Indian Journal of Agricultural Sciences **80** (3): 250–3, March 2010

Effect of land configuration and irrigation on sole and linseed (*Linum usitatissimum*) intercropped chickpea (*Cicer arietinum*)*

I P S AHLAWAT[1] and B GANGAIAH[2]

Indian Agricultural Research Institute, New Delhi 110 012

Received: 10 June 2009; Accepted: 30 December 2009

Key words: Chickpea, Intercropping, Irrigation, Land configuration, Linseed, Water productivity

Chickpea (*Cicer arietinum* L.) is the most important winter pulse crop of India occupying 6.93 million (m) ha with an annual production of 5.6 million tonnes (FAO 2006). It is predominantly grown on residual soil moisture as is evident from the fact that of the total area in the country, only 1.96 million ha (28.3%) is irrigated (FAI 2005). The moisture stress at some of the critical stages of growth often leads to its lower productivity. Further, high incidence of pests, especially pod borer (*Helicoverpa armigera* Hubner) has rendered the chickpea cultivation uneconomical. Farmers have shifted to its intercropping with linseed (*Linum usitatissimum* L.) in Bundelkhand region of Uttar Pradesh (GOI 2000), and chickpea + linseed replacement series intercropping (2–3: 1 row ratio) has been found promising (Ahlawat *et al.* 2005 a). This practice may not only ensure protein nutritional security of the country, but also improves total productivity and profitability of farming. Modified land configurations, such as furrow irrigated raised bed (FIRB) has shown good promise in enhancing chickpea performance (Jat *et al.* 2005) and water productivity. The information on effect of land configuration in association with irrigation is lacking for chickpea-based intercropping systems in general and chickpea + linseed in particular. In view of the above, the present investigation was undertaken to find out the impact of land configuration in relation to moisture regime in chickpea-based cropping system to maximize the total productivity and profitability.

A field experiment was conducted during winter seasons of 2003–05 at the Indian Agricultural Research Institute, New Delhi. The soil was sandy loam containing 0.36% organic carbon, 14 kg/ha of available P and 165 kg/ha of available K with *p*H 7.8. The field capacity and permanent wilting point values of the soil were 17.3 and 7.5%, respectively, with a bulk density of 1.57 g/cm^3 in the top 90 cm soil. The experiment was conducted in split-plot design with land configuration [flat and furrow irrigated raised bed (FIRB)] in main plots, irrigation (no irrigation, irrigation at 0.2 and 0.4 IW/CPE ratio) in sub-plots and cropping systems (sole chickpea, chickpea + linseed in 2: 1 row ratio) in sub-sub-plots with 3 replications. The crops were sown on 30 and 22 October in 2003 and 2004 and harvested on 30 March and 22 March in 2004 and 2005, respectively. In flat planting, a row spacing of 30 cm both in sole and intercropping treatment was adopted. In sole chickpea FIRB system, 3 rows of chickpea were planted on 60 cm wide raised beds alternated with 30 cm furrows. In intercropped FIRB system, 1 row of linseed and 2 rows of chickpea were planted on 60 cm wide raised beds alternated with 30 cm furrows. The seed rate of chickpea (60 kg/ha) and linseed (30 kg/ha) was kept constant in both methods of planting. A basal fertilizer dose of 100 kg/ha of di-ammonium phosphate was applied to the crops at sowing. Irrigation water (IW) was applied @ 60 mm in each irrigation. The evaporation during the crop growth period was 408.9 mm in 2003–04 and 441.1 mm in 2004–05. The rainfall during the same period was 35.4 mm (21.3 and 14.1 mm in December and January) in 2003–04 and 47.4 mm (2.2, 32.2 and 13.0 mm in January, February and March) in 2004–05. 'BGD 72' chickpea and 'HL 9' linseed was used. After a pre-sowing irrigation, the crops received irrigations as per the treatment and there were 1 and 2 irrigation in 0.2 and 0.4 IW/CPE ratio at 128 days, and 69 and 128 days after sowing in 2003–04; and 129 days, and 57 and 129 days after sowing in 2004–05, respectively. The soil moisture content before and after irrigation and at harvest were estimated from 0–90 cm soil depth (at 30 cm interval) by gravimetric method and used in estimation of consumptive use. Chickpea equivalent yield was calculated using minimum support prices of crops and water productivity was arrived as ratio of economic yield and consumptive use and expressed as kg/m^3.

The growth, yield attributes, yield and harvest index of both chickpea and linseed, and system productivity

*Short note

[1]Head (e mail: ahlawat47@hotmail.com); [2]Senior Scientist (email: bandla_gan@hotmail.com), Division of Agronomy

[expresses in terms of chickpea equivalent yield (CEY)] was not markedly altered by various land configurations (Table 1). Similar plant population of component crops in both the land configurations, having alike conditions led to similar growth and yield attributes of crop plants and finally leading to their grain yield. However, the biological yield of linseed in FIRB was markedly higher (8.9%) than that in flat sowing. The favourable moisture conditions for a longer period in FIRB system resulted in more branching that might be responsible for greater biological yield. Though the CU of water did not differ among two land configurations, the water productivity (WP) was marginally higher in FIRB than that of flat planting. In FIRB system, linseed was grown in furrows and its root system thus started 15 cm below that of chickpea sown on bed. This might have helped in exploitation of different soil profiles for moisture, nutrients, etc. as compared to flat sown crops experiencing competition for these resources owing to similar points of tapping these resources by root growth. Higher water productivity of chickpea grown on raised beds was also reported by Jat and Sharma (2005). The economic analysis indicated that FIRB planting was not economical as additional cost involved in making FIRB was more than the additional income and thus resulting in statistically similar net returns as that of flat planting.

Among the 3 irrigation schedules tested, irrigation at 0.2 IW/CPE ratio resulted in significant increase in plant height (both chickpea and linseed) and number of pods/plant (chickpea) and number of capsules/plant (linseed) (Table 1) over no irrigation. Further increase in IW/CPE ratio irrigation to 0.4 though did not cause any marked improvement in these attributes (except harvest index) in both the crops, but they were at their highest level among all the levels of irrigation. Thus, the higher yield attributes of crop(s) at 0.4 IW/CPE ratio irrigation resulted in markedly higher productivity of chickpea, linseed and the system over no irrigation. The mean system productivity increased by 24.6% (0.30 tonnes/ha) with irrigation at 0.4 IW/CPE ratio over the unirrigated control (Table 2). This increase in yield could be ascribed to favourable moisture conditions resulting from irrigations at critical phenological stages of initiation of flowering and seed filling. Such conditions favoured the growth and development of yield attributes (pods/plant in chickpea and capsules/plant in linseed). The yields obtained with irrigation at 0.2 IW/CPE ratio were at par with no irrigation and irrigation at 0.4 IW/CPE ratio. This could be attributed to the fact that the crop in this treatment (0.2 IW/CPE ratio) received irrigation at a very late stage of seed filling (128 days after sowing in 2003–04 and 129 days after sowing in 2004–05), and thus both the sources as well as sink were operating under sub-optimal levels before the crop received the irrigation. This was probably the reason of similar yield levels in this treatment and no irrigation. Further irrigation at 0.2 IW/CPE ratio was at par with 0.4 IW/CPE ratio because of higher values of yield attributes in the former over that of unirrigated crop. Chickpea and linseed both being drought-hardy and deep-rooted crops are able to effectively utilize soil moisture from deeper soil profiles. Therefore, 1 pre-sowing irrigation coupled with winter rains during December–January and an irrigation at about 128–129 days after sowing was adequate to meet the requirement of the crop(s). A similar increase in yield with irrigation was also reported by Husain *et al.* (2000). The consumptive use and net returns increased with

Table 1 Effect of land configuration and irrigation on growth, yield attributes and yield of chickpea and linseed (pooled data of 2 seasons)

Treatment	Chickpea						Linseed				
	Plant height (cm)	Pods/ plant	1 000-seed weight (g)	Yield (tonnes/ha)		Harvest index	Plant height (cm)	Capsules/ plant	Yield (tonnes/ha)		Harvest index
				Biological	Grain				Biological	Grain	
Land configuration											
Flat	53.2	19.1	214.6	4.03	0.80	19.8	67.2	57.8	3.26	0.95	29.1
FIRB*	54.4	18.9	214.4	3.95	0.79	19.8	66.5	58.2	3.55	1.05	29.6
SEm±	1.3	1.1	3.0	0.10	0.04	0.2	1.5	0.8	0.03	0.06	0.2
CD (*P*=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	0.17	NS	NS
Irrigation schedule (*IW/CPE ratio*)											
Control	50.0	16.7	212.7	3.70	0.72	19.3	63.4	55.7	3.16	0.90	28.5
0.2	54.6	20.3	215.1	3.98	0.80	20.0	68.0	58.7	3.38	0.98	29.0
0.4	57.0	21.7	215.8	4.29	0.88	20.3	69.2	59.5	3.59	1.11	30.9
SEm±	1.1	0.9	2.5	0.08	0.03	0.2	1.3	0.7	0.02	0.05	0.2
CD (*P*=0.05)	3.5	2.5	NS	0.26	0.09	1.0	4.1	2.3	0.08	0.18	0.9
Cropping system											
Sole chickpea	52.6	20.3	214.6	5.08	1.13	22.2					
Intercropping**	55.7	18.2	214.4	2.88	0.46	16.0	66.9	58.0	3.41	1.00	29.4
SEm±	1.2	1.1	3.1	0.08	0.03	0.2					
CD (*P*=0.05)	NS	NS	NS	0.25	0.09	0.9					

* FIRB, Furrow irrigated raised bed, ** Chickpea + linseed intercropping

increasing IW/CPE ratios, and was the highest at 0.4 ratio. On the contrary, the water productivity decreased with increasing irrigation frequency from the highest values with no irrigation to the lowest values with irrigation at 0.4 IW/CPE ratio. The decrease in water productivity could be attributed to the fact that the increase in yield was not in proportion to the increase in consumptive use of water

Intercropping of chickpea with linseed reduced the chickpea yield by 60.3%, although linseed occupied only 33% of the total area. This indicated the competition among the component crops, where linseed was the dominant component. The loss in chickpea yield was compensated by the additional yield of linseed, and thus the system productivity of chickpea + linseed intercropping was increased by 43.4% over that of sole chickpea. Of this increase in system productivity, 65.3 and 34.7% were contributed by higher seed yield and higher minimum support prices of linseed, respectively as compared to chickpea. Better performance of intercropped chickpea with linseed over sole chickpea was also noticed by Hossain *et al.* (2000) and Singh and Pandey (2002). The harvest index was, however, adversely affected by cropping system, as intercropped chickpea tended to produce proportionately lesser seed yield to its biomass, leading to significantly lower harvest index (16.0) as compared to sole chickpea (22.2). Further, linseed plants though taller than chickpea plants could not shade and offer competition for resources to chickpea plants resulting in similar growth and yield attributes. Intercropping of chickpea with linseed enhanced water productivity by 41.9% over that of sole cropping of chickpea. This was due to greater increase (46%) in total productivity in intercropping system than the increase in consumptive use (1.2 mm). Similar results were also obtained by Ahlawat *et al.* (2005 a) in chickpea + Indian mustard (*Brassica juncea* L. Czernj coss.) intercropping system at different irrigation schedules. Intercropping of chickpea gave 2.81 times more net returns to that of sole chickpea.

The interaction effect of land configuration×irrigation on total productivity revealed that total productivity in flat and FIRB planting systems was similar at 0.2 and 0.4 IW/CPE ratio irrigation. However, when crop did not receive irrigation after sowing, FIRB planting recorded higher productivity (0.18 tonnes/ha). The chickpea and linseed crops exploiting moisture from different niches from initial stages in FIRB coupled with better utilization of rainfall received during crop growth consequently led to relatively better performance of the crops in this system. It was observed that FIRB system recorded more returns (Rs 1 506) than flat planting under rainfed conditions only. Since the total productivity in both the land configuration under irrigated conditions was similar, but making FIRB required an additional Rs 1 000 which made this system uneconomical. The interaction effect of irrigation×cropping system revealed that productivity of intercropping system increased with increasing irrigation frequency (up to 0.4 IW/CPE ratio). However, sole chickpea failed to respond beyond 0.2 IW/CPE ratio. Chickpea being a deep-rooted crop is known to utilize moisture from deeper soil profiles. Nevertheless it responds to one or two irrigation

Table 2 Effect of land configuration and irrigation on system productivity (CEY), consumptive use (CU), water productivity (WP) and economics (mean of 2 seasons) of chickpea-based cropping system

Treatment	System productivity (tonnes/ha)			Consumptive use (mm)		Water productivity (kg/m^3)		Cost of cultivation (Rs/ha)	Net returns (Rs/ha)
	2003	2004	Pooled	2003	2004	2003	2004		
Land configuration									
Flat	1.50	1.20	1.35	95.5	98.6	1.57	1.22	14 870	5 707
FIRB*	1.57	1.24	1.42	95.7	100.2	1.64	1.24	15 870	5 648
SEm±	0.055	0.096	0.048						197
CD (*P*=0.05)	NS	NS	NS						NS
Irrigation schedule (*IW/CPE ratio*)									
Control	1.38	1.05	1.22	35.5	40.0	3.89	2.63	14 870	3 764
0.2	1.54	1.25	1.40	95.7	100.0	1.61	1.25	15 370	5 875
0.4	1.68	1.36	1.52	116.8	125.0	1.08	0.74	15 870	7 178
SEm±	0.046	0.08	0.04						165
CD (*P*=0.05)	0.15	0.26	0.12						538
Cropping system									
Sole chickpea	1.31	0.95	1.13	95.6	98.0	1.37	0.97	15 000	2 905
Intercropping	1.75	1.48	1.62	95.1	100.8	1.84	1.47	15 732	8 155
SEm±	0.05	0.087	0.043						180
CD (*P*=0.05)	0.154	0.268	0.13						554

CEY calculated using minimum support price (Rs/tonne): Chickpea, 13 600 and 14 250; Linseed, 16 000 and 16 500 in 2003–04 and 2004–05, respectively; Chickpea stover, Rs 550/tonne in both the years; no value is taken for linseed stover

*FIRB, Furrow irrigated raised bed

depending upon the amount and distribution of rainfall during the crop growth period (Ahlawat *et al*. 2005a). Intercropping was more productive to sole cropping at all irrigation levels. Further, intercropping system receiving irrigation at 0.4 IW/CPE ratio recorded the highest net returns (Rs 9 915/ha) (data not given).

SUMMARY

The 2-year field investigation carried out in a sandy loam soil at New Delhi indicates that furrow irrigated raised bed (FIRB) planting of chickpea + linseed intercropping in 2: 1 row ratio receiving irrigation at 0.4 IW/CPE ratio may be recommended for higher productivity and profitability.

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