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Response of Potato (*Solanum tuberosum* L.) Varieties to Different Levels of Nitrogen under Agroclimatic Conditions of Meghalaya

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***Abstract*:** Nitrogen (N) is a very dynamic yield-limiting plant nutrient and excessive N fertilization beyond crops demand has led to soil acidification and major environmental issues. Nitrogen use efficiency of potato cultivars is vary widely and Nitrogen use efficiency was found to be very low for some cultivars. We investigated the response of potato varieties (Kufri Girdhari and Kufri Himalini) to different levels of nitrogen (0, 70, 140,1 75 kg N ha^{-1}) under Meghalaya conditions. The results of the two-year experiment indicated that total tuber yield was significantly influenced by both potato variety and N fertilizer treatment. Compared to Kufri Girdhari, Kufri Himalini recorded 26 percent higher tuber yield than its counterparts. Regardless of variety, the application of 175 kg N ha^{-1} with RDP and RDK resulted in the highest total potato tuber yield (21.84 t ha^{-1}). The agronomic nitrogen use efficiency decreased linearly as N doses increased. Kufri Himalini was more responsive to nitrogen fertilizer than Kufri Girdhari as it recorded higher Nitrogen use efficiency and Partial factor productivity in all nitrogen levels. Being more responsive to fertilizer nitrogen, Kufri Himalini is cultivated with 175 kg N ha^{-1} to produce the highest net return.

***Keywords*:** Potato**,** Varieties, Nitrogen fertilizer, Tuber yield, NUE, BCR

Adequate nutrient management with a successful agronomic strategy is essential throughout the growth period of potatoes. Due to shallow roots and high nutrient demand, potatoes require more fertilizer than other crops (Munoz et al 2005). According to Tehran et al (2008), the fertilizer use efficiency for the potato to NPK fertilizers is 40-50, 10-15 and 50-60%, respectively. Among the major nutrients, Nitrogen (N) is a critical nutrient in potato production. Nitrogen is the main component for synthesizing chlorophyll, nucleic acids, amino acids, coenzymes, proteins *etc*., (Ahmed et al 2015). The potato plant is sensitive to deficiencies and excess nitrogenous fertilizer levels, affecting the tuber's growth, quality and quantity. Excessive nitrogen application in the early stages prolongs the vegetative phase and interferes with tuberization. Excess nitrogen application in mid-season reduces tuber bulking in favor of vegetative growth (Waddell et al 1999). Low nitrogen rates reduce canopy growth, tuber yields, quality, increased disease and insect susceptibility and premature senescence due to early nitrogen translocation from leaves to tubers. The outcome of low N fertilizer use efficiency and excessive application of N fertilizer causes nitrate leaching and groundwater N contamination (Plosek et al 2017). Furthermore, potato yield response to nitrogen (N) fertilizer varies with cultivar and soil type. ICAR-Central Potato Research Institute, Shimla (India) has developed high-yielding potato varieties for the North-eastern hilly region, which vary in their response to nitrogen (Dubey et al 2012). Among the varieties, Kufri Himalini and Kufri Girdhari are the high-yielding, late blight-resistant potato varieties suitable for cultivation in the Indian hills, including Meghalaya. Therefore, it is necessary to determine the optimal nitrogen fertilizer application rates for maximizing potato yields while minimizing nitrogen pollution. The present study was undertaken to determine the nitrogen requirement of the promising potato varieties and to work out N use efficiency (NUE) in the north-eastern hilly region of India.

MATERIAL AND METHODS

The study was conducted at ICAR Central Potato Research Institute Regional Station, Shillong during the summer season of 2019-2021. Shillong is located in Meghalaya at 25.54 °N Latitude and 91.85 °E Longitude with an altitude of 1738 m above mean sea level. The soil of the experimental field was sandy loam with an acidic pH (4.6), 319 kg available N ha^{-1}, 26 kg available P_2O_5 ha^{-1} and 266 kg available K_2O ha^{-1}. The experiment was laid out in Factorial Randomized Block Design with two potato varieties, Kufri Girdhari and Kufri Himalini and four levels ofN (0, 70, 140 and 175 kgN ha^{-1}) were replicated three times. The basal application of 120 kg P_2O_5 and 60 kg K_2O per hectare and the half rate of the N fertilizers per treatment. Forty-five days after planting, the remaining dose of nitrogen was applied as per the treatments. Urea (46% N), Single superphosphate (16% P) and Muriate of potash (60% K) were used as fertilizer

sources for NPK. The well-sprouted, medium-sized (30-45 g) tubers were planted on ridges 60cm apart with a spacing of 20cm. Potato varieties were planted in the last week of February. All recommended packages of practices were followed to raise a healthy crop.During the growth period, germination percentage (40 days after planting), plant height (cm), number of leaves and shoots (60 days after planting) were recorded. Six plants from each plot were tagged for growth observation. To estimate tuber yield, all the plants in the net plot area were harvested manually. Shade-dried tubers were weighted and graded as very small (< 25 g), small (25-50 g) medium (50-75 g) and large (>75 g). The tuber yield of each plot was calculated and converted into tonnes per hectare. Nitrogen use efficiency (NUE) and Partial factor productivity(PFP)were calculated as below:

i. NUE= (Yf-Yc)/Na - expressed in kg yield per kg N applied
ii. PFP = Yf/Na - expressed in kg yield per kg of N applied.

Where Yf, Yc and Na are yield in the N-fertilized plot, yield in the control plot and quantity of fertilizer N applied (kg/ha), respectively (Dua et al 2007).

RESULTS AND DISCUSSION

Growth parameters: The final plant stand (40 DAP) was more than 90 % in all the treatments, indicating that potato varieties and nitrogen (N) levels did not affect plant emergence (Table 1). Similar results were reported by Kumar et al (2008) and Das *et al.* (2015). Varieties, nitrogen (N) levels, and their interactions had a significant effect on plant height. Variety Kufri Himalini was taller (46.57 cm) than Kufri Girdhari (43.31cm), indicating their inherent varietal difference. An increasing N rate resulted in increasing trends in plant height. The application of 175 kg N ha^{-1} recorded the highest plant height (49.53 cm) and shortest plant height (39.07cm) was recorded at 0 kgN ha^{-1}. Regarding variety by N rate interactions, KufriHimalini recorded the highest plant height (52.46 cm) with 175 kg N ha^{-1} followed by the same variety with 140 kg N ha^{-1} with a mean plant height of 49.97 cm. The lowest plant height (37.21 cm) was recorded with Kufri Girdhari grown in a control plot. A proportional increment in potato plant height in response to the increasing nitrogen applications has also been reported by Biruk (2015). Different N levels significantly increased the number of shoots and leaves per plant compared to control. The highest number of leaves per plant (40.11) and shoots per plant (3.38) were with 175 kg N ha^{-1} although it was at par with the application of 140 kg N ha^{-1}. The varieties and interaction effects were insignificant, indicating that both the varieties responded similarly to increased doses of N. Results of the present experiment agree with the finding of Udom et al (2012) and observed significant effect of increased nitrogen doses on stem number of potato. Increased nitrogen levels had a significant impact on plant height, number of shoots and leaves, which could be due to the role of nitrogen in cell division, cell enlargement and protein synthesis, all of which promote vegetative growth.

Grade-wise tuber yield of potato as influenced by the cultivars and levels of N: Kufri Himalini recorded significantly higher non-marketable tuber yield (3.51 t ha^{-1}) and marketable tuber yield (15.44 t ha^{-1}) (Table 2). Therefore Kufri Himalini would be more acceptable to farmers in terms of marketable tuber yield, as it produced a 26.18% higher total tuber yield (18.94 t ha^{-1}) than Kufri Girdhari (15.01 t ha^{-1}). The differential response of cultivars reflects the genetic variation between the cultivars as the environmental conditions during the growing period was similar. Tehran (2006) and Jatav et al (2013) reported that potato varieties differ widely in their nitrogen requirements. Nitrogen is a critical macronutrient for potato yield and yield components. The application of nitrogen had a significant effect grade-wise as well as on potato yield. Among the nitrogen levels, the application of 175 kg N ha^{-1} recorded the highest yield of non-marketable tuber (4.30 t ha^{-1}) and marketable tuber (17.54 t ha^{-1}). In comparison, the highest non-marketable yield of tuber (2.43 t ha^{-1}) was with 0 kg N ha^{-1}, which has at par effect

Table 1. Effect of varieties and nitrogen application rates on potato growth parameters

N levels (kg/ha)	Germination (%)			Plant height (cm)			No. of leaves/ plant			No. of shoots/plant		
	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean
0	91.94	91.39	91.67	40.92	37.21	39.07	29.66	30.38	30.02	2.77	2.81	2.79
70	90.56	90.28	90.42	42.92	43.80	43.36	35.29	32.19	33.74	2.92	2.54	2.73
140	91.11	90.83	90.97	49.97	45.63	47.80	36.84	38.75	37.80	3.05	3.04	3.05
175	90.28	90.56	90.42	52.46	46.59	49.53	38.31	41.92	40.11	3.19	3.56	3.38
Mean	90.97	90.77		46.57	43.31		35.02	35.81		2.98	2.99	
Factors	V	N	V X N	V	N	V X N	V	N	V X N	V	N	V XN
CD (0.05)	NS	NS	NS	0.86	1.22	1.73	NS	3.62	NS	NS	0.39	NS

V_1: Kufri Himalini, V_2: Kufri Girdhari

with 70 kg N ha^{-1}. Increased nitrogen application increased the number of stolons, number of tuber (Zabihi et al 2010), tuberization and duration of tuber bulking (Kotsyuk 1995), which would have led to large-sized tubers (Zebarth and Rosen 2007) with a higher yield. Maitiet al (2004) and Marguerite et al (2006) reported that tuber yield per unit area increased with increasing nitrogen fertilizer to an adequate level.In this study, potato yield increased with increasing N levels. This result was similar to other findings (Dubey et al 2012, Jatavet al 2013, Das et al 2015, Banerjee et al 2015). Among all treatments, N fertilization produced the highest tuber yield than *non*-fertilized control plots. The highest tuber yield (21.84 tons ha^{-1}) was recorded at 175 kg N ha^{-1} followed by 140 kg N ha^{-1} with a mean tuber yield of 19.90 tons ha^{-1}. The lowest tuber yield (10.29 tons ha^{-1}) was in control. The relationship between N rates and tuber yield fit a convex quadratic function (Fig. 1), while mean tuber yield and N rates increased linearly. Variety Kufri Himalini had a significantly higher yield than Kufri Girdhari at all N levels. This suggests that the Kufri Himalini variety has better environmental adaptability than Kufri Girdhari. The interactions between the varieties and the N rates resulted in significant differences in the total potato tuber yield. Among nitrogen levels, Kufri Himalini with 175 kg N ha^{-1} had the highest total tuber yield (24.59 t ha^{-1}) followed by the same variety (22.14 t ha^{-1}) with the application of 140 kg N ha^{-1} and Kufri Girdhari with 175kg N ha^{-1} (19.08 t ha^{-1}).Several reports confirm this variation in total tuber yield of varieties under different N levels (Dubey et al 2012, Jatav et al 2017, Das et al 2015 Banerjee et al 2015, Jatav et al 2018).

Nitrogen uptake efficiencies of potato: Optimal N rate and timely N application are effective tools for increasing Potato Nitrogen use efficiency (NUE). NUE decreased linearly with increasing N level and maximum (79.77 kg tubers yield /kg N) at 70 kg N ha^{-1} and minimum (66.02 kg tuber/kg N) at the highest N dose of 175 N ha^{-1} (Fig. 2). The most efficient treatments received less N, indicating that NUE was inversely proportional to N amount. Potato grown in a nitrogen-limited environment extracted more nitrogen from the soil, confirming the findings of Cabello et al (2009), Trehan, 2009 and Banerjee et al (2014). NUE was higher in 'Kufri Himalini' potato at all N levels compared to Kufri Girdhari, indicating Kufri Himalini was the most efficient in NUE. Numerous studies have revealed that NUE varies by variety (Kumar et al 2008, Trehan 2009, Jatav et al 2013, Das et al 2015) and maturity class (Errebhi et al 1998, Zebarth et al 2004). Banerjee et al (2015) observed that Kufri Himalini had a higher nitrogen use efficiency under West Bengal

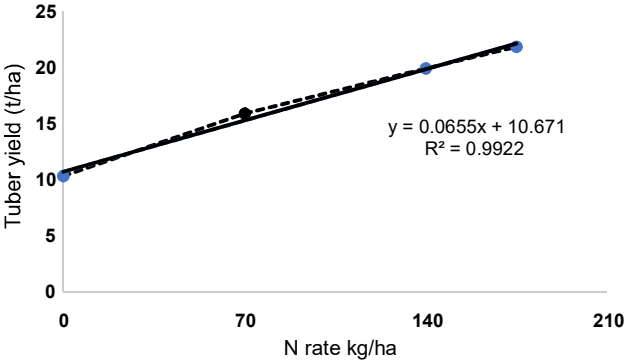

Fig. 1. Relationship between N rates and total tuber yield

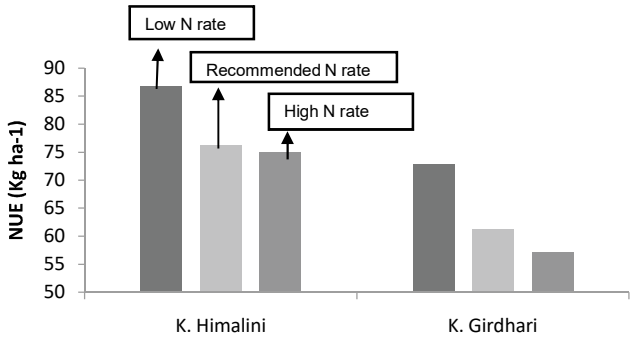

Fig. 2. Nitrogen use efficiency (NUE) under three N levels with two potato varieties

Table 2. Effect of varieties and different nitrogen application rates grade-wise and total tuber yield of potato

N levels (kg/ha)	Non-marketable tuber yield (t/ha)			Marketable tuber yield (t/ha)			Total tuber yield (t/ha)		
	V_1^*	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean
0	2.82	2.03	2.43	8.66	7.06	7.86	11.48	9.09	10.29
70	3.12	2.62	2.87	14.43	11.57	13.00	17.54	14.19	15.87
140	3.52	3.41	3.47	18.63	14.25	16.44	22.14	17.66	19.90
175	4.56	4.03	4.30	20.02	15.05	17.54	24.59	19.08	21.84
Mean	3.51	3.02		15.44	11.98		18.94	15.01	
	V	N	V X N	V	N	V X N	V	N	V X N
CD (p=0.05)	0.40	0.57	NS	1.64	2.31	NS	0.69	0.97	1.37

*V_1: Kufri Himalini, V_2: Kufri Girdhari

Table 4. Economics, net return and B:C ratio of potato crops due to different N levels

N levels (kg/ha)	K. Himalini				K. Girdhari			
	Cost of cultivation (Rs/ha)	Gross return (Rs/ha)	Net return (Rs/ha)	B:C ratio	Cost of cultivation (Rs/ha)	Gross return (Rs/ha)	Net return (Rs/ha)	B:C ratio
0	179250	229600	50350	1.28	179250	181800	2550	1.01
70	184570	350900	166330	1.90	184570	283800	99230	1.54
140	189855	442800	252945	2.33	189855	353200	163345	1.86
175	192550	491800	299250	2.55	192550	381600	189050	1.98

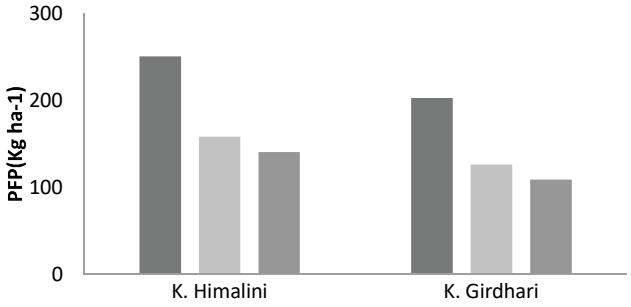

Fig. 3. PFP of N under three N levels with two potato varieties

conditions. Partial factor productivity of N in potato (PFP_N) decreased as the applied N level increased; the rate of decrease varied between varieties (Fig.3). The mean PFP_N was 226.67 kg tuber/kg N when used at 70 kg Nha^{-1}, which declined to 124.28 kg tubers/kg N when applied at 175 kg N/ha. This pattern reflects the law of diminishing returns as N increases and the response to N decreases. A similar trend was observed during the different decades (Dua et al 2007). PFP_N of varieties was compared, Kufri Himalini had the highest PFP_N (250.62) at 70 kg N/ha while Kufri Girdhari had the lowest (202.72).

Economics of potato cultivation: The cost of cultivation, net returns per hectare and B:C ratio increased with increasing nitrogen dose (Table 4). Cultivation without nitrogen had the lowest cost cultivation. K. Himalini and K. Girdhari at a higher N dose (175 kg N ha^{-1}) had the highest gross and net returns due to increased marketable and total tuber yield. Higher tuber yields increased gross return, net return, and cost-benefit ratio.K. Himalini had the best cost-benefit ratio (2.55 and 2.33)with applications of 175 kg and 140 kg of N followed by K. Girdhari with an application of 175 kg of N (1.98).

CONCLUSIONS

In terms of highest marketable and total tuber yield, NUE and net returns, 'Kufri Himalini' is a more profitable variety for cultivation under Meghalaya conditions. Kufri Himalini is more responsive to nitrogen fertilizer and can be grown with 175 kg N $ha^{-1}$to maximize net return.

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