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Standardization of spacing and varieties for production of tubers from apical rooted cuttings

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Abstract
The experiment entitled "Standardization of spacing and varieties for production of tubers from apical rooted cuttings" was carried out during 2021 - 2022 under irrigated condition. The treatments composed of apical rooted cuttings of two varieties namely Kufri Jyotthi and Kufri Himalini and three different row to row spacing and followed two Factorial Randomized Complete Block Design (RCBD) for the experiment conducted at RHREC (Regional Horticulture Research and Extension center), UHS Campus, GKVK, Bengaluru under the University of Horticultural Sciences, Bagalkot (Karnataka). Observations was recorded for plant height (cm), number of stems per hill, leaf length (cm), number of compound leaves per plant, days to maturity, number of tubers per plant, average tuber weight (g) total tuber yield per plant (g) total tuber yield per plot (kg) and late blight disease incidence (%). Among the treatments Kufri Himalini apical rooted cuttings with the spacing of 45 × 20 cm showed better results with respect to growth parameters *viz.*, plant height, number of stems per hill and number of compound leaves per plant. While leaf length was maximum Kufri Jyoti apical rooted cuttings with the spacing of 45 × 20 cm as compared to other treatments.

Keywords: Potato, ARC, apical rooted cuttings, seed tubers, validation

1. Introduction
Potato (*Solanum tuberosum* L.) from genus Solanum belongs to the family Solanaceae, is an annual crop, with the chromosome number; 2n=48. The production of high-quality tubers from apical rooted cuttings offers immense potential for meeting the global demand for nutritious and sustainable food sources. Apical rooted cuttings provide a rapid and reliable means of propagating crops, facilitating the development of robust root systems and accelerated growth. However, achieving optimal tuber yields from apical rooted cuttings requires the careful consideration of two critical factors: spacing and variety selection. Spacing, the arrangement of plants within a given area, plays a pivotal role in determining the growth, development, and tuberization of crops. Proper spacing practices facilitate efficient resource utilization, including light, water, and nutrients, leading to enhanced physiological processes. Additionally, an appropriate spacing strategy reduces competition among plants, enabling them to reach their maximum yield potential.

Variety selection, on the other hand, is a crucial aspect of tuber production that directly influences the performance and productivity of apical rooted cuttings. Different crop varieties exhibit variations in their growth habits, tuberization patterns, and adaptability to specific environmental conditions. Choosing the right variety can significantly impact the overall tuber yield, quality, and marketability of the final product. Despite the growing adoption of apical rooted cuttings for tuber production, the establishment of standardized recommendations regarding optimal spacing and variety selection remains a challenge. Current practices often rely on empirical knowledge and individual experience, leading to inconsistent outcomes and suboptimal yields. Therefore, there is an urgent need for systematic research to investigate and establish scientifically supported protocols for spacing and variety selection specific to apical rooted cuttings.

This research article aims to address this critical knowledge gap by presenting a comprehensive study on the standardization of spacing and variety selection for enhanced tuber production from apical rooted cuttings. By meticulously examining the effects of different spacing configurations and a range of varieties, this study seeks to provide valuable insights into optimizing the spacing and variety selection strategies to maximize tuber yields. Furthermore, this research article also investigates the interaction between spacing, variety,

and key physiological processes that govern tuber formation and growth in apical rooted cuttings. By elucidating the underlying mechanisms and responses, we aim to enhance our understanding of the complex factors influencing tuber production and identify key determinants for achieving optimal yields.

The findings of this study have significant implications for growers, breeders, and researchers involved in the development and cultivation of potato from apical rooted cuttings. The establishment of standardized spacing and variety selection recommendations will enable farmers to optimize resource allocation, reduce production costs, and improve overall tuber yield and quality.

2. Material and Methods

The study was conducted on the potato (*Solanum tuberosum* L.) crop at the Regional Horticultural Research and Extension Centre (RHREC) located in Bengaluru, Karnataka. The experiment aimed to evaluate standardization of spacing for production of tubers from apical rooted cuttings. Two potato varieties were selected for this study, Kufri Jyothi and Kufri Himalini. These varieties were chosen based on their known adaptability to apical rooted cuttings and their potential for tuber production. The characteristics and attributes of each variety were considered to ensure a diverse representation of potato genotypes. Three different spacing configurations were implemented to evaluate their impact on tuber production from apical rooted cuttings: a) S_1: 30 cm × 20 cm (Row to row) and (plant to plant). b) S_2: 45 cm × 20 cm (Row to row) and (plant to plant). c) S_3: 60 cm × 20 cm (Row to row) and (plant to plant). The experiment followed two Factorial Randomized Complete Block Design (RCBD). The selected potato varieties were propagated using apical rooted cuttings obtained from healthy and disease-free mother plants. The cuttings were prepared by removing the apical shoots from the mother plants and ensuring the presence of healthy and well-developed roots. The prepared cuttings were planted in the designated plots according to the predetermined spacing configurations. Planting was carried out by making suitable holes or furrows in the soil to accommodate the cuttings, ensuring proper alignment and spacing between plants within rows and rows themselves. Throughout the growing season, standard agronomic practices were followed, including regular irrigation, fertilization, and pest management, to ensure optimal growth and development of the potato plants. Observations recorded for 16 characters *viz*., plant height at 45, 60 and 75 days after planting (cm), number of stems per hill, leaf length at 45, 60 and 75 days after transplant (cm), number of compound leaves per plant at 45, 60 and 75 days after transplant, days to maturity, number of tubers per plant, average tuber weight (g) total tuber yield per plant (g) total tuber yield per plot (kg) and late blight disease incidence (%). The statical analysis was done using ANOVA tool.

3. Results and Discussion

3.1 Growth parameters

Significant differences were observed due to spacing and varieties with respect to growth parameters *viz*., plant height, number of stems per hill, leaf length and number of compound leaves per plant for tubers produced through apical rooted cuttings (G_0). Plant height showed significant variation among different spacing as well as between varieties. Kufri Himalini produced through apical rooted cuttings (G_0) plants were significantly taller than Kufri Jyoti produced through apical rooted cuttings (G_0) (Table 1). The plant spacing and variety affected the plant height after 45, 60 and 75 days of planting (DAP). The spacing of 30 × 20 cm is still the best one among other spacing, because with a wider spacing it does not have real effect. According to Hafsan *et al*., (2018) [4], wider spacing ensures the basic nutritional requirements but decreases the total number of plants as well as total yield.

Kufri Himalini produced through apical rooted cuttings (G_0) produced significantly a greater number of stems per hill as compared to Kufri Jyoti produced through apical rooted cuttings (G_0) which may be attributed to its genetic feature. More number of stems per hill were observed in wide spacing (45 × 20 cm) compared to narrow one (30 × 20 cm) (Table 2). Difference in plant vigour of varieties under similar condition can be attributed to specific genotypic response for plant growth behaviour (Sharma and Singh, 2010) [14]. Number of stems and compound leaves per plant showed a gradual and significant decrease with the increasing plant density. Number of stems between the cultivars and compound leaves per plant were higher in Kufri Himalini tuber produced through apical rooted cuttings (G_0) (Table 3). Reduction in number of leaves and stems per plant with increasing plant population can be attributed to the availability of limited space for the proper development of plant (Khurana and Pandita 1982) [8]. Reduction in plant vigour (stems and leaves) may also be due to lack of space on account of increasing plant population and thus posing a barrier for plant development (Singh *et al*. 1997) [15], (Nxumalo *et al*. 2020) [10], (Hasan *et al*. 2017) [5], (Singh *et al*. 2019) [16] and (Tarkalson *et al*. 2011) [17]. With respect to leaf length, Kufri Jyoti tuber produced through apical rooted cuttings (G_0) exhibited much better leaf length than Kufri Himalini apical rooted cuttings (Table 4). Variation in leaf length due to varieties can be attributed to variation in plant height and number of compound leaves per plant of these cultivars (Singh *et al*., 2019) [16].

3.2 Yield parameters

In the present study, Kufri Himalini tuber produced through apical rooted cuttings (G_0) yielded better in terms of numbers and weight of tubers per plant as well as per unit area compared to the variety Kufri Jyoti tuber produced through apical rooted cuttings (G_0) (Table 5 & 6). Increasing plant density resulted in a significant increase in the number of tubers/ha. Increase in number of tubers per unit area with increasing plant population may be due to a greater number of plants or stems per unit area as tuber number is known to be directly related to stem number (Khurana and Pandita 1982, Kushwah and Singh 2013 and Zamil *et al*. 2010) [8, 9, 178]. Reducing tuber yield of potato at low plant density may be due to large size of the tubers obtained on account of decrease in number of tubers. Among the cultivars, total potato yield was more in Kufri Himalini tuber produced through apical rooted cuttings (G_0) than Kufri Jyoti tuber produced through apical rooted cuttings (G_0). Higher tuber yield in Kufri Himalini than Kufri Girdhari have also been reported by the breeders of these cultivars (Joseph *et al*. 2011) [6] as well as by Sharma and Pandey (2015) [13].

With respect to late blight disease incidence, minimum late blight incidence was ehibited in Kufri Himalini apical rooted cuttings with a spacing of 45 × 20 cm as compared to other treatments, while maximum was observed in Kufri Jyoti apical rooted cuttings with spacing of 30 × 20 cm. Here also the microclimate inside the crop canopy had a marked effect on severity of the disease. The level of resistance or susceptibility of a variety to a particular disease mainly

depends on the genotypic character as well as prevailing weather conditions during the cropping period. The dense population also may favour the spread of the disease. These results are in agreement with the findings of Dey and Chakraborty (2016) [1], Santhosh (2010) [11], Getachew *et al*. (2012) [2], Kaushik *et al*. (2007) [8] and Gulluoglu (2009) [3].

Table 1: Effect of spacing, varieties and their interaction on plant height in potato G_0 tubers

Treatments		Plant height (cm)			
		45 DAP	60 DAP	75 DAP	Average
Spacing	45 × 20 cm (Kufri Jyoti and Kufri Himalini)	45.15	52.19	58.05	51.80
	30 × 20 cm (Kufri Jyoti and Kufri Himalini)	36.98	44.39	45.77	42.38
Varieties	Kufri Jyoti tubers produced through apical rooted cuttings (G_0)	37.69	45.77	48.03	43.83
	Kufri Himalini tubers produced through apical rooted cuttings (G_0)	44.44	50.81	55.80	50.35
Interaction between spacing and varieties	Kufri Jyoti tubers produced through apical rooted cuttings (G_0) 45 × 20 cm	40.23	51.28	54.55	48.69
	Kufri Jyoti tubers produced through apical rooted cuttings (G_0) 30 × 20 cm	35.16	40.27	41.51	38.98
	Kufri Himalini tubers produced through apical rooted cuttings (G_0) 45 × 20 cm	49.03	53.10	60.56	54.23
	Kufri Himalini tubers produced through apical rooted cuttings (G_0) 30 × 20 cm	38.81	48.52	50.04	45.79
Average		40.94	48.29	51.79	-
S. Em±	Spacing	1.48	1.55	1.89	-
	Variety	1.48	1.55	1.89	-
	Spacing × Variety	2.09	2.19	2.67	-
CD at 5%	Spacing	4.72	4.96	6.04	-
	Variety	4.72	4.96	6.04	-
	Spacing × Variety	6.67	7.02	8.54	-
CV (%)		10.16	9.0	10.28	-

G_0- Tubers produced from apical rooted cuttings

Table 2: Effect of spacing, varieties and their interaction on number of stems per hill in potato G_0 tubers

Treatments		Number of stems/hill			
		45 DAP	60 DAP	75 DAP	Average
Spacing	45 × 20 cm (Kufri Jyoti and Kufri Himalini)	4.97	5.59	6.04	5.53
	30 × 20 cm (Kufri Jyoti and Kufri Himalini)	4.14	4.24	4.64	4.34
Varieties	Kufri Jyoti tubers produced through apical rooted cuttings (G_0)	4.30	4.53	4.91	4.58
	Kufri Himalini tubers produced through apical rooted cuttings (G_0)	4.81	5.31	5.76	5.29
Interaction between spacing and varieties	Kufri Jyoti tubers produced through apical rooted cuttings (G_0) 45 × 20 cm	4.60	5.25	5.80	5.22
	Kufri Jyoti tubers produced through apical rooted cuttings (G_0) 30 × 20 cm	3.77	3.80	4.03	3.87
	Kufri Himalini tubers produced through apical rooted cuttings (G_0) 45 × 20 cm	5.00	5.94	6.28	5.74
	Kufri Himalini tubers produced through apical rooted cuttings (G_0) 30 × 20 cm	4.55	4.69	5.25	4.83
Average		4.52	4.92	5.34	-
S. Em±	Spacing	0.10	0.19	0.15	-
	Variety	0.10	0.19	0.15	-
	Spacing × Variety	0.15	0.27	0.21	-
CD at 5%	Spacing	0.33	0.62	0.47	-
	Variety	0.33	0.62	0.47	-
	Spacing × Variety	0.47	0.88	0.66	-
CV (%)		6.44	11.13	7.77	-

G_0- Tubers produced from apical rooted

Table 3: Effect of spacing, varieties and their interaction on number of compound leaves per plant in potato G_0 tubers

Treatments		No of compound leaves/plant			
		45 DAP	60 DAP	75 DAP	Average
Spacing	45 × 20 cm (Kufri Jyoti and Kufri Himalini)	27.30	37.02	42.46	35.59
	30 × 20 cm (Kufri Jyoti and Kufri Himalini)	21.35	30.98	35.65	29.33
Varieties	Kufri Jyoti tubers produced through apical rooted cuttings (G_0)	23.21	32.70	36.93	30.95
	Kufri Himalini tubers produced through apical rooted cuttings (G_0)	25.44	35.30	41.18	33.97
Interaction between spacing and varieties	Kufri Jyoti tuber produced through apical rooted cuttings (G_0) 45 × 20 cm	25.21	35.68	40.11	33.67
	Kufri Jyoti tubers produced through apical rooted cuttings (G_0) 30 × 20 cm	21.21	29.72	33.75	28.23
	Kufri Himalini tubers produced through apical rooted cuttings (G_0) 45 × 20 cm	29.39	38.36	44.81	37.52
	Kufri Himalini tubers produced through apical rooted cuttings (G_0) 30 × 20 cm	24.32	32.24	37.54	31.37
Average		24.68	34.00	39.05	-
S. Em±	Spacing	1.01	0.88	1.36	-
	Variety	1.01	0.88	1.36	-
	Spacing × Variety	1.43	1.24	1.92	-
CD at 5%	Spacing	3.23	2.81	4.35	-
	Variety	3.23	2.81	4.35	-
	Spacing × Variety	4.57	3.97	6.15	-
CV (%)		11.76	7.30	9.85	-

G_0- Tubers produced from apical rooted cuttings

Table 4: Effect of spacing, varieties and their interaction on leaf length in potato G_0 tubers

Treatments		Leaf length (cm)			
		45 DAP	60 DAP	75 DAP	Average
Spacing	45 × 20 cm (Kufri Jyoti and Kufri Himalini)	6.49	7.71	8.33	7.51
	30 × 20 cm (Kufri Jyoti and Kufri Himalini)	5.21	6.49	7.43	6.38
Varieties	Kufri Jyoti tubers produced through apical rooted cuttings (G_0)	6.02	7.46	8.12	7.20
	Kufri Himalini tubers produced through apical rooted cuttings (G_0)	5.67	6.74	7.64	6.68
Interaction between spacing and varieties	Kufri Jyoti tubers produced through apical rooted cuttings (G_0) 45 × 20 cm	6.81	8.17	8.50	7.83
	Kufri Jyoti tubers produced through apical rooted cuttings (G_0) 30 × 20 cm	5.23	6.76	7.74	6.58
	Kufri Himalini tubers produced through apical rooted cuttings (G_0) 45 × 20 cm	6.16	7.25	8.17	7.19
	Kufri Himalini tubers produced through apical rooted cuttings (G_0) 30 × 20 cm	5.18	6.23	7.12	6.18
Average		5.85	7.10	7.88	-
S. Em±	Spacing	0.13	0.22	0.19	-
	Variety	0.13	0.22	0.19	-
	Spacing × Variety	0.19	0.31	0.26	-
CD at 5%	Spacing	0.43	0.70	0.60	-
	Variety	0.43	0.70	0.60	-
	Spacing × Variety	0.60	0.99	0.85	-
CV (%)		6.44	8.74	6.72	-

G_0- Tubers produced from apical rooted cuttings

Table 5: Effect of spacing, varieties and their interaction from days to maturity, number of tubers per plant and average tuber weight in potato G_0 tubers

Treatments		Days maturity	Number of tubers per plant	Average tuber weight (g)
Spacing	45 × 20 cm (Kufri Jyoti and Kufri Himalini)	82.25	11.68	54
	30 × 20 cm (Kufri Jyoti and Kufri Himalini)	84.50	9.76	43
Varieties	Kufri Jyoti tubers produced through apical rooted cuttings (G_0)	84.00	10.31	46
	Kufri Himalini tubers produced through apical rooted cuttings (G_0)	82.75	11.14	52
Interaction between spacing and varieties	Kufri Jyoti tubers produced through apical rooted cuttings (G_0) 45 × 20 cm	82.75	11.33	52
	Kufri Jyoti tubers produced through apical rooted cuttings (G_0) 30 × 20 cm	85.25	9.28	40
	Kufri Himalini tubers produced through apical rooted cuttings (G_0) 45 × 20 cm	81.75	12.03	57
	Kufri Himalini tubers produced through apical rooted cuttings (G_0) 30 × 20 cm	83.75	10.24	47
Average		83.38	10.72	48.88
S. Em±	Spacing	1.26	0.25	0.02
	Variety	1.26	0.25	0.02
	Spacing × Variety	1.78	0.36	0.03
CD at 5%	Spacing	4.03	0.81	0.06
	Variety	4.03	0.81	0.06
	Spacing × Variety	5.70	1.14	0.09
CV (%)		4.27	6.64	11.00

G_0 - produced from apical rooted cuttings Tubers

Table 6: Effect of spacing, varieties and their interaction on total tuber yield and late blight incidence in potato G_0 tubers

Treatments		Total tuber Yield per plant (g)	Total tuber Yield per plot (kg)	Late blight incidence (%)
Spacing	45 × 20 cm (Kufri Jyoti and Kufri Himalini)	780	13.91	10.58
	30 × 20 cm (Kufri Jyoti and Kufri Himalini)	680	16.55	11.48
Varieties	Kufri Jyoti tubers produced through apical rooted cuttings (G_0)	710	14.35	11.80
	Kufri Himalini tubers produced through apical rooted cuttings (G_0)	760	15.40	10.26
Interaction between spacing and varieties	Kufri Jyoti tubers produced through apical rooted cuttings (G_0) 45 × 20 cm	736	12.93	11.24
	Kufri Jyoti tubers produced through apical rooted cuttings (G_0) 30 × 20 cm	660	15.77	12.36
	Kufri Himalini tubers produced through apical rooted cuttings (G_0) 45 × 20 cm	820	13.46	9.92
	Kufri Himalini tubers produced through apical rooted cuttings (G_0) 30 × 20 cm	710	17.34	10.59
Average		732.00	14.96	11.03
S. Em±	Spacing	0.02	0.41	NS
	Variety	0.02	0.41	NS
	Spacing × Variety	0.03	0.59	NS
CD at 5%	Spacing	0.08	1.33	NS
	Variety	0.08	1.33	NS
	Spacing × Variety	0.11	1.87	NS
CV (%)		9.10	7.88	NS

G_0 - produced from apical rooted cuttings Tubers

4. Conclusion

It may be concluded that the variety Kufri Himalini apical rooted cuttings with the spacing of 45 × 20 cm showed better results with respect to growth parameters *viz*., plant height, number of stems per hill, number of compound leaves per plant, minimum days to maturity, late blight incidence and maximum number tubers per plant, average tuber weight and total tuber yield. Hence, the variety Kufri Himalini with the spacing of 40 × 20 will be ideal to obtain higher growth and yield.

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