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Research Paper

Irrigation and nitrogen management in potato (*Solanum tuberosum*) and their residual effects on succeeding maize (*Zea mays*)

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ABSTRACT

Field experiment was conducted in two consecutive *rabi* and summer seasons (October–July) of 2007-08 and 2008-09 at New Delhi to study the effect of irrigation and nitrogen management on productivity of potato (*Solanum tuberosum* L.) and their residual effect on succeeding maize (*Zea mays* L.). The experiment was laid out in split plot design with two irrigation methods (conventional furrow irrigation and alternate furrow irrigation) and three irrigation regimes (60, 80 and 100 mm CPE) in the main plots and four nitrogen levels (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/ hathrough urea) in sub-plots with three replications. Results indicated that significantly higher number of shoots/ hill, plant height, fresh and dry weight of haulms, fresh and dry weight of tubers/hill, yield of different grade tubers and total tuber and biological yields were obtained with conventional furrow irrigation as compared with alternate furrow irrigation in rotation. Among the irrigation regimes, irrigation at 60 mm CPE recorded significantly the highest growth characters, yield attributes and total tuber and biological yields over irrigation at 80 and 100 mm CPE. Effects of N management on growth, yield components and yield was maximum with application of 120 kg N (urea) + 30 kg N/ha through (FYM), which was at par with 150 kg N/ha through urea. Residual effect of irrigation methods and regimes applied to potato on grain, stover and biological yields of maize was found to be non-significant. Significant residual effect of N management treatments applied to potato was noticed on maize. Residual effect of 120 kg N (urea) + 30 kg N/ha through (FYM) applied to potato recorded the highest grain, stover and biological yields and protein content of maize and it was at par with 150 kg N/ha through urea applied to potato.

Key words: Irrigation methods, Irrigation regimes, Maize, N management, Potato

Potato is an important food crop and ranks fourth among major food crops of the world, occupying an area of 19.26 million ha with annual production and productivity of 320.71 mt and 16.64 t/ha, respectively (*http:// www.fao.org*). Because of its high economic value and demand, it is cultivated by a large number of farmers in India, particularly in sandy loam soil-dominated regions. In India the acreage under potato is 1.86 million ha and it produces around 42.34 million tonnes of potatoes that contribute to approximately 8% of the world's total produce (*www.nhb.gov.in/area-pro/annex.pdf*). In India more than 80% of the potato crop is raised in the Indo-Gangetic Plains during winter season. However, its share in world's potato export is only 0.52% (Kumar *et al.*, 2007). It is a heavy feeder of nutrients having high requirement of N, P, K and other nutrients (Chatterjee *et al.*, 2010). Despite all the progress, productivity of potato in our country is quite low, when compared with European countries, where value ranges between 30 to 45 t/ha (Sarkar *et al.*, 2011).

Being a shallow rooted crop, it requires frequent irrigation for optimum growth and yield (Panigrahi *et al.*, 2001). Crop water requirement is a function of crop type, soil and climatic conditions. Producers seek to adopt the best irrigation management practices to optimize yield and economic return, while minimizing adverse environmental effects. Potato yield and production efficiency are directly related to irrigation practices, where water stress occur. As potato is a highly input intensive crop, fertilization with inorganic sources of nutrients plays an important role for its higher production. But due to increased cost and detrimental effect on soil fertility and human health, supplementing the nutrients through organic sources like FYM and other organic manure has become necessary to sustain production and improve soil health (Kumar *et al.*, 2011). Nitrogen is considered to be the most important nutrient for potato production, thus proper N management is criti-

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cal for optimal potato yield and quality, but is also one of the most difficult to manage. Synthetic fertilizer N is easily lost from the crop system, with consequent economic and environmental costs. Trehan *et al.* (2001) reported that the N applied to potato at 200 kg/ha showed significant residual effect on the yields of succeeding wheat and maize crop, each raised with 40 kg N/ha. The application of N through urea at earthing-up was more effective in its direct effect on potato as well as residual effect on wheat and maize yield.

Irrigation and N fertilization generally increased tuber yield of potato, but the response varied with sites and climatic conditions. N fertilization and irrigation also affect tuber characteristics such as tuber size and other related character (Belanger *et al.*, 2002). Potato is sensitive to moisture stress and can lead to dramatic fluctuations in yield due to poor irrigation management. There is a need to improve water management strategies, which can increase the yield of the crop under varied agro-climatic conditions (Panigrahi *et al.*, 2001). The earlier studies around the world have either focused on furrow irrigation or irrigation scheduling for determining the yield of potato under a wide range of irrigation supply conditions, but there are very few research articles published in peer-reviewed journals regarding the impact of irrigation regimes, methods and N management on potato yield in India. Therefore, present study was undertaken to study the effect of irrigation and nitrogen management on growth and yield of potato and their residual effect on succeeding maize under potato-maize cropping system

MATERIALS AND METHODS

The study was conducted during the *rabi* and summer season (October- July) of 2007-08 and 2008-09 at Division of Agronomy, Indian Agricultural Research Institute, New Delhi. This is geographically located 28°38'N latitude and 77°11' E, longitude at an elevation of about 238 m above mean sea level. It has semi-arid sub-tropical type of climate with dry and hot summer and cold winter. The total rainfall in the study area during the crop growing season (24th October to 31st March) was 1.8 mm and (1st April to 31st July) was 434.5 mm during 2007-08 and similarly 14.6 and 174.9 mm in 2008–09, respectively. The mean minimum and maximum air temperature during the study period ranged from 9.72 – 26.08°C and 23.32–34.83°C, and 11.34–26.53°C and 24.98–38.18°C and mean minimum and maximum relative humidity from 49.58 –50.23% and 73.33–83.83%, respectively and from 38.87–41.97% and 81.23–87.18%, respectively in 2007–08 and 2008–09, respectively. The average evaporation from study area during the crop growing season (24th October to 31st July) was 6.13 and 6.18 mm/day, average sunshine hour 5.85 and 6.91 hr/day and wind velocity 3.08 and 3.15 km/hr during 2007-08 and 2008-09, respectively. The physico-chemical analysis of the soil was done by collecting soil samples from a depth of 0-30 cm. 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),bulk density (1.45 g/cm^3), low in organic carbon (0.42 and 0.41%)and available N (208 and 216 kg/ha) and medium in P (11.32 and 12.11 kg/ha) and K (227 and 239 kg/ha). 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 sub plots were replicated thrice. Frequency of irrigation was the same as in each furrow and in alternate furrow irrigation. The numbers of irrigations were 4, 3 and 2 and 3,2 and 2 at 60, 80 and 100 CPE irrigation treatment during first and second year, respectively. Pre-determined quantity of water was applied by using Parshall flume. The uniform application of P (80 kg P_2O_5/ha) and K (100 kg K_2O/ha); and half of N as per treatments were applied on demarcated lines in each plots before planting. At optimum moisture after the pre- sowing irrigation, double disking was done followed by planking for better seedbed. Ridges and furrows were made by the tractor drawn ridge and furrow maker at 60 cm spacing. Potato tubers of variety 'KufriBahar' were planted in furrows with plant to plant spacing of 20 cmon 24th October, 2007 and 16th 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 100mm CPE through conventional furrow irrigation and alternate furrow irrigation in rotation according to treatment combination. The earthing up was done at 35 days after planting along with weeding to facilitate the development of tubers at the stolon tips. During earthing up the remaining nitrogen dose was side dressed and mixed thoroughly with the soil. Potato crop was adversely affected by frost in both the years of experimentation. After harvesting of potato crop, each plot was manually ploughed and sowing of maize was done at 60 × 20 cm row spacing. The experiment was conducted at the same site without altering the layout plan and randomization of treatments in both the seasons. All the general crop management practices were applied to both the crops.

Observations on plant height, stem number/hill, fresh and dry weight of haulms/hill, fresh weight of tubers and dry weight of tubers were recorded 60 days after planted of crop (Table 2). In addition, number of tubers/hill,

weight of tubers/hill (g), weight of individual tuber (g), and number were recorded as grade A (50 g and above), B (30-50 g) and C (less than 30 g),harvest index and total tuber andbiological yieldsof potato and maize yield (t/ha) were recorded at harvest. Biological yield was calculated by adding the weight of haulm and tuber yield at the time of harvest. Tuber and stalk samples for dry matter accumulation were dried in oven at 65°C until constant weight. The potato crop was harvested manually on 28th February, 2008 and 20th February, 2009. Maize crop was harvested on 26th July, 2008 and 11th July, 2009. The experimental data pertaining to growth and yield was analysed statistically to draw valid conclusions.

RESULTS AND DISCUSSION

Weather conditions and crop growth

Weather condition was fairly good for growth and development of potato crop during both the years of investigation (Table 1). In general, there was a gradual drop in temperature from October to January, which favoured the formation and development of tubers. Maximum and minimum temperature was also favourable for the growth and development of tubers. The relative humidity although low in the beginning showed an increase as the crop advanced in age from November to middle of February. Period of bright sunshine hours during both the years was normal with slight fluctuation due to cloudy weather or rainfall occurrence. Potato growth and yield, however, were highly affected in 2007–08 due to frost incidence as compared to the incidence of frost during 2008–09, which probably resulted in reduced growth and development, and ultimately the lower yield of potato.Weather conditions were quite congenial during both the years for summer maize. There was gradual drop in relative humidity from April onwards due to rise in maximum temperature. The temperature was not favourable during both the years. In 2007–08, during maize crop season a usual rain (136.6 mm and 100.7 mm) occurred during May and June. Unusual rain (166.2 mm) occurred in July during crop maturity resulting increased incidence of termite. Heavy incidence of termite was observed at early stage of crop during 2008–09. Crop stand, however, was maintained by gap filling. These factors resulted in reduction of maize yield in 2008–09.

Growth and development

The growth attributes of potato were significantly affected by irrigation and N applied duringboth the years (Table 2). Conventional furrow irrigation recorded significantly highernumber of shoots/hill, plant height, fresh and dry weight of haulms, fresh and dry weight of tubers/hillover alternate furrow irrigation. Among the regimes, irrigation at 60 mm CPE recorded significantly the highest number of shoots/hill, plant height, fresh and dry weight of haulms, fresh and dry weight of tubers/hill. The results corroborate with findings of Sharma *et al.* (2012). Significant increases in plant height, leaf area index, fresh and dry weight of haulms were obtained with higher irrigation frequencies (Panigrahi *et al.*, 2001). Patel and Patel (2001) also reported decrease of plant height and leaf area index in potato when irrigation frequency decreased.

The N management system showed a positive response on influencing the number of shoots/hill, plant height, fresh and dry weight of haulms, fresh and dry weight of tubers/hill of potato. Application of 120 kg N (urea) + 30 kg N/ha by FYM resulted significantly the highest number of shoots/hill, plant height, fresh and dry weight of haulms, fresh and dry weight of tubers/hill as compared to

Table 1. Weather parameters on monthly basis during crop season

Weather parameter	October	November	December	January	February	March	April	May	June	July
					2007-08					
Rainfall (mm)	-	-	-	1.8	-	-	31.0	136.6	100.7	166.2
Evaporation (mm)	199.5	106.3	79.7	81.6	102.5	190.3	302.5	286.3	210.5	193.2
Max. Temp (°C)	32.9	28.2	21.7	19.5	22.1	32.1	35.5	36.1	33.8	33.9
Min. Temp (°C)	14.9	10.6	6.1	5.4	7.0	14.3	19.3	22.9	25.4	25.7
Mean RH (max.)	77.6	91.0	91.1	89	78.3	76	59	62	83	85.3
Mean RH (min.)	40.8	62.0	62.3	68	37.4	27	24	40	66	70.9
Sunshine (hours)	7.9	3.7	4.0	4.9	5.2	6.4	8.2	6.4	3.6	7.2
					2008-09					
Rainfall (mm)	-	-	-	4.2	6.5	3.9	2.0	43.3	5.4	124.2
Evaporation (mm)	139.7	81.2	57.7	56.6	68.8	162.0	237.7	304.3	344.1	243.0
Max. Temp (°C)	32.9	27.7	23.4	20.5	24.6	30.1	36.6	39.0	41.3	35.8
Min. Temp (°C)	18.6	10.9	8.2	7.2	9.4	13.7	21.7	24.2	27.4	26.6
Mean RH (max.)	83.2	86.8	89.7	94	88.4	81	54	60	54	76.9
Mean RH (min.)	35.4	39.1	48.9	60	39.4	29	25	37	34	59.5
Sunshine (hours)	5.8	4.4	4.0	4.6	7.6	7.6	8.9	8.9	8.7	6.1

Table 2. Effect of irrigation and N management on growth of potato in potato-maize cropping system

Treatment	No of shoots/hill at 60 DAS		Plant height at 60 DAS (cm)		Fresh weight of haulms at 60 DAS (g)		Dry weight of haulms at 60 DAS(g)		Fresh weight of tubers (g/hill)		Dry weight of tubers (g/hill)	
	2007-08	2008-09	2007-08	2008-09	2007-08	2008-09	2007-08	2008-09	2007-08	2008-09	2007-08	2008-09
Irrigation methods												
Conventional furrow irrigation	3.4	3.7	34.0	36.9	113.0	123.0	12.6	13.7	141.5	153.5	31.9	34.7
Alternate furrow irrigation	3.3	3.5	32.2	34.9	104.5	113.7	11.5	12.4	111.0	120.5	25.6	27.9
SEm±	0.03	0.03	0.31	0.28	0.81	0.80	0.09	0.10	2.28	1.29	0.44	0.48
CD (P=0.05)	0.09	0.09	0.98	0.90	2.55	2.52	0.29	0.31	7.18	4.05	1.40	1.50
Irrigation regimes												
60 mm CPE	3.4	3.7	33.3	36.6	111.3	121.1	12.3	13.4	134.0	145.4	29.7	32.3
80 mm CPE	3.3	3.6	33.7	36.2	108.2	117.7	12.1	13.1	127.0	137.8	29.1	31.7
100 mm CPE	3.3	3.5	32.2	34.9	106.7	116.1	11.7	12.7	117.7	127.7	27.5	29.9
SEm±	0.03	0.04	0.38	0.35	0.99	0.98	0.11	0.12	2.79	1.57	0.54	0.58
CD (P=0.05)	0.11	0.12	1.20	1.10	3.13	3.09	0.35	0.38	8.79	4.96	1.71	1.83
Nitrogen management												
90 kg N + 30 kg N/ha by FYM	3.3	3.5	32.2	35.0	105.0	114.2	11.9	12.9	122.8	133.2	28.0	30.5
120 kg N/ha (urea)	3.2	3.5	31.6	34.3	104.3	113.5	11.6	12.6	121.1	131.4	27.5	30.0
120 kg N (urea)+ 30 kg N/ha by FYM	3.5	3.8	34.4	37.3	114.0	124.0	12.4	13.4	131.6	142.8	30.0	32.6
150 kg N/ha (urea)	3.4	3.6	34.1	37.0	111.8	121.6	12.2	13.2	129.5	140.5	29.6	32.2
SEm±	0.04	0.04	0.31	0.36	0.84	0.95	0.06	0.07	1.04	2.03	0.65	0.72
CD (P=0.05)	0.11	0.12	0.90	1.02	2.40	2.74	0.18	0.19	2.99	5.81	1.87	2.07

other N management treatments during both the years under study (Table 2). This might be due to balanced nutrition through chemical fertilizer and organic manures. The significant influence of N on above growth characters could be explained from the fact that N is an integral part of chlorophyll and structural constituent of amino acid, alkaloids, proteins and protoplasm of cell. As the N availability increases, the formation of protein increases which leads to the greater synthesis of plant tissue. This is in conformity with the finding of Kumar *et al.*(2011) and Sharma *et al.* (2012). Adequate supply of N helps in the increased production of larger, thick, blue green and succulent leaves due to proper meristematic activities in the cell. This turn helped the maximum utilization of sunlight and other growth factors which ultimately resulted in production of more photosynthates and translocation from leaves to tubers (Baishya *et al.,* 2010).

Graded yield and yield attributes

The result showed remarkable variation in yield attributes due to irrigation and N management (Table 3). In general, there was maximum production of 'B' grade tubers followed by grade 'A' and 'C'. Significantly higher tubers of all the grades were recorded in conventional furrow irrigation than alternate furrow irrigation. This might be due to the adequate availability of soil moisture for prolonged period.

Among the irrigation regimes, irrigation at 60 mm CPE recorded significantly the highest tubers grade ('A', 'B' and 'C') as compared to irrigation at 80 and 100 mm CPE. Kumar *et al.* (2007) reported that higher irrigation level resulted in significantly more branches, tubers/plant, tuber weight and higher foliage coverage than the lower irrigation level. Application of 120 kg N by urea + 30 kg N/ha by FYM gave significantly the highest tubers grade ('A', 'B' and 'C') than other N management treatments, which were at par with crop receiving 150 kg N/ha by urea. The increase in yield attributes might be due to the higher availability of nutrients. These results are close conformity with the research findings of Sarkar *et al.* (2011) and Baishya *et al.* (2010). The results emphasized the need of combined use of N through inorganic fertilizers and organic sources (FYM) for producing high tuber yield of different grades at NCR. The favourable effect of combined use of N through both inorganic fertilizers and organic manures on increasing the different grades tuber production was also reported by Kumar *et al*. (2008).

Tuber yield

The higher potato yields were obtained in 2008–09 as compared to 2007-08, were possibly due to better growing season and less effect of frost (Table 3).Conventional

furrow irrigation recorded significantly highertotal tuber yieldover alternate furrow irrigation. Among the irrigation regimes, irrigation at 60 mm CPE recorded significantly the highest tuber yield as compared to 80 and 100 mm CPE. The results corroborate with findings of Sharma *et al.* (2012). The N management system showed a positive response on influencing the total tuber yield of potato. Application of 120 kg N (urea) + 30 kg N/ha by FYM resulted significantly higher total tuber yield as compared to other N management treatments under study. Results are in close conformity with the research findings of Baishya *et al*. (2010).

Residual effect on grain and stover yield of maize

Residual effect of irrigation methods and regimes applied to potato on grain, stover and biological yield of maize was found to be non- significant (Table 4). The significant residual effect of N management treatments applied to potato was observed on grain, stover and biological yield and protein content of maize. Greater residual N

Table 3. Effect of irrigation and N management on graded and total yield of potato in potato-maize cropping system(Pooled mean of two years)

Treatment	Tuber yield (t/ha)			
	Grade 'A'	Grade 'B'	Grade 'C'	Total
Irrigation methods				
Conventional furrow irrigation	5.85	8.96	2.79	17.59
Alternate furrow irrigation	5.15	7.89	2.48	15.52
SEm±	0.06	0.08	0.02	0.15
CD (P=0.05)	0.18	0.24	0.07	0.50
Irrigation regimes				
60 mm CPE	5.79	8.88	2.77	17.44
80 mm CPE	5.42	8.32	2.59	16.33
100 mm CPE	5.28	8.08	2.54	15.90
SEm±	0.07	0.09	0.03	0.20
CD (P=0.05)	0.22	0.30	0.09	0.60
Nitrogen management				
90 kg N + 30 kg N/ha by FYM	5.33	8.21	2.56	16.10
120 kg N/ha (urea)	5.31	8.09	2.53	15.92
120 kg N (urea)+ 30 kg N/ha by FYM	5.73	8.78	2.75	17.26
150 kg N/ha (urea)	5.64	8.61	2.71	16.95
SEm±	0.06	0.07	0.03	0.55
CD (P=0.05)	0.16	0.20	0.08	1.50

Table 4. Residual effect of irrigation methods, regimes and nitrogen management applied to potato on yield and protein content of maize (Pooled mean of two years)

Treatment	Grain yield (t/ha)	Stover yield (t/ha)	Biological yield (t/ha)	Protein content (%)
Irrigation methods				
Conventional furrow irrigation	1.42	5.78	7.20	-
Alternate furrow irrigation	1.48	6.02	7.50	-
SEm±	0.04	0.14	0.18	-
CD (P=0.05)	NS	NS	NS	-
Irrigation regimes				
60 mm CPE	1.48	6.11	7.58	-
80 mm CPE	1.45	5.91	7.36	-
100 mm CPE	1.42	5.69	7.11	-
SEm±	0.21	0.17	0.39	-
CD (P=0.05)	NS	NS	NS	-
Nitrogen management				
90 kg N + 30 kg N/ha by FYM	1.36	5.55	6.91	9.87
120 kg N/ha (urea)	1.32	5.38	6.70	9.78
120 kg N (urea)+ 30 kg N/ha by FYM	1.57	6.41	7.98	10.61
150 kg N/ha (urea)	1.56	6.28	7.84	10.47
SEm±	0.02	0.08	0.11	0.03
CD (P=0.05)	0.06	0.24	0.30	0.10

effect, which was the result of 120 kg N by urea + 30 kg N/ha by FYM applied to potato was exhibited through the grain and stover yields and protein content of maize crop. Results are corroborated with the findings of Trehan *et al.* (1998) who found that N applied to potato exhibited residual effect on maize grown in sequence.

On the basis of two years experimentation, it can be concluded that conventional furrow irrigation, irrigation at 60 mm CPE and application of 120 kg N by urea + 30 kg N by FYM was the best for higher productivity of potato. In the present study, irrigation management treatments applied to potato failed to carry forward their residual effects on the succeeding crop, whereas N management treatmentsexhibited residual effect on maize grown in sequence.

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