Pure Appl. Biol., 9(4): 2577-2588, December, 2020
http://dx.doi.org/10.19045/bspab.2020.90274

Research Article

Supplemental application of phosphorus improves yield, quality and net returns of *Gossypium hirsutum*

Ayaz Ahmad[1*], Hakoomat Ali[1], Shabir Hussain[1], Waseem Hassan[1] and Riaz Ahmad[2]
1. Department of Agronomy, Bahauddin Zakariya University, 60800 Multan-Pakistan
2. Department of Horticulture, Bahauddin Zakariya University, 60800 Multan-Pakistan
**Corresponding author's email:* ayazagronomist@gmail.com

Citation
Ayaz Ahmad, Hakoomat Ali, Shabir Hussain, Waseem Hassan and Riaz Ahmad. Supplemental application of phosphorus improves yield, quality and net returns of *Gossypium hirsutum*. Pure and Applied Biology. Vol. 9, Issue 4, pp2577-2588. http://dx.doi.org/10.19045/bspab.2020.90274

Received: 09/04/2020 Revised: 01/07/2020 Accepted: 10/07/2020 Online First: 06/08/2020

Abstract

Cotton is a white gold due to its high economic values. Phosphorus is an important constituent that is essential for seed development and yield. Efficient use of phosphorus plays a significant role to achieve quality production in form of yield to overcome the problems. A field study comprised of four phosphorus levels *viz*. (P_0= 0 kgha^{-1}, P_1 =50 kgha^{-1}, P_2 =100 kg ha^{-1} P_3 =150 kg ha^{-1}) and cultivars *viz* CIM-598, MNH-886, CIM-616, CIM-612, FH-LALAZAR during 2015 and 2016. Application of phosphorous significantly improved quality and yield in terms of plant height (161.33 cm), bolls number plant^{-1} (31.667), number of nodes plant^{-1} (49.000), boll weight (2.200 g), seed cotton harvest (3481.3 %), seed cotton yield (2928.3 kg ha^{-1}), seed lint yield (56.667 kg ha^{-1}), biological yield (0.960 kg ha^{-1}), and ginning out turn (0.0227 %). Significant increase was observed for leaf area index (0.980 m^{-2}), crop growth rate (1.416 g m^{-2} day^{-1}), net assimilation rate (1.480 g m^{-2} day^{-1}), leaf area duration (871.33), phosphorus concentration (0.270), fiber uniformity (70.667), staple length (47.500 mm), fiber strength (33.500 tppsi) and micronair (5.166 µg inch^{-1}). Phosphorus spray of 150 kg ha^{-1} is more suitable for greater cotton production.

Keywords: Cotton; Cotton quality; Economic benefits; Fiber uniformity; Phosphorus

Introduction

Cotton *Gossypium hirsutum* L. belongs family Malvaceae and comprised of approximately 50 species **[1]**. Cotton is a unique natural fiber provides medicinal compounds, vegetable oil, organic matter and energy sources to fertile soil, meal and hull for livestock feed and industrial lubricants **[2]**.

Deficiency of phosphorus is major problem in calcareous soils all over the world specially Pakistan **[3]**. Deficiency of phosphorus decreased in plant growth, photosynthesis and yield **[4]**. Phosphorus demand has been increased due to the maximum production of cultivars as well as sufficient increase of growth as well as development due to regulation of photosynthesis with rise of CO_2 concentrations **[3]**. However, evaluation of carbon dioxide increased yield, photosynthesis mechanism as well as plant growth. However, phosphorus has a major nutrient for plant response to elevated carbon dioxide **[3, 5]**.

Phosphorus deficiency resulting in reduction of dry matter and poor development of cotton roots **[6, 7]**. While the minimization of phosphorus impact on cotton plants which could be retained 35% phosphorus in its roots, compared with 14% in phosphorus sufficient cotton **[8]**. Moreover, phosphorous utilization occurred maximum in growing season when the root system is fully developed **[9]**.

Phosphorus fertilizer application mainly depends on fertilizer application of phosphorus, type of soil, agronomic implications and geographical site of cultivated crop mainly resulting in improvement of crop productivity **[5, 10]**. Different types of genotypes have different efficiency to perform in absorbing fertilizer efficiently due to difference in genetic makeup **[11]**. The important genetically differences among cotton cultivars can be exploited for breeding efficient cultivars because of fertilizer enhances efficiency **[12]**. It would preferable to select and identify the important traits between various cotton cultivars that are directly relate to phosphorus efficiency.

Many previous studies have been carried out to investigate the deficiency of phosphate on cotton growth as well as physiological process due to the projected atmospheric carbon dioxide conditions which are limited **[8]**. So, the maximum root assimilation growth due to stress of phosphorus of cotton could be conflicted on a significant advantage in soluble phosphorus acquisition by cotton. Therefore, suitable cultivars selection according to the prevailing conditions of the region along with important management practices is even more importance for cotton production, although high yield potential is a principal concern.

Materials and methods

Experimental details

Investigate the response of various cotton cultivars to phosphorus application during 2015-2016 (Fig. 1). Eco-meteorological data of experimental site was listed below. Experimental treatments comprises of four phosphorus levels viz. To= 0 kgha^{-1}, T_1= 50 kgha^{-1},T_2= 100 kgha^{-1}T_3= 150 kgha^{-1} and five cultivars viz. CIM- 598, MNH - 886,CIM - 616, CIM- 612, FH-LALAZAR. The preparation of seed bed cotton was sown by having row -row distance of 75 cm as well as plant – plant distance of 25 cm during 28 May 2015 and 31 May 2016. Urea fertilizers 36 kgha^{-1} applied as per standard role and four Phosphorous levels (0, 50, 100 and 150 kgha$^{-1)}$, respectively. Randomized complete block design (RCBD) was applied along with three replications. Irrigation as well as crop protection needs were performed as per requirement of the crop. Harvesting was done on 05-11-2015 to 13-11-2016 with the picking interval of 2 weeks.

Observations recorded

Agronomic traits

Plant height was determined from five collected plants through measuring scale. Same plants were used to measure number of bolls per plant. One hundred good open bolls were choose for picking to get 100 boll weights (g) from each treatment. Seed cotton yield was recorded after picking and then weighed to get the yield per hectare (kg ha^{-1}).Ginning out turn (%) was calculated through weighing cotton lint and cotton seed. According to previous studies **[13, 14]**.

Allometry traits

Leaf area index was measured by dividing leaf area over the land area. Crop growth rate was measured by collected weighed samples of 20, 40, 50 g of green leaves, stalks and bolls which were gained from different stages of crop growth and were dried in the oven at 80 C^0. Hunt [20] gave the formula to calculate net assimilation rate.

Statistical analysis

The statistical software, Statistix 8.1 (Tallahassee Florida, USA) was used to examine two years collected data. Due to two factors; cultivars and treatment three-way analysis of variance were applied. Year interaction was non-significant and did not described. Means were separated through LSD test at 5% level of probability.

Results

Descriptive statistics for individual effect of cultivars, phosphorus levels and their interactive effects was presented in the (Table 1). Regarding the individual effect of cultivars, larger plant height was calculated in cultivars MNH-886 and CIM-616, while smaller plant height was measured in cultivars CIM-616 and FH-Lalazar. Number of bolls plant^{-1} were higher in cv. CIM-616, while lower was in CIM-598 and FH-Lalazar. CIM-616 had the maximum number of nodes plant^{-1} and boll weight as compared to all other studied traits. The performance of all the studied cultivars was similar for the seed cotton yield and seed cotton harvest. The highest lint yield was measured in MNH-886, while lowest was in CIM-616. CIM-612 had the highest biological yield, followed by CIM-616 than all the studied cultivars. FH-Lalazar, followed by CIM-616 and CIM-598 had the highest ginning out turn as compared to other cultivars (Table 2). CIM-616 had the highest leaf area index, crop growth rate and micronair, while the lowest leaf area index, crop growth rate, net assimilation rate and leaf area duration was in FH-Lalazar (Table 3). MNH-886 had the maximum net assimilation rate, leaf area duration, phosphorus concentration, fiber uniformity, staple length and fiber strength (Table 3).

Regarding the effect of phosphorus on agronomic and yield related traits, phosphorus concentration (150 kg ha^{-1}) showed the better results as compared to other concentrations. The highest plant height, number of boll plant^{-1}, number of nodes plant^{-1}, boll weight, seed cotton yield, lint yield, biological yield, seed cotton harvest and ginning out turn were recorded during phosphorus application as 150 kg ha^{-1} than other application doses (Table 4). Individual effect of phosphorus on physiological and fiber quality traits were presented (Table 5). Phosphorus application (150 kg ha^{-1}) significantly enhanced leaf area index, crop growth rate, net assimilation rate, leaf area duration, phosphorus concentration, fiber uniformity, staple length, fiber strength and micronair (Table 5).

As regards, the interaction of cultivars and phosphorus effect on agronomic and yield related traits, the highest plant height was recorded during ($P_3 \times V_2$) and ($P_3 \times V_3$), while the lowest plant height was measured during ($P_0 \times V_4$) and ($P_0 \times V_5$) as compared to other genotypes. The maximum number of bolls plant^{-1} was counted in ($P_3 \times V_3$), while the minimum number of bolls plant^{-1} was calculated in ($P_0 \times V_5$) and ($P_0 \times V_1$). Number of nodes plant^{-1} were not significantly varied in the current studied. Boll weight was higher in ($P_3 \times V_1$), ($P_3 \times V_2$), ($P_0 \times V_5$) and ($P_3 \times V_5$), while lower boll weight was in ($P_0 \times V_3$), followed by ($P_0 \times V_1$), ($P_0 \times V_2$), ($P_1 \times V_3$) and ($P_0 \times V_4$). The maximum seed cotton yield was in ($P_3 \times V_2$) and ($P_3 \times V_4$), while the minimum was measured in ($P_0 \times V_4$). Lint yield was higher in ($P_3 \times V_2$), followed by ($P_3 \times V_4$). However, the lowest was measured in ($P_0 \times V_5$) and ($P_1 \times V_5$). The highest biological yield was measured in ($P_3 \times V_4$), followed by ($P_2 \times V_4$), while the lowest was calculated in ($P_0 \times V_2$) and ($P_1 \times V_2$). Phosphorus application and cultivars were not showed significant effect on ginning out turn (Table 6). Effect of phosphorus on physiological and fiber quality traits of cotton cultivars were presented (Table 7). The maximum leaf area index was measured in ($P_2 \times V_3$), while the minimum leaf area index was measured in ($P_0 \times V_1$), followed by ($P_3 \times V_5$). Crop growth rate and net assimilation rate were significantly higher in ($P_3 \times V_4$), while lower were measured in ($P_0 \times V_1$). The highest leaf area duration was measured in ($P_3 \times V_2$), while the lowest was calculated in ($P_0 \times V_5$). The highest phosphorus concentration was calculated ($P_1 \times V_3$) and ($P_3 \times V_5$), followed by ($P_0 \times V_3$), ($P_2 \times V_3$), ($P_3 \times V_3$), ($P_2 \times V_2$) and ($P_2 \times V_5$). However, the lowest phosphorus concentration was measured in ($P_2 \times V_3$). Fiber quality traits i.e. fiber uniformity, staple length and fiber strength were significantly higher in ($P_3 \times V_2$). The highest micronair was recorded in ($P_3 \times V_3$) than all other interactions of the current study (Table 7). Detailed description of cost benefit ratio was evaluated as presented in the (Table 8).

Discussion

Plant height was the highest in MNH-886 and CIM-616 treated with phosphorus 150 kgha^{-1} (T_3), while the lowest was in CIM-612, followed by FH-LALAZAR as control (T_0). Current work is accordance to previous results because these exhibited a positive reaction of phosphorus supplement in cotton crop **[15]**. Number of bolls per plant is an anticipated trait that is involved in seed cotton yield. Spray of phosphorus concentration (150 kg ha^{-1}) significantly improved the number of bolls per plant than controlled treatment. Among micronutrients i.e. phosphorus is considered to be important for cell enlargement as well as for meristematic tissue development. Furthermore, phosphorus is causing an encouraging effect on flower buds as well as plant bolls. These consequences are in line with earlier consequences as described **[15, 16]**. Number of nodes per plant was the greatest in cultivar CIM- 616 treated with phosphorus 150 kgha^{-1} (T_3) and the minimum numbers of nodes were in four cultivars such as CIM-612, CIM- 598, MNH- 886 and FH-LALAZAR without any treatment of phosphorus (T_0). These results correlated with **[17]**. Micronutrients especially phosphorus is also meaningfully increased boll weight than controlled treatment, as treatment rate was improved up to 150 kg ha^{-1} **[18]**. However, photosynthetic balance as well as stomatal regulation was limited. However, carbon dioxide was found to be decreased when phosphorus deficiency occurs. Present results are in accordance with the findings of previous studies as obtained by Sawan *et al*. **[19]**. Phosphorus is macronutrient significantly involved in stimulation of flowering of cotton cultivars. Therefore, current study indicated that increase of flowering and boll development provides higher crop yield to farmers. Earlier results confirmed that phosphorus had significantly enhances seed cotton yield **[16, 20]**. Furthermore, present consequences were also agreed by earlier research **[21]**. Lint and biological yield as well as seed cotton harvest was the maximum from the highest concentration applied (150 kg ha^{-1}). However, current findings were in accordance as stated Sawan *et al*. **[19]** because good nutrient response as well as their ease of use resulting in initiation as well as formation of higher number of fibers per seed. Ginning out turn was enhanced due to higher phosphorus concentration. Environmental factors, different biotic and abiotic stresses and genetic make-up are major cause of variation in production of different agronomic crops **[2]**.

Leaf area index and crop growth rate were the maximum in CIM- 616 and phosphorus treated with 100 kg ha^{-1} (T_2), while leaf area index as well as crop growth rate was the minimum in cultivar FH-LALAZAR treated as control (T_o). Net assimilation rate was the maximum in cultivar CIM-612 (1.480) and the phosphorus level was treated as 150 kgha^{-1} (T_3). Leaf area duration and phosphorus concentration were the highest in cultivar MNH-886 (871.33) which treated with phosphorus level of 150 kgha^{-1} (T_3) of phosphorus. The maximum fiber uniformity, staple length, fiber strength were in cultivar MNH-886 (70.667) and treatment was 150 kg ha^{-1}(T_3). Micronair value was the maximum in cultivar CIM-616 (5.166) and phosphorus level was150 kg ha^{-1}. Current study in line to previous work because supplemental application of phosphorus improves yield, quality and net returns of cotton **[22-24]**.

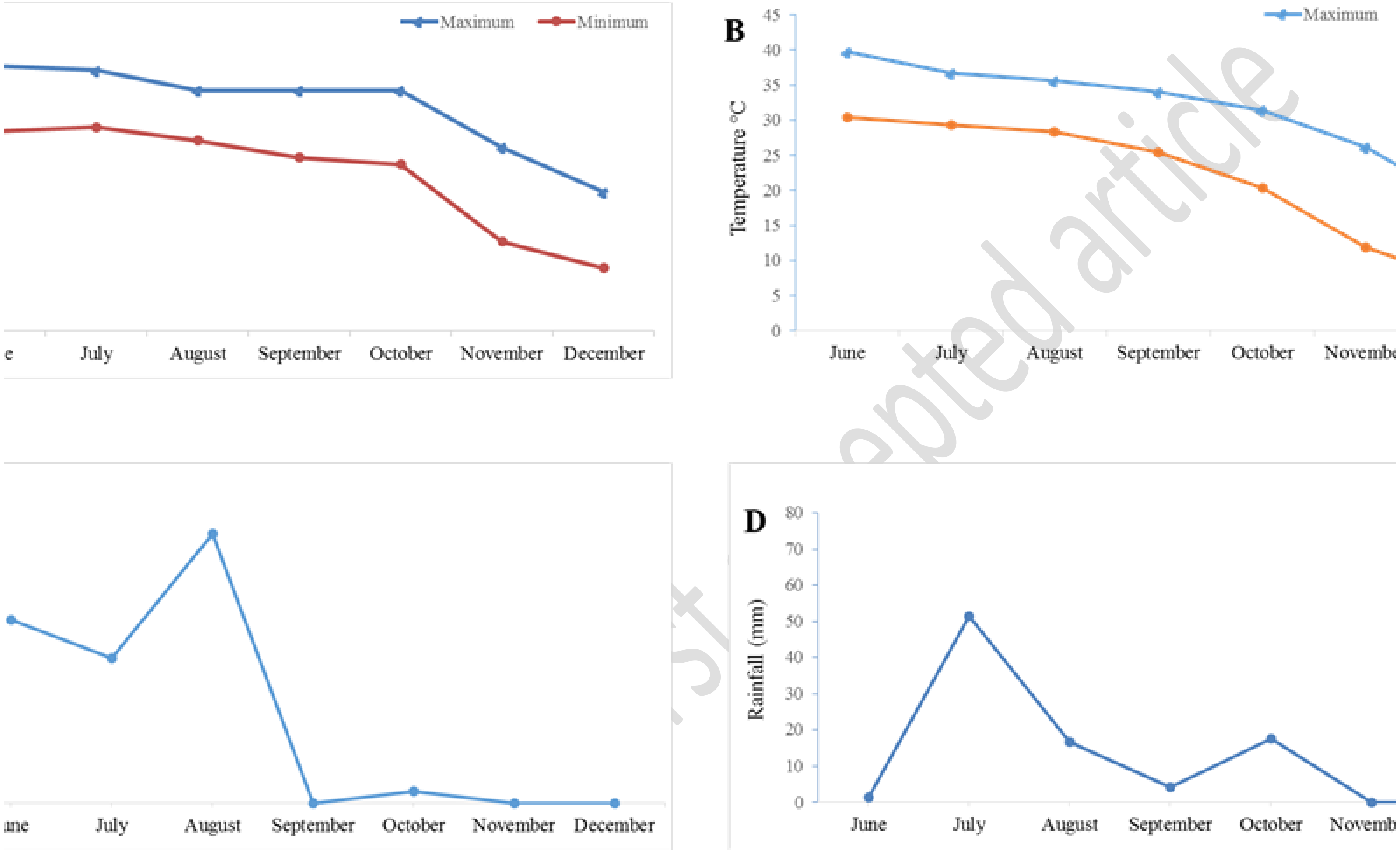

Figure 1. Eco-meteorological data of Multan, Punjab (Pakistan) during 2015 (A & C) and during 2016 (B & D)

Table 1. Significance level of agronomic, yield and fiber related traits as affected by cultivars and phosphorus concentrations

Parameters	Cotton cultivars	Phosphorus application	Cotton cultivars × phosphorus application
Plant height (cm)	352.500**	464.222**	7.167**
Number of bolls plant^{-1}	53.8917**	77.2667**	1.2806**
Number of nodes plant^{-1}	44.2667**	46.8167**	2.4000ns
Boll weight (g)	0.39208**	1.12044**	0.19586**
Lint yield (kg ha^{-1})	552.442**	118.333**	16.264**
Biological yield (kg ha^{-1})	0.06262**	0.18012**	0.00310**
Seed cotton harvest (%)	156.659**	200.623ns	5.546**
Ginning out turn (%)	2.244 **	1.350ns	3.711ns
Leaf area index	0.20759**	0.02123**	0.01455**
Crop growth rate (g m^{-2} day^{-1})	0.31000**	0.17217**	0.24411**
Net assimilation rate (g m^{-2} week^{-1})	0.01003**	0.01784**	0.00232**
Leaf area duration (days)	0.01003**	0.01784**	0.00232**
Phosphorus concentration	0.20759**	0.02123**	0.01455**
Fiber uniformity	589.142**	466.000**	71.986**
Staple length (mm)	651.608**	125.022**	34.953**
Fiber strength (tppsi)	7.889ns	105.933**	34.194**
Micronair (μ inch^{-1})	0.29142**	0.16950**	0.24411**

NS = non-significant; * = significant ($P < 0.05$) and ** = highly significant ($P < 0.01$)

Table 2. Individual effect of cultivars on agronomic and yield related traits

Cultivars	Plant height (cm)	Number of bolls/plant	Number of nodes/plant	Boll weight (g)	Seed cotton yield (kg ha^{-1})	Lint yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Seed cotton harvest (%)	Ginning out turn (%)
CIM-598	146.67 b	23.00 c	40.58 b	1.49 b	2289.0 a	41.41 c	0.83 ab	22 a	0.020 ab
MNH-886	152.50 a	25.66 b	40.58 b	1.45 b	2138.8 a	53.50 a	0.58 c	21 a	0.017 c
CIM-616	152.50 a	28.03 a	44.91 a	1.20 c	2161.9 a	39.33 d	0.81 ab	21 a	0.020 ab
CIM-612	141.67 c	24.75 b	40.75 b	1.48 b	2354.1 a	47.33 b	0.89 a	23 a	0.019 b
FH-lalazar	141.67 c	23.00 c	40.58 b	1.70 a	2590.5 a	36.58 e	0.79 b	25 a	0.021 a

Mean values sharing similar letter(s) in a column are statistically non-significant at p = 0.05 (LSD test)

Table 3. Individual effect of cultivars on physiological and fiber quality traits

Cultivars	Leaf area index	Crop growth rate (g m^{-2} day^{-1})	Net assimilation rate (g m^{-2} $week^{-1}$)	Leaf area duration (days)	Phosphorus concentration	Fiber uniformity	Staple length (mm)	Fiber strength (tppsi)	Micronair (μ $inch^{-1}$)
CIM-598	0.58 c	4.28 bc	1.31 c	546.5 c	40.25 c	40.25 c	21.75 c	24.83 c	4.28 bc
MNH-886	0.70 b	4.30 bc	1.38 a	760.1 a	48.16 a	58.16 a	36.16 a	30.66 a	4.30 bc
CIM-616	0.80 a	4.63 a	1.37 ab	461.7 d	45.83 b	45.83 b	19.58 d	24.50 c	4.63 a
CIM-612	0.81 a	4.25 b	1.36 b	637.5 b	45.75 b	45.75 b	24.50 b	28.16 b	4.25 b
FH-lalazar	0.51 d	4.23 c	1.32 c	404.2 e	42.00 c	42.00 c	17.33 e	23.58 c	4.23 c

Mean values sharing similar letter(s) in a column are statistically non-significant at p = 0.05 (LSD test)

Table 4. Individual effect of phosphorus on agronomic and yield related traits

Treatment	Plant height (cm)	Number of bolls/ plant	Number of nodes/ plant	Boll weight (g)	Seed cotton yield (kg ha^{-1})	Lint yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Seed cotton harvest (%)	Ginning out turn (%)
Control (P_0)	140.73 d	22.33 d	39.26 c	1.30 b	2116.9 a	40.40 c	0.73 b	21 a	0.018 a
50 kg/ha (P_1)	145.13 c	24.13 c	40.93 b	1.30 b	2221.3 a	43.00 b	0.75 b	22 a	0.018 a
100 kg/ha (P_2)	149.13 b	25.40 b	42.46 a	1.38 b	2221.4 a	43.93 b	0.80 ab	22 a	0.018 a
150kg/ha (P_3)	153.87 a	27.73 a	43.26 a	1.47 a	2667.9 a	47.29 a	0.83 a	26 a	0.019 a

Mean values sharing similar letter(s) in a column are statistically non-significant at p = 0.05 (LSD test)

Table 5. Individual effect of phosphorus on physiological and fiber related traits

Treatment	Leaf area index	Crop growth rate (g m^{-2} day^{-1})	Net assimilation rate (g m^{-2} week^{-1})	Leaf area duration (days)	Phosphorus concentration	Fiber uniformity	Staple length (mm)	Fiber strength (tppsi)	Micronair (μ inch^{-1})
Control (P_0)	0.64 c	4.24 b	1.31 d	495.9 d	41.00 c	41.00 c	20.33 d	24.73 b	4.24 b
50 kg ha^{-1} (P_1)	0.66 b	4.32 ab	1.33 c	538.1 c	44.80 b	44.80 b	23.40 c	25.46 b	4.32 ab
100 kg ha^{-1} (P_2)	0.71 a	4.46 a	1.35 b	582.6 b	45.60 b	45.60 b	24.40 b	27.20 a	4.46 a
150kg ha^{-1} (P_3)	0.71 a	4.46 a	1.39 a	631.4 a	54.20 a	54.20 a	27.33 a	28.00 a	4.46 a

Mean values sharing similar letter(s) in a column are statistically non-significant at p = 0.05 (LSD test)

Pure Appl. Biol., 9(4): 2577-2588, December, 2020
http://dx.doi.org/10.19045/bspab.2020.90274

Table 6. Interactive effect of phosphorus and cotton cultivars on agronomic and yield related traits

Treatment	Plant height (cm)	Number of bolls/ plant	Number of nodes/ plant	Boll weight (g)	Seed cotton yield (kg ha^{-1})	Lint yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Seed cotton harvest (%)	Ginning out turn (%)
P_0V_1	140.67 h	20.500 h	38.667 h	1.133 gh	2091.3 de	39.00 g	0.800 c-f	880.0 a-c	0.021 bc
P_1V_1	144.67 f	22.000 g	40.500 fg	1.333 de	2174.7 d	41.333 f	0.832 c-e	2174.7 b-d	0.020 bc
P_2V_1	148.83 d	23.833 f	41.667 de	1.400 cd	2428.3 bc	41.333 f	0.830 c-e	2428.3 a-d	0.020 bc
P_3V_1	152.83 c	26.000 d	41.833 d	2.133 a	2471.7 bc	44.500 e	0.865 b-d	2471.7 a-d	0.019 bc
P_0V_2	144.83 f	24.000 f	38.667 h	1.150 f-h	1923.7 fg	48.333 d	0.527 h	2928.3 ab	0.011 e
P_1V_2	149.33 d	25.833 de	40.667 e-g	1.333 de	1831.3 gh	54.167 c	0.492 h	1831.3 cd	0.009 f
P_2V_2	155.17 b	26.000 d	41.667 de	1.333 de	1903.7 fg	55.333 bc	0.665 g	1903.7 b-d	0.012 e
P_3V_2	161.33 a	27.167 c	41.833 d	2.083 a	2928.3 a	56.667 a	0.6667 g	1923.7 b-d	0.012 e
P_0V_3	144.83 f	25.000 e	41.667 de	1.033 h	2027.7 ef	37.667 hi	0.790 d-f	2027.7 b-d	0.020 a-c
P_1V_3	149.33 d	27.667 bc	43.500 c	1.200 e-h	2350.7 c	39.500 g	0.840 c-e	2350.7 b-d	0.021 ab
P_2V_3	155.17 b	28.500 b	45.833 b	1.366 de	2128.0 de	39.333 g	0.801 c-f	2128.0 b-d	0.020 bc
P_3V_3	161.33 a	31.667 a	49.000 a	1.283 d-g	2174.7 d	41.667 f	0.830 c-e	2174.7 b-d	0.019 bc
P_0V_4	136.17 i	22.000 g	38.500 h	1.200 e-h	1648.01 j	41.000 f	0.828 c-e	2361.7 b-d	0.020 bc
P_1V_4	141.00 h	23.500 f	40.333 g	1.316 d-f	2495.0 b	44.167 e	0.866 b-d	2495.0 a-d	0.019 bc
P_2V_4	143.00 g	25.333 de	41.500 d-f	1.550 c	2361.7 c	48.333 d	0.926 ab	2878.3 a-c	0.019 cd
P_3V_4	146.33 e	28.000 bc	42.333 d	1.833 b	2878.3 a	55.667 ab	0.960 a	1648.0 d	0.017 d
P_0V_5	136.50 i	20.333 h	38.667 h	2.050 a	1698.0 ij	36.167 j	0.730 fg	1698.0 d	0.020 bc
P_1V_5	141.17 h	22.167 g	40.667 e-g	1.333 de	1763.0 h-j	36.167 j	0.766 ef	1763.0 d	0.021 ab
P_2V_5	143.00 g	23.667 f	41.667 de	1.333 de	1801.3 g-i	36.667 ij	0.8233 c-e	1801.3 d	0.0227 a
P_3V_5	146.67 e	26.167 d	42.167 d	2.200 a	1814.7 g-i	38.500 gh	0.880 a-c	3481.3 a	0.022 a

Mean values sharing similar letter(s) in a column are statistically non-significant at p = 0.05 (LSD test)

Table 7. Effect of phosphorus on physiological and fiber quality traits of cotton cultivars

Treatment	Leaf area index	Crop growth rate (g m^{-2} day^{-1})	Net assimilation rate (g m^{-2} week^{-1})	Leaf area duration (days)	Phosphorus concentration	Fiber uniformity	Staple length (mm)	Fiber strength (tppsi)	Micronair (μ inch^{-1})
P_0V_1	0.558 k	0.725 o	0.768 mn	492.67 g	0.185 gh	39.667 gh	20.000 g	24.333 de	4.066 f
P_1V_1	0.5700 j	0.751 n	1.315 h	515.67 f	0.196 e-h	39.333 h	20.333 fg	25.000 de	4.166 ef
P_2V_1	0.590 i	0.785 m	1.331 fg	584.67 e	0.201 d-h	40.500 f-h	22.833 de	25.833 cd	4.416 cd
P_3V_1	0.618 h	0.825 l	1.336 f	594.67 de	0.205 c-h	41.667 e-g	24.000 d	24.333 de	4.500 c
P_0V_2	0.680 g	0.903 k	1.330 fg	613.33 d	0.220 b-g	43.500 e	25.833 c	27.167 c	4.750 b
P_1V_2	0.681 g	0.940 j	1.380 d	755.67 c	0.2250 b-f	57.333 c	35.333 b	29.000 b	4.066 f
P_2V_2	0.711 f	0.993 hi	1.398 c	805.33b	0.231 a-e	62.000 b	36.500 b	33.500 a	4.200 ef
P_3V_2	0.743 e	1.056 c	1.421 b	871.33 a	0.241 a-c	70.667 a	47.500 a	33.500 a	4.250 de
P_0V_3	0.768 cd	1.026 ef	1.336 f	415.33 hi	0.248 ab	42.33 ef	17.667 h	23.333 e	4.266 de
P_1V_3	0.776 c	1.050 cd	1.350 e	430.00 h	0.270 a	45.667 d	20.833 fg	24.667 de	4.416 cd
P_2V_3	0.980 a	1.361 b	1.388 cd	494.33 fg	0.178 h	40.000 gh	20.333 fg	25.000 de	4.733 b
P_3V_3	0.708 f	1.003 gh	1.413 b	512.33 fg	0.186 f-h	56.000 c	21.333 f	25.667 cd	5.166 a
P_0V_4	0.740 e	0.983 i	1.330 fg	588.00 e	0.190 f-h	40.333 f-h	22.667 e	25.667 cd	4.400 cd
P_1V_4	0.765 d	1.016 fg	1.331 fg	593.00 de	0.201 d-h	41.667 e-g	24.000 d	25.667 cd	4.500 c
P_2V_4	0.776 c	1.038 de	1.333 f	611.67 d	0.218 b-g	43.333 e	25.667 c	29.000 b	4.733 b
P_3V_4	0.956 b	1.416a	1.480 a	755.67 c	0.236 a-d	57.667 c	25.667 c	32.333 a	4.066 f
P_0V_5	0.4733 n	0.615 q	1.298 i	372.00 j	0.230 b-e	39.667 gh	16.000 i	23.667 e	4.200 ef
P_1V_5	0.5117 m	0.676 p	1.321 gh	406.33 i	0.240 a-d	40.500 f-h	17.167 hi	23.333 e	4.150 ef
P_2V_5	0.531 l	0.710 o	1.336 f	417.00 hi	0.250 ab	43.167 e	17.500 h	23.500 e	4.283 de
P_3V_5	0.565 jk	0.768 mn	1.355 e	431.67 h	0.270 a	45.667 d	19.833 g	24.667 de	4.400 cd

Mean values sharing similar letter(s) in a column are statistically non-significant at p = 0.05 (LSD test)

Table 8. Role of phosphorus foliar application on benefit cost ratio (BCR) of cotton 2015 & 2016

Years	Treatments	Yield (kg ha^{-1})	Value (Rs ha^{-1})	Stick value (Rs ha^{-1})	Gross value (Rs ha^{-1})	Total cost (Rs ha^{-1})	Net return (Rs ha^{-1})	BCR
2015	Control (P_0)	2116.9	148183	8000	156183	109950	46233	1.42
	50 kg ha^{-1} (P_1)	2221.3	155491	8000	163491	110550	52941	1.47
	100 kg ha^{-1} (P_2)	2221.4	155498	10000	165498	110950	54548	1.49
	150 kg ha^{-1} (P_3)	2667.9	186753	10000	196753	112000	84753	1.75
2016	Control (P_0)	1714.7	128602.5	8000	136602.5	106550	30052.5	1.28
	50 kg ha^{-1} (P_1)	1778.0	133350	8000	141350	107400	33950	1.31
	100 kg ha^{-1} (P_2)	1818.0	136350	10000	146350	109540	36810	1.33
	150 kg ha^{-1} (P_3)	1814.7	136102.5	10000	146102.5	108950	37152.5	1.34

BCR = benefit-cost ratio

Conclusion

Excess uses of nutrients over optimum level affects the economy of farmers. In respect to observe the concentration of fertilization that were supplemented to crops. Hence, it is very compulsory to improve endorsement programs that will mentioned the fixed fertilizer doses according to requirements of cotton crop. Present study concluded that the highest rate of phosphorus increase the cotton production and also increase the farmer's economy. Current study encourages the optimum use of phosphorus to avoid the excessive use of phosphors which leading higher input costs for farmer. Present study is also meaningful to improve the endorsement programs that will appropriately determine fertilizer supplements according to other crop needs.

Authors' contributions

Conceived and designed the experiments: H Ali, Performed the experiments: A Ahmad, Analyzed the data: R Ahmad, Contributed materials/ analysis/ tools: H Ali & S Hussain, Wrote the paper: S Hussain & A Ahmad.

Acknowledgements

The authors are very thankful to the Central Cotton Research Institute, Multan for providing the plant material and experimental site and Bahauddin Zakariya University, Multan for the financial support to carry out this work.

References

1. Gallagher JP, Grover CE, Rex K, Moran M & Wendel JF (2017). A new species of cotton from Wake Atoll, Gossypium stephensii (*Malvaceae*). *Syst Bot* 42: 115-123.
2. Ali H, Ahmad A & Hussain, S. (2020). The effect of exogenous phosphorous application on growth, yield, quality and net returns of upland cotton (*Gossipium hirsutum* L.). *Appl Ecol Environ Res* 18(1): 769-781.
3. Lenka NK & Lal R (2012). Soil-related constraints to the carbon dioxide fertilization effect. *Critic. Rev. Plant Sci* 31(4): 342-357.
4. Vance CP, Uhde SC & Allan DL (2003). Phosphorus acquisition and use: critical adaptations by plants for securing a nonrenewable resource. *New Phytol* 157: 423-447.
5. Campbell CD & Sage RF (2006). Interactions between the effects of atmospheric CO_2 content and P nutrition on photosynthesis in white lupin (*Lupinus albus* L.). *Plant Cell Environ* 29(5): 844-853.
6. Maqsood AG, Sabir MS, Ashraf, A & Aziz R (2005). Effect of P-stress on growth, phosphorus uptake and

utilization efficiency of different cotton cultivars. *Pak J Agr Sci* 42: 42-47.
7. Wang X, Tang C, Guppy CN & Sale PWG (2008). Phosphorus acquisition characteristics of cotton (*Gossypium hirsutum* L.), wheat (*Triticum estivum* L.) and white lupin (*Lupinus albus* L.) under phosphorus deficient conditions. *Plant Soil* 312: 117-128.
8. Ahmad Z, Ahmad Z, Gill MA, Qureshi RH, Rehman H & Mahmood T (2001). Phosphorus nutrition of cotton cultivars under deficient and adequate levels in solution culture. *Commun Soil Sci Plant Anal* 32: 171-187.
9. Schwab GJ, Mullins GL & Burmester CH (2000). Growth and nutrient uptake by cotton roots under field conditions. *Commun. Soil Sci. Plant Anal*. 31: 149-164.
10. Amanullah, Asif M & Nawab K (2010). Impacts of planting density and P-fertilizer source on the growth analysis of maize. *Pak J Bot* 42: 2349-2357.
11. Mahpara S, Shahnawaz M, Rehman K, Ahmad R & Khan FU (2019). Nitrogen fertilization induced drought tolerance in sunflower: a review. *Pure Appl Biol* 8: 1675-1683.
12. Aamer M, Sabir MF & Sadiq MA (2014). Exploiting genotypic variability among cotton cultivars for potassium use efficiency. *Develop Country Studies* 4: 7-12.
13. Bednarz CW & Nichols RL (2005). Phenological and morphological components of cotton crop maturity. *Crop Sci* 45(4): 1497-1503.
14. Baloch MJ, Khan NU, Rajput MA, Jatoi WA, Gul S, Rind IH & Veesar NF (2014). Yield related morphological measures of short duration cotton genotypes. *J Anim Plant Sci* 24: 1198-1211.
15. Gill KH, Sherazi SJA, Iqbal J, Ramzan M, Shaheen MH & Ali ZS (2000). Soil fertility investigations on farmers' fields in Punjab, Soil Fertility Res. Inst., Depart. Agri., Govt. of Punjab, Lahore, Pakistan, pp. 133-135.
16. Malewar GU, Badole SB, Mali CV, Siddiqui MB & Syed I (2000). Influence of flyash with and without FYM and fertilizer on physico-chemical properties of sunflower and cotton growing soils. *Annal Agric Res* 21: 187-191.
17. Saleem MF, Shakeel A, Bilal MF, Shahid MQ & Anjum SA (2010). Effect of different phosphorus levels on earliness and yield of cotton cultivars. *Soil Environ* 29: 128-135.
18. Guidi L, Pallini M & Soldatini GF (1994). Influence of phosphorus deficiency on photosynthesis in sunflower and soybean plants. *Agrochi-Mica* 38: 211-23.
19. Sawan ZM, Mahmoud MH & Momtaz OA (1997). Influence of nitrogen fertilization and foliar application of plant growth retardants and zinc on quantitative and qualitative properties of Egyptian cotton (*Gossypium barbadense* L. var. Giza 75). *J Agric Food Chem* 45: 3331-6
20. Hunt, KH (1978). Oxford University Press, USA.
21. Ndor E, Agbede, OO & Dauda SN (2010). Growth and yield response of cotton (*Gossypium* spp) to varying levels of nitrogen and phosphorus fertilization in Southern Guinea Savanna Zone, Nigeria. *PAT* 6: 119-125.
22. Ali H, Ahmad A & Hussain S (2020). The effect of exogenous phosphorous application on growth, yield, quality and net returns of upland cotton (*Gossipium Hirsutum* L.). *Appl Ecol Environ Res* 18(1): 769-781.
23. Ali H, Muhammad D & Abid SA (2005). Weed control practices in cotton (*Gossypium hirsutum* L.) planted on bed and furrow. *Pak J Weed Sci Res* 11: 43-48.
24. Amouzou KA, Naab JB, Lamers JP, Borgemeister C, Becker M & Vlek PL (2018). CROPGRO-Cotton model for determining climate change impacts on yield, water-and N-use efficiencies of cotton in the Dry Savanna of West Africa. *Agric Syst* 165: 85-96.