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Effect of irrigation levels on yield, water-use efficiency and economics of winter maize (*Zea mays*)-based intercropping systems

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ABSTRACT

A field experiment was conducted during winter season of 2002-03 and 2003-04 at Pusa in Bihar to study the effect of four irrigation levels, based on Irrigation water (IW): cumulative pan evaporation (CPE) ratio and four intercropping systems. The plant height, leaf-area index, yield attributes except number of cobs/plant and grain yield of maize increased significantly with increase in IW:CPE ratio. Application of five irrigations each of 6 cm depth gave the maximum maize-equivalent yield, and net return/Re of investment. Intercroping of maize (*Zea mays* L.) reduced the maize yield but significant reduction was recorded only in french bean (*Phaseolus vulgaris* L.) and *toria* (*Brassica campustris* L. var. toria) intercropping system. However, water-use efficiency (WUE) decreased with increase in IW:CPE ratio and was maximum at IW:CPE 0.6. Among the intercrops, maximum WUE (on the basis of maize-equivalent yield) was obtained with maize + potato (*Solanum tuberosum* L.) (561.89 kg/ha-cm) and minimum with maize + *toria* (256.0 kg/ha-cm). All the intercrops with maize recorded significantly higher maize-equivalent yield than sole cropping of maize. Maize + potato recorded the highest (123.48 and 140.07 q/ha) maize-equivalent yield and net return, whereas, sole cropping of maize recorded the maximum net return per rupee of investment. Among intercropping systems, maize+potato generated the highest net return (Rs 28,781 and 35,661), followed by maize + rajmash.

Key words : Intercropping, Winter maize, Irrigation, Maize-equivalent yield, Water-use efficiency, Economics

Maize (*Zea mays* L.) is now one of the important crops of winter season because of its higher yield compared with wheat, oilseeds and pulses. Its yield is almost double that of rainy-season maize, and is also more than that of the summer crops. Therefore area under winter maize is increasing at a faster rate, especially in north Bihar. The winter (*rabi*) crop sown in October-November makes little growth till mid-February, leaving enough scope for intercropping during the period. It is planted in rows 60 cm apart and takes first 3 months to pick up the growth. In view of such eco-situation there is an ample scope to utilize the vacant wider inter-row space during its initial slow growth period by introducing some compatible crop for increased productivity. Hence, due to the long-duration nature of maize, short-duration crops like potato, radish, lentil, faba-bean, pea and coriander are generally intercropped to get handsome income (Prasad and Prasad, 1988). However, french bean (*Phaseolus vulgaris* L.) has been identified to be a very profitable *rabi* pulse crop in Bihar plains (Singh, 1991).

Till now most of the work on scheduling the irrigation of crops is based on either soil or plant parameters as a guide. There is a need to quantify the irrigation need of pure crop as well as of intercrops on the basis of latest approach of scheduling irrigation i.e. irrigation water (IW): cumulative pan evaporation (CPE) ratio. This approach incorporates soil and atmospheric continuum in a much better way. Therefore it is necessary to evaluate irrigation need as well as suitable intercrops with *rabi* maize to obtain more yield and economic returns. Hence a study was taken up to evaluate the optimum level of irrigation for winter maize-based intercropping system.

MATERIALS AND METHODS

An experiment was conducted for two consecutive cropping seasons during 2002-03 and 2003-04 at University Farm, Pusa. The soil was Entisol with sandy-loam textural class, containing 222 kg/ha available N, 8.15 kg/ha available P and 88.2 kg/ha available K. The soil pH was 8.6 with 28.7 per cent free $CaCO_3$. Soil moisture at one-third atmospheric pressure in 0-30, 30-60 and 60-90 cm soil layer was 22.5, 21.26 and 20.87 per cent by weight

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basis, whereas at 15 atmospheric pressure it was 8.2, 7.8 and 7.77 per cent respectively. The bulk density of the respective soil layers was 1.46, 1.49 and 1.47 g/cc.

The experiment was laid out in split-plot design with irrigation in main plot and intercrops in sub plots, followed with three replications. There were 16 treatment combinations, consisting of four intercropping systems and four irrigation levels. The crop treatments comprised sole crop of winter maize and its intercropping combination with potato (1:1), rajmash (1:2) and *toria* (1:2). The four irrigation levels were based on irrigation water (IW):cumulative pan evaporation (CPE) ratios of 0.6, 0.8, 1.0 and 1.2 with a common irrigation at a depth of 6 cm. These ratios were observed when cumulative pan evaporation reached 100, 75, 60 and 50 mm at IW:CPE ratios 0.6, 0.8, 1.0 and 1.2 respectively.

The crop was sown on 15 November 2002 and 12 November 2003. In intercropping, potato was planted on ridges 60 cm apart and maize was sown at the base of the potato ridges. The plant-to-plant distance in potato was 20 cm, in rajmash 10 cm and in *toria* 10 cm, whereas in maize it was 20 cm. A common recommended dose of fertilizer used was: for maize 120 kg N, 60 kg P_2O_5 and 40 kg K_2O/ha ($N_{120}P_{60}K_{40}$), for potato $N_{100}P_{60}K_{80}$, for rajmash $N_{90}P_{50}K_{30}$, and for *toria* $N_{60}P_{40}K_{40}$. Urea, single superphosphate and muriate of potash were used as the sources of nitrogen, phosphorus and potassium respectively. Half the N and full quantities of P_2O_5 and K_2O were applied basal at the time of sowing and the remaining half N was applied a month after sowing just after the first common irrigation.

The requisite irrigation depth was maintained by Parshall flume, having a throat width of 7.5 cm, installed at the head of experimental plot. The time required to irrigate the plot was calculated and the water was applied accordingly. The number of irrigations were 5, 4, 4 and 3 at IW:CPE ratios 1.2, 1.0, 0.8 and 0.6 respectively in both the years. The total water applied on the basis of average of 2 years was 30, 24, 24 and 18 cm respectively. The water requirement of maize and maize-based intercrops was calculated on the basis of irrigation water applied, effective rainfall and moisture difference between sowing and harvesting of the crop.

Maize-equivalent yield was calculated on the basis of prevailing market price, based on the yield of intercrops potato, rajmash and *toria* for statistical analysis.

RESULTS AND DISCUSSION

Growth parameters

The plant height and leaf-area index (LAI) of maize increased significantly with increase in the level of irrigation. Maximum plant height and LAI were recorded under five irrigations scheduled through IW:CPE ratio 1.2, and the minimum plant height and LAI were recorded at IW:CPE 0.6 in both the years (Table 1). This finding is in conformity with the work of Prasad and Prasad (1989). Intercropping of *toria* and rajmash significantly reduced the plant height of maize. However, LAI decreased significantly under all the intercropping systems. Among the intercropping systems maize+*toria* recorded the lowest LAI, which was even significantly lower than that of other two intercropping systems. This was because the growth of *toria* was faster during vegetative stage of maize, which suppressed growth of the latter crop. The intensity was lesser when maize was intercropped with potato and rajmash compared with the sole crop of maize.

Yield attributes

Yield attributes of maize were significantly influenced by different levels of irrigaion and intercrops. Among the levels of irrigation, irrigation scheduled through IW:CPE 1.2 recorded the maximum girth of cob, effective length of cob, grains/cob and 1,000-grain weight. Girth of cob decreased with subsequent decrease in the level of irrigation. This was because the water stress resulted in poor plant growth due to the restriction imposed on nutrient translocation, photosynthesis and metabolic activity in the plant system. Among intercrops the maximum and minimum girths of cob were recorded under potato and *toria* respectively. The length of the cob was relatively less affected by potato than by *toria* or rajmash. Among the intercrops, maximum and minimum number of grains/cob were noticed under sole crop and maize+*toria* respectively. Among intercrops the maximum and minimum test weights were obtained under potato and *toria* combination respectively. Higher values of these yield-attributing characters under maize + potato intercropping system might be due to improvement in most of the growth parameters under most suitable environmental situation than under maize + rajmash and maize + *toria* intercropping systems. The interaction effect of irrigation and intercrops was non-significant.

Yield and maize-equivalent yield

The frequency of irrigation caused significant variation in grian yield of maize and maize-equivalent yield (Table 2). Maximum grain yield (50.26 and 52.85 q/ha) and maize-equivalent yield (87.16 and 92.84 q/ha) were recorded at 1.2 IW:CPE ratio. A decrease in IW:CPE ratio significantly reduced both of them. The lowest yield and maize-equivalent yield were recorded under 0.6 IW:CPE ratio. Among intercrops, maize + potato recorded the maximum maize yield followed by maize + rajmash and maize + *toria* respectively. The maximum yield reduction

Table 1. Effect of irrigation and intercropping systems on growth and yield attributes of winter maize

Treatment	Plant height (cm) (150 DAS)		LAI (150 DAS)		Cobs/ plant		Length of cob (cm)		Girth of cob (cm)		Grains/ cob		Test weight (g)	
	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2
Irrigation (IW:CPE)														
0.6	134.3	135.4	2.78	2.92	1.31	1.38	14.09	14.63	12.03	12.30	362.1	365.4	192.6	195.1
0.8	140.2	141.2	3.03	3.13	1.32	1.39	15.43	15.85	12.55	12.89	375.9	379.8	199.7	203.6
1.0	143.3	144.4	3.19	3.39	1.33	1.42	16.30	16.71	12.77	13.08	379.7	388.0	201.4	204.1
1.2	145.5	146.6	3.39	3.55	1.35	1.43	16.49	16.85	12.93	13.24	391.6	390.1	206.3	211.3
CD (P=0.05)	10.4	10.6	0.18	0.20	NS	NS	0.92	0.87	0.73	0.76	20.9	21.0	10.7	9.9
Intercropping system														
Sole maize	154.9	155.9	3.75	3.90	1.40	1.47	16.58	16.98	13.42	13.77	400.4	404.2	212.78	216.2
Maize + potato	146.0	147.0	3.38	3.54	1.35	1.42	15.97	16.56	13.10	13.41	389.8	393.2	203.04	206.2
Maize + rajmash	137.5	138.6	3.00	3.11	1.28	1.37	15.36	15.70	12.46	12.74	375.3	378.9	197.92	201.2
Maize + *toria*	125.8	126.9	2.26	2.44	1.28	1.36	14.40	14.80	11.30	11.59	343.8	347.0	186.21	190.5
CD (P=0.05)	12.9	12.8	0.30	0.31	NS	NS	1.46	1.44	1.18	1.21	35.7	36.0	18.44	19.3

DAS = Days after sowing; Y_1 = 2002-03; Y_2 = 2003-04

Table 2. Effect of irrigation and intercropping systems on yield, water-use efficiency (WUE) and economics of winter maize

Treatment	Grain yield of maize (q/ha)		Yield of intercrops (q/ha)		Maize-equivalent yield (q/ha)		Water requirement (cm)		WUE (kg/ha-cm) on the basis of maize-equivalent yield		Net return/ha (Rs)		Net profit/rupee of investment (Rs/Re)	
	2002-03	2003-04	2002-03	2003-04	2002-03	2003-04	2002-03	2003-04	2002-03	2003-04	2002-03	2003-04	2002-03	2003-04
Irrigation (IW:CPE)														
0.6	35.18	36.51			69.45	75.00	44.98	38.60	385.85	416.65	15,084	16,926	1.81	1.85
0.8	41.97	42.64			78.88	83.67	50.81	44.37	328.69	348.71	19,486	20,969	2.03	2.04
1.0	47.82	48.81			84.68	89.65	50.67	43.82	352.84	373.54	22,494	24,163	2.21	2.22
1.2	50.26	52.85			87.16	92.84	56.86	49.97	290.54	309.46	23,486	25,685	2.25	2.30
CD (P=0.05)	3.90	3.97			8.25	6.40	0.20	0.44	37.16	31.15	3,960	3,106	0.24	0.21
Intercropping system														
Sole maize	55.13	56.59			55.13	56.59	50.86	44.38	213.73	237.41	16,635	16,633	2.33	2.26
Maize + potato	51.67	52.80	161.40	196.34	123.48	140.07	50.98	44.33	526.16	597.62	28,781	35,661	1.93	2.14
Maize + rajmash	40.94	42.60	10.72	10.01	83.83	82.64	50.60	43.76	352.77	348.59	22,270	21,250	2.19	2.11
Maize + toria	27.49	28.82	8.51	9.29	57.73	61.86	50.88	44.28	247.26	264.74	12,864	14,199	1.85	1.90
CD (P=0.05)	6.62	7.44			7.44	8.16	0.26	0.31	31.01	35.32	3,754	4,172	0.24	0.24

Sale price (q): Maize grain, Rs 450, potato, Rs 200, rajmash grain, Rs 1,800; *toria* grain, Rs 1,600 in *toria* was due to its exhaustive growth, showing poor compatibility with maize. For rajmash there was greater reduction in yield of maize than of potato. It was because the growth of rajmash was also fast in early stages of maize growth; besides, the total biomass was much higher in rajmash, which depleted more nutrients and water compared with potato. Singh (2003) also reported higher grain yield with more number of irrigations. Among intercropping systems, the maximum maize-equivalent yield was recorded under maize+potato combination, which followed the same trend as grain yield of maize. Minimum maize-equivalent yield was recorded under sole cropping of maize in both the years. Maize being a tropical crop was almost dormant during late December – mid-February. This led to greater requirement of water for potato than for maize during the low-temperature period. Similarly, in intercropping system the response to irrigation was up to IW:CPE 1.2, perhaps due to greater evapotranspiration caused by more foliage in the intercropping stand than in the pure crop of maize. The interaction between irrigation and intercrops was non-significant during both the years.

Water-use efficiency

Among the different depths, maximum utilization of water was recorded from 0-30 cm soil layer than from 30-60 cm and 60-90 cm depths (Table 3). It was because the root proliferation was maximum in the upper layer (0-30 cm), extracted more water from this layer. As the root development was relatively less in 60-90 cm soil layer, the depletion was the lowest in this layer.

Table 3. Soil-moisture depletion from different soil depths (average data of 2 years)

Treatment	0-30 cm depth	30-60 cm depth	60-90 cm depth	Average mean total at 0-90 cm
Irrigation (IW:CPE)				
0.6	16.40	13.76	11.41	41.57
	(39.45)	(33.10)	(27.45)	(100)
0.8	20.50	16.67	13.51	50.68
	(40.45)	(32.89)	(26.66)	(100)
1.0	19.05	14.73	11.51	42.29
	(42.06)	(32.52)	(25.42)	(100)
1.2	23.25	18.09	14.05	55.39
	(41.97)	(32.66)	(25.37)	(100)

Figures in parentheses indicate value in percentage

Maximum water requirement of was recorded under five irrigations at IW:CPE 1.2, which was significantly higher than other treatments, whereas the minimum water requirement was recorded under IW:CPE 0.6 (Table 2). The water requirement increased with increase in IW:CPE ratio except under 0.8 and 1.0 in the first year, because the treatments received the same number of irrigations (four) in both the years. There was also significant effect in water requirement due to different intercropping systems. In both the years water requirement was lowest in maize + rajmash. This was significantly lower than the rest of the combinations. The water requirements among sole maize, maize+potato and maize + *toria* were on a par among themselves. This finding is in close conformity with those of Mallikarjunaswamy *et al.* (1997). Water-use efficiency, decreased with increase in irrigation level. Among the intercrops, maximum WUE was obtained with potato and minimum with *toria*.

Economics

The net profit per hectare and net return per rupee of investment (Table 2) increased with increase in the level of irrigation. The maximum net returns and net return/Re investment were recorded at irrigation level IW:CPE 1.2, and the net returns were minimum at IW:CPE 0.6. Higher net profit and net profit per rupee investment at higher level of irrigation was due to higher yield. Though the cost of irrigation was higher when the number of irrigations was increased, the net profit was relatively higher because the magnitude of increase in yield was more. This finding is in close conformity with those of Singh (2003). The economic benefit of different intercrops varied differently in the two seasons. In 2002-03, maize+potato system generated the maximum net profit and net return per rupee investment followed by rajmash and maize sole respectively. But in 2003-04 the net profit and net return per rupee investment were maximum in potato followed by rajmash and maize sole. Higher maize-equivalent yield under maize + potato and maize + rajmash caused such a variation in net return and net return per rupee investment.

REFERENCES

Mallikarjunaswamy, S.N., Ramachandrappa, B.K. and Nanjappa, H.V. 1997. Water requirement, water-use efficiency and moisture extraction pattern in maize as influenced by irrigation schedules. *Mysore Journal of Agricultural Sciences* **31**(3): 236–240.

Prasad, T.N. and Prasad, U.K. 1989. Effect of irrigation, pattern of sowing and intercrop on the growth, yield and water-use efficiency of winter maize. *Annals of Agricultural Research* **10**(2): 139–144.

Prasad, U.K. and Prasad, T.N. 1988. Production potential of intercrops with winter maize. *Indian Farming* **38**(7): 9–10.

Singh, A.K. 1991. Response of pre-flood, early rainy season maize (*Zea mays*) to graded levels of nitrogen and phosphorus in Ganga *diara* tract of Bihar. *Indian Journal of Agronomy* **36**(4): 508–510.

Singh, A.K. 2003. 'Response of winter maize + potato intercropping to irrigation and graded levels of NPK.' Ph.D. thesis, RAU, Pusa (Samastipur), Bihar.