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Full Length Research Paper

Effects of planting date and fertilizer dose on plant growth attributes and nutrient uptake of potato (*Solanum tuberosum* L.)

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Potato is a high input intensive and a shallow rooted crop which requires an efficient cropping management to ensure adequate nutrient uptake to attain optimum crop growth. The experiment was conducted with four planting dates (22nd October, 1st, 11th and 21st November) and four fertilizer rates *viz*. 75, 100, 125and 150% of recommended fertilizer dose (RFD; 150:50:100 kg ha^{-1} of NPK) in the region for optimum productivity in a randomized complete block design with three replications. Data was recorded on plant height, leaf, and stem weight, and leaf area index and NPK uptake. Planting date had significant effect on all vegetative characteristics and recorded the highest values at 1st November planting date and lowest in 21st November planting date. Maximum uptake of nitrogen, phosphorus and potassium by leaves, stems and tubers was also observed at 1st November planting date. Plant height, leaf area index, leaf and stem weight increased with increase in fertilizer dose. Thus, the results of this study suggested that optimum planting time (1st November) is very critical for maximum nutrient uptake of the applied fertilizer dose to the potato crop under semi-arid conditions.

Key words: Nitrogen, nutrient uptake, phosphorous, planting date, potato, potassium.

INTRODUCTION

Knowledge of the growth patterns and nutrient uptake of potato is very important for understanding the optimum fertilizer requirements for producing high yields of quality tubers. The previous studies have shown that season, soil fertility status, soil types, potato cultivar and other environmental factors have marked impact on the growth and nutrient uptake of potatoes which necessitate the region and cultivar specific fertilizer recommendations for potatoes.

In 2012, India produced 45 million tons of potatoes on a 1.9 million hectares area (FAO, 2013). The Indo-Gangetic plains region contributes 90% of total potato production in India. In this region, the potatoes are usually grown on light textured soils having low water holding capacity. Further, shallow root system of potatoes makes them more prone to nutrient losses than other field crops. Inefficient nutrient management results in reduction in tuber quality, yield, and environmental degradation (Pehrson et al., 2011). Thus, judicious use of balanced dose of fertilizers like nitrogen, phosphorus and potassium for different planting times is very critical for higher tuber yield (Rai et al., 2002) and environmental protection.

Higher tuber yield with optimum planting time is a result of greater leaf area index and crop growth rate (Ezekiel and Bhargava, 1992).Further, nutrient supply also plays a major role in growth and development of plants as well as yield because nitrogen is an essential constituent of protein and chlorophyll.

Among fertilizers, nitrogen is second most important nutrient after potassium. Nitrogen is essential for maintaining higher haulm growth, increased bulking rate, quality of tuber and more dry matter production (Roy and Jaiswal, 1998). On the other hand, potassium is responsible for translocation of carbohydrates and increased resistance to withstand drought and frost stresses.

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The present investigation was conducted to investigate the impact of planting time and fertilizer dose on vegetative growth parameters and nutrient uptake of potato crop under sandy loam soils of Hisar.

MATERIALS AND METHODS

The experiment was conducted at the Vegetable Research Farm and laboratory of the Department of Vegetable Science, CCS Haryana Agricultural University, Hisar, India during crop seasons of 2003-04 and 2004-05. The experimental soil was sandy loam in texture and had 8.7 pH, 0.6% Organic carbon, 143.8 kg ha^{-1} N. 23 kg ha^{-1} P_2O_5 and 381 kg ha^{-1} K_2O (Sandhu et al., 2013).The experimental design was factorial based on randomized complete block design with three replicationsand sixteen treatments. Experimental factors included nitrogen fertilizer at four levels of recommended dose and four planting dates with Kufri badshah cultivar(Table 1).

Experiment comprised of four planting dates and four fertilizer rates (details are given in Table 1). Planting of potato tubers was done at an interval of ten days during both the years.Seventy five per cent of nitrogen, whole of P_2O_5 and K_2O were band placement on both sides of the tubers before furrows making and remaining twenty five per cent of nitrogen was applied at the time of earthling up after 30 days of plantings. Planting was done at 60 cm (between) x 20 cm (within) spacing in a randomized block design with three replications. All the recommended cultural practices were adopted during the course of experimentation. The crop was haulm cut after 100 days of planting. The treatments were harvested after ten days of haulm-cutting to allow tuber curing in the field.

Potato leaves, stems and tubers were collected just before haulm cutting from each treatment. These haulm and tubers were washed, dried in hot air oven at 65^{o}C for three days and grounded in stainless steel wiley mill, then passed through 40 mesh sieve and thereafter used for analysis as per standard procedure. Dried and ground plant material was digested in a di-acid mixture of H_2SO_4 and $HClO_4$ (4:1) for the analysis of N, P and K. After digestion, the final volume was made 50 ml with distilled water. Then digestion mixture was filtered and stored for further analysis. The extracts were analyzed for N, P and Kby following the standard methods described by Nelson and Sommers (1980), Ayiannidis and Voulgaropoulos (1990), and Isaac and Kerber (1971) respectively.

Ten plants from each plot or replication were selected at random and marked for height measurement. Height of the tallest shoot was measured from the soil surface to the base of last leaf unfolded at 60, 80 and 100 days after planting. Leaf area index was calculated by using disc method on 100th day of planting before haulm cutting. Hundred discs of leaves were taken with the help of a cork borer and leaf area was calculated on fresh weight basis of leaves. Leaf area index was worked out by using the following formula. For recording data on leaf and stem weight, total fresh weight haulm was recorded at 100 DAP. A representative sample of one kg haulm was taken for recording data on weight of leaf and stem separately. 100g sample each of leaves and stems was taken and dried in oven to constant weight. Finally data were converted into quintals per hectare.

Data recorded on plant height, leaf area index, leaf and stem weight and nutrient uptake was subjected to analysis of variance (ANOVA, $p \leq 0.05$) suggested by Hoshmand (2006) and means comparisons were done at $P \leq 0.05$. Percentages were computed using the least square means from respective ANOVA and tables and figures were drawn using MS excel 2010 program.

RESULTS AND DISCUSSION

Growth attributes

Plant height: The effect of planting dates and fertilizer doses on plant height was recorded at 60, 80 as well as 100 days after planting during both the years(Table2). Date of planting had significant effect on planting at all measuring dates. First November (D_2) planting recorded the highest plant height at60, 80 and 100 days after planting as compared to D_1, D_3 and D_4 planting dates during both the years. These differences in plant height can be attributed to the differences in the prevailing weather conditions. The highest plant height recorded at D_2, can be attributed to the most favorable environment for plant growth during the cropping season. The lowest plant height recorded at D_4can be due to the lower temperature experienced by the plants after emergence compared to other planting dates(data not shown), thus lower temperature might have reduced allocation of assimilates for growth than the remaining three planting dates. Similar findings have also been reported by Ezekiel and Bhargava (1992) and (Singh and Khurana, 1997).

Fertilizer dose also had significant effect on plant height. Plant height increased with increase in fertilizer dose and plants were significantly tallest with the highest dose of N:P: K that is 150% of the recommended fertilizer dose (RDF_4) when recorded on 100th day old crop (89.42 cm, 93.60 cm) during both the years and this treatment was significantly superior to RDF_1 and RDF_2 on all the three dates of observation. This can be attributed to the enhanced the availability of nutrients to the crop increased, which may have resulted in increased photosynthetic efficiency of the plant. Increased metabolic activities of the plant with increase in fertilizer dose have been reported by (Raietal, 2002). Similar report of increase in all evaluated vegetative traits on app-

Table 1. Experimental details.

A. Planting dates		**Season**		
		2003-04		**2004-05**
D_1		22 October		22 October
D_2		1 November		1 November
D_3		11 November		11 November
D_4		21 November		21 November.
B. Fertilizer does (kg ha^{-1})				
		N	P_2O_5	K_2O
RFD_1	75% RFD	112.5	37.5	75
RFD_2	100% RFD	150	50	100
RFD_3	125% RFD	187.5	62.5	125
RFD_4	150% RFD	225	75	150

Table 2. Effect of planting dates and fertilizer doses on plant height in potato.

Treatment	**Plant height (cm) Days after planting**					
	60		**80**		**100**	
	2003-04	2004-05	2003-04	2004-05	2003-04	2004-05
Planting date						
D_1	57.51	58.04	73.81	72.83	88.72	91.92
D_2	59.54	60.08	77.40	78.79	91.35	93.92
D_3	53.70	57.89	72.83	72.01	89.79	93.31
D_4	44.64	47.88	54.99	61.78	71.61	78.22
CD at 5%	2.93	3.40	2.80	2.29	2.55	1.48
Fertilizer dose N:P:K (kgha^{-1})						
RFD_1	48.73	50.98	64.83	66.41	79.54	83.69
RFD_2	53.03	55.08	68.67	69.88	84.18	88.29
RFD_3	55.95	57.89	71.64	73.61	88.36	91.79
RFD_4	57.68	59.95	73.89	75.52	89.42	93.60
CD at 5%	2.93	3.40	2.80	2.29	2.55	1.48

Abbreviations: 22ndOctober (D1), 1st (D2), 11th (D3) and 21stNovember (D4); 75% RFD (RFD_1), 100% RFD (RFD_2), 125% RFD (RFD_3), 150% RFD (RFD_4)

-lication of nitrogen rate of 150 kg ha^{-1} was given by (Yourtchi et al., 2013 and Ezzat et al., 2011).

Leaf area index: Leaf area index was recorded on 100 day old crop(Table3). The highest leaf area index (2.66 and 2.72 in 2003-04 and 2004-05 respectively) was observed atD_2 planting date which closely followed by the one atD_3 and D_1 planting dates during both the years, but these did not differ significantly among themselves.

Table 3. Effect of planting dates and fertilizer doses on Leaf area index, leaf and stem weight in potato.

Treatment	Leaf Area Index			Leaf weight (q ha^{-1})			Stem weight (q ha^{-1})		
	2003-04	2004-05	Mean	2003-04	2004-05	Means	2003-04	2004-05	Mean
Planting date									
D_1	2.59	2.61	2.60	16.39	16.61	16.50	12.66	12.71	12.68
D_2	2.66	2.72	2.69	16.78	16.80	16.79	13.24	13.32	13.23
D_3	2.65	2.61	2.63	16.68	16.71	16.69	12.45	12.65	12.55
D_4	2.26	2.29	2.27	15.07	15.15	15.11	11.00	11.01	11.00
CD at 5%	0.13	0.18		0.54	0.64		0.73	0.86	
Fertilizer dose N:P:K (kg ha^{-1})									
RFD_1	2.23	2.29	2.26	15.07	15.21	15.14	10.54	10.65	10.59
RFD_2	2.42	2.40	2.41	15.72	15.68	15.70	11.66	11.68	11.67
RFD_3	2.64	2.65	2.64	16.63	16.80	16.71	13.06	13.21	13.13
RFD_4	2.86	2.89	2.87	17.50	17.59	17.54	14.09	14.14	14.11
CD at 5%	0.13	0.18		0.54	0.64		0.73	0.86	

Abbreviations: 22ndOctober (D1), 1st (D2), 11th (D3) and 21stNovember (D4); 75% RFD (RFD_1), 100% RFD (RFD_2), 125% RFD (RFD_3), 150% RFD (RFD_4)

Table 4. Effect of planting dates and fertilizer doses on NPK uptake by leaves, stem and tubers of potato.

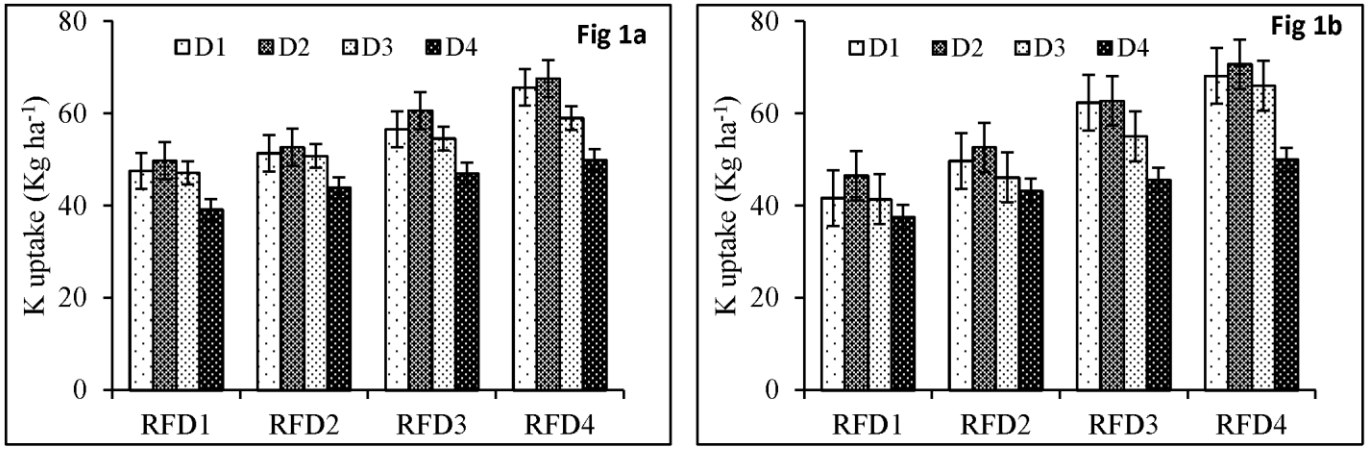
Treatment	Leaves (kg ha^{-1})						Stem (kg ha^{-1})						Tubers (kg ha^{-1})					
	2003-04			2004-05			2003-04			2004-05			2003-04			2004-05		
	N	P	K	N	P	K	N	P	K	N	P	K	N	P	K	N	P	K
Planting date																		
D_1	66.52	4.61	55.27	67.17	4.45	53.42	28.14	1.97	55.46	27.22	1.80	53.77	76.65	9.78	98.72	76.04	9.40	97.88
D_2	68.63	4.88	57.65	66.91	4.55	55.92	30.03	1.96	58.15	28.58	1.92	56.95	89.40	11.58	114.50	88.68	11.22	112.73
D_3	65.05	4.37	52.86	64.02	4.12	52.03	26.67	1.74	52.13	25.94	1.69	51.95	84.46	10.09	100.52	79.87	9.42	96.42
D_4	54.34	3.69	45.00	54.27	3.61	46.63	21.21	1.42	44.08	20.94	1.43	44.03	65.74	8.33	75.73	65.28	7.99	77.13
CD at 5%	2.29	0.15	1.94	2.60	0.16	2.49	1.58	0.12	2.91	1.82	0.11	3.41	2.89	0.53	4.07	2.41	0.32	3.33

Table 4. Cont.

Fertilizer dose N:P:K (kg ha $^{-1}$)																	
RFD_1	55.34	3.40	45.88	55.32	3.35	45.93	17.44	1.02	41.72	17.38	1.06	42.40	61.87	6.79	76.90	60.63	6.60	75.86
RFD_2	59.24	3.90	49.67	58.59	3.73	48.44	23.16	1.45	47.93	22.53	1.45	47.58	74.34	9.27	90.69	72.18	8.81	88.35
RFD_3	67.25	4.80	54.69	67.13	4.52	53.91	30.14	2.12	56.42	29.15	1.97	55.47	86.72	10.87	107.59	85.73	10.74	106.18
RFD_4	72.72	5.45	60.54	71.33	5.14	59.73	35.31	2.50	63.70	33.61	2.36	61.24	93.33	12.86	114.29	91.33	11.88	113.78
CD at 5%	2.29	0.15	1.94	2.60	0.16	2.49	1.58	0.20	2.91	1.82	0.11	3.21	2.89	0.53	4.07	2.41	0.32	3.33

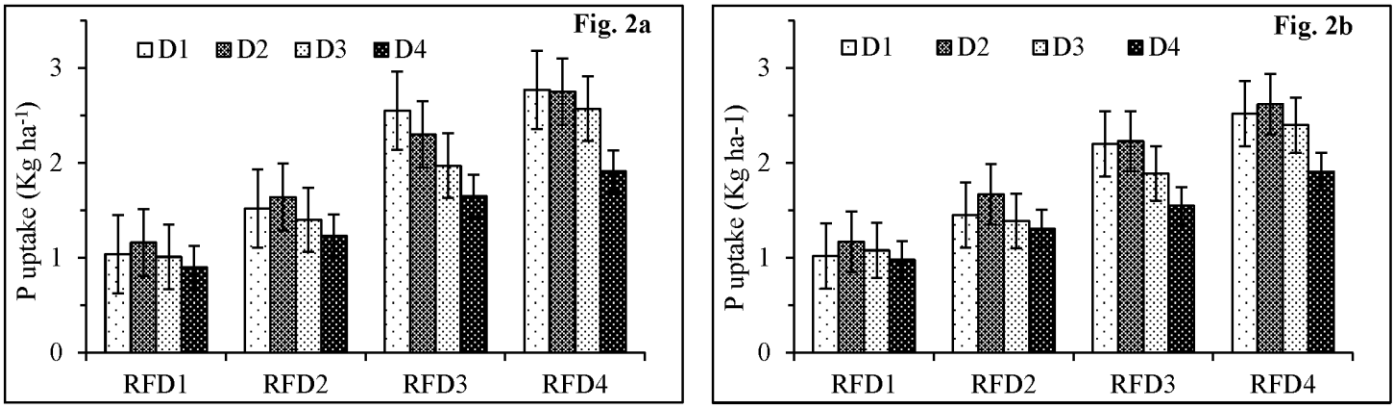
Abbreviations: 22ndOctober (D1), 1st (D2), 11th (D3) and 21stNovember (D4); 75% RFD (RFD_1), 100% RFD (RFD_2), 125% RFD (RFD_3), 150% RFD (RFD_4)

Figure 1. Interaction effects on K uptake by leaves (Fig 1a; 2003-04) and (Fig 1b; 2003-04).



Abbreviations: 22ndOctober (D1), 1st (D2), 11th (D3) and 21stNovember (D4); 75% RFD (RFD_1), 100% RFD (RFD_2), 125% RFD (RFD_3), 150% RFD (RFD_4)

Figure 2. Interaction effects on Puptake by leaves (Fig 2a; 2003-04) and (Fig 2b; 2004-05).



Abbreviations: 22nd October (D1), 1st (D2), 11th (D3) and 21stNovember (D4); 75 % RFD (RFD_1), 100% RFD (RFD_2), 125% RFD (RFD_3), 150% RFD (RFD_4)

The leaf area index was also influenced by fertilizer dose. In both the years, significantly highest leaf area index was observed from the crop fertilized with RDF_4, which was 2.86and 2.89 in 2003-04 and 2004-05 respectively. All fertilizer treatments differed significantly among themselves except RDF_1 and RDF_2during 2004-05.

Leaf weight: Planting date also had significant effect on leaf weight (Table 3). Maximum leaf weight on dry weight basis was observed atD_2 planting which was 16.78 and 16.80 q ha^{-1} during 2003-04 and 2004-05respectively. An increasing trend in leaf weight was observed with an increase in fertilizer dose. Maximum leaf weight was observed with the highest dose of fertilizers i.e. RFD_4 which was 17.50and 17.5 q ha^{-1}during2003-04 and 2004-05 respectively. Improvement in leaf weight with an increase in fertilizer dose from RDF_1 to RDF_2, RDF_2-RDF_3 and RDF_3-RDF_4 was significant during 2003-04, while during 2004-05 significant improvement was recorded with an increase in fertilizer dose from RDF_2-$RDF_3$and RDF_3-RDF_4.

Stem weight: Planting also had variable effect on stem dry weight (Table 3). The highest dry stem weight was recorded with D_2planting during both the years which was 13.24, 13.32 q ha^{-1} during 2003-04 and 2004-05 respectively and was similar to the stem weight recorded atD_1 during 2003-04, D_1 and D_3 during 2004-05. D_4 planted crop recorded significantly lowest dry stem weight during both the years.

The effect of fertilizer doses on stem dry weight was also significant during both the years of investigation. With the increase in fertilizer dose, there was a significant improvement in stem dry weight during both the year. This might be because of the fact that prevailing temperature after the crop emergence was more near to optimum in case of D_2 planted crop as compared to other three planting dates, which resulted in better growth. On the other hand, D_4 planted crop revealed lowest values in respect of leaf area index, leaf and stem weight. It may be attributed that temperature after crop emergence was lowest in this planting time which may have resulted in lowest photosynthetic efficiency of the plant (Sandhu et al., 2013; Singh and Khurana, 1997; Sharma and Brar, 2008; Ezekiel and Bhargava, 1992). Highest leaf area index, leaf and stem weight were observed from the treatment supplied with highest fertilizer dose (150% of RFD). It may be due to the fact that application of higher fertilizer dose resulted in increased uptake of nutrients leading to improved photosynthetic efficiency of the plant (Sandhu et al., 2013; Yourtchiet al., 2013; Ezzat et al., 2011; Singh and Mangal, 1996).

Nutrient uptake

NPK uptake by leaves: In 2003-04, the highest uptake of N (68.66 kg ha^{-1}), P(4.88 kg ha^{-1}) and K (57.65 kg ha^{-1}) by leaves was recorded at D_2 planting followed by D_1, D_3 and D_4 plantings (Table4). While in 2004-05, the highest uptake of N by leaves (67.17 kg ha^{-1}) was recorded from D_1 planted crop (2004-05) followed by D_2 (66.91 kg ha^{-1}), D_3 (64.02 kg ha^{-1}) and D_4(54.27 kg ha^{-1}). On the other hand P and K uptake was highest from D_2 planting followed by D_1, D_3 and D_4 plantings. The lowest uptake of N (54.34 and54.27 kg ha^{-1}), P (3.69 kg ha^{-1}) and K (3.61 kg ha^{-1}) was recorded from D_4planting in both the years and (45.00 and 46.63 kg ha^{-1}). The highest uptake of N, P and K by leaves increased with increasing fertilizer dose and was recorded highest with RDF_4 followed by RDF_3, RDF_2 and RFD_1 during both the years.

Interaction effects of planting dates and fertilizer doses were significant during 2003-04 in respect of potassium uptake by leaves (Figure 1). The Highest uptake of

potassium (67.56 kg ha^{-1}) was from the treatment combination of D_2
planting supplied RDF_4followed by D_1 planting with same level of fertilizer dose (65.64 kg ha^{-1}) these two treatments were similar but differed significantly from the remaining treatment combinations.

NPK uptake by stems: In both the years, NPK uptake by stems was highest during 2003-04 and 2004-05 from D_2 planted crop followed by D_1, D_3 and D_4 plantings (Table 4). Highest uptake of N (35.31 and 33.61 kg ha^{-1}), P (2.5and 2.36 kg ha^{-1}), K (63.70 and 61.24 kg ha^{-1}) by stems was observed with the highest fertilizer dose applied (150 per cent of RFD) followed by RDF_3, RDF_2 and RFD_1 during both the years respectively.

Planting dates and fertilizer doses revealed significant interaction effects in respect of phosphorus uptake by stems during both the years of study (Figure 2). Maximum uptake of phosphorus by stems was recorded from D_1 planted crop (2.77 kg ha^{-1}) fertilized with highest dose of fertilizers closely followed by D_2 planting (2003-04), on the other hand, D_2 planted crop revealed highest uptake of P by stems (2.62 kg ha^{-1}) closely followed by D_1planted crop at same fertility level during 2004-05 (Figure 2).Interactive effects of planting dates and fertilizer doses in respect of potassium uptake by stems (Figure 1) revealed that highest uptake of K by stems was recorded from D_2 planted crop fertilized with highest dose of fertilizers followed by D_1 planted crop (2003-04).

NPK uptake by tubers: NPK uptake by tubers (Table4) differed significantly due to planting dates. The highest uptake of N, P and K by tubers was observed from D_2 planting followed by D_3, $D_1$and D_4 plantings and all the four dates of plantings differed statistically from one another during both the years except potassium uptake. The effect of fertilizer doses on NPK uptake by tubers was also significant. Highest uptake of NPK was observed with highest fertilizer dose applied (RDF_4) followed by RDF_3, RDF_2 and RFD_1 and all the fertilizer treatments statistically differed from one another.

Highest uptake of N, P and K (kgha^{-1}) from D_2planted crop was due to better crop growth and higher NPK concentration in plant resulted in high tuber yield which ultimately resulted into higher NPK uptake by leaves, stems and tubers (Singh and Khurana, 1997; Ezekiel and Bhargava, 1992).

NPK uptake by leaves stems and tubers increased significantly with increase in their rates of application. Among the fertilizer treatments, application of 150 per cent of the recommended dose gave the highest NPK uptake in both the years.

It is due to increase in availability of nutrients in the soil. The nutrient uptake by tubers was found closely linked with productivity and their higher concentration in plant (Sandhu et al., 2013; Shaheen et al., 2013; Haase et al., 2007).

CONCLUSION

From the results and discussion of this study, it can be concluded that the maximum uptake of nitrogen, phosphorus and potassium by leaves, stems and tubers was observed in 1st November planted crop. Overall, increase in fertilizer dose from RFD1 to RFD_4 also caused an increasing trend in plant height, leaf area index, leaf weight and stem. N, P and K uptake increased with each increase in fertilizer dose and highest NPK uptake was recorded when 150 per cent of recommended NPK was applied to the potato crop. Thus, 1st November planting and highest fertilizer dose resulted in enhanced vegetative growth and nutrient uptake in potato.

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