Nitrogen and phosphorus effects on growth, and yield of black-eyed bean (*Vigna unguiculata* L.)

WA Seerat[1], R Nazir[1#], H Nimgrri[1], M Yahyazai[1] and K Khaleeq[1]

Summary

The combination of nitrogen and phosphorous plays a vital role in increasing the productivity of black-eyed bean. Therefore, a study was carried out at the Research Farm of Afghanistan National Agriculture Sciences and Technology University (ANASTU), Kandahar, Afghanistan during the spring of 2020 to evaluate the effect of nitrogen (N) and phosphorus (P) doses on the growth, yield and economics of black-eyed bean (*Vigna unguiculata* L.). The treatment consists of four levels of nitrogen (0, 20, 30 and 40 kg ha^{-1}) in main plots and four levels of phosphorus (0, 30, 60 and 90 kg ha^{-1}) in a sub-plot laid out in a split-plot design and replicated thrice. The plant height, LAI and dry matter accumulation in blacked-eye bean was significantly affected by N and P doses. The grain yield, biological yield and net return of black-eyed bean were significantly higher with the application of 30 kg N ha^{-1} in combination with 60 kg P_2O_5 ha^{-1} in the sandy clay loam soil of Kandahar, Afghanistan.

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Introduction

Afghanistan is an agrarian-based economy where wheat, rice, maize and pulses are major field crops. In developing countries like Afghanistan where protein malnutrition poses a serious challenge due to cereal-based dietary patterns, the inclusion of pulses into the staple diet could help in overcoming the crisis of malnourishment. Further, the protein obtained from pulses is comparatively cheaper than animal-based protein sources *i.e*., meat, egg and fish, owing to the low market prices of pulses. Pulses are an important source of proteins, vitamins and minerals for the predominantly vegetarian population and are popularly known as "Poor man's meat" and "rich man's vegetable" (Singh & Singh 1992, Bana et al. 2022; Haldhar et al. 2023). Globally, the black-eyed bean is cultivated in an area of 14.91 million hectares with a yield of 0.60 tons' ha^{-1} and a total production of 8.99 million tons (FAOSTAT. 2021). However, the cultivated area and production of pulses in Afghanistan are very low with only 77466 ha and 42417.3 tonnes, respectively with an average productivity of 0.54 tonnes ha^{-1} (FAOSTAT. 2021). Black-eyed bean is mostly grown in the spring season and warmer regions of the country like Kunduz, Helmand, Kandahar, Nangarhar, Parwan, Laghman, Takhar, Herat and Kapisa provinces (Babazoi. 2018 & Khaleeq et al. 2023a). So, there is a massive scope to improve its cultivation in Afghanistan for which the supplement of nutrient elements viz., nitrogen (N) and phosphorous (P) in proper doses is of paramount importance. Phosphorus is the most needed element for crop production in many tropical soils due to its deficiency in this type of soil. Legumes are phosphorus-loving plants and they require phosphorus for their optimum growth and seed development most especially in N-fixation which is an energy-driving process. Application of phosphorus is therefore recommended for black-eyed bean production on soils low in phosphorus. P not only enhances root growth but also promotes early plant maturity. Cowpea is a short-duration crop that often suffers from P deficiency during its growth stages. Similarly, in cowpea N application plays an important role a dose of 20 kg nitrogen ha^{-1} was more than sufficient for vegetative growth (Nazir et al. 2022; Musa et al. 2021).

[1]Afghanistan National Agricultural Sciences and Technology University (ANASTU)
[#]*Corresponding author: R Nazir, E-mail*: r.nazir@anastu.edu.af

Methods and Materials

A field experiment was carried out in the spring season of 2020 at Afghanistan National Agricultural Sciences and Technology University, Kandahar, Afghanistan. The experimental field was located at 31° 30' -31° 61' latitude and 65° 42' - 65° 71' E longitude. The mean maximum and minimum temperatures during the growing period were 36.33 and 14.53 °C, respectively. The wind speed during the growing period ranged Between 10.49 to 18.05 km per hour. Moreover, the maximum and minimum relative humidity was recorded at 53.86% and 18.38%, respectively. The total rainfall received during the growing season was only 33.79 mm with the maturity period coinciding with no rainfall. The treatments consisted of four levels of nitrogen (0, 20, 30 and 40 kg ha^{-1}) in main plots and four levels of phosphorus (0, 30, 60 and 90 kg ha^{-1}) in sub-plots combined to practice sixteen treatments combination which were laid out in a split-plot design and replicated thrice. The source of nitrogen was urea and that of phosphorus was triple super phosphate and these fertilizers were applied in each plot as per treatment to the crop. The total amount of Triple Super Phosphate (TSP) was applied to plots as basal, while urea was applied in three equal splits as basal, 25 DAS and at flowering stages, besides these fertilizers, 20 kg K_2O ha^{-1} was applied as basal dose uniformly to all plots. The Black-eyed bean variety (*Chesham bulbuli*) seeds were evenly dried and sown by line sowing, with a spacing of 30 cm between line to line and 15 cm between plant to plant. The plant height, leaf area and dry matter accumulation were recorded using standard procedure. The grain and straw yield of each plot were recorded and the final yield was expressed in kg ha^{-1}. The economics of Black-eyed bean viz., cost of cultivation (Afghani ha^{-1}), net returns (Afghani ha^{-1}) and benefit: cost ratio was calculated using standard procedure and formula.

Result and Discussion

The result showed that significantly higher plant height of black-eyed bean was recorded with the application of 30 kg N ha^{-1} at 30, 60, 90 DAS and harvest. Conversely, the black-eyed bean does not require too much nitrogen fertilizer as it fixes its nitrogen from the air using the nodules in its roots and extra N application might lead to luxuriant growth in pulses. As well, Nitrogen levels had a significant effect on leaf area cm^2 $plant^{-1}$ at 30, 60 and 90 DAS. At 30 and 60 DAS, a significantly higher leaf area was recorded with the application of 30 kg N ha^{-1} but at 90 DAS, the highest leaf area was obtained with the application of 40 kg N ha^{-1}. Increases in plant height and leaf area index might be due to nitrogen playing a key role in crop canopy development which is crucial for light interception, CO_2 fixation and dry matter production. These results are in close conformity with the findings of (Raghuveer et al. 2017). Significantly higher plant dry matter accumulation (g $plant^{-1}$) was recorded with the application of 30 kg N ha^{-1} at all growth stages. this might be due to nitrogen accelerated growth in terms of higher plant height, a greater number of leaves $plant^{-1}$ and a greater number of branches $plant^{-1}$. *Further, nitrogen application increased the photosynthetic efficiency of leaves and thus increased availability of photosynthates for better growth of crops might have resulted in an overall increase in dry matter* production. The results are in line with those (Meena & Chand. 2014; Samim et al. 2023 & Gul Agha et al. 2023). Different phosphorus levels had a significant influence on the plant height of black-eyed bean at 30, 60, 90 DAS and harvest and in this study, the result showed that significantly higher plant height was recorded with the application of 60 kg P_2O_5 ha^{-1}, where it remained at par with 90 kg P_2O_5 ha^{-1}. The different levels of phosphorus application had a significant effect on leaf area at 60 and 90 DAS but at 30 DAS were found to be non-significant. The highest leaf area cm^2 $plant^{-1}$ at 30 and 60 DAS was recorded with the application of 60 kg P_2O_5 ha^{-1}. Similarly, the application of 60 kg P_2O_5 ha^{-1} recorded significantly the highest dry matter accumulation of black-eyed beans at all stages of crop growth. Phosphorus effects on plant height, leaf area index and plant dry matter accumulation might be due to the crucial role phosphorus plays in root development and physiological processes of protein synthesis, similarly, phosphorus plays an important role in energy transfer in plants, causing rapid cell division and cell elongation in the meristematic region of the plant, the result of the study was in a close agreement with those reported by (Nkaa et al. 2014; Balai et al. 2017; Namakka 2017; Ehsan et al. 2017; Baboo & Mishra 2001).

The result revealed that grain yield and biological yield were significantly affected by different levels of nitrogen. Application of 30 kg N ha^{-1} produced significantly highest grain yield (2909 kg ha^{-1}) and biological yield (7987 kg ha^{-1}) of black-eyed bean, Treatment without nitrogen application N_0 produced significantly lowest grain yield (2506 kg ha^{-1}) and biological yield (7024 kg ha^{-1}), The increase in grain yield of black-eyed bean due to application of N_{20}, N_{30} and N_{40} over N_0 was 10.0, 16.1 and 13.4 percent, respectively. The increase in biological yield of black-eyed bean due to the application of N_{20}, N_{30} and N_{40} over N_0 was 9.9, 13.7 and 12.4 per cent, respectively, it might be due to that the optimum supply of N plays a vital role in alleviating nutritional deficiency in plants, particularly at the reproductive phase which resulted in producing a greater number of pods per plant, grains per pod and finally higher grain yield (Mishra 2003 & Lal 2004). The result revealed that application of phosphorus at the rate of 60 kg P_2O_5 ha^{-1} recorded significantly highest grain yield (2883 kg ha^{-1}) which was statistically at par with two other P levels of P_{90} and P_{30}, the highest biological yield of black-eyed bean was recorded under application of 30 kg P_2O_5 ha^{-1} (8009 kg ha^{-1}), which was at par with two other P levels of 60 kg P_2O_5 ha^{-1} (7864 kg ha^{-1}) and 90 kg P_2O_5 ha^{-1} (7478 kg ha^{-1}), it might be due to phosphorus seeming to produce and retain photosynthetic activity, uptake of other nutrients, reproductive activity and photosynthetic translocation from source to sink. A similar trend of results was reported by (Majumdar et al. 2004; Vikrant et al. 2005; Singh et al. 2006). The interaction effects of phosphorus and nitrogen on yield were significant in the present investigation (Fig.1), the highest grain and biological yield was obtained from $N_{40}P_{30}$ (40 kg N ha^{-1} and 30 kg P_2O_5 ha^{-1}), which remained at par with the treatment combination of $N_{30}P_{60}$.

The cost of cultivation is largely dependent on the amount of nutrients applied and their price in the market. The result showed that the maximum cost of cultivation (38829 AFN ha^{-1}) occurred in the treatment 40 kg N ha^{-1} followed by 30 and 20 kg ha^{-1} and the least (35789 AFN ha^{-1}) in the N_0 treatment. Data about net return showed that application of 30 kg N ha^{-1} was recorded higher (230×10^3 AFN ha^{-1}) which was significantly superior to over control and 20 kg N ha^{-1} however, it was closely at par with 40 kg N ha^{-1}. The maximum B: C ratio (3.99) was obtained with the application of 30 kg N ha^{-1} which remained at par with N_{40} and statically superior to over control and $N_{20.}$

Based on different phosphorus levels, the result showed that the maximum cost of cultivation (45345 AFN ha^{-1}) was obtained with the application of 90 kg P_2O_5 kg ha^{-1} followed by 60 and 30 kg ha^{-1} and least (29655 AFN ha^{-1}) in P_0 treatment. Data revealed that the application of 30 kg P ha^{-1} obtained maximum net returns (228×10^3 AFN ha^{-1}) and it was found closely at par with the rest of the phosphorus treatments. The respect of B: C ratio was observed maximum with the P_{30} level and it was found closely at par with the control and P_{60} levels.

Whenever P_{30} level of phosphorus was significantly superior to over P_{90}.

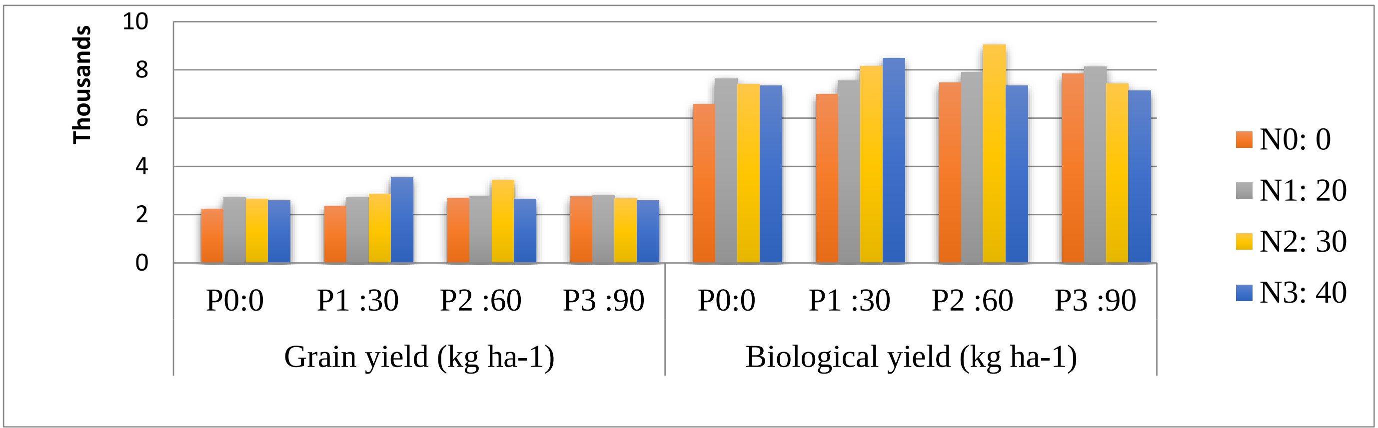

Figure 1. Interaction effects of different nitrogen and phosphorus levels on grain and biological yield of black-eyed bean

Table 1. Effect of different nitrogen and phosphorus levels on plant height, leaf area and dry matter accumulation in black-eyed bean at various growth stages

Treatment	Plant height (cm)				Leaf area (cm² plant⁻¹)			Dry matter accumulation (g plant⁻¹)			
	30 DAS	60 DAS	90 DAS	At harvest	30 DAS	60 DAS	90 DAS	30 DAS	60 DAS	90 DAS	At harvest
Nitrogen application rates kg ha⁻¹											
N_0: 0	3.71	20.36	35.64	40.15	19.0	687	820	0.33	9.03	18.73	34.70
N_1: 20	3.85	21.54	36.31	42.43	19.4	703	839	0.35	9.58	20.88	36.91
N_2: 30	3.98	21.68	37.86	42.98	20.7	726	860	0.41	10.72	24.51	39.20
N_3: 40	3.92	21.63	36.75	42.57	19.2	719	911	0.33	9.54	20.60	39.06
SEm±	0.028	0.13	0.25	0.27	0.20	5.95	9.92	0.004	0.068	0.184	0.331
LSD (P=0.05)	0.081	0.37	0.73	0.79	0.57	17.17	28.65	0.011	0.196	0.530	0.956
Phosphorus application rates kg ha⁻¹											
P_0: 0	3.75	20.65	34.64	40.84	19.5	678	802	0.34	9.22	20.54	35.76
P_1: 30	3.87	21.21	36.53	42.40	19.7	727	896	0.38	9.66	20.13	38.22
P_2: 60	3.96	21.68	37.77	42.90	20.1	741	874	0.35	10.06	21.77	39.08
P_3: 90	3.88	21.67	37.61	41.98	19.1	688	857	0.34	9.92	22.29	36.79
SEm±	0.069	0.31	0.62	0.67	0.48	14.56	24.30	0.010	0.166	0.450	0.811
LSD (P=0.05)	0.199	0.91	1.79	1.93	NS	42.06	70.19	0.028	0.481	1.299	2.243

Table 2. Effect of different nitrogen and phosphorus levels on yield components and economics of black-eyed bean

Conclusion

Treatment	Grain yield (kg ha⁻¹)	Biological yield (kg ha⁻¹)	Cost of cultivation (AFN ha⁻¹)	Net returns (×10³ AFN ha⁻¹)	B: C ratio
Nitrogen application rates kg ha⁻¹					
N_0: 0	2506	7024	35780	191	3.36
N_1: 20	2757	7718	37305	216	3.78
N_2: 30	2909	7987	38067	230	3.99
N_3: 40	2843	7896	38829	223	3.86
SEm±	44.1	67.4	-	4.0	0.07
LSD (P=0.05)	127.5	194.8	-	11.6	0.20
Phosphorus application rates kg ha⁻¹					
P_0: 0	2557	7273	29655	199	3.67
P_1: 30	2872	8009	34882	228	4.04
P_2: 60	2883	7864	40108	226	3.86
P_3: 90	2703	7478	45335	207	3.41
SEm±	108.1	165.2	-	13.9	0.17
LSD (P=0.05)	312.3	477.0	-	40.1	0.49

Best on the result it can be concluded that the application of 30 kg nitrogen per hectare along with 60 kg P_2O_5 per hectare could be the best nutrient levels and optimum for growth, and yield attributes. However, in respect of net return and B: C ratio 30 kg nitrogen per hectare along with 30 kg P_2O_5 per hectare could be the best N, P levels of Black-eyed bean in the semi-arid region of Kandahar, Afghanistan. However, this study was done in a site-specific area for one year and needs to be replicated for more validation and specific findings.

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Declaration of Interests

The authors have no conflict of interest to declare.

Data Sharing

All relevant data are within the manuscript.

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