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N AND P FERTILIZATION MANAGEMENT AND THEIR EFFECTS ON GROWTH, PRODUCTIVITY AND QUALITY OF COTTON CV. SUPER GIZA 86

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ABSTRACT: A field experiment was executed at El-Gemmeiza Agricultural Research Station, El-Gharbia Governorate, Egypt, in 2019 season and repeated in 2020 season to study the effects of N**,** P fertilization and their interaction on cotton cv. Super Giza 86 (*Gossypium barbadense*, L.). A strip plot design was used with three and four replications in the two growing seasons, respectively. The obtained results indicated that two equal N splits significantly increased growth measurements, flowering and bolls retention measurements (except percentage of bolls shedding which was reduced), yield of seed cotton/feddan and its contributary traits (open bolls number /plant, weight of boll, seed cotton yield /plant, lint percentage and earliness index) and length uniformity index in the two growing seasons as well as seed index and length of fiber in one season. However, length of fiber increased in the second season in favour of four equal N splits. Fiber strength and fineness were not affected.

Sources of P application when used in combination or foliar spraying with 5 cm^3 organic phosphorus [Pro Phos™ 0-20-0]/L twice significantly increased growth measurements, seed cotton yield/feddan and its contributed traits in the two growing seasons. Foliar spraying with 5 cm^3 organic phosphorus [Pro Phos™ 0-20-0]/L twice significantly increased number of total bolls set/plant, number of total flowers/plant and bolls retention% in both seasons, fiber length and uniformity index in the first season. However, bolls shedding% was decreased. Sources of P application when used in combination gave the highest values of micronaire reading and fiber strength in one season. However, foliar spraying with 1.5 cm^3 phosphoric acid /L twice recorded a significant increase in fiber strength in the first season. Fiber length, uniformity index and micronaire reading were not affected in the second season.

Two equal N splits combined with P sources used combination or with foliar spraying with 5 cm^3 organic phosphorus [Pro Phos™ 0-20-0]/ L twice gave the best results. Therefore, the farmers can use either of the two interaction treatments to rise cotton output and fiber quality particularly in vigour's cultivar of cotton (Super Giza 86) under the environmental conditions like El-Gemmeiza area.

Key words: Seed cotton; spraying; P source; Splitting N; Timing of N addition.

INTRODUCTION

Egyptian cotton occupies a distinguished position because of its quality characteristics, stability, and popularity in the markets. It is the mainstay of the textile industry in Egypt, oil, and animal food production. The use of fertilizers as an efficient mean to supply cotton with necessary nutrients is the major cost component in cotton cultivation. It is account for 50% of the cotton growing cost. Lopsided use of chemical fertilizer is a problem in cotton production. Suitable nutrient management is necessary to maximize cotton output and sustain agricultural production while reducing passive effects on the soil productivity. Nitrogen (N) is a vital nutrient for the growing and development of cotton plant. Urea is an ordinary fertilizer that is widely, and ideal N carrier for application because it contains high percentage of N (46%), uptake, metabolism, and translocation rapidly after its application. Split N application is one avenue to promote N utilization by the crop and reduce the nutrient loss through leaching and volatilization. Gospodinova and Panayotova (2019) found that about 33% of N fertilizer is absorbed, 25% stays in the soil at maturity, and the remainder (about 42%) is lost

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from the system. Nitrogen feeding is an important agent to increase the yield of cotton and fiber quality. Future elevated CO_2 will not have any adverse impacts on quality of cotton fiber if nitrogen is optimum (Reddy *et al*., 2004). There is a constant need to know the optimal time for the nitrogen application. There is an essential need to improve strategy of N management for cotton that will not only improve N utilization efficiency but also reduce the possibility of nitrogen leaching. Timing of fertilizer addition and number of its splits are low-cost strategies for minimizing nutrient leaching so that nutrient supply coincides with plant nutrient demand. Cotton is a long duration crop with an indefinite growth habit. The period of nutrient supplementation of splits can be increased, which provides a significant amount of time from square formation to development of boll. So, an effective nutrient management program is the key in the light of the passive nutrient equilibrium. The pattern of nutritional supplementation by split application becomes important because it is ideally supplied at the time when crop is critically needed. Weaver *et al*. (2022) found that differing N timing (single or split) did not affect yield and indicated that sufficient mineralization was occurring. Subsequent applications of N are not critical when levels are sufficient and mineralization occurs, highlighting the need for N sampling with plant-based techniques to avoid over-fertilization and to improve efficiency.

Fertilizers of P are closely fixed in the soil especially in alkaline soils. Plants seldom absorb about 20% of the phosphorus used. Generally, ~ 20-30 percent of the P fertilizer applied is used by the crop in the year of application, and the remaining P in the soil will be bound up and may be used for later. Plants need P to grow throughout their life cycle, especially during the early growth and development stages. Grant *et al*. (2001) reported that since P will not stir through the soil, it must be put in a posture which make the roots of plant can absorb it early in the season. During early season growth, an adequate supply of P is crucial in obtaining maximum yield under field conditions. Therefore, the use of a P-dissolving microorganism may promote the efficiency of plants to utilize P from the soil. Aimen *et al.* (2022) concluded that fertilizer recommendation must include the evaluation of soil properties for better response to the applied fertilizer. Nachimuthu *et al*. (2022) reported that cotton roots depend on the topsoil (0~20 cm) as important source of available water and P to plant, where P fertilizer is added. Soil P depletion in the subsoil is higher than in the topsoil. This conflict between P uptake zones and resupply may increase available P stratification in the soil profile. Quayle (2018) mentioned the advantages to soil of P during the growing season either via the transformation of organic P to mineral P from manure or from the liberate of P from other mineral sources.

The present study was undertaken to assess the influence of N splitting number and its addition timings as well as P sources, timing and method of application and their interaction on growth, flowering and bolls retention, productivity, and fiber quality of vigour's cultivar of cotton like Super Giza 86 (*Gossypium barbadense*, L.).

MATERIALS AND METHODS

A field experiment was carried out at El-Gemmeiza Agricultural Research Station, El-Gharbia Governorate, Egypt, in 2019 season and repeated in 2020 season using the cotton cultivar Super Giza 86 (*Gossypium barbadense*, L.). A strip plot design was used with three and four replications in 2019 and 2020 seasons, respectively, where N splits number and its application timings occupied the horizontal plots. Nitrogen was added to the soil as urea $CO(NH_2)_2$ which contains 46% N at the recommended rate (45 kg N/fed) especially for Super Giza 86.

The N treatments examined as follows:

a_1- Two equal splits serving as a control. The first split application was done before the first irrigation (at 30 days after sowing "DAS") and the second split before the 2nd irrigation (at 45 DAS).

a_2- Three equal splits (at 30, 45 and 60 DAS). The first split application was done before the 1st irrigation (at 30 DAS), the second split before the 2nd irrigation (at 45 DAS) and the third split before the 3rd irrigation (at 60 DAS).

a_3- Four equal splits (at 30, 45, 60 and 75 DAS). The first split application was done before the 1st irrigation (at 30 DAS), the second split before the 2nd irrigation (at 45 DAS), the third split before the 3rd irrigation (at 60 DAS) and the fourth split before the 4th irrigation (at 75 DAS).

The vertical plots contained the following five treatments of phosphorus (sources, timing, and method of application):

b_1- Add calcium superphosphate (SP),15.5% P_2O_5 at the recommended rate of 22.5 kg P_2O_5 /fed. It was incorporated during seed bed preparation (serving as a control).

b_2- Seeds inoculation with 400 g bio-fertilizer (Phosphorein)/20 kg seeds per feddan at sowing (Bio-P). After sowing, the irrigation immediately done.

b_3- Foliar spraying with 1.5 cm^3 phosphoric acid H_3PO_4 [85%], (PA)/L twice [after thinning and six days after the third irrigation (at 66 DAS)].

b_4- Foliar spraying with 5 cm^3 organic phosphorus (OP) in the form of Pro Phos™ 0-20-0/L twice [after thinning and six days after the third irrigation (at 66 DAS)].

b_5- Combination of P sources used: add half dose of calcium superphosphate during seed bed preparation + inoculated seeds with bio-fertilizer (Phosphorein) at sowing + foliar spraying with 1.5 cm^3 phosphoric acid/L twice [after thinning and six days after the third irrigation (at 66 DAS)] + foliar spraying with 5 cm^3 organic phosphorus [Pro Phos™ 0-20-0]/L twice [at the squaring stage (45 DAS) and flowering initiation (80 DAS)].

Organic phosphorus (Ferticell® Pro Phos™ 0-20-0) derived from Rock Phosphate (20% P_2O_5) was used as foliar application. Ferticell® Pro Phos™ 0-20-0 was confirmed to utilized for organic use, mineral sourced, liquid phosphorus fertilizer and designed to supply this main nutrient in an easily mineralizable form. Ferticell® Pro Phos™ 0-20-0 is used as micronization technology and algae extract components to work together to provide this necessary nutrient for the plant growth and productivity.

Foliar spraying with phosphoric acid and organic phosphorus [Pro Phos™ 0-20-0] using hand operated sprayer compressed at a low volume of 200 liter/fed. The upper leaf surface was sprayed until wetted as well as the lower leaf surface. Tween™ 20 (0.5%) as wetting agent was used.

The bio-fertilizer called Phosphorein used in the present study is commercial multi-strains of phosphorus dissolving bacteria. The inoculation of Phosphorein was performed by coating cotton seeds at the rate of 400 g Phosphorein/20 kg seeds per feddan using sticking substance (Arabic gum, 5%) just before sowing; cotton seeds were sown in dry soil and then immediately irrigated.

Soil samples represented the surface layer (0-30 cm depth) were taken from the experimental soil site in each season before ten days of sowing and prepared for analysis as described by Estefan *et al.* (2013). The soil of the experimental plots is classified as a clayey in texture, alkaline in reaction and had relatively high clay content. It had low salinity. Available P was ranged between low and medium as shown from the data of the soil analysis which presented in Table 1.

Seeds of cotton cultivar Giza 86 (*Gossypium barbadence*, L.) were obtained from CRI, ARC, Egypt and sown on 10/4/2019 and 14/4/2020 after Egyptian clover (*Trifolium alexandrinum,* L.) “berseem” in hills 25 cm apart, leaving 2 strong seedlings/hill at the time of thinning (28 DAS) to assure 48000 plant/feddan.

In the two growing seasons, the size of each sub plot was 19.6 m^2, (4 m x 4.9 m) included 7 rows of 70 cm wide and 4 meters long. The two outer rows were left to avoid border effect (the net size of each sub plot was 14 m^2). Standard cultural practices were done as recommended by CRI, ARC, Egypt for traditional cotton seeding in the local production area. Potassium fertilizer was added as potassium sulphate (48% K_2O) at a rate of 24 kg K_2O/fed in one dose before the first irrigation.

Table (1): The particulars of the experimental soil site in 2019 and 2020 seasons.

Particulars	Optimal Value (Ankerman and Large, 1974)	Season	
		2019	**2020**
Mechanical analysis			
Clay%		44.2	48.60
Silt%		33.0	31.20
Sand%		22.8	20.20
Soil texture		Clayey	Clayey
Chemical analysis			
pH using an automated pH analyser	6.7-7.3	8.1	7.9
EC (ds/m at 25 ˚C) using electrical conductivity meter	1.5	0.99	0.64
Organic matter %	2.6-3	1.40	1.25
Total N (mg/100g)	30-60	49.00	43.75
Available macronutrients (mg/100g):			
P	1.2-2.7	1.28	0.96
Exchangeable K	21-30	31.0	20.0
Mg	30-180	23	20
Available micronutrients (ppm)			
Fe	10-16	12.4	10.7
Mn	8-12	3.9	3.1
Zn	1.5-3.0	1.12	1.20
Cu	0.8-1.2	1.7	0.9

Studied characters

Ten representative plants were taken at random from the second row of each sub-plot, labelled and numbered to record some of the following observations:

I. Growth measurements

At 90 DAS (after 10 days from the last treatment application), six plants of three guarded hills were taken from each sub-plot carefully. Samples were transferred to the laboratory and separated into different organs after removing their roots. The different plant organs were washed, and dried in an electric oven to a constant weight at 70 C^0 where their dry weights were obtained as an expression of total dry weight of plant above ground (g). Leaf area index (LAI) as total area of leaves on the plant per area of land occupied by the plant according to Hunt (1978). Final height of the cotton plant from the two cotyledonary nodes to the terminal bud (cm) and number of fruiting branches/plant were obtained from the ten tagged plants at harvesting.

II. Flowering and bolls retention% measurements

The following measurements were determined from the ten tagged plants: 1- Number of total flowers/plant (Kadapa, 1975). 2- Number of total bolls set/plant. 3-Bolls retention (setting) as percentage of number of total bolls set/plant to number of total flowers/plant. 4- Percentage of bolls shedding as 100-bolls retention% (Richmond and Radwan, 1962).

III. Yield of seed cotton/feddan and its contributory traits

Data were taken from the 10 tagged plants to estimate the following yield contributory traits at harvest: 1-Open bolls number/plant by counting it before the first and the second pickings. 2- Yield of seed cotton per plant as an average of the yield of the tagged plants in grams. 3-Average weight of boll (g) by dividing the yield of seed cotton/plant on respective number of its open bolls. 4-Lint percentage as percentage of lint cotton to seed cotton after ginning. 5-Seed index (weight of 100 cotton seeds in grams). 6- The seed cotton yield/feddan was hand-picked two times from the five inner rows of each sub-plot (net sub-plot size = 14 m^2) in kilograms and transformed to kentars per feddan (one feddan=4200.83 m^2 and one kentar =157.5 kg).7-Earliness index was determined as percentage of the first pick yield to total yield of the two pickings.

IV. Fiber quality traits

Fiber tests were made according to A.S.T.M. (2012) at the CRI laboratories, ARC, Giza, Egypt. Fiber traits included: a)- Upper half mean length (mm) and uniformity index (%) using fibrograph instrument. b)- Micronaire reading (a combined measure of fiber fineness and maturity) measured by micronaire apparatus. c)-Strength of fiber as Pressley index, using Pressley tester.

Statistical analysis

The obtained data collected were subjected to statistical analysis as outlined by Le Clerg *et al.* (1966). Whenever, the results were found to be significant, the means were compared using Duncan's Multiple Range Test (DMRT) at 0.05 level of probability (Duncan, 1955), where in Tables 2 to 9 means in the same column, under the same trait which designated by the same letter are not significantly different.

RESULTS AND DISCUSSION

I-Growth measurements

I.1. Effect of N splits number and its application timings

Leaf area index and total dry weight of plant above ground (g) at 90 DAS, final plant height (cm) and its number of fruiting branches at harvesting were differed significantly by different splits of N application in the two growing seasons (Tables 2 and 3). Addition of N fertilization in two equal splits recorded the best results in this respect. It was followed by the addition of N fertilization in three and four equal splits, respectively. These results may be due to the low leaching of N fertilizer system. Moreover, the two splits may help cotton plants to meet their requirements through the early growth stages. Thus, the addition of N fertilization in two different periods corresponding to the growth stages of the plant, was the better application.

In this concern, Hallikeri *et al.* (2010) stated that N fertilization of cotton should applied in two different periods corresponds to the stages of plant growth. They added that four equal splits of N fertilization provide enough time for nitrogen to become unavailable form, but in this case, there is a greater risk of N loss, particularly in low temperatures or heavy rain and delayed N supply can cause excessive vegetative growth and delayed maturation. This delayed supply should only be applied in soils with low N reserves and under irrigation conditions. During the early growth stages, cotton's requirements of this nutrient are much higher, due to the greater ability of roots and shoots to assimilate and accumulate to meet the future needs (Ahmed *et al.*, 2016). Nitrogen (N) is the most plentiful essential mineral in plants, accounting for 1.5% to 2% dry matter in plants and about 16% plant protein (Frink *et al*., 1999). Knowles *et al.* (1993) found that addition of nitrogen fertilizer in splits supply an adequate amount of nitrogen during the growing season without increasing nitrogen fertilizer losses by denitrification and/or leaching. Arain *et al.* (2001) found that addition of N fertilizer in one dose significantly reduced height of plant in contrast to use it in splits. Split addition of nitrogen fertilizer significantly increased plant height (Soomro *et al*., 2001). Jat and Nanwal (2013) found that the maximum plant height and its sympodia number were obtained from splitting fertilization into three split applications of N fertilizer as compared with two split applications. On the other hand, Darwish *et al*. (1999) found that number of N application timings had insignificant effect on final plant height and its number of fruiting branches. Insufficient nitrogen supply at improper time usually affects the processes of cotton growth and development, resulting in decreased values of leaf area index (LAI), concentration of leaf chlorophyll, photosynthetic rate, and production of biomass (Zhao and Oosterhuis, 2000), in addition to lower yield of lint and inferior fibre quality (Reddy *et al*., 2004).

I.2. Effect of P sources, timing and method of application

Leaf area index and total dry weight of plant above ground (g) at 90 DAS, final plant height (cm) and number of fruiting branches/plant at harvesting were differed significantly due to the tested P application treatments in both seasons

Table (2): Effect of N splits number and its application timings as well as P sources, timing and method of application and their interaction on certain growth measurements of cotton grown in 2019 season.

Treatments \ Traits		Total dry weight of plant above ground (g)	LAI	Final plant height (cm)	Fruiting branches number per plant
		at 90 DAS		at harvesting	
A- N splits number and its application timings:					
a_1- 2 equal splits at 30 and 45 DAS (control)		86.37 a	2.98 a	166.48 a	15.58 a
a_2- 3 equal splits at 30, 45 and 60 DAS		79.18 b	2.87 b	162.55 b	14.38 b
a_3- 4 equal splits at 30, 45, 60 and 75 DAS		73.56 c	2.79 c	159.59 c	14.09 b
F-test		*	*	*	*
B- P sources, timing and method of application:					
b_1-SP during land preparation (control)		76.92 d	2.89 c	163.33 b	14.23 c
b_2- Bio-P covers the seeds before sowing		71.79 e	2.54 d	156.88 c	13.56 d
b_3- Spraying PA at 28 and 66 DAS		79.90 c	2.94 bc	163.72 b	14.54 c
b_4- Spraying OP at 28 and 66 DAS		83.72 b	2.99 ab	164.54 b	15.06 b
b_5- Combination of P sources used		86.18 a	3.02 a	165.89 a	16.02 a
F-test		*	*	*	*
A x B interaction:					
a_1	b_1	80.44 de	3.07 ab	166.83 abc	15.33 cd
	b_2	79.24 ef	2.56 e	159.63 fg	14.23 e
	b_3	85.61 c	3.06 ab	167.93 ab	15.67 bc
	b_4	92.25 b	3.07 ab	169.33 a	16.00 b
	b_5	94.30 a	3.11 a	168.67 ab	16.67 a
a_2	b_1	78.17 f	2.85 c	163.70 cd	13.67 f
	b_2	71.75 i	2.48 f	157.77 g	13.50 f
	b_3	79.42 ef	2.89 c	162.67 def	14.00 ef
	b_4	81.99 d	3.00 b	162.97 def	14.97 d
	b_5	84.59 c	3.10 a	165.67 bcd	15.77 bc
a_3	b_1	72.17 i	2.74 d	159.47 f g	13.70 ef
	b_2	64.39 j	2.59 e	153.23 h	12.93 g
	b_3	74.66 h	2.85 c	160.57 ef	13.97 ef
	b_4	76.92 g	2.89 c	161.33 ef	14.20 e
	b_5	79.65 ef	2.86 c	163.33 de	15.63 bc
F-test		*	*	*	*

* = significant at 0.05 level of probability.

Table (3): Effect of N splits number and its application timings as well as P sources, timing and method of application and their interaction on certain growth measurements of cotton grown in 2020 season.

Treatments \ Traits		Total dry weight of plant above ground (g)	LAI	Final plant height (cm)	Fruiting branches number per plant
		at 90 DAS		at harvesting	
A- N splits number and its application timings:					
a_1- 2 equal splits at 30 and 45 DAS (control)		93.49 a	3.19 a	166.71 a	16.45 a
a_2- 3 equal splits at 30, 45 and 60 DAS		87.11 b	3.02 b	158.65 b	14.91 b
a_3- 4 equal splits at 30, 45, 60 and 75 DAS		83.38 c	3.00 b	156.51 c	14.99 b
F-test		*	*	*	*
B- P sources, timing and method of application:					
b_1-SP during land preparation (control)		84.78 d	3.07 b	159.46 d	15.33 b
b_2- Bio-P covers the seeds before sowing		79.38 e	2.81 c	160.23 c	14.09 c
b_3- Spraying PA at 28 and 66 DAS		88.44 c	3.09 b	160.23 c	15.47 b
b_4- Spraying OP at 28 and 66 DAS		92.49 b	3.20 a	161.14 b	16.03 a
b_5- Combination of P sources used		94.85 a	3.20 a	162.04 a	16.32 a
F-test		*	*	*	*
A x B interaction:					
a_1	b_1	86.98 d	3.23 b	162.88 d	16.48 b
	b_2	85.69 e	2.94 f	167.75 b	14.95 ef
	b_3	93.15 b	3.15 c	165.55 c	16.28 bc
	b_4	100.05 a	3.32 a	167.33 b	17.65 a
	b_5	101.58 a	3.34 a	170.03 a	16.88 b
a_2	b_1	85.74 e	2.97 ef	160.15 e	14.40 f
	b_2	79.25 g	2.81 g	156.83 i	13.68 g
	b_3	87.47 d	3.09 cd	159.33 ef	14.93 ef
	b_4	90.32 c	3.15 c	158.18 gh	15.88 cd
	b_5	92.76 b	3.10 c	158.75 fg	15.68 de
a_3	b_1	81.64 f	2.99 ef	155.35 j	15.13 e
	b_2	73.21 h	2.68 h	156.13 ij	13.65 g
	b_3	84.71 e	3.03 de	155.80 j	15.20 e
	b_4	87.10 d	3.14 c	157.93 h	14.55 f
	b_5	90.22 c	3.16 c	157.35 h	16.40 bc
F-test		*	*	*	*

* = significant at 0.05 level of probability.

(Tables 2 and 3). Combination of half dose of calcium superphosphate during land preparation+ seeds inoculation with bio-fertilizer (Phosphorein) at sowing+ foliar spraying with 1.5 cm^3 phosphoric acid/L twice [after thinning and six days after the third irrigation (at 66 DAS)] + foliar spraying with 5 cm^3 organic phosphorus [Pro Phos™ 0-20-0]/L twice [at the squaring stage (45 DAS) and flowering initiation (80 DAS)] gave the best results in this respect. It was followed by treated plants with foliar spraying with 5 cm^3 organic phosphorus [Pro Phos™ 0-20-0]/L twice [after thinning and six days after the third irrigation (at 66 DAS)]. The minimum values of growth parameters resulted from inoculated seeds with 400 g bio-fertilizer (Phosphorein)/20 kg seeds per feddan at sowing.

The proper effect of using the combination of the four P treatments on growth measurements is mainly due to the following: 1- The useful effect of P on root formation proliferation and growth. 2-The direct stimulation effect of P on cellular activities and efficient translocation of certain growth stimulating compounds to the roots. Phosphorus as a component of the cell nucleus is necessary for cell division and meristematic tissues development, and therefore will have a stimulating effect on the increase in the leaf area. Seed inoculation with bio-fertilizer (Phosphorein) increased phosphorous availability in cotton crop and this maximized nitrogen absorption resulting in enhanced cell growth and expansion. Photosynthesis process, transfer of energy, division and enlargement of cell, formation and growth of root required P. Phosphorus improves water use and consequently improves growth resulting in taller plant. It is the component of cell nucleus and is needful for meristematic tissues formation and division of cell (Tisdale *et al*., 1993). Phosphorus plays an important function in the pyridoxal formation which is necessary for chlorophyll biosynthesis and conversion of CO_2 into sugar (Uchida, 2000). Phosphorus, which is a component of cell nucleus is also necessary for cell division and meristematic tissue development, and therefore will have activating impact on further plant growth. Also, P is needed in great amounts in young cells, like shoots and root tips, where metabolism is high and cell division is fast. Since the sympodial branches grow in an acropetal pattern thus, as the plant height was greater, the greater number of sympodial branches per plant will also be. Phosphorus lacks leads to a decrease in the expansion rate of leaf and photosynthesis per unit leaf area (Mai *et al*., 2018). Higher P supply increased cell expansion by increasing hydraulic conductivity within plants, which could lead to increased plant size and leaf area expansion. The dry matter cumulation was higher due to better photosynthesis, which improved photosynthetic supply and assimilation to the fruit, where a high supply of P favoured nitrogen and potassium and photosynthates transmission towards the reproductive parts rather than vegetative organs. In this concern, optimizing the supply of P in cotton crop will eventually improve the plant growth as LAI rises (Arya and Singh, 2001), more leaves protraction, increased light objection, increased plant height, and promoted the sympodial branches. Ahmad *et al.* (2020) indicated that addition of phosphorous significantly improved cotton growth in articulation of leaf area index, height of plant and its nodes number. Ali *et al*. (2020) reported that reducing availability of phosphorous reduced growth of the cotton plant.

I.3. Effect of the interaction treatments

Data in Tables 2 and 3 showed that, the highest values of leaf area index and total dry weight of plant above ground (g) at 90 DAS, final plant height (cm) and its number of fruiting branches at harvesting were obtained from splitting N in two equal doses combined with the mixture of different P sources or with foliar spraying with organic P twice.

II. Flowering and bolls retention measurements

II.1. Effect of N splits number and its application timings

Results in Tables 4 and 5 indicated that number of total bolls set/plant, number of total flowers/plant and bolls retention% were increased significantly in both seasons, with a favour of the addition of N fertilization in two equal splits.

However, bolls shedding% was significantly reduced. An increase in sympodial branches number may lead to an increase in the bolls number, where superior sympodial branches observed with two N splits, but significantly lower sympodial branches were observed from three and four equal splits of N fertilization. Nitrogen (N) is a key nutrient element restricting cotton production. The lack of nitrogen from the seedling emergence to the beginning of flowering leads to insufficient vegetative growth, which leads to a decrease in fruiting (Sattar *et al*., 2017). Darwish *et al*. (1999) found that number of N addition timings had insignificant impact on total bolls number set/plant in both seasons.

Table (4): Effect of N splits number and its application timings as well as P sources, timing and method of application and their interaction on flowering and bolls retention measurements of cotton grown in 2019 season.

Treatments \ Traits		Number of total flowers per plant	Number of total bolls set per plant	Bolls retention%	Bolls shedding%
A- N splits number and its application timings:					
a_1- 2 equal splits at 30 and 45 DAS (control)		26.59 a	17.08 a	64.16 a	35.84 b
a_2- 3 equal splits at 30, 45 and 60 DAS		25.99 b	14.26 b	54.85 b	45.15 a
a_3- 4 equal splits at 30, 45, 60 and 75 DAS		25.61 c	14.20 b	55.36 b	44.64 a
F-test		*	*	*	*
B- P sources, timing and method of application:					
b_1-SP during land preparation (control).		26.58 a	15.78 b	59.32 b	40.68 b
b_2- Bio-P covers the seeds before sowing		25.39 c	12.96 d	51.06 c	48.94 a
b_3- Spraying PA at 28 and 66 DAS		25.78 b	15.10 c	58.41 b	41.59 b
b_4- Spraying OP at 28 and 66 DAS		26.31 a	16.48 a	62.55 a	37.45 c
b_5- Combination of P sources used		26.26 a	15.58 b	59.29 b	40.71 b
F-test		*	*	*	*
A x B interaction:					
a_1	b_1	26.77 a	18.00 b	67.24 b	32.76 h
	b_2	25.67 d	14.10 g	54.93 fg	45.07 cd
	b_3	26.77 a	17.27c	64.51 c	35.49 g
	b_4	26.87 a	18.87 a	70.23 a	29.77 i
	b_5	26.88 a	17.17 c	63.90 cd	36.10 fg
a_2	b_1	26.40 abc	13.90 g	52.65 h	47.35 b
	b_2	25.60 d	11.90 i	46.48 i	53.52 a
	b_3	25.87 d	14.83 f	57.33 e	42.67 e
	b_4	26.07 bcd	16.10 d	61.76 d	38.24 f
	b_5	26.00 bcd	14.57 fg	56.04 ef	43.96 de
a_3	b_1	26.57 ab	15.43 de	58.07 e	41.93 e
	b_2	24.90 e	12.89 h	51.77 h	48.23 b
	b_3	24.70 e	13.19 h	53.40 gh	46.60 bc
	b_4	26.00 bcd	14.47 fg	55.65 fg	44.35 cd
	b_5	25.90 cd	15.00 ef	57.92 e	42.08 e
F-test		*	*	*	*

* = significant at 0.05 level of probability.

Table (5): Effect of N splits number and its application timings as well as P sources, timing and method of application and their interactions on flowering and bolls retention measurements of cotton grown in 2020 season

Treatments \ Traits		Number of total flowers per plant	Number of total bolls set per plant	Bolls retention%	Bolls shedding%
A- N splits number and its application timings:					
a_1- 2 equal splits at 30 and 45 DAS (control)		27.20 a	17.17 a	62.94 a	37.06 c
a_2- 3 equal splits at 30, 45 and 60 DAS		25.24 b	14.58 b	57.74 c	42.26 a
a_3- 4 equal splits at 30, 45, 60 and 75 DAS		24.83 c	14.76 b	59.44 b	40.56 b
F-test		*	*	*	*
B- P sources, timing and method of application:					
b_1-SP during land preparation (control)		25.69 b	16.02 b	62.21 a	37.79 c
b_2- Bio-P covers the seeds before sowing		24.70 c	13.38 c	54.23 c	45.77 a
b_3- Spraying PA at 28 and 66 DAS		25.64 b	15.83 b	61.63 a	38.37 c
b_4- Spraying OP at 28 and 66 DAS		26.40 a	16.53 a	62.37 a	37.63 c
b_5- Combination of P sources used		26.36 a	15.77 b	59.76 b	40.24 b
F-test		*	*	*	*
A x B interaction:					
a_1	b_1	27.63 b	17.99 b	65.11 b	34.89 h
	b_2	25.28 e	13.67 i	54.07 h	45.93 b
	b_3	27.23 bc	17.57 bc	64.52 b	35.48 h
	b_4	28.96 a	19.39 a	66.95 a	33.05 i
	b_5	26.90 c	17.23 c	64.05 b	35.95 h
a_2	b_1	24.14 gh	14.32 h	59.32 ef	40.68 de
	b_2	24.95 ef	12.16 j	48.74 i	51.26 a
	b_3	25.04 e	15.13 fg	60.42 de	39.58 ef
	b_4	25.84 d	15.95 d	61.73 cd	38.27 fg
	b_5	26.24 d	15.35 ef	58.50 f	41.50 d
a_3	b_1	25.30 e	15.74 de	62.21 c	37.79 g
	b_2	23.88 h	14.30 h	59.88 ef	40.12 de
	b_3	24.65 fg	14.78 gh	59.96 ef	40.04 de
	b_4	24.40 g	14.26 h	58.44 f	41.56 d
	b_5	25.95 d	14.72 gh	56.72 g	43.28 c
F-test		*	*	*	*

* = significant at 0.05 level of probability.

I.2. Effect of P sources, timing, and method of application

Flowering and bolls retention measurements (total flowers number/plant, number of total bolls set/plant and bolls retention%) were increased in the two growing seasons (Tables 4 and 5) due to P application, with a favour of treated plants with foliar spraying with 5 cm^3 organic phosphorus [Pro Phos™ 0-20-0]/L twice. However, it was found that the lowest values of these measurements in respect resulted from inoculated seeds with 400 g bio-fertilizer (Phosphorein)/20 kg seeds per feddan at sowing. The opposite trend was detected in bolls shedding% in both seasons. A comparable tendency has been reported by Abdel-Aal *et al*. (2011). Bronson *et al*. (2001) reported that P may prohibit leaves senescence and consequently prolonged photosynthesis and fixation of carbon leading to increased boll setting. The role of phosphorus in stimulate early flowering, cell division and elongation were detected (Singh, 2003). Chiles and Chiles (1991) indicated that P may altered balance of nitrogen in cotton plant for early maturity. The increases in sympodial branches may result in more bolls per plant, whereas seeds inoculation with 400 g bio-fertilizer (Phosphorein)/20 kg seeds per feddan at sowing lowered sympodial branches. Russell (1973) claimed that phosphorus was important for cell division and meristematic tissue development, and thus had a revitalizing effect to increase bolls and flowers number per plant. The stimulating effect of P on the number of total flowers and bolls set per plant was also noticed in this study. Dohary *et al*. (2004) found that lack of phosphorous availability in cotton crop affects the growth of flower buds. Ali *et al*. (2020) added that reducing the availability of phosphorous reduced blooming, imbalanced pollination and prevented necrosis of flower bud.

II.3. Effect of the interaction treatments

Data in Tables 4 and 5 showed that splitting N in two equal doses combined with foliar spraying with organic P twice significantly increased number of total flowers/plant, number of total bolls set/plant and percentage of bolls retention in the two growing seasons. However, this interaction treatment lowered values of bolls shedding%.

III. Yield of seed cotton/feddan and its contributory traits

III.1. Effect of N splits number and its application timings

Nitrogen application in two equal splits significantly increased number of open bolls/plant, weight of boll, seed cotton yield /plant, lint percentage and earliness index (%) in both seasons, seed index in the second season over the addition of N fertilization in three and four equal splits (Tables 6 and 7). The two equal splits significantly increased yield of seed cotton/fed by 21.10% and 22.47%; 16% and 18.43% as compared with the addition of N fertilization in three and four equal splits in 2019 and 2020 seasons, respectively. This enhance in yield of seed cotton/fed was jointly owing to relative relation of various yield contributes like sympodial branches number, bolls number and weight of boll. The significant increase in open bolls number/plant in the two growing seasons due to the highest bolls retention%. Nitrogen application in 2 equal splits recorded a significant increase in the weight of boll compared to the rest of the treatments used in this investigation due to the role of nitrogen on cotton growth and its productivity. In this concern, Choudhry and Sarwar (1999) found that enough nitrogen supply is essential for fully developed growth, fruiting and yield of cotton plant, an increase in harvested open bolls number/plant and weight of boll. To achieve high yields multiple applications of N are need (Rochester and Constable, 2015; Rochester and Bange, 2016). Split application of nitrogen fertilizer significantly increased weight of boll, bolls number/plant and yield of seed cotton (Arain *et al.*, 2001). On the other hand, Soomro *et al.* (2001) revealed that seed cotton yield and number of bolls/plant were significantly affected by adding nitrogen fertilizer at different times and splits. The highest values were obtained when nitrogen addition was divided into four equal parts and applied at different growing stages compared with the other treatments. It is therefore suggested that to obtain maximum yield, nitrogen fertilizer should be applied in splits at the right time. Splitting nitrogen fertilization in three equal splits significantly increased bolls number and weight as well as seed cotton yield (Hassan *et al*., 2003). Alagudurai *et al.* (2006) found that apply four equal splits registered the highest yield of seed cotton compared with two and three equal splits. Anjum *et al.* (2007) found that split addition of nitrogen increased number of total bolls and average weight of boll. However, yield of seed cotton was not affected by split N application. Raju *et al.* (2008) found that three splits of fertilizer application produced 15% more seed cotton yield over two splits. Hallikeri *et al.* (2010) found that yield of seed cotton was not affected due to the increase in the number of splits. Increase in splits number though numerically unaffected at lower nitrogen doses but at higher levels. Jat and Nanwal (2013) reported that splitting N fertilizer gave insignificant effect on weight of boll. However, Darwish *et al*. (1999) found that splitting number of N application timings into two or three equal doses had insignificant effect on open bolls number/plant, boll weight, seed index, lint%, earliness% and seed cotton yield/feddan in both seasons. They added that yield of seed cotton/feddan and its components were not affected due to N splitting numbers and their application timings. Bhati and Singh (2015) revealed that seed cotton yield /plant, number of bolls, boll weight, seed index and ginning% were not affected by split addition of N.

Table (6): Effect of N splits number and its application timings as well as P sources, timing and method of application and their interaction on yield of seed cotton per feddan and its contributary traits of cotton grown in 2019 season.

Treatments \ Traits		Open bolls number per plant	Weight of boll (g)	Seed cotton yield per plant (g)	Lint %	Seed index (g)	Earliness index (%)	Yield of seed cotton (kentar per fed)
A- N splits number and its application timings:								
a_1- 2 equal splits at 30 and 45 DAS (control)		16.51 a	2.88 a	47.55 a	39.73 a	10.48	51.05 a	11.88 a
a_2- 3 equal splits at 30, 45 and 60 DAS		13.89 b	2.81 b	39.01 b	39.18 b	10.48	42.72 b	9.81 b
a_3- 4 equal splits at 30, 45, 60 and 75 DAS		13.91 b	2.76 c	38.45 b	38.40 c	10.37	40.55 c	9.70 b
		*	*	*	*	NS	*	*
B- P sources, timing and method of application:								
b_1-SP during land preparation (control).		15.19 b	2.67 d	40.66 d	39.65 b	10.25 b	45.87 c	10.12 d
b_2- Bio-P covers the seeds before sowing		12.88 c	2.69 d	34.62 e	38.51 c	9.96 c	37.64 e	9.03 e
b_3- Spraying PA at 28 and 66 DAS		14.80 b	2.84 b	42.08 c	38.52 c	10.80 a	43.31 d	10.48 c
b_4- Spraying OP at 28 and 66 DAS		15.96 a	2.77 c	44.33 b	38.30 c	10.51 ab	49.32 a	11.06 b
b_5- Combination of P sources used		15.00 b	3.11 a	46.67 a	40.54 a	10.71 a	47.74 b	11.62 a
F-test		*	*	*	*	*	*	*
A x B interaction:								
a_1	b_1	17.08 b	2.74 ef	46.80 b	39.75 bc	10.47	49.70 d	11.66 b
	b_2	14.00 ef	2.76 de	38.64 e	39.20 de	10.03	39.80 h	9.81 e
	b_3	16.70 b	2.82 d	47.09 b	39.24cde	10.65	52.90 c	11.72 b
	b_4	18.38 a	2.82 d	51.83 a	39.17 de	10.73	57.75 a	12.91 a
	b_5	16.37 b	3.26 a	53.37 a	41.32 a	10.54	55.12 b	13.30 a
a_2	b_1	13.71 fg	2.69 f	36.88 f	39.71bcd	10.40	43.50 fg	9.16 f
	b_2	11.76 i	2.75 ef	32.34 g	38.60 f	9.91	36.30 i	8.59 g
	b_3	14.59 de	2.79 de	40.71 d	38.85 ef	11.00	44.50 f	10.12 d
	b_4	15.31 c	2.78 de	42.56 c	38.52 f	10.34	47.20 e	10.58 c
	b_5	14.10 ef	3.02 b	42.58 c	40.25 b	10.75	42.10 g	10.59 c
a_3	b_1	14.79 de	2.59 g	38.31 e	39.49 cd	9.87	44.40 f	9.54 e
	b_2	12.89 h	2.55 g	32.87 g	37.75 g	9.93	36.83 i	8.69 g
	b_3	13.12 gh	2.93 c	38.44 e	37.49 g	10.76	32.53 j	9.61 e
	b_4	14.19 ef	2.72 ef	38.60 e	37.21 g	10.45	43.00 g	9.69 e
	b_5	14.54 de	3.03 b	44.06 c	40.05 b	10.85	46.00 e	10.97 c
F-test		*	*	*	*	NS	*	*

NS = non-significant; * = significant at 0.05 level of probability.

Table (7): Effect of N splits number and its application timings as well as P sources, timing and method of application and their interaction on yield of seed cotton per feddan and its contributary traits of cotton grown in 2020 season.

Treatments \ Traits		Open bolls number per plant	Weight of boll (g)	Seed cotton yield per plant (g)	Lint %	Seed index (g)	Earliness index (%)	Seed cotton yield (kentar per fed)
A- N splits number and its application timings:								
a_1- 2 equal splits at 30 and 45 DAS (control)		14.80 a	3.23 a	47.90 a	40.25 a	12.66 a	61.80 a	11.89 a
a_2- 3 equal splits at 30, 45 and 60 DAS		13.83 b	2.97 b	40.95 b	39.12 b	11.66 b	52.34 b	10.25 b
a_3- 4 equal splits at 30, 45, 60 and 75 DAS		14.67 a	2.71 c	39.77 b	37.86 c	10.89 c	51.24 c	10.04 b
F-test		*	*	*	*	*	*	*
B- P sources, timing and method of application:								
b_1-SP during land preparation (control)		14.87 a	2.84 d	42.20 c	38.74 d	11.58 b	53.70 d	10.56 c
b_2- Bio-P covers the seeds before sowing		12.98 b	2.88 d	37.28 d	38.45 e	11.54 b	48.06 e	9.40 d
b_3- Spraying PA at 28 and 66 DAS		14.50 a	2.96 c	42.94 c	39.02 c	11.65 b	55.02 c	10.72 c
b_4- Spraying OP at 28 and 66 DAS		14.82 a	3.04 b	45.20 b	39.43 b	11.94 a	57.83 b	11.34 b
b_5- Combination of P sources used		15.00 a	3.12 a	46.75 a	39.75 a	11.97 a	61.03 a	11.61 a
F-test		*	*	*	*	*	*	*
A x B interaction:								
a_1	b_1	15.35 ab	3.14 c	48.20 c	39.62 cd	12.59 b	61.07 c	11.96 c
	b_2	13.02 f	3.07 de	40.10 f	39.37 de	12.11 c	51.96 g	10.13 f
	b_3	14.90 bc	3.22 b	48.00 c	39.96 c	12.59 b	61.04 c	11.93 c
	b_4	15.51 a	3.37 a	52.26 a	40.86 b	12.92 a	66.63 b	13.04 a
	b_5	15.21 ab	3.35 a	50.95 b	41.44 a	13.11 a	68.30 a	12.39 b
a_2	b_1	13.64 e	2.88 f	39.24 g	38.91 fg	11.41 ef	49.80 h	9.81 g
	b_2	11.69 g	3.03 de	35.45 h	39.34 de	12.09 c	45.99 i	8.99 h
	b_3	13.89 e	3.01 e	41.81 f	39.07 ef	11.57 de	53.37 f	10.34 f
	b_4	14.68 cd	3.01 e	44.13 e	39.11 ef	11.75 d	56.14 e	11.05 e
	b_5	15.23 ab	2.90 f	44.16 e	39.20 ef	11.51 e	56.40 e	11.04 e
a_3	b_1	15.61 a	2.51 i	39.17 g	37.71 i	10.75 g	50.22 h	9.91 g
	b_2	14.22 d	2.55 i	36.28 h	36.66 j	10.44 h	46.22 i	9.07 h
	b_3	14.72 cd	2.65 h	39.02 g	38.03 hi	10.81 g	50.66 h	9.89 g
	b_4	14.26 d	2.75 g	39.22 g	38.31 gh	11.16 f	50.73 gh	9.93 g
	b_5	14.56 d	3.10 cd	45.14 d	38.61 g	11.29 f	58.38 d	11.40 d
F-test		*	*	*	*	*	*	*

* = significant at 0.05 level of probability.

Cotton is an indefinite crop with a tall period, proper time of addition N in splits may increase bolls, dry matter cumulation/plant, resulting in higher yield of seed-cotton/plant. Split addition of N assists more dry-matter build-up and finally leads to higher yield (Srinivasan, 2003). Wayne (1986) highlighted that the totally addition of N may be wasted from the system of soil plant via leaching and denitrification leading to yield decrease.

III.2. Effect of P sources, timing and method of application

Data in Tables 6 and 7 indicated that combination of P sources used significantly increased weight of boll, seed index, lint%, yield of seed cotton per plant as well as per feddan in the two growing seasons and open bolls number/plant and earliness index (%) in the second season, followed by foliar spraying with 5 cm^3 organic phosphorus [Pro Phos™ 0-20-0]/L twice which recorded the highest values of open bolls number /plant and earliness index (%) in the first season. Combination of P sources used [add half dose of calcium superphosphate during seed bed preparation + inoculated seeds with bio-fertilizer (Phosphorein) at sowing + foliar spraying with 1.5 cm^3 phosphoric acid/L twice after thinning and six days after the third irrigation (at 66 DAS) + foliar spraying with 5 cm^3 organic phosphorus [Pro Phos™ 0-20-0]/L twice at the squaring stage (45 DAS) and flowering initiation (80 DAS)] significantly increased yield of seed cotton per feddan by 14.82, 28.68, 10.88 and 5.06%; 9.94 , 23.51, 8.30 and 2.38% compared to adding a full dose of calcium superphosphate during seed bed preparation, inoculated seeds with bio-fertilizer at sowing, foliar spraying with 1.5 cm^3 phosphoric acid/L twice and foliar spraying with 5 cm^3 organic phosphorus [Pro Phos™ 0-20-0]/L twice in 2019 and 2020 seasons, respectively. Foliar spraying with 5 cm^3 organic phosphorus [Pro Phos™ 0-20-0]/L twice (after thinning and six days after the third irrigation at 66 DAS) significantly increased yield of seed cotton per feddan by 9.29, 22.48 and 5.53%; 7.39, 20.64 and 5.78% compared to add full dose of calcium superphosphate during land preparation, seeds inoculation with bio-fertilizer at sowing and foliar spraying with 1.5 cm^3 phosphoric acid/L twice in the 2019 and 2020 seasons, respectively. The favourable effect of P on yield of seed cotton/feddan and its contributary traits is primarily due to its influence on increasing number of fruiting branches/plant. It results in more open bolls number/plant, which ultimately leads to enhanced yield. Superior fruiting branches as well as number of open bolls/plant, weight of boll, seed index, lint%, boll retention and earliness index were noted with using these two treatments. In this concern, Ambrose and Easty (1977) reported that P is necessary for chlorophyll biosynthesis as pyridoxal must be present for its biosynthesis which improved the motivation of photosynthates and directly affected weight of boll which coincides with the increase in seed index. Ahmad *et al.* (2020) stated that addition of phosphorous significantly improved cotton yield in terms of open bolls number/plant, weight of boll, yield of seed cotton and ginning out turn. Ali *et al*. (2020) found that reduction availability of phosphorous led to a decrease in the weight and size of the cotton boll as well as seed production more than seed size.

III.3. Effect of the interaction treatments

Data in Tables 6 and 7 showed that splitting N in two equal doses combined with the mixture of different P sources or with foliar spraying with 5 cm^3 organic phosphorus [Pro Phos™ 0-20-0]/L twice recorded the highest values of yield of seed cotton/fed and its contributed traits [open bolls number/plant, weight of boll, yield of seed cotton/plant, lint% and earliness index] in both seasons and seed index in the second season. The highest seed cotton yield per feddan (12.91 and 13.30 kentar; 13.04 and 12.39 kentar) was recorded due to splitting N in two equal doses combined with foliar spraying with 5 cm^3 organic phosphorus [Pro Phos™ 0-20-0]/L twice or with the mixture of different P sources used [add half dose of calcium superphosphate during seed bed preparation + inoculated seeds with bio-fertilizer (Phosphorein) at sowing + foliar spraying with 1.5 cm^3 phosphoric acid/L twice after thinning and six days after the third irrigation (at 66 DAS) + foliar spraying with 5 cm^3 organic phosphorus [Pro Phos™ 0-20-0]/L twice at the squaring stage (45 DAS) and flowering initiation (80 DAS)] in 2019 and 2020 seasons, respectively.

IV- Fiber quality traits

IV.1. Effect of N splits number and its application timings

Addition of N fertilization in two equal splits significantly increased fiber length in the first season and length uniformity index in the two growing seasons. Fiber length increased in the second season in favour of four equal N splits. Fiber strength and fineness were not affected (Tables 8 and 9). The positive liaison between carbohydrate supply and the nitrogen application during boll development was detected (Tewolde and Fernandez, 2003). Bauer and Roof (2004) and Read *et al*. (2006) reported that reduction of N availability led to a reduction in values of cotton fiber length, strength and micronaire. Micronaire is linearly related to enough supply of carbohydrate for the development of bolls that are provided by the photosynthesis of the canopy (Bauer *et al*., 2000). The deposition degree of cellulose in the fiber cell is greatly affected by the factors affecting photosynthesis (Bange *et al*., 2009). This is due to the affirmative relationship between N and concentration of chlorophyll in cotton leaf (Buscaglia and Vacro, 2002). Gawade *et al*. (2014) observed that fiber quality parameters remained unchanged due to split applications of nitrogen. On the other hand, Darwish *et al*. (1999) found that splitting number of N application timings into two or three equal doses had insignificant effect on fiber traits (2.5% and 50% span lengths in mm, length uniformity (%) and fineness) in both seasons.

IV.2. Effect of P sources, timing and method of application

Sources of P application when used in combination gave the highest values of micronaire reading (4.58) in the first season and fiber strength (11.03 Pressley unit) in 2020 season. In 2019 season, the longest fibers (33.92 mm) and the highest value of uniformity index (86.21%) were obtained from foliar spraying with 5 cm^3 organic phosphorus [Pro Phos™ 0-20-0]/L twice. However, foliar spraying with 1.5 cm^3 phosphoric acid/L twice recorded a significant increase in fiber strength in the first season. Fiber length, uniformity index and fineness were not affected in the second season (Tables 8 and 9). Keller (1997) indicated that the low micronaire was substitute by a relatively high bolls number per plant. Increased bolls load or a large bolls number leads to an increase in demand for assimilates of each boll and increased competition may reduce the amount of cellulose available for each fibre and thus reduce the fineness of the fibre (Kelly *et al*., 2008). Ahmad *et al.* (2020) found that P addition significantly improved cotton fiber quality. Significant increase was observed for fiber uniformity, staple length, fiber strength and micronaire.

IV.3. Effect of the interaction treatments

Regarding the interaction effect, data in Tables 8 and 9 showed that, in the first season the longest fibers were obtained from applying N at two equal splits combined with foliar spraying with 1.5 cm^3 phosphoric acid/L twice and from applying N at three equal splits combined with foliar spraying with organic P twice. The highest fiber strength was obtained from applying N at two equal splits combined with add full dose of calcium superphosphate during land preparation (control) in the first season and from applying N at four equal splits combined with foliar spraying with organic P twice in the two growing seasons. The addition of N at four equal splits combined with foliar spraying with 1.5 cm^3 phosphoric acid/L twice increased uniformity index in 2020 season. The addition of N in two equal splits combined with seeds inoculation with 400 g bio-fertilizer (Phosphorein)/ 20 kg seeds per feddan at sowing (Bio-P) increased micronaire reading in the first season.

Table (8): Effect of N splits number and its application timings as well as P sources, timing and method of application and their interaction on fiber quality traits of cotton grown in 2019 season.

Treatments \ Traits		Fineness of fiber (Micronaire reading)	Strength of fiber (Pressley index)	Upper half mean length (mm)	Uniformity index (%)
A- N splits number and its application timings:					
a_1- 2 equal splits at 30 and 45 DAS (control)		4.59	10.36	33.93 a	85.81 ab
a_2- 3 equal splits at 30, 45 and 60 DAS		4.51	10.30	33.57 b	86.31 a
a_3- 4 equal splits at 30, 45, 60 and 75 DAS		4.43	10.37	33.50 b	85.34 b
F-test		NS	NS	*	*
B- P sources, timing and method of application:					
b_1-SP during land preparation (control)		4.40 c	10.33 b	33.76 a	85.17 b
b_2- Bio-P covers the seeds before sowing		4.58 a	10.23 b	33.19 b	85.81 ab
b_3- Spraying PA at 28 and 66 DAS		4.48 b	10.47 a	33.82 a	86.13 a
b_4- Spraying OP at 28 and 66 DAS		4.51 b	10.33 b	33.92 a	86.21 a
b_5- Combination of P sources used		4.58 a	10.36 ab	33.66 a	85.79 ab
F-test		*	*	*	*
A x B interaction:					
a_1	b_1	4.37 e	10.60 a	34.10 ab	85.17
	b_2	4.77 a	10.10 d	33.40 cd	85.70
	b_3	4.57 c	10.50 ab	34.37 a	85.80
	b_4	4.57 c	10.30 bcd	33.70 abc	86.30
	b_5	4.67 b	10.30 bcd	34.10 ab	86.10
a_2	b_1	4.47 d	10.20 cd	33.50 bc	85.57
	b_2	4.50 cd	10.40 abc	33.30 cd	86.57
	b_3	4.50 cd	10.40 abc	33.30 cd	86.60
	b_4	4.50 cd	10.10 d	34.37 a	86.67
	b_5	4.57 c	10.40 abc	33.40 cd	86.17
a_3	b_1	4.37 e	10.20 cd	33.67 bc	84.77
	b_2	4.47 d	10.20 cd	32.87 d	85.17
	b_3	4.37 e	10.50 ab	33.80 abc	86.00
	b_4	4.47 d	10.60 a	33.70 abc	85.67
	b_5	4.50 cd	10.37 bc	33.47 bcd	85.10
F-test		*	*	*	NS

NS = non-significant; * = significant at 0.05 level of probability.

Table (9): Effect of N splits number and its application timings as well as P sources, timing and method of application and their interaction on fiber quality traits of cotton grown in 2020 season.

Treatments \ Traits		Fineness of fiber (Micronaire reading)	Strength of fiber (Pressley index)	Upper half mean length (mm)	Uniformity index (%)
A- N splits number and its application timings:					
a_1- 2 equal splits at 30 and 45 DAS (control)		4.57	10.83	34.19 b	85.67 a
a_2- 3 equal splits at 30, 45 and 60 DAS		4.53	10.72	34.21 b	85.17 b
a_3- 4 equal splits at 30, 45, 60 and 75 DAS		4.63	10.89	34.46 a	85.50 ab
F-test		NS	NS	*	*
B- P sources, timing and method of application:					
b_1-SP during land preparation (control)		4.58	10.82 ab	34.37	85.69
b_2- Bio-P covers the seeds before sowing		4.52	10.52 c	34.30	85.42
b_3- Spraying PA at 28 and 66 DAS		4.63	10.71 bc	34.00	85.84
b_4- Spraying OP at 28 and 66 DAS		4.66	10.98 a	34.31	85.53
b_5- Combination of P sources used		4.51	11.03 a	34.44	84.76
F-test		NS	*	NS	NS
A x B interaction:					
a_1	b_1	4.63	10.83 bcd	34.27	85.87 abc
	b_2	4.70	10.37 e	34.47	85.33 cd
	b_3	4.57	11.13 abc	33.53	85.63 bc
	b_4	4.60	10.97 abcd	34.33	86.27 ab
	b_5	4.37	10.83 bcd	34.37	85.27 cd
a_2	b_1	4.50	10.93 abcd	34.33	85.60 bc
	b_2	4.30	10.53 e	33.87	85.57 c
	b_3	4.70	10.30 e	34.17	85.37 cd
	b_4	4.77	10.63 de	34.23	84.83 de
	b_5	4.40	11.20 ab	34.43	84.50 e
a_3	b_1	4.60	10.70 cde	34.50	85.60 bc
	b_2	4.57	10.67 de	34.60	85.37 cd
	b_3	4.63	10.70 cde	34.30	86.53 a
	b_4	4.60	11.33 a	34.37	85.50 c
	b_5	4.77	11.07 abcd	34.53	84.50 e
F-test		NS	*	NS	*

NS = non-significant; * = significant at 0.05 level of probability.

CONCLUSION

It could be concluded that growth, bolls retention, yield and its components as well as fiber quality of cotton were increased due to the addition of N at two equal splits combined with the mixture of different P sources used or with foliar spraying with organic phosphorus [Pro Phos™ 0-20-0] twice. So, the farmers can use either of the two interaction treatments to increase cotton yield and fiber quality particularly in vigour's cultivar (Super Giza 86) under the environmental conditions like El-Gemmeiza district.

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إدارة التسميد النيتروجينى والفوسفورى وتأثيرهما على نمو وإنتاجية وجودة القطن صنف سوبر جيزة ٨٦

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الملخص العربى

أجريت تجربة حقلية بمحطة البحوث الزراعية بالجميزة محافظة الغربية فى موسم ٢٠١٩م وتم تكرارها فى موسم ٢٠٢٠م لدراسة تأثير عدد مرات وميعاد أضافة السماد الأزوتى (إضافة المعدل الموصى به من النيتروجين على مرتين، ثلاث مرات، أربع مرات متساوية) وتحديد أفضل مصدر للفوسفور وميعاد وطريقة الإضافة (مصدر معدنى، عضوى، حيوى، حمض فوسفوريك، مخلوط منهم) والتفاعل بينهما فى زيادة النمو، العقد، المحصول ومكوناته وجودة التيلة للقطن صنف سوبر جيزة ٨٦. واستخدم تصميم الشرائح المتعامدة فى ثلاث مكررات فى الموسم الأول، أربع مكررات فى الموسم الثانى لتنفيذ التجربة حيث وضع عدد مرات وميعاد إضافة السماد الأزوتى فى الشرائح الافقية ووضعت مصادر الفوسفور وميعاد وطريقة الإضافة فى الشرائح الرأسية.

أعطى تجزئ معدل النيتروجين (يوريا) الى دفعتين متساويتين زيادة معنوية فى قياسات النمو، قياسات التزهير وعقد اللوز (بإستثناء النسبة المئوية للتساقط التى انخفضت) ، ومحصول القطن الزهر/الفدان والصفات المرتبطة به (عدد اللوز المتفتح على النبات، وزن اللوزة، محصول القطن الزهر للنبات ، النسبة المئوية للتيلة ودليل التبكير) ومؤشر أنتظام الطول فى الموسمين وكذلك معامل البذرة وطول التيلة في موسم واحد ،بينما زاد طول التيلة في الموسم الثاني لصالح تجزئ معدل النيتروجين (يوريا) الى أربعة دفعات متساوية و لم تتأثر متانة التيلة والنعومة.

أدت إضافة توليفة المصادر المختلفة للفوسفور أو إضافة الفوسفور العضوى (Pro Phos™ 0-20-0) مرتين الى زيادة معنوية فى قياسات النمو، ومحصول القطن الزهر/الفدان والصفات المرتبطة به(عدد اللوز المتفتح على النبات، وزن اللوزة، محصول القطن الزهر للنبات، النسبة المئوية للتيلة ودليل التبكير). وقد أعطى الرش الورقي باستخدام ٥ سم^{٣} من الفوسفور العضوي (Pro Phos™ 0-20-0)/ لتر مرتين زيادة معنوية فى عدد اللوز الكلي/ النبات ، عدد الأزهار الكلية / النبات والنسبة المئوية لعقد اللوز فى الموسمين وطول التيلة ومؤشر أنتظام الطول فى الموسم الاول بينما انخفضت النسبة المئوية للتساقط وأعطى مزيج المصادر المختلفة للفوسفور أعلى القيم من قراءة الميكرونير ومتانة التيلة فى موسم واحد فقط بينما سجل الرش الورقي باستخدام ١,٥ سم^{٣} من حمض الفوسفوريك / لتر مرتين زيادة معنوية فى متانة التيلة فى الموسم الأول ولم يتأثر طول التيلة ومؤشر أنتظام الطول والنعومة في الموسم الثاني.

أعطت معاملتى التفاعل [أضافة النيتروجين على دفعتين متساويتين مع إضافة توليفة المصادر المختلفة للفوسفور أو مع رش الفوسفور العضوى (Pro Phos™ 0-20-0) مرتين] أفضل النتائج للصفات المدروسة. لذلك يمكن للمزارعين استخدام أى من معاملتى التفاعل سابقة الذكر لزيادة إنتاجية محصول القطن وجودة الألياف لصنف قوى النمو مثل سوبر جيزة ٨٦ وذلك تحت الظروف البيئية المشابهة لمنطقة الجميزة.