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Effect of fertilizers and tillage management in rice (*Oryza sativa*)–chickpea (*Cicer arietinum*) cropping system under varying irrigation schedules

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ABSTRACT

A field experiment was carried out during 2000–01 and 2001–02 at the Indian Institute of Pulses Research, Kanpur, to study the effect of fertilizers, tillage and irrigation management in chickpea (*Cicer arietinum* L.) raised after rice (*Oryza sativa* L.). Significantly higher growth and yield attributes of chickpea were obtained under-treatment 30:60:40 kg NPK/ha, deep ploughing with spade (23 cm deep) and cumulative pan evaporation (CPE) of 60 mm compared to 20:40:40 kg NPK/ha, normal ploughing and CPE of 80 mm. Significantly higher grain and straw yield of chickpea, chickpea-equivalent yield and monetary returns were obtained with 30:60:40 kg NPK/ha than 20:40:40 kg NPK/ha. Among the various tillage practices, deep ploughing with spade (23 cm deep) recorded significantly higher grain and straw yields of chickpea, chickpea-equivalent yield and economics than normal ploughing. Significantly higher productivity and monetary returns of chickpea was obtained at CPE of 80 mm compared to CPE of 80 mm. The NPK uptake by rice and chickpea and total uptake by the system were significantly higher under CPE of 60 mm, deep tillage and 30:60:40 kg NPK/ha than CPE of 80 mm, normal tillage and 20:40:40 kg NPK/ha. Bulk density, particle density, water-holding capacity, pore space and volume expansion of soil were greatly influenced by different tillage and nutrients management. The residual effect of nutrients management and tillage practices applied during the winter (*rabi*) season was also seen in the preceding crop of rice in second year.

Key words : Physical properties, Moisture depletion pattern, Water-use efficiency, Cropping system, Monetary returns, Tillage

In northern part of India, rice–chickpea is the predominant cropping system next to rice–wheat system. Inclusion of pulses such as chickpea in the existing rice–wheat cropping system not only increases the overall productivity of the system but also improves physico-chemical properties of the soil. This is possible because chickpea can increase the productivity both in terms of N saving from fertilizer source and build up soil fertility through biological source of N (Kumar Rao *et al.*, 1998; Kumar and Prasad, 1999). Continuous growing of rice in the same field not only disturbs the physical condition of the soil but also causes great depletion of nutrients due to higher demand of rice plant and loss by leaching. Hence deep tillage practice improves physico-chemical properties of soil, providing good nutrient opportunity to the succeeding crops in rice–chickpea cropping system. Irrigation also plays a vital role in not only increasing the productivity of chickpea but also improving the physico-chemical properties of soil in intensive cropping systems. Hence, an experiment was laid out to study the nutrient management and tillage practices on growth, yield, physical properties of soil, moisture utilization pattern and nutrients uptake by chickpea in rice–chickpea cropping system under varying irrigation levels.

MATERIALS AND METHODS

A field experiment was conducted during 2000–01 and 2001–02 at the Indian Institute of Pulses Research, Kanpur. The treatment combination comprising chickpea crop with 2 levels of nutrients (20:40:40 kg NPK/ha and 30:60:40 kg NPK/ha), 2 levels of tillage practices [normal ploughing (3 ploughings with harrow) and deep ploughing with spade (23 cm deep)] and 2 irrigation levels, viz., CPE of 60 mm and 80 mm. However, rice crop was raised with recommended package of practices during both the years. The experiment was performed in factorial randomized block design with 3 replications. The experiment was conducted on fixed site. The experimental field was sandy loam in texture with pH 7.5. The soil was low in organic carbon (0.31%) and available nitrogen (251 kg/ha) and

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medium in available phosphorus (17.4 kg/ha) and potassium (202 kg/ha). The rice crop was transplanted on 8 July 2000 and 30 July 2001 to complete the rice–chickpea cropping sequence, whereas the chickpea was sown on 8 December 2000 and 29 November 2001. Rice was harvested, respectively, on 20 November 2000 and 18 November 2001 and chickpea on 7 April 2001 and 10 April 2002. 'Saket 4' and 'KPG 59' varieties of rice and chickpea, respectively, were chosen for the experiment with fertilizer schedules as per treatments. Chickpea was irrigated thrice in CPE of 60 mm and once in CPE of 80 mm in first year; however 2 irrigations in CPE of 60 mm and 1 irrigation in CPE of 80 mm were given during second year. Total rainfall received during the cropping season was 683 and 780 mm during 2000–01 and 2001–02 respectively.

RESULTS AND DISCUSSION

Effect of fertilizers

Application of 30:60:40 kg NPK/ha significantly increased the plant height, number of functional leaves and dry-matter/plant of chickpea compared to 20:40:40 kg NPK/ha (Table 1). Application of 30 60:40 kg NPK/ha significantly reduced the mean number and dry weight of root nodules compared to 20:40:40 kg NPK/ha. Pods/plant and 100-seed weight of chickpea were significantly increased with application of 30:60:40 kg NPK/ha compared to 20:40:40 kg NPK/ha.

The application of 30:60:40 kg NPK/ha resulted in significantly higher grain and straw yields of chickpea and chickpea-equivalent yield than 20:40:40 kg NPK/ha. The increase in grain and straw yields of chickpea and chickpea-equivalent yield with 30:60:40 kg NPK/ha was 15.5, 15.2 and 13.4% over 20:40:40 kg NPK/ha respectively. Application of 30:60:40 kg NPK/ha recorded maximum net return and benefit : cost ratio than 20:40:40 kg NPK/ha. Patil *et al.* (2001) reported that the inclusion of legumes and effective capture of biologically fixed N and soil N through direct-seeded rice system in rainfed lowlands may help in improving the rice yield of resource-poor farmers. Bhagat and Dhar (1996) found that in rice–chickpea cropping system, rice, chickpea and rice-equivalent yields and net returns were highest when rice cv 'IR 36' was given 80 kg N + 40 kg P_2O_5 + 20 kg K_2O/ha and followed by chickpea given 20 kg N + 60 kg P_2O_5/ha.

Application of 30:60:40 kg NPK/ha slightly decreased bulk density, particle density and water-holding capacity of the soil while pore space and volume of expansion were increased than application of 20:40:40 kg NPK/ha (Table 2).

Table 1. Growth and yield attributes, yield and economics of chickpea as influenced by different treatment in rice–chickpea system (average of 2 years)

Treatment	Plant height (cm)	No. of functional leaves/plant	Dry matter/ plant (g)	No. of effective root nodules	Dry weight of root nodules (g)	Pods/ plant	100-seed weight (g)	Yield of rice (q/ha)		Yield of chickpea (q/ha)		Chickpea-equivalent yield (q/ha)	Net return (Rs/ha)	Benefit : cost ratio
								Grain	Stover	Grain	Straw			
Nitrogen management (kg NPK/ha)														
20:40:40	45.0	21.7	19.6	20.7	1.5	41.4	16.2	38.3	58.1	20.0	32.3	37.2	27,141	1.9
30:60:40	50.0	26.0	23.8	15.4	1.3	47.3	18.5	42.3	62.5	23.1	37.2	42.2	33,497	2.1
Tillage practice														
Normal ploughing	45.8	20.2	19.5	15.7	1.2	41.1	15.3	39.1	59.0	20.1	33.1	37.7	29,640	2.1
Deep ploughing with spade (23 cm deep)	49.2	27.6	23.9	20.3	1.5	47.6	19.3	41.5	61.7	23.1	36.4	41.8	34,272	2.2
Irrigation level														
CPE of 60 mm	49.1	29.4	23.2	17.2	1.3	47.4	18.8	41.7	61.6	24.3	37.2	43.1	37,091	2.3
CPE of 80 mm	45.9	18.3	19.9	18.8	1.5	41.4	15.9	38.9	58.5	18.8	32.3	36.3	27,185	2.0
CD (P=0.05)	3.1	2.0	2.6	1.6	0.2	3.1	2.1	3.6	4.0	1.1	1.4	3.1		

Application of 30:60:40 kg NPK/ha significantly increased the nitrogen, phosphorus and potassium uptake of rice and chickpea over 20:40:40 kg NPK/ha respectively (Table 4). Significantly higher total nitrogen, phosphorus and potassium uptake of the system was recorded in 30:60:40 kg NPK/ha than 20:40:40 kg NPK/ha. Application of 20:40:40 NPK/ha recorded significantly higher N content; however, P and K content in rice and chickpea was recorded significantly higher in 30:60:40 kg NPK/ha in rice and chickpea in rice–chickpea cropping system.

Effect of tillage

Deep ploughing with spade (23 cm deep) recorded significantly higher plant height, number of functional leaves, dry matter/plant; total number and dry weight of root nodules/plant than normal ploughing (Table 1). Significantly higher pods/plant and 100-seed weight of chickpea were obtained with deep ploughing with spade (23 cm deep) than normal ploughing.

Grain and straw yields of chickpea and chickpea-equivalent yield were also higher in deep ploughing with spade (23 cm deep) compared to normal ploughing in the respective years. The increase in grain and straw yields of chickpea and chickpea-equivalent yield in deep ploughing was 14.9, 10.0 and 10.9% over normal ploughing, respectively. Maximum net return and benefit : cost ratio were recorded in deep ploughing with spade (23 deep) compared to normal ploughing.

Deep ploughing reduced the bulk density and particle density; however water-holding capacity, pore space and expansion volume of the soil were increased over normal ploughing (Table 2).

Deep ploughing with spade (23 cm deep) recorded significantly highest nitrogen and potassium uptake by rice and chickpea than normal ploughing (3 ploughings with harrow) respectively (Table 4). Total nitrogen, phosphorus and potassium uptake were significantly higher in deep tillage than normal tillage practices in rice–chickpea cropping system. Deep ploughing recorded significantly higher N, P and K content in rice and chickpea than normal ploughing.

Effect of irrigation

Cumulative pan evaporation (CPE) of 60 mm produced significantly higher mean plant height, number of functional leaves and dry matter/plant than CPE of 80 mm (Table 1). Application of more number of irrigation, i.e. CPE of 60 mm, significantly reduced the number and dry weight of root nodules compared to CPE of 80 mm. Three irrigations given at CPE of 60 mm proved beneficial in increasing all the yield attributes of chickpea than 2 irrigations given at CPE of 80 mm.

Significantly higher grain and straw yields of chickpea and chickpea-equivalent yield were obtained with 3 irrigations given at CPE of 60 mm than CPE of 80 mm (Table 1). The increase in grain and straw yield of chickpea and chickpea-equivalent yield with CPE of 60 mm was 29.2, 15.2 and 18.7% compared with that of 80 mm respectively. The CPE of 60 mm recorded maximum net return and benefit : cost ratio than CPE of 80 mm. The present investigation also supported with the findings of Patil *et al.,* (2001) and Bhagat and Dhar (1996), who worked on rice and pulse-based cropping systems. Sarkar *et al.* (1993) found that the highest returns and benefit : cost ratio were achieved with rice–chickpea sequences than single cropping system. The physical properties of the soil after harvest of second year crop did not show much variation with various irrigation schedules (Table 2).

The soil moisture-depletion pattern showed that the maximum depletion was recorded from 15–30 cm soil layer in both the irrigation levels followed by 0–15, 30–45, 45–60 and 75–90 cm layers. More moisture was depleted in case of 2 irrigations given at CPE of 80 mm as compared to 60 mm during both the years. The contribution

Table 2. Physical properties of the soil as influenced by different treatments in rice–chickpea cropping system (after harvest of second year)

Treatment	Bulk density (g/cc)	Water-holding capacity (%)	Particle density (g/cc)	Pore space (%)	Volume of expansion (%)
Nutrient management (kg NPK/ha)					
20:40:40	1.50	36.0	2.23	45.0	11.5
30:60:40	1.49	35.3	2.22	47.6	14.0
Tillage practice					
Normal ploughing	1.51	35.3	2.23	44.7	11.0
Deep ploughing with spade (23 cm deep)	1.48	36.0	2.22	48.0	14.6
Irrigation level					
CPE of 60 mm	1.50	36.3	2.23	46.8	13.6
CPE of 80 mm	1.49	35.0	2.22	45.8	12.0
Initial	1.53	33.8	2.24	40.1	10.5

Table 3. Water-use efficiency of chickpea as influenced by irrigation levels

Irrigation levels	No. of irrigation	Irrigation requirement (mm)	Effective rainfall (mm)	Water requirement (mm)	Consumptive use (mm)	Water-use efficiency (kg/ha-mm)
1999–2000						
CPE of 80 mm	2	142.8		142.8	165.2	13.92
CPE of 60 mm	3	214.2		214.2	244.9	11.44
2000–2001						
CPE of 80 mm	1	143.2	52	195.1	170.1	8.62
CPE of 60 mm	2	216.4	52	268.4	253.5	8.13

Table 4. Uptake of N, P and K by rice and chickpea and total uptake by cropping system as influenced by different treatments in rice–chickpea cropping system

Treatment	Nitrogen uptake (kg/ha)			Phosphorus uptake (kg/ha)			Potassium uptake (kg/ha)		
	Rice	Chickpea	Total	Rice	Chickpea	Total	Rice	Chickpea	Total
Nutrient management (kg NPK/ha)									
20:40:40	74.3	73.7	148.0	8.4	7.0	15.4	58.6	24.0	82.6
30:60:40	78.6	81.4	160.0	10.6	9.5	20.0	71.0	29.6	100.6
Tillage practice									
Normal ploughing	71.5	69.8	141.3	8.2	6.8	15.0	58.6	23.8	80.4
Deep ploughing with spade (23 cm deep)	81.8	85.9	167.7	10.8	9.7	20.5	71.0	29.8	100.8
Irrigation level									
CPE of 60 mm	78.3	86.5	164.8	10.4	9.7	20.1	68.9	30.6	99.5
CPE of 80 mm	74.6	68.5	143.2	8.6	6.8	15.3	60.7	23.0	83.7
CD (P=0.05)	3.6	3.7	7.1	1.5	1.2	5.7	4.5	2.4	6.1

made from 0–15, 15–30 and 30–45 cm soil depths in CPE of 80 mm was 25.9, 27.5 and 17.3% in 1999–2000 and 27.8, 29.6 and 19.5% in 2000–2001 respectively. It was observed that 2 and 1 irrigations given at CPE of 80 mm showed higher water-use efficiency (13.91 and 8.62 kg/ha-mm) compared to CPE of 60 mm during 1999–2000 and 2000–2001 respectively (Table 3). Sharma *et al.* (1998) found that number and dry weight of root nodules and water-use efficiency consistently decreased by irrigations applied at IW : CPE of 0.6 than no irrigation.

Significantly higher nitrogen, phosphorus and potassium uptake by rice and chickpea was obtained in CPE ratio of 60 mm than CPE of 80 mm respectively (Table 4). Significantly higher total nitrogen, phosphorus and potassium uptake by the system was recorded in CPE of 60 mm than CPE of 80 mm. Similar trend was also obtained in respect P and K content in rice and chickpea with CPE of 60 mm; however, CPE of 80 mm recorded significantly higher nitrogen content in rice and chickpea than CPE of 60 mm.

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