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PRODUCTION POTENTIAL OF NEWLY RELEASED POTATO (*Solanum tuberosum* L.) CULTIVARS UNDER DIFFERENT NITROGEN LEVELS

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ABSTRACT

Field experiments were conducted during *rabi* seasons of 2011-12, 2012-13, 2013-14 and 2014-15 at C-unit research farm of Bidhan Chandra Krishi Viswavidyalaya, Kalyani, Nadia, West Bengal, India to study the effects of different levels of nitrogen on the productivity of newly released potato (*Solanum tuberosum* L.) cultivars under lower Gangetic plains of West Bengal. The experiment was laid out in a factorial randomized block design with four replications having ten treatment combinations *viz.* two levels of newly released cultivars (V_1 - Kufri Himalini and V_2 - Kufri Shailja) as factor A and five levels of nitrogen (N_0 -0 kg ha^{-1}, N_{75} -75 kg ha^{-1}, N_{150} -150 kg ha^{-1} N_{225}-225 kg ha^{-1} N_{300} -300 kg ha^{-1}) as factor B. Experimental results revealed that highest tuber yield (25.77 t ha^{-1}) was recorded with Kufri Himalini receiving 300 kg N ha^{-1} followed by 24.64 t ha^{-1} and 23.64 t ha^{-1} with 225 kg N ha^{-1} and 150 kg N ha^{-1} respectively which is quite higher than the state average of 22.02 t ha^{-1} obtained from the state recommended dose of 200 kg N ha^{-1}, 150 P_2O_5 ha^{-1} and150 K_2O ha^{-1}. Thus recently released variety Kufri Himalini, having moderate resistance against late blight, which is a serious problem in the state at present can be a better option for the farmers of the state to raise the potato production. Kufri Himalini produced significantly higher (14.1%) total tuber yield over Kufri Shailja and it was found to be more acceptable to the farmers in terms of production of marketable tuber (> 75 g grade). Grade wise tuber yield of potato was significantly influenced by N levels. Irrespective of cultivars application of 300 kg N ha^{-1} along with recommended dose of P and K recorded the highest total potato tuber yield (23.55 t ha^{-1}) which was found statistically at par with the application of 225 kg N ha^{-1} and 150 kg N ha^{-1}. Nitrogen fertilization improved the tuber yield of potato by 49.5 to 82.1% over control. Kufri Himalini was more responsive to fertilizer nitrogen than Kufri Shailja as it recorded higher agronomic efficiency

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(AE_N), apparent recovery (RE_N) and physiological efficiency (PE_N) at all nitrogen levels. There was a positive balance of nitrogen found in all treatments. Net gain of soil N was highest with 'Kufri Himalini' receiving 150 kg N ha^{-1}. Kufri Himalini gave highest net return with 300 kg N ha^{-1}.

Keywords: Cultivars, economics, nitrogen balance, nitrogen uptake efficiency, potato, tuber yield

INTRODUCTION

West Bengal is the second largest potato growing state in India with a production of 9.0 million tonnes from an area of 409.7 thousand hectares, while the productivity was 22.02 t ha^{-1} during 2013-14 (Directorate of Agriculture, WB, 2014). The state accounts for one-third of the country's total potato production. The problems in potato cultivation in this area are lack of quality seed, new fertilizer responsive cultivar and appropriate doses of fertilizers. This situation can be overcome by using improved potato cultivars having better yield potential and also adopting proper nutrient management practices. The two new potato cultivars 'Kufri Himalini' and 'Kufri Shailja', having higher yield potential may provide stability to potato cultivation where late blight disease is a recurring feature. Potato crop being highly exhaustive and responsive, and having high rate of production per unit area and time, requires higher amount of nutrients especially nitrogen (N). On an average, a 90 days potato crop producing 20 tonnes tubers per hectare requires about 100 kg nitrogen to be removed in the form of tuber and haulm. Nitrogen uptake on per day basis is sometime even more than 1.5 kg ha^{-1} during active growth period (Kumar and Trehan, 2012). Nitrogen plays an important role in crop growth and development resulting in increased size and number of tubers ultimately enhancing total yield (Kumar et al., 2007). In addition, under or oversupply of N may affect tuber production. Moreover, maintaining an adequate supply of N in the root zone of potato without leaching is important for optimal production of marketable quality tubers. On the contrary, excessive application leads to delayed maturity, poor tuber quality and occasional reduction in tuber yield (Alva, 2004). Agronomic research on macro-nutrient management aspect showed that some newly released potato cultivars for processing requires approximately 150% higher nitrogen and potassium over current table-purpose potato cultivars. Recent diagnostic survey also indicates that in many intensively cultivated areas, farmers have resorted to use of greater than the recommended dose of fertilizer (RDF), particularly N to maintain crop productivity. Potato cultivars differ in their growth behaviour and yield potential, and therefore, it is important to evaluate each genotype for its attributes. Keeping the above facts in view, this experiment was initiated with the objective to investigate the effects of different levels of nitrogen on the productivity, nitrogen uptake efficiency, nitrogen balance and economics of two newly released potato (*Solanum tuberosum* L.) cultivars under lower Gangetic plains of West Bengal.

MATERIALS AND METHODS

Field experiments were conducted for four years at C-unit research farm (Kalyani) of Bidhan Chandra Krishi Viswavidyalaya, Nadia, West Bengal, India situated at 22º58' N latitude and 88º3'E longitude with an altitude of 9.75m above mean sea (MSL) during *rabi* 2011-12, 2012-13, 2013-14 and 2014-15. The soil of the experimental field was sandy loam in texture and slightly alkaline in reaction (pH 7.2) having an organic carbon content of 0.56%, 183.26 kg available N ha^{-1}, 16.8 kg available P_2O_5 ha^{-1}, 132 kg available K_2O ha^{-1}. The experiment was laid out in a factorial randomized block design with four replications having ten treatment combinations *viz.* two levels of cultivars (V_1 -Kufri Himalini and V_2 - Kufri Shailja) as factor A and five levels of nitrogen (N_0 -0 kg ha^{-1}, N_{75} -75 kg ha^{-1}, N_{150} -150 kg ha^{-1} N_{225}-225 kg ha^{-1} N_{300} -300 kg ha^{-1}) as factor B with a plot size of 5 m X 3 m. The crop was planted on fourth week of November, 2011-12, 2012-13, 2013-14 and 2014-15 respectively. Tubers weighing 30–40 g each were planted in the furrows with a depth of planting of 3–4 cm and spacing of 60 cm X 20 cm and finally covered with soil. Phosphorus and potassium were applied at their recommended doses i.e. 150 kg ha^{-1}. Nitrogen (N), phosphorus (P) and potassium (K) were applied through urea, single super phosphate and muriate of potash respectively. Half of N, full dose of P and K were applied as basal. Rest half N was top dressed at 30 days after planting (DAP) followed by earthing up. Pre-emergence application of Sencor (Metribuzin) @ 0.75 kg a.i. ha^{-1} was done at 3 DAP followed by 1 hand-weeding at 20 DAP to promote early crop growth. As a prophylactic measure, spraying (twice) with Dithane M-45 (Mancozeb) @ 0.2% at 40 and 60 DAP was done against late blight. Dimethoate (Rogor) @ 0.1% was also sprayed (twice) at 45 and 65 DAP for controlling aphids and other insects. Haulms were cut in the last week of February in all the three seasons after the crop attained maturity. Harvesting was done 15 days after haulm cutting, and the crop lines were opened with the help of plough. Potato tubers were dug out from each plot manually. Data on grade wise tuber yield (t ha^{-1}) and total tuber yield (t ha^{-1}) were recorded at harvest from each net plot area. Nitrogen efficiency was calculated using following formulae cited by Singh and Singh (2012).

Agronomic efficiency of N (AE_N) = Y_N-Y_C / Na

Apparent recovery of N (RE_N) = U_N-U_C / Na

Physiological efficiency of N (PE_N) = Y_N-Y_C / U_N-U_C

where, Y and U refer to yield of potato and nitrogen uptake by potato and subsequently N and C refer to nitrogen fertilizer and control plots respectively. Na is nutrient added. All values are in kg ha^{-1}. Estimation of nutrient-use efficiencies followed the framework described by Cassman et al. (1998). Soil and plant samples were analysed for total N following standard procedures. The economic parameters (cost of cultivation, gross returns and net returns) were worked on the basis of prevailing market prices of inputs and outputs. Nutrient uptake was calculated by multiplying the yield with the concentration of particular nutrient. Analysis of variance of the data in the experimental design and comparison of means at $p \leq 0.05$ were carried out, using MSTAT-C software.

RESULTS AND DISCUSSION

Performance of cultivars

Experimental results revealed that plant emergence of potato was not significantly influenced by cultivars. It was 92.83% in case of Kufri Himalini and 91.21% in Kufri Shailja. Irrespective of nitrogen levels the variety Kufri Himalini recorded significantly higher plant height (75.15 cm), number of shoots per plant (5.17) and leaf area index (0.83) at 50 DAP (Table 1). Experimental results also revealed that grade wise tuber production was significantly influenced by the cultivars (Table. 2). Kufri Himalini recorded significantly higher tuber yield with respect to 0-25 g grade tubers (3.25 t ha^{-1}) and > 75 g grade tubers (8.90 t ha^{-1}) but both the cultivars were found statistically at par with respect to yield of 25-50 g grade tubers and 50-75 g grade tubers. Thus, it was evident that Kufri Himalini would be more acceptable to the farmers in terms of production of marketable tuber i.e. > 75 g grade. Kufri Himalini also produced significantly higher (14.1%) total tuber yield (21.45 t ha^{-1}) over Kufri Shailja (18.80 t ha^{-1}) might be owing to higher LAI acted over the tuber bulking period resulting in increased dry-matter accumulation and greater tuber bulking rate as reported my Mozumder et al. (2014).

Effect of nitrogen

Experimental results revealed that plant emergence of potato was not significantly influenced by nitrogen (N) levels. It ranged from 90.31 to 93.85%. Irrespective of cultivars, plant height of potato was significantly influenced by nitrogen levels. Application of 225 kg N ha^{-1} recorded highest plant height (81.28 cm) which was found at par with application of 300 kg N ha^{-1} (Table.1). Application of nitrogen at different doses increased the plant height of potato by 41.4 to 68.7%. Different N levels significantly increased the number of shoots per plant and leaf area index over control. Highest number of shoots per plant (5.00) was recorded with the application of 150 kg N ha^{-1} and highest LAI (1.01) at 50 DAP was recorded with 300 kg N ha^{-1} though it was at par with the application of 225 kg N ha^{-1},150 kg N ha^{-1} and 75 kg N ha^{-1}. Experimental results revealed that grade wise tuber yield of potato was significantly influenced by N levels (Table. 2). Application of 300 kg N ha^{-1} recorded highest amount of 0-25 g grade tubers (3.52 t ha^{-1}), 50-75 g grade tubers (5.92 t ha^{-1}) and > 75 g grade tubers (9.89 t ha^{-1}) whereas, application of 225 kg N ha^{-1} recorded highest amount of 25-50 g grade tubers (5.32 t ha^{-1}). Thus, it was evident that application of 300 kg N ha^{-1} produced more amount of marketable tubers i.e. 50-75 g grade and >75 g grade tubers. Application of nitrogen fertilizer significantly increased the total tuber yield of potato. Response to higher fertilization may be linked to the increase in total leaf area which in turn increased the amount of solar radiation intercepted, and more photo-assimilate might have been produced and assimilated to the tubers (Baishya et al., 2013). Minimum total tuber yield was recorded in the control (12.93 t ha^{-1}). Total tuber yield showed increasing trend with the increase in N levels up to 300 kg N ha^{-1}. This result corroborated with the findings of Sarkar et al. (2011), Jatav et al. (2013) and Vaezzadeh and Naderidarbaghshahi (2012). Among the nitrogen levels, application of 300 kg N ha^{-1} along with recommended dose of P and K recorded the highest total potato tuber yield (23.55 t ha^{-1}) which was found statistically at par with the application of 225 kg N ha^{-1} and 150 kg N ha^{-1} along with recommended dose of P and K. Similar findings was also reported by Mozumder et al. (2014). Nitrogen fertilization improved the tuber yield of potato by 49.5 to 82.1% over control.

Interaction effect

Experimental results revealed that maximum tuber yield for both the cultivars was obtained with 300 kg N ha^{-1}. Plant emergence of potato, plant height, number of shoots per plant and LAI were not significantly influenced by interaction of cultivars and N-levels (Table 1). It was also observed that grade wise tuber production was not significantly influenced by the interaction of cultivars and N-levels except in case of 25-50 g tuber grade (Table 2). Interaction effect of these two factors had no significant impact on the total potato tuber yield. However, highest tuber yield (25.77 t ha^{-1}) was recorded with Kufri Himalini receiving 300 kg N ha^{-1} followed by 24.64 t ha^{-1} and 23.64 t ha^{-1} with 225 kg N ha^{-1} and 150 kg N ha^{-1} respectively with the same variety which is quite higher than the state average of 22.02 t ha^{-1} obtained from the state recommended dose of 200 kg N ha^{-1}, 150 P_2O_5 ha^{-1} and150 K_2O ha^{-1}. Thus recently released variety Kufri Himalini, having moderate resistance against late blight can be a better option for the farmers of the state to raise the potato production. Lowest tuber yield (12.86 t ha^{-1}) was recorded with Kufri Shailja grown under control plot. It was also observed that Kufri Himalini was more responsive to fertilizer nitrogen than Kufri Shailja (Figure 1).

Nitrogen uptake efficiencies

Agronomic efficiency (AE_N) was higher in 'Kufri Himalini' potato at all levels of N compared to 'Kufri Shailja' (Table 3). Agronomic efficiency was the maximum at 75 kg N ha^{-1}, and decreased to lowest at highest N dose (300 kg N ha^{-1}). It decreased linearly with every incremental dose of N, confirming the findings of Love et al. (2005), Kumar et al. (2008) and Mozumder et al. (2014). Among the cultivars under study, maximum AE_N was observed when minimum dose of N was applied. This was due to the fact that input-output relationship follows the law of diminishing return as far as the relationship between N and yield is concerned. In general, agronomic use efficiency decreased with increasing dose of N. The efficient cultivars gave higher tuber yield under nutrient stress (i.e. with less dose of N) than less efficient cultivars. The main reason for higher nitrogen efficiency in the presence or absence of N was the capacity of a genotype to use/ absorb more N per unit from soil (Trehan, 2009). Thus 'Kufri Himalini' produced more yield with less dose of nitrogen. Apparent recovery (RE_N) was higher in 'Kufri Himalini' at all levels of N compared to 'Kufri Shailja'. Highest apparent recovery for both the cultivars were recorded at 150 kg N ha^{-1} and lowest with 225 kg N ha^{-1}. Physiological efficiency (PE_N) was recorded higher in 'Kufri Himalini' at all levels of N compared to 'Kufri Shailja'. In both the cultivars, physiological efficiency decreased with the increase in N level from 75 to 300 kg N ha^{-1}. Data also revealed that both the cultivars showed lower PE_N (42.1 and 37.2) with highest N level (300 kg N ha^{-1}).

Nitrogen balance

There was a positive balance of nitrogen in all treatments (Table 4). Fixed nitrogen might have been made available to potato and enriched the soil, resulting in positive balance of N observed in these treatments (Mozumder et al., 2014). Net gain (+) of N was highest in plots with 'Kufri Himalini' receiving N 150 kg N ha^{-1}. The lowest nitrogen balance was recorded in the plots with Kufri Shailja receiving 300 kg N ha^{-1}. In case of Kufri Shailja the nitrogen balance or net gain of soil nitrogen gradually decreased with the increase in the levels of nitrogen application, which was mainly due to increased N-uptake by the crop with the increase in the levels of nitrogen application resulting in to increased tuber yield.

Economics

The results showed that cultivation of newly released variety 'Kufri Himalini' is more profitable than 'Kufri Shailja' as Kufri Himalini gave highest net return (Rs. 56,704) with 300 kg N ha^{-1} (Table. 5). Next best net return (Rs. 50,902) was recorded with the same variety receiving 225 kg N ha^{-1}. Higher economic returns were obtained with 'Kufri Himalini' at higher N doses because of increased marketable and total tuber yield realized at higher N application.

CONCLUSION

It can be concluded that cultivation of 'Kufri Himalini' is more profitable than 'Kufri Shailja' as the cultivar met all the necessary requirements, especially higher yield, highest net returns and higher nitrogen uptake efficiency under new alluvial zone of West Bengal. Being more responsive to fertilizer nitrogen Kufri Himalini may be grown along with 300 kg N ha^{-1} to get the maximum net return.

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Table 1. Effect of newly released cultivars and nitrogen levels on growth of potato (pooled data of 4 years)

Treatment	Plant emergence (%)			Plant height (cm) at 70 DAP			No. of shoots/plant at 90 DAP			Leaf area index at 50 DAP		
	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean
N_0	91.04	91.67	91.36	50.81	45.56	48.19	3.31	3.13	3.22	0.32	0.23	0.28
N_{75}	96.46	91.25	93.85	74.25	62.00	68.13	5.38	4.00	4.69	0.84	0.78	0.81
N_{150}	92.08	91.46	91.77	80.81	72.06	76.44	5.50	4.5	5.00	0.91	0.87	0.89
N_{225}	90.00	90.63	90.31	86.88	75.69	81.28	5.75	4.06	4.91	0.98	0.90	0.94
N_{300}	94.58	91.04	92.81	83.00	73.69	78.34	5.89	3.63	4.76	1.09	0.93	1.01
Mean	92.83	91.21		75.15	65.80		5.17	3.86		0.83	0.74	
Factors	V	N	V ×N	V	N	V ×N	V	N	V ×N	V	N	V ×N
SEm(±)	0.8	1.3	1.9	1.0	1.6	2.3	0.2	0.3	0.4	0.02	0.1	0.6
CD (P=0.05)	NS	NS	NS	2.8	4.5	NS	0.5	0.8	NS	0.06	0.3	NS

V_1 = K. Himalini, V_2 = K. Shailja

Table 2. Effect of newly released cultivars and nitrogen levels on grade wise tuber yield and total tuber yield of potato (pooled data of 4 years)

Treatments	Yield of 0-25 g tuber (t ha^{-1})			Yield of 25-50 g tubers (t ha^{-1})			Yield of 50-75 g tubers (t ha^{-1})			Yield of > 75 g tubers (t ha^{-1})			Total potato yield (t ha^{-1})		
	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean	V_1	V_2	Mean
N_0	2.05	2.04	2.05	2.58	2.52	2.55	3.97	3.93	3.95	4.40	4.37	4.39	13.00	12.86	12.93
N_{75}	2.91	2.34	2.63	4.20	3.92	4.06	5.25	6.12	5.69	7.83	6.09	6.96	20.20	18.47	19.33
N_{150}	3.74	2.44	3.09	4.06	3.86	3.96	5.76	5.91	5.83	10.09	7.91	9.00	23.64	20.12	21.88
N_{225}	3.51	3.00	3.26	4.73	5.91	5.32	5.54	5.31	5.42	10.87	7.00	8.93	24.64	21.22	22.93
N_{300}	4.06	2.98	3.52	4.03	4.39	4.21	6.37	5.46	5.92	11.32	8.47	9.89	25.77	21.32	23.55
Mean	3.25	2.56		3.92	4.12		5.38	5.35		8.90	6.77		21.45	18.80	
Factors	V	N	V ×N	V	N	V ×N	V	N	V ×N	V	N	V ×N	V	N	V ×N
SEm(±)	0.13	0.20	0.28	0.17	0.26	0.37	0.18	0.29	0.41	0.29	0.46	0.64	0.56	0.88	1.24
CD (P=0.05)	0.4	0.6	NS	NS	0.7	1.0	NS	0.8	NS	0.8	1.3	NS	1.6	2.5	NS

V_1 = K. Himalini, V_2 = K. Shailja

Table 3. Nitrogen uptake efficiencies of potato as influenced by the cultivars and levels of N (Mean data of 4 years)

Nitrogen levels ($kg\ ha^{-1}$)	Agronomic Efficiency (AE_N)		Apparent Recovery (RE_N)		Physiological Efficiency (PE_N)	
	K. Himalini	K. Shailja	K. Himalini	K. Shailja	K. Himalini	K. Shailja
N_0	-	-	-	-	-	-
N_{75}	96.0	74.8	1.08	0.86	89.2	87.0
N_{150}	70.9	48.4	1.17	0.90	60.7	56.2
N_{225}	51.7	37.2	0.97	0.75	53.5	49.4
N_{300}	42.6	28.2	1.01	0.76	42.1	37.2

Table 4. Nitrogen balance ($kg\ N\ ha^{-1}$) in soil after harvest of potato as influenced by cultivars and N levels (Mean data of 4 years)

Treatment combination	Initial soil N status (a)	N added through fertilizer (b)	Total N (c=a+b)	Crop uptake (d)	Expected balance (e=c-d)	Actual balance (f)	Net gain (+) or loss (-) (f-e)
V_1N_0	183.26	0	183.26	127.4	55.86	131.2	75.34
V_1N_{75}	183.26	75	258.26	208.1	50.16	126.1	75.94
V_1N_{150}	183.26	150	333.26	302.6	30.66	132.1	101.44
V_1N_{225}	183.26	225	408.26	345	63.26	134.8	71.54
V_1N_{300}	183.26	300	483.26	430.4	52.86	137.4	84.54
V_2N_0	183.26	0	183.26	125.1	58.16	133.5	75.34
V_2N_{75}	183.26	75	258.26	189.6	68.66	129.2	60.54
V_2N_{150}	183.26	150	333.26	254.2	79.06	135.3	56.24
V_2N_{225}	183.26	225	408.26	294.2	114.06	138.8	24.74
V_2N_{300}	183.26	300	483.26	352.8	130.46	142.3	11.84

V_1 = K. Himalini, V_2 = K. Shailja

Table 5. Economics of potato production per hectare as affected by cultivars and N levels

Treatments	Yield (t ha^{-1})	Cost of cultivation (Rs ha^{-1})			Cost (Rs ha^{-1})		Sale price (Rs.t^{-1})	Net returns (Rs.ha^{-1})
		Seed	Fertilizer	Cultivation	Inputs	Produce		
V_1N_0	13.00	32000	12004	50000	94004	78000	6000	-16004
V_1N_{75}	20.20	32000	12978	50000	94978	121200	6000	26222
V_1N_{150}	23.64	32000	13960	50000	95960	141840	6000	45880
V_1N_{225}	24.64	32000	14938	50000	96938	147840	6000	50902
V_1N_{300}	25.77	32000	15916	50000	97916	154620	6000	56704
V_2N_0	12.86	32000	12004	50000	94004	77160	6000	-16844
V_2N_{75}	18.47	32000	12978	50000	94978	110820	6000	15842
V_2N_{150}	20.12	32000	13960	50000	95960	120720	6000	24760
V_2N_{225}	21.22	32000	14938	50000	96938	127320	6000	30382
V_2N_{300}	21.32	32000	15916	50000	97916	127920	6000	30004

V_1 = K. Himalini, V_2 = K. Shailja

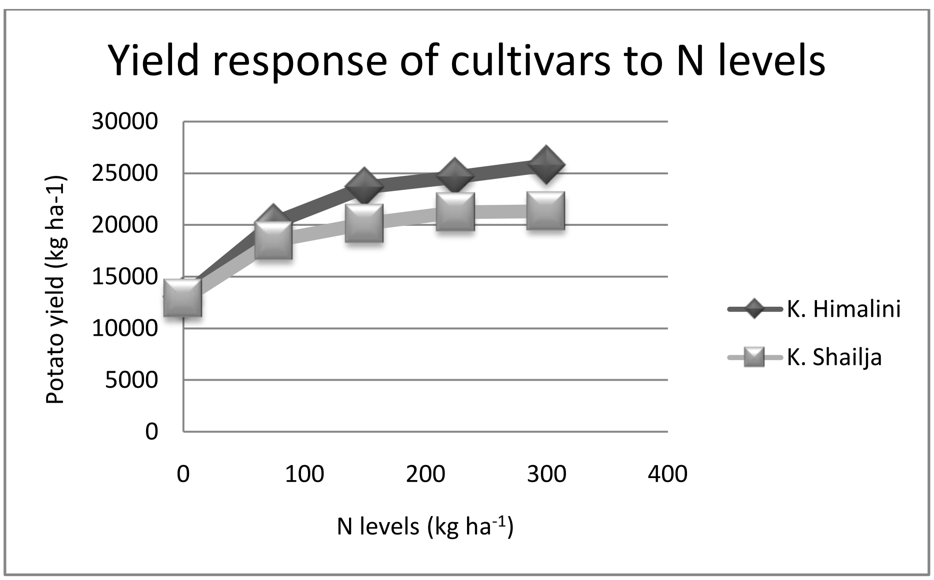

Figure 1. Yield response of two potato cultivars to Nitrogen level