Indian Journal of Ecology (2025) 52(5): 988-993
DOI: https://doi.org/10.55362/IJE/2025/4604

Manuscript Number: 4604
NAAS Rating: 5.38

Evaluation of Potato Varieties under Various Crop Geometry for Tuber Yield and Quality

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Abstract: The present study was carried out at, Chaudhary Charan Singh Haryana Agricultural University- Hisar, India during *Rabi* season of 2021-22. The field experiment was conducted in split plot design with three potato varieties (Kufri Neelkanth, Kufri Bahar and Kufri Lima) in four different spacing (60×10 cm, 60×15 cm, 60×20 cm with cut tuber and 60×20 cm with whole tuber). The spacing 60×20 cm with whole tuber and varieties Kufri Neelkanth was best for total tuber yield (394.5 q/ha) and biological yield (528.2 q/ha). The maximum foliage dry matter (11.38 %), tuber dry matter content (18.26 %), reducing sugar content (252.2 mg/100g), total sugar (618.4 mg/100g) and total marketable tuber yield (374.4 q/ha) were observed maximum in Kufri Lima, while ascorbic acid content in tuber of Kufri Bahar (27.61 mg/ 100 g). The present studies open up new doors for farmers and researchers to sustainably produce potatoes, which could significantly enhance economic and nutritional benefits.

Keywords: Potato, Crop geometry, *Solanum tuberosum* L

Potato (*Solanum tuberosum* L.) is one of the most important commercial vegetable crops, originated in Andes of Peru and Bolivia and widely grown throughout the world. The world's population is expected to reach 10.5 billion by 2050, increasing food demand by 60% (Alexandratos and Bruinsma 2012). The major problem of potato's low tuber yield are the unavailability and high cost of seed tuber, lack of well-adapted cultivar, and poor agronomic practices (Arega et al., 2018). Maintaining optimal plant population through inter-row and intra-row spacing, as well as other cultural practices, is critical for increasing tuber yield and quality. Cutting seed tuber has been adopted because of the lack of adequate availability of whole seed tuber and also by reducing the seed cost. For normal production, a reasonable size of tuber pieces called as seed tuber should be of about 40 to 50 g. Weather conditions, cultivars, crop geometry, planting of cut tubers, planting date, nutrition and irrigation are only a few of the aspects that influence potato output. Potato plant growth and yield are also determined by the genetic potential of a variety and spacing requirements (Kumar et al., 2009). Soil and time of planting have great influence on potato yield and quality of tubers.

Good quality seed is almost universally considered a requirement for high productivity in all potato production systems. Much of the yield gap currently constraining productivity is attributed to the poor quality of seed. Potato seed sector development is thus a major concern of governments, researchers, development agencies and civil society organizations (Forbes et al., 2020). Cutting seed tuber has been adopted because of the lack of adequate availability of whole seed tuber and also by reducing the seed cost. However, cut surface may be susceptible to attack by soil borne fungi, particularly during the cool and wet conditions. Whole seed tubers of potato (*Solanum tuberosum* L.) have been reported to have some performance advantages over seed pieces produced by cutting whole tubers, even if the cut seed is treated with a fungicide (Kawakami et al., 2003). Small and medium size seed tubers are preferred by farmers engaged in small scale cultivation to reduce seed cost under Bangladesh conditions (Islam et al., 2012). Therefore, this study planned to find out the optimum crop geometry using cut seed tuber of potato and to evaluate the performance of different varieties using cut seed tuber plantation for higher yield.

MATERIAL AND METHODS

The present study was carried out at, Chaudhary Charan Singh Haryana Agricultural University, Hisar. The experimental site is situated at 29°10"N latitude and 75°46"E longitude with 215.2 m above mean sea level in north-west part of India coming under Trans- Gangetic Plains agro climatic zone. The treatments comprising of three potato varieties; (V_1):- Kufri Neelkanth, (V_2):- Kufri Bahar and (V_3):- Kufri Lima (V_3) and four different spacing; (S_1):- 60×10 cm with cut tuber, (S_2):- 60×15 cm with cut tuber, (S_3):- 60×20 cm with cut tuber and (S_4):- 60×20 cm in a randomized block

design (factorial) with three replications keeping gross plot size 4.8 x 3.6 m^2 net plot size 3.6 x 3.0 m^2. Tubers of 2.5-3.0 cm diameter disease free certified seed tubers were used and recommended package of practices (Singh et al., 2022). The foliage weight and total tuber yield was recorded at the time of harvesting. The tubers above 75 g were counted in 'A' grade, 50-75 g were placed in 'B' grade, 25-50 g were kept in 'C' grade and less than 25 g were noted in 'D' grade.

The mean weekly maximum temperature ranged between 17.1 to 32.0ºC and minimum between 5.2 to 19.6ºC and relative humidity ranged between 88 to 97 per cent. Field soil belongs to inceptisol order and sandy loam texture with 55% sand, 34% silt and 11% clay. Field soil contain organic carbon (0.44 %), available nitrogen (128 kg/ha), medium phosphorus (28.5 kg/ha) and available potassium (378 kg/ha), the fertility status of the experimental area was poor. Field soil is also little bit alkaline having pH value of 7.9. The month wise total precipitation, average maximum & amp; minimum temperature, relative humidity, sunshine hours and evaporation of experimental site of the crop seasons (Table 1). The data were statistically analysed by using OPSTAT-Online Statistical Analysis Tools.

RESULTS AND DISCUSSION

Dry matter foliage and tuber: The dry matter of foliage (12.06 %) and dry matter of tubers (18.04%) was significantly higher in 60×20 cm spacing with whole tuber planting, while lowest dry matter of foliage (10.22 %) and dry matter of tubers (16.56 %) was with 60×10 cm spacing with cut tuber planting (Table 2). The highest dry matter content under wider spacing with whole tuber planting may be due to proper plant stand and receiving proper sunlight which resulted in higher photosynthetic activity and accumulation of higher dry matter (Nayak 2022).

The higher dry matter of foliage (11.38 %) was maximum in Kufri Lima followed by Kufri Neelkanth (11.17 %) and dry matter of tubers in Kufri Lima (18.26 %) which was significantly higher as compared to other two varieties of potato. The higher dry matter in Kufri Lima may be due to the better foliage growth and large size leaves in Kufri Lima variety of potato. Mozumder et al. (2014) found that the maximum dry matter of both haulms and tubers for the cultivar Kufri Shailja and Kufri Himalini as compared to the cultivar Kufri Jyoti under climatic conditions of West Bengal. Nagar *et al.* (2019) recorded significantly higher tuber dry matter for variety Kufri Bahar followed by Kufri Pukhraj, Yadav et al. (2022) also reported higher number of tubers in Kufri Sadabahar as compared to Kufri Khyati under the climatic conditions of Hisar.

Total sugar content, non-reducing sugar content and ascorbic acid in tuber: Maximum reducing sugar, non-reducing sugar and total sugar were recorded (254.6, 348.7 & 603.2 mg/100g) with spacing of 60×20 cm using whole tuber for planting, which was significantly at par with 60×20 cm using cut tuber for planting except non reducing sugar, while minimum sugar content, non-reducing sugar and total sugar (220.3, 322.9 & 543.2 mg/100g) were with 60×10 cm) spacing using cut tuber for planting (Table 3).

Among varieties, the significantly higher reducing sugar content and total sugar were observed in Kufri Lima (252.2 & 618.4 mg/100g) followed by Kufri Neelkanth (237.8 & 575.6 mg/100g) except non reducing sugar content in Kufri bahar

Table 2. Effect of plant spacing using cut seed tuber and potato varieties on dry matter of foliage and dry matter content of tubers (%)

Plant spacing	Dry matter of foliage (%)	Dry matter of tuber (%)
S_1	10.22	16.56
S_2	10.33	16.96
S_3	11.00	17.16
S_4	12.06	18.04
CD (p=0.05)	0.82	0.83
Varieties		
V_1	11.17	17.15
V_2	10.17	16.13
V_3	11.38	18.26
CD (p=0.05)	0.71	0.72

Table 1. Monthly actual weather parameters of the experimental site during 2021-22

Rabi season	T max (°C)	T min (°C)	RH (%)	Sunshine (hours)	Rainfall (mm)	Evaporation (mm)
October	32.0	19.6	88	7.3	3.2	3.2
November	27.9	9.9	90	5.5	0.0	1.8
December	21.3	6.3	95	5.0	0.0	1.3
January	17.1	5.2	97	3.9	10.4	1.0
February	22.7	6.8	93	7.2	10.9	2.1
March	25.9	12.4	92	6.1	95.2	3.1

Tmax- maximum temperature, Tmin- minimum temperature, RH-relative humidity

(286.4 mg/100g) followed by Kufri Lima (366.3 mg/100g). Verma et al. (2022) recorded significant variation in reducing sugar content among the varieties, being maximum with Kufri Gaurav and minimum with AICRP-P-39. The results are in accordance with findings of Kumar et al. (2003), Jatav et al. (2017), Kumar and Ezekiel (2006) and Kaur and Khurana (2017).

The ascorbic acid was observed highest (26.16 mg/100g) with 60×20 cm spacing using whole tuber for planting, however lowest ascorbic acid content (22.82 mg/100g) was in spacing 60×20 cm with cut tuber planting. Significantly maximum (27.61 mg/ 100 g) ascorbic acid was in Kufri Bahar and considerably lowest ascorbic acid (20.91 mg/ 100 g) was recorded in Kufri Lima. Significant difference in ascorbic acid content in potato varieties might be due to the genetic characteristic of the variety. These findings are supported by Brar (2013).

Total number of tubers and different potato grades: The total number of tubers, number of tubers in different grades, *viz*. up to 25, 25-50, 50-75 and >75 g per square meter area recorded in the range of 61.7-75.3, 12.4-21, 17.6-22.5, 14.5-18 and 14.4-17, respectively (Table 4 and 5). The maximum

Table 5. Effect of plant spacing using cut seed tuber of different potato varieties weight of tubers (kg/m^2)

Plant spacing	"A" Grade (>75)	"B" Grade (50-75)	"C" Grade (25-50)	"D" Grade <25)
S_1	2.15	1.08	0.81	0.28
S_2	2.11	1.00	0.78	0.34
S_3	1.94	0.90	0.76	0.38
S_4	2.24	1.07	0.83	0.25
CD (p=0.05)	0.16	0.12	0.06	0.05
Varieties				
V_1	1.99	1.00	0.94	0.45
V_2	1.83	0.90	0.93	0.36
V_3	2.50	1.14	0.52	0.13
CD (p=0.05)	0.14	0.14	0.09	0.04

Table 3. Effect of plant spacing using cut seed tuber of different potato varieties on reducing and non-reducing sugar content in tuber, total sugar content and ascorbic acid in tuber

Plant spacing	Reducing sugar content in tuber	Non-reducing sugar content in tuber	Total sugar in potato tuber	Ascorbic acid in tuber
S_1	220.3	322.9	543.2	25.0
S_2	233.6	326.1	559.7	24.2
S_3	249.1	323.0	571.1	22.8
S_4	254.6	348.7	603.2	26.2
CD (p=0.05)	18.5	21.2	26.4	0.65
Varieties				
V_1	237.8	337.8	575.6	25.1
V_2	228.3	286.4	514.7	27.6
V_3	252.2	366.3	618.4	20.9
CD (p=0.05)	16.0	28.7	22.9	0.5

Table 4. Effect of plant spacing using cut seed tuber of different potato varieties on total number of tubers (kg/m^2)

Plant spacing	Total no of tubers/m^2	"A" Grade (>75)	"B" Grade (50-75)	"C" Grade (25-50)	"D" Grade <25)
S_1	75.3	15.9	17.0	21.4	21.0
S_2	67.7	15.6	16.2	19.5	16.0
S_3	61.7	14.4	14.5	17.6	15.2
S_4	70.3	17.0	18.0	22.5	12.4
CD (p=0.05)	5.9	1.2	1.6	2.6	4.4
Varieties					
V_1	62.4	18.5	17.5	15.8	10.6
V_2	68.0	13.2	14.9	21.7	18.0
V_3	75.9	15.5	16.9	23.7	19.9
CD (p=0.05)	5.1	1.1	1.4	2.4	3.9

number of up to 25 g size tubers per square meter (21.0) was observed with 60×10 cm spacing using cut tuber for planting and minimum was found (12.4) with 60×20 cm spacing using whole tuber for planting.

More number of small size tubers in closer spacing may be due to more competition among the plants resulted lesser accumulation of photosynthate and finally tubers remains small size, while under wider spacing, less number of small size tuber may be due to that plants accumulate more food which stored in tubers ultimately tubers became large size. The number of tubers per square meter in 25-50, 50-75 & >75 g grade under different plant spacing were recorded significantly maximum (22.5, 18.0 & 17.0) with whole tuber planting at 60×20 cm spacing which was significantly at par with cut tuber planting at 60×10 cm (21.4, 17.0 & 15.9). Total number of tubers was recorded significantly maximum (75.3) with 60×10 cm spacing using cut tuber for planting, which was significantly maximum as compared to other plant spacing. This may be due to more plant population per unit area under closer spacing resulted more number of tubers per unit area. Kumar et al. (2009) and Arega et al. (2018) also reported that cut tuber produced significantly higher number of tubers per plant as compared to the whole tubers planted.

Among the varieties, maximum number of tubers up to 25 & 25-50 g grade (19.9 & 23.7) were recorded under Kufri Neelkanth and was closely followed with Kufri Bahar (18.0 & 21.7) and maximum number of 50-75 g grade tubers (17.5/m^2) was recorded in Kufri Lima which was closely followed by Kufri Neelkanth (16.9/m^2). Kufri Lima produced significantly maximum number of tubers (18.5/m^2) of >75 g grade as compared to other varieties (Table 4). Total number of tubers per square meter area (75.9) was recorded significantly maximum in Kufri Neelkanth which was significantly higher as compared to other two varieties. The maximum number of tubers in Kufri Neelkanth may be due to genetic makeup of this variety. The results of the present investigation are supported by findings of Banjare et al. (2014) and Kumar et al. (2009). Yadav et al. (2022) also reported higher number of tubers in Kufri Sadabahar as compared to Kufri Khyati under the climatic conditions of Hisar.

The yield of tubers in different grades viz. up to 25, >25-50, >50-75 and >75 g size affected by different plant spacings was found in the range of 0.25-0.38, 0.76-0.83, 0.90-1.08 and 1.94-2.24 kg/m^2, respectively (Table 5). The maximum yield of up to 25 g size tubers per square meter (0.38 kg) was observed with 60×20 cm spacing using cut tuber for planting which was at par with 60x15 cm spacing using cut tuber for planting. The maximum yield of tuber in >25-50 g grade under different plant spacing was recorded significantly maximum (0.83 kg) with whole tuber planting at 60×20 cm spacing which was significantly at par with cut tuber planting at 60×10 cm (0.81 kg) and also 60×15 cm (0.78 kg). The maximum yield of tuber in >50-75 g grade (1.08 kg/m^2) was noted with plant spacing 60×10 cm using cut tuber for planting, which was significantly at par with 60×20 cm (1.07 kg/m^2) using whole tuber and 60×15 cm (1.0 kg/m^2) using cut tuber for planting. Maximum yield of >75 g grade tubers (2.24 kg/m^2) with 60×20 cm spacing using whole tuber for planting, which was significantly higher than cut tuber planting under same spacing and at par with 60x10 cm spacing (2.15 kg/m^2) as well as 60x15 cm (2.11 kg/m^2) using cut tuber. This may be due to that under wider spacing and whole tuber planting there was a proper growth and development of the plant resulted more yield of large size tubers, while under closer spacing using cut tuber there was higher plant population per unit area which increases the yield of all size tuber. The present findings were also confirmed the results of Malik et al. (2002) and Birhanu et al. (2018) reported that the yield per plant and tuber yield per hectare were higher with whole tubers planting as compared to cut tubers.

Among different potato varieties, significantly maximum yield of small size tubers (up to 25 & 25-50 g) were recorded (0.45 & 0.94 kg/m^2) in Kufri Neelkanth as compared to other two varieties and minimum (0.13 & 0.52 kg/m^2) were in Kufri Lima. Kufri Lima yielded maximum weight of large size tuber (50-75 & >75 g grade), which was significantly higher as compared to other varieties except Kufri Neelkanth in 50-75 & >75 g size and the minimum yield of tubers (0.90 & 1.83 kg/m^2) was in Kufri Bahar. More number of large size tubers in Kufri Lima may be due to early bulking behaviour of this variety because of good foliage spread, more area was exposed to sunlight that increased photosynthesis activity

Table 6. Effect of plant spacing using cut seed tuber of different potato varieties on total tuber yield, marketable tuber yield and biological yield (q/ha)

Plant spacing	Total tuber yield (q/ha)	Marketable tuber yield (q/ha)	Biological yield (q/ha)
S_1	389.0	363.6	568.8
S_2	380.9	349.9	548.8
S_3	357.3	323.4	506.0
S_4	395.8	373.0	583.9
CD (p=0.05)	21.75	19.9	26.25
Varieties			
V_1	394.5	354.3	582.2
V_2	361.5	328.7	520.5
V_3	386.2	374.4	552.8
CD (p=0.05)	18.84	17.3	22.74

Table 7. Effect plant spacing using cut seed tuber of different potato varieties on economics of different treatments

Treatments	Total cost (Rs.)	Gross return (Rs.)	Net return (Rs.)	B:C ratio (ha)
V_1S_1	178354	397975	219621	2.23
V_1S_2	153354	393325	239971	2.56
V_1S_3	128354	378867	250513	2.95
V_1S_4	128354	407842	279488	3.18
V_2S_1	178354	369450	191096	2.07
V_2S_2	153354	359267	205913	2.34
V_2S_3	128354	339775	211421	2.65
V_2S_4	128354	377500	249146	2.94
V_3S_1	178354	399467	221113	2.24
V_3S_2	153354	390033	236679	2.54
V_3S_3	128354	353179	224825	2.75
V_3S_4	128354	401967	273613	3.13

and thus increased starch accumulation, which led to more number of large size tubers. The present findings are in accordance with the results reported by Arega et al. (2018) and Qasim et al. (2013) in potato*.*

Yield: The data as shown in revealed that different plant spacing's and potato varieties had a remarkable impact on total tuber yield , marketable yield and biological yield (Table 6). The maximum total tuber yield (395.8 q/ha) was with plant spacing 60×20 cm using whole tuber for planting, which was significantly at par with 60×10 cm and 60×15 cm using cut tuber for planting and the maximum total marketable tuber yield (373.0 q/ha) was with plant spacing 60×20 cm using whole tuber for planting, which was significantly higher as compared to other spacing except 60×10 cm spacing using cut tuber for planting (363.6 q/ha).

Significantly, the maximum biological yield (583.9 q/ha) was with plant 60×20 cm spacing using whole tuber for planting, which was significantly at par (568.8 q/ha) with plant 60×10 cm spacing using cut tuber for planting. This may be due to that under wider spacing and whole tuber planting there was a proper growth and development of the plant resulted more yield of large size tubers which ultimately increases the marketable yield, total yield as well as biological yield, while under closer spacing using cut tubers there was higher plant population per unit area which increases the yield of all of size tuber. Malik et al. (2002) and Birhanu et al. (2018) also reported that the tuber yield per hectare were higher with whole tubers planting as compared to cut tubers under same plant spacing.

Among potato varieties, the total tuber yield varied between 361.5 to 394.5 q/ha. Significantly maximum total tuber yield was observed in Kufri Neelkanth, which was statistically at par with Kufri Lima, while Kufri Lima resulted maximum total marketable tuber yield (374.4 q/ha) which was significantly higher as compared to other varieties. The biological yield varied between from 520.5 to 582.2 q/ha. Significantly maximum in Kufri Neelkanth as compared to other varieties. The maximum tuber yield in Kufri Neelkanth may be due to better growth parameters which resulted higher yield. Kufri Lima produced more number of large size tuber because of their genetic behaviour resulted higher marketable and biological yield. The varietal difference in potato varieties with respect to tuber yield, marketable yield as well as biological yield was also observed by Yadav et al. (2022). The present findings are in accordance of results reported by Abrha et al. (2014) and Birhanu et al. (2018). The interaction effect between different plant spacings and potato varieties was found non-significant for tuber yield, marketable yield as well as biological yield.

Economics: The data on economics of different treatments of different spacing's (Table 6), the maximum net income (Rs. 2,79,488/ha) and benefit-cost ratio (3.18) was obtained from Kufri Neelkanth variety of potato planted at a spacing of 60×20 cm with whole tuber.

This may be due to higher total tuber yield under this treatment combination and less cost of cultivation because of less seed rate was used under 60x20 cm spacing as compared to closer spacing's. Yadav et al. (2022) also reported higher net return and benefit cost ratio in the treatment where maximum tuber yield was obtained. The present results are accordance with the findings of Agrawal et al. (2016) and Alam et al. (2016).

CONCLUSION

The study highlights the importance of choosing the right potato variety and spacing to maximize both yield and profitability. Based on above study the planting of 50-60 g size of cut tubers at a spacing of 60 cm × 15 cm was viable

option for growing potato for higher yield. The Kufri Neelkanth and Kufri Lima could be used for getting higher returns by the farmers. Potato tubers must be stored properly in order to ensure a consistent supply in the market. This study also suggests the proper monitoring of tuber quality at harvest and storage conditions in storage for maintenance of tuber quality.

AUTHORS CONTRIBUTION

Conceptualization of research (Sandeep Dagar), Designing the experiment & Contribution of experimental materials (V.P.S. Panghal), Execution of field/lab experiments and data collection (Dharmendra K. Janghel), Analysis of data and interpretation (Vijay Daneva) and preparation of the manuscript (Harender Dagar).

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Received 12 July, 2025; Accepted 23 September, 2025