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Effect of nitrogen scheduling on growth and yield performance of potato (*Solanum tuberosum* L.)

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Abstract
Efficient use of nitrogen fertilizer for plant growth is critical both from economic as well as environmental aspect. Hence, to study the effect of nitrogen scheduling on growth and yield of potato, a two year research experiment was carried out at Vegetable Research Centre, GBPUAT, Pantnagar, India during *Rabi* season of 2014-15 and 2015-16. The experiment was consisted of ten treatments (nitrogen schedules) replicated thrice in Randomized Complete Block Design. All the cultural practices were carried out under scientific management. During the study, various observations such as emergence per-cent, growth and yield attributes were evaluated in response to various nitrogen levels. The emergence per-cent was recorded at 20 and 30 DAP. The growth characters *viz.* Plant height, number of haulms, number of leaves, diameter of haulm and dry weight per plant were recorded at 30 DAP, 45 DAP, 60 DAP and at de-haulming stage whereas the yield and yield attributing characters were recorded at the time of harvest. Significant variations were observed among all the treatments with respect to the growth and yield characters except emergence per-cent and number of haulms per plant. The study revealed that split application of nitrogen was found most effective for potato growth and tuber bulking. Among the ten treatments, 25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP was proved the best with respect to growth as well as tuber yield.

Keywords: Potato, nitrogen, foliar spray, tuber yield, marketable yield, harvest index

Introduction
Potato is a short duration, high yielding and nutrient exhaustive crop. Use of balanced fertilizers with best management practices is necessary and pre-requisite to get better tuber yield of the crop. One of the foremost management priorities in potato cropping systems is the application of nitrogen (Stark *et al*., 2004) which determines the quantity, yield, chemical composition and quality of tuber (Kolodziejczyk, 2014) [11]. The plant responses to different nitrogen levels can be justified by vigorous growth, increased leaf area, large tuber size as well as their number. In the deficiency of nitrogen the plants remain stunted with only a few thin stems and few tubers, which ultimately lead to the lesser yield. On the other hand, excess nitrogen application increases environmental losses of nitrogen, including nitrate leaching to groundwater and emissions of nitrous oxide, a major greenhouse gas in the atmosphere (Blumenthal *et al*., 2008) [3]. Beside this, application of nitrogen by improper method at inappropriate stage is also reduced tuber yield and increased nitrogen losses to the environment while ideal level of nitrogen ensures increased leaf formation and adequate photosynthates production in the leaves consequently more yield. There are different methods of application such as broadcast, banding, sidedressing and foliar among which band placement is chiefly used in potato. Foliar spray of nutrients is an important additional way to mitigate the nutrient deficiency immediately and a good tool in crop management to maximize yield of crop as well as saving of fertilizers. In soil fertilization, plants absorb nutrients by root and they are translocated to the upper parts while in foliar application, nutrients enter to the leaf cuticle and then in the cells thus, crop shows immediate response in lesser time (Fageria *et al.*, 2009) [6]. However, broadcast or band placement is more responsive at earlier stage when plant is small with scanty foliage. Therefore, it is necessary to recognize critical stages of the plant at which it respond more to the nitrogen application by a particular method. Optimal nitrogen application at right time by right method is essential for better growth of the plant that consequently results in more tuber yield. The time of fertilizer application is adjusted in such a way that the requisite amount of N is made available at aforesaid critical periods. Keeping these views in consideration a field experiment was conducted to standardize the nitrogen schedule to enhance growth and yield of potato.

Materials and methods
The present field experiment was conducted during winter (*Rabi*) season of 2014-15 and and 2015-16 with the potato variety Kufri Sadabahar at Vegetable Research Centre (VRC) of G.B.

Pant University of Agriculture and Technology, Pantnagar, Udham Singh Nagar, Uttarakhand. There were ten treatments (nitrogen schedules) including control which were replicated thrice in Randomized Complete Block Design. The recommended dose of fertilizers ($N:P_2O_5:K_2O$) was 160:100:120 kg ha^{-1}. Full dose of P_2O_5 and K_2O was applied through Single Super Phosphate and Muriate of Potash at the time of planting whereas, nitrogen was applied in the form of urea according to the treatment.

For planting well sprouted, disease free, medium sized (2.5-5.0 cm diameter) tubers having 50-75 g weight were selected and planted at 60 cm × 20 cm spacing. All the cultural practices were carried out under scientific management. The emergence percent was taken by counting the emerged plant in each plot at 20 and 30 DAP. Observations for plant height, number of haulm, number of leaves, diameter of haulm and dry weight per plant was recorded in 5 randomly selected plants at 30 DAP, 45 DAP, 60 DAP and at de-haulming stage and averaged. However, yield and yield attributed characters were recorded on per plot basis and then converted into the hectare. Marketable yield was calculated by excluding diseased, damaged and small sized tubers (0-25 g). The data was analysed by using STPR3 programme, designed and developed by Department of Mathematics and Statistics, College of Basic Sciences and Humanities, G.B. Pant University of Agriculture & Technology, Pantnagar, and Uttarakhand. The treatments were as follows:

T_1:	50% N of RDF as basal + 50% top dressing at 25 DAP
T_2:	50% N of RDF as basal + 25% topdressing at 25 DAP + one foliar spray of urea @ 2% at 40 DAP
T_3:	25% N of RDF as basal + three foliar spray of urea @ 2% at 25, 40 & 55 DAP
T_4:	50% N of RDF as basal + two foliar spray of urea @ 2% at 25 & 40 DAP
T_5:	50% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP
T_6:	50% N of RDF as basal + three foliar spray of urea @ 3% at 25, 40 & 55 DAP
T_7:	50% N of RDF as basal + two foliar spray of urea @ 3% at 25 & 40 DAP
T_8:	25% N of RDF as basal + 75% top dressing at 25 DAP
T_9:	25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP
T_{10}:	Control (No application of nitrogen)

Results and discussion

As far as the plant emergence per-cent is concerned, nitrogen scheduling did not show any significant variation. Tuber emergence depends on the physiological stage and sprouts present on the tuber. Sahu *et al.* (2016) [15] and Hosseini *et al.* (2017) [8] also observed a similar effect of nitrogen treatments on plant emergence of potato. Sharma *et al.* (2015) [15] reported highest tuber germination due to good quality seed tubers. According to Ayyub *et al*. (2006) [1], tuber emergence depends upon genetic makeup of the plant and effect of microclimate.

It was perceived from the data that nitrogen treatment significantly affected plant height at later stages. At earlier stage (30 DAP), the longest plants were measured with treatment T_6 (27.9 cm) and minimum with treatment T_{10} (25.3 cm). At 45 DAP, the plant height was measured maximum with treatment T_9 (51.2 cm) which was at par to treatments T_8 (50.5 cm), T_7 (49.7 cm) and T_2 (48.8 cm). The minimum plant height was measured with treatment T_{10} (39.7 cm). Maximum plant height at 60 DAP was measured with treatment T_2 having 55.7 cm height which was statistically similar with treatments T_8 and T_9 (55.4 cm) and minimum with T_{10} (44.7 cm). Finally at de-haulming stage, the longest plants were measured with treatment T_9 (61.2 cm) which was at par to T_2 (59.5) while the shortest plants were measured with treatment T_{10} (48.8 cm). At all the stages longest plants were measured in split nitrogen application as basal + topdressing + foliar. This might be due to better availability of nitrogen to the plants and the enhancing effect of nitrogen on vegetative growth by greater cell division and cell elongation which indirectly affect tissue formation and consequently height of the plant. Treatment T_{10} showed the importance of nitrogen for the proper growth of the plant as throughout the growing period, slow growth was noticed, resultant shortest plants at all the stages. Similar to this Rizk *et al.* (2013) [14] in their study obtained taller potato plants with foliar spray of urea.

Different nitrogen scheduling showed insignificant effect on number of haulms per plant at all the growth stages except at 60 DAP. At 60 days after planting, all the treatments registered 5 haulms per plant except treatment T_9 which showed maximum number of haulms (6 per plant) and minimum haulms (4 per plant) was recorded with treatment T_{10}.

Finally at de-haulming stage, maximum haulms (6 per plant) were recorded with treatments T_8 and T_9, while 5 haulms per plant were recorded in rest of the treatments. Number of haulm depends upon the cultivar and physiological stage of the seed tuber rather than fertility of the soil. Similar results were reported by Chowdhury *et al*. (2002) [4]. According to Jasim (2013) [9], number of haulm could not affect by foliar spray of nitrogen. In fact, haulms were formed after planting and could not influence by foliar spray of nitrogen.

Significant difference was observed among nitrogen scheduling with respect to leaves per plant at all the stages. At 30 DAP, maximum number of leaves was counted with treatment T_8 (24 per plant), which was at par to treatments T_9 (23 per plant), T_2, T_3 and T_4 (20 per plant) while it was counted minimum with T_5, T_6 and T_{10} having 18 leaves per plant. At 45 DAP, maximum number of leaves was counted with treatment T_9 (36 per plant), which was at par to treatments T_8 (34 per plant), T_1 (33 per plant), T_2 (32 per plant) and T_6 (31 per plant), respectively while it was counted minimum with treatment T_{10} having 22 leaves per plant. At 60 DAP maximum number of leaves was counted with treatment T_9 (44 per plant), which was at par to treatment T_8 (41 per plant) and T_1 (38 per plant). The minimum number of leaves per plant (23 per plant) was counted with treatment T_{10}. At de-haulming, maximum leaves (43 per plant) were counted with treatment T_9 which was at par to T_8 (40 per plant), whereas minimum number of leaves (22 per plant) was counted with treatment T_{10}. More number of leaves per plant was counted in the treatments having more plant height as it had more number of nodes that subsequently resulted in more leaf formation. This might be due to the fact that the split application of nitrogen improved soil as well as plant nutrient status which help in better growth of the plant in comparison to without application of nitrogen and recommended dose. The study of Peter *et al.* (2015) [13] also reported that both nitrogen fertilizer rate and split frequency increased number of leaves per hill. At de-haulming, the number of leaves per plant in some treatments got decreased due to maturation or senescence. A similar reduction in number of leaves at later stage was also recorded by Jatav *et al*. (2017) [10].

Diameter of haulm significantly varied with different nitrogen application methods at all the stages except at 45 DAP. At 30 DAP, maximum diameter of haulm (8.2 mm) was measured with treatment T_6, which was at par to T_9 (7.7 mm) and was recorded minimum (6.7 mm) with treatment T_{10}. At 60 DAP, it was found maximum (9.2 mm) with treatment T_2 which was at par to all other treatments except treatment T_{10} in which it was recorded minimum (7.4 mm). At de-haulming, maximum haulm diameter was measured with treatment T_7 having 8.9 cm diameter which was at par to all other treatments except T_4 and T_{10} while, the minimum diameter (7.0 mm) was recorded with treatment T_{10}. The reduction at later stage in haulm diameter was observed due to maturation resulting in shrinking of tissues that consequently led to lesser diameter. Minimum diameter at all the growth stages was recorded with treatment T_{10} that ascertains the application of nitrogen as prerequisite with respect to haulm growth. The results indicated that haulm diameter was increased with split application of nitrogen especially with foliar spray. It might be due to more production of photosynthate in plants that leads to increased haulm thickness. Our results also supported by Rizk *et al.* (2013) [14] who found more haulm thickness with 3% foliar spray of nitrogen.

Different nitrogen scheduling did not affect the dry weight per plant at earlier stages, whereas at later stages the effect was significant. At 30 DAP, highest dry weight of the plant was recorded with treatment T_9 (15 g per plant) which was statistically similar with treatment T_6 (14 g per plant) and T_2, T_3, T_7 and T_8 (12 g per plant). The minimum dry weight was recorded with treatment T_{10} (9 g per plant). Maximum plant dry weight at 45 DAP was recorded with treatment T_9 (22 g per plant) which was at par to all other treatments except T_5. It was repeatedly observed minimum with T_{10} (16 g per plant). At 60 DAP it was recorded maximum with treatment with treatment T_9 (32 g per plant) which was at par to treatments T_7 and T_8 (29 g per plant). Similarly at de-haulming maximum dry weight was recorded with treatment T_9 (43 g per plant) which was at par to all other treatments except T_3, T_4, T_5 and T_{10}. The minimum dry weight of the plant was recorded with treatment T_{10} (32 g per plant).

The above data shows that adequate nitrogen supply at vegetative growth stage and additional foliar application leads to more dry matter accumulation in the plants. Foliar application at later stage facilitates speedy absorption of nitrogen by leaf tissues which enhances photosynthesis process resulting in more dry matter assimilation in shoot. There was an increase in dry weight due to increased plant height, number of leaves and thickness of haulm. Our results were in close conformity with the results obtained by the studies of Kumar, (2015) [12] who recorded maximum dry weight of the plant in 50% basal N + 25% topdressing at 25 DAP + 2% spray of urea at 40 DAP.

Nitrogen scheduling was significantly varied with respect to the number of tubers per plant. Maximum number of tubers per plant was counted with treatment T_9 and T_8 having 12 tubers per plant. However, minimum number of tubers (8 per plant) was counted with treatment T_{10}. Nitrogen had a positive effect on tuber initiation and its number per plant as more tubers were produced with treated plants especially with split application. It might be due to more absorption of nutrients which increased photosynthetic activity as well as translocation of photosynthates consequently led to more plant vigour which was responsible for formation of tubers. Similar observation was reported by Sahu *et al.* (2016) [15]. The study of Tekalign and Hammes, (2005) registered that nitrogen may increase the number of tubers by enhancing individual stem vigour, although effects are not always consistent.

The fresh weight of tubers per plant was ranged from 340 g to 559 g which was recorded maximum with treatment T_9, which was superior to other treatments, whereas it was recorded minimum with treatment T_{10}. It is evident from the data (Table-2) that adequate amount of nitrogen at tuberization leads to increase in tuber weight per plant because of the strong sink formation which increased tuber bulking period ultimately more weight of tuber. Moreover, additional foliar spray enhanced tuber bulking due to speed absorption of nitrogen by leaves as recorded in T_9. Banjare *et al.* (2014) observed an increase in fresh and dry weight of tuber per plant with increased nitrogen fertility.

Highest number of tubers were counted with treatment T_9 having 720 thousand tubers ha^{-1} which was at par with treatment T_8 having 672 thousand tubers ha^{-1}. Lowest number of tubers was counted with treatment T_{10} (430 thousand tubers ha^{-1}). It was observed that split application of nitrogen may increases the sink strength by increasing the number of tubers. More number of tubers might be due to more number of haulms and more nitrogen uptake as recorded in treatment T_9. Similar results were obtained by Sahu *et al.* (2014). The findings of Zabihi-e-Mahmoodabad *et al.* (2010) also reported that the number of tubers increases with increase in number of stolons, number of haulm and nitrogen uptake.

Tuber yield is the function of tuber growth rate and the duration of bulking period. Nitrogen affects both these processes. Highest tuber yield per hectare was recorded with treatment T_9 (34.08 t) which was statistically similar with treatment T_8 (32.33 t). Minimum tuber yield per hectare was recorded with treatment T_{10} (18.90 t). The data indicated that maximum tuber yield was recorded when adequate amount of nitrogen (basal + topdressing + foliar) was applied at tuber bulking stage and it was not substituted by consecutive foliar spray. Plants having more plant height, number of leaves, LAI produced more tuber yield because of more photosynthate production and their translocation as well as accumulation in the tuber. It was also due to more number and weight of tubers per plant. The findings were supported by Getie *et al*. (2015) [7]. Badr *et al.* (2012) [2] reported that more yield was due to the combined action of number of tuber and tuber weight per plant.

Similarly highest marketable tuber yield was registered with treatment T_9 (31.76 t ha^{-1}) which was at par with treatment T_1 (29.9 t ha^{-1}) and T_8 (29.57 t ha^{-1}). The lowest marketable tuber yield (16.10 t ha^{-1}) was registered with treatment T_{10}. Nitrogen plays an important role in tuber size enlargement. The results revealed that an increase in marketable tuber is due to more yield of medium, large and extralarge grade tubers which was produced in split application of nitrogen (basal + topdressing or basal + topdressing + foliar). However, application of nitrogen only through foliar method could not meet the need of the plant hence produces small sized tubers. Our findings are supported by Kumar (2015) [12] who recorded maximum marketable yield per hectare with 50% basal N + 25% top dressing at 25 DAP + one foliar spray of urea @ 2% at 40 DAP. Das *et al.* (2015) [5] reported that maintaining an adequate supply of N in the root zone without leaching is important for optimal production of marketable quality tubers.

Table 1: Effect of nitrogen scheduling on growth characters of potato

Treatments	Emergence (%)		Plant height (cm)				Number of haulms per plant				Number of leaves per plant				Diameter of haulm (mm)				Dry weight (g per plant)			
	20 DAP	30 DAP	30 DAP	45 DAP	60 DAP	At de-haulming	30 DAP	45 DAP	60 DAP	At de-haulming	30 DAP	45 DAP	60 DAP	At de-haulming	30 DAP	45 DAP	60 DAP	At de-haulming	30 DAP	45 DAP	60 DAP	At de-haulming
T_1	78	88	26.9	46.9	50.8	59.1	4	4	5	5	19	33	38	37	7.5	8.4	8.9	8.3	11	20	26	42
T_2	78	89	27.3	48.8	55.7	59.5	4	5	5	5	20	32	36	35	7.5	9.1	9.2	8.0	12	21	25	40
T_3	79	88	26.5	44.3	51.7	56.4	4	5	5	5	20	30	34	35	7.6	8.3	8.6	8.0	12	19	23	39
T_4	72	86	26	45.6	49.5	56.7	4	4	5	5	20	30	33	33	7.4	7.7	8.3	7.5	10	20	27	39
T_5	76	84	26.6	44.8	51.7	56.3	4	4	5	5	18	29	35	36	7.6	8.4	9	8.1	10	18	29	39
T_6	80	89	27.9	45.8	51.4	56.7	4	5	5	5	18	31	35	34	8.2	8.5	8.6	8.0	14	20	26	42
T_7	75	91	27.2	49.7	52.3	54.4	4	4	5	5	21	29	34	35	7.6	8.3	8.4	8.9	12	21	29	41
T_8	79	90	25.5	50.5	55.4	58.4	5	5	5	6	24	34	41	40	7.5	8.2	8.6	8.4	12	21	29	42
T_9	85	93	27.7	51.2	55.4	61.2	5	5	6	6	23	36	44	43	7.7	8.1	8.4	8.5	15	22	32	43
T_{10}	88	89	25.3	39.7	44.7	48.8	4	4	4	5	18	22	23	22	6.7	7.1	7.4	7.0	9	16	20	32
SEm.±	4	2	1.6	0.9	1	0.7	0.3	0.3	0.2	0.3	1	2	2	2	0.18	0.47	0.31	0.2	1	1	1	1
CD at 5%	NS	NS	NS	2.7	2.9	2	NS	NS	0.73	NS	4	5	6	5	0.5	NS	0.9	1	3	3	4	3

Table 2: Effect of nitrogen scheduling on yield and yield attributing characters of potato

Treatments	Number of tubers per plant	Fresh Weight of tubers per plant (g)	Number of tubers ('000) ha^{-1}	Tuber yield (t ha^{-1})	Marketable yield (t ha^{-1})	Harvest index (%)
T_1	11[	469	651	31.78	29.9	67.3
T_2	11	461	580	28.68	25.93	68.7
T_3	10	398	564	24.75	21.26	62.1
T_4	10	415	562	25.95	22.84	65.2
T_5	10	445	554	28.76	26.58	63.3
T_6	9	445	622	27.74	25.88	64.5
T_7	10	432	577	30.60	27.95	66.2
T_8	12	513	672	32.33	29.57	69.4
T_9	12	559	720	34.08	31.76	71.2
T_{10}	8	340	430	18.90	16.1	60.4
SEm.±	0.22	10.37	21	0.81	0.77	0.7
CD at 5%	0.7	31	62	2.28	2.3	2.1

Harvest index is calculated by division of biological yield to the economic yield. Maximum harvest index was recorded with treatment T_9 (71.2%) followed by treatment T_8 (69.4%). It was recorded minimum with treatment T_{10} (60.4%). Critical observation of the data (Table 2) revealed that adequate amount of nitrogen application either through topdressing or topdressing + foliar spray at tuberization stage gave more harvest index due to the synchrony between nitrogen demand and supply of nitrogen rather than basal or later application. Sun *et al.* (2012) has recorded maximum harvest index in potato with application of nitrogen at planting in conjunction with topdressing at 20 days after emergence.

On the basis of present investigation it might be concluded that among different nitrogen scheduling, 25% N of RDF as basal + 50% top dressing at 25 DAP + one foliar spray of urea @ 3% at 40 DAP was proved to be the best with respect to growth as well as yield and yield attributing characters of potato. To get more tuber yield of potato these doses could be recommended to the farmers.

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