Agronomy Journal of Nepal. ***8**(1):180-188*
ISSN: 2091-0649 (Print)
DOI: https://doi.org/10.3126/ajn.v8i1.70858

Performance of Black gram (*Vigna mungo* L. Hepper) under Different Levels of Phosphorus at Bardiya, Nepal

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Received: April 12, 2024
Revised: August 26, 2024
Published: October 18, 2024

The authors declare thatthere is no conflict of interest.

ABSTRACT

A field experiment was conducted during the spring season of 2023 in Badhaiyatal Rural Municipality-7, Bardiya district to evaluate the performance of black gram at various levels of phosphorus. A randomized complete block design (RCBD) consisting of four treatments and five replications were used for the study. The treatments consisted of different levels of phosphorous viz. 0 Kg ha^{-1} (control), 20 Kg ha^{-1}, 40 Kg ha^{-1} and 60 Kg ha^{-1}. Black gram var. BLG 0093-1 was sown at spacing of 40 cm x 5 cm in the plots sized 8 m^2. All the growth parameters and yield obtained from each treatment were compared at 5% level of significance. The results showed significantly greater number of branches (13.84), flower buds (11.33), root length (16.27 cm) and secondary roots (16.05) at 60 Kg phosphorus per ha followed by 40 Kg ha^{-1}. However, plant height, pods per plant, seeds per pod, weight of pods per plant, biomass and grain yield showed non-significant results at similar levels of phosphorus (60 Kg ha^{-1}). Though non-significant, higher number of fruiting branch, number of nodules, effective nodules, 1000 grain weight and harvest index were observed at 40 Kg ha^{-1} phosphorus. The findings suggested a gradual increase in the yield with increasing levels of phosphorus with the highest gross return from 60 Kg ha^{-1} phosphorus. However, since the variation in grain yield among the treatments was not significant, the cost involved with the 60 Kg ha^{-1} was greater as compared to 40 Kg ha^{-1} phosphorus, greater benefit was observed with the latter. So, on grounds of greater net return and better BC ratio, 40 Kg ha^{-1} phosphorus seems to be more profitable for the farmers.

Keywords: Economic analysis, flower bud count, harvest index, nodules, root length

How to cite this article:

Niraula S and R Sharma. 2024. Performance of black gram (*Vigna mungo* L**.** Hepper) under different levels of phosphorus at Bardiya, Nepal. Agronomy Journal of Nepal. **8**(1):180-188. DOI: https://doi.org/10.3126/ajn.v8i1.70858

INTRODUCTION

Black gram (*Vigna mungo* L.) a short duration crop, mostly grown in bunds around paddy field, can also be grown after wheat and before transplanting rice during the fallow period. Primarily grown as pulse crop, this crop plays important role in cropping system beside adding nitrogen to the soil and imparting proper nutrition in Nepalese diet. Black gram rich in proteins, minerals, fibres and bioactive compounds (Saeed et al 2020), contains ten times more phosphoric acid than other pulses (Shekhawat et al 2018). This crop is primarily consumed as daal (soup) as well as in the form of phuraula, bara, batuk, knwati, khichadi, mashyaura and phado in Nepal. A cheap source of protein to both human and animal diet, black gram can also be grown as green manuring crop and used as fodder green fodder for livestock, after harvesting of pods (Dwivedi and Singh 2020). Being quick maturing crop, rice-mustard-black gram-wheat cropping system can also be suggested in the area with good irrigation system for improving cropping intensity. This in turn can also break the disease cycle of rice-wheat cropping system.

The second important pulse crop after lentil, black gram is grown in 28,383 ha land and contributes 6.39% to the national pulse production in Nepal. Nepal produces 26,114 Mt of black gram annually with the productivity of 0.92 Mt ha^{-1} (MoALD 2023). Despite the greater demand of black gram within the country where soil, climate and environment is suitable for cultivation, we still rely on imported black gram due to insufficient production in Nepal. Higher vegetative growth, lesser flowering, insufficient pods, and lesser grain filling are the major problems associated with this crop in Nepal (Farmers, personal communication February 2023) which might be the reason for lesser area and production in the country. Lesser number of grains per pods and higher vegetative growth of black gram might be due to imbalanced amount of available nutrients in the soil, especially during the critical growth stages of crop (Satya and Sanjay-Swami 2021). Phosphorus is an essential element for growth and development of crop that enhances the symbiotic nitrogen fixation which is crucial for promoting the mobility of bacterial cells to plant organ for increasing the nodulation in crop root. Application of necessary amount of phosphorus to the crop can enhance photosynthesis, energy conservation, transportation, cell division and meristematic growth in living tissues, and grain quality. Farmers of Nepal consider black gram as ensured crop and cultivate it without applying scientific doses of fertilizers or they rarely or don't use the fertilizers. Hence there is low level of phosphorus in the soil and also decreases the amount of nitrogen as phosphorus plays an important role in increasing nitrogen fixing bacteria to the root region of black gram (Mitran et al 2018). The gradual decline of phosphorus levels in our soil is posing a challenge for enhancing the productivity of black gram over time. So, to address the proper amount of phosphorus levels required for better performance of crop, this research is needed.

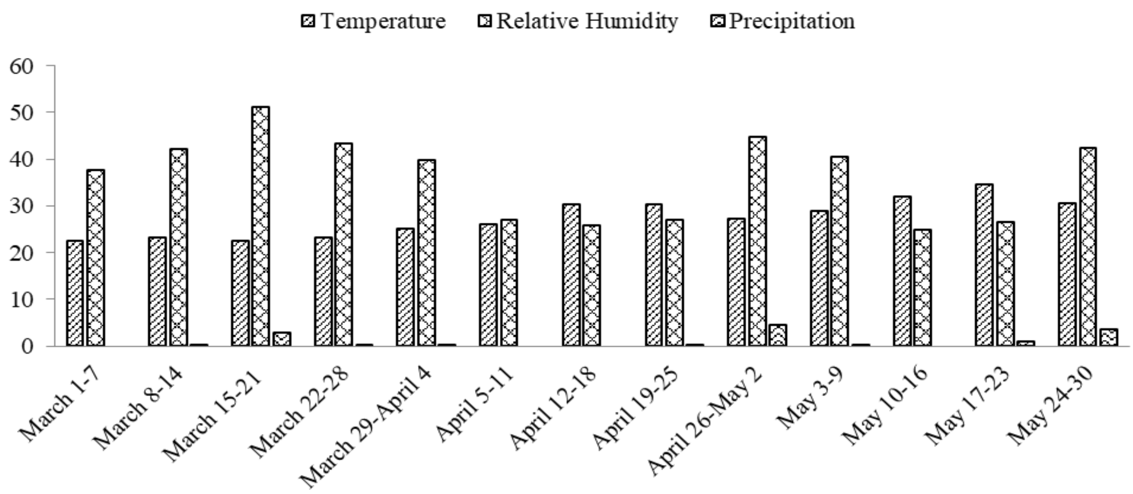
This study particularly investigates optimum phosphorus requirements for greater yield of Black gram while collecting some evidence that the proper application of phosphorus can surge the productivity of it. This may help in guiding farmers about the necessity of proper fertilization for better results needed for fulfilling the total crop requirement as pulse crop.

MATERIALS AND METHODS

Experimental site

A field experiment was conducted during the spring season from 1st March to 27th May 2023 at farmer's field of Badhaiyataal Rural Municipality-7, Bardiya district of Lumbini Province. The experimental site was located at 138m above sea level with Latitude from 28 07' North to 28 39" North and Longitude from 81 03' East to 81 41" East. The experimental site had sandy loam soil with soil pH of 6.2, 1.23% organic matter, 0.06% nitrogen, 302.2 Kg ha^{-1} phosphorus and potash content at 812.5 Kg ha^{-1} which was excessively high.

During the experimental period, the average temperature ranged from 22.47°C to 34.59°C, with the highest during 3rd to 4th week of May and was found lowest during the 1st week of March as shown in figure 1. Similarly, the average relative humidity ranged from 24.87% to 51.11%, with the highest during the 3rd week of March and lowest during 2nd week of May. The site received total precipitation of 13.22mm, with 0.91mm on 3rd week of May, 2.99mm on 3rd week of March, 4.50mm on last week of April (flowering and pod formation), and 3.54mm during May i.e. at the time of harvest.



(Source: POWER NASA, 2023)

Figure 1. Weather data of research site during field experiment

Experimental design

A randomized complete block design (RCBD) with four treatments and five replications was used for the study. For supplying the nutrient contents, urea (46% N), single super phosphate (16% P_2O_5) and muriate of potash (60% K_2O) were applied. Nitrogen and potassium were applied at 20 Kg ha^{-1} whereas phosphorous was applied as per the treatments as shown in table 1. Farmyard manure was applied at 6 t ha^{-1} one day before to sowing at the time of final land preparation. All the chemical fertilizers were applied as basal dose just before to sowing, as per the treatments.

Table 1. **Treatment details**

Treatments	Remarks
T_1 -20:0:20 NPK Kg ha^{-1}	No application of Phosphorus
T_2-20:20:20 NPK Kg ha^{-1}	Recommended dose of phosphorus
T_3-20:40:20 NPK Kg ha^{-1}	Phosphorus doubled on R.D
T_4-20:60:20 NPK Kg ha^{-1}	Phosphorus dose increased by 3 times on R.D

Cultivation practices

Black gram var. BLG 0093-1 was sown in the field on 1st March 2023 at spacing of 40cm x 5cm, at 1 cm depth. Pre-sowing irrigation was given 7 days before sowing. Thinning and gap filling was done at 15 DAS due to undistributed growth of the crop. Weeding was done three times manually at 15, 30 and 55 days after sowing due to excessive weeds in the experimental field. Irrigation was given at 15, 30, 45 days after sowing. Pods were harvested twice when 85% of the pods turned black i.e. matured i.e. 80 days after sowing and 87 days after sowing. Threshing was done manually after proper sun drying of the seeds for three days.

Data collection and observation

Ten plants were randomly selected and tagged on each plot for observation on root and shoot parameters at regular interval of 25 days whereas yield and yield attributing traits were recorded at the time of harvest. The shoot parameters for observation of the plants were plant height (cm), leaf number, branch number, fruiting branch number, and biomass per plant (g). Likewise, the root parameters were the number of nodules, effective nodules, root length (cm), and secondary roots. Whereas flower bud number, pods per plant, empty pods per plant, number of seeds per pod, weight of pods per plant (g), 1000 grain weight (g), and grain yield (t ha^{-1}) were noted to be the yield and yield attributing traits.

Data analysis

Randomized complete block design one-way ANOVA was used to analyze data. Treatment means were compared at 5% level of significance ($P \leq 0.05$) and the simple linear correlation and regression were also established. Data recorded at 75 DAS for all the growth parameters and at harvest for the yield and yield attributing traits were analyzed using the package 'doebioresearch' from the software R studio 4.3.1 version.

Economic analysis

For calculating cost of cultivation, all the cost incurred for each treatment and the amount obtained from selling the grains were calculated for all the 4 treatments. The cost of cultivation and gross return was determined on the basis of local market price of study site. The monetary value of total grain and straw were taken as gross return. The net return was calculated by subtracting total cost from gross return. The benefit cost ratio was computed as

Benefit Cost Ratio = Net return/ Cost of cultivation (total cost)

RESULTS AND DISCUSSION

Plant height

Statistically there was no significant difference in plant height among the treatments at 5% level of significance (Table 2). This may be due to the predominance of inaccessible forms of soil phosphorus which often restricts its intake by plants (Pani 2024). Contradictory to this, Mahesh et al (2021) reported statistically significant differences in plant height at different levels of phosphorous. Numerically, plant height was the highest at 60 Kg ha^{-1} phosphorous, which might be due to increased availability of phosphorous in the root zone. Comparatively higher plant height of black gram at same level of phosphorous was also recorded by Ahsan (2017) in his study.

Leaf number

Statistically no significant difference in leaf number was observed at early growth stage of the crop whereas significant differences among the treatments were observed at later stages (Table 2). The number of leaf increased by 15.29% as compared to control upon treatment at 60 Kg ha^{-1} with the lowest leaf number at 20 Kg ha^{-1}. Leaf number (16.5) was found to be the highest when 60 Kg phosphorous ha^{-1} was applied compared to control. Similar to the findings, Mir et al (2014) also recorded higher number of leaves of black gram at 60 Kg phosphorus ha^{-1}. Contrary to this, Gokila et al (2017) found increased number of leaves at 20 Kg ha^{-1} and 40 Kg

ha^{-1} phosphorus respectively.

Branch number

Significant differences in number of branches among the treatments were observed (Table 2). Branch count ranged from 10 to 13 with the highest number (13.84) recorded at 60 Kg ha^{-1} phosphorus followed by 40 Kg ha^{-1} and control with the lowest number at 20 Kg ha^{-1}. Awadhiya et al (2021) also found significantly influenced number of branches per plant at 60 Kg ha^{-1} phosphorus. Our findings showed increase in the number of branches by 14.95% at 60 Kg ha^{-1} phosphorus as compared to control.

Fruiting branch number

Non-significant difference among the treatments in fruiting branch count was observed at a 5% level of significance (Table 2). Fruiting branch number was found to be the highest (7.89) when 40 Kg ha^{-1} phosphorous was applied, when compared with control. The count ranged from 6 to 7, with the lowest number (6.28) at 60 Kg ha^{-1}. The positive effect of phosphorus application on fruiting branch per plant might be due to the better enzymatic activities which controlled flowering of black gram. The higher fruiting branch with higher phosphorus rates was attributable to better and effective nodulation in the root zone of black gram and higher flower buds during flowering stage of the crop.

Table 2. Performance of shoot parameters of black gram under different levels of phosphorus at Bardiya, Nepal, during Spring 2023

Treatment	Plant height (cm)	No. of leaf per plant	No. of branch per plant	No. of fruiting branch per plant
Control	16.80	14.36^{b}	12.04^{ab}	7.10
Phosphorous @ 20 Kg ha^{-1}	16.38	11.57^{c}	10.21^{b}	6.44
Phosphorous @ 40 Kg ha^{-1}	16.82	12.58^{bc}	13.03^{a}	7.89
Phosphorous @ 60 Kg ha^{-1}	17.57	16.56^{a}	13.84^{a}	6.28
Grand Mean	16.89	13.77	12.28	6.93
SEm (±)	0.34	0.66	0.73	0.46
$LSD_{0.05}$	1.03	2.04	2.25	1.42
F-test	ns	***	*	ns
CV (%)	4.44	10.73	13.29	14.93

Note: SEm: Standard error of mean, LSD: Least Significant Difference, CV: Coefficient of Variance, ns: non-significant, *: significant at 0.5 level of significance, ***: significant at 0.01 level of significance, Same letter(s) within column represent non-significant difference at 0.05 level of significance based on Duncan multiple range test

Root length

A significant variation among the treatments was observed in root length at later growth stages (Table 3), which was not distinct during early growth stags. Similar to our results, Abraham et al (2021) also recorded significantly higher root length per plant of black gram with the application of phosphorus. The longest root measurement was found at 60 Kg ha^{-1} phosphorus which was 25.35% increase over the control. Treatments 20 Kg ha^{-1} phosphorus and control measured statistically similar root length as that at 40 Kg ha^{-1}. This showed that phosphorous application at higher rates improves the length of root.

Secondary roots

The results on number of secondary roots showed significant difference among the treatments at 5% level of significance (Table 3). Treatments 20 Kg ha^{-1} phosphorus and control constitutes statistically similar number of secondary roots as that with 40 Kg ha^{-1} phosphorus. The number of secondary roots increased by 24.42% at 60 Kg ha^{-1} phosphorus compared to control, which might be due to growth of secondary roots from the increased root length. Statistically the highest secondary root count was recorded at 60 Kg ha^{-1} phosphorus at all growth stages which might be due to increased availability of phosphorous in the root zone.

Number of root nodules

Significant differences among the treatments were observed at 5% level of significance on the number of root nodules (Table 3). The highest number of nodules (13.67) was recorded at 40 Kg ha^{-1} phosphorus compared to control, which was statistically at par with 20 Kg ha^{-1}. The lowest number of nodules were observed at control plots, which might be due to the limited supply of phosphorus to the root zone which limits the availability of phosphorus and nitrogen to chloroplast that ultimately affect the photosynthetic processes as well as photosynthate supply to nodules. Similar results were concluded by several researches (Mir et al 2014, Philip et al 2021). However, the number of root nodules decreased at higher level of phosphorous. In line with our research, a report by Sulieman et al (2013) observed increase in root nodules up to 12 μM but phosphorous toxicity was observed in *M. truncatula* plants when the phosphorous concentration was increased beyond 12 μM.

Effective nodules

At early growth stage, effective nodules were not found in the root zone of black gram which may be due to the less nodule formation at initial phase of crop growth. Formation of effective nodules started later, after one month of sowing. However, the highest number of effective nodules was found at treatment with phosphorus level 40 Kg ha^{-1} followed by 60 Kg ha^{-1}, at later growth stages. The differences among the treatments were non-significant. As opposed to our findings, Shekhawat et al (2018) reported significant increase in number of effective nodules per plant with every increase in the rate of phosphorus application up to 40 Kg ha^{-1}.

Table 3. Performance of root parameters of black gram under different levels of phosphorus at Bardiya, Nepal, during Spring 2023

Treatment	Root length (cm)	No. of secondary roots	No. of nodules	No. of effective nodules
Control	12.98^{b}	12.90^{b}	10.43^{b}	2.43
Phosphorous @ 20 Kg ha^{-1}	12.23^{b}	11.95^{b}	13.13^{a}	2.27
Phosphorous @ 40 Kg ha^{-1}	13.78^{b}	13.55^{b}	13.67^{a}	2.73
Phosphorous @ 60 Kg ha^{-1}	16.27^{a}	16.05^{a}	11.10^{b}	2.67
Grand Mean	13.82	13.61	12.08	2.53
SEm (±)	0.51	0.62	0.54	0.30
$LSD_{0.05}$	1.57	1.90	1.65	0.93
F-test	***	**	**	ns
CV (%)	8.24	10.13	9.91	26.59

Note: SEm: Standard error of mean, LSD: Least Significant Difference, CV: Coefficient of Variance, ns: non-significant, **: significant at 0.1 level of significance, ***: significant at 0.01 level of significance, Same letter(s) within column represent non-significant difference at 0.05 level of significance based on Duncan multiple range test

Yield and yield attributing traits of black gram under different levels of phosphorus

Flower bud number

Significant differences among the treatments were observed in the number of flower buds (Table 4). The flower bud count was recorded at 50 DAS indicating 80% of the plants had reached the flowering stage. Flower bud number (11.33) was found to be the highest when 60 Kg ha^{-1} phosphorous was applied followed by 40 Kg ha^{-1} and 20 Kg ha^{-1} compared to control. Flower bud count ranged from 8 to 11, with the lowest number (8.56) at control. Statistically, 20 Kg ha^{-1} phosphorous and control yielded same number of flower buds. Similarly, treatment 40 Kg ha^{-1} phosphorus yielded statistically similar number of flower bud as yielded by 60 Kg ha^{-1} implying that phosphorous at 40 Kg ha^{-1} yields higher number of flower bud and for flower formation this dose is recommended.

Number of pods and empty pods per plant

Number of pods per plant ranged from 8 to 10 with the lowest number (8.07) at control (Table 4). Statistically, no significant variation among the treatments in number of pods per plant was observed at the time of harvest of black gram at 5% level of significance. Again a small increase in number of pods per plants was observed at 60 Kg ha^{-1} phosphorous, which was 32.38% increase over control. Similar to this finding, Choudhary et al (2017) also recorded significantly maximum number of pods per plant at 60 Kg ha^{-1} phosphorus. Also, the numbers of empty pods per plant were the highest for control (0.28) with the lowest one at treatment where phosphorus was applied at 60 Kg ha^{-1}. Gradual decline in empty pods for successive increase in the treatment with phosphorus were observed, indicating the significance of phosphorous in grain formation.

Seeds per pod

Statistically no significant difference among the treatments in number of seeds per pod was observed in black gram at 5% level of significance (Table 4). The number of seeds per pod increased gradually with increase in phosphorous, though the increase was non-significant. These findings are in accordance with the findings from Parashar et al (2020) who concluded that the application of phosphorus increased the symbiotic nitrogen fixation power and in turn, increased number of pods per plant, number of seeds per pod and 1000 grain weight and ultimately grain yield.

Weight of pods per plant

Statistically no significant difference among the treatments in weight of pods per plant was observed at the time of harvest of black gram at 5% level of significance (Table 4). Weight of pods per plant was found to be the highest (3.84 g) at the treatment with phosphorus level at 60 Kg ha^{-1} followed by 40 Kg ha^{-1} (3.30 g) and control (2.59 g). Weight of pods per plant was increased by 48.49% in the treatment with phosphorus level at 60 Kg ha^{-1} as compared to that of control. Weight of pods per plant ranged from 2.5 g to 3.8 g with the lowest weight 2.58 g observed at the treatment with phosphorus level at 20 Kg ha^{-1}.

The increased weight of pods per plant at 60 Kg ha^{-1} phosphorus level compared to other levels of phosphorus in the experiment can be attributed due to the various related growth and yield attributing parameters such as; maximum number of pods per plant and seeds per pod with the lowest number of empty pods of black gram in such level which can be directly obtained due to the improved root development of the crop as phosphorus is the quintessential nutrients which carryout various functions to improve the root development of leguminous crops.

Grain yield

The highest grain yield was found with the highest level of phosphorous used in the study and the lowest was observed in the control (without the use of phosphorus), though statistically non-significant. An increasing trend in grain yield with increasing levels of phosphorous was observed in our result with 28.98% higher grain yield in 60 Kg ha^{-1} phosphorus as compared to control. The increase in grain yield with the increasing phosphorus, as shown by our results might be attributed to better root proliferation, maximum number of flower buds, grains per pod and pods per plant favoring plant growth and vigor (Satya and Sanjay-Swami 2020). In line with our findings increase in grain yield with the increasing levels of phosphorus was reported in a study recording the highest yield at 50 Kg ha^{-1} P (Jagannath et al 2014). Contradictory to this, significant and higher grain yield was observed with the application of phosphorus at 40 Kg ha^{-1} in several researches (Pongen and Nongmaithem 2017; Shahin et al 2018). Increased translocation of photosynthates as a result of good root growth might be the reasons for higher yield and yield attributes at higher level of phosphorous (Tomar et al 2013). But in contradictory to our findings, Awadhiya et al (2021) recorded significantly higher grain yield at 60 Kg ha^{-1} phosphorus.

Harvest index

The data showed non-significant difference in the harvest index among the treatments at 5% level of significance. However, 40 Kg ha^{-1} phosphorus recorded the highest value of (0.23) followed by phosphorus level at 20 Kg ha^{-1} (0.19) and control (0.17).

Table 4. Performance of yield attributing traits of black gram under different levels of phosphorus at Bardiya, Nepal, during Spring 2023

Treatment	No. of flower buds per plant	No. of pods per plant	No. of empty pods per plant	No. of seeds per pod	Weight of pods per plant
Control	8.56[b]	8.07	0.28	5.57	2.59
Phosphorous @ 20 Kg ha^{-1}	8.69[b]	8.46	0.14	5.59	2.58
Phosphorous @ 40 Kg ha^{-1}	10.29[a]	10.11	0.09	5.57	3.30
Phosphorous @ 60 Kg ha^{-1}	11.33[a]	10.69	0.08	5.60	3.84
Grand Mean	9.72	9.33	0.15	5.58	3.08
SEm (±)	0.48	1.01	0.08	0.24	0.33
$LSD_{0.05}$	1.48	3.11	0.24	0.73	1.02
F-test	**	ns	ns	ns	ns
CV (%)	11.06	24.17	119.48	9.46	24.00

Note: SEm: Standard error of mean, LSD: Least Significant Difference, CV: Coefficient of Variance, ns: non-significant, **: significant at 0.1 level of significance, Same letter(s) within column represent non-significant difference at 0.05 level of significance based on Duncan multiple range test

Overall low harvest index is observed due to higher biological yield of the Black gram as compared to the economic yield. Observed results showed that the successive increase in phosphorus levels significantly increased number of nodules and effective nodules of plant along with high economic yield is close to 40 Kg ha^{-1} P. 40 Kg ha^{-1} P appreciably improved harvest index over other levels of phosphorus application and control as it is the function of grain yield and thousand grain weight and is also recorded highest in treatment with phosphorus level at 40 Kg ha^{-1}. Lower harvest index i.e. 0.17 at 60 Kg ha^{-1} phosphorus might be due to increased values of both biomass and yield of black gram in the same ratio. Abraham et al (2021) also reported a non-significant difference in harvest index with the highest value of (0.32) at 40 Kg ha^{-1} phosphorus. But in contradiction to this, Parashar et al (2020) recorded significant result with increased harvest index of black gram at similar level i.e. 40 Kg ha^{-1} phosphorus.

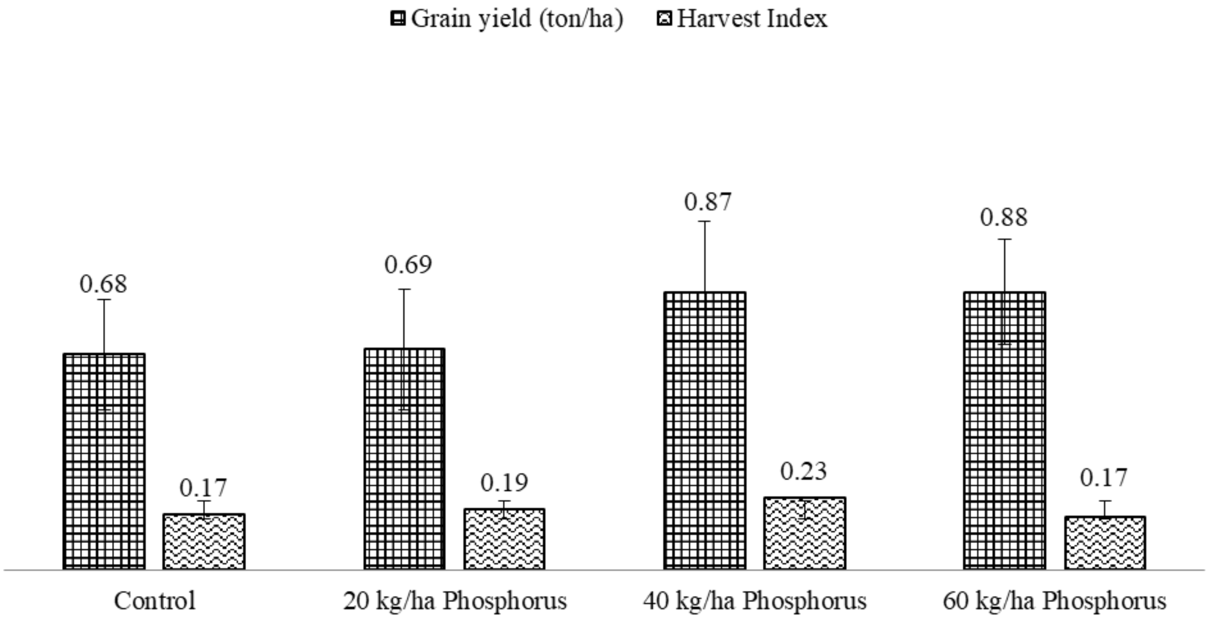


Figure 2. Grain yield and harvest index of black gram under different levels of phosphorus at Bardiya, Nepal, during Spring 2023

Economic analysis of black gram under different levels of phosphorus

The highest production cost was recorded in 60 Kg ha^{-1} (Rs.48, 789.17) followed by 40 Kg ha^{-1} (Rs.47, 989.17),20 Kg ha^{-1} (Rs.47,189.17) and control (Rs.46,389.17). The data reveals that the highest gross return was for the treatment level 60 Kg ha^{-1} followed by 40 Kg ha^{-1}, then 20 Kg ha^{-1} and control. The net return for the treatment level 40 Kg ha^{-1} was the highest. The lowest net return was found at control. Benefit cost ratio was highest for treatment level 40 Kg ha^{-1} (2.63) followed by 60 Kg ha^{-1} and 20 Kg ha^{-1} with the lowest (1.93) at control. However, the benefit seems to have plateaued at 40 Kg ha^{-1} as there was no further BC ratio increase at 60 Kg ha^{-1}. This suggests that 40 Kg ha^{-1} is the best as greater return is available at lower cost compared to 60 Kg ha^{-1}. Similarly, findings from several studies also show the maximum gross return, net return and BC ratio with the application of phosphorus at 40 Kg ha^{-1} (Pathak et al 2015; Singh et al 2020). Contrary to this, Saikishore et al (2020) recorded the highest net return, gross return and BC ratio of black gram at 50 Kg ha^{-1} phosphorus. The highest BC ratio was found at 50 Kg ha^{-1} phosphorus applied plots (Kadam et al 2014). Similarly, Divyavani et al (2020) found significant higher net returns and BC ratio of black gram at 60 Kg ha^{-1} phosphorus as compared to other treatments.

Table 5. Cost of cultivation, gross return, net return and benefit cost ratio of different treatments at Bardiya, Nepal, during Spring 2023

Treatment combinations	Cost of cultivation)Rs ha^{-1}(	Gross Return)Rs ha^{-1}(	Net Return)Rs ha^{-1}(	BC Ratio
Control	46389.17	135744.60	89355.43	1.93
Phosphorous @ 20 Kg ha^{-1}	47189.17	138892.80	91703.63	1.94
Phosphorous @ 40 Kg ha^{-1}	47989.17	174398.60	126409.40	2.63
Phosphorous @ 60 Kg ha^{-1}	48789.17	175079.20	126290.00	2.59

CONCLUSIONS

The result showed significant increase in root length, root branches and early flower buds initiation at higher levels of phosphorous, which increased with increasing levels of phosphorus up to 60 Kg ha^{-1}. The highest values for most of the root and shoot parameters including yields were recorded at 60 Kg ha^{-1} phosphorous except for number of root nodules. Though, non-significant, the highest black gram grain yield was obtained with 60 Kg ha^{-1} phosphorous with benefit cost ratio of 2.59. But, the highest net return and benefit cost ratio of 2.63 was recorded at 40 Kg ha^{-1} phosphorus, making it to be the most profitable in the western terai of Nepal.

ACKNOWLEDGEMENTS

The author acknowledges the research platform provided by Integrated Agriculture and Livestock Development Office (IALDO), Bardiya and Faculty of Agriculture, Far Western University, Tikapur, Kailali, Nepal. We would like to acknowledge the support and guidance received from Agriculture Technician from NGLRP, Mr. Kumar Subedi, and the officers from IALDO, Bardiya, Mr. Sagar Dhakal, Mr. Santosh Pathak and Mr. Tirtha Khadka throughout the research period. We would like to thank Mr. Ramesh Karki for his support during the field layout; the farmers Mr. Kamal Subedi and Laxmi Subedi for providing their land to conduct this research.

AUTHOR'S CONTRIBUTION

Satya Niraula, under the supervision of Asst. Prof. Raksha Sharma, formulated the research proposal, accomplished the experiment and prepared the manuscript. Raksha Sharma guided her in all aspects including the write-up of the manuscript.

CONFLICTS OF INTEREST

The authors have no any conflict of interest to disclose.

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