J. of Plant Production, Mansoura Univ., Vol., 12 (8): 847-860 , 2021

Journal of Plant Production

Journal homepage: www.jpp.mans.edu.eg
Available online at: www.jpp.journals.ekb.eg

Effect of Plant Distribution Patterns and Growth Regulators on Morphological, Yield and Technological Characters of Egyptian Cotton

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ABSTRACT

A field experiment was conducted at the Experimental Farm, Faculty of Agriculture, Menoufia University, Shebin El-Kom, Egypt during 2019 and 2020 seasons to study the effect of plant distribution patterns *i.e.* D1 (sowing cotton in furrows 70 cm width in one ridge with 25 cm between hills and two plants/hill), D2 (sowing cotton in furrows 70 cm width in one ridge with 12.5 cm between hills and one plant/hill), D3 (sowing cotton in beds 140 cm width in two ridges with 25 cm between hills and two plants/hill), D4 (sowing cotton in beds 140 cm width in two ridges with 12.5 cm between hills and one plant/hill) and foliar application with plant growth regulators *i.e.* control, kinetin (15 ppm), naphthalene acetic acid (15 ppm), mepiquat chloride (100 ppm), mepiquat chloride + kinetin and mepiquat chloride + naphthalene acetic acid at 80 and 95 DAS and on light intensity, morphological traits, flowering and abscission, yield and its components and seed and fiber quality of Egyptian cotton (Giza 86 cv.). The results indicated that sowing cotton plants with D3 pattern surpassed the other plant distribution patterns in most studied characters, while D1 increased plant height but decreased fiber fineness. On the other hand, number of squares/plant, boll weight, 100-seed weight, fiber strength and uniformity index were not significantly affected by plant distribution patterns. Application of growth regulators either single or dual caused a positive effect. NAA or MC+NAA were the superior treatments in most characters studied. However, unsprayed cotton plants increased total abscission. It could be concluded that sowing plants in beds with plant distribution pattern (D3) and foliar application with 100 ppm MC at 80 DAS followed by 15 ppm NAA at 95 DAS was the best interaction treatment in comparison to other interaction treatments to obtain the highest values of light intensity, total dry weight/plant, number of open bolls / plant, seed cotton yield per plant and fed, oil yield /fed and protein yield /fed).

***Keywords*:** Gossypium barbadense, Plant distribution, Growth regulators, Light intensity, Abscission, Productivity and Quality.

INTRODUCTION

Cotton (*Gossypium sp.*), also known as "white gold'', is one of the most important fiber crops in the world due to its importance in agriculture and industrial economy (Udikeri and Shashidhara, 2017). Cotton is the important fiber crops. Cotton oil ranking fifth in the world among edible oils. Egyptian cotton is preferred around the world because it is long fiber cotton that makes it softer and stronger at the same time. For many years, it was so valuable that most of the crop was exported to European countries (Ali and Abd El-Aal, 2012). It is necessary to increase cotton productivity to face the wide gap between the production and consumption of fiber and oils (Abdel-Aal *et al*., 2011). The cultivated area of Egyptian cotton in Egypt is annually fluctuated where reached 231000 and 183000 fed in 2019 and 2020 seasons, respectively with an average seed cotton yield about 8 kentar/fed (FAO, 2020). There has been an increasing interest in developing cotton cultivation. The extension of cotton cultivation in Egypt may hampered by several factors, 1) the land is occupying by maize, rice, sugarcane and summer vegetables, which need to be cultivated in fertility soils. 2) crop rotation was left to the discretion of farmers, who responded too readily to the whims of the market, resulted in decreasing the cultivated area of cotton due to price policy. 3) trend of Egyptian cotton cultivars to vegetative agitation, especially when growing in the fertility soils.

Inappropriate cultural practices are one of constraints that lead to low productivity. The cotton yield is associated with management practices that provide better canopy and good performance of leaves during the boll filling period. Managing the balance of vegetative and reproductive growth is the essence of managing a cotton crop (Abdel-Aal *et al*., 2011). An optimal canopy structure is important for achieving a high cotton seed yield (Zhao *et al*., 2019) due to receive better light intensity which is the most critical environmental factor beside temperature affecting in crop physiology. Also, Wu *et al.* (2018) mentioned that light intensity is the main factor which is control the process of photosynthesis, buds and flower initiation and cell division in soybean plants. Suitable canopy can be achieved by various factors, *e.g.* distribution of plants in the field and application of growth regulators either single or dual. Furrowing width, number of cultivated ridges, plant spacing and number of plants per hill are the major factors that determining plant distribution.

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DOI: 10.21608/jpp.2021.85866.1044

Plant growth regulators (PGRs) may be possible to modify plant performance in desirable ways. It could be used to keep leaves as strong sources at the same time that plant builds the fruiting sinks. Application of growth regulators have been reported to interfere with the endogenous levels of other plant hormones (Wahdan, 2000). The application of PGRs at the optimum concentration in the suitable time during plant development may improve the boll production and boll set. Growth promoters like auxins, gibberellins and cytokinins have been widely used to reduce abscission and to increase boll number and seed cotton yield (Brar *et al*., 2001). Plant growth retardants such as mepiquat chloride are applied to reduce unwanted longitudinal shoot growth without reducing productivity. Most growth retardants act by inhibiting gibberellin (GA) biosynthesis. It is quite apparent that application of growth regulators could increase cotton productivity (Kassem *et al*., 2009, Abdel-Aal *et al*., 2011 and Parveen *et al*., 2017) and improve fiber quality (Echer and Rosolem, 2017) as well as seed quality (Zohaib *et al*., 2018).

The main objectives of this study were to:

- Study the effect of foliar application with some plant growth regulators on the light intensity and morphological traits, flowering and abscission, yield and its components, seed chemical composition and fiber quality of Egyptian cotton grown under different plant distribution patterns.
- Obtain the best planting geometry in the field treated with the suitable growth regulators which can exploit environmental resources and expressing this with highest productivity and better quality of fiber and seed.

MATERIALS AND METHODS

Experimental procedures

A field experiment was conducted at the Experimental Farm, Faculty of Agriculture, Menoufia University, Shebin El-Kom, Egypt (latitude 30°31'42" N, longitude 31°04'08" E) during 2019 and 2020 seasons. The presented investigation was designed to study the effect of foliar spray with some plant growth regulators (promoters and retardant) on the light intensity, growth, flowering and abscission, yield and its components, seed chemical composition and fiber technology of Egyptian cotton (*Gossypium barbadense*, L. "Giza 86 cv.") grown under different plant distribution patterns. Each experiment included twenty-four treatments which were the combination of four plant distribution and six growth regulators as follows:

A- Plant distribution patterns:

Four plant distribution patterns (using staple plant density 48000 plants/fed) were experienced as shown in Table 1.

Table 1. Plant distribution patterns used in the experiment

Plant distribution patterns	Furrowig width (cm)	No. of cultivated ridges	Spacing hill (cm)	No. of plants /hill
D1 (Ordinary)	70 cm	1	25.00	2
D2	70 cm	1	12.50	1
D3	140 cm	2	25.00	2
D4	140 cm	2	12.50	1

B- Growth regulators:

Six treatments of growth regulators were foliar applied at 80 and 95 days after sowing (DAS), as single or dual application, as follows:

1- Control: Water sprayed twice at 80 and 95 DAS.

2- Kinetin (Kin): as growth regulator promoter was applied twice (80 and 95 DAS) at the rate of 15 ppm in each spray.

3- Naphthalene acetic acid (NAA): as growth regulator promoter was applied twice (80 and 95 DAS) at the rate of 15 ppm in each spray.

4- Mepiquat chloride (MC): as growth regulator retardant in the form of Blender 5% was applied twice (80 and 95 DAS) at the rate of 100 ppm in each spray.

5- Mepiquat chloride (MC) + Kinetin (Kin): MC was applied once (80 DAS) at the rate of 100 ppm, followed by Kin applied once (95 DAS) at the rate of 15 ppm.

6- Mepiquat chloride (MC) + Naphthalene acetic acid (NAA): MC was applied once (80 DAS) at the rate of 100 ppm, followed by NAA applied once (95 DAS) at the rate of 15 ppm.

Experimental design

Split plot design with three replications was used in this experiment. The four plant distributions patterns were arranged at random in the main plots, whereas the six treatments of growth regulators were assigned at random in the sub-plots.

Experimental site description

Samples were randomly collected from the experimental soil before sowing at depths of 0–30 cm to estimate the mechanical and chemical properties of soil (Jackson, 1973 and Chapman and Pratt, 1978) as presented in Table 2.

Table 2. Soil mechanical and chemical properties of the experimental site during 2019 and 2020 seasons.

Season	Texture	EC. (dS/m)	pH	O.M %	N (ppm)	P (ppm)	K (ppm)
2019	Clay loam	0.68	7.36	1.72	31.02	11.53	283.21
2020	Clay loam	0.61	7.41	1.75	33.42	11.89	291.36

Agronomic practices

The experimental field was prepared after Egyptian clover harvesting. The area of each experimental plots was 12.6 m^2 (3 m length and 4.2 m width) including 6 furrows or 3 beds according the tested plant distribution patterns. Empty area (1.4 m) was left as buffer area between all sub-plots in order to eliminate any interfere effect of foliar spray. Cotton seeds (Giza 86 cv.) were sown on 28^{th} and 15^{th} April 2019 and 2020, respectively. The experiment was irrigated eight times, where the first irrigation was applied at 30 DAS and the following irrigations were applied every 20 days. First ginning was done at 150 and 156 DAS in the first and second seasons, respectively when 60 % of bolls/plant were opened. The second ginning was done at 20 days later from the first one. Other normal cultural practices of sowing cotton were conducted according to recommendations of Egyptian Ministry of Agriculture and Land Reclamation.

Plant measurements

1- Light intensity

1- Light intensity (lux): It was determined by lux meter to estimate the amount of light falling on plant surface at height of meter from ground surface. The determination was done during 7.00-8.00 Am at 110 DAS.

2- **Light intensity % =**

$$\frac{\text{Light intensity (lux) at 1 m}}{\text{Light intensity (lux) at a top of plant}} \times 100$$

2- Morphological characters

Samples of six guarded plants were randomly taken from each experimental plot at 110 DAS to estimate root length "main root" (cm), root dry weight (g), plant height (cm), number of leaves/plant, number of fruiting (sympodial) branches/plant, number of bolls/plant, leaf area/plant (cm^2) and total dry weight (stem + leaves + bolls)/plant (g).

3- Flowering and abscission

Sample of six plants were randomly marked to record number of squares/plant, number of total bolls /plant (at harvest) and total abscission/plant (%).

$$\text{Total abscission} = \frac{\text{No. of squares/plant} - \text{number of total bolls /plant}}{\text{No. of squares/plant}} x100$$

4- Yield and yield components

At each experimental plots, random sample of six guarded plants was labeled before first pick to determine numbers of open and total bolls/plant, boll weight (g), 100-seed weight (g), seed cotton yield/plant (g) and lint cotton yield/plant (g). The plants in inner two furrows (in D1 and D2 patterns) or inner one bed (in D3 and D4 patterns) were harvested (ginned) at first and second picks and weighted and then converted to seed cotton yield/fed (kentar = 157.5 kg). Earliness (%) was calculated from the following formula:

$$\text{Earliness (\%)} = \frac{\text{Seed cotton yield of the first pick}}{\text{Total seed cotton yield (first + second picks)}} x100$$

5- Chemical composition of seeds

Protein (%): nitrogen % was determined in dried seeds according to the methods designed by **AOAC (2019)** using micro Kjeldahl method and then protein was calculated by multiplying the N% by factor 5.30**.** Protein yield (kg/fed) was determined by multiplying seed yield/fed by seed protein %.

Oil (%) was determined according to the methods described by AOAC (2019) using soxhlet apparatus with hexane 40-60 C° as a solvent. Oil yield (kg/fed) was determined by multiplying seed yield/fed by seed oil %.

6- Technological characters of fiber

Samples of lint (50 g) from each experimental plot were taken to determine the following technological characters at the laboratories of Cotton Technology Research Division, Cotton Institute, Giza, Egypt:

1- **Fiber length** expressed as upper half mean length (UHM) in mm was ere determined on digital Fibrograph instrument.
2- **Fiber fineness** (Micronaire reading): it was determined by Micronaire Instrument as reported by A.S.T.M. (2012).
3- **Fiber strength** (Pressley index): it was determined by Pressley instrument as reported by A.S.T.M. (2012).
4- **Uniformity index (UI %)** staple uniformity is expressed as:

$$UI\% = \frac{50\%\ \text{span length}}{2.5\%\ \text{span length}} x100$$

Statistical analysis

The obtained data during the two seasons in this study were analyzed according to the methods described by Snedecor and Cochran (1994). The differences among the means of different treatments were tested using least significant difference (LSD) at level of probability of 0.05.

RESULTS AND DISCUSSION

A- Effect of plant distribution patterns

1- Light intensity and morphological characters

Light intensity (lux) at 1 m height from soil surface and light intensity (%) were significantly affected ($P \leq 0.05$) by different tested plant distribution patterns (D1, D2, D3 and D4) as presented in Table 3. Plants grown in beds (140 cm width) in two ridges with wide distance of 25 cm between hills and two plants per hill (D3) ranked firstly in this respect, while sowing plants in furrows (D1 or D2) exhibited the lowest values in the two seasons. The response of light intensity (%) goes parallel with that of light intensity (lux). Light intensity is the most critical environmental factor for crop physiology (Yang *et al*., 2018). The suitable distribution is decrease competition among plants in furrows and within hill to meet environmental requirements (Deshish, 2021). The changes in light intensity leads to considerable changes in leaf morphology and structure (Wu *et al*., 2017). In this concern, Udikeri and Shashidhara (2017) reported that wider plant spacing achieved a significant higher light transmission ratio, while closer plant spacing recorded the highest significant rank in light absorption ratio.

Plant distribution patterns significantly differed in root length and root dry weight/plant at 110 DAS in the second season. Cotton plants grown in the beds (140 cm width) in two ridges with wide distance of 25 cm between hills and two plants per hill (D3) surpassed other distribution patterns by recording the highest values of both traits. However, the lowest values were obtained by sowing cotton in furrows (70 cm width) cultivated in one ridge with wide distance of 25 cm between hills and two plants per hill (D1). This result may be due to varied light intensity on plants that resulting from various plant distribution patterns. In this concern, Yang *et al.* (2014) stated that dry matter of soybean roots was decreased under light intensity reduction conditions.

Data recorded in Table 3 indicated that sowing plants in furrows (70 cm width) recorded the tallest plants in favor of D1 during the two growing seasons, while planting cotton in beds (140 cm width) registered the shortest plants in favor of D3. This result means that plants cultivated in furrows may be suffering from some intra-competition resulted in more increases in plant height. In this respect, Mahdi (2016) found that decreasing hill spacing from 25 to 15 cm increased plant height.

It can be noticed from Table 3 that there is significant variation among the plant distribution patterns in numbers of leaves, fruiting branches and bolls/plant, leaf area, chlorophyll content and total dry weight /plant during both growing seasons. The highest significant values of these characters were obtained by sowing cotton in beds in favor of D3 pattern followed by D1, indicating that sowing plants in wide distance between hills (25 cm) caused simulative effects in comparison with narrow distance

(12.5 cm). D3 pattern caused an increase in total dry weights over D2 by 44.04 and 28.79% in the first and second seasons, respectively. The superiority of D3 in the total dry weight may be attributed to the significant increases in leaf area and chlorophyll content which might be caused increases in the amounts of metabolites and synthesized and this in turn increased the capacity of dry matter accumulation in different plant organs. In this concern, Mahdi (2016) and Udikeri and Shashidhara (2017) found significant increases in leaf area, numbers of fruiting branches and bolls /plant and total dry weight/ plant by sowing cotton plants in wide spacing.

Table 3. Mean values of light intensity and morphological traits as affected by plant distribution patterns during 2019 and 2020 seasons.

Plant distribution patterns	Light intensity (lux)	Light intensity (%)	Root length (cm)	Root dry weight (g)	Plant height (cm)	No. of leaves / plant	No. of fruiting branches /plant	No. of bolls /plant	Leaf area / plant (cm^2)	Chlorophyll (SPAD value)	Total dry weight/plant (g)
						2019 season					
D1	617.22	7.10	32.19	12.04	159.50	52.49	9.57	12.62	570.61	47.23	110.13
D2	641.67	7.35	34.28	13.15	162.66	43.44	9.07	10.63	471.58	45.96	91.60
D3	760.00	8.74	34.87	14.88	157.68	61.11	10.47	14.93	618.95	47.40	131.94
D4	717.22	8.25	33.51	12.59	159.20	50.80	9.11	12.69	549.56	46.92	108.54
LSD 0.05	79.52	0.69	NS	NS	4.17	11.05	0.81	0.92	41.67	1.39	4.55
						2020 season					
D1	628.89	7.23	34.15	13.13	151.80	49.95	10.33	16.98	580.54	45.02	124.97
D2	522.22	6.00	37.85	15.78	157.39	44.71	9.67	15.49	575.30	44.50	111.91
D3	723.89	8.32	39.18	16.20	147.69	59.54	11.17	19.44	714.19	47.12	144.13
D4	570.00	6.55	36.38	14.81	148.06	53.54	9.88	16.36	571.04	44.39	123.50
LSD 0.05	146.49	0.88	4.26	2.03	3.12	6.94	1.04	1.71	82.40	1.57	10.75

D1: Sowing in furrows (70 cm width), in one ridge, with 25 cm between hills and two plants / hill.
D2: Sowing in furrows (70 cm width), in one ridge, with 12.5 cm between hills and one plant / hill.
D3: Sowing in beds (140 cm width), in the two ridges, with 25 cm between hills and two plants / hill.
D4: Sowing in beds (140 cm width), in the two ridges, with 12.5 cm between hills and one plant / hill.

2- Flowering and abscission

Total number of squares /plant in both seasons and total abscission percentage in the first season were not significantly affected by the tested plant distribution patterns. Meanwhile, total number of bolls per plant in both growing seasons and total abscission percentage were significantly affected in the second one (Table 4). Sowing plants in beds (140 cm) with wide plant spacing (D3 pattern) exhibited the highest values of total bolls and lowest abscission %. As an average of the two seasons, sowing plants with D3 increased number of total bolls by 7.08, 17.37 and 9.51% and reduced total abscission pattern by 3.84, 11.08 and 3.57% compared to D1, D2 and D4 patterns, respectively. Thus, it could be concluded that plant distribution (D3 pattern) helped form a suitable plant type for receiving high light intensity and increase photosynthetic activity to improve the nutritional regimes of squares and bolls and consequently reduce abscission. Also, nutritional factors have been shown to have an effect on the abscission process. In this concern, Zaxos *et al.* (2012) showed that number of squares/m^2 were not significantly affected by furrowing width (75 and 93 cm). However, Udikeri and Shashidhara (2017) declared that sowing cotton plants with wide plant geometry (60x15 cm) cause an increase in total bolls/plant more than other planting geometries (45x10 and 45x15 cm). Moreover, Mahdi (2016) showed that abscission percent was decreased by increasing plant spacing from 15 cm to 25 cm.

3- Yield and seed quality

Data in Table 5 showed significant positive response of plant distribution patterns on open bolls and total bolls / plant in the two growing seasons. However, the differences among the plant distribution patterns did not reach the level of significance for boll weight and 100-seed weight. Sowing cotton plants in beds (140 cm) with wide distance (25 cm) between hills (D3 pattern) was the most effective distribution pattern for producing more numbers of open bolls and weights of boll and 100-seed weight than the other plant distribution patterns. These results may be due to changes in light intensity and photosynthetic pigments as previously discussed, which stimulate photosynthetic activity and subsequently amounts of metabolites synthesized by different vegetative growth of the plants and this in turn increase the formation of fully matured bolls. In this respect, Gebregergis *et al.* (2020) reported that sowing cotton with wide planting geometry (80 x25 cm) increased open bolls compared to narrow planting geometry (60 x 10 cm). Boll weight and seed index were increased by increasing furrow width (96 cm) in comparison with (50 and 75 cm) as reported by Darawsheh *et al.* (2019).

Table 4. Mean values of squares and bolls production and total abscission as affected by plant distribution patterns during 2019 and 2020 seasons.

Plant distribution patterns	No. of squares / plant	No. of bolls/plant at harvest	Total abscission (%)
		2019 season	
D1	39.65	21.97	44.59
D2	37.39	18.62	50.00
D3	42.30	23.43	44.60
D4	37.84	20.05	47.01
LSD 0.05	NS	1.60	NS
		2020 season	
D1	57.88	28.04	51.50
D2	59.26	27.31	53.91
D3	58.42	30.48	47.80
D4	57.01	29.18	48.81
LSD 0.05	NS	2.33	5.74

D1: Sowing in furrows (70 cm width), in one ridge, with 25 cm between hills and two plants / hill.
D2: Sowing in furrows (70 cm width), in one ridge, with 12.5 cm between hills and one plant / hill.
D3: Sowing in beds (140 cm width), in the two ridges, with 25 cm between hills and two plants / hill.
D4: Sowing in beds (140 cm width), in the two ridges, with 12.5 cm between hills and one plant / hill.

Significant differences could be discerned among the tested plant distribution patterns with concerning to seed cotton yield/plant, lint yield/plant and seed cotton yield/fed in both seasons. The superiority of seed cotton yield was obtained when the cotton plants were sown in beds with wide distance between hills (D3 pattern). However, sowing plants in furrows with narrow distance between hills (D2 pattern) gave the lowest significant values compared to the other plant distribution patterns. The superior treatments in seed cotton yield (D3 pattern) had a higher lint cotton yield/plant in both seasons. As an average of both growing seasons, D3 pattern recorded increases over D1, D2 and D4 patterns amounted to 6.31, 18.41 and 3.66% for seed cotton yield/fed and 10.29, 25.79 and 8.47% for lint cotton yield/plant, respectively. The superiority of D3 pattern may be owing to its effect on improving light intensity, root traits, dry matter accumulation and probably associated with enhancement of open bolls/plant. Alterations of plant canopy that allow more light permeation into the lower depths of the canopy may be a way to increase cotton yield through greater boll production. Kumar and Ramachandra (2019) found that seed cotton yield /plant was increased by sowing plants in wide planting geometry (90x60 cm) compared to narrow planting geometries, *i.e*. (45x15 cm), (45x20 cm) and (60x10 cm). Moreover, Mahdi (2016) indicated that increasing hill spacing caused an increase in lint cotton yield/plant up to 35 cm apart (Siddiqui *et al*., 2007) and lint % up to 25 cm.

Sowing cotton plants in beds with wide distance between hills (D3 pattern) caused a significant increase in the earliness percentage more than the other plant distribution patterns in first season, while the differences among plant distribution patterns did not reach the level of significance in the second season. The favorable effect of D3 pattern in earliness % might be ascribed to the increase in number of open bolls per plant and boll retention which reflect on early boll opening and early harvest more than other plant distribution patterns. Mahdi (2016) showed the importance of sowing cotton plants in wide plant spacing for earliness compared with sowing in narrow spacing.

Sowing plants with D3 pattern had the greatest oil % and oil yield /fed in the two growing seasons (Table 5). In second season, the differences among D3 and D1 patterns for oil % as well as D3, D4 and D1 patterns for oil yield/fed did not reach the level of significance. As an average of two seasons, D3 pattern increased oil% and yield more than D2 pattern by 9.35 and 27.70%, respectively. The simulative effect of D3 on oil percentage might be due to that pattern significantly enhanced root length and dry weight (Table 3) and consequently mineral uptake. Moreover, the increment in oil yield resulting from D3 pattern could be attributed to its role in increasing cotton seed yield /fed and oil %. Similar trend was recorded by Mahdi (2016).

Table 5. Mean values of yield and seed quality of cotton as affected by plant distribution patterns during 2019 and 2020 seasons.

Plant distribution patterns	No. of open bolls / plant	No. of total bolls / plant	Boll weight (g)	100-seed weight (g)	Seed cotton yield / plant (g)	Lint cotton yield / plant (g)	Seed cotton yield / fed (kentar)	Earliness (%)	Oil		Protein	
									%	Yield (kg/fed)	%	Yield (kg/fed)
							2019 season					
D1	20.32	21.97	3.42	9.96	49.83	19.23	9.71	55.35	25.10	235.76	30.51	286.58
D2	16.51	18.62	3.35	9.94	41.49	15.70	8.97	54.71	24.82	218.11	29.08	255.53
D3	21.63	23.43	3.47	10.00	56.38	21.70	10.31	56.67	27.22	271.95	29.68	296.54
D4	18.19	20.05	3.30	9.82	50.40	19.27	9.95	53.57	25.42	246.31	31.12	301.54
LSD 0.05	1.58	1.60	NS	NS	0.99	0.75	0.21	1.33	0.77	13.41	1.41	18.89
							2020 season					
D1	27.30	28.04	3.60	9.59	56.88	22.04	11.04	58.84	26.43	278.86	28.23	296.87
D2	26.23	27.31	3.56	9.47	54.02	20.95	9.64	57.43	24.70	233.44	27.12	256.61
D3	29.49	30.48	3.69	9.60	63.00	23.75	11.75	62.10	26.93	305.16	28.34	321.03
D4	28.23	29.18	3.65	9.25	57.58	22.76	11.33	59.28	26.19	286.97	28.53	311.88
LSD 0.05	2.08	2.33	NS	NS	3.43	1.29	1.51	NS	0.70	42.85	0.96	42.81

D1: Sowing in furrows (70 cm width), in one ridge, with 25 cm between hills and two plants / hill.
D2: Sowing in furrows (70 cm width), in one ridge, with 12.5 cm between hills and one plant / hill.
D3: Sowing in beds (140 cm width), in the two ridges, with 25 cm between hills and two plants / hill.
D4: Sowing in beds (140 cm width), in the two ridges, with 12.5 cm between hills and one plant / hill.

Concerning the protein percentage and its yield/fed, it is evident from the same table that there was a considerable amount of variation among the plant distribution patterns in both seasons. It is evident that sowing cotton plants at D4 pattern generally recorded the highest protein percentage and its yield followed by D3 and D1 patterns without significant among them. Sowing cotton plants with D2 pattern recorded the lowest ones in both seasons. As an average of two seasons, the increment caused by D4 and D3 more than D2 was amounted to 6.11 and 3.28% for protein % and 19.77 and 20.57% for protein yield/fed, respectively. Mahdi (2016) found that highest values of protein content were obtained from widest spacing (25 cm) compared to hill spacing (15 cm).

4- Technological characters of fiber

Data in Table 6 showed that tested plant distribution patterns caused significant differences on fiber fineness (in the two seasons) and fiber length (in one season). However, the differences among all tested plant distribution patterns did not reach the level of significance for fiber strength and uniformity index in the both seasons. With regard fiber length, sowing cotton plants in furrows was the superior one in comparison with sowing cotton plants in beds in the second season, while the differences did not reach the level of significance in the first season. Concerning fiber fineness, sowing cotton plants in beds with wide distance between hills (D3 pattern) recorded the best fineness of cotton fiber followed by sowing cotton plants in beds with narrow distance between hills (D4 pattern) without significant between them in the second season. These results are in accordance with Baumhard *et al.* (2018) who showed that sowing cotton plants in wide furrows gave the highest values of fiber length in comparison with narrow furrows. However, Deshish (2021) stated that uniformity index, micronaire reading and pressley index were not significantly affected by plant distribution patterns.

Table 6. Mean values of technological characters of fiber as affected by plant distribution patterns during 2019 and 2020 seasons.

Plant distribution patterns	Fiber length (mm)	Fiber fineness (Micronaire reading)	Fiber strength (Pressley index)	Uniformity index (%)
		2019 season		
D1	33.40	4.56	10.81	85.78
D2	33.28	4.55	10.88	85.38
D3	33.12	4.44	10.90	85.50
D4	32.96	4.50	10.36	84.99
LSD 0.05	NS	0.03	NS	NS
		2020 season		
D1	32.41	4.64	10.54	84.66
D2	32.23	4.55	10.58	84.39
D3	31.32	4.37	10.73	84.29
D4	31.23	4.41	10.53	83.98
LSD 0.05	0.64	0.18	NS	NS

D1: Sowing in furrows (70 cm width), in one ridge, with 25 cm between hills and two plants / hill.
D2: Sowing in furrows (70 cm width), in one ridge, with 12.5 cm between hills and one plant / hill.
D3: Sowing in beds (140 cm width), in the two ridges, with 25 cm between hills and two plants / hill.
D4: Sowing in beds (140 cm width), in the two ridges, with 12.5 cm between hills and one plant / hill.

B- Effect of growth regulators

1- Light intensity and growth characters

The results in Table 7 showed generally that, there are significant differences in light intensity (lux) and light intensity (%) at 110 DAS due to different growth regulators application in both seasons. Foliar application of naphthalene acetic acid (NAA), mepiquat chloride + kinetin (MC+Kin) and mepiquat chloride + naphthalene acetic acid (MC+NAA) produced the highest mean values followed by kinetin and MC compared to untreated plants (control) in the two seasons in this respect. It is well established that PGRs play an important role in growth, better penetration of light and improving mineral ions uptake and stimulating nitrogen metabolism. All these processes are interlinked through several interactions and influence on light intensity. In this concern, Mao *et al*. (2014) stated that light use efficiency was slightly increased in cotton canopy by the application of MC due to the modification of plant structure.

Various foliar treatments of plant growth regulators either single or dual application significantly increased root length and root dry weight /plant generally in the two seasons compared to untreated plants (Table 7). The highest root length and heaviest root dry weight were given by application of MC+Kin. It is worthy to note that the root length and root dry weight were also generally enhanced by the application of kinetin, NAA, MC+NAA and MC in deseeding order in both seasons. MC and/or kinetin can modify root development patterns, if considered its effect on hormones balance which could increase the root growth and provides root length and weight. Moreover, cytokinins are synthetic in root tips and active in the maintenance of ongoing process and nutrients mobilization in the shoots. Chen *et al*. (2018) reported that MC significantly increased endogenous IAA levels in the roots, which promoted lateral root initiation and subsequently increasing lateral root quantity and elongation.

Table 7. Mean values of light intensity and morphological characters of cotton as affected by growth regulators during 2019 and 2020 seasons.

Growth regulators	Light intensity (lux)	Light intensity (%)	Root length (cm)	Root dry weight (g)	Plant height (cm)	No. of leaves / plant	No. of fruiting branches /plant	No. of bolls / plant	Leaf area / plant (cm^2)	Chlorophyll (SPAD value)	Total dry weight/plant (g)
						2019 season					
Control	546.67	6.29	31.07	11.15	157.98	45.87	8.37	9.78	480.41	43.71	88.78
Kinetin	657.50	7.56	34.41	12.91	164.24	55.07	9.82	12.65	575.48	47.01	116.75
NAA	755.83	8.69	33.39	13.64	161.72	54.38	9.73	13.37	616.63	46.80	116.72
MC	657.50	7.56	33.67	12.93	153.67	50.52	9.98	12.80	517.36	46.99	112.01
MC+ Kinetin	740.00	8.51	35.59	14.57	161.35	51.32	9.28	12.55	532.31	48.02	109.51
MC+NAA	746.67	8.69	34.15	13.78	159.59	54.62	10.13	15.17	593.88	48.74	119.56
LSD 0.05	74.12	0.85	1.71	2.11	3.44	5.28	0.53	0.60	55.38	1.39	4.37
						2020 season					
Control	520.00	5.98	34.12	12.59	157.65	48.48	8.98	14.87	517.92	41.95	104.33
Kinetin	550.83	6.33	37.19	14.18	166.20	54.14	10.63	16.93	626.44	44.83	129.02
NAA	690.83	7.94	36.78	14.94	162.90	52.42	10.42	16.08	653.32	44.34	130.13
MC	595.00	6.84	36.39	15.80	134.83	53.40	10.70	17.97	591.91	46.18	126.40
MC+ Kinetin	633.33	7.28	38.68	16.68	143.57	49.35	10.03	16.67	612.31	46.54	128.08
MC+NAA	677.50	7.79	38.19	15.70	142.25	53.81	10.80	19.88	659.70	47.70	138.81
LSD 0.05	83.41	1.08	2.04	1.86	9.10	NS	0.81	1.84	100.98	1.95	13.37

Data recorded in the same table showed clearly that, the lower plant height was recorded with foliar application of MC, while kinetin recorded the tallest plants compared to other treatments. MC application decreased plant height due to reduce internode length, resulting in a reduction in overall plant height and length of vegetative branches. In addition, MC is an anti-gibberellin that inhibits the production of gibberellins in the plants which normally would enlarge the plants cells by blocking the cyclization of geranylgeranyl pyrophosphate to capatyl pyrophosphate and also blocks further trans of capatyl pyrophosphate to ent-kaurene in the gibberellic acid biosynthesis pathway. Similar results were obtained by other investigators who found that foliar application of growth regulators such as kinetin at a rate of 20 ppm (Kassem *et al*., 2009), NAA at a rate of 30 ppm (Kataria and Khanpara, 2011 and Sabale *et al*., 2017) significantly increased plant height compared to untreated plants.

However, Priyanka and Dalvi (2019) reported that application of MC decreased plant height.

Application of all growth regulators either as single or dual application significantly increased numbers of leaves, fruiting branches and bolls/plant compared to untreated plants in both seasons except number of leaves in the second season. Foliar application of MC+NAA produced the highest values of numbers of fruiting branches and bolls/plant followed by MC and NAA. Meanwhile, kinetin recorded firstly followed by MC+NAA for increasing number of leaves/plant. From these results, it can be suggested that the tested plant growth regulators (PGRs) such as cytokinin, auxin and MC are play important roles in all phases of plant development from cell division and cell enlargement up to the formation of leaves, branches and bolls. It is well established that PGRs play an important role in flower formation and fruit-set, modifying processes such as photosynthesis rate in leaves in such a way that more photosynthetic products are mobilized and brought the developing fruits. In this respect, Priyanka and Dalvi (2019) found that MC increased numbers of fruiting branches and bolls/plant in comparison with unsprayed plants. However, Parveen *et al.* (2017) stated that application of NAA at rate of 0.045 g/100L increased number of leaves/plant and number of bolls/plant compared to control treatment.

NAA either single or dual application with MC significantly recorded higher leaf area/plant in both seasons (Table 7). The reduction in leaf area/plant by MC might be due to thicker mesophyll tissues, which is associated with higher chlorophyll content thus making the leaves to be dark green in color and photosynthetically active for longer period. Moreover, MC+NAA recorded the highest total chlorophyll and total dry weight /plant in both seasons compared to other test regulators and control treatment. PGRs especially MC either single or dual application with NAA or Kin cause leaves to be thicker due to an increased layer of developed cells. The thicker leaves and smaller cells of cotton plants had a more concentrated dark-green color. The superiority in total dry weight may be related to the important of these growth regulators in increasing the numbers of leaves, fruiting branches and bolls/plant as previously mentioned. Cytokinins and auxin delay senescence, that helps in increasing photosynthesis and mobilization of photoassimilate towards reproductive sink. However, application of MC shifts nutrients uptake at vegetative growth to developing bolls and a greater proportion of boll production than other treatments. In this respect, leaf area/plant was increased by the application of NAA at rate of 0.045g/100 L (Parveen *et al*., 2017). Chlorophyll content was significantly increased by foliar application of growth regulators such as NAA (Parveen *et al*., 2017), MC (Sabale *et al.* 2017) and kinetin (Kassem *et al*., 2009) compared to untreated cotton plants. Moreover, Sarlach and Sharma (2012) stated that application of NAA at rate of 20 µg/ml increased stem, leaves and total dry weights/plant compared to untreated plants.

2- Flowering and abscission

Number of squares/plant and number of total bolls/plant at harvest as well as total abscission percentage seemed to be significantly affected by the tested growth regulators in the both seasons except number of squares/plant in the second season (Table 8). It is evident that application of growth regulators augmented the number of squares and bolls/plant compared with untreated plants without significant differences among them in both traits. Slight increase in the number of squares/plant was observed when the plants were sprayed by kinetin in the first season compared to untreated plants. With regarded to total abscission percentage, the reverse was true, where MC+NAA treatment followed by MC+Kin, NAA and MC resulted in reducing abscission %. However, untreated plants had more total abscission percentage (squares and bolls) than the other tested growth regulators. Thus, it could be concluded that there is a negative relationship between abscission percentage and growth regulators under study which were useful for increasing number of bolls per plants and decreasing abscission percentage. From the physiological point of view, fruit shedding in cotton is considered a physiological disorder and cotton yield could be considerably increased by reducing it, which could be approached via ensuring regulator supply of photosynthetic and nutrients to the developing fruits. Otherwise, the supply of assimilates during boll development stage is restricted by poor synchronization between carbon production and its utilization by diverting boll since leaf photosynthesis and carbon production cotton peak prior to maximum carbon demand by bolls. When stimulators growth regulators are applied to young fruits, there is a stimulation in growth and a retardation of abscission by delaying leaf senescence. In this regard, other researchers reported that number of squares/plant was increased by application of 1 ml MC/L (Abdel-Aal *et al*., 2011) and kinetin at 20 ppm (Kassem *et al*., 2009). Moreover, number of bolls/plant was increased by the application of NAA (Parveen *et al*., 2017) and MC (Priyanka and Dalvi., 2019 and Hussain *et al*., 2021). On the other hand, many investigators found that abscission percentage could be decreased by foliar application of NAA at rate of 30 ppm (Sabale *et al*., 2017 and Geethanjali *et al*., 2018). Also, abscission % was decreased by the application of MC (300 ppm), NAA (50 ppm) and kinetin (50 ppm) in comparison with the control treatment as reported by Deol *et al.* (2018).

Table 8. Mean values of squares and bolls production and total abscission as affected by growth regulators during 2019 and 2020 seasons.

Growth regulators	No. of squares / plant	No. of total bolls/plant at harvest	Total abscission (%)
		2019 season	
Control	36.81	18.14	50.70
Kinetin	37.94	19.97	47.35
NAA	40.62	21.55	46.94
MC	40.32	21.52	46.61
MC+ Kinetin	39.23	22.33	43.06
MC+NAA	40.86	22.60	44.70
LSD 0.05	3.04	1.41	3.68
		2020 season	
Control	59.22	25.38	57.14
Kinetin	60.42	28.50	52.81
NAA	58.25	30.00	48.46
MC	55.95	28.20	49.58
MC+ Kinetin	59.27	30.10	49.20
MC+NAA	55.75	30.33	45.58
LSD 0.05	NS	2.02	5.05

3- Yield and seed quality

It is obvious from the results in Table 9 that spraying cotton plants with the tested plant growth regulators had a marked effect on seed cotton yield/plant and its components in comparison with the untreated plants. The highest number of open bolls and total bolls /plant were recorded by the foliar application of MC+NAA, NAA and MC+Kin followed by MC and kinetin in a descending order, while the untreated plants produced the lowest ones. Two hypotheses have been advised regarding enhancement of plant growth regulators on boll retention in the cotton plant. One possibility is improved light penetration into the middle canopy, resulting in a more favorable light environment for leaves. A second possible explanation is that an enhanced supply of carbohydrates for bolls through positive effects of PGRs in photosynthetic pigments (Table 7). In addition, PGRs improve early flower production, increase fruit retention and decrease abscission percentage (Table 8). In this concern, number of open bolls/plant was increased by the application of growth regulators, *i.e*. NAA (50 ppm), kinetin (50 ppm) and MC (300 ppm) in comparison with control as reported by Deol *et al*. (2018). Moreover, Sarlach and Sharma (2012) found that total number of bolls/plant was increased by spraying 20 ppm NAA compared to untreated plants.

Boll weight and 100-seed weight were greatly influenced by the application of the tested growth regulators compared to the control treatment in both seasons. The heaviest boll and seed weights were obtained by MC+NAA and MC+Kin without significant between them as well as with NAA in the second season for 100-seed weight. Boll weight seemed to be primarily determined by hormonal interaction within the inflorescence period. The superiority of boll weight may be due to the increase in the photosynthetic production and photoassimilate translocation from leaves to fruits (Zhao and Oosterhuis, 2000). Boll weight and seed index could be increased by application of 30 ppm NAA (Kataria and Khanpara, 2011), and 42 g MC /ha (Hussain *et al*., 2021) compared to unsprayed cotton plants.

There are positive effects of the tested growth regulators on seed cotton yield per plant and fed and lint yield per plant as comparison with the untreated plants in both seasons (Table 9). Foliar spraying of MC+NAA and NAA seemed to be the most effective growth regulators for increasing such traits followed by MC+Kin, MC and kinetin in a descending order. As an average of the two seasons, MC+NAA increased seed cotton yield/plant, seed cotton yield/fed and lint yield per plant more than untreated plants by 23.36, 29.07 and 24.44 %, respectively. The most probable explanation for this result is that will agree with the concomitant increases in root traits and leaf area/plant (Table 7) and yield components, *i.e*. number of open boll/plant and boll weight (Table 9). Therefore, the increases in seed cotton yield may be resulted from increasing the percentage of boll retention per plant when plant growth regulators acting as a reducer of abscisic acid and stimulator to auxin and cytokinin's as discussed earlier by Xu and Taylor (1992). NAA can promote the initiation and development of a greater number of fibers on seed. Kataria and Khanpara (2011) found that seed cotton yield and lint yield/ plant were increased by foliar application of 30 ppm NAA compared to the control. Moreover, Deol *et al*. (2018) found that foliar application of MC (300 ppm), NAA and kinetin (50 ppm) increased seed cotton yield in comparison with the control treatment.

Table 9. Mean values of yield and seed quality of cotton as affected by growth regulators on during 2019 and 2020 seasons.

Growth regulators	No. of open bolls / plant	No. of total bolls / plant	Boll weight (g)	100-seed weight (g)	Seed cotton yield / plant (g)	Lint cotton yield / plant (g)	Seed cotton yield / fed (kentar)	Earliness (%)	Oil %	Oil Yield (kg/fed)	Protein %	Protein Yield (kg/fed)
							2019 season					
Control	15.82	18.14	3.20	9.50	42.41	16.00	8.51	55.44	24.66	205.85	28.50	237.91
Kinetin	17.75	19.97	3.38	9.78	47.83	18.15	9.11	57.60	25.78	229.60	30.92	275.37
NAA	20.01	21.55	3.34	10.06	52.93	20.50	10.24	60.18	26.07	257.78	29.95	296.14
MC	19.77	21.52	3.39	9.93	49.40	19.05	9.97	51.12	25.32	244.52	30.58	295.31
MC+ Kinetin	20.55	22.33	3.43	10.14	51.43	19.59	9.78	53.72	25.54	243.55	30.15	287.51
MC+NAA	21.07	22.60	3.57	10.18	54.65	20.54	10.80	52.38	26.48	276.56	30.47	318.23
LSD 0.05	1.35	1.41	0.16	0.26	1.58	0.68	0.24	1.32	0.74	9.69	1.66	17.67
							2020 season					
Control	23.98	25.38	3.42	9.07	52.36	19.71	9.41	60.22	25.32	234.61	26.60	245.65
Kinetin	27.15	28.50	3.55	9.35	57.07	22.06	10.02	54.32	26.26	254.08	29.01	280.78
NAA	29.48	30.00	3.72	9.40	59.62	23.94	12.18	63.26	26.36	303.32	27.53	315.76
MC	27.37	28.20	3.59	9.50	58.00	22.06	10.58	58.27	25.73	265.98	28.51	294.26
MC+ Kinetin	29.23	30.10	3.70	9.68	58.47	22.72	11.12	59.83	26.13	280.06	28.36	303.53
MC+NAA	29.67	30.33	3.78	9.88	61.71	23.75	12.33	60.57	26.57	318.60	28.33	338.02
LSD 0.05	2.08	2.02	0.17	0.20	2.55	1.51	0.87	NS	0.88	24.97	1.17	24.62

With regard to the earliness percentage, the data declared that foliar application of NAA increased the earliness percentage compared to other tested growth regulators and untreated plants in both seasons. In the second season, the differences among control treatment and the other growth regulators treatments were insignificant. The increase in earliness % obtained by NAA could be a resulted of its enhancing effect on translocation and utilization of photosynthetic metabolic product and consequently might stimulated physiological maturity. Foliar application of growth regulators such as NAA (Parveen *et al*., 2017), kinetin (Kassem *et al*., 2009) significantly enhanced earliness percentage of cotton compared to control.

The data showed that there were significant differences among the plant growth regulators in oil percentage and its yield/fed as observed in Table (9). Foliar application of MC + NAA had significant increase in oil percentage. However, there were no statistically significant differences between such treatment and each of kinetin and

NAA in the first season and other growth regulators in the second season. Concerning oil yield, foliar application of MC + NAA had the greatest oil yield /fed but without significant difference with NAA treatment in the second season. However, untreated plants recorded the lowest value in the two growing seasons. Application of MC + NAA caused an increase in the oil yield/fed amounted to 34.35 and 35.79% more than the untreated plants in the first and second seasons, respectively. The increment in oil yield due to applying growth regulators could be attributed to their roles in increasing cotton seed yield /fed and oil percentage in the seeds. In this respect, oil yield/ha was found to be increased by spraying MC at rate of 70 mg/L in comparison with control treatment as previously reported by Zohaib *et al.* (2018).

It could be noticed from the data presented in Table 9 that foliar application of the tested growth regulators significantly increased protein percentage and protein yield/fed as compared with untreated plants during both seasons. It can be noticed that foliar application of kinetin was found to be the most effective regulators for producing more seed protein %. The superiority in protein yield/fed due to application of MC + NAA may be due to the increase in each of the cotton seed yield/fed and seed protein percentage. Application of MC + NAA caused an increase in the protein yield/fed amounted to 33.76 and 37.60% more than the untreated plants in the first and second seasons, respectively. In this concern, Zohaib *et al.* (2018) found that application of 70 mg MC /L increased protein yield/ha compared to untreated plants.

4- Technological characters of fiber

It is interesting to note that the traits of fiber length, fineness and strength as well as uniformity index were found to reach the level of significance in the two seasons (Table 10). Application of growth regulators increased fiber length in favor of NAA in both season but without significant differences with the other tested growth regulators in the first season. Whereas, in the second season, the control treatment and other tested growth regulators except NAA recorded the lowest values. Concerning fiber fineness (Micronaire reading), data also showed that control treatment in both seasons and MC in the second season gave the highest mean value as comparison with the MC+NAA. On the other hand, fiber fineness remarked relatively constant or insignificantly by foliar application of kinetin, NAA, MC+NAA and control treatment. The data in the same table demonstrate that fiber strength and uniformity index were increased by the application of the tested plant growth regulators in comparison to the control treatment in both seasons. Moreover, it can be noted that the differences among all tested growth regulators were various in both seasons. MC+NAA was higher one in fiber strength, while NAA was the best one in the uniformity index. Meanwhile, the rest plant growth regulators were in between of the two extremes. Thus, PGRs could become a useful tool for cotton to attain high productivity and preserve the superior quality of fibers. In this respect, fiber strength was increased by spraying MC (Echer and Rosolem, 2017). Moreover, Copur *et al.* (2010) found that fiber length, fineness and strength as well as uniformity index were not affected by 50 g/L MC compared to untreated plants.

Table 10. Mean values of technological characters of fiber as affected by growth regulators during 2019 and 2020 seasons.

Growth regulators	Fiber length (mm)	Fiber fineness (Micronaire reading)	Fiber strength (Pressley index)	Uniformity index (%)
	2019 season			
Control	32.85	4.59	10.30	84.81
Kinetin	33.11	4.55	10.70	85.48
NAA	33.58	4.50	11.00	86.10
MC	33.25	4.46	10.54	85.14
MC+ Kinetin	33.38	4.51	10.76	85.43
MC+NAA	32.96	4.46	11.13	85.51
LSD 0.05	0.59	0.08	0.37	0.50
	2020 season			
Control	31.70	4.56	10.21	83.96
Kinetin	31.54	4.49	10.49	84.30
NAA	32.51	4.44	10.80	85.10
MC	31.33	4.54	10.64	84.13
MC+ Kinetin	31.86	4.51	10.44	84.19
MC+NAA	31.84	4.41	11.01	84.31
LSD 0.05	0.57	0.08	0.26	0.63

C- Effect of the interaction

The interaction between the tested plant distribution patterns and growth regulators was found to be significant in the two seasons for light intensity (lux) and light intensity % (Fig 1), root dry weight and total dry weight/ plant (Fig 2), number of open bolls/plant, seed cotton yield/plant and seed cotton yield/fed (Fig 3) as well as oil and protein yields/fed (Fig 4). This means that the cotton plants differed in their response to growth regulators from plant distribution pattern to another for these traits. However, the rest characters studied herein were not significantly affected by the interaction between the two tested factors, consequently the data were excluded.

The data illustrated in Fig 1 showed that sowing two plants / hill, 25 cm apart in both ridges of beds 140 cm width (D3 pattern) and foliar application with growth regulators namely MC at 80 DAS followed by NAA at 95 DAS is the best interaction treatment to obtain the highest values of light intensity (900 and 960 lux) and light intensity % (10.36 and 11.05 %) at 110 DAS in the first and second seasons, respectively. This means that D3 was the most suitable one for increasing the light penetration within the plant canopy especially when the plants were sprayed with MC + NAA more than the other tested plant distribution patterns and growth regulators. On the other hand, sowing one plant/hill, 12.5 cm apart in one ridge of furrows 70 cm width (pattern D2) without any growth regulators application (control) produced the lowest values (470 and 410 lux) for light intensity and (5.41 and 4.72%) for light intensity %, in the first and second seasons respectively. This reduction in the light intensity may be due to the decrease in the distance between furrows (70 cm) and hills (12.5 cm) presented in plant distribution pattern (D2) led to a decrease in the amount of light to plant canopy especially under without application of any growth regulators.

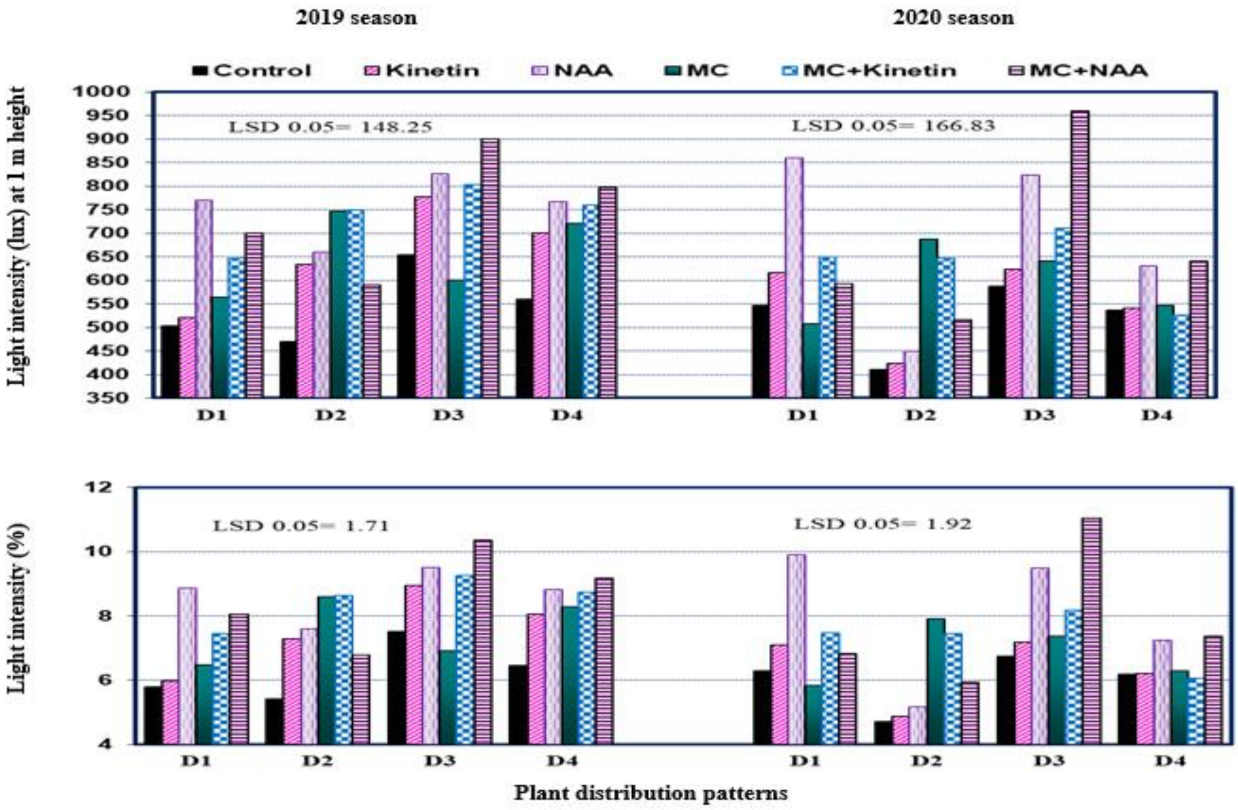

Figure 1. Effect of the interaction between plant distribution and growth regulators on light intensity (lux) and light intensity (%) at 110 DAS during 2019 and 2020 seasons.

D1: Sowing in furrows (70 cm width), in one ridge, with 25 cm between hills and two plants / hill.
D2: Sowing in furrows (70 cm width), in one ridge, with 12.5 cm between hills and one plant / hill.
D3: Sowing in beds (140 cm width), in the two ridges, with 25 cm between hills and two plants / hill.
D4: Sowing in beds (140 cm width), in the two ridges, with 12.5 cm between hills and one plant / hill.

The data graphically in Fig 2 showed the effect of the interaction between the tested plant distribution patterns and growth regulators on root and total dry weights/plant at 110 DAS in 2019 and 2020 seasons. The data reveal that the foliar application of any tested growth regulators caused an increase in the both traits compared to untreated plants (control) under all experienced plant distribution patterns in both seasons. The highest values of root dry weight/plant (16.72 and 18.76 g) were obtained when the plants were sown at pattern D3 and foliar applicated with MC + Kin in the first and second seasons, respectively. However, plants sown at pattern D3 and sprayed with MC + NAA produced the highest values of total dry weight/plant (145.11 and 165.38 g) in the first and second seasons, respectively. The superiority of both traits under such interaction treatments may be due to the increase in the amount of light to plants vegetation as well as leaf area which increased the efficiency of photosynthesis and consequently increased the dry matter production of different plant organs. On the other hand, untreated plants with any tested growth regulators (control treatment) produced the minimum values of such traits when the plants were sown at plant distribution patterns D1 for root dry weight, and D2 for total dry weight/plant in the both seasons, The inferiority of those traits may be due to the decrease in the distance either between furrows (D1 and D2) which increased in the intra competition between the plants on the light, water and the essential nutrients and consequently decreased the dry matter production/plant especially in absence of the growth regulators. In this respect, Mahdi (2016) found that the highest value of total dry weight /plant was obtained when cotton plants were sown at hill spacing of 25 cm and treated with 50 mg MC /L compared to other combinations between hill spacing (15 and 20 cm) and MC concentrations (100 and 150 mg/L).

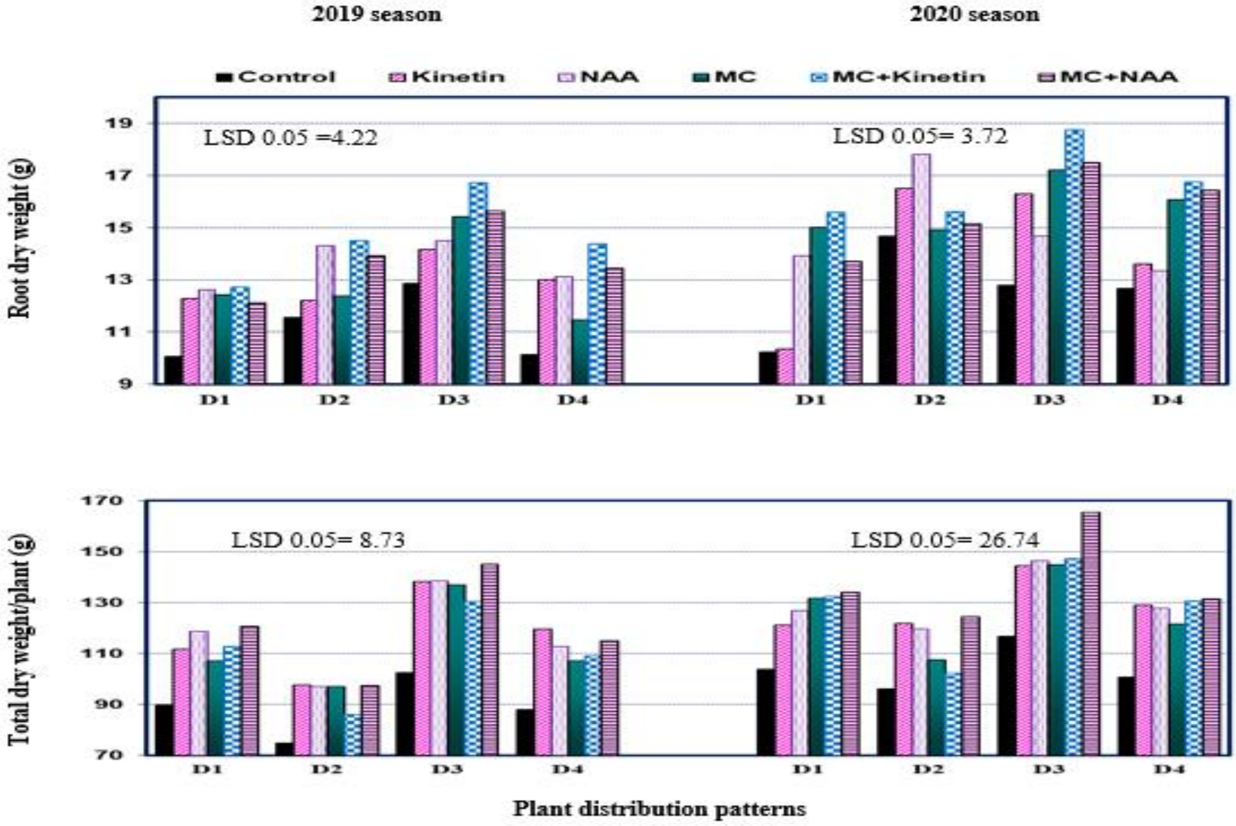

Figure 2. Effect of the interaction between plant distribution patterns and growth regulators on root and total dry weights/plant at 110 DAS during 2019 and 2020 seasons.
(D1, D2, D3 and D4: see Fig 1)

The data in Fig 3 showed that the highest values of open bolls / plant (23.72 and 32.53), seed cotton yield / plant (61.23 and 67.43 g) and seed cotton yield / fed (12.66 and 14.43 kentar) were obtained when the plants were grown in beds (140 cm width) in the two ridges with 25 cm between hills and two plants / hill (D3 pattern) and sprayed with growth regulators MC + NAA in the first and second seasons, respectively. This means that the dual application of MC with NAA showed an additive effect on seed cotton yield especially under wide spacing between the beds and hills (D3 pattern) rather than their separately application. The reason for the superiority of seed cotton yield / fed under such interaction treatment (D3 x MC+NAA) may be due to the increase in the light intensity (Fig 1), dry matter production (Fig 2) as well as number of open bolls and seed cotton yield / plant (Fig 3). On the other hand, the interaction treatment of growing plants in plant distribution D2 pattern without foliar application of any growth regulators (control) produced the lowest values of open bolls number/plant (17.33), seed cotton yield/plant (41.58) as an average of both seasons. In this concern, Mahdi (2016) found that the highest value of the number of open bolls/plant, seed cotton yield/fed were obtained when the plants were sown in hills 25 cm apart and sprayed with MC at a rate of 150 mg/L) compared to other combinations between hill spacing (15 and 20 cm) and MC concentrations (50 and 100 mg/L). Moreover, Hasab and Al-Naqeeb (2019) found that the highest values of number of open bolls/plant and seed cotton yield/plant were obtained by planting one plant/hill and spraying pix (mepiquat chloride) at beginning of flowers appearance. However, the highest seed cotton yield/ha was recorded by planting two plants/hill and spraying pix.

The data illustrated in Fig 4 showed that the cotton plants which were sowing in beds (140 cm width) in the two ridges with distance of 25 cm between hills and two plants per each hill (D3 pattern) and sprayed with growth regulators (MC+NAA) produced the highest values of oil yield (351.00 and 384.48 kg/ fed) and protein yield (377.24 and 410.29 kg/ fed) in the first and second seasons, respectively. This means that the favorable effect of growth regulators namely MC and NAA for increasing oil and protein production/fed were more pronounced when the plants were grown and arranged in D3 plant distributed pattern. The superiority of protein and oil yields/fed obtained by such interaction treatment may be due to the significant increase in seed cotton yield/fad as show previously in Fig 3. However, it can be noted that the lowest values of oil yield (198.78 and 208.81 kg/fed) and protein yield (229.28 and 223.45 kg/fed) in the first and second seasons, respectively were obtained by sowing cotton plants in furrows (70 cm width) in one ridge with distance of 12.5 cm between hills and one plant per each hill (D2 pattern) and without foliar application of any growth regulators (control). In this concern, Mahdi (2016) found that cotton plants grown in wide spacing between plants (25 cm) and treated with MC at a rate of 150 mg/L exhibited significant increases in oil and protein content as compared to other combination treatments between plant spacing (15 and 20 cm) and MC levels (50 and 100 mg/L).

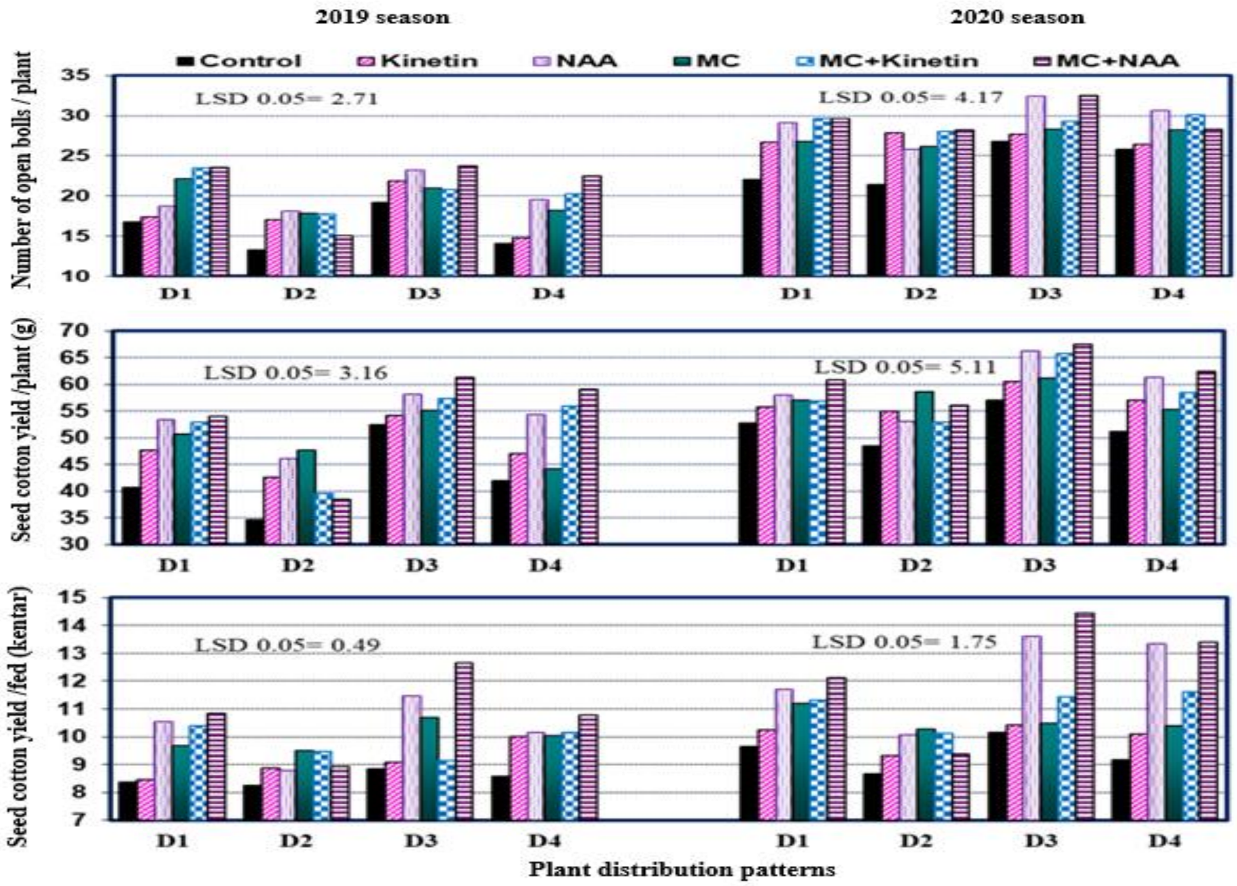

Figure 3. Effect of the interaction between plant distribution patterns and growth regulators on number of open bolls / plant and seed cotton yield /plant and fed during 2019 and 2020 seasons.
(D1, D2, D3 and D4: see Fig 1)

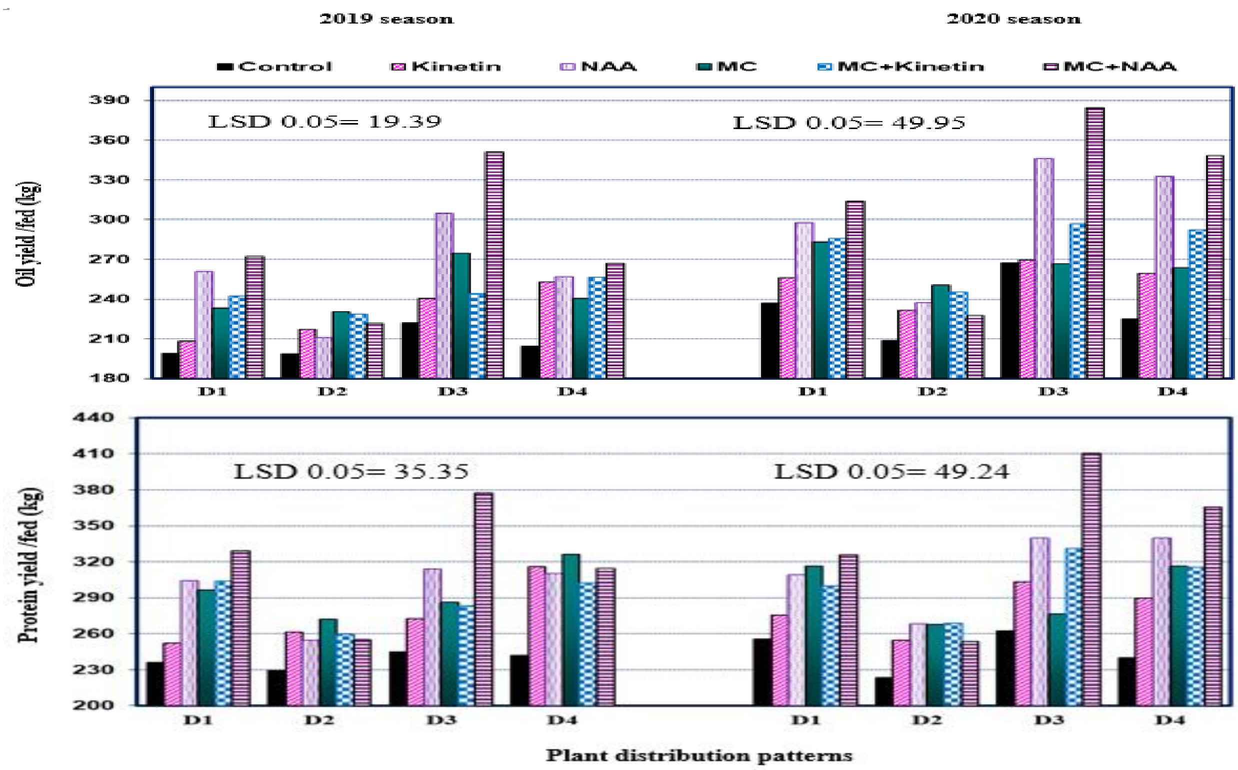

Figure 4. Effect of the interaction between plant distribution patterns and plant growth regulators on oil yield /fed and protein yield /fed during 2019 and 2020 seasons.
(D1, D2, D3 and D4: see Fig 1)

CONCLUSION

Finally, on the light of the obtained interaction results, it can be concluded that cotton yield is associated with good management practices that provide better plant canopy. Alterations of plant canopy that allow more light permeation into the lower depths of the canopy may be a way to increase cotton yield. It may be possible to use plant growth regulators either single or dual application to modify plant performance in desirable ways. Sowing cotton plants (Giza 86 cv.) in beds (140 cm width) in the two ridges with wide plant spacing between hills (25 cm) in presence of two plants /hill (D3 pattern) associated with foliar application of growth regulators (MC+NAA) was the most effective treatment for increasing the seed cotton yield (12.66 and 14.43 kentar/fed), oil yield (351.00 and 384.48 kg/ fed) and protein yield (377.24 and 410.29 kg/ fed) during both growing seasons compared to the other combination treatments under the environmental conditions of this study.

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تأثير نظم توزيع النباتات ومنظمات النمو على الصفات المورفولوجية والمحصولية والتكنولوجية للقطن المصري

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أجريت تجربة حقلية بالمزرعة البحثية لكلية الزراعة- جامعة المنوفية بشبين الكوم- مصر لدراسة تأثير نظم توزيع النباتات وهى النظام الاول (زراعة النباتات على خطوط عرض 70 سم على ريشة واحدة من الخط وعلى مسافة 25 سم بين الجور ونباتين بالجورة) والنظام الثانى (زراعة النباتات على خطوط عرض 70 سم على ريشة واحدة من الخط وعلى مسافة 12.5سم بين الجور ونبات واحد بالجورة) والنظام الثالث (زراعة النباتات على مصاطب عرض 140سم على ريشتى المصطبة وعلى مسافة 25سم بين الجور ونباتين بالجورة) والنظام الرابع (زراعة النباتات على مصاطب عرض 140سم على ريشتى المصطبة وعلى مسافة 12.5سم بين الجور ونبات واحد بالجورة) مع الرش ببعض منظمات النمو (الكنترول للمقارنة ، الكينتين مرتين بمعدل 15جزء فى المليون فى كل مرة ، والنفثالين أسيتك أسيد مرتين بمعدل 15 جزء فى المليون فى كل مرة ، والميبكوات كلورايد مرتين بمعدل 100 جزء فى المليون فى كل مرة ، والميبكوات كلورايد ثم الكينتين ، والميبكوات كلورايد ثم النفثالين أسيتك أسيد) عند عمر 80 و 95 يوم من الزراعة على صفات شدة الإضاءة ، الصفات المورفولوجية ، التزهير والتساقط ، المحصول ومكوناته ، التركيب الكيماوى للبذور ، الصفات التكنولوجية لألياف القطن المصرى (صنف جيزة 86) خلال موسمي الزراعة 2019 ، 2020. وقد خلصت نتائج الدراسة إلى تفوق زراعة نباتات القطن بالنظام الثالث لتوزيع النباتات عن باقى نظم التوزيع المختبرة فى معظم الصفات المدروسة فى حين أدى زراعة النباتات بالنظام الأول إلى زيادة طول النباتات مع تقليل نعومة الألياف. وعلى الجانب الآخر لم تتأثر معنويًا عدد البراعم الزهرية للنبات ، ووزن اللوز ، ودليل البذور ، متانة ومعدل إنتظام الألياف بنظم توزيع النباتات المختبرة. أثرت الاضافة المنفردة أو المزدوجة لمنظمات النمو المختبرة تأثيرا إيجابيا على معظم الصفات المدروسة. أدى رش النباتات بمنظمات النمو (النفثالين أسيتك أسيد) ، (الميبكوات كلورايد + النفثالين أسيتك أسيد) إلى زيادة معظم الصفات المدروسة. هذا وقد سجلت النباتات غير المعاملة أعلى القيم للنسبة المئوية للتساقط الكلى. هذا ويمكن التوصية بزراعة نباتات القطن بالنظام الثالث مع الرش الورقى بمنظمات النمو (الميبكوات كلورايد بمعدل 100 جزء فى المليون عند عمر 80 يوم من الزراعة ثم الرش بالنفثالين أسيتك أسيد بمعدل 15 جزء فى المليون عند عمر 95 يوم من الزراعة) لتحقيق أعلى القيم لصفات شدة الإضاءة ، الوزن الجاف الكلى للنبات ، عدد اللوز المتفتح/نبات ، محصول القطن الزهر للنبات والفدان ، محصول الزيت للفدان ، ومحصول البروتين للفدان وذلك مقارنة بمعاملات التفاعل الأخرى المختبرة.