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Response of Heat Tolerant Variety (Kufri Surya) of Potato (*Solanum tuberosum*) under Different Levels of Nitrogen

Urjashi Bhattacharya[1*], Augustina Saha[2] and Asok Saha[3]

[1]Department of Agronomy, Faculty of Agriculture, Bidhan Chandra Krishi Viswavidyalaya (B.C.K.V), Mohanpur, West Bengal – 741252, India.
[2]Directorate of Plant Protection, Quarantine and Storage, Regional Plant Quarantine Station, Kolkata, West Bengal-700097, India.
[3]Department of Agronomy, Faculty of Agriculture, Uttar Banga Krishi Vishwavidyalaya (U.B.K.V), Pundibari, Cooch Behar, West Bengal-736165, India.

Authors' contributions

This work was carried out in collaboration among all authors. Author UB performed the study, the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author Augustina Saha managed the literature searches. Author Asok Saha designed the study and managed the analyses of the study. All authors read and approved the final manuscript.

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ABSTRACT

Keeping in view, the deficiency of detailed information on adoption of heat tolerant potato (*Solanum tuberosum*) variety 'Kufri Surya' in Terai Agro-Climatic situation of West Bengal, the field experiment was conducted at the Instructional farm of Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar, West Bengal during the *rabi* season of 2016 to study the effect on heat tolerant variety (Kufri Surya) with different nitrogen levels. Experiment was laid out in a Split-plot design taking two varieties 'Kufri Jyoti' and 'Kufri Surya' as main plot with six different levels of nitrogen of 0 kg N ha^{-1}, 50 kg N ha^{-1}, 100 kg N ha^{-1}, 150 kg N ha^{-1}, 200 kg N ha^{-1} and 250 kg N ha^{-1} as subplot. Results of

**Corresponding author: E-mail: urjashibhattacharya@gmail.com;*

the experiment showed that the higher values of the growth attributes like dry matter accumulation, leaf area index, in all the sampling dates of experimentation was recorded with 100 kg N ha^{-1}. Owing to the higher leaf area index and dry matter accumulation in shoot, tuber yield was recorded highest from the treatment having 100 kg N ha^{-1} (28.46 t ha^{-1}).

Keywords: Potato; nitrogen; Kufri Surya; Kufri Jyoti; heat tolerant variety.

1. INTRODUCTION

Potato (*Solanum tuberosum* L.) is the third most important food crop in the world after rice and wheat in terms of human consumption. India ranks as the world's 2^{nd} largest potato producing nation after China. Production in India is about 48.52 million tonnes [1] of which 26% are produced by West Bengal itself. Potato is a cool season long day crop. High temperatures and long days favour assimilate partitioning to the above ground vegetative parts, as a result, above ground bio-mass and plant height is increased and tuber yield is reduced [2]. Potato gives good yield at day temperature of 30-35°C. But if night temperature go beyond 22°C, there will be little tuberization even when day temperature is 25-27°C. Due to intense climate change the favourable temperatures for its growth is increased at its later stages hampering the tuberization. On this context, whether the heat tolerant variety ‘Kufri Surya’ could perform better than check variety ‘Kufri Jyoti’ was brought into notice from the experiment. Nitrogen is beneficial for the tuber quality, dry matter production, size of tubers etc. More application of nitrogen fertilizers can increase size of tubers and hence the yield but there is a particular dose limit up to which it will show positive results; beyond that limit the application of nitrogen fertilizer will not increase the yield but rather it would be harmful because of deposition of nitrogen in tubers in the form of nitrates [3] which is not at all favourable for human consumption and moreover excessive application can cause environmental pollution. The use of low N results in reduction in yield of potato. Judicious use of balanced dose of fertilizers is very critical for higher tuber yield. Keeping the above facts in view, a field experiment was undertaken to study the effect of different levels of nitrogen on growth and yield of potato cultivars ‘Kufri Surya’ and check variety of ‘Kufri Jyoti’.

2. MATERIALS AND METHODS

A field experiment was conducted to study the effect of different doses of nitrogen on two different varieties of potato that is, ‘KufriJyoti’ and heat tolerant variety ‘Kufri Surya’ at Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Bihar, West Bengal during *rabi* season of 2016. The farm is situated at 26°12'78"N latitude and 89°24'55" E longitude at an elevation of 43 meters above mean sea level. The climatic zone where the farm is situated is in *Terai* zone which is subtropical in nature having its prominent characteristics of very high rainfall, high humidity and a prolonged winter season. The average rainfall of this zone varies from 2000-3000 mm. The soil of the experimental field was sandy loam in texture, a true representative of the *terai* region of West Bengal with a pH of 5.6 .The experiment was carried out in split plot design with two varieties of potato ‘Kufri Surya’ and ‘Kufri Jyoti’ as main plots and six nitrogen levels as subplots i.e, 0 kg N ha^{-1}, 50 kg N ha^{-1}, 100 kg N ha^{-1},150 kg N ha^{-1},200 kg N $ha^{-1}$and 250 kg N ha^{-1}. The experiment had three replications with a plot size of 5m x 3.45 m and a spacing of 45 x 15 cm. The crop was planted on 26^{th} November of 2016 and harvested on 4^{th} March of 2017.

Healthy cut tubers were selected each having two-three eyes weighing 25-40 g. The seed tubers were treated to protect them from an attack of fungal diseases when planted in the field. So, before planting, the seed tubers were dipped in solution of Acetochlor @ 2.5 g $lit.^{-1}$+ streptomycin (Plantamycin) @ 2.5 g $lit.^{-1}$ of water for 15 minutes and then they were dried in shade to protect it from direct sunlight prior to planting. Farmyard manure was applied on the field @ 5t ha^{-1} at the time of final land preparation. The different doses of nitrogen were 0, 50, 100, 150, 200 and 250 kg N ha^{-1}+ 100 kg P_2O_5 ha^{-1}+100 kg K_2O ha^{-1} were given respective plots. Out of these doses 1/3rd of nitrogen and full dose of P_2O_5 and full dose of K_2O were applied as basal at the time of planting of tubers. The rest half of the 2/3rd nitrogen was given in two equal splits, one as first top dressing at 21 DAP (days after planting) and the second split of Nitrogen was applied at second top dressing at 41 DAP. The fertilizers were applied by broadcasting method in the form of Urea, Single Super Phosphate (SSP) and Muriate of Potash (MOP) as the sources of N, P_2O_5 and K_2O respectively. Two irrigations were given to the crop. First irrigation was given at 22 DAP after first top dressing and earthing up. Second irrigation was given at 44 DAP after second top dressing. Before 10 days of harvesting of the crop dehaulming was done.

The growth attributes like number of haulms per plant, leaf area index (LAI), crop growth rate (CGR), net assimilation rate (NAR) were recorded at 20, 40, 60 and 80 DAP (days after planting). The photosynthetic and transpiration parameters like net photosynthesis rate, leaf stomatal conductance, transpiration rate were recorded at 20, 40, 60 DAP. Since at 80 DAP plants starts showing senescence no parameters were recorded. Though the photosynthetic and transpiration parameters were recorded by the instrument CI -340 Handheld Photosynthesis system.

The CI-340 Handheld Photosynthesis System is a portable, light-weight single-handed tool that measures photosynthesis, respiration, transpiration, stomatal conductance, PAR and internal CO_2. It was designed for field use. It has some optional accessory modules which allow researchers to control CO_2, H_2O, temperature, light intensity, and measure chlorophyll fluorescence, while the ten different customized chambers can accommodate any leaf size, including conifer needles and cacti. Direct chamber connection to the CO_2/H_2O gas analyzer reduces measurement delay and enables rapid measurement of gas exchange with minimal delay. For measurement of photosynthetic activity, simply a potato leaf was secured within the CI-340 chamber and thereby “ambient” or “closed” system measurement was choosen. In moments, leaf function data was recorded and stored in the instrument, as the CI-340 analyzed photosynthesis rate, transpiration rate, and stomatal conductance rate. The data was downloaded from computer afterwards from the data memory chip present in the instrument.

Theory of how the CI-340 Handheld Photosystem works is as follows: The rate at which photosynthesis occurs is determined by measuring the rate at which a known leaf area assimilates the CO_2 concentration in a given time. It is known that transpiration is the primary determinant of leaf energy balance and plant water status. The rate of transpiration is determined by the accumulation of water vapor flux per one-sided leaf area in a given time. Stomatal conductance is the water loss of a leaf’s conductance considered in parallel or series. It can be obtained by measuring the transpiration and leaf surface temperature (°C).The required parameters can be obtained by applying following calculations [4].

The Net Photosynthesis Rate (Pn) (micro mol m^{-2} s^{-1}) is calculated by the following formula:

$$Pn = -W \times (C_0 - C_i) = -2005.39 \times (V \times P / T_a \times A) \times (C_0 - C_i)$$

Where, C_0(C_i): outlet (inlet) CO_2 concentration (ppm or micro mol/ mol)

W = Mass flow rate per leaf area, V = Leaf chamber volume,T_a = air temperature (K), P = Atmospheric pressure (bar) ,A = Leaf area (cm^2).

The Transpiration Rate (E) (milimol m^{-2} s^{-1}) was calculated by:

$$E = (e_0 - e_i / P - e_0) \times W \times 10^3$$

$$e_0 = hr_0 \times es100^{-1}$$
$$e_i = hr_i \times es100^{-1}$$

Where, e_0(e_i): Outlet (inlet) water vapour (bar), W = Mass flow rate per leaf area ,T_a = air temperature (K) ,P = Atmospheric pressure (bar), hr_0 (hr_i) = Outlet (inlet) relative humidity (%).

$$\text{Leaf Stomatal Conductance} = W / (e_{leaf} - e_0 / e_0 - e_i) \times (p - e_0 / p) \times 1000$$

Where, eleaf = saturated water vapour at leaf temperature (bar) W = Mass flow rate per leaf area, P = Atmospheric pressure (bar), e0 (ei): outlet (inlet) water vapour (bar) Rb = leaf boundary layer resistance (m^2s mol^{-1}) 0.3 m^2s mol^{-1} is used. Observation were done at 20, 40, 60 DAP.

The data collected from the field and laboratory experiments were subjected to statistical analysis with appropriate design and treatment variations were tested for significance by F-test [5]. The standard error of mean and critical difference is indicated in the tables. For determination of critical difference at 5% level of significance Fisher and Yate [6] table was consulted. The statistical analysis was evaluated by SPSS software.

3. RESULTS AND DISCUSSION

3.1 Effect on Growth Attributes and Yield

Among the two varieties ‘Kufri Surya’ and ‘Kufri Jyoti’ both of them have given statistically similar results for most of the growth attributes at 20 and 80 DAP. This was because at 20 DAP the plants are yet to be developed because of its early stages of growth and at 80 DAP the plants started showing symptoms of senescence in stems and leaves. But quite significant differences were observed when the observations were taken at 40 and 60DAP because it was the peak period of vegetative growth of the potato crop. In case of number of haulms per plant at any stages of the crop there were no significant differences among the varieties. At 40 and 60 DAP it was observed that ‘Kufri Jyoti’ had performed 29% better than ‘Kufri Surya’ at 40 DAP and 24% better at 60 DAP. This can be pertained to ‘Kufri Jyoti’ having higher leaf area than ‘Kufri Surya’ whose leaves are narrower in shape resulting in lesser leaf area. Dry matter accumulation at 40 DAP was 19% more in ‘Kufri Jyoti’ because of more leaf area index, for which photosynthesis was more resulting in better accumulation of photosynthates and at 60 DAP Kufri Surya (303.13 g m^{-2}) performed better than Kufri Jyoti (279.53 g m^{-2}). This was due to mild attack of *Phoma spp.* on Kufri Jyoti at 60 DAP for which growth of the plant was hampered. In case of crop growth rate Kufri Jyoti performed better at 20-40 DAP (7.315 g m^{-2} day^{-1}) and at 40-60 DAP Kufri Surya (8.569 g m^{-2} day^{-1}) gave maximum crop growth rate. Crop growth rate was hampered for Kufri Jyoti due to the same reason for which the dry matter accumulation was less at 60 DAP. Net assimilation rate which is the amount of dry matter produced in gram per unit area of leaf per day was found significant at 40-60 DAP for both the varieties due to its peak period of growth in which Kufri Surya has performed 65% better than Kufri Jyoti at 40-60 DAP as it was resistant to pathogen attack. Though Kufri Jyoti (25.80 t ha^{-1})was mildly affected by *Phoma* spp. at 60DAP,timely control measures had helped immensely to revert back its negative effects on yield and hence had shown better yield compared to Kufri Surya (19.76 t ha^{-1}). The reasons might be due to bigger size and weight of tubers per plant in case of Kufri Jyoti [7].

Nitrogen is a very essential nutrient for growth of plants because its an important constituent of key photosynthetic enzyme RuBP carboxygenase / oxygenase. Total sugar accumulation in leaves and tubers are positively influenced by nitrogen application. Total sugar increased with the rate of N-fertilizer application. The higher sugar content was due to higher photosynthetic rate, which is enhanced due to enzymatic activity. Increase in nitrogen levels increases the carbohydrate production by more number of chlorophylls. But there is a limit of nitrogen application beyond which if nitrogen fertilizers are added the plants won’t show a positive result. It was observed that number of haulms increased linearly with increase in dose of nitrogen since nitrogen has a positive role in increase in vegetative growth of plant [8]. There was significant difference for most of the growth attributes in all the stages among the various nitrogen levels except 20 DAP because of early stages of growth. So, in 40 DAP maximum number of haulms were observed in the treatment of 200 kg N ha^{-1} (3.35) and in 60 DAP for 250 kg N ha^{-1} (5.75). For dry matter accumulation 100 kg N ha^{-1} was found optimum for the maximum dry matter production at 40 DAP(171.46 g m^{-2}) and 60 DAP (322.25 g m^{-2}). These results were in accord with the findings of [9,10]. This might be assigned to LAI at 40 DAP and 60 DAP having the highest value for 100 kg N ha^{-1} as it was optimum amount nitrogen required for enlargement of leaves resulting in production of more photosynthates . Crop growth rate among the various nitrogen levels for both 20-40 DAP and 40-60 DAP were statistically at par with each other. There was no significant difference among the various nitrogen levels in 20-40 DAP except 40-60 DAP. Maximum net assimilation rate (g m^{-2} day^{-1}) was observed at 200 kg N ha^{-1} in 40-60 DAP (1.087). Highest yield was obtained at 100 kg N ha^{-1} due to better tuber development at the optimum level [11].

3.2 Effect on Photosynthetic Parameters

There were significant differences among the varieties, maximum net photosynthesis rate was observed in 20 DAP (7.7 micro mol m^{-2} s^{-1}), 40 DAP (14.77micro mol m^{-2} s^{-1}) in KufriJyoti and in 60 DAP in Kufri Surya (10.88 micro mol m^{-2} s^{-1}) which might be due to the possible reason of attack of pathogen on Kufri Jyoti hampering its healthy leaf growth and hence the photosynthetic activity. Both the varieties were statistically at par with each other with respect to transpiration rate. Maximum stomatal conductance rate was in Kufri Surya (269.42 millimol m^{-2} s^{-1}) at 20 DAP, in Kufri Jyoti (368.55 millimol m^{-2} s^{-1}) at 40 DAP which might be due to faster development of leaves of Kufri Surya at 20 DAP and better development of leaves and number of stomata in Kufri Jyoti at 40 DAP.

Table 1. Effect of variety and nitrogen levels on number of haulms per plant, LAI and dry matter accumulation of plant

Treatments	Number of haulms per plant			Leaf area index(LAI)				Dry matter accumulation(g m^{-2})			
Variety	**20 DAP**	**40 DAP**	**60 DAP**	**20 DAP**	**40 DAP**	**60 DAP**	**80 DAP**	**20 DAP**	**40 DAP**	**60 DAP**	**80 DAP**
V_1	2.50	2.87	4.47	0.15	3.98	4.46	2.20	8.26	150.97	279.53	274.55
V_2	2.38	2.93	5.00	0.14	3.08	3.60	2.10	8.68	131.75	303.13	272.66
SEm(+)	0.01	0.03	0.59	0.05	0.12	0.02	0.09	0.24	2.83	1.18	.94
CD(0.05)	NS	NS	NS	NS	0.72	0.10	NS	NS	17.24	7.18	NS
Nitrogen levels											
N_0	2.15	2.25	3.40	0.11	3.04	3.39	1.78	7.21	112.78	218.01	218.33
N_1	2.40	2.65	4.30	0.12	3.50	3.77	1.93	8.25	136.15	290.72	261.76
N_2	2.70	2.90	5.05	0.13	4.40	4.70	2.45	9.53	171.46	322.25	327.76
N_3	2.30	3.05	5.00	0.19	4.01	4.18	2.69	8.54	154.28	321.60	306.71
N_4	2.75	3.35	4.90	0.17	3.10	4.53	1.97	9.15	128.46	297.72	263.63
N_5	2.35	3.20	5.75	0.16	3.14	3.60	2.11	8.15	145.03	297.66	263.44
SEm(+)	0.17	0.13	0.20	0.01	0.14	0.10	0.06	0.41	3.88	7.34	5.75
CD(0.05)	NS	0.39	0.58	NS	0.41	0.30	NS	NS	11.46	21.65	16.96

V1-Kufri Jyoti, V2-Kufri Surya.N0-0 kg ha^{-1}, N1-50 kg ha^{-1}, N2-100 kg ha^{-1}, N3- 150 kg ha^{-1},N4-200 kg ha^{-1}, N5-250 kg ha^{-1}

Table 2. Effect of variety and nitrogen levels on crop growth rate, net assimilation rate and yield of crop

Treatments	Crop growth rate (g m^{-2})		Net assimilation rate(g m^{-2} day^{-1})		Yield(t ha^{-1})
Variety	**20- 40 DAP**	**40-60 DAP**	**20-40 DAP**	**40-60 DAP**	
V_1	7.135	6.428	2.734	0.679	25.80
V_2	6.153	8.569	2.825	1.120	19.76
SEm(+)	0.130	0.083	0.057	0.045	0.19
CD(0.05)	0.789	0.503	NS	0.142	1.17
Nitrogen levels					
N_0	5.278	5.262	2.458	0.641	9.28
N_1	6.395	7.729	2.832	0.789	20.45
N_2	8.116	6.313	2.861	0.985	28.46
N_3	7.287	8.366	2.954	0.905	26.78
N_4	5.947	9.690	2.555	1.087	26.08
N_5	6.844	7.632	3.016	0.991	25.63
SEm(+)	7.135	6.428	0.082	0.061	0.45
CD(0.05)	NS	NS	NS	0.179	1.33

V1-Kufri Jyoti, V2-Kufri Surya.N0-0 kg ha^{-1}, N1-50 kg ha^{-1}, N2-100 kg ha^{-1}, N3- 150 kg ha^{-1},N4-200 kg ha^{-1}, N5-250 kg ha^{-1}

Table 3. Effect of variety and nitrogen levels on photosynthetic parameters

Treatments	Stomatal conductance rate (millimol m^{-2} s^{-1})			Transpiration rate (millimol m^{-2} s^{-1})			Net photosynthesis rate (micro mol m^{-2} s^{-1})		
Variety	**20 DAP**	**40 DAP**	**60 DAP**	**20 DAP**	**40 DAP**	**60 DAP**	**20 DAP**	**40 DAP**	**60 DAP**
V_1	235.43	368.55	355.63	1.06	2.80	2.85	7.77	14.17	9.19
V_2	269.42	343.33	365.55	0.99	3.19	2.95	5.66	12.64	10.88
SEm(+)	1.44	2.79	0.58	0.07	0.05	0.05	0.04	0.02	0.23
CD(0.05)	8.76	16.98	NS	NS	0.30	NS	0.27	0.10	1.42
N_0	220.60	315.27	355.89	0.72	3.18	2.04	4.29	11.94	7.97
N_1	229.09	333.97	353.43	1.01	2.44	2.54	5.45	13.14	8.77
N_2	244.39	365.07	387.76	1.04	2.94	3.04	7.46	13.60	9.34
N_3	292.51	389.69	395.33	1.33	3.68	3.54	10.15	15.05	12.52
N_4	258.91	371.73	349.98	1.02	2.85	3.13	7.16	13.07	11.49
N_5	269.06	359.92	321.16	1.04	2.87	3.09	5.77	13.65	10.14
SEm(+)	2.49	3.96	10.02	0.09	0.10	0.09	0.21	0.16	0.15
CD(0.05)	7.35	11.68	29.57	0.26	0.29	0.26	0.62	0.47	0.44

V1-Kufri Jyoti, V2-Kufri Surya.N0-0 kg ha^{-1}, N1-50 kg ha^{-1}, N2-100 kg ha^{-1}, N3- 150 kg ha^{-1},N4-200 kg ha^{-1}, N5-250 kg ha^{-1}

Significant differences were observed between different nitrogen levels for various photosynthetic parameters. All the photosynthetic characters have been recorded maximum at 150 kg N ha^{-1}. Stomatal conductance rate is the rate at which carbon dioxide is uptaken and water vapour is released through stomata. Nitrogen plays an important role in stomatal conductance by cell expansion and altering the cation and anion concentration of cytoplasmic environment which can actually change the stomatal conductance rate [12]. More nitrogen application also increases the leaf growth and hence the number of stomata increasing the stomatal conductance rate. Highest stomatal observations were found at 150 kg nitrogen ha^{-1}, for all the stages with a maximum of 395.33 millimol m^{-2} s^{-1} at 60 DAP because this was the optimum dose above which no such effect was seen. Since stomatal conductance rate is closely related with transpiration rate, maximum transpiration rate similarly observed at 150 kg N ha^{-1} at all stages of growth. Net photosynthetic rate may be assigned to the possible reasons of larger number of chlorophyll and stomata due to optimum doses of nitrogen.

4. CONCLUSION

From the above experiment it can be concluded that Kufri Surya didn't perform better than check variety Kufri Jyoti because the high temperature at which Kufri Surya might have shown better performance with respect to yield than Kufri Jyoti due to its heat tolerant characteristics which was not obtained.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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