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Water productivity of furrow-irrigated rainy-season pulses planted on raised beds

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ABSTRACT

Water use, yield and economics of furrow-irrigated raised-bed system (FIRBS) of planting in pigeonpea, [*Cajanus cajan* (L.) Millsp.] clusterbean [*Cyamopsis tetragonoloba* (L.) Taub.] and greengram [*Phaseolus radiatus* (L.) Hepper] were studied under three moisture regimes, *viz.* irrigations at 150, 200 and 250 mm cumulative pan evaporation (CPE), during 2001 and 2002. FIRBS resulted in 22% higher grain yield of pigeonpea, 8% of clusterbean and 15% of greengram compared with flat-sown crops. In FIRBS 21.6, 18.8 and 14.4 cm irrigation water was applied in the three respective crops, with 25% saving compared with flat sown. Irrigation-water productivity (WP_{irri}) of pigeonpea, clusterbean and greengram under FIRBS was 76, 44 and 54% more than that of flat-sown crops. In all three crops, it was lowest in irrigation at 150 mm CPE and highest in irrigation at 250 mm CPE moisture regime. FIRBS-planted pigeonpea, clusterbean and greengram gave additional net benefit of Rs 2,820, 830 and 1,465/ha respectively compared with flat-sown crops.

Key words : Water productivity, Raised bed, Moisture regimes, Pigeonpea, Clusterbean, Greengram

Many areas, especially the semi-arid regions of the world are experiencing increasingly severe water scarcity. In future, due to competing demands for non-agriculture sectors, water for irrigation is going to be scarcer (IWMI, Colombo, 2002). Water is a finite natural resource, and to meet the food and fibre requirement of the growing population one of the options of alleviating water scarcity is to increase the efficiency of water use. At the field level this can be done by minimizing the losses (15-40%) during water application and distribution. Furrow-irrigated, raised-bed system (FIRBS) of planting crops can be a viable technology in reducing these losses. Its other advantages, as envisaged by Hobbs (2002), are maximum harvesting and utilization under low rainfall, avoidance of temporary flooding, improved drainage under high-intensity rainfall, higher N-use efficiency and less lodging. In Mexico the farmers achieved 10% higher yield by adopting FIRBS (Sayre, 2000a). North-west India has a monsoonal regime of rainfall, whore intensity is highly variable. The performance of rainy-season (*kharif*) pulses is highly dependent on rainfall pattern. Under such situations a promising technology like FIRBS needs to be validated for *kharif* pulses. Therefore to work out the water use and water productivity of FIRBS, studies were carried out on pigeonpea (*Cajanus cajan*), clusterbean (*Cyamopsis tetragonoloba*) and greengram (*Phaseolus radiatus*) under different moisture regimes, to help explore the posssibility of its introduction and to realize the immense benefits of this technique in the semi-arid region.

MATERIALS AND METHODS

A field experiment was conducted at the Research Farm of CCS HAU, Hisar during 2001–02 on a sandy-loam soil. The bulk density of the soil was 1.43 to 1.58 g/cm^3 and basic infiltration rate 4-5 mm/hr. It contained 19.3% moisture at –0.03 MPa and 6.9% at –1.5 MPa. The total rainfall received was 153 mm in greengram and 179 mm in clusterbean and pigeonpea. The open-pan evaporation (from sowing to harvest) in these crops was 1063, 1242 and 1398 mm respectively. The water-table during the crop season varied from 185 cm at sowing to 225 cm at harvest. Three moisture regimes, *viz.* irrigation at 150, 200 and 250 mm CPE in pigeonpea, clusterbean and greengram, were studied in furrow-irrigated raised-bed system (FIRBS). In this system the two rows of crops at 20 cm spacing were planted on top of each bed, 70 cm apart. Irrigation water was applied in furrows between the beds. These were compared with conventional flat sowing at a row spacing of 45 cm. Planting was done in the second fortnight of May. Greengram was harvested on 14 September, clusterbean on 17 October and pigeonpea on 22 November. The number of irrigations

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applied were: 7, 5 and 3 in pigeonpea; 6, 4 and 3 in clusterbean, and 5, 3 and 2 in greengram under 150, 200 and 250 mm cumulative pan evaporation (CPE) respectively. The amount of irrigation water applied is given in Table 1.

Ground-water contribution

Flux density of the soil water from ground water-table to root zone was estimated using Darcy's law for steady-state conditions, as proposed by Giesel *et al.* (1972).

$q = K_\theta\ (dh/dz-1)$

in which q = water flux density; K_θ= capillary conductivity; h = soil-water suction at the bottom of crop-root zone; and z = depth of water-table from the bottom of crop-root zone.

The capillary conductivity (K_θ) at moisture content (θ) was estimated from saturated hydraulic conductivity (K_s), using Campbell (1974) equation. Soil-water suction was determined by using soil-moisture characteristic curves. The ground-water contribution was thus estimated from the flux density assuming that the flux entering the lower layers of the root zone is the potential contribution. The total water use was estimated using the following water-balance equation:

Water use (ET) = S + I + P + C – D – R

in which S = change in soil moisture in root zone; I = irrigatioin water applied; P = effective rainfall; C = ground-water contribution from shallow water-table; D = downward drainage from crop-root zone; and R = surface water run-off.

Depletion of soil moisture was determined as its change, measured by sampling at successive intervals. The total amount of rainfall received was considered as effective. Downward drainage and surface run-off were negligible, as the maximum depth of irrigation or rainfall during the low and normal rainfall years was less than the soil-moisture deficit. The total and irrigation-water productivity was calculated as the production of grain yield per unit of total or irrigation water used.

The saving under FIRBS was calculated on the basis of present prices by taking into account the cost of saved water and income from the increased yield as gross additional income; and the cost of production for additional yield and FIRBS, making as cost of production over that of flat-sown crops. The net additional saving under FIRBS was calculated as the difference between additional income and additional cost.

RESULTS AND DISCUSSION

Yield

Planting of pigeonpea, clusterbean and greengram in FIRBS (paired rows 70–20–20 cm) gave higher grain yield than that in flat sown (Table 2). The yield of pigeonpea increased by 22% under FIRBS over flat sowing. Similarly, it increased by 15% in greengram. The grain yield of clusterbean was, however, not significant over that of flat sown. Shelke *et al.* (1999) observed increased yield of pigeonpea planted on beds.

Among the moisture regimes, application of irrigation at 200 mm CPE (5 in pigeonpea, 4 in clusterbean and 3 in greengram) gave higher grain yields compared with that at 250 mm CPE (Table 2). The differences in all the three crops between irrigations at 150 mm and 200 mm CPE were not marked.

Water use

Total water use in flat-sown crops was more than that in FIRBS. In pigeonpea it was 61.0 cm under flat sown and 55.4 cm under FIRBS. Similarly, it was 56.4 and 51.6 cm in clusterbean and 45.6 and 41.7 cms in greengram (Fig. 1). This was on account of substantially less amount

Table 2. Grain yield (q/ha) of flat- and FIRBS-planted crops under different moisture regimes

Treatment	Crop		
	Pigeonpea	Clusterbean	Greengram
Irrigation at CPE			
150 mm	11.18	9.68	8.40
200 mm	11.45	9.22	7.65
250 mm	8.24	8.08	6.44
CD (P=0.05)	1.57	1.12	1.09
Methods of planting			
Flat	9.27	8.65	6.97
FIRB	11.31	9.34	8.02
CD (P=0.05)	1.41	0.96	0.93

Table 1. Irrigation water applied (cm) in flat- and FIRBS-planted crops under different moisture regimes

Moisture regime (irrigation at)	Pigeonpea		Clusterbean		Greengram	
	Flat	FIRBS	Flat	FIRBS	Flat	FIRBS
150 mm CPE	39.2	29.4	33.7	25.2	28.1	21.0
200 mm CPE	29.0	22.0	23.2	17.6	17.4	13.2
250 mm CPE	18.3	13.5	18.3	13.5	12.2	9.0
Mean	28.8	21.6	25.1	18.8	19.2	14.4

of irrigation water applied in FIRBS than in flat-sown crops. Under the respective two planting methods the amount of irrigation water applied was 21.6 and 28.8 cm in pigeonpea; 25.1 and 18.8 cm in clusterbean; and 19.2 and 14.4 cm in greengram. On an average, 25% less irrigation water could be applied in FIRBS than the flat-sown crops. In Mexico, reduction in irrigation-water requirement up to 35% under FIRBS was reported by the farmers (Sayre, 2000b). Likewise, in north-west India, Yadav *et al.* (2002) recorded up to 36% saving of irrigation water in wheat. The trend of ground-water contribution and soil-moisture depletion in all the three crops was reverse, and was marginally higher in flat-sown crops than in the FIRBS. A comparison of the three moisture regimes showed that the total water use in all the three crops was highest in the treatment receiving irrigation at 150 mm

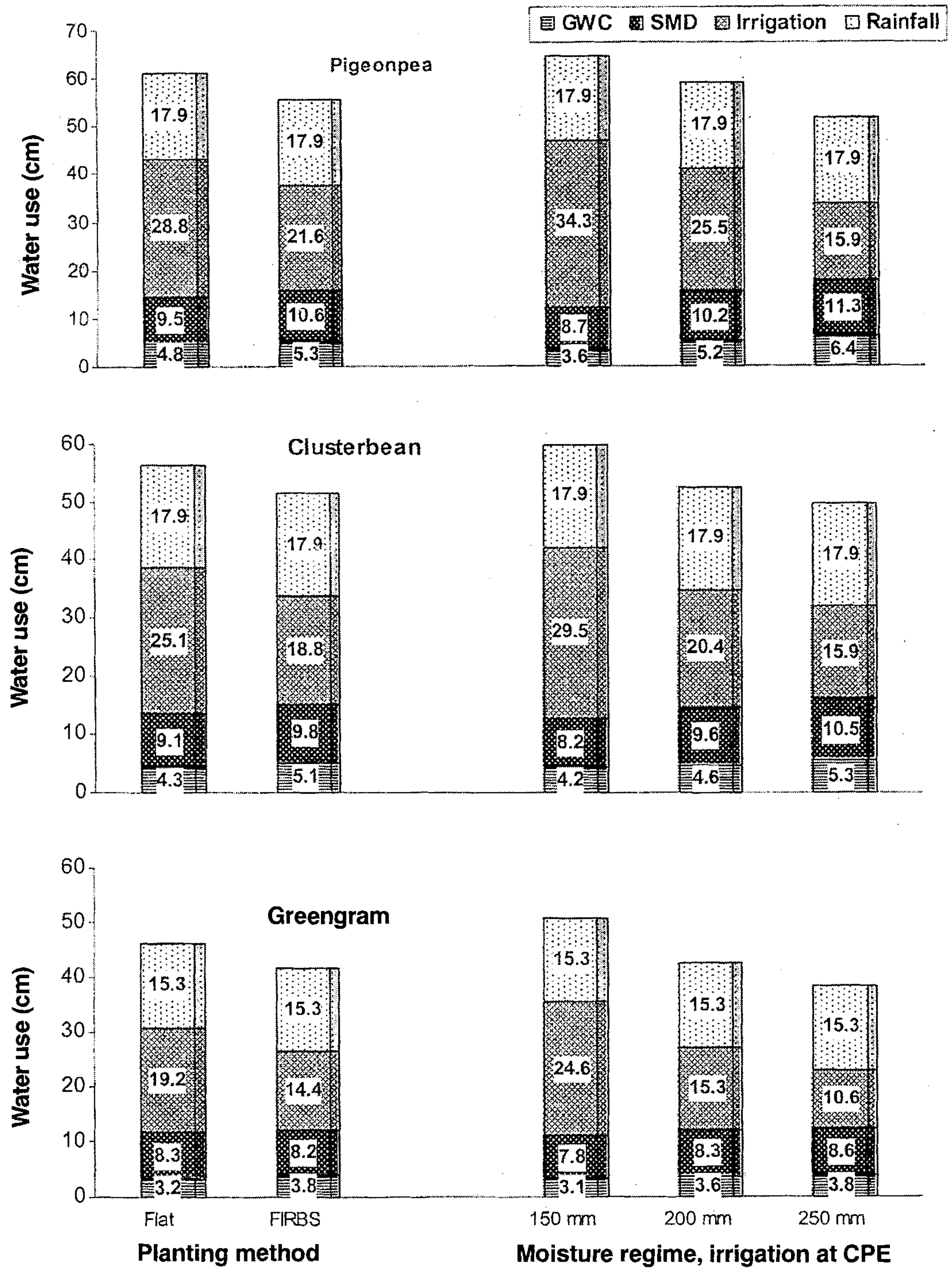

Fig. 1. Water-use components of flat and FIRBS crops under different moisture regimes
GWC, Ground-water contribution; SMD, soil-moisture depletion; CPE, cumulative pan evaporation

CPE and lowest at 250 mm CPE. In these moisture regimes of irrigation at 150, 200 and 250 mm CPE, the respective total water use was 64.5, 58.8 and 51.5 cm for pigeonpea; 59.8, 52.5 and 49.6 cm for clusterbean; and 50.8, 42.5 and 38.3 cm for greengram (Fig. 1). This was due to higher amount of irrigation water applied in the former (150 mm CPE) moisture regime than in the latter ones (200 and 250 mm CPE). The amount of irrigation-water use was 34.3, 25.5 and 15.9 cm in pigeonpea; 29.5, 20.4 and 15.9 cms in clusterbean; and 24.6, 15.3 and 10.6 cm in greengram in the three respective moisture regimes. Although the ground-water contribution and soil-moisture depletion were reverse (more in 250 and less in 150 mm CPE), these were substantially less in compensating the amount of irrigation water as a share of the total water use.

Water productivity

Irrigatioin-water productivity (WP_{irri}) of pigeonpea, clusterbean and greengram under FIRBS was 76, 44 and 54% more than that of their respective flat-sown crops (Fig. 2). It shows that pigeonpea is better suited under FIRBS in terms of irrigation water saving than greengram and clusterbean. In all the three crops it was lowest in irrigation at 150 mm CPE and highest in irrigation at 250 mm CPE moisture regime. Kaushik and Lal (1998) and Singh *et al.* (1998) in pigeonpea also reported higher water-use efficiency by furrow irrigation system. The total water productivity (WP_{total}) of flat-sown crops was 153 g/m^3, which increased by 34% in pigeonpea, 18% in clusterbean and 25% in greengram under FIRBS. The differences in WP_{total} were marginal among the different moisture regimes in all the three crops.

Monetary benefit

The net additional saving under FIRBS over the flat-sown crops was maximum in pigeonpea, followed by greengram and minimum in clusterbean (Table 3).

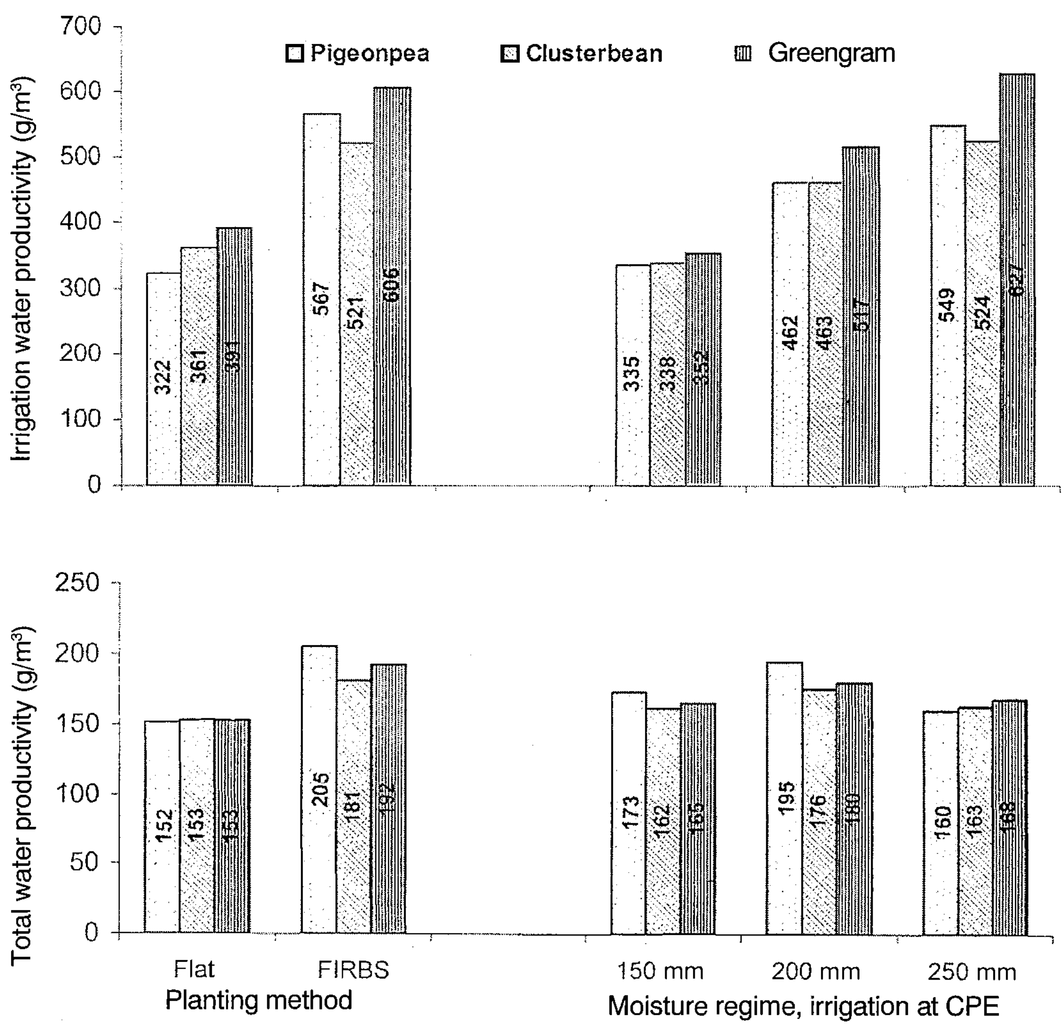

Fig. 2. Water productivity (irrigation and total) of flat and FIRBS crops under different moisture regimes

Table 3. Net saving (Rs/ha) under FIRBS over flat-sown crops

Crop	Cost of saved water	Income from additional	Gross saving	Production cost of additional yield	Cost of FIRBS making	Net additional saving under FIRBS
Pigeonpea	720	2,960	3,680	610	250	2,820
Clusterbean	630	585	1,215	135	250	830
Greengram	480	1,495	1,975	260	250	1,465

Thus the furrow-irrigated raised-bed system (FIRBS) of planting proved a resource-conservation technology. Planting of *kharif* pulses, *viz.* pigeonpea, clusterbean and greengram, on FIRBS increased the crop yields by 8–22% and simultaneously saved 25% of irrigation water over flat-sown system. The FIRBS-planted crops had higher irrigation-water productivity (44–72%) and total water productivity (18–34%) as compared with flat-sown crops. FIRBS increased the monetary benefit over the flat sown in all the three crops.

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