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

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ABSTRACT

The productivity and competitive ability of chickpea (Cicer arietinum L.) and coriander (Coriandrum sativum L.) were evaluated under different row ratios of intercropping and phosphorus management in a field experiment that took place at the Norman E. Borlaug Crop Research Centre in Pantnagar, Uttarakhand, during the winter (rabi) seasons of 2012–13 and 2013–14. In comparison to intercropping systems, solitary cropping produced much more seeds from both input crops. Even though the chickpea-equivalent yield was comparable to that of solo cropping at 3.40 t/ha, the combination of chickpeas and coriander (4:2) (3.71 t/ha) produced a far greater yield. The chickpea + coriander (4:2) system outperformed the others in terms of land-equivalent ratio (1.32) and production efficiency (27.49 kg/ha/day). There was no evidence that intercropping systems affected the relative crowding coefficient (RCC) or aggressiveness (A). Chickpea plus coriander (4:2) resulted in a much lower chickpea competition ratio (CR) compared to chickpea + coriander (3:1). The phosphorus absorption by grains of solo chickpea was much greater than that of sole coriander, although it was on level with the other systems. When comparing solo chickpea and sole coriander, the chickpea plus coriander (4:2) combination yielded higher net yields (120.59×10^1 /ha). With a benefit-to-cost ratio of 3.42, chickpeas and coriander in a 4:1 ratio were just as effective as solitary coriander. While there were no statistically significant differences in the phosphorus levels in terms of chickpea-equivalent yields, LER, RCC, production efficiency, or phosphorus absorption by grains, there were significant differences in terms of phosphorus levels. While there was no statistically significant difference between the various phosphorus doses, the competition ratio exhibited a reversal pattern, falling sharply as the dosage increased. At 30 kg P2O5 + phosphate-solubilizing bacteria/ha, however, the benefit-cost ratio was greater (2.65).

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

A significant portion of the pulses grown in the country are chickpeas, which are also called gram or Bengal gram. With over 75% of the world's total output, India is clearly the leading chickpea producer. During the winter (rabi) season, this crop is cultivated either alone or in conjunction with other crops such as linseed, mustard, coriander, wheat, and barley. Paul et al. (2015) found that growing chickpeas as an intercrop reduced pod-borer infestation while increasing cropping intensity, productivity, and profitability. The herb and leafy green crop known as coriander is cultivated in rabi arrives. Vitamin A and carotene may be found in abundance in its leaves. Chickpea production is severely restricted in many regions due to the pod-borer, a devastating insect. In regions with access to irrigation, the chickpea and coriander intercropping method has been quite successful. Because of its natural insect repellent properties, coriander is becoming more popular as an intercrop with chickpeas in regions where pod borer is a major pest. The infestation of pod-borers was shown to decrease as the plant density of coriander intercropped with other crops (Paul et al., 2015). Plant density optimization of component crops is essential in many agro-ecological contexts for improved crop development and production. Intercropping chickpeas and coriander requires a lot of phosphorus, even though chickpeas fix atmospheric nitrogen and satisfy the nitrogen need as a leguminous crop.

phorus. Root growth and, in the long run, biological nitrogen fixing are both aided by phosphorus. According to Tanwar et al. (2014), while using a chickpea and

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linseed intercropping system with a higher recommended dosage of fertilizer (20 kg N+17.2 kg P/ha), there was an increase in both grain and biological yield. It sheds light on the significance of fertiliser, and phosphorus in particular, for crops grown in an intercropping system based on chickpeas. This is why we set out to study the tarai foothills of Uttarakhand to determine the optimal row ratio of component crops and phosphorus-management method for chickpea and coriander intercropping.

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

When it came to chickpea and coriander grain output, as well as chickpea-equivalent yield, intercropping and phosphorus levels determined the game. According to Table 1, the grain production of chickpeas and coriander was much greater when grown in a single stand compared to when they were intercropped. Due to a decline in plant population, intercropping caused a considerable drop in chickpea and coriander output. The chickpea + coriander 3: 1 and 4: 2 intercropping systems reduced chickpea production by 39.7 and 27.6%, respectively, and coriander output by 40.9 and 40.0%. The results of Ahlawat et al. (2005) are supported by our research. The yields of coriander and chickpea were equivalent at 3.71 and 3.40 t/ha, respectively, regardless of the intercropping ratio (4: 2 or 3: 1). In contrast to solo chickpea and 3:1 chickpea + coriander intercropping, 4:2 intercropping produced a much greater chickpea yield. Chickpea, coriander, and chickpea-equivalent yields were 19.9%, 1.5, and 9.2% greater, respectively, when compared to chickpea and coriander in a 3:1 ratio and a 4:2 ratio. The control group had a considerable decrease in chickpea, coriander, and chickpea-equivalent output, whereas all phosphorus levels showed a marked increase. At 45 kg P2O5/ha, the chickpea-equivalent yields were 3.44 t/ha, which was much higher than at 30 kg P2O5/ha, but it was still on par with the previous level.

+ PSB/ha and 30 kg P2O5/ha. Additionally, Kumar et al. (2009) described 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.

acreage-to-buildings ratio

The land-equivalent ratio (LER) measures the amount of land needed to grow a single crop in comparison to the amount of land needed to grow the same crop when intercropping is used. If the LER is more than 1, then the system in question has a higher biological efficiency. Due to greater LER values of 1.32 in the former and 1.20 in the latter, the in-tercropping of chickpea + coriander (4:2) was biologically more effective than chickpea + coriander (3:1). The LER was greatly affected by phosphorus levels (Table 1). Phosphorus levels were shown to be significantly associated with increased LER compared to the control. Ahlawat et al. also reported a similar outcome (2005).

Crowding index relative

The relative crowding coefficient (RCC) for chickpea in the 3:1 intercropping of chickpea and coriander was 0.51, which is less than 1, suggesting that the crop yielded less than anticipated under these conditions. One possible explanation is that there is less room for chickpeas when the two crops are intercropped at a ratio of 3:1 rather than 4:2. Both planting strategies had coriander RCC values greater than 1, suggesting an above-average harvest. It might be because of a more aggressive attitude. If the relative crowding coefficient of the system (RCC) is more than 1 in both intercropping ratios, then producing chickpeas and coriander together is

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 (×₹ 10^3/ha)	Net return (×₹ 10^3/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 to be beneficial. Table 2 shows that the biological sustainability of chickpea and coriander (4:2) was greater than that of chickpea and coriander (3:1), which had a lower RCC of 2.20. Possible causes include variations in time and space. Relative crowding coefficient values in chickpea-based intercropping systems were reported similarly by Ahlawat et al. (2005) and Tripathi et al. (2005). Among the phosphorus levels, the RCC value was considerably greater when 30 kg P2O5 + PSB and 45 kg P2O5/ha were applied compared to the control.

Efficient production

Table 2 shows that compared to solitary cropping, intercropping resulted in more efficient output. Intercropping chickpea and coriander in a 4:1 ratio was more productive than 3:1, growing chickpeas alone (18.82%) or coriander alone (23.11%). Consistent with what Kour et al. (2015) found, these outcomes are satisfactory. With respect to phosphorus management, production efficiency rose in direct proportion to the amount of phosphorus applied; at 45 kg P2O5/ha, it was 26.8% higher than the control (no phosphorus), but at 30 kg P2O5 + PSB/ha, the difference was barely perceptible.

Level of aggression

Each crop's competitiveness in an intercropping system is defined by its aggressiveness (A). Component crops are competitive when the aggressiveness value is zero. Unless otherwise specified, the numerical value of the two harvests will be same; nevertheless, the domini-

Some species will be dominantly positive, while others will be dominantly negative. Chickpea in the 3:1 and 4:2 intercropping patterns with coriander had a negative value of -1.56 and -0.72, respectively, according to Table 2. Based on the data, it seems that chickpeas and coriander were the most popular crops. The rapid growth and abundant foliage of the coriander crop, together with its superior light intercepting and soil resource consumption abilities, likely contributed to its early suppressive ability, making it more efficient in resource usage compared to chickpea. Additionally, the results showed that the degree of dominance of coriander was about twice as high in a 4:2 planting pattern as in a 3:1 one. The results of our study corroborate those of Kour et al. (2015) about the aggressiveness of intercropping Indian mustard and chickpeas. A larger positive value of aggression was seen with phosphorus levels compared to the control, while the difference was not statistically significant.

Competitiveness ratio

The degree to which one crop competes with another is measured by the competition ratio (CR). The fact that coriander had a higher CR value than chickpea indicated that it was the more competitive herb. It is possible to plant coriander and chickpeas as an intercrop since the CR value for the chickpeas is less than one. Additionally, coriander exhibited stronger intra-specific than inter-specific competition, as seen by a higher CR value under a 3:1 row ratio compared to a 4:2 row ratio (Table 2). There was a lot of rivalry for resources since coriander had rather quick early development, especially

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

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that remained throughout the duration of the crop, including water, nutrients, and space. The findings of Tanwar et al. (2011) in the system of chickpea + linseed intercropping are supported by this outcome. Additionally, phosphorus levels showed that coriander outcompeted chickpea. Among the phosphorus levels, coriander had a higher CR value than chickpea.

Uptake of phosphorus
In comparison to solitary coriander, sole chickpea showed much greater phosphorus absorption (Table 2). Having said that, the chickpea and coriander (4:2) and third

1) measured phosphorus uptake at a comparable level. Phosphorus absorption was 31.5, 46.7, and 52.2 percent more in 30 kg P2O5, 30 kg P2O5 + PSB, and 45 kg P2O5, respectively, compared to the control.

Business and finance
When compared to solitary cropping, intercropping yielded higher net returns. The reason for this can be because intercropping produces a larger chickpea-equivalent yield compared to solitary cropping. Chickpea and coriander intercropped in a 4:2 row ratio produced higher net yields (12,775/ha) than chickpea and coriander intercropped in a 3:1 ratio. Due to its higher market value as a spice, coriander is a more profitable crop to grow than chickpea. Net returns were greater in this intercropping because the coriander population was more heavily distributed among the chickpeas (4:2). Similarly, compared to chickpea + coriander (3:1) intercropping, the net returns and benefit:cost ratio were greater in the 4:2 intercropping arrangement. When looking at the economics of chickpeas and Indian mustard, Kour et al. (2015) found similar conclusions. Up to 30 kg P2O5 + PSB/ha, the net return-to-cost ratio rose as phosphorus levels rose; beyond that, it fell as a result of less of an effect on grain production from higher dosages. Thirty kilograms of P2O5 + PSB/ha had the best benefit-to-cost ratio (3.72). The results of a comparable study on

As the dosage of fertilizer was increased, Pandey and Tiwari (2017) observed a greater rate of phosphorus absorption.
In terms of chickpea-equivalent yield, net returns, and benefit:cost ratio, the aforementioned study found that a 4:2 intercropping row ratio of chickpea and coriander was the most promising, compared to a 3:1 intercropping row ratio and sole cropping. The most cost-effective application amount of phosphorus was determined to be 30 kg P2O5.

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