directly affects the growth and development of the crop. Timely sowing ensures optimal utilization of environmental resources, such as temperature and sunlight, leading to better crop establishment, growth, and ultimately, higher yields. Early sowing of cotton during April was found to increase seed cotton and lint yields through improving yield attributes such as number of bolls per plant and boll weight, in addition to reduction of infestation with bollworms which affect productivity and quality of fibers **Hamed (2012) Abd El-Moneim *et al.*, (2017) and Copur *et al.*, (2019).** Conversely, delayed sowing can expose the crop to adverse weather conditions, pest attacks, and diseases, resulting in reduced productivity and compromised fiber quality **(Ali *et al.*, 2009, Elayan *et al.*, 2015 and Singh *et al.*, 2018).** Plant density, another important factor, refers to the number of cotton plants per unit area. Choosing suitable varieties and manipulating plant density are crucial management aspects in any cropping system that goals to improve yield, quality and the balance between plant demand and environmental resource availability. Plant density is a yield contributing parameter and has a direct effect on the yield of cotton crop. It plays a significant role in crop productivity by influencing light interception, competition for nutrients and water, and overall crop architecture **Meng *et al.*, (2016) and Jalilian (2023).** The appropriate plant density for Egyptian cotton depends on various factors, including soil fertility, cultivar characteristics, and desired yield goals. Contradicting reports for effect of plant density on seed cotton yield of Egyptian cultivars were found where **Swan *et al.*, (2008) and Ibrahim *et al.*, (2022),** stated that low plant densities gave higher yield due to increase in number of bolls/ plant and boll weight, whereas **Abd El-Aal *et al.*, (2014).** On other hand, **Abd El-Aal *et al.*, (2014) and Ghoprial *et al.*, (2018)** reported that intermediate to high plant densities gave higher seed cotton and lint yields due to higher number of plants per unit area. Potassium (K) is an essential macronutrient required for various physiological processes in plants. It plays a vital role in photosynthesis, water and nutrient uptake, enzyme activation, and osmoregulation. Adequate potassium supply is crucial for maximizing cotton yield and fiber quality **Tsialtas *et al.*, (2016), Abd El-Gayed and Bashandy (2018).** Insufficient potassium levels can lead to reduced photosynthetic efficiency, poor nutrient uptake, increased susceptibility to pests and diseases, and compromised fiber development **(Ibrahim *et al.*, 2022).** Therefore, optimizing potassium fertilizer rates is vital to ensure a sufficient supply of this essential nutrient without causing imbalances or wastage **Hussain *et al.*, (2021) and Kumar (2023)**. In recent years, extensive research has been conducted to investigate the individual and combined effects of sowing date, plant density, and potassium fertilizer rate on Egyptian cotton production and fiber quality. These studies have employed various experimental designs, to elucidate the complex interaction among these factors and their impact on cotton crop performance. The present investigation aimed to study the effect of those three factors, and their interactions, on growth, yield and yield components, and fiber quality of Egyptian cotton cultivar Extra Giza 96 employing a central composite design **(Box and Wilson, 1951)** in both seasons.

MATERIAL AND METHODS

The study was carried out at the Agricultural Research Station, Faculty of Agriculture, Alexandria University, Egypt (31°12'53.0"N, 29°59'13.0"E), during the two summer seasons of 2019 and 2020. The Egyptian cotton cultivar used in both seasons was Giza 96 which was modified to Extra Giza 96 in 2022 **(MOALR, (2022)**; Ministerial decree 206, 2022). That cultivar is a hybrid [(Giza84* (Giza70* 51B)) *S62)], belonging to extra-long staple category (***G. barbadense*** L.) with an average growing season of 155: 170 days. Before sowing, soil samples were taken from the experimental site (0-50 cm from soil surface) to determine the chemical and physical properties of soil in the two seasons **Table (1)**. The meteorological data for the two seasons are presented in **Fig 1**. These included minimum and maximum temperatures (°C), average humidity (%) and wind speed (km/hr), sunlight duration (hours). The data were obtained from www.wunderground.com

Table 1: Soil Physical, Chemical and Nutritional properties as an average of the two seasons

	Values
Physical Properties	
Sand %	62.5
Silt %	20.0
Clay %	17.5
Texture	Sand loam
Chemical Properties	
pH	8.36
EC (dS/m)	2.23
Ca^{+2} (meq/ L)	7.50
Mg^{+2} (meq/ L)	4.00
Na^{+} (meq/ L)	20.21
Cl^{-} (meq/ L)	15.00
CO_3^{-2} (meq/ L)	2.40
HCO_3^{-} (meq/ L)	4.00
$CaCO_3$ (%)	9.86
SAR	5.96
Nutritional Properties	
Av. N (%)	0.01
Av.P (ppm)	9.60
Av. K (meq/ L)	0.84
Organic matter	0.52

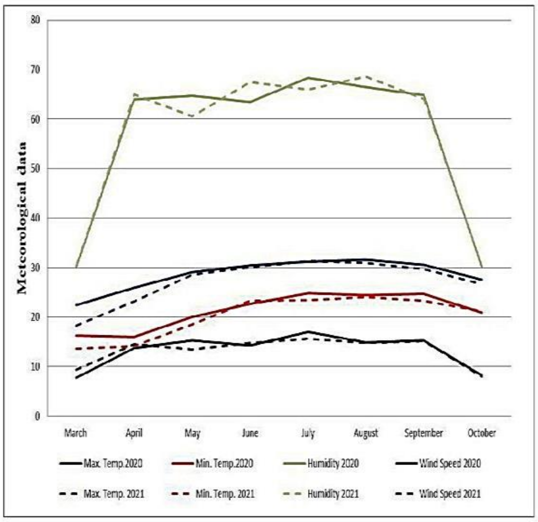

Fig. 1: Meteorological data of the two seasons

Table 2: Coded and actual levels of studied factors in central composite design

Coded Level Factors			Units	-S -α (-1.6818)	- F (-1)	Central Points (0)	+F (+1)	+S +α (+1.6818)
Sowing date	(SD)	(X_1)	m^3/ ha	16th March	1st April	20th April	10th May	25th May
Plant density/ ha	(PD)	(X_2)	plants/ha	72000	96000	132000	168000	192000
Potassium Fertilization (kg K_2O/ha)	(K)	(X_3)	Kg/ha	0	36	86.4	136.8	172.8

S: Star points, F: Factorial points, - , + : minimum and maximum levels, respectively.

A five-levels, three-factors rotatable central composite design was adopted in the present study. That design included (8) factorial points, (6) central points (2*number of factors) and (6) star points (2*number of factors). The total number of experimental units used was 20. The minimum and maximum ranges of factors investigated, and the full experimental plan, with respect to their values in coded and actual forms, are listed in **Table (2)**. Upon completion of experiment, the studied characters were taken as dependent variable or response (Y). The Experimental unit area was 48 m^2 (20 ridges each of width 0.6 m and 4 m length). Sowing was on one side of the ridge in hills (the distance between hills for experimental unit varied according to the levels of plant density) and the plants were thinned to two plants/ hill after 30 days from sowing. The site of experiment was prepared by ploughing three times followed by harrowing and levelling. Irrigation was applied as surface irrigation. The first irrigation, after sowing irrigation, was applied at 30 DAS, followed by irrigation at 15 days interval. All P levels were applied during land preparation at the level of 56.0 kg P_2O_5 /ha using calcium monophosphate (15.50% P_2O_5). Nitrogen fertilizer was added at the rate of 144 kg N/ha using ammonium nitrate (33.5% N). Application of N was divided into two equal doses, each of 72 kg N/ha, at 30 and 60 days from sowing (DAS). Potassium fertilization levels were added either in one dose of 36 and 86.4 K_2O/ha at 30 DAS, while higher doses of 136.8 and 172.8 kg K_2O/ha were added in split application at 30 and 60 DAS. Experimental units were kept weed-free, to eliminate the weeds effect by spraying Stomp (Pendimethalin) CS 45.5% at the rate of 4.0 liters/ha as pre-emergence followed by hand hoeing at 40 DAS. Control of leaf and boll worms was carried out using the appropriate pesticides whenever needed. Development cotton picking was performed manually by hand in two stages for each sowing date, the first at 60% opened bolls and the second at 90% opened bolls. Only fully matured and non-infested boll were picked. Seed cotton yield for each plot was ginned at the faculty ginning unit using a conventional single roller gin-stand (McCarthy). The gin-stand adjustments were set according to the adjustment's settings, which were usually followed with respect to the variety Extra Giza 96. The studied characters included vegetative characters, i.e., plant height and number of fruiting branches (sympodial), and they recorded as an average of five random plants per experimental unit. Yield and yield components traits included number of bolls per plant (average of three plants), infestation percent (average of 10 plants), bolls weight (five mature bolls taken from three plants for each experimental unit, seed cotton yield (weight of seed cotton picked from 18 guarded rows and transformed to kg/ha) and lint cotton yield (weight of lint cotton of 18 guarded rows after ginning and transformed to kg/ha). Fiber properties (upper half mean length (UHML), fiber bundle strength (FBS) was determined by the High-Volume Instrument USTER® **HVI** 1000 system at the laboratory of the Cotton Arbitration and Testing General Organization (CATGO), Alexandria, Egypt. Random representative samples of lint were preconditioned for 48 hours and tested according to the standard method reported by ASTM (D-5867, 2012), under standard condition of test: relative humidity 65% ± 2% and 20 ± 1ºC temperature. Nep count (NC) in lint cotton tested by Nep tester.

Statistical analysis was carried out according to **Dykstra (1960) and Petersen (1985)**, using the statistical software package **"STATISTICA 7.0", (StatsSoft, 2012)**. Response surface and contour diagrams for significant Linear * Linear interactions were performed by **STATISTICA 7.0 (StatSoft, 2012)**, while linear and quadratic responses of main effects were performed by Curve Expert, ver. 1.34 **(Hyams, 2005)**. The experimental site in two seasons was the same and the previous winter crop was berseem clover (*Trifolium alexandrinum*, L.) in the two seasons to maintain the homogeneity of experimental units in the two seasons, hence the data of the two seasons were averaged and analyzed. (**Idrees and Khan, 2009**).

RESULTS

The objective of the present investigation was determining the role of sowing date, plant density and potassium level in influencing the vegetative, yield and yield components of cotton cultivar Extra Giza 96, in addition to its fiber quality characteristics. The attained results will be presented herein in four categories as follows: vegetative characters, yield, and yield components., HVI fiber properties and nep count.

1. **Vegetative characters:** This group of characters included: plant height (cm) and number of fruiting branches (sympodia). The results obtained for these characters are presented in the following:

1.1. Plant Height: Data in Table **(3)** showed that the plant height was significantly and negatively influenced by linear components of sowing date, significantly and positively influenced by linear and quadratic components of plant density and quadratic component of potassium levels. None of the linear interactions between studied factors were significant. **Table (4)** describing the equations to response of plant height to the studied factors. Star point values for that character **Table (5)** revealed that early sowing, high plant density and highest potassium level, gave higher values than late sowing, lowest plant density and lowest K level. Similar results were obtained with factorial levels where early sowing (F-) on April 1st gave taller plants (187.5 cm) compared to late sown plants (F+) on May 10th (182.0). Similarly lower (F-) plant density and K fertilization level gave lower value (178.5 and 182.5 cm) than higher (F+) plant density and K fertilization level (191.3 and 187.5 cm), respectively. Hence, early sowing date, higher plant density and higher K level (F_4) gave taller plant height (198 cm) compared to late sowing date, lower plant density and lower K level (F_5), which gave plant height of 177 cm.

Table 3: Mean squares for analysis of variance and regression coefficients (β) for vegetative characters as affected by sowing date, plant density, potassium fertilization and their linear interactions.

S.O.V.		d.f.	Plant height		No. of fruiting branches	
			M.S	β	M.S	β
	β0			164.30		19.84
SD(L)	β1	1	126.11*	-3.04	11.28**	-0.91
SD (Q)	β11	1	35.23	1.56	23.46**	-1.27
PD (L)	β2	1	371.01**	5.21	25.68**	-1.37
PD (Q)	β22	1	300.82**	4.57	2.22	-0.39
K (L)	β3	1	63.33	2.15	8.43*	0.78
K (Q)	β33	1	195.69*	3.68	8.01*	-0.74
SD × PD (L)	β12	1	66.12	-2.88	0.50	0.25
SD × K (L)	β13	1	3.12	-0.62	0.50	-0.25
PD × K (L)	β23	1	6.13	-0.88	0.50	0.25
Lack of Fit		5	473.35**		1.60	
Pure Error		5	13.77		0.57	
R^2			0.31		0.89	

*, **: significant at 0.05 and 0.01 probability levels, respectively.

Table 4: Regression formulae for significant components of factors affecting cotton characters of Extra Giza 96.

Character	Regression Formulae
Vegetative Characters	
Plant Height	$\hat{Y} = 164.30 - 3.04\ SD + 5.21\ PD + 4.57\ PD^2 + 3.68\ K^2$
Number of Fruiting Branches (Sympodia)	$\hat{Y} = 19.84 - 0.91\ SD - 1.27\ SD^2 - 1.37\ PD + 0.78\ K - 0.74\ K^2$
Yield and Yield Components	
Number of Bolls/Plant	$\hat{Y} = 19.47 - 1.96\ SD - 2.35\ SD^2 - 1.64\ PD - 1.28\ PD^2 - 0.84\ K^2$
Infestation %	$\hat{Y} = 1.84 + 0.56\ SD + 2.66\ SD^2 + 0.30\ PD + 0.28\ PD^2 - 0.41\ K + 0.95\ K^2 - 0.74\ SD{*}PD - 0.18\ PD{*}K$
Bolls Weight	$\hat{Y} = 3.32 - 0.084\ SD - 0.122\ PD + 0.087\ K + 0.051\ K^2$
Seed Cotton Yield (kg/ha)	$\hat{Y} = 2750.1 - 121.1\ SD - 118.5\ SD^2 + 224.9\ PD^2 + 339.0\ K - 58.8\ K^2 + 386.5\ SD{*}PD - 459.0\ SD{*}K + 389.7\ PD{*}K$
lint Cotton Yield (kg/ha)	$\hat{Y} = 1156.9 - 63.12\ SD - 22.19\ SD^2 + 116.48\ PD + 132.40\ PD^2 + 44.86\ K$
HVI Fiber Properties	
Upper Half Mean Length (UHML) mm	$\hat{Y} = 36.28 - 0.60\ SD - 0.35\ SD^2$
Fiber Bundle Strength (gm/tex)	$\hat{Y} = 50.34 - 0.67\ SD - 0.79\ SD^2$
Nep Count in Lint Cotton	
Nep Count	$\hat{Y} = 84.23 + 3.79\ SD + 1.86\ PD - 3.48\ K^2$

Table 5: Values of vegetative characters as affected by sowing date, plant density, potassium fertilization levels and their linear interactions.

Trt's	Levels			Plant height (cm)	No. of fruiting branches
	SD	PD	K		
F_1	-1	-1	-1	173	19
F_2	-1	-1	1	184	20
F_3	-1	1	-1	196	15
F_4	-1	1	1	198	17
F_5	1	-1	-1	177	18
F_6	1	-1	1	180	18
F_7	1	1	-1	183	15
F_8	1	1	1	188	16
S_1	-1.6818	0	0	159	19
S_2	1.6818	0	0	148	21
S_3	0	-1.6818	0	156	14
S_4	0	1.6818	0	168	17
S_5	0	0	-1.6818	157	16
S_6	0	0	1.6818	162	20
C1	0	0	0	166	19
C2	0	0	0	162	20
C3	0	0	0	165	20
C4	0	0	0	160	21
C5	0	0	0	168	19
C6	0	0	0	170	20

As observed from **Fig 2,** plant height decreased linearly with delaying sowing date. On the other hand, **Fig 3,** showed that plant height increased significantly, linearly, and quadratically, with increasing plant density. The optimal plant density calculated from the quadratic equation was obtained at plant density 148199 plants/ha. Regarding K fertilization level, the relationship with plant height was quadratic and the optimal K level was 122.2 K_2O/ha, as seen in **Fig 4.**

2.1. Number of fruiting branches (sympodia): Results in **Table (3)** indicated that number of fruiting branches (sympodia) were highly significantly and negatively influenced by linear and quadratic components of sowing date, significantly and negatively influenced by linear component of plant density, and significantly influenced, positively and negatively by linear and quadratic components of K fertilization, respectively. None of the linear interactions between studied factors were significant. **Table (4)** describing the equation of response of that character to the studied factors. Star point values for that character **Table (5)** revealed that early sowing date, low plant density and highest K level gave higher values compared with other studied factors. Similar results were obtained with factorial levels where early sowing date (F-) on April 1st gave highest number of fruiting branches (18) compared to late sowing date (F+) on May 10th (17), similarly higher plant density and lower potassium fertilization gave lowest values (16 and 17) than highest K fertilization level and lowest plant density (18 and 19), respectively. Moreover, early sowing date, lower plant density and higher K level (F_2) gave higher number of fruiting branches (20) compared to late sowing date, higher plant density and lower K level (F_8), which gave (15) fruiting branches. As observed from **Fig. 5,** the linear component showed an increase in number of fruiting branches with delayed sowing, while the quadratic response revealed that the increase of that character occurred later than April 20th. **Fig 6.** showed that the number of fruiting branches decreased significantly and linearly with increasing the plant density. The relationship between number of fruiting branches and K fertilization levels showed a positive and significant linear response **Fig.7**, while the quadratic response showed an increase in that character occurred beyond 57.6 kg K_2O/ha.

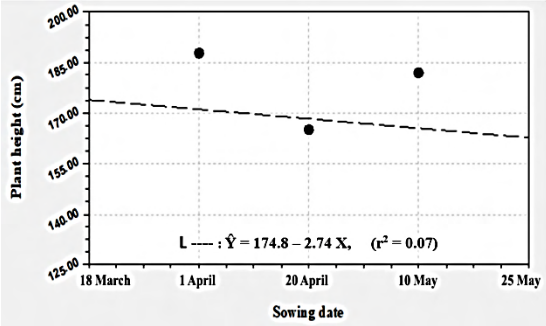

Fig 2. Effect of sowing date on plant height

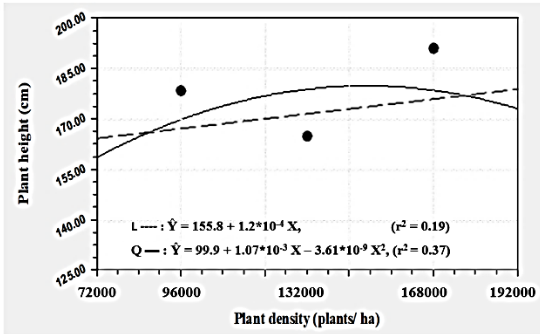

Fig 3. Effect of plant density on plant height

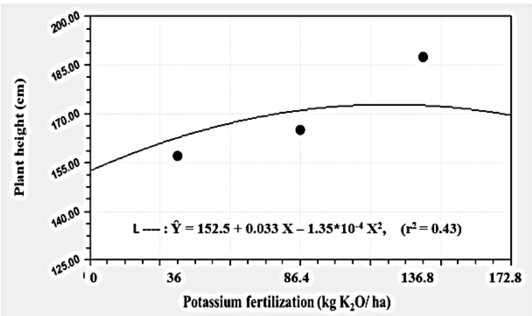

Fig 4. Effect of potassium fertilization on plant height

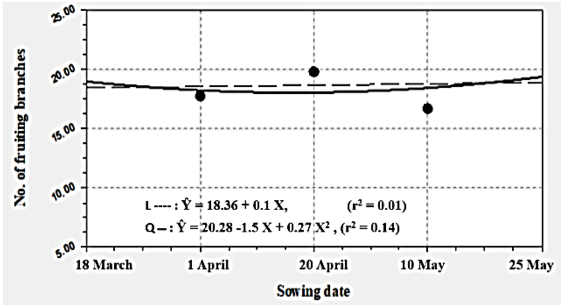

Fig 5. Effect of sowing date on number of fruiting/ branches

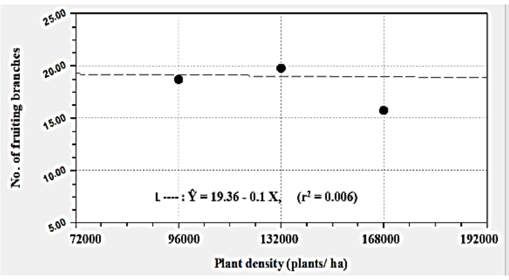

Fig 6. Effect of plant density on number of fruiting/ branches

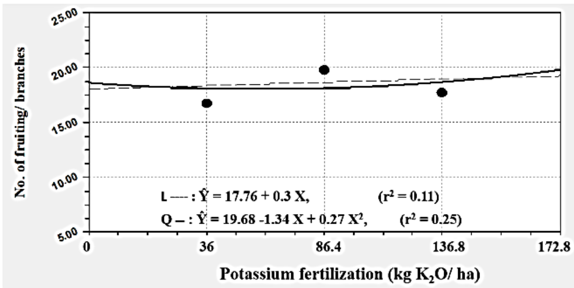

Fig 7. Effect of potassium fertilization on number of fruiting/ branches

2. Yield and yield components:

This group of characters included: **1.** Number of bolls/plant, **2.** Infestation percent, **3.** Bolls weight/plant, **4.** Seed cotton yield and **5.** Lint cotton yield. The results obtained for these characters are presented in the following:

2.1. Number of bolls/plant: Data in **Table (6)** showed that number of bolls/plant was significantly and negatively influenced by linear and quadratic components of sowing date and plant density. Also, it was highly significantly and negatively influenced by quadratic components of potassium levels. None of the linear interactions between studied factors were significant. **Table (4)** the equation response number of bolls/plant to the studied factors. Star point values for that character **Table (7)** revealed that early sowing, low plant density and highest potassium level, gave higher values than late sowing, highest plant density and lowest K level. Similar results were obtained with factorial levels where early sowing (F-) on April 1st gave the highest number of bolls/plant (17.52) compared to late sown plants (F+) on May 10th (12.48). Similarly lower (F-) plant density gave a higher value of that character (15.90) than higher (F+) plant density (14.09). Higher (F+) K fertilization level gave a higher value of that character (15.27) than lower (F-) K fertilization level (14.73). Hence, early sowing date, lower plant density and higher K level (F_2) gave higher number of bolls/plant (19.11) compared to (F_7) late sowing date, higher plant density and lower K level, which gave (11.80) bolls/plant. On the other hand, **Fig 8,** showed that number of bolls/plant decreased linearly with delaying the sowing date. Whereas the quadratic effects showed that number of bolls/plant increased up to April 20th then decreased with delaying sowing date up to May 25th. Hence, the optimal sowing date for that character was April 20th. **Fig 9.** clarified that number of bolls/plant decreased significantly and linearly with increasing plant density. Whereas the quadratic effects showed that number of bolls/plant was nearly constant for lower plant densities then decreased with increasing plant density up to 192000 plants/ ha. The optimal plant density was found to be 83333 plants/ ha. Regarding potassium fertilization level **Fig 10,** number of bolls/plant increased quadratically with increasing potassium fertilization level. The optimal potassium level was obtained at 100 kg K_2O/ ha**.**

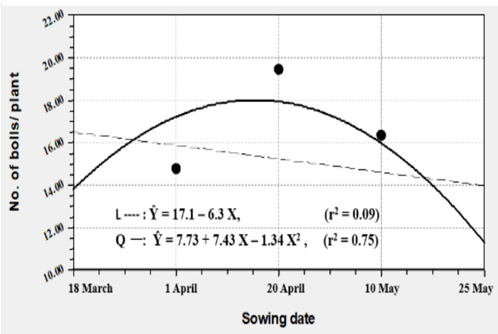

Fig 8. Effect of sowing date on number of bolls/plant

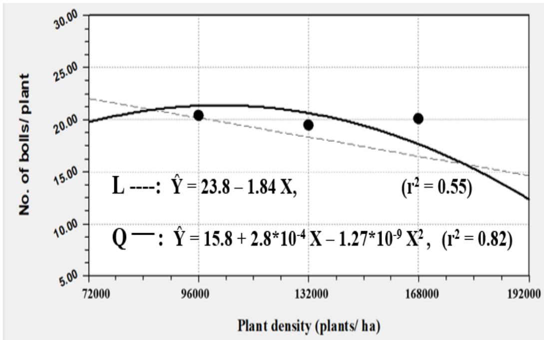

Fig 9. Effect of plant density on number of bolls/plant

Table 6: Mean squares for analysis of variance and regression coefficients (β) for yield and yield components as affected by sowing date, plant density, potassium fertilization and their linear interactions.

S.O.V.		d.f.	Number of bolls/plant		Infestation %		Bolls weight (g)		Seed cotton yield (kg/ ha)		Lint cotton yield (kg/ ha)	
			M.S	β	M.S	β	M.S	β	M.S	β	M.S	β
	β0			19.47		1.84		3.32		2750.1		1156.9
SD(L)	β1	1	52.61**	-1.96	4.38**	0.56	0.096**	-0.084	200324.9**	-121.1	54423.1**	-63.12
SD (Q)	β11	1	79.95**	-2.35	102.03**	2.66	0.0001	0.003	202613.3**	-118.5	7100.6**	-22.19
PD (L)	β2	1	37.03**	-1.64	1.23**	0.30	0.205**	-0.122	1519.0	-10.5	185301.6**	116.48
PD (Q)	β22	1	23.63**	-1.28	1.19**	0.28	0.012	0.029	729414.1**	224.9	252651.1**	132.40
K (L)	β3	1	1.65	0.35	2.30**	-0.41	0.104**	0.087	1569684.6**	339.0	27490.1**	44.86
K (Q)	β33	1	10.09**	-0.84	13.19**	0.95	0.037**	0.051	49832.7**	-58.8	2665.6	13.60
SD × PD (L)	β12	1	1.14	0.36	4.35**	-0.74	0.016	0.045	1194980.7**	386.5	4982.1	-24.95
SD × K (L)	β13	1	0.02	-0.05	0.16	0.14	0.004	-0.025	1685723.4**	-459.0	1674.5	-14.46
PD × K (L)	β23	1	0.008	-0.03	0.28**	-0.18	0.00005	0.002	1215162.5**	389.7	3245.7	-20.14
Lack of Fit		5	3.37**		4.85**		0.0111		775453.3**		40000.5**	
Pure Error		5	0.27		0.03		0.002		2110.53		878.4	
R^2			0.91		0.84		0.87		0.64		0.73	

*, **: significant at 0.05 and 0.01 probability levels, respectively.

Table 7: Values of yield and yield components as affected by sowing date, plant density, potassium fertilization levels and their linear interactions.

Trt's	Levels			Number of bolls/plant	Infestation %	Bolls weight (g)	Seed cotton yield (kg/ ha)	Lint cotton yield (kg/ha)
	SD	PD	K					
F_1	-1	-1	-1	18.49	3.70	3.55	2893.5	1186.34
F_2	-1	-1	1	19.11	2.85	3.68	3219.8	1352.32
F_3	-1	1	-1	15.91	5.60	3.18	3557. 8	1517.39
F_4	-1	1	1	16.57	4.20	3.36	3665.1	1576.01
F_5	1	-1	-1	12.70	5.00	3.40	2929.2	1214.13
F_6	1	-1	1	13.30	4.92	3.48	3099.2	1295.45
F_7	1	1	-1	11.80	4.15	3.25	3361.5	1418.57
F_8	1	1	1	12.10	3.12	3.30	3410.6	1446.11
S_1	-1.6818	0	0	14.79	8.70	3.58	2739.2	1139.51
S_2	1.6818	0	0	10.85	12.8	3.10	1985.2	780.18
S_3	0	-1.6818	0	20.40	1.37	3.61	2899.7	1194.68
S_4	0	1.6818	0	11.32	3.45	3.22	3768.1	1599.58
S_5	0	0	-1.6818	16.35	6.60	3.25	2376.8	978.07
S_6	0	0	1.6818	17.88	5.26	3.70	2685.7	1144.12
C1	0	0	0	18.90	1.64	3.27	2685.9	1110.62
C2	0	0	0	20.30	1.68	3.40	2760.2	1175.82
C3	0	0	0	19.70	1.47	3.32	2752.0	1155.84
C4	0	0	0	19.35	1.88	3.28	2829.2	1196.76
C5	0	0	0	18.95	1.96	3.36	2752.2	1179.30
C6	0	0	0	19.65	1.94	3.30	2739.2	1169.64

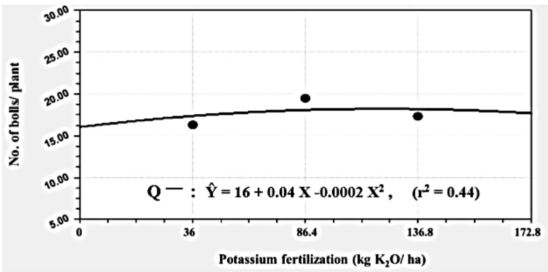

Fig 10. Effect of potassium fertilization on number of bolls/plant

2.2. Infestation %: The results of **Table (6)** indicated that infestation % was highly significantly and positively influenced by linear and quadratic components of sowing date, highly significantly and positively influenced by linear and quadratic components of plant density. On other hand, that character was highly significantly and negatively influenced and positively influenced by linear and quadratic component of plant density and potassium fertilization levels, respectively. The linear interaction between sowing date and plant density were highly significant and negative relationship. Similarly, the linear interaction between plant density and potassium fertilization levels were highly significant and of negative relationship. **Table (4)** the equation explaining the relationship between infestation percent and to the studied factors. Star point values for infestation percent **Table (7)** revealed that early sowing, low plant density and highest potassium level, gave lowest value than late sowing date, high plant density and lowest K level. Similar results were obtained with factorial levels where early sowing (F-) on April 1st gave lowest infestation % (4.08) compared to late sown plants (F+) on May 10th (4.3). Similarly lower (F-) plant density gave a lower value of that character (4.12) than higher (F+) plant density (4.30). And higher (F+) K fertilization level gave lower value of that character (3.77) than lower (F-) K fertilization level (4.61). With regards to factorial points, the lowest infestation percent (2.85%) was obtained at early sowing date, lower plant density and higher K level (F_2). The higher infestation percent was obtained with (F_3) 5.60% which had the higher plant density and lower K level at late sowing date. Otherwise, **Fig 11,** showed that infestation percent increased significantly and linearly, whereas the quadratic effects showed that infestation % was high at early sowing date then decreased with delaying sowing date up to 20th April then increased progressively with delaying sowing to May 10th. The relationship between infestation percent and plant density showed a significant linear effect **Fig. 12**, which indicated the increase in infestation % with increasing the plant density, whereas the quadratic effects showed that infestation percent increased slightly with lower plant densities followed by rapid and progressive increase with higher plant densities. As observed from **Fig. 13,** infestation percent decreased linearly with increasing K fertilization levels. However, the quadratic relationship showed a progressive decrease in infestation % with increasing K level up to

86.4 kg K_2O/ha then it gradually increased with higher applications of K. The response surface for infestation percent is affected by sowing date and plant density, at the central levels of potassium fertilization. **Fig 14,** showed that infestation percent increased with delaying sowing date and/or increasing plant density. The lowest infestation % was obtained at 20th April sowing date. The response surface for infestation percent is affected by plant density and potassium fertilization levels at the central levels of sowing date.

Fig 15, showed that infestation % was lowest at K level of 86.4 4 kg K_2O/ha and increased with the decrease or increase of K fertilization beyond that level. Moreover, at the highest plant density, infestation % was highest at zero levels of K fertilization and decreased with increasing K levels up to 86.4 kg K_2O/ha then increased gradually with high K levels.

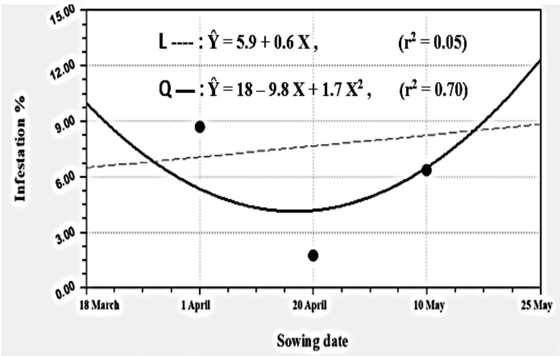

Fig 11. Effect of sowing date on infestation percent

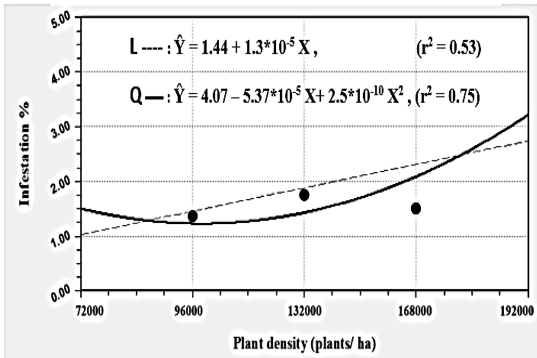

Fig 12. Effect of plant density on infestation percent

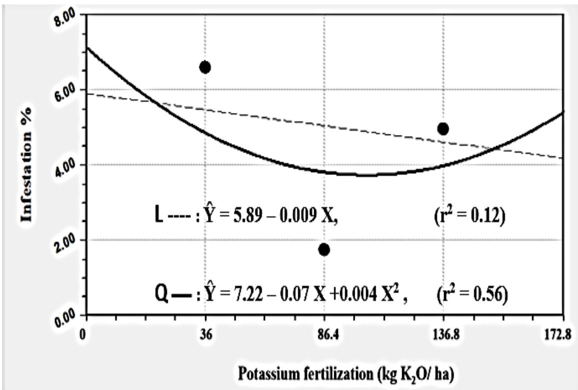

Fig 13. Effect of potassium fertilization on infestation percent

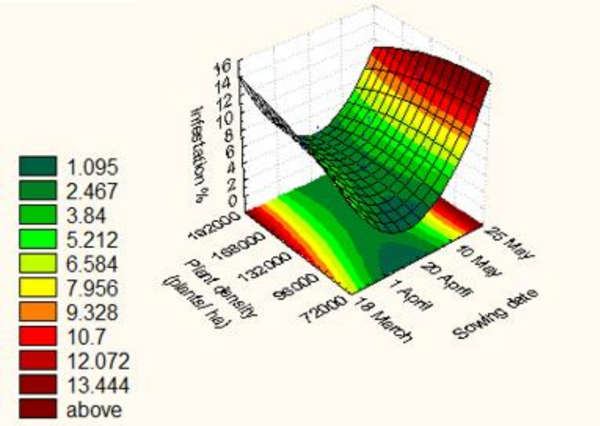

Fig 14. Response surface for infestation percent as affected by sowing date and plant density at central levels of potassium fertilization

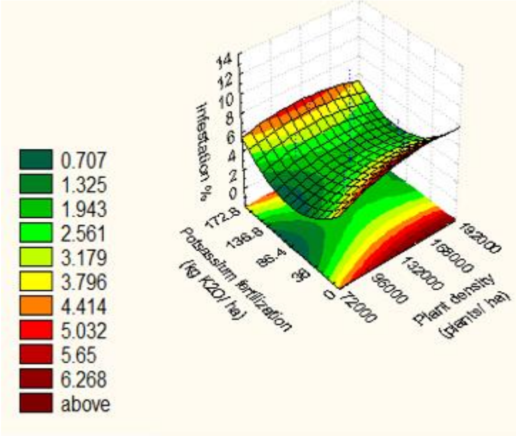

Fig 15. Response surface for infestation percent as affected by plant density and potassium fertilization at central levels of sowing date

2.3. Bolls weight: The results of **Table (6)** showed that bolls weight was significantly and negatively influenced by linear components of sowing date and plant density, significantly and positively influenced by linear and quadratic components of potassium fertilization levels. None of the linear interactions between studied factors were significant. **Table (4)** describing the response equation of that character to the studied factors. Star point values for bolls weight **Table (7)** revealed that early sowing, low plant density and highest potassium level, gave highest weight than late sowing date, high plant density and lowest K level. With regard to factorial points, the highest boll weight (3.68g) was obtained at early sowing date, lower plant density and higher K level (F_2). The lowest boll weight was obtained with F_3 and F_7 which had the higher plant density and lower K level at early and late sowing dates, respectively. **Fig. 16,** showed that bolls weight decreased significantly and linearly with delaying sowing. The relationship between bolls weight and plant density had decreased significantly and linearly, **Fig. 17**. The relationship between bolls weight and K fertilization levels was positive as affected by linear and quadratic effects **Fig. 18**, which revealed the increase in bolls weight with increasing K fertilization levels.

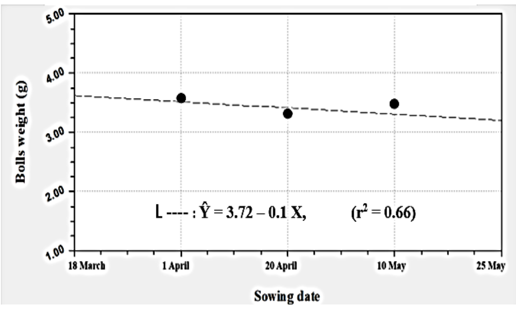

Fig 16. Effect of sowing date on bolls weight

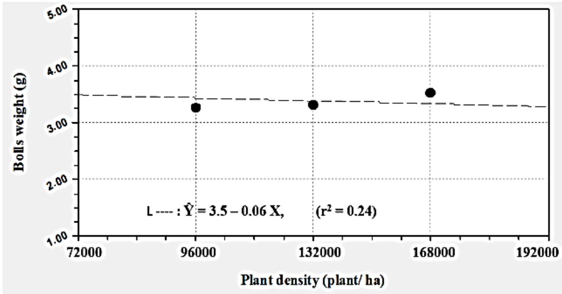

Fig 17. Effect of plant density on bolls weight

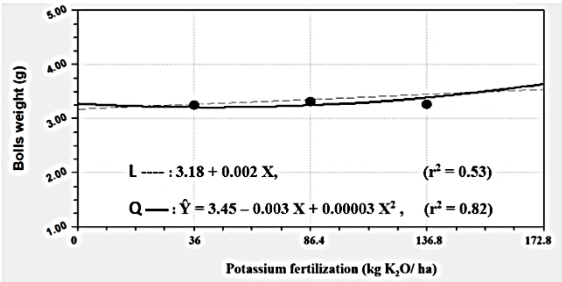

Fig 18. Effect of potassium fertilization on bolls weight

2.4. Seed cotton yield (kg/ha):

Table (6) showed that seed cotton yield was significantly and negatively influenced by linear and quadratic components of sowing date. On other hand, seed cotton yield was significantly and positively influenced by quadratic component of plant density, significantly and positively influenced by linear and negatively by quadratic components of potassium fertilization levels. The linear interaction between sowing date and plant density were highly significant and of positive relationship. Similarly, the linear interaction between plant density and potassium fertilization levels were highly significant and of positive relationship. Otherwise, the linear interaction between sowing date and potassium fertilization levels were significant and of negative relationship. **Table (4)** describing the equation response of plant height to the studied factors. Star point values for that character **Table (7)** revealed that early sowing, high plant density and highest potassium level, gave higher values of seed cotton yield than late sowing, lowest plant density and lowest K level. Similar results were obtained with factorial levels where early sowing (F-) on April 1st gave higher seed cotton yield (3334.05 kg/ha) compared to late sown plants (F+) on May 10th (3200.12 kg/ha). Similarly lower (F-) plant density and K fertilization level gave lower value (3035.42 kg/ha and 3185.50 kg/ha) than higher (F+) plant density and K fertilization levels (3498.75 kg/ha and 3348.67 kg/ha), respectively. Seed cotton yield was highest (3665.1 kg/ha) at early sowing date, higher plant density and K level (F_4). On the other hand, the lowest seed cotton yield was obtained with lower plant density and K levels (F_1 = 2893.5 and F_5 = 2929.2 kg/ha) at early and late sowing dates, respectively. As observed from **Fig 19,** seed cotton yield (SCY) decreased significantly and linearly with delaying sowing date. The optimal sowing date was obtained on **13th April.** The quadratic effect of plant density on seed cotton yield **Fig 20,** revealed that increasing plant density up to 132000 plants/ha gave lower seed cotton yields compared to higher plant densities of 168000 and 192000 plants/ha. On the other hand, **Fig 21,** showed that seed cotton yield increased significantly, linearly and quadratically up to (136.8 kg K_2O/ ha) then plateaued up to 172.8 kg K_2O/ ha. The optimal potassium level was obtained at **145 kg K_2O/ ha.** The response surface for seed cotton yield as affected by sowing date and plant density, at the central levels of potassium fertilization. **Fig 22** indicated that delaying sowing or increasing plant density alone resulted in lower seed cotton yield. Highest yields were obtained with early sowing and lower plant density or with late sowing and higher plant density. The response surface for seed cotton yield as affected by sowing date and potassium fertilization levels at the central levels of plant density. **Fig 23** showed increasing K level increased seed cotton yield at early and late sowing dates. Similarly**,** the response surface for seed cotton yield as affected by plant density and potassium fertilization, at the central levels of sowing date. **Fig 24** showed that seed cotton yield increased significantly with increasing potassium fertilization up to 82.4 kg K_2O/ha at lower plant densities, and up to 172.8 kg K_2O/ha at higher plant densities.

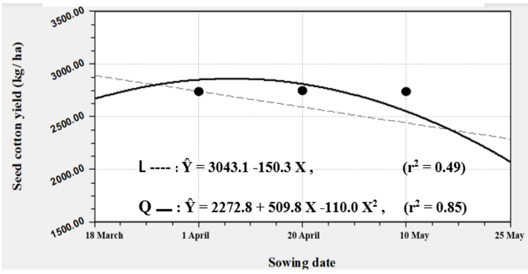

Fig 19. Effect of sowing date on seed cotton yield

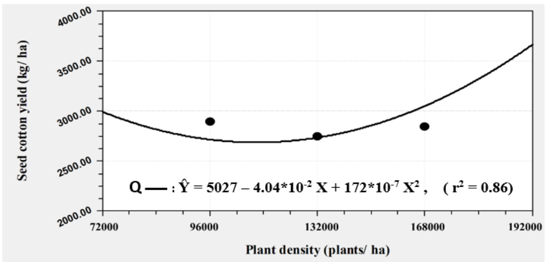

Fig 20. Effect of plant density on seed cotton yield

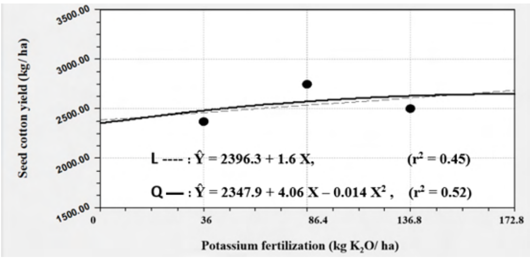

Fig 21. Effect of potassium fertilization on seed cotton yield

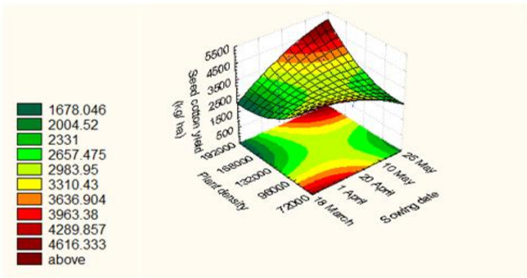

Fig 22. Response surface for seed cotton yield as affected by sowing date and plant density at central levels of potassium fertilization

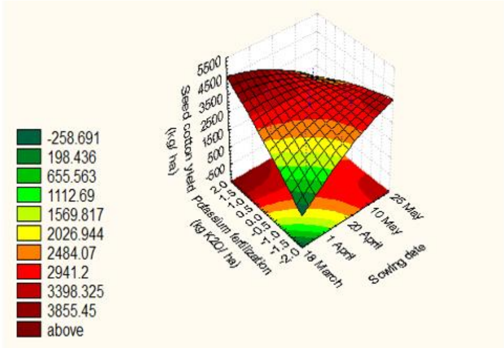

Fig 23. Response surface for seed cotton yield as affected by sowing date and potassium fertilization at central levels of plant density

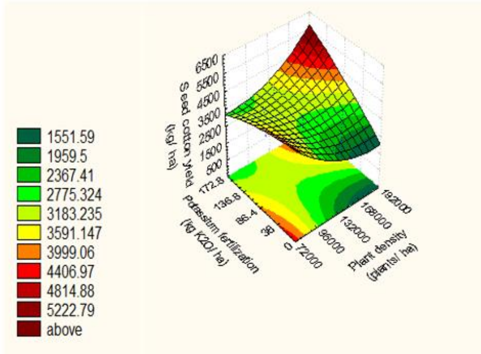

Fig 24. Response surface for seed cotton yield as affected by plant density and potassium fertilization at central levels of sowing date

2.5. lint cotton yield (kg/ha):

Results in **Table (6)** indicated that lint cotton yield was highly significant and negatively influenced by linear and quadratic components of sowing date. Whereas, it showed a significant and positive trend for linear and quadratic components of plant density. Data in same table showed that lint cotton yield was significantly and positively influenced by linear component of potassium fertilization. None of linear interactions between studied factors were significant. **Table (4)** describing the response equation of that character to the studied factors. Star point values for that character **Table (7)** revealed that early sowing date, high plant density and highest K level gave higher lint cotton yield values compared with other studied factors. Similar results were obtained with factorial levels where early sowing date (F-) on April 1st gave higher lint cotton yield (1408.01 kg/ha) compared to late sowing date (F+) on May 10th (1343.56 kg/ha). Similarly, lower (F-) plant density and potassium fertilization gave lowest values (1262.06 and 1334.10 kg/ha) than higher plant density and K fertilization level (1489.52 and 1417.47 kg/ha), respectively. As observed from **Fig. 25,** lint cotton yield decreased significantly and linearly with delaying sowing date. On the other hand, it increased quadratically with earlier sowing dates then decreased progressively with delaying sowing dates. The optimal lint cotton yield was obtained on the sowing date April 13th. Lint cotton yield increased significantly linearly with increasing PD **Fig. 26,** while it decreased with lower PD then increased significantly quadratic, with increasing the plant density. Lint cotton yield increased significantly and linearly, with increasing potassium fertilization levels **Fig 4.27.**

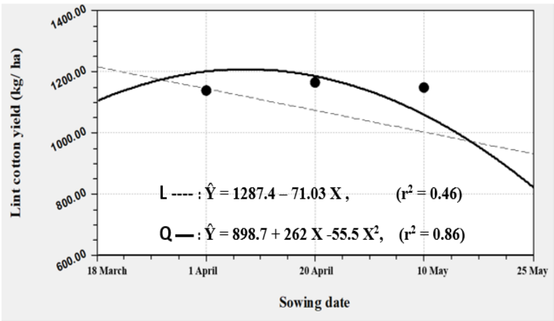

Fig 25. Effect of sowing date on lint cotton yield

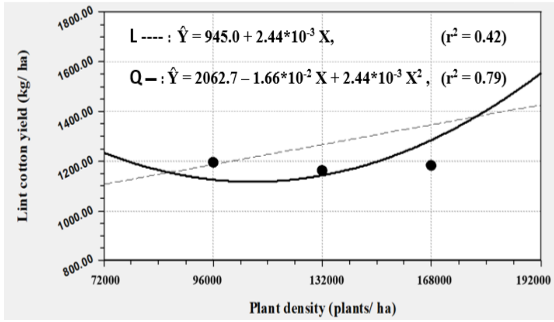

Fig 26. Effect of plant density on lint cotton yield

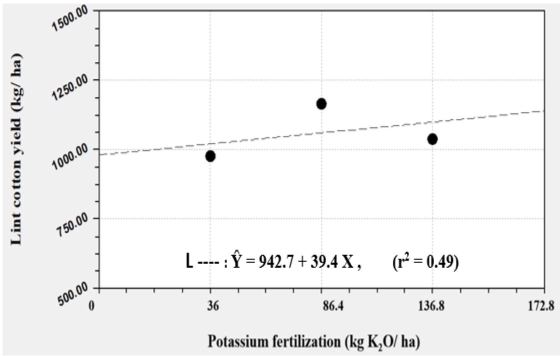

Fig 27. Effect of potassium fertilization on lint cotton yield

3. HVI Fiber properties:

This group of characters included: upper half mean length (UHML, mm), and fiber bundle strength (gm/tex). The results obtained for these characters are presented in the following:

3.1. Upper half mean length (UHML) mm:

The results of **Table (8)** indicated that UHML was significantly and negatively influenced by linear and quadratic components of sowing date. On other hand, other factors and interactions showed insignificant effects on that character. **Table (4)** explaining the equation relationship between UHML and to the sowing dates. Star point values for UHML **Table (9)** showed that early sowing gave the highest values than late sowing date. Similar results were obtained with factorial levels where early sowing (F-) on April 1st gave the highest UHML (36.3 mm) compared to late sown plants (F+) on May 10th (34.50 mm). Regarding factorial points, the F_2 (early sowing, lower plant density and higher K level) gave the highest UHML (36.95 mm), while F_7 (later sowing date, higher plant density and lower K level) gave the least UHML (34.26 mm). **Fig 28,** showed that UHML decreased significantly, linearly and quadratically with delaying sowing date. The optimal UHML was obtained on the sowing date April 1st.

Table 8: Mean squares for analysis of variance and regression coefficients (β) for HVI characters and nep count as affected by sowing date, plant density, potassium fertilization and their linear interactions.

S.O.V.		d.f.	UHML (mm)		Fiber Bundle Strength (gm/tex)		Nep Count	
			M.S	β	M.S	β	M.S	β
	β0			36.28		50.34		84.23
SD(L)	β1	1	4.93**	-0.60	6.09**	-0.67	196.61**	3.79
SD (Q)	β11	1	1.79*	- 0.35	8.98**	-0.79	4.98	0.59
PD (L)	β2	1	0.75	-0.23	0.28	0.14	47.27**	1.86
PD (Q)	β22	1	0.42	-0.17	0.42	-0.17	1.26	-0.30
K (L)	β3	1	0.31	0.14	0.26	0.14	9.53	-0.84
K (Q)	β33	1	0.33	-0.15	0.97	-0.26	174.31**	-3.48
SD × PD(L)	β12	1	0.09	0.11	0.02	-0.05	1.13	-0.37
SD × K (L)	β13	1	0.04	0.07	0.13	-0.13	1.12	-0.37
PD × K (L)	β23	1	0.20	-0.16	0.32	0.20	6.12	0.87
Lack of Fit		5	0.39		1.47		10.16*	
Pure Error		5	0.14		0.32		1.47	
R^2			0.76		0.65		0.88	

*, **: significant at 0.05 and 0.01 probability levels, respectively.

Table 9: Values of HVI characters and nep count as affected by sowing date, plant density, potassium fertilization levels and their linear interactions.

Trt's	Levels			UHML (mm)	Fiber Bundle Strength (gm/tex)	Nep Count
	SD	PD	K			
F_1	-1	-1	-1	36.50	50.0	77
F_2	-1	-1	1	36.95	50.9	74
F_3	-1	1	-1	36.10	49.5	79
F_4	-1	1	1	35.65	49.8	82
F_5	1	-1	-1	34.50	49.5	86
F_6	1	-1	1	34.94	49.5	84
F_7	1	1	-1	34.26	48.7	89
F_8	1	1	1	34.35	49.1	88
S_1	-1.6818	0	0	35.50	49.1	79
S_2	1.6818	0	0	34.87	45.7	89
S_3	0	-1.6818	0	35.90	49.4	79
S_4	0	1.6818	0	35.50	48.9	84
S_5	0	0	-1.6818	35.30	48.4	75
S_6	0	0	1.6818	36.20	49.4	70
C1	0	0	0	36.78	50.5	86
C2	0	0	0	35.80	50.3	85
C3	0	0	0	36.20	50.8	84
C4	0	0	0	36.10	49.3	83
C5	0	0	0	35.75	50.6	85
C6	0	0	0	36.10	50.8	83

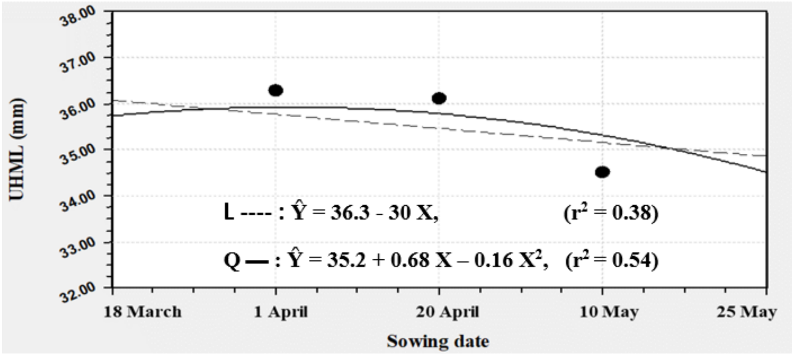

Fig 28. Effect of sowing date on UHML

3.2. Fiber bundle strength (gm/tex):

Results in **Table (8)** indicated that fiber bundle strength was highly significant and negatively influenced by linear and quadratic components of sowing date, while the remaining factors and linear interactions were of insignificant effect on that character. **Table (4)** describing the formula response of that character to sowing date. Star point values for that character **Table (9)** revealed that early sowing date, high plant density and highest K level gave higher values compared with other studied factors. Similar results were obtained with factorial levels were early sowing date (F-) on April 1st gave highest value of fiber bundle strength (50.0 gm/tex) compared to late sowing date (F+) on May 10th (49.2 gm/tex), similarly lower (F-) potassium fertilization and plant density gave lowest values (49.6 and 49.3 gm/tex), respectively. Regarding factorial points, the F_2 (early sowing, lower plant density and higher K level) gave the highest fiber bundle strength (50.9 gm/tex), while F_7 (later sowing date, higher plant density and lower K level) gave the least fiber bundle strength (48.7 gm/tex). As observed from **Fig. 29,** fiber bundle strength decreased significantly and linearly with delaying sowing date. However, quadratic response showed an increase up to April 20th then has a progressive decrease up to May 10th. The optimal value of fiber bundle strength calculated from the quadratic equation was obtained at sowing date April 20th.

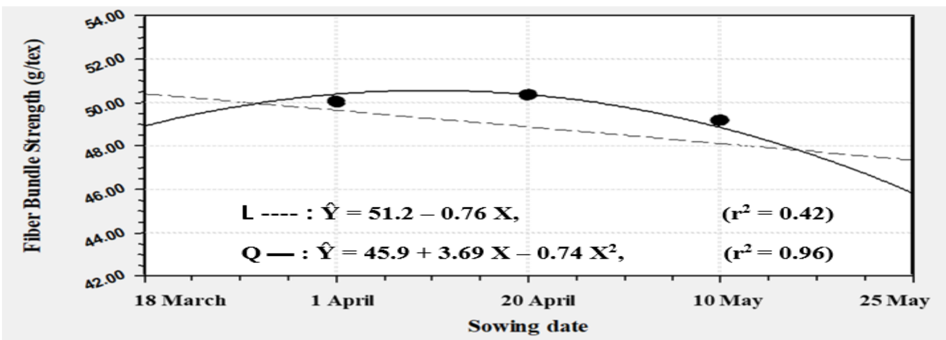

Fig 29. Effect of sowing date on fiber bundle strangth

4. Nep count in lint cotton tested by Nep tester: The results obtained for this character are presented in the following:

4.1. Nep count: Results in **Table (8)** indicated that nep count was highly significant and positively influenced by linear component of sowing date and plant density. Also, it was highly significant and negatively influenced by quadratic component of potassium fertilization. None of the linear interactions between studied factors were significant. **Table (4)** describes the response equation of that character to the studied factors. Star points for that character **Table (9)** revealed that early sowing date gave the lowest nep count, compared with other studied dates. Similar results were obtained with factorial levels where early sowing date (F-) on April 1st gave lowest nep count (78) compared to late sowing date (F+) on May 10th (87), similarly lower (F-) plant density gave low value (80) than highest plant density (85). Moreover, factorial points F_2 (early sowing, lower plant density and higher K level) gave the lowest nep count (74), while F_7 (later sowing date, higher plant density and lower K level) gave the highest nep count (89).

As observed from **Fig. 30,** nep count increased significantly and linearly with delaying sowing date. Similarly, **Fig. 31** showed that nep count increased significantly and linearly, with increasing the plant density. On the other hand, **Fig. 32** showed that nep count yield increased with increasing K level up to 86.4 kg K_2O/ha then decreased with increasing potassium fertilization level up to 172.8 kg K_2O/ha. The optimal level of potassium fertilization level calculated from the quadratic equation was **125 kg K_2O/ ha**.

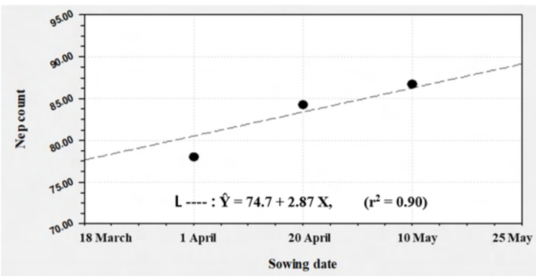

Fig 30. Effect of sowing date on nep count

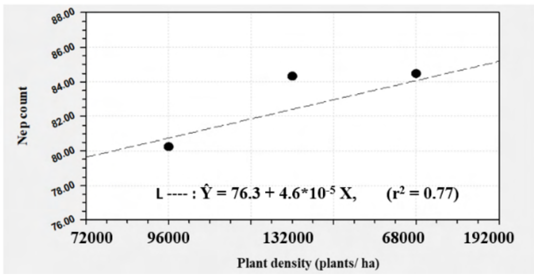

Fig 31. Effect of plant density on nep count

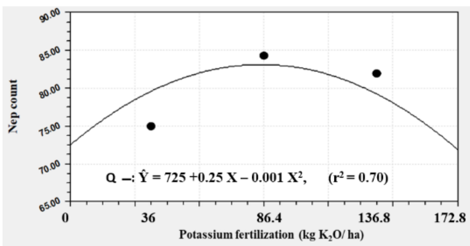

Fig 32. Effect of potassium fertilization on nep count

DISCUSION

The obtained results showed that delayed sowing, especially after April 15th, decreased vegetative characters of cotton, i.e., plant height and number of fruiting branches per plant compared to early sowing dates. Delaying sowing of cotton affects the growth and development of the cotton plant since the crop is exposed to adverse weather conditions which may affect the length of growing seasons. These findings were in accordance to those reported by **Afzal (2011), AbdEl-Moneim *et al.* (2017) and Singh *et al.* (2018). Iqbal *et al.* (2023)** emphasized the importance of sowing date in establishment and growth of the cotton plant and that sowing date has become a key factor in response to climate change. Similar effect for sowing date was observed on seed cotton yield and yield components, where early sowing gave higher seed cotton and lint yields. The optimal sowing date was found to be April 20th. Number of bolls/plant and bolls weight, in addition to the reduction in fruiting branches, were reduced with delaying sowing beyond April 20th leading to the observed reduction in seed and lint cotton yields. That reduction in seed cotton yield due to delayed sowing may be explained by adverse environmental conditions, especially high temperature, which affects physiological maturity of the plant. In addition, delaying of sowing caused a progressive increase in bollworm infestation percentage, which further affected the seed and cotton yields. These results were in harmony with those reported by **Elayan *et al.* (2015), Ahmed *et al.* (2018), Copur *et al.* (2019), Deshish *et al.* (2020) and Deho (2023).** With regard to fiber quality characters, the data showed that delaying sowing date led to reduction in fiber length and fiber strength, while nep count was increased, that may be due to the impaired growth of cotton plant and increased infestation percentage due to unfavorable environmental conditions. These results confirm those obtained by **Elayan *et al.* (2015), Usman *et al.* (2016), Singh *et al.* (2018) and Deshish *et al.* (2020).** Plant density significantly affected vegetative characters, where increasing plant density beyond 148000 plants/ha increased plant height linearly and quadratically. That may be due to the competition between plants, in dense populations, for light and avoidance of shading. These findings were in accordance with reported by **Khan *et al.*, (2001), Afzal (2011), Liaqat *et al.*, (2018) and El-Sayed and El-Hendawy (2023).** On the other hand, increasing plant density beyond 83000 plants/ha decreased number of fruiting branches/plant due to increased crowding and limited space between plants, in addition to the shading effect due to higher density. These results were in harmony with those reported by **Meng *et al.*, (2016), Shah *et al.*, (2017) and Ibrahim *et al.*, (2022).** Plant density had a significant effect on yield and yield components. Increasing plant density negatively affected number of bolls/plant and the optimal plant density for that character was 83000 plants/ha. That may be attributed to the decrease in number of fruiting branches/ plant with higher plant densities. **Iqbal *et al.*, (2012), Aslam *et al.*, (2013), Ghoprial *et al.*, (2018) and Jililian *et al.*, (2023)** all reported that number of bolls were higher in low plant densities due to wider spacings between plants which allow for better growth of sympodia and boll setting. On the other hand, infestation with bollworms increased with increasing plant density due to favorable conditions of shading and increased humidity within the cotton canopy which favors the development and spread of the insect. These findings were in agreement with those of **Gutierrez (2018) and Qader and Saber (2021).** A linear negative effect was observed on boll weight with increasing plant density, and that may be related to the lower efficiency of photosynthetic processes, due to higher shading in dense plant canopies, which led to lower production of photosynthates and their translocation to reproductive organs (bolls). These findings were in agreement with those reported by **Sawan *et al.*, (2008), Aslam *et al.*, (2013), Meng *et al.*, (2016), Zhi *et al.*, (2016) and Ibrahim *et al.*, (2022).** Although yield components were negatively affected by increasing plant density, seed cotton and lint yields/ha were increased at the higher plant densities of 168 and 192 thousand plants/ha compared to lower densities. The higher number of plants per unit area compensated for the lower values of yield components/ plant. Thus, seed cotton and, consequently, lint cotton yields were increased. Similar findings were reported by several researchers on Egyptian cotton (**Abd El-Aal., (2014), Ghoprial *et al.*, (2018) and Ibrahim *et al.*, (2022))** and Upland cotton **(Afzal *et al.*, (2011), Meng *et al.*, (2016) and Zhang *et al.*, (2021)).** Moreover, only nep count was the only character that was affected by plant density where it increased with increasing plant density, that effect may be related to lower maturity of fibers due to shortage of translocated assimilates to the bolls as influenced by shading in dense cotton canopies. Several researchers reported the insignificant effect of plant density on fiber properties such as **Akhtar *et al.*, (2002), Norton (2005), Iqbal and Khan (2011) and Shah *et al.*, (2017).** However, **Meng *et al.*, (2016)** found that maturity ratio decreased significantly at higher plant densities. Potassium is an important macronutrient that is involved in several bioprocesses in the cotton plant, and the peak requirements of that nutrient occur at flowering time **(Fageria *et al.*, 2011).** The results obtained from the present study revealed that K fertilization levels significantly affected the response of vegetative, yield and yield components characters in addition to nep count. Increasing K fertilization levels increased plant height quadratically, and the optimal level was about 122 kg K_2O/ha. Similarly, K fertilization increased number of fruiting branches when K_2O levels were above 86.4 kg/ha, reaching its maximum at 172.8 kg K_2O/ha. These findings were in accordance with those reported by **Katooch (2014), Koshik and Armin (2016), Deshish *et al.*, (2020) and Hussain *et al.*, (2021).** With regard to number of bolls/plant, the data showed that this character increased with increasing K levels up to an optimal level of 100 kg K_2O/ha, then decreased at higher levels of K_2O. As reported by several researchers, higher levels of K than optimal may cause an imbalance uptake by the cotton plant, especially at the flowering stage, which may have caused that decrease in number of bolls/plant (**Lokhande and Reddy (2015) and Gormus *et al.*, (2016)).** On the other hand, increasing K fertilization level decreased infestation with boll worms up to 100 kg K_2O/ha. That may be attributed to the role of potassium in increasing the resistance of cotton plants to diseases infection and insects infestation **Mesbah *et al.*, (2020), Mishra and Babu, (2020) and Awad, (2022).** The increase in infestation percentage beyond 100 kg K_2O/ha may be due to the aforementioned imbalance of nutrients uptake and may be a cause of the lower number of bolls/plant. With regard to boll weight, the data indicated that boll weight increased linearly and quadratically with increasing K fertilization level. That may be attributed to the role of potassium in translocation of assimilates to the bolls which led to better lint formation and higher boll weight. **El-Nour *et al.*, (2000), Sawan *et al.*, (2006), Gomaa *et al.*, (2014) and Hussain *et al.*, (2021).** Reported that boll weight was increased with increasing K fertilization level. Similar trends were found for seed cotton yield where it increased up to 145 kg K_2O/ha then plateaued. That may be due to the positive effect of K application in increasing number of fruiting branches, number of bolls/plant, bolls weight and decreasing infestation percentage. Lint yield followed a similar trend where it increased with increasing K fertilization level. Similar findings were reported by **Sharma and Singh (2007), Sary *et al.*, (2008), Dewedar and Rady (2013), Hamoda (2017) and Shao *et al.*, (2023).**

None of the studied fiber characters were affected by K fertilization levels. Generally, technological characters of cotton fiber are characteristic to the variety and are genetically controlled with little effect of environmental conditions. These findings were in accordance with the findings of **Abd-ElAal *et al.*, (2015) and Abd El-Gayed and Bashandy (2018).** However, nep count was decreased quadratically with increasing K level, and that response may be related to the better formation of fibers as a result to the higher translocation of metabolites to the bolls. The interactions between the studied factors accentuated the response of characters to main effects of factors. The negative PD*K interaction for infestation indicated that K application counteracted the higher infestation by bollworms due to higher plant populations. Similarly, the negative SD*PD interaction for that character revealed that early sowing resulted in lower infestation % even at higher plant populations. With regard to seed cotton yield, the negative SD*K interaction indicated that the response to increasing K fertilization levels was more pronounced at early sowing dates compared to later sowings. Moreover, the positive PD*K interaction was in accordance with the increase in plant density and higher K fertilization level.

CONCLUSION

The results of the present investigation indicated that the three studied factors influenced the development and productivity of the cotton cultivar Extra Giza 96, in addition to fiber quality characteristics, and it is important to optimize the levels of these factors to ensure higher productivity and quality. The analysis of the data showed that optimal date for sowing that cultivar was 10 to 20 April, which contradicts with the recommendation of sowing in mid-March. This may be due to the change in climatic conditions which caused cold weather to prevail during March. The optimal plant density was above 168000 plants/ha for higher seed cotton yield, however higher plant densities may cause an increase in bollworm infestation which may affect cotton fiber quality. Potassium fertilization in the range of 125 -145 kg K_2O/ha was optimal for productivity and nep count.

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