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Hussain S
1. Department of Horticulture, FAST AKS University, Satna, Madhya Pradesh, India
2. Research Scholar, Department of FLA, CoA, IGKV Krishak Nagar, Raipur, Chhattisgarh, India

Nag K
1. Department of Horticulture, FAST AKS University, Satna, Madhya Pradesh, India
2. Research Scholar, Department of FLA, CoA, IGKV Krishak Nagar, Raipur, Chhattisgarh, India

Singh T
Department of Horticulture, FAST AKS University, Satna, Madhya Pradesh, India

Correspondence
Hussain S
Nag K
1. Department of Horticulture, FAST AKS University, Satna, Madhya Pradesh, India
2. Research Scholar, Department of FLA, CoA, IGKV Krishak Nagar, Raipur, Chhattisgarh, India

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Effect of nitrogen levels and size of tuber on growth, yield of potato (*Solanum tuberosum* L.) Var. *Kufri Badshah*

Hussain S, Nag K and Singh T

Abstract
The treatments comprised four nitrogen levels (0, 80, 100 and 120 kg/ha) and three size of tuber (25, 35 and 45 g). The significantly tallest plants were recorded with the application of N_{120} at all the growth stages. The height was up to 77.93 cm at harvest stage, where as it was only 53.94 cm under N_0 nitrogen. The highest plant height was recorded by largest 45 g tuber size at all the stages of observations. The lowest height was noted from smallest 25 g tuber size. At harvest stage, 45 g tuber size recorded 67.47 cm height as against only 63.30 cm under 25 g tuber sizes. The varying levels of nitrogen showed significant effect upon number of branches/plant at all the stage of observations. At harvest stage, the maximum branches were 4.73/plant due to N_{120}, where as minimum 3.11/plant under without nitrogen. The tuber size of 45 g recorded significantly more branches/plant over 25 g tuber sizes only at every stage. At harvest stage, maximum branches from 45 g tuber size were 4.09/plant which were decreased to 3.73/plant under 25 g tuber size. The significantly highest leaves/plant was recorded due to N_{120} over the preceding N-levels at every stage. The maximum leaves count at N_{120} was 58.29/plant at against only 43.18/plant under N_0 nitrogen. The largest tuber size (45 g) recorded non-significantly highest leaves count at 30 and 60 DAS, but significantly highest (51.31/plant) at harvest stage. The smallest tuber size (25 g) recorded minimum leaves count at every stage (50.60 cm at harvest). The stem diameter was influenced significantly due to N-levels at every stage. At harvest stage, N_{120} resulted in significantly highest stem diameter (6.24 cm) over all the preceding N-levels.

Keywords: Potato (*Solanum melongena* L.), *Kufri Badshah*, nitrogen level, tuber size, growth, yield & quality

Introduction
Potato (*Solanum tuberosum* L.) is one of the most important vegetables having high production per unit area as well as per unit time. Potato production can effectively help not only in enhancing potato requirement of large segment of population, however produces more calories per unit time than any other major food crops. Manorial requirement of potato crop is quite high and the application of fertilizer and organic manures are considered essential to obtain high economic yields (Grewal, 1990) [7]. Nitrogen is the first limiting factor for potato crop, it improves the vegetative growth and increase the tubers per plant as well as tuber size. Quick availability of nitrogen in the soil accelerates root growth. Seed tubers with early and well established root system ensure quick emergence of the plant above the ground. At the time of planting, nitrogen must be available in adequate quantity to stimulate root growth in the seed tuber. The application of nitrogen invariably increase yield. The potato plants with sufficient nitrogen are characterized by vigorous growth, increased leaf area, large tuber size as well as number. Nitrogen is the major nutrient in potato production and much variability exists in nitrogen requirements between cultivars. Cultivars generally show increased yield as nitrogen rate is increased (Belanger *et al.*, 2000 and Arsenault *et al.*, 2001) [3, 2]. However, excessive nitrogen lead to poor tuber quality, delayed crop maturity and excessive nitrate leaching, while nitrogen deficiency usually result in poor growth and low yields. Nitrogen is necessary to the potato from germination to maturity. The demand for this nutrient increases rapidly after germination and falls when 75 percent of the plant growth is completed.

Any delay in making this nutrient available, particularly during early active phases of growth, result in a set back to the crop. Information on the optimum dose of nitrogen to be applied for potato crop under different agro-climatic condition is necessary for a judicious use of fertilizer and also to obtain higher yields. Fertilizer trails conducted during the past years at the regional centers of the Central Potato Research Institute, have shown that potato invariably responds to inorganic nitrogen, phosphorus and potash, Hence, it was considered appropriate to initiate the research work on nitrogen requirement for the crop grown through seed tubers, as nitrogen is primarily important for the crop and on the other hand, soils of M.P. state are also deficient in nitrogen.

Materials and Methods

The present investigation was carried out in the well protected field of the experimental farm, AKS University, Satna (M.P.). The field experiment was conducted during *rabi* (winter) season of 2016-17.

Details of the experiments

Table 1: Treatment combinations

$W_1 N_0$	$W_2 N_0$	$W_3 N_0$
$W_1 N_1$	$W_2 N_1$	$W_3 N_1$
$W_1 N_2$	$W_2 N_2$	$W_3 N_2$
$W_1 N_3$	$W_2 N_3$	$W_3 N_3$

Table 2: The experimental details are as follows

Name of crop	**:**	**Potato (*Solanum tuberosum* L.)**
Design	:	Factorial Randomized Block Design
Replications	:	03
Treatments	:	12
Replication distance	:	75 cm
Plot distance	:	50 cm
Row to row distance	:	60 cm
Tuber size	:	25, 35 and 45 g
Nitrogen levels	:	0, 80, 100 and 120 kg/ha
Variety	:	*Kufri badshah*

Results

(A) Growth parameters

(i) Plant height

The height at the initial stage on 30 DAS, in general, ranged from 8.88 to 21.14 cm under various treatments. The height went up to more than thrice up to the harvest stage i.e. ranging from 53.94 to 77.93 cm under different treatments. As regards with the applied treatments, nitrogen levels exerted significant influence upon this parameters at every stage of observations. The increasing levels of nitrogen up to N_{120} increased the plant height almost significantly at every stage. Accordingly, at the harvest stage, the plant height went up to 77.93 cm due to N_{120} as against only 53.94 cm under N (no nitrogen). Thus N_{120} proved significantly superior to rest of the N-levels at every stage of observations.

(ii) Number of branches/plant

The formation of branches at 30 DAS stage ranged from 1.09 to 1.93/plant in different treatments. The branches enhanced up to more than twice at harvest stage i.e. 1.11 to 4.73/plant due to various treatments. The different nitrogen levels and size of tuber brought about significant influence upon this parameter at every stage of observations. However, applied N-levels × tuber size interactions were found to be non-significant. Application of nitrogen up to P_{120} brought about significant increase in this parameter at every stage of observations. According nitrogen, up to N_{120} resulted in significant rise in the formation of branches/plant. Thus N_{120} proved significantly superior to rest of the N-levels at every stage. The number of branches, at harvest stage, was up to 4.73/plant with P_{120} as compared to only 3.11/plant under without nitrogen. The different size of tuber influenced the number of branches/plant significantly at every stage. Thus largest tuber size (45 g) enhanced this parameter significantly as compared to the smaller size tubes. At harvest stage, branches were 4.09/plant over 3.73 branches under 25 g tuber size.

(iii) Number of leaves/plant

The number of leaves/plant was counted treatment wise periodically and the data so obtained were subjected to statistical analysis. Accordingly the leaves formation became more than three fold up to the harvest stage. At 30 DAS, the leaves, in general, ranged from 8.98 to 17.27/plant in different treatments. At harvest stage the leaves count reach from 43.18 to 58.29/plant due to various treatments. The different N-levels exerted significant influence upon this parameter at every stage of observations. The tuber size influences this parameter significantly only at harvest stage. Similarly treatment interactions were also significant at harvest stage only. The highest level of nitrogen (N_{120}) increased the leaves count significantly over the preceding N-levels at every stage. At harvest stage, the maximum leaves were 58.29/plant as against only 43.18/plant under without nitrogen. The tuber size up to 45 g resulted in significantly higher leaves count 51.31/plant as compared to 25 and 35 g tuber size (50.60 to 50.73/plant). This was noted at harvest stage.

(iv) Stem diameter

The results presented that the stem diameter of potato was enhanced at the faster rate between 30 and 60 DAS growth period thereafter increased very slightly up to the harvest stage. The stem diameter, in general, ranged from 3.38 to 4.49 cm at 30 DAS in different treatments. At harvest stage it ranged from 5.60 to 6.24 cm. Nitrogen levels exerted significant influence upon this parameter at every stage of observations. The maximum N-level (N120) resulted in significantly higher stem diameter over the preceding N-level. Thus at harvest stage, the stem diameter under N_{120} was 6.24 cm as against only 5.60 cm under N_0. The tuber size brought about significant impact upon this parameter only at 60 DAS and harvest stages. Thus almost significantly higher stem diameter i.e. 5.51 and 5.93 cm was obtained due to 45 g tuber size at 60 DAS and harvest stages, respectively. The corresponding values were 5.40 and 5.78 cm due to 25 g tuber size of potato.

(B) Yield-attributing characters

(i) Number of tubers/plant

The mean data were subjected to statistical analysis and thereafter presented at this yield-attributing parameter was influenced significantly due to nitrogen levels but not due to tuber size as well as their interactions. There was significant increase in number of tubers/plant up to N_{120} level of nitrogen where the number of tuber was 27.33/plant. The tubers count was significantly lowest (20.27/plant) in case of without nitrogen. The different size of tubers did not change significantly the number of tubers formation /plant. It ranged

from 23.65 tubers in case of 25 g tuber size to 24.0 tubers/plant in case of 45 g tuber size.

(ii) Fresh weight of tubers/plant

The perusal of data in revealed that the fresh tuber weight/plant was influenced significantly due to nitrogen levels but not due to size of tubers and the treatment interactions. Each increment in N-levels up to N_{120} brought about significant rise in the fresh tuber weight (194 g/plant). Thus, N_{100} was also found significantly superior to all the lower levels of nitrogen. The significantly lowest tuber weight (24.1 g) was obtained from without nitrogen. There was very slight rise in tuber weight due to increasing size of tubers, thus the fresh tuber weight ranged from 264 to 267 g/plant.

Table 1: Fresh weight of tubers/plant (g) of potato at harvest as influenced by N-levels, size of tuber.

Nitrogen levels (kg/ha)	Size of tuber (g)			
	25	**35**	**45**	**Mean**
0	232	248	242	241
80	263	253	260	259
100	272	271	278	274
120	289	296	297	294
Mean	264	267	269	
S.Em+	4.18	3.62	7.24	
C.D. (P=0.05)	12.26	NS	NS	

(ii) Dry weight of tubers/plant

Application of nitrogen levels only exerted significant influence upon this parameter. In addition to tuber size, the treatment interactions were also found to be non-significant. This parameter changed up to significant extent due to nitrogen levels applied up to N_{120}. Accordingly, the maximum dry weight/plant noted (51.17 g) from N_{120}, followed by N_{100} (46.51 g) and then N_{80} (42.73 g). The significantly lowest weight (38.56 g) was noted from N_0. The increasing size of tubers brought about no any significant enhancement in dry weight of tubers, the value ranged from 43.95 to 45.25 g/plant.

(iii) Number of tubers/plot

Application of nitrogen levels as well as tuber size exerted significant influence upon the number of tubers per plot. However the treatment interactions were found to be non-significant. This parameter changed up to significant extent due to nitrogen levels applied up to N_{120}. Accordingly, the maximum tuber count was noted (132/plot), followed by N_{100} (127 tubers) and then N_{80} (119 tuber). The significantly lowest tuber count (112/plot) was noted from N_0. Tuber size up to as compared to significantly lowest (121/plot) from 25 g tuber size.

(iv) Tuber yield/ha

Perusal of data indicated that each increment in N-level up to N_{120} brought about significant increase in the tuber yield. Accordingly, N_{120} resulted in significantly higher tuber yield (29.54 t/ha) over rest of N-levels. Eventually the significantly lowest tuber yield (21.68 t/ha) was noted from without nitrogen. Tuber size up to 45 g augmented tuber yield up to significant extent (27.01 t/ha) in comparison to the smaller size tubers. The tuber size of 25 g recorded significantly lowest tuber yield (24-59 t/ha).

Discussion

Plant height: It is obvious from the data the significant difference in plant height was observed at all the stages of observation (30, 60 DAS and at harvest) due to tuber size and varying levels of nitrogen in potato. There was slow growth of potato plants up to 30 DAS and thereafter, there was sharp increase in plant height up to harvest stage. The highest plant height was recorded by largest 45 g tuber size at all the stages of plant growth, which was found significantly superior than all the lower tuber size in this study. The lowest plant height was observed in 25 g tuber size at every stage of case of observations. At harvest stage, 45 g tuber size recorded maximum plant height up to 67.47 cm as against only 63.30 cm under smallest tuber size (25 g). It was primarily due to high food reserve in large size tubers. Similar results have also been reported by Malik *et al.* (2002) [12], Sonawane and Dhoble (2004) [23], Nandekar (1992) and Gavrilov and Semenov (2006) [6]. Number of branches per plant: The tuber size of 45 g recorded significantly more number of branches per plant as compared to 25 g tuber size only. This trend was noticed at every stage of observations. At harvest stage, the maximum branches were 4.09/plant under 25 g tuber size. Large size tubers contained high food reserve which helped in development of more auxins which promotes the growth of lateral buds and later developed as branches. These results are in conformity with those of Hussain *et al.* (1995), Mukhopadhyay (1997) [15], Arsenault *et al.* (2001) [2], Meiteri *et al.* (2005) and Ali and Chattopadhyay (2006) [1]. Number of leaves per plant: It is revealed from the data that the significantly highest number of leaves per plant was recorded with 120 kg N/ha over the preceding N-levels at every stage. At harvest stage, the maximum leaves count was 58.29/plant as against only 42.18/plant under no nitrogen. This increase may be due to increased uptake of nutrients, which resulted in increased synthesis of carbohydrates, which are utilized in building up of new cell. These results are in conformity with the findings of Malik *et al.* (1998) [13], Sharma and Singh (1998), Deka and Datta (1999) [5], Singh *et al.* (1999) [21], Kavvadis *et al.* (2002), Zebarth *et al.* (2004) [26], and Ali and Chattopadhyay (2006) [1]. As regards with the effect of size of tuber, larger 45 g tuber size recorded non-significantly highest leaves count (13.49 and 30.83/plant at 30 and 60 DAS, respectively) and significantly highest (51.31/plant) at harvest stage. This was due to high food reserve in the large size tubers which allowed more rapid synthesized carbohydrate for further growth. The smallest tuber size (25 g) recorded the minimum leaves count at every stage. The similar results have been reported by Nandekar (2005), Ali and Chattopadhyay (2006) [1] and Gravrilov and Semenov (2006). Stem diameter: The perusal of data in Summary of reveal that the stem diameter was influenced significantly due to N-levels at every stage of observations. At harvest stage, N_{120} resulted in significantly highest stem diameter (6.24 cm) over all the preceding N-levels. Whereas the lowest stem diameter (5.60 cm) was noted in case of without nitrogen. The increase in stem diameter is due to the fact that nitrogen is one of the major plant nutrients which is an integral part of the chlorophyll and all proteins thereby increased photosynthesis and vigorous growth of all parts of the plant. The largest 45 g tuber size enhanced the stem diameter up to significant extent at 60 DAS and harvest stages. At harvest stage, 45 g tuber size resulted in 5.93 cm stem diameter, being significantly higher to 25 and 35 g tuber size. The smallest tuber size 25 g recorded the lowest stem diameter (5.78 cm). In fact, the largest size tubers already possessed the highest food reserve for early and rapid growth of all parts of the plant as

compared to the smaller size tubers. Yield-attributes: It is apparent from the data that the highest level of nitrogen (N_{120}) resulted in significantly highest yield-attributes *viz.* number of tubers (27.33/plant), fresh weight of tubers (294 g/plant), dry weight of tubers (51.17 g/plant) and number of tubers (132/plot) as compared to the preceding N-levels. These results are fairly comparable to the results reported by many researchers (Singh *et al.*, 1999; Patel *et al.*, 2000; Singh and Raghav, 2000; Patel and Patel, 2001; Veer *et al.*, 2002; Hamedani, 2003; Pashalidis *et al.*, 2003; Zebarth *et al.*, 2004; Bhat *et al.*, 2005 and Yenagi *et al.*, 2005) [21, 18, 19, 22, 24, 8, 17, 26, 4, 25]. The largest seed tuber size (45 g) recorded non-significantly highest number of 24 tubers/plant, fresh and dry weight of tubers (269 and 45.25 g/plant, respectively) and significantly highest 124 tubers/plot as compared to the smaller (25 and 35 g) seed tuber size. Tuber yield of potato/ha: An application of nitrogen up to N_{120} gave significantly higher tuber yield (29.54 t/ha) which was higher by 7.86 t/ha over no nitrogen and higher by 2.45 t/ha over N_{100}. Such an increase in tuber yield might be due to maximum increase in the yield-attributes under N_{120}. These findings are in conformity with those of Veer *et al.* (2002) [24], Hamedani (2003) [8], Pashalidis *et al.* (2003) [17], Zebarth *et al.* (2004) [26], Yenagi *et al.* (2005) [25] and Bhat *et al.* (2005) [4]. The largest seed tuber size (45 g) resulted in significantly higher tuber yield (27.01 t/ha) which was higher by 2.42 t/ha over smallest (25 g) seed tuber size.

Summary

The treatments comprised four nitrogen levels (0, 80, 100 and 120 kg/ha) and three size of tuber (25, 35 and 45 g). The significantly tallest plants were recorded with the application of N_{120} at all the growth stages. The height was up to 77.93 cm at harvest stage, where as it was only 53.94 cm under N_0 nitrogen. The highest plant height was recorded by largest 45 g tuber size at all the stages of observations. The lowest height was noted from smallest 25 g tuber size. At harvest stage, 45 g tuber size recorded 67.47 cm height as against only 63.30 cm under 25 g tuber sizes. The varying levels of nitrogen showed significant effect upon number of branches/plant at all the stage of observations. At harvest stage, the maximum branches were 4.73/plant due to N_{120}, where as minimum 3.11/plant under without nitrogen. The tuber size of 45 g recorded significantly more branches/plant over 25 g tuber sizes only at every stage. At harvest stage, maximum branches from 45 g tuber size were 4.09/plant which were decreased to 3.73/plant under 25 g tuber size. The significantly highest leaves/plant was recorded due to N_{120} over the preceding N-levels at every stage. The maximum leaves count at N_{120} was 58.29/plant at against only 43.18/plant under N_0 nitrogen. The largest tuber size (45 g) recorded non-significantly highest leaves count at 30 and 60 DAS, but significantly highest (51.31/plant) at harvest stage. The smallest tuber size (25 g) recorded minimum leaves count at every stage (50.60 cm at harvest). The stem diameter was influenced significantly due to N-levels at every stage. At harvest stage, N_{120} resulted in significantly highest stem diameter (6.24 cm) over all the preceding N-levels. Where the lowest stem diameter (5.60 cm) was noted in case of N_0 nitrogen. The largest 45 g tuber size enhanced the stem diameter significantly at 60 DAS and harvest stages. At harvest stage, 45 g tuber size resulted in 5.93 cm stem diameter, being significantly higher to 25 and 35 g tuber size. The smallest 25 g tuber size recorded the lowest stem diameter (5.78 cm). The highest level of nitrogen (N_{120}) resulted in significantly highest yield-attributes *viz.* number of tubers (27.33/plant), fresh weight of tubes (294 g/plant), dry weight of tubers (51.17 g/plant) and number of tubers (132/plot) as compared to the preceding N-levels. The largest size of seed tubers (45 g) recorded non-significantly highest number of 24 tubers/plant, fresh and dry weight of tubers (269 and 45.25 g/plant, respectively) and significantly highest 124 tubers/plot as compared to the smaller (25 and 35 g) seed tuber size. Application of nitrogen up to N_{120} gave significantly higher tuber yield (29.54 t/ha) which was higher by 2.45 t/ha over N_{100}, and 7.86 t/ha over N_0 nitrogen. The largest seed tuber size (45 g) resulted in significantly higher tuber yield (27.01 t/ha) which was higher by 2.42 t/ha over smallest 25 g seed tuber size.

Conclusion

Based on one year experimental results, it is concluded that amongst the nitrogen levels 120 kg N/ha recorded almost significantly higher growth and yield-attributing parameters, tuber yield and its carbohydrate content from potato *var. Kufri Badshah.* Thus 120 kg N/ha recorded maximum tuber yield (29.54 t/ha) and carbohydrate content (21.04%). Similarly the biggest seed tuber size (45 g) recorded almost significantly higher growth and yield attributing parameters, tuber yield (27.01 t/ha).

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