Indian Journal of Agronomy **57** (4): 357–361 (December 2012)

Research Paper

Effect of irrigation and cropping system on potato (*Solanum tuberosum*) grown sole or intercropped with French bean (*Phaseolus vulgaris*)

V.K. TYAGI[1], O.V.S. THENUA[2], DINESH KUMAR[3] AND NAIN SINGH[4]

Indian Agricultural Research Institute, New Delhi 110 012

Received : March 2011; Revised accepted : October 2012

ABSTRACT

A field experiment was conducted on sandy loam soil analysing low in N and medium in P and K during winter season of 2004-05 and 2005-06 at Indian Agricultural Research Institute, New Delhi. The treatments comprised 5 irrigation levels (irrigation at critical stages of potato (*Solanum tuberosum* L.), irrigation at critical stages of French bean (*Phaseolus vulgaris* L.), and irrigation at 0.8, 1.2 and 1.6 IW/CPE ratio) as main plots and 3 cropping systems (sole potato, sole French bean and potato + French bean in 2:3 row ratio) replicated thrice in a split plot design. Irrigation at IW/CPE ratio of 1.6 produced the highest tuber yield followed by irrigation at 1.2 IW/CPE ratio, while the lowest tuber yield was achieved with irrigation at 0.8 IW/CPE ratio. Although the tuber yield with irrigation applied at critical growth stages (CGS) of potato was significantly lower than with IW/CPE ratio of 1.6, but the water use efficiency (WUE) with CGS of potato was higher. In French bean, both seed yield and WUE was higher with irrigation at CGS of French bean than that obtained with the irrigation at all the three IW/CPE ratios studied. Tuber yield of potato was higher in sole potato than when intercropped with French bean. Potato + French bean intercropping system recorded much higher B:C ratio (2.53) as against 1.54 with sole potato and 1.97 with sole French bean.

Key words : French bean, Intercropping, Irrigation, Potato

Potato is the most popular food crop used as vegetable in every household of the country. India is one of the important countries producing about 25 million tonnes of potato from an area of 1.34 million ha with an average productivity of 18.6 t/ha. Earlier studies have shown that potato and French bean could successfully be intercropped for higher productivity and monetary returns (Ali and Lal, 1991 and Ahlawat, 1998). Potato and French bean both require frequent and liberal supply of irrigation water for realizing the maximum productivity. In potato, there are four critical stages of irrigation being earthing up, stolonization, tuberization and tuber enlargement, where lack of moisture adversely affects the productivity of the crop. Water requirement, however, vary from location to location depending on soil type, duration of crop, cultivar and climatic conditions. The crop should be irrigated at 15-20 mm CPE during the critical stages of growth (Gaur and Pandey, 1992). Similarly, seedling, branching, flowering and pod development are the critical stages of irrigation in French bean. These stages usually coincide with 25, 50, 75 and 100 days after sowing. Water is a scarce and costly input in the present day agriculture. It is also likely to be the most important input in future agriculture. Therefore, it has to be used in the most efficient manner to realize the maximum water productivity. This study included the critical stages of irrigation in potato along with irrigation at graded levels of IW/CPE ratio (0.8, 1.2 and 1.6 IW/CPE ratio) in sole and intercropped potato with French bean. Keeping in view the above, the present study was undertaken to study the response of sole and intercropped potato to irrigation at the Indian Agricultural Research Institute, New Delhi during *rabi* 2004-05 and 2005-06.

[3]Corresponding author Email: dineshctt@yahoo.com

[1&4]Technical Officer; [3]Principal Scientist, [2]Reader & Head (Agronomy), A.S. College of Agriculture, Lakhaoti, Bulandshahar, U.P.

MATERIALS AND METHODS

A field experiment was conducted at the Indian Agricultural Research Institute, New Delhi during *rabi* seasons of 2004-05 and 2005-06. The soil was a sandy loam with pH 7.9 and EC of 0.41 mmhos cm^{-1}. It was low in organic matter (0.42%) and total nitrogen (0.035%), and medium in Olsen's available P (19 kg/ha) and 1 M ammonium acetate exchangeable K (185kg/ha) as per procedures described by Prasad *et al.* (2006). The values of field capacity and permanent wilting point moisture and bulk density of 0-90 soil layer were 19.10%, 6.64% and 1.51 Mg/m^{-3},

respectively. The treatments comprised 5 irrigation treatments (I_{1-} irrigation at critical growth stages (CGS) of potato (earthing up, stolonization, tuberization and tuber enlargement), I_{2-} irrigation at critical growth stages of French bean (seedling, branching, flowering and pod development), I_3 – irrigation at IW/CPE ratio of 0.80, I_4 – irrigation at IW/CPE ratio of 1.20, and I_5– irrigation at IW/CPE ratio of 1.60 as main plot treatments and 3 cropping systems [sole potato, sole French bean and potato intercropped with French bean in 2:3 row ratio (2 rows of potato at 50 cm alternated with 3 rows of French bean at 30 cm)] as sub- plot treatments, replicated thrice in a split plot design. Variety 'Kufri Badshah' of potato and 'Amber' of French bean was used in the experiment. Both sole and intercropped potato received 60 kg P_2O_5/ha as single superphosphate and100 kg K_2O /ha as muriate of potash at the time of sowing. Nitrogen application (120 kg N/ha) as urea was made in two equal splits, half at sowing and remaining half after 45 days of sowing. Crops were sown on 27 October in 2004 and 20 October in 2005. In sole potato, spacing was 60 cm × 20 cm; where as in intercropping, 2 rows of potato at 50 cm were alternated by 3 rows of French bean at 30 cm. Irrigation was applied as per treatments at critical stages of potato, critical stages of French bean, IW/CPE ratios of 0.80, 1.20 and 1.60. Parshall flume was used to measure the irrigation water. Each irrigation received 60 mm of water. Pendimethalin at 1.0 kg/ha as pre-emergence was used to control weeds.

RESULTS AND DISCUSSION

Irrigation x cropping system interaction was not significant for any character, hence the results are discussed separately for these factors.

Effect of Irrigation

Water is the key input in potato production. However, both water deficit and excess water conditions adversely affect the plant growth, development and productivity. Although the scheduling of irrigation in potato crop is affected by number of factors like climate and weather conditions, ability of root system to withstand moisture stress without any adverse effect on yield, method of crop establishment, and method of irrigation etc. but the basic principle is maintaining adequate moisture in the root profile at the critical stage where even a small moisture stress could result in proportionately high losses in yield.

Growth attributes of potato

Irrigation schedules caused marked variations in growth attributes of potato at successive stages of crop growth (Table 1). Irrigation at IW/CPE ratio of 1.2 and 1.6 recorded taller plants compared with other irrigation treatments at 40 days as these treatments received two irrigations by that time compared to one in other treatments. However, leaf area index was not affected due to irrigation treatments at this stage (Table 1). During the next 40 days (at 80 days stage), both the above irrigation treatments and irrigation at critical stages of potato received more irrigation than others, and produced taller plants. Similar behaviour was also noticed in leaf area index at this stage. However, irrigation at 1.6 IW/CPE ratio recorded higher leaf area index than irrigation at critical stages of potato crop. It is well known that potato needs liberal supply of water through irrigation to maintain turgidity. The crop requires moist conditions throughout the life cycle and may suffer if more than 40-50% of available water in soil

Table 1. Plant height, leaf area index, tubers/plant and fresh tuber weight of potato as affected by irrigation and cropping system (Data pooled over 2 years)

Treatment	Plant height (cm)			Leaf area index (LAI)		Tubers/ plant	Tuber weight/ plant (g)
	40 DAS	80 DAS	Harvest	40 DAS	80 DAS		
Irrigation							
CGS potato	42.7	59.6	62.8	1.41	3.22	9.8	278.0
CGS F.bean	39.5	50.7	53.4	1.40	3.12	8.9	265.4
IW/CPE 0.8	42.8	48.2	52.1	1.40	2.44	8.01	235.7
IW/CPE 1.2	46.3	58.0	61.9	1.42	3.19	10.6	298.0
IW/CPE 1.6	47.6	61.4	64.3	1.44	3.19	11.1	356.1
SEm±	0.84	0.95	0.96	0.02	0.05	0.15	9.1
CD (P=0.05)	2.7	3.04	3.08	NS	0.17	0.47	29.2
Cropping system							
Sole potato	46.5	59.2	61.8	1.45	3.27	10.8	298.8
Potato + French bean	41.5	53.9	56.1	1.38	2.98	8.6	262.2
SEm±	0.83	0.90	1.06	0.02	0.05	0.14	7.9
CD (P=0.05)	2.68	2.87	3.38	NS	0.17	0.46	25.2

CGS potato- Irrigation applied in potato based upon critical growth stages; CGS F.bean - Irrigation applied in French bean based upon critical growth stages

is depleted. Higher leaf area index and taller plants with increasing frequency of irrigation have also been reported by Sharma (1994), Patel and Patel (2001) and Yadav *et al*. (2003). Higher crop growth rate, relative growth rate and net assimilation rates have also been observed with increasing irrigation regimes from 1.00 to 1.75 IW/CPE ratio by Patel and Patel (2000) working at Krushinagar in Gujarat.

Yield attributes and tuber yield of potato

The nature of development of yield attributes with irrigation was finally reflected in tuber yield. The maximum tuber yield was produced with the highest frequency of irrigation i.e., irrigation at 1.6 IW/CPE ratio; it was on par with irrigation at 1.2 IW/CPE ratio and greater than other irrigation treatments (Table 2). The improved plant growth with increasing frequency of irrigation was also reflected in the size of potatoes. Irrigation applied at 1.2 and 1.6 IW/CPE ratio produced bigger size (tubers with 4-5 cm diameter and >5 cm diameter) tubers followed by irrigation at critical stages of potato. However, there was not much variation in small tubers (<4 cm diameter) (Table 2). Similar behaviour was observed in number of tubers and fresh weight of tubers/plant (Table 1), except that irrigation at 1.2 IW/CPE ratio and irrigation at critical stages of potato recorded more or less similar values of these parameters. Yadav *et al*. (2003) also reported that medium and large size tubers were the maximum with the wettest irrigation regime of 20 mm. Similarly, Patel and Patel (2001) recorded higher fresh weight of tubers with increasing IW/CPE ratio from 1.00 to 1.75. It thus confirms the observations of earlier workers that potato responds to frequent and liberal supply of water for maximum production (Sharma, 1994; Raghuwanshi and Verma, 1991; Patel and Patel, 2000 and Chandra *et al*., 2002).

Consumptive use of water and water use efficiency (WUE)

As would be expected consumptive use of water was most (443.5 mm) with IW/CPE ratio of 1.6 (6 irrigations) and the least (279.6 mm) with IW/CPE ratio of 0.8 (3 irrigations) (Table 3). The other treatments were in-between. As a contrast the WUE was the lowest with IW/CPE ratios of 1.2 or 1.6. The WUE was the highest when irrigation was applied at critical growth stages (CGS) of potato or French bean. This suggests that for potato and French bean irrigation at CGS may be the best approach.

Net return and B:C ratio

Net return and B:C ratio was the highest with IW/CPE ratio of 1.6, significantly more than the irrigation at IW/PCE ratio of 0.8, which recorded the lowest values. B:C ratio with irrigation at CGS of potato or French bean was at par with irrigation at IW/CPE ratios of 1.2 and 1.6 (Table 3).

Seed yield of French bean

The highest yield of French bean was recorded when irrigation was applied at 4 critical growth stages (CGS) and the lowest with irrigation at IW/CPE ratio of 0.8. Irrigation at CGS of potato produced significantly lesser yield of French bean than irrigation at CGS of French bean, indicating that each crop has the need of irrigation at its own critical growth stages (Table 2). Irrigation at IW/CPE ra-

Table 2. Potato tuber yield, seed yield of French bean and potato equivalent yield of the cropping system (Data pooled over 2 years)

Treatment	Potato tuber yield (t/ha)				French bean seed yield (t/ha)	Potato equivalent yield (t/ha)
	>5 cm diameter	4-5 cm diameter	<4 cm diameter	Total		
Irrigation						
CGS potato	10.2	7.4	4.9	22.6	1.06	23.3
CGS F.bean	9.6	7.0	4.9	21.6	1.23	27.0
IW/CPE 0.8	8.3	6.5	4.6	19.5	0.66	14.5
IW/CPE 1.2	11.1	8.2	4.8	24.2	1.09	24.0
IW/CPE 1.6	12.1	9.2	4.7	26.1	1.13	24.9
SEm±	0.21	0.20	0.22	0.58	0.04	0.36
CD (P=0.05)	0.68	0.67	0.72	1.87	0.13	1.17
Cropping system						
Sole potato	12.1	9.4	5.1	26.6	-	26.6
Sole French bean	-	-	-	-	1.44	31.7
Potato + French bean	8.0	6.2	4.9	19.0	0.62	14.1
SEm±	0.16	0.19	0.13	0.28	0.02	0.29
CD (P=0.05)	0.52	0.61	0.43	0.89	0.06	0.83

CGS potato- Irrigation applied in potato based upon critical growth stages; CGS F.bean - Irrigation applied in French bean based upon critical growth stages

tios of 1.2 and 1.6 also reduced the seed yield of French bean as compared to irrigation at its CGS.

Potato equivalent yield

Potato equivalent yield (PEY) of French bean was the most when irrigation was applied at its 4 critical growth stages (CGS), significantly more than other irrigation treatments, while it was the lowest with IW/CPE ratio of 0.8, which received only 3 irrigations (Table 2). Thus application of 4 irrigations (as per CGS) or more is required for potato and its intercropping with French bean.

Effect of Cropping System

In the present experiment, sole potato had 100% plant density, whereas only 40% area was occupied by potato in intercropping system. Since the present study was made in replacement series of intercropping, the plant density of component crops depended on the replacement series of each other in the cropping system.

Growth attributes of potato

Sole potato recorded taller plants than intercropped potato at all the three stages of potato (40 DAS, 80 DAS and harvest). Leaf area index (LAI) of potato in sole and intercropped potato did not differ significantly at 40 days stage, but sole potato had higher LAI than intercropped potato at 80 DAS (Table 1). This was because the maximum growth of potato takes place during 60-70 DAS. Since the overall growth of potato was poor in intercropping system, the intercropped potato recorded lower LAI as compared with sole potato. Sole potato recorded 25% more tubers/plant and 14% more fresh weight of tubers per plant as compared to intercropped potato (Table 1). This was due to better plant growth and higher LAI in sole potato. Singh and Rathi (1984) also made similar observation in potato + mustard intercropping system.

Yield attributes and tuber yield of potato

Sole potato recorded significantly higher tuber (40.2%) yield than intercropped potato (Table 2). Sole potato also recorded more yield of bigger (>5.0 cm diameter) and medium (4-5 cm diameter) size tubers as compared with intercropped potato. Ahlawat (1998) also reported similar results while working with potato + French bean intercropping system.

Seed yield of French bean

Seed yield of sole French bean was 2.5 times of that in intercropped system (Table 2). This was because it occupied only 60% area in intercropped system.

Potato equivalent yield

The potato equivalent yield (PEY) was significantly higher (31.7 t/ha) in sole French bean than sole potato (26.6 t/ha) and potato+French bean (14.1 t/ha) intercropping system (Table 2).

Net return and B: C ratio

Net return was the highest (₹56.9 × 10^3/ha) with potato+French bean intercropping system; 17.5 % higher than sole potato and 70.5% higher than sole French bean (Table 3). B:C ratio was also the highest (2.53) with potato+ French bean intercropping than sole cropping of potato or French bean. These results are in accord with

Table 3. Net return, benefit: cost ratio, consumptive use of water and water use efficiency for irrigation and cropping system (Data pooled over 2 years)

Treatment	Net return (×10^3 ₹/ha)	B:C ratio	Consumptive use of water (mm)	Water use efficiency (kg/ha-mm)
Irrigation				
CGS potato	46.6	2.07	337.1	69.1
CGS F.bean	48.4	2.21	337.8	70.8
IW/CPE 0.8	31.8	1.39	279.6	64.9
IW/CPE 1.2	50.0	2.15	385.4	63.9
IW/CPE 1.6	54.1	2.25	443.5	60.9
SEm±	0.8	0.03	-	-
CD (P=0.05)	3.0	0.11	-	-
Cropping system				
Sole potato	48.4	1.54	362.1	73.4
Sole French bean	33.3	1.97	351.1	47.7
Potato + French bean	56.9	2.53	357.0	74.0
SEm±	0.7	0.03	-	-
CD (P=0.05)	2.9	0.09	-	-

CGS potato- Irrigation applied in potato based upon critical growth stages; CGS F.bean - Irrigation applied in French bean based upon critical growth stages

those reported by Ali and Lal (1991) and Ahlawat (1998).

Consumptive use of water and WUE

Consumptive use of water as well as WUE was the highest with sole potato than with potato+ French bean intercropping or sole French bean (Table 3). Sole French bean was the poorest in respect of water use efficiency. Thus from thw WUE viewpoint, sole potato is the best.

The present study brings out that although from the WUE point of view sole potato is better but from the net return and B:C ratio point of view potato + French bean was superior and is recommended to be practiced.

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