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Response of Cotton Varieties to Phosphorus Fertilizer on Growth, Yield and Economic Efficiency in northeast of Afghanistan

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ABSTRACT

A field experiment was conducted at the research farm of Kunduz Spinzar State-Owned Corporation in Collaboration with Kunduz University to evaluate response of cotton varieties to phosphorus fertilizer on growth, yield and economic efficiency in northeast of Afghanistan, the experimental design was Randomized Complete Block Design (RCBD) With split arrangement each replicated thrice, The study involved three cotton varieties (CD-401, AND-123 and K-01) and four phosphorus fertilizer levels (control, 30 kg p_2o_5/ha, 60 kg p_2o_5/ha and 90 kg p_2o_5/ha), different cotton varieties and phosphorus have significant impact on yield and economic parameters, the maximum Lint Cotton yield (1,749.02 kg/ha), Seed Cotton yield (3,666.07 kg/ha), Lint Cotton Yield (187,390AFN/ha), Seed Cotton yield (167,539 AFN/ha), gross return (354,929 AFN/ha), net return (339,876 AFN/ha) and B: Cost ratio (7.67) was in AND-123 variety compared with CD-401 and K-01 varieties respectively. The highest Lint Cotton yield (1,627.50 kg/ha), Seed Cotton yield (3,110.38 kg/ha), Lint Cotton Yield (174,370AFN/ha), Seed Cotton yield (142,144 AFN/ha), gross return (316,515 AFN/ha), net return (297,790 AFN/ha) and B: Cost ratio (7.67) was in 90 kg P_2O_5 kg ha^{-1} followed by phosphorus application of 60 kg P_2O_5 kg ha^{-1}, 30 kg P_2O_5 kg ha^{-1} and control respectively. It can be concluded AND-123 cotton variety along with 90 kg p_2o_5/ha is the best combination for cotton productivity and profitability in northeast of Afghanistan.

Keywords- Cotton, Phosphorus, Growth, Yield, Variety.

I. INTRODUCTION

Phosphorus is the second most limiting nutrient in cotton (*Gossypium hirsutum L.)* production after nitrogen, it is an essential plant nutrient required for all physiological processes during plant development, reproduction, and environmental adaptation (*Seleiman et al., 2020*). It is vital for photosynthesis and energy metabolism, biosynthesis of organic compounds, nucleic acids and phospholipids, enzymatic activities, and gene regulation as well as signaling (*Seleiman and Abdelaal 2018*). The application of sufficient Phosphorus increases the soil's available Phosphorus content and promotes the biomass accumulation of cotton (*Gossypium hirsutum*), especially the reproductive organs (*Cheptoek et al., 2021*). In each growth period of cotton, the accumulation of cotton biomass has a direct impact on the yield and quality of cotton (*Saleem et al., 2011*). Previous studies have found that a single cotton plant absorbs 0.5–0.6 g of phosphate in its lifetime, of which about 43–50% is used for vegetative organs (leaves > fruit branches > stems > roots), while 50–57% is used for reproductive organs development (cottonseed > boll > shell > bud > young boll > fiber). Moreover, the seedling stage (10–25 days after emergence) and the flowering and boll-setting stage (15–16 days after flowering) were the two critical periods for

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cotton's P requirement. Subsequently, low P significantly decreased the number of bolls, boll weight, seed cotton yield, and fiber quality (*Sawan et al., 2008* and *Farkhari et al., 2023*). This decrease in cotton yield and quality is due to an unbalanced source-sink relationship. As the reduction in cotton yield is due to low boll weight and number (low storage capacity), the decrease in boll weight is due to insufficient sources (*Aslam et al., 2009*). Thus, the lower yield under low Phosphorus condition is due to a poor source-sink relationship. More than 90% of the cotton yield comes from photosynthesis, but the source capacity of cotton is not only reflected in photosynthetic capacity, but also in the temporary storage capacity of leaves for excess photosynthetic products when effective photosynthesis is insufficient (*Sawan et al., 2008*). Photosynthesis produces carbohydrates in the form of sucrose and starch that are important for cotton growth and development (*Khaleeq et al., 2023b and Yang et al., 2014*) and are the basis for cotton yield and quality (*Echer et al., 2020*). Thus, under low P, the enzymatic activities related to sucrose metabolism are dependent on species and different tissue of the same species. A previous study found carbohydrate accumulation and distribution in cotton leaves under low P (*Ahmadet et al., 2021*). Phosphorus element plays an important role in plant growth and development, hence considered as critical for sustainable production of fiber worldwide (*Rose et al., 2016*). However, cotton cultivars differ for Phosphorus sensitivity, uptake, and acquisition. Furthermore, Phosphorus deficiency negatively affects the crop growth, yield, and quality. Previous studies reported that Phosphorus sensitivity resulted in notable differences in many indices among different genotypes (*Santos et al., 2015*). Thus, selecting cultivars with low-P tolerance can be a good strategy to enhance productivity.

Cultivar selection for a sustainable production system is considered a basic decision. However, a lot of literature are available on the cultivar evaluation with respect to Phosphorus sensitivity in various crops (*Ramaekers et al., 2010*), but a very few studies provide information on Phosphorus sensitivity in cotton cultivars. Previous studies also differed on the base of screening indices in cotton cultivars (*Li et al., 2010*). Furthermore, these studies concluded that biomass and Phosphorus content are important indices of cultivar evaluation especially, at the seedling stage. Unluckily, the previous studies have not directed that what are the indices indicated efficient evaluation in seedling (*Rose et al., 2016*). And what are the factors that may affect the final yield and fiber quality at the harvest in cotton. Therefore, in order to select cotton genotype with different Phosphorus sensitivities, evaluation on the base of difference in agronomic traits at the seedling stage, yield, and fiber quality is important to enhance the low-Phosphorus tolerance ability of cotton. The objectives of this study were, to determine the effect of different phosphorus levels on growth and yield of cotton varieties and to contribute to the development of sustainable practices for cotton production through informed phosphorus management.

II. MATERIALS AND METHODS

A field experiment was conducted at the Research farm of Kunduz Spinzar State-Owned Corporation in Collaboration with Kunduz University, Afghanistan during the cropping season of 2023. The experimental design was Randomized Complete Block Design (RCBD) with split arrangement replicated thrice. The study involved three cotton varieties (CD-401, AND-123 and K-01) and four phosphorus levels (control, 30 kg p_2o_5/ha, 60 kg p_2o_5/ha and 90 kg p_2o_5/ha), The experiment combination were twelve treatments *viz.* CD-401+0 kgP_2O_5/ha, CD-401+30 kgP_2O_5/ha, CD-401+60 kgP_2O_5/ha, CD-401+90 kgP_2O_5/ha, AND-123+0 kgP_2O_5/ha, AND-123+30 kgP_2O_5/ha, AND-123+60 kgP_2O_5/ha, AND-123+90 kgP_2O_5/ha, K-01+ 0 kgP_2O_5/ha, K-01+30 kgP_2O_5/ha, K-01+60 kgP_2O_5/ha and K-01+90 kgP_2O_5/ha. The soil texture was clay loam with an alkaline pH of 7.5. Each plot measured 6 m in length and 3 m in width, with four rows of cotton crop. The seedbed was prepared by cultivating the field twice with a tractor-mounted cultivator, followed by planking. Sowing was done on May 11, 2023, using a single row hand drill with a row spacing of 0.75 m and a plant-to-plant distance of 0.30 m maintained by thinning at the third true leaf stage. A dose of 100 kg N/ha and phosphorus as per treatment were applied in the form of urea and single super phosphate, respectively. All of the phosphorus was applied at sowing, while nitrogen was applied in three equal splits at sowing, after 35 days of sowing and after 65 days of sowing. Eight irrigations were applied, and weeds were controlled by two hoeing sessions at 30 and 65 days. All other agronomic practices were kept normal and uniform for all treatments. Data were collected on different parameters and analyzed statistically using Web Agri Stat Package 2.0 (WASP) for analysis of variance. Means were separated using Fisher's protected least significant difference (LSD) test at a 5% probability level as described by Steel et al. (1997).

III. RESULT AND DISCUSSION

Response of phosphorus levels on Growth of Different Cotton Varieties

The analysis of variance revealed (table 1), different cotton varieties have significantly affected on growth parameters, plant height, sympodial branches/plant and bolls/plant, the highest plant height was in K-01variety (97.44 cm) followed by AND-123 (86.38 cm) and CD-401 (85.55 cm) respectively, the maximum sympodial branches/plant was in AND-123 variety (11.88) followed by K-01 (11.19) and CD-401(10.72) varieties respectively, the highest bolls/plant was in AND-123 (29.41) followed by CD-401 (17.66) and K-01 (17.33) varieties respectively. However, the cotton

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varieties did not affected in leave area, leave area index, leaves/plant and monopodial branches/plant. Phosphorus application was significantly affected in all growth parameters, the heights leave area, leave area index, plant height, sympodial branches/plant and bolls/plant was recorded 6,250.72 cm^2, , 2.77, 98.44 cm, 12.88, and 24.11 respectively in 90 kg P_2O_5 kg ha^{-1}, followed by 60 kg P_2O_5 kg ha^{-1}. However, phosphorus management did not affected leaves/plant and monopodial branches/plant. *Sadiq et al., (2023)* and *Singh et al., (2013)* indicated that phosphate deficiency decreased plant growth and photosynthesis, thereby reduced biomass accumulation and yield. *Russell (2001)* claimed that phosphorus, as part of the cell nucleus, was important for cell division and the development of meristematic tissue, and therefore had a stimulating effect to increase the number of bolls and flowers per plant. *Saleem et al. (2010*) and *Khaleeq et al. (2023a)* observed that Phosphorus applications increased plant height, number of Sympodial branches/plant and number of monopodial branches/plant compared to control. (*Copur, 2006*). Number of monopodial branches/plant decreased while number of sympodial branches/plant increased with increasing Phosphorus levels. *Anwar et al. (2002)* reported significant differences among the varieties for the number of bolls per plant while increase in number of bolls per plant with increasing Phosphorus levels is also well documented. Boll weight is an important yield determining factor that varies among varieties (*Nazir et al., 2022* and *Hofs et al., 2006)* and with P levels (*Sawan et al., 2008*) reported that positive correlation exists between seed cotton weight per boll and seed cotton yield per plant; the same was confirmed in present studies (*Hemmat et al., 2023)*.

Table 1: Influence of phosphorus levels on leave area, Leaf area index, Plant height (cm), Leaves/plant, Monopodial Branches/plant (MBP), Sympodial Branches/plant (SBP) and Bolls/plant of Different Cotton Varieties

Treatments	Leaf area (cm^2)	Leaf area index	Plant height (cm)	Leaves/plant	MBP	SBP	Bolls/ plant
Cotton Varieties							
CD-401	5,049.77	2.24	85.55	45.27	1.47	10.72	17.66
AND-123	4,242.86	1.88	86.38	49.36	3.08	11.88	29.41
K-01	6,119.71	2.72	97.44	58.39	1.86	11.19	17.33
SE m±	639.98	0.28	2.48	5.20	0.82	0.21	1.00
CD (P=0.05)	NS	NS	10.02	NS	NS	0.87	4.03
Phosphorus Fertilizer							
0 kg P_2O_5 kg ha^{-1}	3,836.93	1.70	83.22	46.03	2.744	9.77	18.33
30 kg P_2O_5 kg ha^{-1}	4,844.65	2.15	86.14	53.99	1.742	10.59	21.68
60 kg P_2O_5 kg ha^{-1}	5,617.50	2.49	91.37	57.92	2.107	11.81	21.75
90 kg P_2O_5 kg ha^{-1}	6,250.72	2.77	98.44	46.07	1.963	12.88	24.11
SE m±	435.18	0.19	1.74	4.77	0.39	0.30	1.057
CD (P=0.05)	1,303.01	0.58	5.23	NS	NS	0.90	3.16

Response of phosphorus levels on yield and economic efficiency of Different Cotton Varieties

The results of this research indicated on (table2), different cotton varieties have significant impact on yield and economic parameters, the maximum Lint Cotton yield (1,749.02 kg/ha), Seed Cotton yield (3,666.07 kg/ha), Lint Cotton Yield (187,390AFN/ha), Seed Cotton yield (167,539 AFN/ha), gross return (354,929 AFN/ha), net return (339,876 AFN/ha) and B: Cost ratio (7.67) was in AND-123 variety compared with CD-401 and K-01 varieties. The analysis of variance show on (table2) different phosphorus levels have significantly affected on yield and economic efficiency of cotton varieties, the highest Lint Cotton yield (1,627.50 kg/ha), Seed Cotton yield (3,110.38 kg/ha), Lint Cotton Yield (174,370AFN/ha), Seed Cotton yield (142,144 AFN/ha), gross return (316,515 AFN/ha), net return (297,790 AFN/ha) and B: Cost ratio (7.67) was in 90 kg P_2O_5 kg ha^{-1} followed by phosphorus application of 60 kg P_2O_5 kg ha^{1}, 30 kg P_2O_5 kg ha^{-1} and control respectively. *(Sawan et al., 2006* and *Khaleeq et al., 2023c*) found that phosphorus application at three concentrations (i.e. 600, 1200, and 1800 ppm P) significantly increased the seed cotton yield compared to control (9.49% 17.12%). Meanwhile, Variety MNH-786 produced maximum seed cotton yield because of its more plant height, more number of bolls per plant and more boll weight than other varieties under study. Varieties differ with respect to seed cotton yield (*Samim et al., 2023* and *Ehsan et al., 2008*) so the aforementioned three plant growth characters may be used for variety selection. P increased the seed cotton yield per plant (11.06-17.71%) and seed cotton yield per hectare (9.34- 14.95%) than the control treatment (*Sawan et al., 2008*), however this increase was non-significant

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between two higher levels (60 and 90 kg ha-1). Significantly less yield with control or low level of P (30 kg ha-1) might be due to the reason that P deficiency is associated with restricted growth and development (*Havlin et al., 2007*) and the non-significant differences between higher levels show that 60 kg ha^{-1} might have met the demand of plant and any further addition of P may not be utilized by the plant leading to environment and economic concerns.

Table 2: Influence of phosphorus levels on yield and economic efficiency of Different Cotton Varieties

Treatments	Lint Cotton yield (kg/ha)	Seed Cotton yield (kg/ha)	Lint Cotton Yield (AFN/ha)	Seed Cotton yield (AFN/ha)	Gross return (AFN/ha)	Net return (AFN/ha)	B: Cost ratio
Cotton Varieties							
CD-401	1,201.97	2,547.84	128,779	116,436	245,216	230,163	5.23
AND-123	1,749.02	3,666.07	187,390	167,539	354,929	339,876	7.67
K-01	1,289.52	1,917.29	138,159	87,620	225,779	213,687	6.02
SE m±	22.66	38.82	2,429.21	1,773.75	3,940.46	5,544.56	0.10
CD (P=0.05)	91.36	156.50	9,794.02	7,151.12	15,886.4	22,353.9	0.41
Phosphorus Fertilizer							
0 kg P_2O_5 kg ha^{-1}	1,152.65	2,230.69	123,495	101,942	225,438	214,754	6.69
30 kg P_2O_5 kg ha^{-1}	1,382.49	2,597.73	148,120	118,716	266,837	254,821	7.04
60 kg P_2O_5 kg ha^{-1}	1,491.36	2,902.79	159,785	132,657	292,442	277,604	6.19
90 kg P_2O_5 kg ha^{-1}	1,627.50	3,110.38	174,370	142,144	316,515	297,790	5.29
SE m±	28.163	41.89	3,017.25	1,914.61	3,952.01	4,106.12	0.11
CD (P=0.05)	84.326	125.447	9,034.29	5,732.63	11,832.9	12,294.4	0.33

IV. CONCLUSION

The cotton variety of AND-123 along with 90 kg P_2O_5/ha was found to be the best treatment combination for maximizing cotton lint yield, seed cotton yield and economic efficiency for cotton production. Therefore, farmers are recommended to cultivate AND-123 variety with an appropriate level of Phosphorus fertilizer for achieving better yields and profits. Further research is needed to investigate the effect of other factors such as irrigation, plant density and pest management on cotton production.

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