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Research Article

Effect of different phosphorus levels and varieties on the productivity of cowpea (*Vigna unguiculata* L.) at Khairahani, Chitwan, Nepal

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ABSTRACT

A field experiment was undertaken during the summer season of 2023 at Khairahani, Chitwan, with the objective of evaluating the effect of different phosphorus levels on the growth, yield attributes, and grain yield of two cowpea (*Vigna unguiculata* L.) genotypes and determine the optimum phosphorus dose for higher productivity under rainfed lowland conditions. Two cowpea genotypes, namely Surya and Gajale, and four phosphorus levels (0, 20, 40, and 60 kg P_2O_5/ha) were evaluated in a two-factor factorial Randomized Complete Block Design (RCBD) with three replications. The height of the plants, the index of leaf area, the length of the pods, and the number of pods on one plant were, however, not affected at all by the cowpea varieties or the phosphorus levels. The Gajale variety along with the highest phosphorus level (60 kg P_2O_5/ha) recorded the maximum number of grains per pod (12). On the contrary, grain yield was heavily depending on the variety and the phosphorus application, with the Gajale variety produced the highest yield (1.19 t/ha) and at 60 kg P_2O_5/ha (1.24 t/ha), followed by 40 kg P_2O_5/ha (1.13 t/ha). The interaction between cowpea varieties and phosphorus levels was observed to be statistically significant and thus, the Gajale variety with 60 kg P_2O_5 /ha obtained the maximum grain yield (1.35 t/ha). Hence, it can be stated that the cultivation of Gajale variety with the application of 60 kg P_2O_5/ha under rainfed lowland conditions in eastern Chitwan is the producer of cowpea productivity in the highest way possible.

Keywords: Cowpea, Phosphorus levels, Grain yield, Varieties, Rainfed condition

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INTRODUCTION

Cowpea (*Vigna unguiculata* L. Walp.), which is popularly known as black pea, Lobia, or barbati, is a multi-purpose leguminous crop that is classified under the genus Vigna and the subfamily Fabaceae (Leguminosae). It is an ancient crop that has been cultivated by humans, and it is still widely grown in a variety of regions with different agro-ecological conditions. The main reason for its extensive adaptability is the fact that cowpea is especially suitable to the climatic conditions of Nepal, mainly during the summer and monsoon seasons. The crop is commonly called "vegetable meat" due to its excellent nutrition with dry seeds having 22–24% protein content (Pant *et al.*, 2021). However, notwithstanding its nutritional and agronomical importance, cowpea still stands as a minor grain legume in Nepal and hence,

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receives less research and production attention comparatively (Aryal *et al.*, 2021). Generally, cowpea seeds are found to contain 23–25% of their dried weight as protein and 50–67% as carbohydrates, and the crop is appreciated for its production of different plant parts, leaves, green pods, both immature and mature seeds, from one single plant (Oboh *et al.*, 2015).

Botanically, cowpea is a diploid species (2n = 22) belonging to the Leguminosae family. Its place of origin is recognized as Central Africa but today cowpea is grown very widely in Asia, Africa, Central America, and South America. Leguminous crops, among which cowpea is included, are of great importance in the agrarian economy for their capability of fixing atmospheric nitrogen, creating deep root systems, and making soil nutrients available to plants, thus increasing soil fertility. The global cowpea production is significantly supported by the Asian nations like Bangladesh, China, India, and Indonesia. Cowpea is seen as the top contributor in organic and low-input agriculture, for its adaptability to harsh conditions and its capability of enriching soil. Cowpea provides various services: it can be used as a cover plant, recycling soil nutrients, fixing nitrogen, and controlling weed growth. The use of organic matter is widespread in hilly agro-ecosystems, providing not only the necessary nutrients but also the growth-promoting substances that improve soil fertility and the overall productivity of the area. Cowpea, on the other hand, needs sufficient phosphorus (P) and other mineral nutrients to develop strong roots, for nodulating, and maintain biological nitrogen fixation through its entire life cycle (Pardhi *et al.*, 2022).

Cowpea is a very versatile crop which can be grown in different ways such as rainfed, irrigation, and with the help of the remaining moisture like in the flood plains on the rivers and lakes. The best conditions for its growth are tropical climates with night temperatures of 28°C, daytime temperatures of 30°C, and annual rainfall of 600 to 900 mm (Madamba *et al.*, 2006). Nevertheless, early maturing varieties allow cowpea cultivation even in regions receiving less than 500 mm of rainfall, such as the Sahel. The crop performs well in poor, sandy soils and exhibits considerable drought tolerance, although it is sensitive to salinity; however, it can tolerate soils with high aluminum content (Nkaa *et al.*, 2014).

Throughout the entire crop growth cycle, having adequate supply of nutrients is very necessary for getting the cowpea yield at its peak, and phosphorus is the element that is most critical in that process. Phosphorus is the element that takes care of root growth, nodulation, energy transfer, and able nitrogen fixation among others. But also, Nitrogen is needed in the early stages of growth to speed up seed germination, vegetative growth, branching, pod formation, and eventually more seeds harvested. In legumes, phosphorus is the main raw material of proteins, phospholipids, and large amounts of potassium, while trace substances like molybdenum have a positive impact on cowpea yield by controlling nitrogen-fixing enzymes, such as nitrogenase and nitrate reductase, which are necessary for the proper functioning of nodules (Dhakal *et al.*, 2019). Cowpea not only helps in yielding more crops but also plays an important role in eco-system sustainability by fixing nitrogen in the soil and keeping it healthy.

Cowpea is a legume that is cultivated in more than 100 countries worldwide (Singh *et al.*, 2011), and its production is expected to grow from 9.8 million tons in 2020 to 12.3 million tons in the year 2030 (Boukar *et al.*, 2018). However, the global increase in cowpea cultivation has not changed the fact that very little knowledge exists about the different cowpea genotypes' reactions to the changes in phosphorus levels under Nepalese rainfed

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lowland conditions. Moreover, the optimum phosphorus application rates for enhancing cowpea productivity are still largely unrecorded in the form of recommendations which are location specific. Hence, it is inferred that the responses of cowpea genotypes in terms of growth and yield to phosphorus fertilization are different and that an ideal phosphorus level is there to produce maximum grain yield in rainfed lowland environments. In this context, the present study was undertaken to evaluate the effect of different phosphorus levels on the growth, yield attributes, and grain yield of selected cowpea genotypes and to identify the optimum phosphorus dose and suitable variety for enhancing cowpea productivity under rainfed lowland conditions of eastern Chitwan, Nepal. However, as the study was conducted during a single growing season and at one location, the findings may not fully capture seasonal and spatial variability, indicating the need for further multi-location and multi-season investigations to validate the results.

MATERIALS AND METHODS

Experimental Location

The research farm of Rampur Campus in Khairahani, Chitwan, Nepal was the location of a field experiment that ran during the summer of 2023. The experimental site is situated geographically in the Inner Terai region of Nepal at 27°36′ N parallel and 84°34′ E meridian and has an altitude of 203 m above sea level. The location of the site is approximately 18 km to east of Bharatpur, the district capital of Chitwan in Bagmati Province. The experimental field had a level and uniform surface, plus all the physically and infrastructurally necessary facilities for effective experiment conduct were available. The experimental field was cultivated prior to the study, using a Rice–Fallow–Buckwheat cropping pattern. The harvesting of buckwheat took place before the experiment began, and then the field was left fallow for approximately two weeks. It was an area with low elevation that had rich soil, thus making it an ideal place for leguminous plants to grow. Nepal's weather has three separate seasons: the monsoon season from May to October, winter from November to February, and spring from March to April. The place where the study took place had a subtropical monsoon climate, which was characterized by very hot and humid conditions in summer. The NASA POWER database provided the weather data for the experiment. Generally, the monsoon starts around mid-June and goes on until late September. The summer of 2023 (the month of the experiment), the highest temperature was a scorching 42.89°C (in May–June), and the lowest was a cool 15.6°C. The average monthly rainfall was steadily increasing from 105.72 mm in April to 844.68 mm in July, with the same trend for average relative humidity, which went up from 31.42% to 72.62%.

Plant Materials

The test crop was cowpea. Two cowpea varieties were used in the experiment: Surya and Gajale. These varieties were selected based on their adaptability and popularity among farmers in the region. They were brought from certified local seed suppliers from Parsa, Chitwan.

Experimental Design and Treatment Details

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. A total of eight treatment combinations, consisting of two cowpea varieties and four levels of phosphorus, were evaluated, resulting in 24 experimental plots.

Each plot measured 2 m × 3 m (6 m²). A spacing of 60 cm × 20 cm was maintained between rows and plants, respectively. A distance of 0.5 m was kept between adjacent plots to

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minimize treatment interference. Five representative plants were randomly selected and tagged from each plot for recording growth and yield observations.

The treatments consisted of different levels of phosphorus applied along with a uniform dose of nitrogen and potassium, as detailed below:

Table 1: Treatment details used in this study

Treatment symbol	Treatment Details
T_1	Surya + 20:0:20 kg $N:P_2O_5: K_2O$ /ha
T_2	Surya + 20:20:20 kg $N:P_2O_5: K_2O$ /ha
T_3	Surya + 20:40:20 kg $N:P_2O_5: K_2O$ /ha
T_4	Surya + 20:60:20 kg $N:P_2O_5: K_2O$ /ha
T_5	Gajale + 20:0:20 kg $N:P_2O_5: K_2O$ /ha
T_6	Gajale + 20:20:20 kg $N:P_2O_5: K_2O$ /ha
T_7	Gajale + 20:40:20 kg $N:P_2O_5: K_2O$ /ha
T_8	Gajale + 20:60:20 kg $N:P_2O_5: K_2O$ /ha

Cultural Practices

The initial preparation of the land was done one month prior to sowing the seeds using a tractor-drawn cultivator to loosen the soil and shatter the layers that were compacted. On the same day, planking and harrowing were performed at the same time as the fieldwork. The area was then left in the open for 2-3 days to kill off soil-borne insects and weeds because of the heat. The day of sowing saw the final land preparation through manual toil with spades and hoes to clear as much of the remaining weeds and crop residues as possible. The experimental layout was then opened with measuring tape and pegs. FYM at the rate of 6 tons per hectare was spread over the whole area during land preparation. The application of nitrogen was at the rate of 20 kg/ha, that of phosphorus at 0, 20, 40, and 60 kg/ha, and that of potassium at 20 kg/ha according to the treatment. Nitrogen was applied in two equal portions: 50% initially and the remaining 50% later during flowering. The dibbling method was used for sowing following the specified planting geometry. Two seeds were sown in one place to ensure germination and later thinning was done to have only one healthy plant per hill. A seed rate of 25 kg/ha was employed. Gap filling was carried out 10 days after sowing (DAS) in areas with poor germination and thinning was done on 15 DAS to achieve the desired plant population. The experiment was conducted primarily under rainfed conditions, with supplemental irrigations provided at intervals of 7–8 days depending on weather and soil moisture status. At early growth stages, fungal rot symptoms were observed; therefore, Saaf fungicide was sprayed uniformly across the field as a preventive measure.

Data Collection

Growth Parameters: The counting of total leaves of each sample plant was done 30 days after sowing, 45 days after sowing, and 60 days after sowing. Plant Height was measured from one randomly selected sample plant in each plot. Plant height Was measured at 30,45 and 60 days after sowing respectively. The total number of branches was counted in the sample plants just before harvesting. Leaf Area Index stands for the total area of leaves per unit of ground area and thus it is indirectly related to the amount of light that can be intercepted by the plants. It is expressed as the one-sided green leaf area per unit area of ground surface

LAI=Leaf area (cm^2)/ Ground area (cm^2) ……………. Eq. (1)

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Leaf area index was determined at 30 days after sowing, 45 days after sowing and 60 days after sowing.

Yield attributing characters: The counting of pods in the net plot was carried out on the five plants selected from those already marked, and the number of pods from each sample plant was averaged and then used to calculate the number of pods per plant. The process of measuring pod length was performed on ten pods from each of the five plants selected at random, and the total length of these ten pods from the respective experimental plot was taken to determine the mean pod length. The planting rows of the net plot were the source of the five marked plants from which the number of seeds in ten pods of the five plants was counted after harvesting. The average value was used to calculate the number of seeds per plant. Five marked plants were taken from the net plot; pod counts were done on ten pods from the five plants, and the average value was used to determine the number of pods per plot. The counting and weighing of the thousand seeds were done from the seed yield of net plot in each experimental pot and the weighing was done using an electronic balance to determine the thousand seed weight in grams.

Yield characters

Grain yield (t/ha): The total plot was harvested to determine the seed yield of each experimental plot. The pods were sun-dried after harvesting, then threshed, and finally the seeds were cleaned to get the final weight of the seed from each experimental plot. The computation of seed yield per hectare was done for each treatment and each replication based on the net plot seed yield. The moisture percentage of the seed from each net plot was determined by an automated moisture meter and the final seed yield was adjusted at 10% moisture content using the following formula.

Actual grain yield (at 10% MC) = Harvest Yield × (1-harvest moisture)/ (1-standard moisture) …………………. Eq. (2)

Where MC = Initial moisture content of fresh sample in percent.

Biological yield (t/ha): Once the harvest was done from the specific net plots, all the plants with their entire parts such as stems and leaves were taken out from the soil; a sickle was then used to cut off their roots. The plants obtained together with the husk from the pods were dried under the sun and their weights were taken afterward. With this, we were able to determine the total stover yield for every experimental plot.

Harvest Index: The percentage of Harvest index was calculated by the ratio of economic yield to biological yield according to the formula given below.

Harvest Index (HI) % = Economic (grains) yield/Biological (Grains + Stover) yield) ×100…… Eq. (3)

Statistical Analysis

All collected data were first tabulated in Microsoft Excel and subsequently analyzed using R Studio software. Analysis of Variance (ANOVA) was performed to test the significance of treatment effects. Mean comparisons were carried out using Duncan's Multiple Range Test (DMRT) at a 5% level of significance.

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RESULTS AND DISCUSSION

Yield Attributing Characters

Branch Numbers per plant: The effect of variety and Phosphorus level on branch numbers was found to be nonsignificant. Highest number of branches were observed in Phosphorus 40 kg/ha which is in accordance with Aryal *et al.* (2021), which also corroborates with findings of Musa *et al.* (2017) and Namakka *et al.* (2017). Variety had no significant effect on the number of branches of cowpea at P levels of 0, 20, 40, and 60 kg P_2O_5 ha which is in accordance with Singh *et al.*(2011) and Daramy *et al.* (2017).

Pods number per plant: The effect of variety on pod number was found to be non-significant whereas the effect of Phosphorus doses on Pod number was found to be significant. The highest pod number was found on phosphorus doses 40 kg/ha (12.78) whereas the lowest was on phosphorus doses 0 kg/ha (9.52). Similar results were observed by Singh and Singh (2017) and Singh *et al.* (2011). Similar results were observed by Tirkey *et al.* (2020), Adjei-Nsiah *et al.* (2018), Karikari *et al.*(2015) and Ndor *et al.* (2012). This might be due to application of phosphorus, which might have resulted in increased carbohydrate accumulation and their remobilization to reproductive parts of the plants, being the closest sink and hence, resulted in increased plant growth, flowering and fruiting. Same results were also observed by (Nadeem *et al.*, 2018) and (Khandelwal *et al.*, 2012).

Grains per pod: Grains per pod was found to be significantly impacted by variety. The Gajale variety had the most grain per pod (12.10). Similarly, it was discovered that phosphorus doses had a considerable impact on grain per pod. The lowest grain per pod was discovered at 20 kg/ha (10.28), while the greatest grain per pod was found at 60 kg/ha (12.00), which is statistically comparable to phosphorus doses of 40 kg/ha (11.30). Sudharani *et al.* (2020) and Kumar *et al.* (2025) discovered that phosphorus doses had a considerable impact on grain per pod. The lowest grain per pod was discovered on 20 kg/ha(10.28), while the greatest grain per pod was found at 60 kg/ha (12.00), which is statistically comparable to phosphorus doses of 40 kg/ha (11.30). Sudharani *et al.* (2020) and Konnepati *et al.* (2023) also reported similar results. Plant development, photosynthesis, blooming, seed setting, and nitrogen fixation may have contributed to the notable and highest number of grains per pod with the application of phosphorus (50 kg/ha), which eventually improved yield qualities. Quiroz *et al.* (2018) reported similar results. Plant development, photosynthesis, blooming, seed setting, and nitrogen fixation may have contributed to the notable and highest number of grains per pod with the application of phosphorus (50 kg/ha), which eventually improved yield qualities.

Pod Length (cm): The effect of variety and levels of phosphorus was found to be non-significant on pod length of cowpea. Similar results were also obtained by Singh *et al.* (2007) on increasing the levels of phosphorus from 0 kg/ha to 90 Kg/ha.

Test weight (g): Likewise, the effect of variety on test weight was found to be significant. The highest test weight was found on Gajale variety 91.86 whereas the lowest was found on Surya variety. phosphorus doses were also found to be significant. The highest Test Weight was found on Phosphorus doses 60 kg/ha (84.82) which is statistically at par with Phosphorus doses 40 kg/ha (84.15). Similar results were recorded by (Henshaw, 2008). Test weight increased by increasing the phosphorus level up to 60 kg/ha.

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Table 1: Effect of different varieties and phosphorus levels on yield attributing characters of cowpea at Khairahani, Chitwan during 2023

Treatments	No. of branches per plant	Pods number Per plant	No. of grains per pod	Pod Length (cm)	Test weight (g)
Variety					
Surya	7.55	10.80	9.91[b]	15.99	73.51[b]
Gajale	7.30	12.425	12.10[a]	16.34	91.86[a]
LSD (0.05)	2.05	6.68	1.13	0.51	4.59
SEM (±)	1.37	14.50	0.58	0.08	6.85
F-test	NS	NS	*	Ns	**
CV%	15.74	32.79	6.90	1.79	3.17
Phosphorus level (kg/ha)					
0	7.70	9.52[a]	10.44[b]	15.70	80.54[a]
20	7.13	11.45[ab]	10.28[b]	16.55	81.22[a]
40	7.46	12.78[b]	11.30[a]	15.83	84.15[b]
60	7.40	12.70[b]	12.00[a]	16.55	84.82[b]
LSD (0.05)	1.50	2.07	0.80	1.14	1.18
SEM (±)	1.42	2.70	0.40	0.82	0.88
F-test	NS	*	**	NS	***
CV%	16.07	14.15	5.77	5.60	1.13
Grand Mean	7.43	11.61	11.00	16.16	82.68

Significant at 0.05 level, ** significant at 0.01, * Significant at 0.001, CV: coefficient of variance, LSD: least significant difference, SEM: standard error of means*

Yield characters

Grain yield (t/ha): It was revealed that the effect of variety on grain weight was significant, the Gajale variety bearing the highest weight of 1.21 t/ha while the Surya variety only yielded the lowest of 0.94 t/ha. Likewise, the effect of phosphorus doses on grain weight was also significant with the highest weight being recorded at 60 kg phosphorus per hectare while 0 kg phosphorus resulted in the lowest grain weight. Konnepati *et al.* (2023) observed similar findings when increasing the levels of Phosphorus dose from 30 kg/ha to 50 kg/ha. (Namakka *et al.*, 2017) and (Mawo *et al.*, 2016) reported increasing the levels of phosphorus from 0 kg/ha to 40 kg/ha also yielded similar results. (Nkaa *et al.*, 2014) also found that while increasing the levels of Phosphorus dose yield levels were also increasing. The increase in grain yield due to phosphorus application can be attributed to the important contribution of the element in improving the photosynthesis process facets such as number of leaves per plant and leaf area.

Biological Yield: The impact of variety on biological yield was determined to be non-significant, while the impact of phosphorus doses on biological yield was determined to be significant, with the highest biological yield gained at phosphorus doses of 60 kg/ha and the least yield at 0 kg/ha. Similar results were observed by (Singh *et al.*, 2011).

Harvest Index: The effect of variety and phosphorus doses were found to be non-significant on harvest index of cowpea. Similar results were obtained by (Konnepati *et al.*, 2023).

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Table 2: Effect of different varieties and phosphorus levels on yield attributing characters of cowpea at Khairahani, Chitwan during 2023.

Treatments	Grain yield t/ha	Biological yield (t/ha)	Harvest Index (%)
Variety			
Surya	0.94^{b}	4.75	19.66
Gajale	1.21^{a}	5.70	21.14
LSD (0.05)	0.24	1.56	33.93
SEM (±)	0.01	0.80	10.22
F-test	*	NS	NS
CV%	12.83	17.17	28.55
Phosphorus level (kg/ha)			
0	0.90^{d}	4.62^{d}	19.70
20	0.99^{c}	5.00^{c}	19.76
40	1.13^{b}	5.50^{b}	20.57
60	1.24^{a}	5.80^{a}	21.57
LSD (0.05)	0.07	0.26	1.88
SEM (±)	0.002	0.04	2.25
F-test	***	***	Ns
CV%	5.12	3.95	7.35
Grand mean	1.06	5.23	20.39

** Significant at 0.05 level, ** significant at 0.01, *** Significant at 0.001, CV: coefficient of variance, LSD: least significant difference, SEM: standard error of means*

CONCLUSION

The study evaluated the effects of cowpea varieties and phosphorus levels on growth and yield at Khairahani, Chitwan. Growth parameters, including plant height, number of leaves, and leaf area index, were not significantly influenced by either variety or phosphorus level. However, yield attributes were affected: the Gajale variety produced the highest grains per pod (12.10), test weight (91.86 g), and grain yield (1.19 t/ha). Among phosphorus levels, 60 kg P /ha significantly enhanced grains per pod, test weight, biological yield (5.80 t/ha), and grain yield (1.24 t/ha). Pod number, pod length, and harvest index were largely unaffected. The results indicate that while cowpea growth was not significantly influenced, yield can be optimized by cultivating the Gajale variety with a phosphorus dose of 60 kg/ha in Khairahani, Chitwan.

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Authors' contributions

Aashish Bandhu Aryal, Sagar Dhakal and Aakriti Poudel designed and performed the experiment. Bibek Aryal recorded the data, and all four members analyzed the data and wrote the manuscripts at certain levels.

Conflicts of Interest

The author has no relevant financial or non-financial interests to disclose.

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Ethics Approval Statement

This field-based study did not involve humans or animals. Experimental activities were carried out with prior approval from relevant authorities and in accordance with environmental and biosafety guidelines.

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