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Research Paper

Influence of phosphorus fertilization on productivity and biological sustainability of chickpea (*Cicer arietinum*) + coriander (*Coriandrum sativum*) intercropping system

D.K. SHUKLA[1], V.K. SINGH[2], CHANDRA BHUSHAN[3] AND AJAY KUMAR[4]

Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, Uttarakhand 263 145

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ABSTRACT

A field experiment was conducted during winter (*rabi*) season of 2012–13 and 2013–14 at Norman E. Borlaug Crop Research Centre, Pantnagar, Uttarakhand, to assess the productivity and competing ability of chickpea (*Cicer arietinum* L.) and coriander (*Coriandrum sativum* L.) under different row ratios of intercropping and phosphorus management. Both the component crops, gave significantly higher seed yield in sole cropping compared to intercropping systems. Chickpea + coriander (4 : 2) (3.71 t/ha), being at par with chickpea + coriander (3 : 1) (3.40 t/ha), recorded significantly higher chickpea-equivalent yield than that of sole cropping. Land-equivalent ratio (1.32) and production efficiency (27.49 kg/ha/day) were significantly higher in chickpea + coriander (4 : 2) than rest of the systems. Relative crowding coefficient (RCC) and agressivity (A) did not show influence of intercropping systems. Competition ratio (CR) of chickpea reduced significantly in chickpea + coriander (4 : 2) than chickpea + coriander (3 : 1). Sole chickpea revealed significantly higher phosphorus uptake by grains over sole coriander but at par with rest of the systems. Higher net returns (120.59×10^3 ₹/ha) was recorded in chickpea + coriander (4 : 2) over sole chickpea and sole coriander. Chickpea + coriander (4 : 2), being at par with sole coriander, recorded significantly higher benefit: cost ratio (3.42). Phosphorus levels resulted in significantly higher chickpea-equivalent yields, LER, RCC, production efficiency and phosphorus uptake by grains than that of the control, but differences between the phosphorus levels were non-significant on these aspects. Competition ratio followed reverse trend and significantly lower competition ratio was observed at higher dose of phosphorus but difference amongst the phosphorus levels was not significant. However, higher benefit: cost ratio was observed owing to 30 kg P_2O_5 + phosphate-solubilizing bacteria/ha (2.65).

***Key words* :** Aggressivity, Chickpea-equivalent yield, Competition ratio, Land-equivalent ratio, Production efficiency, Relative crowding coefficient

Chickpea, also known as gram or Bengal gram, accounts for about 45% of total pulses produced in the country. India is the major chickpea-producing country, contributing more than 75% of total world production. This crop is grown in winter (*rabi*) season as sole or in intercropping with other crops like linseed, mustard, coriander, wheat, barley. Growing of intercrop with chickpea increases the cropping intensity, productivity, and profitability by optimally utilizing soil, water, nutrients and sunlight, and minimizing the pod-borer infestation (Paul *et al.,* 2015). Coriander is a spice, and leafy vegetable crop grown in *rabi* season. Its leaves are a good source of vitamin A and carotene. Pod-borer is a serious pest of chickpea and limits its cultivation in many parts of the country. Chickpea + coriander intercropping system has proved profitable in the area where irrigation facility is available. Growing of coriander as an intercrop in chickpea is gaining momentum in the areas where chickpea is largely affected by pod-borer, as insect repellent ability of coriander helps in minimizing the insect attack on chickpea. Pod-borer infestation reduced with increased plant density of coriander as an intercrop (Paul *et al.*, 2015). Optimization of plant density of component crops is necessary in different agro-ecological situations, as it helps in facilitating better crop growth and yield. Being a leguminous crop, chickpea fixes atmospheric nitrogen and meets the nitrogen demand but phosphorus has an important role in chickpea + coriander intercropping because both crops require high amount of phos-

[1]**Corresponding author's Email**: shukladk1974@rediffmail.com
[1]Junior Research Officer, [2,3] Professor and [4]Assistant Professor, Department of Agronomy, College of Agriculture, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, Uttarakhand 263 145

phorus. Phosphorus is beneficial for root development and eventually for biological nitrogen fixation. Higher grain and biological yield was reported by Tanwar *et al.* (2014) in chickpea + linseed intercropping system at higher recommended dose of fertilizer (20 kg N+17.2 kg P/ha). It enables us to understand the importance of proper crop nutrition, particularly phosphorus in chickpea-based intercropping system. Keeping these aspects in mind, present investigation was planned to find out the suitable row ratio of component crops and phosphorus-management strategy in chickpea + coriander intercropping system in foothills (*tarai*) of Uttarakhand.

MATERIALS AND METHODS

A field experiment was conducted at the N. E. Borlaug Crop Research Centre, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, Uttarakhand during *rabi* seasons of 2012–13 and 2013–14. The soil of experimental site was silty clay loam in texture, slightly acidic in reaction (*p*H 6.7), high in organic carbon (1.18 %) and medium in phosphorus (10.5 kg/ha) and potassium (162 kg/ha). The mean monthly maximum and minimum temperature ranged from 10.7 to 38.7 and 2.5 to 19.5°C during the winter season of 2012–13, whereas the corresponding values during 2013–14 were 16.1 to 37.5°C and 5.9 to 17.9°C. Total rainfall of 200.1 and 346.2 mm was received at experimental site in 11 and 21 rainy days during crop season of 2012–13 and 2013–14, respectively. The experiment was laid out in a split-plot design with 3 replications. Sixteen treatments comprising 4 intercropping systems, viz. chickpea sole, coriander sole, chickpea + coriander (3 : 1) and chickpea + coriander (4 : 2) were kept in main plots and 4 phosphorus doses, viz. control (no phosphorus), 30 kg P_2O_5/ha, 30 kg P_2O_5/ha + seed treatment with phosphate-solubilizing bacteria and 45 kg P_2O_5/ha were applied in subplots. For nutrient management, recommended dose of nitrogen and potash for chickpea only as 20 kg N and 30 kg K_2O/ha was applied basal with equal distribution to both the crops. The phosphorus was applied as per the treatment at the time of sowing. All fertilizers were applied in furrows below the seeds. The furrows were opened manually with the help of tractor-drawn furrow opener at a specified row-to-row distance of 30 cm. A seed rate of 75 kg and 15 kg/ha for chickpea and coriander was used in their sole plots, respectively. In intercropping which was in replacement series, seed rate of both the crops was adjusted as per the row ratio. The seeds of chickpea variety 'Pant G 3' and coriander variety 'Pant Haritima' were sown in furrows by *kera* method. Crops were sown in the first week of December in both the years. The chickpea was harvested in the last week of April and coriander 15 days before harvesting chickpea. For the assessment of intercropping, different indices, viz. chickpea-equivalent yield (CEY), land-equivalent ratio (LER), relative crowding coefficient (RCC), aggressivity (A), crop competition ratio (CR), were calculated using standard method. Production efficiency (kg/ha/day) was calculated by dividing chickpea-equivalent yield with total duration of crops (135 days). Economics of the treatment was also calculated using market cost of inputs and output. Standard formulae were used for the calculating of these indices except production efficiency (Bhatnagar, 2014). The production efficiency was calculated by formula:

$$\text{Production efficiency (kg/ha/day)} = \frac{\text{Total production of sequence}}{\text{Total duration of crop in sequence (days)}}$$

$$\text{Land-equivalent ratio (LER)} = \frac{Yab}{Yaa} + \frac{Yba}{Ybb}$$

where Yab, yield of crop a grown with crop b; Yba, yield of crop b grown with crop a; Yaa, yield of crop a in pure stand; Ybb, yield of crop b in pure stand.

$$\text{Aggressivity (Aab)} = \frac{Yab}{Yaa \times Zab} - \frac{Yba}{Ybb \times Zba}$$

where Aab, aggressivity value; Yab, mixture a grown with crop b; Yba, mixture yield of crop b grown with crop a; Yaa, pure yield of crop a; Ybb, pure yield of crop b; Zab, sown proportion of crop a in mixture with crop b; Zba, sown proportion of crop b in mixture with crop a.

$$\text{Relative crowding coefficient (RCC) Kab} = \frac{Yab \times Zba}{(Yaa - Yab) \times Zab}$$

$$\text{Relative crowding coefficient (RCC) Kba} = \frac{Yba \times Zab}{(Ybb - Yba) \times Zba}$$

K= Kab × Kba

where RCC Kab, is RCC for crop a intercropped with crop b; Kba, RCC for crop b intercropped with crop a; Yaa, yield of crop a as sole crop; Ybb, yield of crop b as sole crop; Yab, yield of crop a grown in combination with crop b; Yba, yield of crop b grown in combination of crop a; Zab, sown proportion of crop a in combination with crop b; Zba, sown proportion of crop b grown in combination with crop a.

$$\text{Aggressivity (Aab)} = \frac{Yab}{Yaa \times Zab} - \frac{Yba}{Ybb \times Zba}$$

$$\text{Competition ratio (CR)} = \frac{Yab}{Yaa \times Zab} - \frac{Yba}{Ybb \times Zba}$$

where Yab, yield of crop a in combination with crop b; Yba, yield of crop b in combination with crop a; Yaa, yield of crop a as sole stand; Ybb, yield of crop b as sole stand; Zab, sown proportion of crop a in combination with crop b; Zba, sown proportion of crop b grown in combination with crop a.

RESULTS AND DISCUSSION

Productivity

Grain yield of chickpea and coriander, and chickpea-equivalent yield were significantly influenced by intercropping and phosphorus levels. Grain yield of chickpea and coriander was significantly higher in their sole stand than their respective crop yield in intercropping (Table 1). Chickpea and coriander yield decreased significantly in intercropping because of reduction in plant population. Reduction in yield was 39.7 and 27.6% in chickpea and 40.9 and 40.0% in coriander under chickpea + coriander 3 : 1 and 4 : 2 intercropping system, respectively. Our result confirms the findings of Ahlawat *et al.* (2005). Both the ratios of intercropping (4 : 2 and 3 : 1) of chickpea + coriander were at par for coriander and chickpea-equivalent yields (3.71 and 3.40 t/ha). However, 4 : 2 intercropping yielded significantly higher chickpea yield than 3 : 1 chickpea + coriander intercropping and sole chickpea. Chickpea + coriander in 4 : 2 ratio resulted in 19.9, 1.5 and 9.2% higher chickpea yield, coriander yield and chickpea-equivalent yield than that of chickpea + coriander (3 : 1). All phosphorus levels registered significantly higher chickpea yield, coriander yield and chickpea-equivalent yield over the control. The chickpea-equivalent yields increased with successive increase in phosphorus levels showing significantly higher value (3.44 t/ha) at 45 kg P_2O_5/ha; however, it was at par with that of 30 kg P_2O_5 + PSB /ha and 30 kg P_2O_5/ha. Kumar *et al.* (2009) also reported that application of 50 kg P_2O_5 /ha recorded significantly higher average grain yield of chickpea over control. Tripathi *et al.* (2005) reported similar results in chickpea + Indian mustard intercropping.

Land-equivalent ratio

Land-equivalent ratio (LER) is the relative land area under sole crops required to produce same yield obtained under intercropping system. The LER > 1 indicates that the biological efficiency of such a system is higher. The intercropping of chickpea + coriander (4 : 2) was biologically more efficient than chickpea + coriander (3:1) owing to higher LER values of 1.32 in the former one and 1.20 in latter one. Phosphorus levels significantly influenced the LER (Table 1). Significantly higher LER was recorded with phosphorus levels over the control. Similar result was also reported by Ahlawat *et al.* (2005).

Relative crowding coefficient

In chickpea + coriander (3 : 1) intercropping relative crowding coefficient (RCC) for chickpea was 0.51 i.e. than 1 indicating that less chickpea yield was obtained than expected in this intercropping. This may be due to less space available for chickpea in chickpea + coriander (3 : 1) intercropping than chickpea + coriander (4 : 2) intercropping. Coriander RCC was more than 1 in both the planting patterns indicating that this crop produced more yield than expected. It may be owing to higher aggressivity. The relative crowding coefficient of system (RCC) was found >1 in both the ratios of intercropping which indicated that growing of chickpea + coriander was

Table 1. Effect of intercropping and phosphorus levels on yield of crops, chickpea-equivalent yield (CEY) and economics (means of 2 years pooled data)

Treatment	Yield (t/ha)			Cost of cultivation (×₹10³ /ha)	Net return (×₹10³ /ha)	Benefit: cost ratio
	Chickpea	Coriander	CEY			
Intercropping						
Chickpea sole	2.54	0	2.54	36.93	69.75	1.89
Coriander sole	0	1.56	3.12	30.65	100.39	3.27
Chickpea + coriander (3 : 1)	1.53	0.92	3.40	34.86	107.81	3.09
Chickpea + coriander (4 : 2)	1.84	0.93	3.71	35.27	120.59	3.42
SEm±	0.06	0.06	0.12	–	5.43	0.07
CD (P=0.05)	0.25	0.235	0.41	–	18.8	0.25
Phosphorus levels						
Control	1.74	0.93	2.71	29.10	55.58	1.91
30 kg P_2O_5/ha	2.07	1.12	3.23	30.10	75.67	2.51
30kg P_2O_5/ha + PSB	2.15	1.19	3.39	30.60	81.14	2.65
45 kg P_2O_5/ha	1.95	1.31	3.44	31.10	82.11	2.64
SEm±	0.09	0.06	0.10	–	6.15	0.06
CD (P=0.05)	0.15	0.17	0.30	–	17.97	0.18

Selling price: Coriander (₹8,400/q); Chickpea (₹4,200/q) found advantageous. However, chickpea + coriander (4 : 2) with higher RCC (3.92) was biologically more sustainable than chickpea + coriander (3 : 1) RCC (2.20) (Table 2). This might be due temporal and spatial variability. Ahlawat *et al.* (2005) and Tripathi *et al.* (2005) reported similar results for relative crowding coefficient in chickpea-based intercropping systems. Among the phosphorus levels, application of 30 kg P_2O_5 + PSB and 45 kg P_2O_5/ha recorded significantly higher RCC value over control.

Production efficiency

Higher production efficiency was recorded in intercropping than the sole cropping (Table 2). However, chickpea + coriander (4 : 2) intercropping exhibited higher production efficiency (27.49%) than chickpea + coriander (3 : 1), sole chickpea (18.82%) and sole coriander (23.11%). These results are in agreement with the findings of Kour *et al.* (2015). With regard to phosphorus management, production efficiency increased with successive increase in phosphorus levels and highest production efficiency was recorded (25.45%) with 45 kg P_2O_5/ha which was 26.8% more than the control (no phosphorus) but the difference was not much more over 30 kg P_2O_5 + PSB/ha.

Aggressivity

Aggressivity (A) determines the competitive ability of the component crops in an intercropping system. The zero value of aggressivity indicates that component crops are equally competitive. For any other situations, both crops will have the same numerical value but the sign of dominant species will be positive and that of dominated negative. Among the intercropping patterns negative values of -1.56 and -0.72 were recorded for chickpea in chickpea + coriander (3 : 1) and chickpea + coriander (4 : 2), respectively (Table 2). The trend shows that coriander was the dominant crop and chickpea was dominated crop. This probably happened owing to early suppressive ability of the fast-growing, profuse foliaged coriander crop along with its better ability to intercept light and utilize soil resources more efficiently which enabled it to become more efficient in resource utilization than chickpea. Results also indicated that degree of domination of coriander was in 4 : 2 rather than 3 : 1 planting pattern (Approximately 2 times). Our results confirm the findings of Kour *et al.* (2015) with regards to aggresivity in chickpea and Indian mustard intercropping. Phosphorus levels recorded higher positive value of agressivity than the control but the difference was non-significant.

Competition ratio

Competition ratio (CR) measures the degree with which crop competes with the other. Higher value of CR in coriander showed that coriander was more competitive than chickpea. The CR value for chickpea less than unit indicated that there was positive benefit of chickpea on coriander and this species can be grown in an intercrop. Further, higher CR value for coriander under 3 : 1 row ratio than under 4 : 2 row ratio (Table 2) indicated that coriander had more intra-specific competition than inter-specific competition. Coriander had relatively rapid initial growth leading to competition for resources, particularly

Table 2. Land-equivalent ratio (LER), relative crowding coefficient, production efficiency, Aggressivity, competition ratio and phosphorus uptake as influenced by intercropping and phosphorus levels (means of 2 years pooled data)

Treatment	LER	Relative crowding coefficient			Production efficiency (Kg/ha/day)	Aggressivity		Competition ratio (CR) of chickpea		P uptake by grains in system (kg/ha)
		Chickpea (K_{ch})	Coriander (K_c)	System ($K = K_{ch} \times K_c$)		Chickpea	Coriander	Chickpea	Corainder	
Intercropping										
Chickpea sole*	1.0				18.82					13.6
Coriander sole*	1.0				23.11					8.6
Chickpea + coriander (3 : 1)	1.20	0.51	4.32	2.20	25.16	(–) 1.56	1.56	0.34	1.83	13.4
Chickpea + coriander (4 : 2)	1.32	1.31	2.99	3.92	27.49	(–) 0.72	0.72	0.60	2.11	13.3
SEm±	0.03	0.10	0.71	0.54	0.41	(–) 0.32	0.32	0.05	0.18	0.21
CD (P=0.05)	0.10	0.48	NS	NS	1.44	NS	NS	0.16	1.05	0.91
Phosphorus levels										
Control	1.28	0.49	3.33	1.63	20.06	(–) 1.10	1.10	0.48	2.05	9.2
30 kg P_2O_5/ha	1.53	1.38	2.22	3.06	23.96	(–) 1.35	1.35	0.41	1.96	12.1
30kg P_2O_5/ha + PSB	1.61	0.99	3.51	3.47	25.10	(–) 1.47	1.47	0.46	1.91	13.5
45 kg P_2O_5/ha	1.61	1.15	3.58	4.12	25.45	(–) 1.87	1.87	0.37	1.97	14.0
SEm±	0.04	0.18	0.53	0.60	0.47	(–) 0.22	0.22	0.03	0.12	0.29
CD (P=0.05)	0.13	0.55	NS	1.80	1.37	NS	NS	0.10	NS	1.12

*Sole crop values for competition indices not included in mean calculation; PSB, phosphate-solubilizing bacteria moisture, nutrients and space which persisted for whole crop period. This result confirms the finding of Tanwar *et al.* (2011) in chickpea + linseed intercropping system. Phosphorus levels also showed that coriander was more competitive than chickpea. Among the phosphorus levels, lower CR values were recorded for chickpea and higher for coriander.

Phosphorus uptake

Sole chickpea revealed significantly higher phosphorus uptake than sole coriander (Table 2). However, the chickpea + coriander (4 : 2) and chickpea + coriander (3 : 1) recorded similar amount of phosphorus uptake. All the phosphorus levels recorded significantly higher phosphorus uptake over the control, being 31.5, 46.7 and 52.2% higher in 30 kg P_2O_5, 30 kg P_2O_5 + PSB and 45 kg P_2O_5 respectively.

Economics

Higher net returns were recorded in intercropping than sole cropping. This may be owing to higher chickpea-equivalent yield in intercropping than sole cropping. Intercropping of chickpea + coriander in row ratio of 4 : 2 gave more net returns (12,775/ha) than that of chickpea + coriander (3 : 1). Growing of coriander was found more beneficial than chickpea because of more market price, as seeds of this crop are used as spice. Higher population proportion of coriander in chickpea + coriander (4 : 2) was the main reason for higher net returns in this intercropping. Likewise, net returns and benefit: cost ratio were also higher in chickpea + coriander (4 : 2) intercropping than chickpea + coriander (3 : 1) intercropping. Similar results on economics under chickpea + Indian mustard was reported by Kour *et al.* (2015). Among the phosphorus levels, net returns and benefit: cost ratio increased with increasing phosphorus levels up to 30 kg P_2O_5 + PSB/ha and decreased thereafter due to less response on grain yield at higher doses. The highest benefit: cost ratio (3.72) was recorded at 30 kg P_2O_5 + PSB/ha. Similar finding of higher phosphorus uptake was obtained with increasing fertilizer doses by Pandey and Tiwari (2017).

From the above study, it can be concluded that chickpea + coriander in row ratio of intercropping 4 : 2 proved to be more promising than chickpea + coriander in row ratio of intercropping 3 : 1 intercropping and sole cropping, as it resulted in more chickpea-equivalent yield, net returns and benefit: cost ratio. Application of 30 kg P_2O_5 was found more economical than the other phosphorus levels.

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