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Productivity and economics of chickpea (*Cicer arietinum*)-fodder sorghum (*Sorghum bicolor*) cropping system as influenced by P sources, bio-fertilizers and irrigation to chickpea

O.V.S. THENUA*, S.P. SINGH AND B.G. SHIVAKUMAR**

Amar Singh Post-Graduate College, Lakhaoti, Bulandshahr, Uttar Pradesh 245 407

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ABSTRACT

Field experiments were carried out for 2 years at Lakhaoti to study in the performance of chickpea (*Cicer arietinum* L.) as influenced as irrigation, sources of P and levels of biofertilizers during 2005-06 and 2006-07. Their residual effect was studied in the succeeding fodder sorghum (*Sorghum bicolor* L.). Two irrigations at flowering and pod filling recorded higher yield attributes and yield (1.56 tonne/ha) of chickpea. Further P in the form of either SSP (1.56 tonne/ha) or DAP (1.53 tonne/ha) was better when compared with rock phosphate (1.40 tonne/ha). The seed inoculation with phosphate solubilizing bacteria (PSB) and vesicular arbuscular mycorrhizae (VAM) (1.55 tonne/ha) followed by PSB alone recorded higher yield of chickpea. The application of rock phosphate and biofertilizer (PSB+VAM) to chickpea showed significant residual effect on the succeeding fodder sorghum. The P uptake and water use efficiency (WUE) in chickpea and fodder sorghum and available P status after their harvest were also significantly affected by irrigation, P sources and PSB + VAM. Chickpea-fodder sorghum as a whole was significantly influenced by combination of irrigation at flowering and pod filling, rock phosphate as source of P and biofertilizer *viz.,* PSB+VAM resulting in higher net returns and net benefit : cost ratio.

***Key words*:** Chickpea, Economics, Irrigation, Organic fertilizers, Phosphorus, Productivity, Sorghum

Chickpea (*Cicer arietinum* L.) is one of the most important *rabi* pulses of India grown on 6.93 million ha area with a production of 5.60 million tonnes (GOI, 2007). It is grown under irrigated conditions in the northern plain zone. When the chickpea is grown in irrigated area, it is necessary to know the optimum time of irrigation to realize maximum return per irrigation as water is scarce for irrigation. Among number of ways of irrigation timing, the critical stages approach has been identified as a useful method in pulses. It is well known that the chickpea responds positively to application of phosphorus which is a costly input. Use of cheaper sources of P will be very important to reduce the cost of cultivation and increase the returns from the investment made on this costly input. The use of phosphate solubilizing bacteria (PSB) like *Pseudomonas striata* will be helpful in increasing the availability of fixed P in the soil, while the vesicular arbuscular mycorhizae (VAM) mobilize the P from the deeper layers to the root zone. These cultures also help in enhancing the use-efficiency of the applied P as fertilizers. Under irrigated conditions, there is a scope for growing of another short duration crop after chickpea. The crop like fodder sorghum (*Sorghum bicolor* L.) seems to be an ideal short duration crop under limited irrigation facility. The growing of chickpea and fodder sorghum will be helpful in sustaining the productivity of the soil in long run. In view of this field experiments were conducted to evaluate the efficiency of time of irrigation, sources of P and biofertilizers on the performance of chickpea and their residual effect on the succeeding fodder sorghum.

MATERIALS AND METHODS

Field experiments were conducted at the Agronomy Research Farm, Amar Singh College, Lakhaoti, Bulandshahr (28.1^0 N latitude and 77.1^0 longitude) during *rabi* and following summer between 2005-06 and 2006-07. The soil of the experimental field was sandy loam in texture, well drained and of medium fertility and slightly alkaline in reaction (pH 7.6). It was low in organic carbon (0.39%), medium in phosphorous (10.56 kg/ha) and high in potassium (186 kg/ha) content. The climate during the experimental period during both the years of experimentation was normal with no inclement weather.

The treatments comprised of 3 times of irrigation viz.

***Corresponding author:** (E mail: ovsthenua@yahoo.com)

Correspondence address: **Division of Agronomy, IARI, New Delhi 110 012

light flooding (5 cm depth) at peak vegetative growth (PVG) (30 DAS) + flowering (F) (75 DAS) (I_1), at PVG + pod filling (PF) (90 DAS) (I_2) and flowering + PF (I_3); three sources of P @ 26.4 kg/ha *viz.,* single super phosphate (SSP) (P_1), di-ammonium phosphate (DAP) (P_2) and rock-phosphate (RP) (P_3) and three biofertilizers *viz.,* control (B_0), PSB (*Pseudomonas striata*) (B_1) and PSB + VAM (*Glomus fasciculatum*) (B_2). These were tried in split-plot design replicated thrice. The combination of time of irrigation and sources of P were placed in main-plots while the biofertilizers in sub-plots. The experiment was conducted in a field kept vacant during the previous *kharif* to have uniform fertility gradient. *Desi* chickpea 'Pusa 256' and fodder sorghum 'Pusa Chari 9' were used as test crops. The chickpea was sown in 30 cm rows using a seed rate of 80 kg/ha on 24 and 22 October and harvested on 31 and 28 March in the first and second year, respectively. The fodder sorghum was also sown in 30 cm rows using a seed rate of 30 kg/ha on 10 and 7 April and harvested on 11 and 9 June in the first and second year, respectively. The crops were raised as per the recommended package of practices except the treatments. Nodulation parameters at 45 and 75 DAS were recorded in chickpea. The succeeding crop of fodder sorghum was grown after the harvest of chickpea with out any additional treatments. The plant and soil samples collected at harvest were analyzed for P content in plants and available P status in soil. The data colleted were statistically analyzed as per the analysis of variance technique for split-plot design.

RESULTS AND DISCUSSION

Chickpea

Growth attributes

Irrigation at peak vegetative growth and pod filling stages, application of P as SSP and application of PSB + VAM recorded significantly higher plant height, drymatter accumulation and number of branches per plant in chickpea at harvest (Table 1). As the irrigation at these stages coincided with peak vegetative growth, the growth attributes were obviously benefited and recorded higher values. A decreasing trend in dry matter accumulation with irrigation was observed after flowering (Guhey and Trivedi, 2001). The easy availability of P which is an important nutrient required for the development of plants, showed its supremacy by recording higher growth attributes when compared with other sources of P. The seed inoculation with PSB and VAM recorded their beneficial effect by making available the fixed P in the soil. The number of nodules and their biomass too were higher with irrigation at peak vegetative growth and flowering and application of P as SSP along with application of PSB + VAM showed higher number of nodules and their biomass. Mukherjee and Rai (2000) also reported the positive effect of bio-fertilizers on chickpea. This may be attributed to irrigation at peak vegetative growth and abundant availability of P due to SSP and bio-fertilizers.

Yield attributes and yield

Irrigation at flowering and pod filling stage (I_3), coupled with application of P as SSP and application of PSB + VAM showed better results in terms of number of pods/plant, pod yield, number of grains/pod and 100-seed weight of chickpea (Table 2). The improved growth due to these treatments and continued good growing conditions resulted in significantly higher yield attributes in these treatments. The chickpea recorded significantly higher grain yield due to application of irrigation at flowering and pod filling stage (I_3) in both the years of experimentation. This may due to the fact that reproductive phases are quite sensitive to moisture stress and adequate moisture helps prevent flower drop and higher grain filling. Naglikar *et al.* (2001) also observed positive effect irrigation at reproductive phase of chickpea. Application of P as SSP showed higher grain as it supplied the P continuously in easily available form throughout the crop growth with little P-fixation. Further the seed inoculation with PSB and VAM recorded higher yield of chickpea followed by improved availability P through solubilization and mobilization of fixed P in different layers of the soil. Jain and Singh (2003) and Shivakumar *et al.* (2004) also observed higher response to biofertilizers in chickpea. The interaction of biofertilizers and RP clearly demonstrated the synergistic effect of these on the availability of fixed P (Fig. 1). Thus the combination of RP and application of PSB + VAM recorded significantly higher grain yield of chickpea when compared with other combinations. Significant interaction between biofertilizers and RP have also been reported by Sapatnekar *et al.* (2002).

Fodder sorghum

Growth attributes and yield

The plant height and drymatter accumulation in fodder sorghum was not influenced by the irrigation treatments (Table 3). As the effect of irrigation is temporary and not long lasting, there could not be any residual effect of the irrigation treatments. Application of P as RP recorded better growth attributes in fodder sorghum. This can be attributed to large unused reserves of P as it is slowly dissolved and made available to crop unlike the SSP or DAP, which are readily available and utilized by the first crop. The application of PSB + VAM also showed significant residual effect by way of greater availability of P through dissolution and mobilization of fixed P. Both fresh and dry fodder yield of sorghum were not significantly influenced by the irrigation treatments. Among the P sources, rock phosphate showed significant impact on the yield of fodder sorghum. This may be due to the fact that it was not fully exhausted by the preceding crop of chickpea and was available to the fodder sorghum. Jat and Ahlawat, (2006) observed the residual effect of P on succeeding crops. Likewise the application of PSB + VAM due to their prolonged activity could enhance the productivity of the fodder sorghum. This corroborate with the findings of Jat and Ahlawat (2004), who also reported residual effect of biofertilizers applied to chickpea on the succeeding fodder

Table 1. Plant height (cm) and nodules/plant and nodule weight (g)/plant in chickpea as influenced the irrigation, sources of P and levels of biofertilizers

Treatment	2005-06	2006-07	2005-06				2006-07			
	Plant height		Nodules/plant		Nodule weight/ plant		Nodules/plant		Nodule weight/ plant	
			45 DAS	75 DAS	45 DAS	75 DAS	45 DAS	75 DAS	45 DAS	75 DAS
Time of irrigation (DAS)										
I_1: 30, 70	49.5	48.6	26.8	160.0	32.0	324.0	29.4	210.0	42.4	376.0
I_2: 30, 90	53.3	52.4	29.0	175.0	34.4	310.0	32.6	235.0	46.2	345.0
I_3: 75, 90	52.4	54.6	16.2	112.0	26.6	198.0	22.0	179.0	34.4	242.0
SEm±	0.7	1.0	1.5	6.3	1.7	20.1	1.1	6.4	0.7	3.2
CD (P=0.05)	2.2	3.0	4.5	18.9	5.1	60.3	3.3	19.2	2.1	9.6
Source of P										
P_1: SSP	52.3	52.2	26.0	166.0	34.0	315.0	30.0	215.0	42.6	332.0
P_2: DAP	52.5	52.0	25.0	174.0	32.0	326.0	28.0	221.0	41.4	322.0
P_3: RP	50.4	48.4	21.0	107.0	27.0	191.0	26.0	188.0	39.0	309.0
SEm±	0.7	1.0	1.5	6.3	1.7	20.1	1.1	6.4	0.7	3.2
CD (P=0.05)	2.2	3.0	4.5	18.9	5.1	60.3	3.3	19.2	2.1	9.6
Biofertilizer										
B_0: control	50.1	47.4	23.0	142.0	29.0	270.0	27.0	194.0	37.0	309.0
B_1: PSB	52.4	52.2	24.0	152.0	32.0	276.0	28.0	214.0	42.0	323.0
B_2 : PSB + VAM	52.8	53.0	25.0	153.0	32.0	285.0	29.0	216.0	44.0	331.0
SEm±	0.6	1.4	0.7	4.2	2.4	5.3	2.2	7.4	3.4	8.6
CD (P=0.05)	1.8	3.9	NS	NS	NS	NS	NS	NS	NS	NS

DAS, Days after sowing.

Table 2. Number of pods per plant, seeds per pod, 1000-seed weight(g), grain yield (t/ha) and harvest index (%) of chickpea as influenced by time of irrigation, sources of P and levels of biofertilizers

Treatment	Pods/plant		Seeds/pod		1,000 seed weight		Grain yield		Harvest index	
	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07
Time of irrigation (DAS)										
I_1: 30, 70	26.08	27.40	1.01	1.02	278.0	273.5	1.43	1.39	28.90	28.50
I_2: 30, 90	28.55	31.20	1.11	1.12	289.0	287.0	1.53	1.50	32.10	31.75
I_3: 75, 90	29.46	32.20	1.12	1.11	291.0	291.6	1.59	1.53	32.50	32.25
SEm±	0.61	1.12	0.23	0.03	3.1	3.1	0.03	0.03	1.01	1.04
CD (P=0.05)	1.83	3.36	NS	0.09	9.3	9.3	0.09	0.10	3.03	3.12
Source of P										
P_1: SSP	28.68	30.80	1.12	1.12	291.5	286.8	1.56	1.55	32.25	31.75
P_2: DAP	28.40	31.20	1.09	1.10	288.8	287.7	1.54	1.52	32.21	32.15
P_3: RP	27.02	28.80	1.03	1.03	277.6	277.5	1.45	1.34	29.04	28.60
SEm±	0.61	1.12	0.23	0.03	3.1	3.1	0.03	0.03	1.01	1.04
CD (P=0.05)	NS	3.36	NS	0.09	9.3	9.3	0.09	0.10	3.03	3.12
Biofertilizer										
B_0: control	27.36	28.60	1.04	1.03	279.0	275.4	1.46	1.33	29.35	28.30
B_1: PSB	28.30	31.00	1.09	1.11	289.2	289.6	1.54	1.53	32.15	32.30
B_2 : PSB + VAM	28.45	31.20	1.10	1.10	289.8	287.0	1.55	1.55	32.00	31.90
SEm±	0.21	0.72	0.21	0.41	2.8	4.4	0.03	0.06	1.12	0.98
CD (P=0.05)	0.60	2.07	NS	1.18	8.0	12.6	0.08	0.16	3.21	2.81

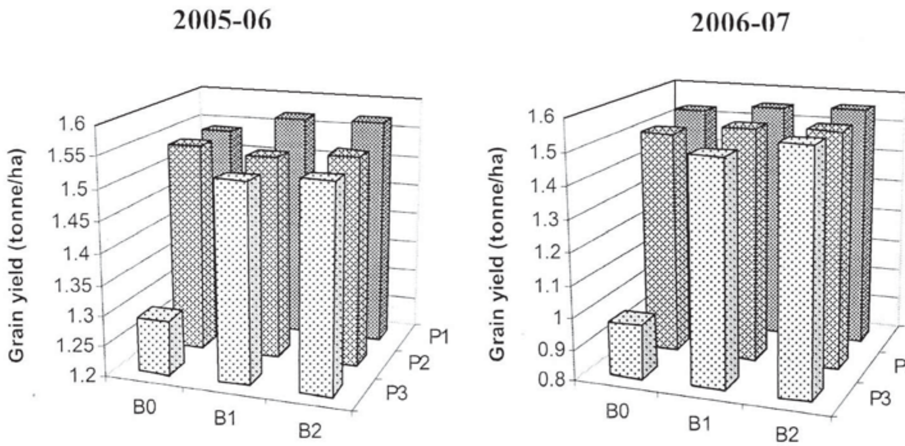

Fig. 1. Grain yield (t/ha) of chickpea as influenced by interaction between sources of P and levels of bio-fertilizers

Table 3. Plant height (cm), fresh and dry fodder yield (t/ha) in fodder sorghum as influenced by residual effect of time of irrigation, sources of P and levels of biofertilizers to preceding chickpea

Treatment	Plant height		Fresh	Dry	Fresh	Dry
	2005-06	2006-07	2005-06		2006-07	
Time of irrigation (DAS)						
I_1: 30, 70	120.3	121.2	16.72	3.34	17.32	3.49
I_2: 30, 90	124.4	123.5	17.12	3.52	18.03	3.56
I_3: 75, 90	123.1	122.3	16.86	3.69	18.05	3.63
SEm±	2.1	1.1	0.23	0.24	0.31	0.21
CD (P=0.05)	NS	NS	NS	NS	NS	NS
Source of P						
P_1: SSP	121.5	122.2	16.30	3.11	17.50	3.30
P_2: DAP	123.5	124.2	16.80	3.36	17.30	3.36
P_3: RP	122.8	120.5	17.60	4.10	18.60	4.02
SEm±	2.1	1.1	0.23	0.24	0.31	0.21
CD (P=0.05)	NS	NS	0.69	0.72	0.93	0.63
Biofertilizer						
B_0: control	120.6	119.5	15.80	3.16	16.50	3.30
B_1: PSB	123.5	124.2	17.20	3.64	18.10	3.67
B_2 : PSB + VAM	123.6	123.3	17.70	3.69	18.80	3.71
SEm±	1.0	1.4	0.38	0.17	0.51	0.11
CD (P=0.05)	2.7	3.9	1.09	0.49	1.46	0.32

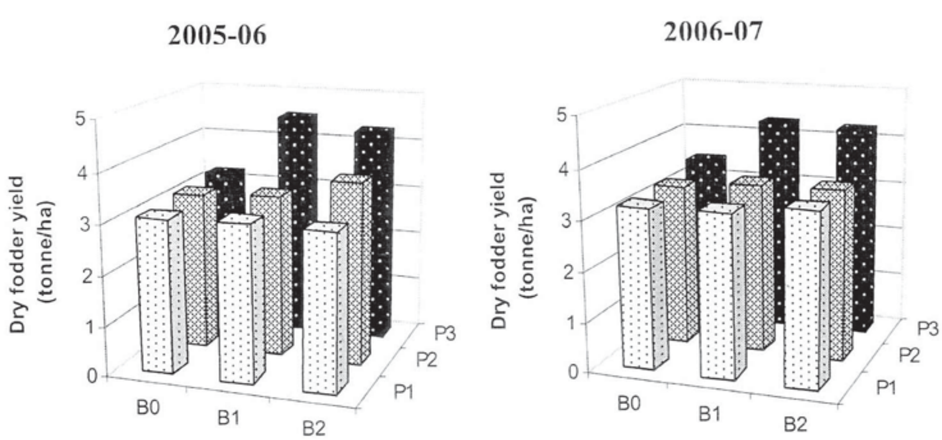

Fig. 2. Dry fodder yield (t/ha) of sorghum as influenced by interaction effect of sources of P and levels of biofertilizers to preceding chickpea

Table 4. P-uptake (kg/ha), available soil P-status (kg/ha) after harvest and WUE (kg/ha-mm) as influenced by time of irrigation, sources of P and levels of bio-fertilizers in chickpea-fodder sorghum cropping system

Treatment	P uptake				Soil P status				WUE*	
	Chickpea		Fodder sorghum		Chickpea		Fodder sorghum		Chickpea	Fodder sorghum
	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07		
Time of irrigation (DAS)										
I_1: 30, 70	14.09	14.20	6.21	6.42	8.94	9.41	8.85	9.31	14.06	34.15
I_2: 30, 90	14.53	14.24	6.83	6.62	9.05	9.36	8.90	9.29	15.14	35.40
I_3: 75, 90	14.92	14.58	7.01	6.72	8.98	9.20	8.96	9.40	15.56	36.60
SEm±	0.14	0.12	0.21	0.09	0.11	0.07	0.34	0.21	0.33	2.25
CD (P=0.05)	0.42	0.36	0.63	0.27	NS	NS	NS	NS	0.97	NS
Sources of P										
P_1: (SSP)	15.02	15.12	5.88	6.01	8.88	9.11	8.80	9.21	15.53	32.05
P_2: (DAP)	14.72	14.62	6.48	6.32	8.86	9.26	8.86	9.26	15.29	33.60
P_3: (RP)	13.79	13.26	7.71	7.44	9.24	9.60	9.05	9.53	13.93	40.60
SEm±	0.14	0.12	0.21	0.09	0.11	0.07	0.34	0.21	0.33	2.25
CD (P=0.05)	0.42	0.36	0.63	0.27	0.33	0.21	NS	NS	0.97	6.75
Biofertilizer										
B_0: (control)	13.58	13.07	5.91	6.01	8.90	8.80	8.92	8.83	13.95	32.30
B_1: (PSB)	14.87	14.78	6.92	6.83	9.02	9.51	8.99	9.56	15.32	36.55
B_2 : (PSB + VAM)	15.15	15.20	7.12	6.97	9.05	9.65	8.80	9.60	15.48	37.00
SEm±	0.43	0.51	0.21	0.03	0.03	0.21	0.08	0.53	0.42	1.40
CD (P=0.05)	1.23	1.46	0.60	0.09	0.09	0.60	NS	NS	1.21	4.05

*Mean of 2 years

Table 5. Gross expenditure (Rs/ha), net return (Rs/ha) and B:C (Rs/Re) from chickpea- fodder sorghum cropping system as influenced by residual effect of time of irrigation, sources of P and levels of bio-fertilizers to preceding chickpea

Treatment	Gross expenditure	2005-06		2006-07	
		Net return	Net B: C ratio	Net return	Net B: C ratio
Time of irrigation					
I_1	21,625	24,020	1.93	23,495	1.94
I_2	21,625	27,235	2.19	26,430	2.15
I_3	21,625	29,070	2.36	27,415	2.23
SEm±		1,030	0.07	810	0.06
CD (P=0.05)		3,059	0.21	2,429	0.18
Source of P					
P_1	22,005	26,325	1.98	26,545	2.05
P_2	21,645	26,835	2.12	26,460	2.09
P_3	21,225	27,225	2.39	24,335	2.18
SEm±		1,030	0.07	810	0.06
CD (P=0.05)		NS	0.21	2,429	0.18
Biofertilizers					
B_0	21,575	24,305	1.90	21,650	1.77
B_1	21,625	27,745	2.26	27,535	2.25
B_2	21,675	28,095	2.29	28,155	2.30
SEm±		1,002	0.09	1610	0.12
CD (P= 0.05)		3,005	0.27	4,827	0.36

maize. The interaction between application of PSB + VAM and rock phosphate showed the availability of P was enhanced by the biofertilizers (Fig. 2).

P uptake and water use efficiency (WUE)

The total P-uptake was increased significantly by irrigation at flowering and pod filling, P as SSP along with PSB and VAM inoculation in chickpea (Table 4). In fodder sorghum the P uptake was not influenced by irrigations to preceding chickpea, but application of P as RP and inoculation with PSB and VAM recorded significantly higher P uptake. The WUE also showed similar trend. The soil P status after harvest showed significant increase with RP as source of phosphorus and PSB alone and PSB + VAM inoculation after chickpea while after fodder sorghum no such differences were observed. This higher P uptake and WUE in chickpea may be attributed to increased yield in chickpea due to irrigations at flowering and pod filling and increased availability of P due to SSP and both PSB + VAM. The slow dissolution of RP and availability of P, and continued activity of both PSB and VAM resulting in increased yield may be reasons for higher P uptake and WUE in fodder sorghum in those treatments. The non-significant variations in P status in soil may be attributed to exhaustive nature of fodder sorghum.

Economics

The net return and B:C ratio were significantly higher with irrigation at flowering and pod filling stage in the chickpea-fodder sorghum cropping system among the different irrigation schedules (Table 5). P source had differential effect on the monetary returns from the cropping system. In first year they were all at par, whereas in second year higher net return were noted with SSP while higher B:C ratio were observed with rock phosphate in both the years. The application of PSB + VAM too recorded higher monetary benefits due to its complementary effect in enhancing the P availability and subsequently higher productivity of the crop.

On the basis of this 2 year study it may be concluded that irrigation at flowering and pod filling stage, along with rock phosphate as source of P and application of PSB + VAM would result in higher system productivity and monetary returns in the North-Western Plains of India.

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