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Yield, economics and water use efficiency of chickpea (*Cicer arietinum*) under various irrigation regimes on raised bed planting system

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ABSTRACT

A field experiment was conducted at Kanpur during *rabi* seasons of 2005-06 and 2006-07 to elucidate the effect of raised bed planting on growth, yield, water use efficiency and economics of chickpea (*Cicer arietinum* L.) under various irrigation depths. Results revealed that raised bed planting increased nodulation significantly by 30.0% and nodule dry weight by 44.4% over flat bed planting. Raised bed planting also encouraged comparatively more root growth than flat bed as evident through higher root: shoot ratio. Branching and podding were significantly higher in raised bed by 52.1% and 23.6%, respectively. Chickpea recorded maximum grain yield (average 2.24 t/ha), water use efficiency (11.69 kg/ha-mm) and net return (Rs 20,810/ha) under raised bed planting system. Among depths, though 30 and 45 mm irrigation recorded significantly higher nodulation, root growth, branching and podding, the maximum grain yield was recorded with 30 mm irrigation (av. 2.22 t/ha) which was at par with 45 mm but significantly higher than 15 and 60 mm irrigations. Thus, on an average, raised bed planting increased grain yield by 17.3% and saved 37.5 to 50% irrigation requirement in chickpea.

Key words: Chickpea, Economics, Irrigation, Water use efficiency

Chickpea is the most important among the pulse crops occupying largest area (6.4 m ha) and production (5.10 m t) in India. In North-Western Plain Zone (NWPZ), irrigated area under chickpea is 26.0% in Uttar Pradesh, 33.4% in Rajasthan, 35.1% in Punjab and 42.7% in Haryana. (Anonymous, 2003). The relatively higher average productivity (923 kg/ha) in these states over the national average (798 kg/ha) also implies that optimum irrigation is required to obtain higher productivity in chickpea. Moreover, the traditional border method of irrigation leads to severe wastage of water resulting in low irrigation efficiency. Moreover, the extensive adoption of water expensive rice-wheat cropping system in NWPZ has caused severe depletion of ground water by 0.1- 0.2 m/year in these states. Thus, saving of irrigation water was found important consideration due to continued drying up of water resources in this zone. In canal command areas also, chickpea after rice is recommended at the tail end of the command areas realizing the less availability of water to support good crop of wheat (Ali, 2004). Thus the uphill task of improving land and water productivity under limited availability of irrigation poses major challenge for higher production in chickpea. Raised bed planting technique has recently emerged as the most potential resource conserving technology in Indo-Gangetic plains of NW India under rice-wheat cropping system. Raised bed planting of cereals, pulses and vegetables, on an average, increased yield by 24.2% and saving of irrigation water by 31.2% (Connor *et al.*, 2003). Raised bed planting also prevented excess moisture problem in heavy soils. Though the average irrigation requirement of chickpea has been found to be 6 cm on sandy loam soil in NWPZ under flat planting system (Singh and Singh, 2004), there is lack of evidence on the potential advantage of raised bed planting technique on irrigation water requirement and grain yield in chickpea. Therefore, the present experiment was conducted at this institute to find out the irrigation requirement of chickpea under raised bed planting system and also to elucidate the extent of water saving and yield advantage with raised bed planting over flat planting.

MATERIALS AND METHODS

A field experiment was conducted at Indian Institute of Pulses Research, Kanpur during *rabi* seasons of 2005 and 2006. The soil of the experimental field was clay loam in texture, neutral in reaction (pH 7.5), low in available N (172.5 kg/ha), medium in available P (15.2 kg/ha) and available K (192.9 kg/ha). The bulk density and soil moisture content at 0.03 MPa and 1.5 MPa were 1.52 g/cm^3,

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25.7 and 8.5% at 0-15 cm, 1.57 g/cm^3, 26.5 and 9.0% at 15-30 cm, 1.59 g/cm^3, 27.3 and 9.5% at 30-45 cm and 1.61 g/cm^3, 27.4 and 9.7% at 45-60 cm, respectively. The soil moisture at 0.03 and 1.5 MPa were determined using pressure plate apparatus and bulk density using core sampler method (Mishra and Ahmad, 1987). The field experiment was conducted in split plot design with two planting techniques (raised bed and flat bed) in the main-plot and four irrigation depths (15, 30, 45 and 60 mm) in sub-plots and all of them replicated thrice. Chickpea 'KWR 108' was drilled on flat and raised bed with 30 cm x 15 cm planting geometry on 17 November, 2005 and 15 November, 2006 after giving pre-sowing irrigation Trapezoidal shape raised beds were made mechanically by tractor driven bed planter. The width of bed was adjusted to 40 cm with two rows of chickpea on each raised bed. The seeds were treated with crop specific strain of *Rhizobium* before sowing. Recommended dose of N, P, K and S @ 20:19.8:33.3:20 kg/ha, respectively were applied as basal before final land preparation and sowing. Precise quantity of water as per varying irrigation depths were applied at branching (35 days after sowing, DAS) and pod development stages (90-95 DAS) of chickpea. The crop was harvested on 3 April, 2006 and 4 April, 2007. Required plant-protection measures were taken as and when found necessary. Nodulation and root growth were studied through destructive plant sampling at various growth stages. Data pertaining to crop growth, yield attributes and yield were collected at harvest and analyzed statistically. Soil moisture was determined thermo-gravimetrically up to 60 cm profile at sowing, before and after each irrigation and at harvest. Profile moisture use was calculated based on depletion of soil moisture following Mishra and Ahmad (1987). The effective rainfall of 25.3 mm and 60.0 mm in 2005-06 and 2006-07, respectively was used for calculation of seasonal consumptive water use by the crop. The B:C ratio was calculated based on the net return and cost of cultivation in each treatment.

RESULTS AND DISCUSSION

Nodulation and root growth

Nodulation and root growth in chickpea at 50 DAS and at flowering were significantly influenced by planting methods and irrigation depths (Table 1). Average nodules/plant and nodule dry weight at 50 DAS and at flowering were maximum in raised bed planting which were significantly higher than flat bed. On an average, raised bed planting recorded 30.0% more nodules and 44.4% higher nodule dry weight than flat bed. Raised bed planting also encouraged more root growth at the initial stage which is evident through significantly higher root: shoot ratio at 50 DAS. Though root: shoot ratio at flowering was higher with raised bed planting, it was at par with flat bed planting. Irrigation depths of 30 mm and 45 mm recorded higher nodules/plant as compared to other irrigation regimes. Nodule dry weight was maximum with 45 mm irrigation at 50 DAS (0.34 g) and with 30 mm irrigation at flowering (0.30 g). Heavy irrigation (60 mm) adversely affected the root nodulation in chickpea as revealed through minimum nodules/plant (av 27.1) and lowest nodule dry weight (0.25 g) at both the growth stages. The maximum root: shoot ratio in chickpea was recorded with 30 mm irrigation both at 50 DAS and at flowering indicating comparatively better root growth under this treatment. Higher irrigation depths (60 mm) resulted in lower root: shoot ratio. It was also revealed that root: shoot ratio at flowering stage was lower than at 50 DAS irrespective of planting techniques and irrigation depths. The interaction effect of planting technique and irrigation depth on chickpea nodulation and root: shoot ratio was found not significant. Relatively lower bulk density (1.53-1.58 g/cm^3) and higher porosity (38.0-40.0%) on raised bed in comparison to flat bed (1.56-1.61 g/cm^3, 34.0-36.0%% , respectively), as recorded in the experiment, may have encouraged better root growth and nodulation under raised bed planting in chickpea. Aggarwal and Goswami (2003) also reported lower bulk density, penetration resistance and higher root length density in wheat under raised bed planting over conventional planting system. However, poor nodulation and root growth under 60 mm irrigation may be attributed to the excess moisture and aeration problem under heavy irrigation in soils of experimental field.

Growth and yield

Plant height in chickpea at harvest was not influenced significantly either by planting methods or irrigation depths (Table 1). However, raised bed planting increased branches significantly by 52.1% over flat bed. Number of pods/plant was also maximum with raised bed planting which was significantly higher by 23.6% than flat bed. Among irrigation depths, branches/plant were maximum with 60 mm irrigation (39.0) while pods/plant were maximum with 30 mm irrigation (94.7) and both of them were at par with 45 mm irrigation. Varying irrigation depths and planting techniques did not influence the 100 seed weight significantly. The interaction effect of planting technique and irrigation regimes on growth and yield attributes was not significant. Chickpea recorded maximum grain yield under raised bed planting in both the years which were significantly higher by 16.8% and 15.9% than flat bed, respectively. Among irrigation regimes, 45 mm irrigation, though recorded maximum grain yield (2.20 t/ha) during

Table 1. Nodulation, root growth, yield attributes and yield of chickpea as influenced by planting methods and irrigation depths (mean of 2 years)

Treatment	Nodules/plant at 50 DAS		Root : shoot ratio at 50 days after sowing	Plant height (cm)	Branches/ plant	Pods/ plant	100 seed weight (g)	Grain yield (t/ha)		Harvest index (%)
	Number	Weight (g)						2005-06	2006-07	
Planting technique										
Flat bed	28.5	0.24	0.32	46.5	34.0	89.4	20.22	1.84	2.01	29.9
Raised bed	36.3	0.33	0.45	48.0	36.5	109.3	20.02	2.15	2.33	38.3
SEm±	0.8	0.01	0.02		1.6	1.5		0.02	0.13	
CD (P=0.05)	4.9	0.07	0.10	NS	9.7	8.9	NS	0.11	0.16	
Irrigation depth(mm)										
15	31.4	0.30	0.43	45.9	33.0	84.0	20.30	2.05	1.90	35.6
30	33.7	0.32	0.46	47.5	37.2	94.7	20.25	2.15	2.34	36.0
45	35.0	0.34	0.31	46.5	37.0	91.5	19.70	2.20	2.18	32.5
60	26.3	0.29	0.31	45.5	39.0	7.3	20.25	1.78	2.02	31.7
SEm±	0.9	0.02	0.04		0.9	2.0		0.07	0.06	
CD (P=0.05)	2.9	0.06	0.12	NS	2.9	6.1	NS	0.19	0.17	

Table 2. Water use and economics in chickpea as influenced by planting methods and irrigation depths

Treatment	Profile moisture use (mm)		Effective rainfall (mm)		Consumptive water use (mm)		Water use efficiency (kg/ha-mm)		Total variable (Rs/ha)	Net return (Rs/ha) cost	B:C ratio
	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07	2005-06	2006-07			
Planting technique											
Flat bed	153.8	145.7	25.3	60.0	179.1	205.7	10.27	9.72	11,480	19,055	1.65
Raised bed	153.0	145.0	25.3	60.0	178.3	205.7	12.06	11.33	13,600	20,810	1.53
SEm±									184	173	
CD (P=0.05)									1,122	1,051	
Irrigation depth (mm)											
15	130.6	127.1	25.3	60.0	155.9	187.1	13.17	10.15	11,492	19,043	1.65
30	145.8	140.0	25.3	60.0	171.1	200.1	12.55	11.69	12,178	22,232	1.82
45	156.1	149.4	25.3	60.0	181.4	209.4	12.11	10.42	13,750	20,195	1.47
60	171.4	163.3	25.3	60.0	196.7	223.3	9.02	9.05	14,614	14,991	1.30
SEm±									242	372	
CD (P=0.05)									745	1,145	

Minimum support price of chickpea: Rs 15,500/t

2005-06, it was at par with 30 mm but significantly higher by 7.3 and 23.6% over 15 and 60 mm irrigations, respectively. However, in the next year, the maximum yield response was recorded at 30 mm irrigation (2.30 t/ha), being at par with 45 mm, which has decreased significantly at 60 mm irrigation. On an average, the maximum grain yield in chickpea was recorded at 30 mm irrigation which was at par with 45 mm irrigation but significantly higher by 12.7 and 16.2 % over 15 and 60 mm irrigations, respectively. Harvest index also revealed the similar trend. Heavy irrigation (60 mm) though favorably influenced vegetative growth (branches/plant), but did not influence the yield attribute (pods/plant) and hence did not improve the yield significantly. Heavy irrigation also adversely affected nodulation and root: shoot ratio. During 2006-07 there was higher effective rainfall than 2005-06, that may have resulted in differential yield response to irrigations in 2 years. Chickpea grain yield was significantly influenced by the interaction effect between planting methods and irrigation depths. It was revealed that the grain yield of chickpea planted on flat bed was increased significantly up to 45 mm irrigation (2.10 t/ha) and decreased with further increase in irrigation depth. However, the maximum grain yield under raised bed planting (2.49 t/ha) was observed with 30 mm irrigation which was also decreased with more irrigation. Generally recommended irrigation depth (60 mm) caused more soil compaction and water logging which may have restricted the response of irrigation to 30 and 45 mm in the present investigation. However, raised bed planting saved 37.5 to 50% irrigation

requirement in chickpea as compared to normally recommended level of irrigation (60 mm). Experiments conducted under AICRP on Chickpea also revealed that raised bed planting increased branches, pods/plant and grain yield by 39.0% in NWPZ (Anonymous, 2004). Saving of irrigation water by 27.3% and increase in yield by 17.1% in chickpea under raised bed planting system was also reported by Connor *et al*. (2003).

Water use and water use efficiency

Irrespective of the treatments, the profile moisture use was more during 2005-06, the seasonal consumptive water use by the crop was more in the next year due to higher amount of effective rainfall in 2006-07 (Table 2). The raised bed planting significantly increased water use efficiency in chickpea by 17.4 and 16.6% during 2005-06 and 2006-07, respectively over flat bed planting. However, the two planting methods did not differ significantly in their consumptive water use in both the years. The consumptive water use by chickpea has increased with the increase in irrigation depths in both the years. The maximum water use efficiency was recorded with 15 mm irrigation (13.17 kg/ha-mm) during 2005-06 and with 30 mm irrigation during 2006-07. However, on an average, the water use efficiency was the maximum with 30 mm irrigation which was higher by 7.63 and 34.2% than 45 and 60 mm irrigations, respectively. Higher irrigation depths though increased the water use by the crop, it did not increase the grain yield proportionately which may have reduced the water use efficiency.

Economics

Raised bed planting in chickpea increased variable costs of cultivation by Rs 2,120/ha over flat bed due to additional preparation of raised bed by special implement (Table 2). Though the gross return was higher in raised bed by Rs 5,115/ha, the net return was narrowed to Rs 1,755/ha resulting slightly lower benefit: cost ratio than flat bed planting. Among the irrigation regimes, on an average, total variable cost was maximum with 60 mm but net return (Rs 22,232/ha) and benefit: cost ratios (1.82) were maximum with 30 mm irrigation. On an average, 30 mm irrigation in chickpea recorded higher net return by Rs 2,037 and Rs 7,241/ha over 45 and 60 mm irrigations, respectively. Jat *et al*. (2005) also reported higher grain yield, water productivity and net return in chickpea under raised bed planting system under irrigated conditions in western Uttar Pradesh.

It is concluded that the raised bed planting of chickpea was superior with respect to nodulation, root growth, branching and podding in chickpea and resulted in significantly higher grain yield over flat bed planting. However, 30 mm irrigation was found optimum in grain yield, economics and water use efficiency in chickpea when compared with conventional depth of 60 mm in the present experiment. Raised bed planting also saved 37.5 to 50% irrigation requirement in chickpea over flat bed planting.

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