Vegetable Science (2017) 44 (2) : 43-48

Nitrogen management in potato for maximum tuber yield, quality and environmental conservation

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Received: July 2017 / Accepted: November 2017

Abstract

The present investigation was undertaken on "Nitrogen management in potato (*Solanum tuberosum* L.)" and to identify a carefully controlled nitrogen application rate and better synchronization between applied nitrogen and potato nitrogen uptake at Vegetable Research Centre of G.B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand during *rabi* season of 2012-13 and 2013-14. The experiment was laid out in Randomized Block Design consisting of nine treatments replicated thrice. The pooled data of two years investigation revealed that the performance of potato crop was significantly influenced by different split nitrogen doses. Among all treatments, treatment T_4 (50% basal N + 25% top dressing at 25 DAP + one foliar spray@ 2% urea at 40 DAP) was found best with respect to overall plant growth, yield (34.98 t/ha), protein content (7.56 %) and benefit: cost ratio (1.81) . The treatment T_4 (50% basal N + 25% top dressing at 25 DAP + one foliar spray@ 2% urea at 40 DAP) not only give 18.09 % and 43.48 % more yield over the treatment T_1 (RDF:50% basal N + 50% top dressing at 25 DAP) and T_9 (No application of nitrogen), respectively, but also saves 22 % nitrogen. The dry matter content of potato was recorded maximum (19.48%) with treatment T_8 and specific gravity (1.09) with treatment T_9. Based on overall performance, it could be concluded that under prevalent climatic conditions of Uttarakhand Tarai region, 50% basal N + 25% top dressing N at 25 DAP + one foliar spray@ 2% urea at 40 DAP is the best in terms of higher and economic yield of potato than RDF (50% basal N + 50% top dressing N at 25 DAP) and also in reducing N losses to the environment.

Keyword: Potato, Nitrogen management, Growth, Yield, Quality

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Introduction

Potato (*Solanum tuberosum* L.) is an important member of the family Solanaceae. It is grown and consumed all around the world and is one of the main vegetable cash crop. Potato is an integral part of human diet. In India, potato is being cultivated on 2.12 million hectare area with a total annual production of 434.17 lakh MT (Anonymous 2016). In Uttrakhand, it is cultivated on 24.71 thousand hectare area with production of 434400.00 MT and a productivity of 17.37 t/ha (Anonymous, 2014). Potato is a prime crop of Uttarakhand state as it is a good source of income and employment generation state also serves as an off-season crop in fulfilling a part of total demand of plains. Nitrogen (N) is recognized as the most limiting nutrient to potato crops (Li et al. 1999). Inadequate N fertilization leads to poorer potato growth and yield while excessive N application leads to delayed maturity, poor tuber quality, and occasionally a reduction in tuber yield (Cerny et al. 2010). With rising environmental concerns for N fertilizer management practices, efficient N use is important for the economic sustainability of cropping systems (Shrestha et al. 2010). It is important that efficient nitrogen management practices are developed that consider cultivar physiological responses to total nitrogen application as well as to the physiological stage when the nitrogen is applied to maximize yields, tuber quality, and economic returns while reducing N losses to the environment. Despite of suitable climatic conditions for potato production in the state, the farmer of the state are unable to harvest it full potential. Out of the several factors responsible for that the imbalance use of fertilizer, particularly nitrogen resulting into low yield realized by farmers.

Materials and Methods

The present investigation was undertaken at Vegetable Research Centre of Govind Ballabh Pant University of Agriculture and Technology, Pantnagar during Rabi season of 2012-13 and 2013-14. The soil of the experimental field is sandy loam having pH 7.10 and available N (145.6 kg/ha), P (21.67 kg/ha), K (180.1 kg/ha) and organic carbon (0.92 %). The experiment was laid out in randomized block design with three replications. The treatments detail comprised of T_1; RDF 160:100:120 NPK kg/ha (50% basal N + 50% top dressing at 25 DAP), T_2; 50% basal N + one foliar spray @ 2% urea at 25 DAP, T_3; 50% basal N + 50% top dressing at 25 DAP + one foliar spray @ 2% urea at 40 DAP, T_4; 50% basal N + 25% top dressing at 25 DAP + one foliar spray@ 2% urea at 40 DAP, T_5; 50% basal N + three foliar spray @ 2% urea at 25, 40, 55 DAP, T_6; 50% basal N + two foliar spray @ 2% urea at 25 and 40 DAP, T_7; 25% basal N + 75% top dressing at 25 DAP, T_8; 25% basal N + 25% top dressing at 25 DAP + one foliar spray @ 2% urea at DAP. The source of nitrogen was urea (46% N). Well-sprouted seed tubers of potato cv. Kufri Sadabahar, size 50-60 g were planted during fourth week of October in both the years. The potato crop was de-haulmed at 90 days after planting. Rest of the agronomic package of practices adopted was as per recommendation for potato cultivation. Observations that were directly and indirectly related to plant height, number of haulms per hill, number of leaves per plant, tuber yield like number of tuber per hectare, etc were recorded. The number of tuber/ha and total yield per hectare was estimated. The observed data were then subjected to statistical analysis of variance (Sukhatme and Amble 1995).

Results and Discussion

Plant growth parameters: The plant growth parameters *e.g.* plant height (54.11cm), number of leaves per hills(42.15), stem girth(8.65 mm) and fresh weight of plant (246.11 g/plant) were showed significant effect and recorded maximum with treatment T_4 (50% basal N + 25% top dressing at 25 DAP + one foliar spray of urea @ 2% at 40 DAP) and lowest with treatment T_9 (No application of nitrogen) whereas emergence per cent after 20 days of planting and numbers of haulms per plant were found non-significant effect. The maximum leaf area index 5.47 was recorded with the treatment T_4 (50% basal N + 25% top dressing at 25 DAP + one foliar spray of urea @ 2% at 40 DAP) which was statistically at par with treatment T_5 (5.05). The data showed significant effect on chlorophyll 'a' content of leaves and found maximum (0.77 mg/ g) with the treatment T3 (50% basal N + 50% top dressing at 25 DAP + one foliar spray of urea @ 2% at 40 DAP) followed by T4 (0.75 mg/ g) and T1(0.73 mg/ g). The highest level of chlorophyll 'b' content was observed 0.90 mg/ g with treatment T4 (50% basal N + 25% top dressing at 25 DAP + one foliar spray of urea @ 2% at 40 DAP) which was statistically at par with treatment T3 (0.88 mg/ g) . In all the plant growth parameters RDF treatment T_1 (RDF: 50% basal N + 50% top dressing at 25 DAP) were found lowest than T4 (50% basal N + 25% top dressing at 25 DAP + one foliar spray of urea @ 2% at 40 DAP). Moshileh et al. (2005) reported that splitting N rates into three doses applied equally at 0, 45, and 60 days after planting improved plant growth characters. A similar finding was also reported by Rizk et al. (2013).

Grade wise number of tuber/ha: The larger size tubers (> 75 g) was recorded maximum (251.54 thousand/ha) with the treatment T4 (50% basal N + 25% top dressing at 25 DAP + one foliar spray of urea @ 2% at 40 DAP) which was statistically at par with treatments T5 (229.60 thousand/ha). Minimum number of tubers was observed (55.80 thousand/ha) with treatment T9 (No application of nitrogen). The results indicated that there is an increase in aggregate number of tuber with mode of application (basal + top dress + foliar spray) or (basal + 3 foliar spray). The highest numbers of >75 g and 51-75 g grade tubers were obtained in treatments T4 (50% basal N + 25% top dressing at 25 DAP + one foliar spray of urea @ 2% at 40 DAP) compared to treatment T2 (50% basal N + one foliar spray of urea @ 2% at 25 DAP) which have the maximum numbers of grade 26-50 g and 0-25g tubers. The grade wise increase in number of tubers may be due to increased

Table 1: Effect of nitrogen management on vegetative parameters of potato

Treatments	Plant height (cm)	No. of leaves per hills	Stem girth (mm)	Fresh weight of plant (g/plant)	LAI	Chlorophyll 'a'	Chlorophyll 'b'
T_1	47.97	37.77	7.19	207.15	4.65	0.73	0.84
T_2	45.72	34.49	6.49	181.59	3.87	0.68	0.81
T_3	53.19	40.64	8.43	240.22	5.24	0.75	0.88
T_4	54.11	42.15	8.65	246.11	5.47	0.77	0.90
T_5	52.33	39.60	8.00	234.36	5.05	0.75	0.86
T_6	52.09	37.82	7.95	230.15	4.30	0.71	0.82
T_7	46.93	35.69	7.19	197.36	3.22	0.70	0.80
T_8	48.32	37.19	6.92	225.68	3.77	0.72	0.83
T_9	42.01	29.69	5.54	157.85	2.34	0.58	0.69
S.Em±	0.62	0.96	0.17	6.79	0.22	0.02	0.01
CD at 5%	1.77	2.73	0.50	19.42	0.64	0.05	0.03

photosynthetic activity and translocation of photosynthates to the roots which might helped in the initiation of more stolon in potato (Anand and Krishnappa 1989). These results supported by the finding of Kumar and Trehan (2012).

Grade wise tuber yield/ha: Maximum yield of 51-75 g tubers recorded (12.57 t/ha) with the treatment T_4 (50% basal N + 25% top dressing at 25 DAP + one foliar spray of urea @ 2% at 40 DAP). It was significantly superior over other treatments. Minimum yield of 51-75 g tuber was recorded (4.74 t/ha) with treatment T_9 (No application of nitrogen). The larger size tubers (> 75 g) yield were recorded maximum (19.80 t/ha) with the treatment T_4 (50% basal N + 25% top dressing at 25 DAP + one foliar spray of urea @ 2% at 40 DAP). It was statistically at par with treatments T_5 (17.80 t/ha). Minimum yield of >75 g tuber was recorded (11.09 t/ha) with treatment T_9 (No application of nitrogen).

Total yield of potato tuber: Maximum yield was observed (34.98 t/ha) with treatment T_4 (50% basal N + 25% top dressing at 25 DAP + one foliar spray of urea @ 2% at 40 DAP). It was significantly superior over others treatments. Lowest yield was recorded (19.77 t/ha) with treatment T_9 (No application of nitrogen). This may be because of a better synchrony between nitrogen supply and demand. These results are consistent with our study in which split application of nitrogen led to higher tuber yield. In order to get an ideal yield, the plant should be kept green during tuber bulking stage to produce carbohydrates, but the plant should senesce near harvest to promote redistribution of carbohydrates to tubers (Lei et al. 2012). Similar results were also found by Chowdhury et al. (2002) and Saeidi et al. (2009). Also Sun (2012) reported that the positive effect of split application of urea on tuber yield might be due to the improvement in plant emergence and early vegetative growth.

Harvest index: The maximum harvest index (69.54%) was obtained from treatment T_4 (50% basal N + 25% top dressing at 25 DAP + one foliar spray of urea @ 2% at 40 DAP). It was statistically at par with the treatments T_3 (68.69%). Minimum harvest index (60.30%) was obtained from treatment T_9 (No application of nitrogen). A critical observation of the data revealed that the harvest index of potato crop was increased because of a better synchrony between N supply and demand. The results indicated that there was an increase in harvest index with the application higher dose along with split application (basal + top dress + spray) of nitrogen. Such increase in harvest index is may be due to the fact that as higher the plant biomass,

Table 2: Effect of nitrogen management on yield and it yield attributing parameters of potato

Treatments	Number of tubers (000/ha)				Grade wise yield of potato tuber (t/ha)				Potato yield t/ ha	Harvest index (%)
	0-25g	26-50 g	51-75 g	>75 g	0-25g	26-50 g	51-75 g	>75 g		
T_1	196.33	173.83	172.16	182.35	1.85	1.41	9.96	15.44	28.65	64.74
T_2	239.17	216.85	142.53	96.70	2.23	1.93	5.96	12.22	22.33	62.57
T_3	177.31	165.34	211.27	233.61	1.66	1.36	10.98	17.82	31.82	68.69
T_4	151.48	136.85	242.47	251.54	1.43	1.18	12.57	19.80	34.98	69.54
T_5	158.15	149.66	218.61	229.60	1.48	1.25	11.31	17.80	31.84	67.25
T_6	185.71	191.08	166.82	167.68	1.77	1.75	9.25	14.20	26.96	63.46
T_7	222.65	199.48	155.68	136.45	2.08	1.81	7.22	14.83	25.93	63.82
T_8	209.07	183.09	157.13	157.25	1.95	1.61	8.35	15.00	26.92	64.68
T_9	158.21	145.06	67.10	55.80	2.10	1.85	4.74	11.09	19.77	60.30
S.Em±	10.44	4.24	10.64	9.48	0.09	0.06	0.35	0.71	0.91	0.76
CD at 5%	29.84	12.14	30.42	27.12	0.27	0.18	1.01	2.03	2.61	2.16

Table 3: Effect of nitrogen management on quality, NUE, NAR and Benefit Cost Ratio

Treatments	Dry matter content (%)	Protein content (%)	Specific gravity (g/cm^3)	Nitrogen use efficiency (kg tuber/kg N)	Nitrogen apparent recovery (%)	B: C Ratio (1st Year)	B: C Ratio (2nd Year)
T_1	16.35	7.25	1.03	55.50	41.63	1.46	2.53
T_2	16.65	7.00	1.07	30.18	51.19	1.25	1.84
T_3	16.57	7.52	1.04	73.16	57.43	1.62	2.82
T_4	18.27	7.56	1.07	122.05	80.01	1.81	3.08
T_5	17.14	7.38	1.06	128.59	75.98	1.61	2.84
T_6	17.05	7.16	1.05	80.59	69.43	1.37	2.43
T_7	15.89	6.87	1.04	38.50	21.56	1.34	2.26
T_8	19.48	6.94	1.08	84.42	71.26	1.48	2.26
T_9	18.65	6.63	1.09	0.00	0.00	1.19	1.72
S.Em±	0.14	0.09	0.01	8.25	5.93		
CD at 5%	0.42	0.28	0.03	23.60	16.95		

the higher will be the flow of assimilates to the tubers hence resulting in higher tuber yield. These results are in close conformity with the findings of Singh and Lal (2012) who reported that the harvest index and bulking rate increased with increase in nitrogen dose up to 150 kg/ha and potassium dose up to 100 kg K_2O/ha.

Dry matter content: Maximum dry matter content was obtained (19.48%) with treatment T_8 (25% basal N + 25% top dressing at 25 DAP + one foliar spray of urea @ 2% at DAP) which were significantly superior over others treatments. Minimum dry matter content was obtained (15.89%) with the treatment T_7 (25% basal N + 75% top dressing at 25 DAP). It was observed that the lower dose of nitrogen and split application gave higher dry matter content of tuber and it was decreased with the increase in nitrogen dose. These results are in close conformity with the findings of Sun et al. (2012) who concluded that the higher tuber dry matter accumulation was associated with a high transportation efficiency of assimilates from vine to tubers after tuberization. The accumulation and distribution of dry matter within plants are important processes determining crop productivity. This is what happened in our study in treatment T_4 (50% basal N + 25% top dressing at 25 DAP + one foliar spray of urea @ 2% at 40 DAP) where total dry matter was relatively higher than T1. Different researchers have reported differently; Singh and Singh (1994) reported that basal dressing cum foliar application had a significant effect on tuber dry matter. On the other hand, Trawczynski (2001) reported that methods of nitrogen application had no significant effect on tuber dry matter.

Protein content of potato tubers: Highest protein content was recorded (7.56%) with treatment T_4 (50% basal N + 25% top dressing at 25 DAP + one foliar spray of urea @ 2% at 40 DAP). It was statistically at par with the treatments T_3 (7.52%) and T_5 (7.38%). Minimum protein content was recorded (6.63%) with the treatment T_9 (No application of nitrogen). The earlier studies of Abd El-Badea et al. (2011), Davoud et al. (2009) on potatoes, and Abd El-Samad et al. (2011) on onion, , all of their results are in good similar of that recorded herein.

Specific gravity: The treatment T_9 (No application of nitrogen) gave highest specific gravity (1.09 g/cm^3) which was at par with T_8 (1.08 g/cm3) and T_4 (1.07 g/cm3) and minimum specific gravity (1.04 g/cm^3) was recorded in treatment T_3 (50% basal N + 50% top dressing at 25 DAP + one foliar spray of urea @ 2% at 40 DAP) and T_7 (25% basal N + 75% top dressing at 25 DAP). It might be due to the better vegetative growth of plants and translocation of photosynthates which resulted in more reserve food accumulation in tubers. The decrease in specific gravity might be due to decrease in dry matter content of tuber with increasing nitrogen dose which is responsible for increased nitrogen content in potato tubers. These finding was in agreement to Zinada (2009).

Nitrogen use efficiency of potato plant: The data indicated that the different nitrogen treatments significantly affect the nitrogen use efficiency of potato plants. Maximum nitrogen use efficiency (128.59 tuber/kg N) with treatment T5 (50% basal N + one foliar spray of urea @ 2% at 40 DAP), which was statistically at par with treatment T4 (122.05 tuber/kg N). The importance of splitting N applications was emphasized by Jaamati et al. (2010) who showed that dividing total nitrogen into two or more applications would assist in enhancing the nutrient efficiency, promote optimum yield and mitigate the loss of nutrients and hence bigger potatoes. Peter et al. (2015) also reported that nitrogen applications which are split between pre-plant and in-season provide opportunities to increase nitrogen use efficiency and minimize leaching by preventing excess availability while

Nitrogen apparent recovery: Data showed significant response of nitrogen management to nitrogen apparent recovery of potato and was recorded maximum (80.01 %) with treatment T4 (50% basal N + 25% top dressing at 25 DAP + one foliar spray@ 2% urea at 40 DAP), which was statistically at par with treatment T5 (50% basal N + three foliar spray of urea @ 2% at 25, 40, 55 DAP), T8 (25% basal N + 25% top dressing at 25 DAP + one foliar spray of urea @ 2% at DAP) and T6 (50% basal N + two foliar spray of urea @ 2% at 25 and 40 DAP) having 75.98%, 71.26% and 69.43% respectively. The results indicated that the split application of nitrogen *i.e.* (basal + top dress + spray) increases the nitrogen apparent recovery per cent. This is might be due to the fact that the split application of nitrogen leads to more efficient nitrogen uptake there by increasing the nitrogen apparent recovery per cent as compared to that of T_1 *i.e.* (basal + top dress). These results are in conformity with the findings of Sharma and Sud (2001) who reported that the recovery efficiencies of K and N fertilizer on potato increased at 100 kg K_2O and 150 kg N/ ha.

Benefit: Cost ratio: In first year experiment, the maximum benefit: cost ratio was recorded (1.81) with treatment T_4 (50% basal N + 25% top dressing at 25 DAP + one foliar spray of urea @ 2% at 40 DAP) followed by treatment T_3 (50% basal N + 50% top dressing at 25 DAP + one foliar spray of urea @ 2% at 40 DAP) having 1.62. The minimum benefit: Cost ratio observed (1.19) with treatment T_9 (No application of nitrogen).In second year, highest benefit: cost ratio (3.08) was recorded with treatment T_4 (50% basal N + 25% top dressing at 25 DAP + one foliar spray of urea @ 2% at 40 DAP) followed by (2.84) with treatment T_5 (50% basal N + three foliar spray of urea @ 2% at 25, 40, 55 DAP). Lowest benefit: cost ratio was observed (1.72) with treatment T_9 (No application of nitrogen).

Conclusion

On the basis of present investigation, it can be concluded that the nitrogen management (Basal + top dressed + foliar) found more beneficial to the potato crop as compared to RDF (basal + top dressing) and control. It not only save the valuable nitrogen but also improve their availability to the crop. Treatment T_4 (50% basal N + 25% top dressing at 25 DAP + one foliar spray @ 2% urea at 40 DAP) produced maximum tuber yield as well as maximum B: C ratio and is more suitable to improve most of the quality characters as compared to rest of the treatments. The treatment T_4 (50% basal N + 25% top dressing at 25 DAP + one foliar spray @ 2% urea at 40 DAP) not only recorded 18.09 % and 43.48 % more yield over the treatment T_1 (RDF:50% basal N + 50% top dressing at 25 DAP) and T_9 (No application of nitrogen) respectively but also saves 22 % nitrogen. The farmers can apply less amount of urea to their field and get maximum return which is the sole object of farmer's to grow potato crop. Because the nitrogen use efficiency and nitrogen apparent recovery was recorded better than RDF, the loss of nitrogen to the environment is also minimized. Hence, on the basis of the present studies, the split application of nitrogen (basal + top dressing + spray) *i.e.* 50% basal N + 25% top dressing at 25 DAP + one foliar spray@ 2% urea at 40 DAP can be recommended to get maximum tuber yield and higher net returns from the potato crop.

Acknowledgements

The help and support provided during the course of investigation by Department of Vegetable Science, College of Agriculture, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, Udham Singh Nagar, Uttarakhand is duly acknowledged.

सारांश

आलू (*सोलेनम ट्यूबरोसम* एल.) में नाइट्रोजन प्रबंधन का मूल्यांकन करने के लिए वर्तमान परीक्षण किया गया और (ध्यानपूर्वक नियंत्रित नाइट्रोजन का आवेदन दर और समकालिक नाइट्रोजन और प्रायोगिक नाइट्रोजन के बीच बेहतर ग्रहण की पहचान) करने के लिए पंत गोविन्द बल्लभ पंत कृषि एवं प्रौद्योगिकी विश्वविद्यालय, पंतनगर (उत्तराखण्ड) 2012–13 और 2013–14 के रबी मौसम के दौरान प्रयोग कोयादृच्छिक ब्लॉक डिजाइन में किया गया था, जिसमें नौ उपचार को तीन बार दोहराया गया था। दो साल की जांच के एकत्रित आंकड़ें से स्पष्ट हुआ कि आलू की फसल का प्रदर्शन अलग–अलग विभाजित नाइट्रोजन की मात्रा से काफी प्रभावित था। सभी उपचारों में, पौधों की वृद्धि व उपज (34.98 टन/हे.) हेतु, प्रोटीन (7.56 प्रतिशत) हेतु तथा लाभ : लागत अनुपात (1:81) हेतु टी$_4$ (50 प्रतिशत बेसल एन + 25 प्रतिशत टॉप, कंद रोपण के 25 दिन उपरान्त + 2 प्रतिशत यूरिया का छिड़काव) उत्तम पाया गया। उपचार टी$_4$ (50 प्रतिशत आधारीय नत्रजन + 25 प्रतिशत टाप डेसींग कन्द रोपण के 25 दिन उपरान्त + 2 प्रतिशत यूरिया का छिड़काव पौध रोपण के 40 दिनों के उपरान्त न केवल 18.09 प्रतिशत और 43.48 प्रतिशत अधिक उपचार उपज देता है। टी$_1$ (आरडीएफ : 50 प्रतिशत + पौध रोपण के 25 दिन के उपरान्त 50 प्रतिशत टाप ड्रेसिंग) और टी$_9$ (नाइट्रोजन का कोई प्रयोग नहीं) से 22 प्रतिशत नाइट्रोजन का बचाव हुआ। आलु शुष्क भार की मात्रा उपचार (टी$_8$) के साथ अधिकतम (19.48 प्रतिशत) और विशिष्ट गुरूत्वाकर्षण (1.09) दर्ज की गयी। समग्र निष्पादन के आधार पर, यह निष्कर्ष निकाला जा सकता है कि उत्तराखण्ड तराई क्षेत्र की प्रचलित जलवायु परिस्थितियों में, 50 प्रतिशत बेसल एन + 25 प्रतिशत नाइट्रोजन टॉप ड्रेसिंग कन्द रोपण के 25 दिनों के उपरान्त तथा 2 प्रतिशत यूरिया का छिड़काव रोपण के 40 दिनों के उपरान्त पत्तियों पर छिड़काव अधिक व आर्थिक उपज हेतु पाया गया।

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