



Crop water use, nutrient content and uptake as influenced by irrigation and nitrogen management in potato (*Solanum tuberosum*) – maize (*Zea mays*) cropping system

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ABSTRACT

Field experiment was conducted in two consecutive *rabi* and summer seasons at IARI, New Delhi to study the effect of methods and regimes of irrigation and levels of nitrogen on water use, nutrient content and uptake in potato–maize cropping system. Significant improvement in crop height, yield attributes, yield, nutrients uptake, consumptive use, rate of water use and soil moisture extraction were with conventional furrow irrigation, irrigation at 60 mm CPE and with integrated nitrogen supply of 120 kg N (urea) + 30 kg N (FYM)/ha. Higher nitrogen dose reduced the specific gravity of potato. The highest water-use efficiency (364.5 kg/ha-cm) was recorded with irrigation at 100 mm CPE. Irrigation methods or regimes used in potato had no effect on succeeding maize. While, application of 120 kg N (urea) + 30 kg N (FYM)/ha recorded significantly higher grain (1.57 tonnes/ha) and stover (6.41 tonnes/ha) yields and nutrients uptake; application 150 kg N/ha through urea was at par.

Key words: DCU, Irrigation methods/regimes, Maize, Moisture extraction pattern, Nitrogen management, Nutrient contents and uptake, Potato, Rate of water use, WUE

Potato (*Solanum tuberosum* L.) is a high value crop used primarily as vegetable throughout the world. India ranks third with an annual production of 39.66 million tonnes from the area of 1.89 million hectare (Anonymous 2011). Potato is a underground tuber crop and nutrients removal by the crop is quite high. The success of potato based cropping systems depends on judicious use of inputs, especially nitrogenous fertilizers and their ultimate effect on soil fertility. Water and fertilization are two important and scarce inputs influencing potato production and farm economy. The micro irrigation being cost prohibitive making conventional irrigation methods efficient and economic is very much needed in popular cropping systems like potato-maize. Already, Singh and Sood (2006) reported 38% saving of irrigation water and 6.1% decrease in tuber yield of potato due to alternate furrow irrigation. Further, the crop due to its high turnover has high nutrient requirement particularly of nitrogen. Irrigation regime is also crucial in determining

plant ability to take up the nitrogen available in the soil, since a well-watered crop is more capable to take benefit of the applied fertilizer. Adequate and timely supply of irrigation and optimum dose of nutrients to crop contribute maximum to the growth and nutrients uptake by crop. Such information is though available for individual crops, information for specific cropping system is scarce and more so for potato – maize system. Considering these facts, the present experiment was conducted to evaluate the effects of irrigation methods and irrigation regimes, and nitrogen levels and sources on water use, nutrient concentration and their uptake in potato-maize cropping system.

MATERIALS AND METHODS

The study was conducted during the *rabi* and summer seasons (October-July) of 2007–08 and 2008–09 at IARI, Pusa, New Delhi having semi-arid subtropical climate with dry and hot summer and cold winter. The total rainfall in the study area during the crop growing season was 436.3 mm and 189.5 mm in 2007–08 and 2008–09, respectively. Soil at the experimental field was sandy loam in texture with adequate internal drainage (neutral in reaction - pH 7.4, EC 0.38 dS/m and bulk density 1.45 g/cm³), low in organic carbon (0.42 and 0.41%) and available N (208 and 216 kg/ha, respectively) and medium in P (11.32 and 12.11 kg/ha,

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respectively) and K (227 and 239 kg/ha, respectively in 2007–08 and 2008–09). The experiment was conducted in split plot design, with two irrigation methods, viz. conventional furrow irrigation and alternate furrow irrigation and three irrigation regimes, viz. 60 mm CPE, 80 mm CPE and 100 mm CPE in the main plots and four N levels, viz. 90 kg N through urea + 30 kg N/ha through FYM, 120 kg N/ha through urea, 120 kg N through urea + 30 kg N/ha through FYM and 150 kg N/ha through urea) in subplots with three replications. Keeping irrigation frequency constant pre-determined quantity of water was applied by using Parshall flume. The entire quantity of P (80 kg P_2O_5 /ha), K (100 kg K_2O /ha) and half of N as per treatment were applied in bands before sowing. Potato tubers were hand planted in open furrows 60 cm apart and 20 within the line on 24 October 2007 and 16 October 2008. CPE was worked out from the daily E_{pan} data taken from IARI observatory. Irrigation was applied to crop at 60, 80 and 100 CPE as per treatment. Top dressing of N was done on 35 DAS followed by earthing up. After harvesting of potato crop, each plot was manually ploughed and sowing of maize was done at 60 cm × 20 cm spacing. The experiment was repeated on the fixed site in the second year. All the general crop management practices were followed to both the crops. The potato crop was harvested manually when about 70% of haulms were dry. Observations on plant height, weight of individual tuber (g), dry weight of tubers/ha and maize yield (tonnes/ha) were recorded at harvest of crop.

Soil moisture determination were made from the soil samples taken from 0–60 cm soil profile at 0–15, 15–30, 30–45 and 45–60 cm depth intervals at the time of sowing, before each irrigation, two-three days after each irrigation and finally at the time of harvest. The samples were dried in electric oven at $105 \text{ }^\circ\text{C} \pm 5 \text{ }^\circ\text{C}$ for 48 hours to the constant weight. The moisture percentage was expressed on oven dry weight basis. From the soil moisture content and available meteorological data, computation of consumptive use of water, rate of water-use, water-use efficiency and moisture extraction pattern were computed (Dastane 1972). Rate of water use by potato crop was calculated by dividing the consumptive use of water values for a particular period by the number of days in that period. Water-use efficiency (WUE) was calculated as: yield (kg/ha)/consumptive use of water (cm). The total seasonal extraction (%) from each layer was calculated for different irrigation treatments. Nutrients contents were determined as per the standard procedures and uptake values were worked out. The experimental data were analysed statistically and interpreted.

RESULTS AND DISCUSSION

Performance of potato

Conventional furrow irrigation and irrigation at 60 mm CPE resulted in significantly higher plant height and dry weight of tubers and yield of different grade tubers (Table 1).

The better development of tuber under irrigated treatments was the a result of better moisture availability, which maintained internal water balance of plant adequately. Increase in yield is due to the increase in the weight of tubers as reported by Kumar *et al.* (2007). Effect of irrigation regimes on specific gravity of potato was not significant. Among the nitrogen treatments, application of 120 kg N by urea + 30 kg N/ha through FYM produced taller plants and improved yield attributes and yield of different grade tubers. Higher nitrogen dose reduced the specific gravity of potato while specific gravity of potato was the highest with 120 kg N/ha supplied entirely through urea; 90 kg N by urea + 30 kg N/ha by FYM was at par. Irrigation at 60 mm CPE through all furrows recorded significantly higher fresh and dry tuber yield at 120 kg N by urea + 30 kg N/ha by FYM (Table 2). Similar results were reported by Khakbazan *et al.* (2009).

Effect on water use

Conventional furrow irrigation and irrigation at 60 mm CPE resulted in higher consumptive use of water and rate of water use (Table 1) due to increased water supply. Results corroborate with the findings of Buttar *et al.* (2006). Similarly, application of 120 kg N by urea + 30 kg N/ha through FYM recorded the highest consumptive use of water and rate of water use. This was due to improved crop growth as a consequence of increased availability of nutrients which in turn increased water uptake. Further, a perusal of the daily pan evaporation data revealed increased evaporation from 1.8–6.1 mm in 2007–08 and 1.1–3.5 mm in 2008–09 from January to February, respectively. This increase in pan evaporation also contributed to the increased consumptive use of water and rate of water use at the later stage in these treatments, because of the fact that more quantity and frequent irrigation was applied. It is quite obvious that water loss will be comparatively more from the soil surface with plenty of water than a surface having less moisture. Conventional furrow irrigation resulted in the highest water-use efficiency

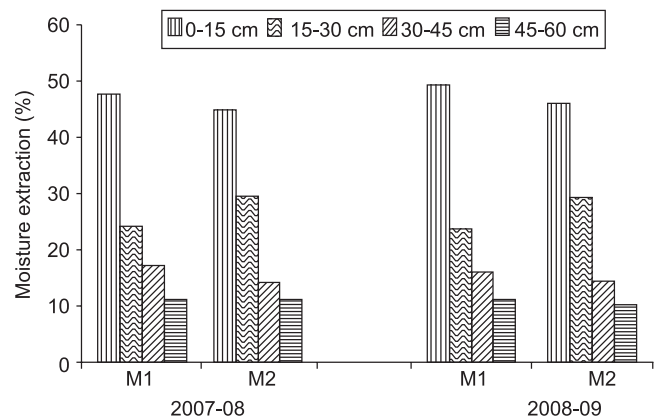


Fig 1 Per cent moisture extraction from different soil depths under different irrigation methods

Table 1 Effect of irrigation and N management on growth, quality, yield attributes, yield and water use by potato and their residual effect on maize in potato maize cropping system (pooled data of two years)

Treatment	Plant height at harvest (cm)	Fresh weight of haulm at harvest (g/hill)	Dry weight of haulm at harvest (g/hill)	Dry weight of haulm at harvest (t/ha)	Specific gravity of tuber	Weight of individual grade tubers at harvest (g/tuber)		Fresh tuber yield at harvest (tonnes/ha)	Dry weight of tubers at water (cm)	Water use by potato		Grain yield of maize (tonnes/ha)	Stover yield of maize (tonnes/ha)		
						'A' grade tubers	'B' grade tubers			'C' grade tubers	Consumptive use of water (mm/day)			Rate of water use (mm/day)	
<i>Irrigation methods</i>															
Conventional furrow irrigation	38.2	172.5	17.0	1.69	3.60	131.2	71.1	27.0	17.6	6.28	54.2	340.5	5.03	1.42	5.78
Alternate furrow irrigation	36.0	161.2	16.2	1.60	3.40	127.8	68.1	23.9	15.5	4.74	46.7	338.0	4.63	1.48	6.02
CD (P=0.05)	1.61	4.08	0.50	0.05	0.09	1.69	1.90	0.86	0.50	0.32				NS	NS
<i>Irrigation regimes</i>															
60 mm CPE	38.5	170.4	17.4	1.69	3.56	132.0	72.0	26.8	17.5	5.94	55.0	319.5	5.14	1.48	6.11
80 mm CPE	36.6	166.1	16.6	1.63	3.44	129.2	69.7	25.0	16.5	5.42	49.7	333.5	4.91	1.45	5.91
100 mm CPE	36.2	164.0	15.9	1.61	3.43	127.3	67.2	24.6	15.9	5.15	46.7	364.5	4.43	1.42	5.69
CD (P=0.05)	1.98	5.00	0.60	0.06	0.11	2.07	2.32	1.05	0.60	0.39				NS	NS
<i>Nitrogen management</i>															
90 kg N + 30 kg N/ha by FYM	36.2	163.4	16.2	1.61	3.40	127.8	67.1	25.0	16.1	5.30	50.3	328.0	4.79	1.36	5.55
120 kg N/ha (urea)	35.3	162.0	16.0	1.59	3.34	125.5	65.2	23.1	16.0	5.17	46.8	322.0	4.71	1.32	5.38
120 kg N (urea) + 30 kg N/ha by FYM	38.7	171.9	17.3	1.70	3.64	133.3	74.1	27.5	17.3	5.86	53.0	369.5	4.95	1.57	6.41
150 kg N/ha (urea)	38.3	169.9	17.0	1.67	3.53	131.3	72.2	26.3	17.1	5.70	51.9	338.0	4.87	1.56	6.28
CD (P=0.05)	1.34	4.05	0.30	0.04	0.11	2.10	2.90	1.09	1.50	0.10				0.07	0.24
Interaction =															
IM × IR × NM									S	S					

Table 2 Interaction effect of irrigation and N management on fresh and dry weight of potato tuber at harvest

Treatment	Dry tubers yield (tonnes/ha)				Fresh tuber yield (tonnes/ha)			
	Nitrogen management				Nitrogen management			
	90 kg N(urea) + 30 kg N/ha by FYM	120 kg N/ha (urea)	120 kg N (urea) + 30 kg N/ha by FYM	150 kg N/ha (urea)	90 kg N (urea) + 30 kg N/ha by FYM	120 kg N/ha (urea)	120 kg N(urea) + 30 kg N/ha by FYM	150 kg N/ha (urea)
<i>2007-08</i>								
CFI × 60 mm CPE	6.28	6.19	6.54	6.34	17.5	17.7	17.9	17.7
CFI × 80 mm CPE	6.13	5.97	6.29	6.37	15.6	15.3	16.9	16.7
CFI × 100 mm CPE	5.26	5.19	5.75	5.80	16.6	16.7	17.3	17.0
AFI × 60 mm CPE	4.66	4.71	5.53	5.32	15.5	15.2	17.2	16.5
AFI × 80 mm CPE	3.89	3.88	4.75	4.35	14.8	14.5	15.7	15.4
AFI × 100 mm CPE	4.21	3.77	4.80	4.70	13.8	13.8	14.9	14.3
	SEm±		0.073				0.20	
	CD (<i>P</i> =0.05)		0.209				0.58	
<i>2008-09</i>								
CFI × 60 mm CPE	6.83	6.73	7.12	6.90	18.9	18.8	19.7	19.2
CFI × 80 mm CPE	6.67	6.50	6.84	6.93	17.4	17.1	19.0	18.9
CFI × 100 mm CPE	5.73	5.64	6.26	6.31	16.9	16.5	18.6	18.5
AFI × 60 mm CPE	5.07	5.13	6.01	5.78	16.1	15.9	18.1	18.1
AFI × 80 mm CPE	4.23	4.22	5.16	4.73	15.4	15.3	16.6	16.5
AFI × 100 mm CPE	4.58	4.11	5.22	4.79	14.6	14.4	16.0	16.1
	SEm±		0.099				0.24	
	CD (<i>P</i> =0.05)		0.284				0.69	

AFI, Alternate furrow irrigation; CFI, Conventional furrow irrigation

Table 3 Effect of irrigation and N management on nutrient concentration and their uptake by haulms of potato in potato-maize cropping system (pooled data of two years)

Treatment (kg/ha)	Nutrient content in haulms (%)			Nutrient content in tubers (%)			Nutrients uptake by haulms		
	N	P	K	N	P	K	N	P	K
<i>Irrigation methods</i>									
Conventional furrow irrigation	1.72	0.182	1.66	1.51	0.299	1.55	28.89	3.07	27.97
Alternate furrow irrigation	1.75	0.187	1.73	1.53	0.302	1.57	27.83	2.99	27.59
CD (<i>P</i> = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
<i>Irrigation regimes</i>									
60 mm CPE	1.74	0.186	1.69	1.51	0.302	1.55	29.22	3.13	28.39
80 mm CPE	1.72	0.185	1.69	1.52	0.297	1.56	27.94	3.01	27.46
100 mm CPE	1.75	0.184	1.72	1.53	0.302	1.57	28.08	2.96	27.69
CD (<i>P</i> = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
<i>Nitrogen management</i>									
90 kg N + 30 kg N/ha by FYM	1.73	0.188	1.68	1.51	0.296	1.55	27.76	3.03	27.05
120 kg N/ha (urea)	1.67	0.176	1.65	1.50	0.288	1.53	26.38	2.79	26.15
120 kg N (urea)+ 30 kg N/ha by FYM	1.79	0.193	1.74	1.54	0.312	1.58	30.25	3.27	29.49
150 kg N/ha (urea)	1.75	0.181	1.72	1.53	0.306	1.56	29.21	3.02	28.72
CD (<i>P</i> = 0.05)	NS	0.011	0.07	NS	0.026	0.05	1.83	0.20	1.41

NS, Non-significant

compared to alternate furrow irrigation, because of higher yield (Table 1). Similar results were also reported by Aujla *et al.* (2007). The water-use efficiency, in general, increased with decrease in number of irrigations and the highest was with irrigation at 100 mm CPE. Application of 120 kg N by urea + 30 kg N/ha through FYM recorded the highest water-use efficiency (359.5 kg/ha cm). This was due to relatively more efficient use of water and production of higher tuber yield under this treatment. Similar results were also reported by Kumar *et al.* (2007).

At 0–15, 30–45 and 45–60 cm soil depths, higher per cent of moisture was extracted under conventional furrow irrigation while, at 15–30 cm soil depth, the moisture extraction was higher with alternate furrow irrigation (Fig 1). Among the irrigation regimes, at 0–15 cm and 30–45 cm soil depth, the highest soil moisture was extracted with irrigation at 60 mm CPE during (Fig 2). Nearly a similar trend was observed for 45–60 cm depth. Whereas, at 15–30 cm soil depth, the highest soil moisture was extracted (28.3% of total profile use) with irrigation at 100 mm CPE. With regard to N management, the highest soil moisture was extracted from 0–15 cm soil depth (47.8% of total profile use) with the application of 120 kg N by urea + 30 kg N/ha through FYM while from 15–30 cm soil depth, the highest soil moisture was extracted (27.3% of total profile use) with 120 kg N/ha by urea. Nearly a similar trend was observed for 30–45 and 45–60 cm depth. Overall, soil moisture extraction was greater from the top soil layer (0–15 cm). Results are in conformity with the findings of Idnani and Singh (2008).

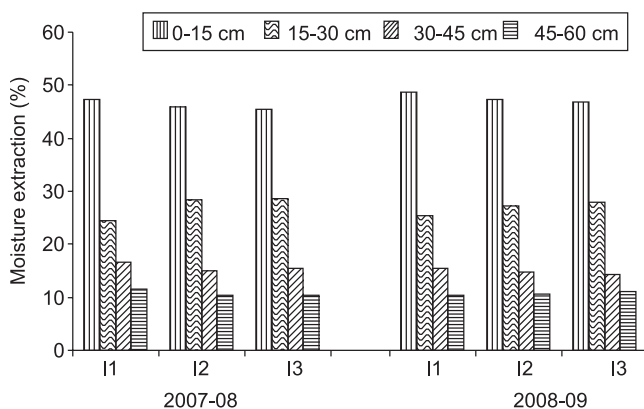


Fig 2 Per cent moisture extraction from different soil depths under different irrigation regimes

Nutrient content and uptake by potato

In potato, irrigation methods and regimes did not affect the total N and K contents (Table 3). However, contents decreased with increasing number of irrigation and moisture availability, which was mainly due to dilution effect as a consequence of increased DM. The higher P content in haulm

and tubers was recorded with conventional furrow irrigation and at 60 mm CPE. Results are corroborated with the findings of Singh *et al.* 2006. N concentration in haulms and tubers increased with increasing nitrogen level and more so with application of 120 kg N by urea + 30 kg N/ha through FYM. Similarly, P and K contents were also higher with the treatment. This might be due to increased availability in presence of FYM and the synergy between N and other nutrients. Similar results were reported by Rose *et al.* (2009).

Conventional furrow irrigation and irrigation at 60 CPE recorded higher N, P and K uptake by haulms and tubers (Table 3, 4). Better soil moisture conditions prevailing in these treatments could have facilitated more uptake of nutrients. In N management, application of 120 kg N by urea + 30 kg N/ha through FYM recorded significantly higher N, P and K uptake. Higher uptake was due to the higher dry matter production and higher nutrient content in different parts of plants, which corroborated the findings of Rose *et al.* (2009).

Performance of maize and nutrient uptake in the system

Residual effect of irrigation methods and regimes applied to potato on grain and stover yields (Table 1) and nutrient uptake of maize (Table 4) was not significant, whereas N had significant influence on yields particularly the application of 120 kg N by urea + 30 kg N/ha through FYM. These results

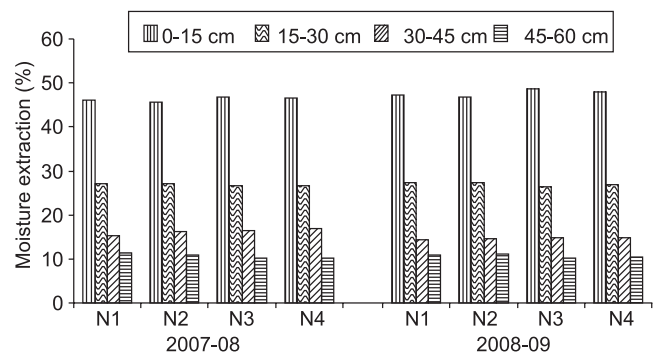


Fig 3 Per cent moisture extraction from different soil depths under different nitrogen levels

are in conformity with the finding of Singh and Sharma (2002). Besides, the treatment also improved the nutrient contents and uptake by maize. As per nutrients uptake in potato - maize system was concerned N, P and K uptake was significantly higher under conventional furrow irrigation and with irrigation at 60 mm CPE (Table 4). Further, application of 120 kg N by urea + 30 kg N/ha by FYM also recorded significantly higher nutrient uptake in the system.

The present study reiterates the fact that irrigation does not have carry over effect unlike nutrients particularly the integrated nutrient supply system.

Table 4 Effect of irrigation and N management on nutrients uptake by potato tubers, residual effect on nutrients content and uptake by maize and total nutrients uptake in potato-maize system (pooled data of two years)

Treatment	Nutrients uptake by tubers (kg/ha)			Nutrient content in maize stover (%)			Nutrient content in maize grains (%)			Nutrient uptake by maize stover (kg/ha)			Nutrient uptake by maize grains (kg/ha)			Total nutrients uptake in the system (kg/ha)		
	N	P	K	N	P	K	N	P	K	N	P	K	N	P	K	N	P	K
<i>Irrigation methods</i>																		
Conventional furrow irrigation	94.7	18.8	97.2	0.61	0.24	1.07	1.63	0.50	0.63	34.8	13.8	61.7	23.0	7.01	8.93	181.5	42.6	195.9
Alternate furrow irrigation	72.2	14.3	74.1	0.66	0.24	1.08	1.63	0.51	0.62	39.6	14.6	64.9	23.9	7.44	9.13	163.4	39.3	175.7
CD (<i>P</i> = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
<i>Irrigation regimes</i>																		
60 mm CPE	89.6	17.9	91.8	0.60	0.24	1.10	1.62	0.50	0.62	36.2	14.6	66.8	23.7	7.29	9.13	178.8	43.0	196.1
80 mm CPE	82.3	16.1	84.5	0.65	0.24	1.05	1.64	0.50	0.62	38.3	14.3	61.9	23.6	7.17	8.97	172.2	40.6	182.9
100 mm CPE	78.4	15.5	80.5	0.65	0.24	1.09	1.65	0.51	0.64	36.9	13.7	61.6	23.3	7.23	9.08	166.6	39.4	178.8
CD (<i>P</i> = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
<i>Nitrogen management</i>																		
90 kg N + 30 kg N/ha by FYM	79.6	15.7	82.0	0.61	0.23	1.06	1.58	0.50	0.62	33.6	12.7	58.4	21.4	6.73	8.42	162.4	38.2	176.0
120 kg N/ha (urea)	77.5	14.9	79.1	0.58	0.21	1.03	1.57	0.48	0.60	31.3	11.0	55.3	20.6	6.32	7.91	155.7	35.1	168.4
120 kg N (urea) + 30 kg N/ha by FYM	90.1	18.2	92.5	0.68	0.27	1.12	1.70	0.52	0.65	43.3	17.5	71.7	26.5	8.12	10.15	190.1	47.1	203.8
150 kg N/ha (urea)	86.8	17.4	88.8	0.66	0.26	1.10	1.68	0.51	0.64	41.3	16.1	69.0	25.9	7.91	9.94	183.2	44.4	196.4
CD (<i>P</i> = 0.05)	NS	1.2	1.5	NS	0.01	0.03	NS	NS	NS	NS	0.9	3.0	NS	0.51	0.62	NS	NS	NS

NS, Non significant; CPE, cumulative pan evaporation

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