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Effect of nitrogen levels and fertigation frequency on the growth parameters and yield of potato tuber (*Solanum tuberosum* L.) *cv*. Kufri Bahar

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Abstract
The present investigation was carried out at Research Farm of the Department of Vegetable Science, CCS HAU, Hisar during winter season of 2014-15. The experiment was conducted in randomized block design with three replication comprising of four levels of nitrogen, *i.e.*, 90(N_1), 120(N_2), 150(N_3) and 180(N_4) kg/ha and three fertigation frequencies, *i.e.*, every 3rd day (F_1), every 6th day (F_2) and every 9th day (F_3). The per cent plant emergence at 30 (96.33%) DAP, plant height at 60 (49.63cm) DAP, number of shoots per hill at 30 (4.43), 60 (4.68) and 90 (4.68) DAP, leaf area index at 30 (1.21), 60 (6.02) and 90 (5.24) DAP and foliage weight (1.21 kg/m^2) were significantly higher with F_1. Nitrogen levels exhibited significant difference for growth. The maximum value for per cent plant emergence at 30 (96.89%) DAP, plant height at 60 (49.83 cm) and 90 (54.98 cm) DAP, number of shoots per hill at 60 (4.64) DAP, leaf area index at 30 (1.17) and 90 (5.14) DAP, foliage weight (1.17 kg/m^2) and total tuber yield () were maximum with N_2. Interaction effect of fertigation frequency and nitrogen levels showed remarkable variation. The maximum leaf area index at 30 (1.43) DAP with F_1N_2. When fertigation applied at every 3rd day with the application of nitrogen @120 kg/ha was found significantly superior to all other treatments combination.

Keywords: drip irrigation, nitrogen, fertigation frequency, growth parameters and tuber yield

Introduction
Potato (*Solanum tuberosum* L.), a member of Solanaceae family, is believed to be the native of South America. The inhabitants of Peru, potato have taken as the bread of life for over the centuries. It is the third most important food crop after rice and wheat, being grown and consumed in 150 countries all over the world (FAO 2014; Singh, 2008) [4]. The major states growing potato are Uttar Pradesh, West Bengal, Bihar and Gujarat accounting for nearly 3/4th of the area and 4/5th of the potato production in our country. The maximum area and production are from Uttar Pradesh followed by West Bengal and Bihar, while highest productivity comes from West Bengal followed by Gujarat. At national level during the last decade, the potato yield and production grew by 1.10 and 5.98% per annum, respectively. The highest growth in area was observed in Bihar (12.74%) followed by Gujarat (9.53%), however, remarkable production growth was noticed in Bihar, Uttar Pradesh and Gujarat to the extent of 23.64, 15.10 and 12.39%, respectively (Saxena and Mathur, 2013) [10]. Chen and Setter (2012) [3] found that if a strong leaf and stem sink capacity is formed before tuber initiation, it will compete with developing tubers for photosynthates. India has the largest irrigation network in the world; its irrigation efficiency has not been more than 40%. Among modern irrigation techniques, drip irrigation has been shown to be a more water efficient alternative than furrow irrigation for potato (Wang *et al*. 2011) [16]. In fertigation nutrient use efficiency could be as high as 90% compared to 40 - 60% in conventional methods. The amount of fertilizer lost through leaching can be as low as 10% infertigation where as it is 50% in the traditional system. Adoption of micro-irrigation systems may help to increase the irrigated area, productivity of crops and water use efficiency.

Materials and Methods
The field experiment was carried out at Vegetable Research Farm CCSHAU, Hisar during Rabi-season 2014-15. Hisar is situated at latitude of 29º10' N, longitude of 75º 46' E and height of 215.2 meters above mean sea level and falls in semi-arid and sub-tropical region with hot and dry summer and sever cold in winter. The soil was sandy loam in available organic carbon (0.66%), available nitrogen (105kg/ha), available phosphorus (8.0k kg/ha) and available potash (225kg/ha) with pH of 8.3.

The air temperature (ºC), relative humidity (%) and sum of precipitation (mm) during the potato vegetation period at the experimental field are summarized in Figure 1.

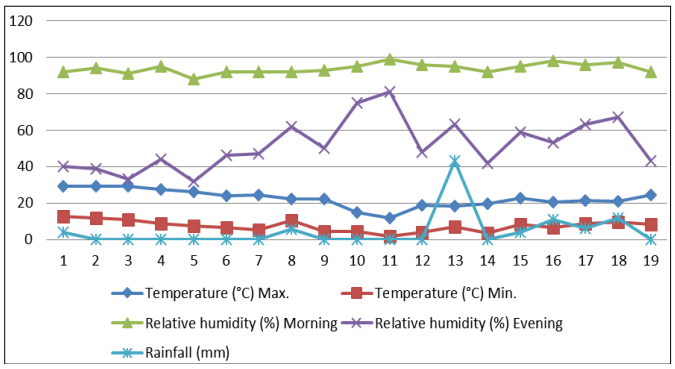

Fig 1: The air temperature (ºC), relative humidity (%) and sum of precipitation (mm) during the potato vegetation period at the experimental field.

The experiment was laid out in randomized block design. The net plot size was two rows of eight-meter length each (8.0 x 1.2 m). Farm yard manure (FYM) @ 50 t/ha was applied prior to field preparation and full dose of phosphorus and potash were applied as basal dose. Potato tubers of cv. Kufri Bahar were planted at 60×20 cm spacing in the last week of October. A common irrigation was applied immediately after planting in all the treatments through conventional furrow method for uniform and rapid germination. The differential drip fertigation treatments were started 20 days after planting.

The crop was subjected to four levels of nitrogen i.e. N_1: 90 kg/ha, N_2: 120 kg/ha, N_3: 150 kg/ha and N_4: 180 kg/ha. Each nitrogen level was coupled with three fertigation frequencies *viz.*, every 3rd day in 30 split doses (F_1), every 6th day in 12 split doses (F_2) and every 9th day in 8 split doses (F_3). Hence, twelve treatment combinations were used for conducting present study. The irrigation was applied at every 3rd day though drip. The plant emergence (%) at 30 DAP, plant height (cm) at 30, 60 and 90 DAP, number of shoots per hill at 30, 60 and 90 DAP, leaf area index at 30, 60 and 90 DAP and foliage weight (kg/m^2) at harvest was recorded.

Results and Discussion

Plant emergence (%)

In the present study, plant emergence at 30 days after planting (DAP) ranging from 92.33 to 99.00% (Table 1) exhibited significant difference among different treatments. The maximum plant emergence at 30 days after planting (96.33%) was with fertigation at every 3rd day (F_1). In case of Nitrogen levels, highest plant emergence (96.89%) was observed with nitrogen 120 kg/ha (N_2). There was no significant effect of interactions among the treatments. The results of the present study are in agreement with the findings of Verma *et al.* (2013) [5], who noted that plant emergence in potato varied from 86.5 to 91.6 % however, the difference was not significant. On the other hand, Singh and Lal (2012) [14] reported that the emergence of plant emergence in potato ranged from 90 to 98%, however there was no effect of fertilizer treatments on the emergence of plant.

Plant height

The plant height was recorded at 30, 60 and 90 days after planting. Plant height at 30 days after planting did not show significant effect of fertigation frequency and nitrogen levels. There were significant effects of fertigation frequency and nitrogen levels on plant height at 60 days after planting (Table 1). The maximum average plant height (49.63 cm) was observed with fertigation after every 3rd day (F_1) followed by (48.40 cm) fertigation at every 6th day (F_2). Effect of fertigation frequency on plant height at 90 days after planting had non-significant. Whereas, nitrogen levels had significant effect on plant height at this stage. The maximum average plant height (54.98 cm) was recorded with nitrogen 120 kg/ha (N_2) which was at par (54.38 cm) with nitrogen 150 kg/ha (N_3). The maximum average plant height was recorded with fertigation every 3rd day (F_1) and nitrogen 120 kg/ha (N_2). This increase in height might be due to increase in uptake of nitrogen. These results are conformation with the findings of Sharma and Singh (1988) [11] who also reported significant increase in the plant height was recorded up to the application of 120 kg N/ha and 120 kg P_2O_5/ha. Similarly, Kumar *et al.* (2006) [7] reported that plant height and number of sprouts increased linearly and significantly with the application of nitrogen up to 200 kg/ha. Nandekar *et al.* (2006) [8]; Khurana and Bhatia (2008) [6] also observed increased plant height with increasing fertilizer levels.

Number of shoots per hill

The number of stems per hill depends upon the uptake of nutrients by the plant at early stages of crop growth and availability of space for the spread of plant. The number of stems per hill was affected significantly by nitrogen levels. Significant effect of fertigation frequency on number of shoots per hill was recorded at 30, 60 and 90 days after planting. The maximum number of shoots at 30 DAP was observed with fertigation at every 3rd day followed by fertigation on every 6th day (Table 1). It might be due to increase in uptake and more availability of nitrogen. At 60 DAP, in case of nitrogen levels, nitrogen @120 kg/ha (N_2) produced significantly higher number of shoots (4.64), which was statistically at par with nitrogen @150 kg/ha (4.31), whereas, minimum number of shoots (3.60) per hill was recorded with nitrogen application @180 kg/ha. Almost similar results were found for number of shoots per hill at 90 days after planting. The present results correspond to those of Sandhu *et al.* (2008) [9], who reported that the stems per unit area increased with each increase in fertilizer dose up to 150%recommended dose of fertilizers. Nandekar *et al.* (2006) [8] also indicated the same trend. Singh, *et al.* (2010) [2] found non-significant effect on stem number per plant with varied irrigation and split application of nitrogen in different potato cultivars. Behnam Etemad and Mansour Sarajuoghi (2012) [1] showed application of different levels of N fertilizer significantly affected the number of stem per square ($P \leq 0.01$). Name Singh *et al.* (2010) [2] found that the number of stem per plant were not affected significantly by varied irrigation levels, fertility levels, split application of nitrogen and potato cultivars.

Leaf area index

The perusal of data with respect to leaf area index at 30 days after planting (Table 1), the maximum average leaf area index (1.21) was recorded with fertigation at every 3rd day (F_1) followed by F_2 (0.98). Among the nitrogen levels, the highest leaf area index (1.17) was recorded with application of nitrogen @120kg/ha (N_2). The interaction studies indicated maximum leaf area index (1.43) was with the F_1N_2, while minimum leaf area index (0.55) was recorded with treatment combination F_3N_4. At 60 days after planting, the maximum average leaf area index (6.02) was observed with fertigation

after every 3rd day. At 90 days after planting the results showed reduced leaf area index as compared to at 60 days after planting. The maximum leaf area index (5.24) was observed with fertigation at every 3rd day (F_1) and the minimum leaf area index (4.43) was recorded with F_3. Among the different nitrogen levels, the maximum leaf area index (5.32) was observed with N_2, which was statistically at par with N_3 (5.09). This might be due to the effect of N on promoting growth to enhance synthesis and accumulation of proteins, amino acids and enzymes responsible for cell division and cell elongation. Sandhu *et al.* (2008) [9] also reported that with the increased fertilizer dose, the uptake of nutrients increased which might have improved the photosynthetic efficiency of plants and thus resulted in improvement in leaf area index. Behnam Etemad and Mansour Sarajuoghi (2012) [1] showed application of different levels of N fertilizer significantly affected the Leaf area Index yield ($P \leq 0.01$).

Foliage weight

Weight of foliage significantly differed due to various fertigation frequency and nitrogen levels (Table1). The maximum average foliage weight (1.21 kg/m^2) was recorded at F_1, followed by F_2 (1.09 kg/m^2). Among the different nitrogen levels the significantly higher foliage weight (1.17 kg/m^2) was observed with N_2, which was found at par with N_3 but significantly superior to all other treatments. The treatment combination had non-significant effect on foliage weight. However, F_1N_2 produced average maximum foliage weight (1.30 kg/m^2). This might be due to more availability of nutrients and increased uptake of nutrients. These results are in agreement with the findings of Sandhu *et al.* (2008) [9] and Yadav *et al.* (2003) [17] who reported maximum foliage weight with 100 kg N/ha in potato. The above mentioned characters have positive correlation with the tuber yield.

Total tuber yield

The total tuber yield (q/ha) was significantly influenced by fertigation frequency and nitrogen levels (Table 1). It is evident from the results that the maximum average total tuber yield (296.50 q/ha) was obtained with F_1 followed by F_2 and minimum (268.00 q/ha) with F_3. The maximum average total tuber yield (292.33 q/ha) was observed with N_2, while minimum yield (264.69 q/ha) was recorded in N_4 (nitrogen 180 kg/ha). The tuber yield also varied significantly due to the interaction of fertigation frequency and nitrogen levels. Interaction effect revealed maximum (307.78 q/ha) total tuber yield with F_1N_2 followed by F_1N_3 (299.06 q/ha) while F_3N_4 recorded lower (252.80 q/ha) total tuber yield. Kumar *et al.* (2006) [7] reported that crop responded to nutrient application rate under drip fertigation with fertilizer level F_1 (Fertigation levels N 187: P_2O_5 63:K_2O 125 kg/ha) producing the highest tuber yield, followed by F_2 (141:47:93 kg/ha) and F_3 (93:32:63 kg/ha). These findings are in conformity with the results of Khalak *et al.* (1993). Similarly, Badr *et al.* (2011) reported the higher tuber yield at higher nitrogen rate compared to the low nitrogen rate and average total yield across fertigation frequencies were 31.25 and 44.03 t/ha for 200 and 300 kg N/ha, respectively. Meyer and Marcum (1998) also reported a positive response of potato yield and quality to increasing N rate, and found that total yield was maximized with nitrogen @224 kg/ha. Behnam Etemad and Mansour Sarajuoghi (2012) [1] showed that the interaction of different levels of N fertilizer × different of application times significantly affected tuber yield ($P \leq 0.05$). A distinct increase tubers yield was observed with T_1 (424.12 Q/ha) (Drip each row) and T_2 (406.75 Q/ha) (Drip each pair) during both the years and in pooled data.

Table 1: Growth parameters and yield of potato tuber influence by the nitrogen application rate and fertigation frequencies.

N rate kg/ha	Fertigation frequency	Plant emergence (%)	Plant height (cm)		Number of shoots per hill		Leaf area index			Foliage Weight (kg/m^2)	Total tuber yield (q/ha)
		30 DAP	60 DAP	90 DAP	30 DAP	60 DAP	30 DAP	60 DAP	90 DAP		
90 (N_1)	F_1	95.67	48.57	54.47	4.40	4.60	1.33	5.83	5.10	1.21	296.95
	F_2	93.67	48.30	54.03	3.93	4.23	1.00	4.38	4.45	1.05	275.13
	F_3	92.67	46.90	53.00	3.20	3.53	0.57	4.37	4.21	0.94	269.93
120 (N_2)	F_1	99.00	51.70	56.47	4.73	5.27	1.43	6.4	5.91	1.30	307.78
	F_2	96.00	49.53	53.73	4.33	4.67	1.13	5.06	5.05	1.16	294.34
	F_3	95.67	48.27	54.73	3.80	4.00	0.95	4.99	4.47	1.05	274.88
150 (N_3)	F_1	96.00	49.80	54.73	4.53	4.73	1.35	6.02	5.55	1.20	299.06
	F_2	95.00	48.67	54.70	4.20	4.40	1.00	4.96	4.50	1.15	292.01
	F_3	93.33	47.97	53.70	3.73	3.80	0.84	4.76	4.46	1.03	274.38
180 (N_4)	F_1	94.67	48.47	53.00	4.07	4.00	0.71	5.80	4.39	1.13	282.22
	F_2	93.33	47.09	52.00	3.60	3.73	0.77	4.20	4.31	1.01	259.04
	F_3	92.33	45.90	50.60	3.07	3.07	0.55	3.60	4.15	0.91	252.80
CD at 5%	Frequency	2.16	1.35	NS	0.51	0.46	0.13	0.65	0.50	0.09	2.85
	Nitrogen	2.49	1.57	1.66	NS	0.53	0.14	NS	0.58	0.08	3.29
	F × N	NS	NS	NS	NS	NS	0.25	NS	NS	NS	5.71

*NS = Non-significant, CD= Critical difference, DAP = Days after planting, N = Nitrogen, F = Frequency

Conclusion

Based on the findings of present study, it may be concluded that when nitrogen @ 120 kg/ha was applied through drip irrigation at every 3rd day (F_1N_2) gave significantly maximum growth parameters and higher total tuber yield followed by F_1N_3.

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