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Economic Analysis of Seed Inoculation and Phosphorus Doses Application in Cowpea (*Vigna unguiculata* L.)

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A R T I C L E   I N F O

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A B S T R A C T

The study about the economic returns of cowpea (*Vigna unguiculata)* by the use of rhizobium seed inoculation and different phosphorus doses was conducted at Bharatpur, Chitwan, from February to May 2022. The experiment was conducted in a two-factor randomized complete block design (RCBD) with three replications and eight treatments. Treatments were set as factor A: seed inoculation i.e., un-inoculated and inoculated; and factor B: four different phosphorus doses (20, 40, 60, 80 kg ha^{-1}). The cowpea variety 'Prakash' was used. Results revealed that the application of seed inoculation provides the highest returns compared to an un-inoculated one; similarly, in case of phosphorus dose of 40 kg P_2O_5 ha^{-1} gives the maximum economic returns compared to other phosphorus doses. Furthermore, the interaction of rhizobium inoculation with 40 kg ha^{-1} gives the highest gross income (NRs. 216005), net return (NRs. 110829.39) and B: C (2.05) compared to all other single inoculation or phosphorus or interaction treatments (1 $ = NRs. 132.53) . From the result, it is concluded that the use of rhizobium inoculation along with 40 kg P_2O_5 ha^{-1} would be economically profitable for the farmers under the Terai conditions of Nepal.

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Introduction

Cowpea (*Vigna unguiculata)* is recognized as an important annual grain legume, native to Africa, belongs to the family Fabaceae and is grown in tropical and subtropical regions all over the world. In Nepal, mostly indigenous varieties of cowpea are cultivated, which are mainly cast off as an intercrop with various other food crops. It is grown for its green pods as vegetables, dry seeds as pulses, and foliage as fodder and is also used for nitrogen fixation in the soil. In cowpea, it is estimated that the average nitrogen fixation ability in the soil during the growth and development of cowpea ranges from 40 to 80 kg N ha^{-1}, sometimes up to 200 kg N ha^{-1} (Meena et al., 2015). In Nepal during 2018, cowpea was grown in an area of 3657 ha, total production was about 3632 tons of cowpea, with a productivity of 0.99 t/ha (MoALD, 2018/019). Similarly, in the world scenario, cowpea was produced on about 14.5 million ha of land, with the total production of 6.5 million MT of dry grains (Boukar et al., 2016), which can be grown well in agro-ecological zones wherever the rainfall range is between 500 and 1200 mm per year (Madamba et al., 2006).

Cowpea's yield potential can be exploited by the adequate amount of nutrient application required by the legumes (Singh et al., 2007). Bio-fertilizers now days have emerged as an alternative form to various hazardous synthetic inorganic fertilizers, which also provide an economically attractive and ecologically sound means of nutrient supply and increase crop productivity. *Rhizobium* was used as a bio-fertilizer for cowpea, which is also the partner of a legume (Beringer, 1974). Rhizobium is a soil gram-negative group bacteria, which are known for their symbiotic relationships with various leguminous plants, used as bio-fertilizers, alternative to urea, which is also eco-friendly in nature. According to Almeida et al. (2010), the use of inoculants separately increases cowpea yield by 29-50% compared to non-inoculated with no nitrogen fertilizer. Phosphorus is a critical factor for cowpea yield, which is required to initiate nodulation, growth stimulation as well as to stimulate the rhizobium-legume symbiosis efficiency, which also helps in lowering the cost of crop production (Haruna et al., 2012). Whereas, application of inoculants together with phosphorus increases grain yield, dry matter, and various other growth and yield parameters compared to the application of only inoculant or phosphorus, which recognizes that cowpea growth and yield are limited by phosphorus deficiency (Boahen *et al.*, 2017).

Cowpea is a major source of protein and an important component of Nepalese cropping systems. However, yields are very low due to a lack of improved cultivars, poor management practices, and limited input use due to lack of economic investments. Therefore, this experiment was conducted to determine the economic profitability of using seed inoculation and different phosphorus levels in cowpea and to detect the best pathway among them, for the farmers.

Methodology

Site description and weather condition

The field experiment was carried out at the agronomy farm present at Bharatpur-10, Chitwan, Nepal during the spring (February to May) of 2022. The agronomy farm was located at 27.6931° N latitude and 84.4498° E longitude, which was 208 m above the mean sea level. The weather conditions during the experimental period of the farm consist of a mean temperature of 7 °C to 16 °C, where the maximum temperature reaches up to 24 °C to 33 °C in May. The relative humidity varies from 46% to 53% with the initial stage of very limited 38.66 mm of rainfall, but May received the highest rainfall of 364.72 mm during the research time interval.

Soil Properties

The soil sample from a depth of 10-20 cm of the experimental plot was collected, air dried, sieved through 2 mm sieves, and then a soil test was done. The soil physical and chemical properties analysis was carried out at the soil testing laboratory where the soil texture was of sandy loam type.

Experimental Detail

Two-factor randomized complete block design (RCBD) with eight treatments and three replications was conducted in a field experiment. Twenty-four plots each having a plot size of 3m x 2m, where each plot consists of 50 plant populations and dibbling with two seeds per hill at 4-5 cm depth. Plant geometry is maintained with row to row spacing of 60 cm and plant to plant spacing of 20 cm. For the experiment, cowpea of the variety "Prakash" was used. The experiment consists of treatments, viz., inoculated seed and un-inoculated seed, and different phosphorus doses of 20, 40, 60, and 80 kg P_2O_5 ha^{-1}.

A six-ton FYM per hectare was applied as a basal dose of manure. Similarly, 20 kg ha^{-1} urea, 20 kg ha^{-1} K_2O, and different doses of P_2O_5 according to treatment were applied. A half dose of nitrogen and a full dose of P_2O_5 and K_2O in the form of urea, single super phosphate, and Muriate of potassium respectively, were applied as a basal dose. The remaining half dose of nitrogen was applied after 30 days of seed sowing as a top dressing. In half of the treatments, seed inoculation was done by bio-fertilizer (*Rhizobium leguminoserum*), which was inoculated to the seed just before seed sowing at the rate of 80g per kg seed. The crop was made free from weeds by hand weeding at 25 days from sowing and 20 days after the first weeding.

Data collection and analysis

Cost of Production (NRs. ha^{-1}): The cost of production of crops under each treatment was calculated on the basis of the existing market price of various inputs. The sum of all the common costs of various inputs and variables, such as labor costs, bio-fertilizer, fertilizer, seed, pesticides, and so on. The details of the total cost of various inputs are accessible in table 3.

Gross returns (NRs ha^{-1}): The grain yield was multiplied by the minimum market price, i.e. NRs. 120/kg and fodder at NRs.3/kg to obtain gross returns.

Net return (NRs. ha^{-1}): Net return was calculated by reducing the total cost from the gross income of cowpea production.

B:C ratio: The benefit cost ratio was calculated by dividing gross returns by the cost of production.

$$\text{Benefit cost ratio} = \frac{\text{Gross returns}}{\text{Cost of production}}$$

The data recorded was systematically arranged in MS-Excel, which was used for simple statistical analysis, the formulation of graphs, tables, and significant data was subjected to DMRT using R-studio.

Table 1. Initial chemical properties of the soil in the experimental field

Details	Mean	Method used for analysis
pH	5.65	Beckman Glass Electrode pH meter
Total N (%)	0.61	Kjeldahl distillation
Available P_2O_5 (kg/ha)	17.41	Spectro photometer
Available K_2O (kg/ha)	70.08	Flame photometer
Organic carbon (%)	4.72	Walkley and Black's titration method

Table 2. Treatment combination used in the experiment during 2022

Treatment	Treatment combination	Symbol
T_1	Non-inoculated seed (I_0) + 20:20:20 kg NPK/ha (F_1)	(I_0F_1)
T_2	Non-inoculated seed (I_0) + 20:40:20 kg NPK/ha (F_2)	(I_0F_2)
T_3	Non-inoculated seed (I_0) + 20:60:20 kg NPK/ha (F_3)	(I_0F_3)
T_4	Non-inoculated seed (I_0) + 20:80:20 kg NPK/ha (F_4)	(I_0F_4)
T_5	Inoculated seed (I_1) + 20:20:20 kg NPK/ha (F_1)	(I_1F_1)
T_6	Inoculated seed (I_1) + 20:40:20 kg NPK/ha (F_2)	(I_1F_2)
T_7	Inoculated seed (I_1) + 20:60:20 kg NPK/ha (F_3)	(I_1F_3)
T_8	Inoculated seed (I_1) + 20:80:20 kg NPK/ha (F_1)	(I_1F_4)

Table 3. Cost of inputs used in different treatments of cowpea cultivation.

Types of input	Cost ((NRs. ha^{-1})
Land charge	6101.69
Tractor charge for Field preparation	5932.20
Bio-fertilizer	200
Seed	6500
Labor charge of manual field preparation and weeding	23728
Farm yard manure	12000
Urea	800
Single super phosphate (20 kg ha^{-1})	384
Single super phosphate (40 kg ha^{-1})	768
Single super phosphate (60 kg ha^{-1})	1152
Single super phosphate (80 kg ha^{-1})	1536
Muriate of potash	640
Pesticides	30608.4
Milk for insect pest treatment	10847.457
Yellow sticky trap	6949.153

Table 4. Effect of rhizobium seed inoculation and phosphorus doses on economic returns of cowpea.

Treatment	Cost of Production (NRs. ha^{-1})	Gross returns (NRs. ha^{-1})	Net return (NRs. ha^{-1})	B:C ratio
Factor A: Rhizobium				
a. Non-Inoculated	105117.6^{b}	157365.7^{b}	52248.10^{b}	1.49^{b}
b. Inoculated	105367.6^{a}	181560.1^{a}	76192.45^{a}	1.72^{a}
LSD value		13126.07	13126.05	0.13
F test	***	*	*	*
CV%		4.41	11.65	4.42
Factor B: Phosphorus level				
a. P1- 20 kg/ha	104591.6^{d}	135468.2^{d}	30876.58^{d}	1.29^{d}
b. P2- 40 kg/ha	105075.6^{c}	201070.8^{a}	95995.22^{a}	1.91^{a}
c. P3- 60 kg/ha	105459.6^{b}	187231.7^{b}	81772.11^{b}	1.78^{b}
d. P4- 80 kg/ha	105843.6^{d}	154080.8^{c}	48237.20^{c}	1.46^{c}
LSD value		8996.8	8996.8	0.086
F test	***	***	***	***
CV%		4.22	11.14	4.22
Interaction				
a. Non-Inoculated x P1	104391.6^{h}	123280.2^{e}	18888.62^{e}	1.18^{e}
b. Non-Inoculated x P2	104975.6^{f}	186136.7^{b}	81161.05^{b}	1.77^{b}
c. Non-Inoculated x P3	105359.6^{d}	168779.2^{c}	63419.55^{c}	1.60^{c}
d. Non-Inoculated x P4	105743.6^{b}	151266.8^{d}	45523.19^{d}	1.43^{d}
e. Inoculated x P1	104791.6^{g}	147656.2^{d}	42864.54^{d}	1.41^{d}
f. Inoculated x P2	105175.6^{e}	216005.0^{a}	110829.39^{a}	2.05^{a}
g. Inoculated x P3	105559.6^{c}	205684.3^{a}	100124.67^{a}	1.94^{a}
h. Inoculated x P4	105943.6^{a}	156894.8^{cd}	50951.20^{cd}	1.48^{d}
LSD value		12723.38	12723.38	0.12
F test	***	*	*	*
CV%		4.22	11.14	4.22

Note: Means followed by the same letter(s) in a column do not differ at 5% level of significance by DMRT; LSD= Least significant difference, CV= Coefficient of variance.

Results and Discussions

Gross returns: The gross return of cowpea was influenced by different treatments, as shown in Table 4. The factor A treatment on gross return was statistically significantly (<0.05) influenced where seed inoculated with bio-fertilizer i.e. *Rhizobium leguminosarum* had the highest gross return (NRs. 105117.6) compared to non-inoculated (NRs. 105367.6). A similar trend of findings was reported by (Meena et al., 2006). At Factor B; the gross return was significantly (<0.001) influenced by different doses of phosphorus. The highest gross return was found at 40kg P ha^{-1} applied plot (NRs. 201070.8) whereas the significantly lowest gross return was found at 20kg P ha^{-1} applied plot (NRs. 135468.2). A similar finding was identified by (Nyoki et al., 2013) which concluded that 40 kg P ha^{-1} application farmers get a higher profit compared to other levels. In interaction treatments, the combination of inoculated and 40 kg P ha^{-1} gives maximum gross return (NRs. 216005) which is also the highest return compared to all solo fertilizer application treatments; whereas, the lowest gross return combination was non-inoculated with 20 kg P ha^{-1} (NRs. 123280.2).

Net returns: Significant effect of the treatments was observed on net return per hectare, as shown in Table 4. The net return per hectare was found to be lowest in non-inoculated (NRs. 52248.10) compared to inoculated (NRs. 76192.45). A similar finding was obtained by (Boahen et al., 2017 and Jat et al., 2013). Among different phosphorus doses, the maximum net return was collected at 40 kg P ha^{-1} (NRs. 95995.22) and the significantly lowest net return was found at 20 kg P ha^{-1} (NRs. 30876.58).

The highest net return was found in the integration of inoculated with 40 kg P ha^{-1} (NRs. 110829.39), whose potency was due to the highest grain yields. The non-inoculated with 20 kg P ha-1 had the lowest net return (NRs. 18888.62). Boahen et al. (2017) also reported a similar finding where the maximum net return was obtained by the interaction between inoculant and P for cowpea at Nampula compared to solo inoculant or phosphorus doses.

Benefit cost ratio: At factor A, inoculated had a higher B: C ratio (1.72) compared to the non-inoculated (1.49). At different doses of phosphorus treatment, the highest B: C ratio was found at 40 kg P ha^{-1} treatment (1.91) and the lowest was (1.29) at 20 kg P ha^{-1} treatment. The results are consistent with those of (Jat et al., 2013). Similarly, the lowest B: C ratio (1.18) was observed with the combination treatment of non-inoculated with 20 kg P ha^{-1}. Whereas, the highest B: C ratio in combined treatment was found in inoculation with 40 kg P ha^{-1} (2.05). Chattopadhyay et al. (2003) also identified similar results where interaction gives maximum compared to a single application.

Conclusion

Cowpea production is one of the profitable ventures in the various developing countries. To obtain maximum benefit with adequate and required economic investment, it is necessary to manage fertilizer efficiently without any depletion in which the farmers operate. Also, the loan subsidy, credit investment and extension service by the government and use of effective alternatives like *Rhizobium leguminosarum* will boost the courage of farmers to make effective investments. From the experiment, it is analyzed that, the interaction of *Rhizobium leguminosarum* inoculated seed along with 40 kg P ha^{-1} provides the maximum gross returns (NRs. 216005), net returns (NRs. 110829.39), and benefit-cost ratio (2.05) compared to all other solo inoculants, un-inoculated or solo phosphorus dose treatments. The finding concluded that neither higher nor lower applications of fertilizer are effective, but the appropriate applications are required to give maximum output. As a result, this discovery will aid major contributions among the cowpea farmers in Bharatpur, Chitwan, along with a myriad of other environmentally and geographically similar areas, to managing economic investment for fruitful cowpea production and uplift the living standard of them.

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