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Agronomical interventions for enhancing seed size tubers in potato (*Solanum tuberosum*) variety kufri khyati

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ABSTRACT

The present experiment was conducted during 2020–21, 2021–22 and 2022–23 at Regional Station, ICAR-Central Potato Research Institute, Gwalior, Madhya Pradesh to evaluate the best spacing combination and dehaulming time for enhancing the seed size potato (*Solanum tuberosum* L.) tubers and profitability under north-central plains of India. Experiment was conducted in a split-plot design (SPD) comprised of 5 spacing combinations, viz. S_1, Ridge and furrow 60 cm × 20 cm (Control); S_2, Ridge and furrow 60 cm × 15 cm; S_3, Flatbed paired row 90 cm bed width (two rows at 40 cm × 20 cm plant to plant spacing); S_4, Flatbed paired row 90 cm bed width (two rows at 40 cm × 15 cm plant to plant spacing); and S_5, Flatbed triple row 90 cm bed width (three rows at 20 cm × 20 cm plant to plant spacing) in main plot and 2 haulm killing dates, viz. 70 and 80 days after planting in sub plots. The treatment S_5, Flatbed triple row 90 cm bed width (three rows at 20 cm × 20 cm plant to plant spacing) spacing combination significantly increased the number and weight of seed size tubers, net seed size and total tuber yield when dehaulming was done after 80 days. The highest increase in seed size and total tubers over control reported when dehaulmed at 70 days. However, the treatment S_3, Flatbed paired row 90 cm bed width (two rows at 40 cm × 20 cm plant to plant spacing) with 80 days haulm killing recorded highest seed size tuber 58.03% and benefit cost (B:C) ratio of 2.51:1 among all other treatment combinations. Though, treatment S_3 i.e. flatbed paired row 90 cm bed width (two rows at 40 cm × 20 cm plant to plant spacing) with 80 days haulm killing combination require higher seed rate but can be an economically viable option for enhancing seed size tuber percent and B:C ratio.

Keywords: Agro-techniques, Haulming, Seed size, Spacing, Variety

High yielding early bulking varieties of potato (*Solanum tuberosum* L.), viz. Kufri Khyati, Kufri Pukhraj, Kufri Mohan and Kufri Lima are very popular for cultivation in India. Among them Kufri Khyati performs well both under very early @60 days and early @75 days (Kumar *et al.* 2009) and when grown under seed production for 70–80 days produces higher percentage of non seed size tubers and less percentage of seed size (25–125 g) tubers (Sadawarti *et al.* 2017) which is less than 50% or around 50% with different agro-techniques (Sadawarti *et al.* 2022). This higher per cent of non-seed size tubers is a major concern/challenge for seed potato producing organizations (formal system) like ICAR-Central Potato Research Institute, State Agricultural Universities (SAU), State Departments (Horticulture/ Agriculture), National Seed Corporation (NSC) and State Farm Corporation of India (SFCI), State Seed Corporation (SSC) and Cooperative societies etc. which are involved in Foundation Seed-I, Foundation Seed -II and certified seed production and also to progressive seed potato growers (informal system).

The size of the seed tuber has a significant impact on overall yield, hence it is important to consider it while determining the seed rate (Dagne *et al.* 2018). Seed makes up 40–50% of the total production cost. Hence, increasing seed size tuber per cent in early bulking variety like Kufri Khyati is of utmost important researchable issue for seed potato production (Singh and Pandey 2013). At field level different agro-techniques like adjustment in planting geometry, canopy management and nitrogen levels have been tried to maximize the seed tuber size by different workers in different varieties (Farahvash and Iranbakhsh 2009, Singh and Singh 2016, Singh *et al.* 2019, Sadawarti *et al.* 2023, Kumar *et al.* 2023, Kumar *et al.* 2023).

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Quantitative differences between the conventional ridge and furrow system and bed planting are scanty (Kumar *et al.* 2023). Economic viability (B:C ratio) needs to be taken into consideration while developing/standardizing different agro-techniques for seed potato production (Kumar *et al.* 2023). With this background present investigation was undertaken with different spacing combinations and haulm killing duration to enhance seed size tubers in high bulking potato variety Kufri Khyati.

MATERIALS AND METHODS

The present experiment was conducted during 2020–21, 2021–22 and 2022–23 at Regional Station, ICAR-Central Potato Research Institute, Gwalior, Madhya Pradesh. Treatments consisted of 5 spacing combinations as main plot, viz. S_1, Ridge and furrow 60 cm × 20 cm (Control) with plot size 10.8 m^2; S_2, Ridge and furrow 60 cm × 15 cm with plot size 10.8 m^2; S_3, Flatbed paired row 90 cm bed width (two rows at 40 cm × 20 cm plant to plant spacing) with plot size 8.1 m^2; S_4, Flatbed paired row 90 cm bed width (two rows at 40 cm × 15 cm plant to plant spacing) with plot size 8.1 m^2; and S_5, Flatbed triple row 90 cm bed width (three rows at 20 cm × 20 cm plant to plant spacing) with plot size 8.1 m^2 and 2 haulm killing dates as sub plots, viz. 70 and 80 days after planting in a split-plot design. Planting was done during the final week of October in 2020–21, 2021–22 and 1st week of November in 2022–23 with well-sprouted 40–50 g tubers. Nitrogen, phosphorus, and potassium, were applied at rates of 150, 80 and 100 kg/ha, respectively. According to standard seed plot techniques, the seed crop was grown. Observations on final emergence at 30 DAP and morphological attributes were recorded at 50 DAP and yield attributes at harvest of the crop respectively. Per cent seed size tuber and net tuber yield obtained by number and weight were calculated as:

$$\text{Per cent seed size tuber} = \frac{\text{Seed size tuber yield by number and weight}}{\text{Total tuber yield by number and weight}} \times 100$$

Net tuber yield obtained by number and weight = Total tuber yield obtained by number and weight - Seed tuber planted by number and weight.

Statistical analysis: Three year's data were pooled and analyzed statistically and means were separated according to the least significant differences (LSD) at 0.05 level of probability.

RESULTS AND DISCUSSION

Emergence and growth characters: The different spacing combinations, haulm killing days and their interactions did not have significant effect on days to initial per cent 50% and final emergence (>93%), number of stems/plant, compound leaves/plant and plant height (Table 1). Present findings were supported by the results of Pavek *et al.* (2018), Singh *et al.* (2019), Sadawarti *et al.* (2022), Kumar *et al.* (2023). This might be due to the fact that uniform-sized, well sprouted and healthy seed tubers were planted (Singh *et al.* 2019). Besides, more or less favourable soil temperature and moisture conditions prevailed in all the plots (Alam *et al.* 2016, Sadawarti *et al.* 2023).

Table 1 Tuber planted/ha, plant population/ha and per cent change in plant population in different spacing combinations

Spacing combinations	Tuber planted (q/ha)	Plant population/ha	Per cent change in plant population
S_1	37.50	83,333	-
S_2	50.00	1,11,111	+33.33
S_3	50.00	1,11,111	+33.33
S_4	66.67	1,48,148	+77.78
S_5	75.00	1,66,667	+100.0

Treatment details are given under Materials and Methods.

Seed tuber yield: Significant increasing trend was recorded in seed size tuber number and weight among spacing combinations and highest was recorded in S_5 (526 thousand/ha by number and 30.70 t/ha by weight) over S_1 control (323 thousand/ha by number and 18.11 t/ha by weight) (Table 2). Similar trend was reported for total and net tuber yield obtained both by number and weight (Fig. 1 and 2). Results are in agreement with studies conducted by Sadawarti *et al.* (2022), Kumar *et al.* (2023). Per cent seed size tubers did not affected significantly and ranged between 55–58% by number and 68–72% by weight (Fig. 3). Per cent seed size tubers were reported to 51% in conventional and 46% in flat bed system (Sadawarti *et al.* 2022). In earlier studies also it reported less or near 50% (Kumar *et al.* 2023). However, in the current study best treatment S_3 which is economically viable having highest B:C ratio of 2.51:1 recorded highest 58.06% seed size tubers over other flatbed systems. Haulm killing at 80 days recorded significantly higher seed size tuber number (452000/ha) and weight (26.94 t/ha) over 70 days haulm killing (417000 by number) and (23.21 t/ha by weight). Similar trend was reported in total and net tuber yield obtained both by number and weight (Table 2 and Fig. 3). 80 days haulm killing with flatbed recorded higher seed size and total tubers over conventional ridge and furrow (Sadawarti *et al.* 2022).

Increasing trend was recorded in magnitude of per cent increase in the seed size and total tuber number over control. Significant increase was reported in S_5 seed size tubers (70.07%) and total tuber (76.03%) at 70 days of haulm killing over control. Similarly, by weight also, the magnitude of seed size tuber increased in S_5 (71.96%) at 80 days haulm killing and total tuber (64.33%) at 70 days haulm killing (Fig. 3). The magnitude of per cent increase in the number of seed size tuber in paired row bed planting was 26.99 under Jalandhar condition of north-western India (Kumar *et al.* 2023) and 20.15% seed size and 24.13% total tuber under Gwalior condition of north-central India over the standard practice ridge and furrow (Sadawarti *et*

Table 2 Effect of different spacing combination and haulm killing days on seed tuber number and weight of potato variety kufri khyati

Spacing combination/ Haulm killing days	Seed tuber number (thousand/ha) <25 g 70 days	<25 g 80 days	<25 g Mean	25–125 g 70 days	25–125 g 80 days	25–125 g Mean	>125 g 70 days	>125 g 80 days	>125 g Mean	Total 70 days	Total 80 days	Total Mean	Seed tuber yield (t/ha) <25 g 70 days	<25 g 80 days	<25 g Mean	25–125 g 70 days	25–125 g 80 days	25–125 g Mean	>125 g 70 days	>125 g 80 days	>125 g Mean	Total 70 days	Total 80 days	Total Mean
S_1	202	184	193	308	339	323	34	43	38	543	566	555	2.12	2.33	2.23	17.08	19.15	18.11	4.87	7.51	6.19	24.08	28.99	26.53
S_2	271	242	256	343	378	361	36	41	38	649	661	655	2.94	2.26	2.60	19.15	23.01	21.08	5.43	7.14	6.29	27.52	32.42	29.97
S_3	272	299	285	442	476	459	37	56	47	751	830	791	3.06	3.22	3.14	25.62	28.03	26.83	6.03	10.06	8.04	34.71	41.31	38.01
S_4	368	326	347	470	541	505	46	64	55	884	931	908	3.69	3.54	3.61	25.70	31.58	28.64	7.14	11.72	9.43	36.53	46.84	41.69
S_5	385	367	376	523	529	526	48	48	48	956	944	950	4.14	3.76	3.95	28.48	32.92	30.70	6.95	8.44	7.69	39.56	45.12	42.34
Mean	300	284		417	452		40	51		757	787		3.19	3.02		23.21	26.94		6.09	8.97		32.48	38.94	
CD (*P*=0.05) Spacing (A)			47.1		28.9			11.9			54.5			0.78			2.76			1.95			3.40	
Haulm killing days (B)			NS		22.4			8.2			28.9			NS			1.55			1.26			1.7	
Factor (B) at same level of A			NS		NS			NS			NS			NS			NS			NS			NS	
Factor (A) at same level of B			NS		NS			NS			NS			NS			NS			NS			NS	

Treatment details are given under Materials and Methods. NS, Non-significant.

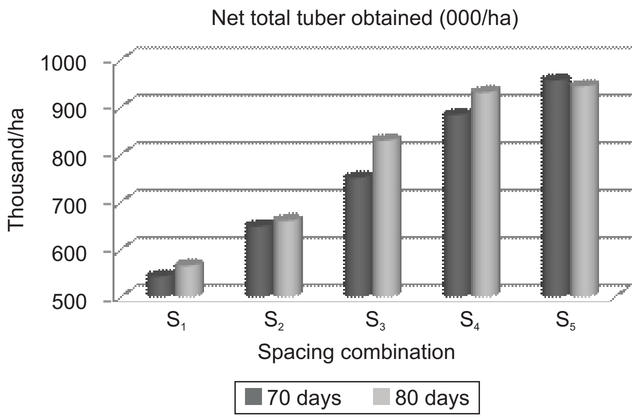

Fig. 1 Effect of different spacing combination and haulm killing days on net total tuber number of potato variety kufri khyati. Treatment details are given under Materials and Methods.

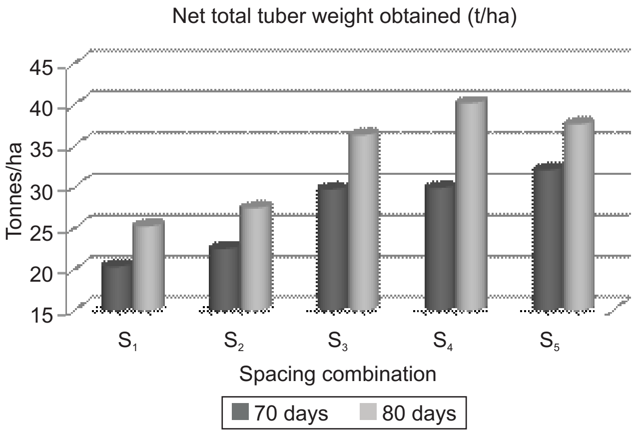

Fig. 2 Effect of different spacing combination and haulm killing days on net total tuber weight of potato variety kufri khyati. Treatment details are given under Materials and Methods.

al. 2022). This increase in bed planting might be due to tendency of roots to grow horizontally rather than vertically downward in furrow planting method, might have helped to extract more nutrients like nitrogen and water from soil, which enhanced more stolon and tuber formation, whereas, runoff from both the sides in ridge and furrow might led to ponding and infiltration which stimulate nitrogen leaching as revealed by Bradley *et al.* (2010). Fisher *et al.* (1993) recorded the increase in water use efficiency in bed planting leading to maximize the yield associated traits.

Like seed size and total tubers, significantly increasing trend was reported in case of small size (<25 g) tubers and highest was reported in closer spacing S_5 (376 thousand/ha by number and 3.95 t/ha) over (Table 2). Khalafalla (2001), Kumar *et al.* (2011), Mangani *et al.* (2015), Dawinder *et al.* (2020) also suggested that closer intra-row spacing resulted in development of greater number of smaller size tubers. Zabihi-Mahmoodabad *et al.* (2010) were of the opinion that increase in planting density creates competition for the nutrients within the plants that might lead to decline in tuber weight and size. Similar finding was reported by Singh *et al.* (2019) and Sadawarti *et al.* (2022). Non-significant but higher small size tuber number and weight was in 70 days

Table 3 Effect of different spacing combination and haulm killing days on economics of potato variety kufri khyati

Spacing combination/ Haulm killing days	70 days haulm killing					80 days haulm killing				
	Yield (q/ha)	Cost of production (₹/ha)	Gross return (₹/ha)	Net return (₹/ha)	Benefit cost ratio	Yield (q/ha)	Cost of production (₹/ha)	Gross return (₹/ha)	Net return (₹/ha)	Benefit : cost ratio
S_1	240.76	222114	433363	211249	1.95	289.88	220071	521780	301709	2.37
S_2	275.20	253188	495359	242171	1.96	324.15	257860	583476	325616	2.26
S_3	347.15	266458	624869	358412	2.35	413.11	295836	743605	447769	**2.51**
5_4	365.32	306027	657580	351554	2.15	468.45	352271	843205	490934	2.39
S_5	395.64	331003	712153	381150	2.15	451.17	362661	812101	449441	2.24

Treatment details are given under Materials and Methods.

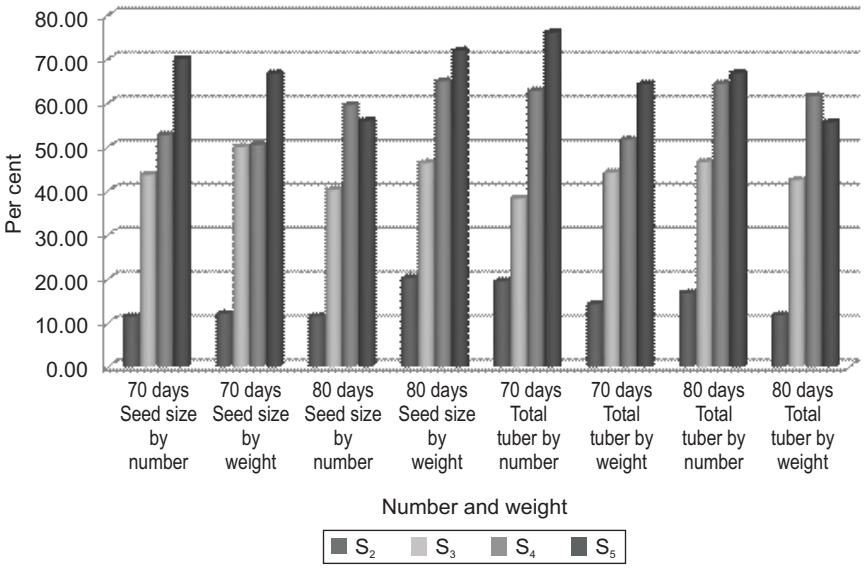

Fig. 3 Per cent tuber number and weight increase of potato variety kufri khyati over control in different spacing combinations and haulm killing days. Treatment details are given under Materials and Methods.

haulm killing over 80 days haulm killing in the present study (Table 2). In earlier studies dehaulming at 70 days recorded higher small size tubers than delayed dehaulming of 80 days (Sadawarti *et al.* 2022, Kumar *et al.* 2023).

In case of large size tubers (>125 g), only S_4, Flatbed paired row 90 cm bed width (two rows at 40 cm apart 15 cm plant to plant spacing) recorded significantly higher tuber number (55 thousand/ha) and weight (9.43 t/ha) over control (Table 2). The higher number of large size tubers in S_4 may be due to production of higher tubers than conventional spacing and wider spacing than S_5, 80 days haulm killing recorded significantly higher tuber number (51 thousand/ha) as well as weight (8.97 t/ha) over 70 days haulm killing. Significantly higher number of tubers was obtained in delayed haulm killing (Sadawarti *et al.* 2023)

Benefit : cost ratio: Any farming has direct relationship to benefits gained from it. Among spacing combinations and haulm killing days for seed potato production in the present study, highest gross return (₹843205/ha) and net return (₹490934/ha) was reported in S_4 at 80 days of haulm killing but highest B:C ratio was obtained in S_3 with 80 days haulm killing (2.51:1) (Table 3). Though higher seed yield, gross and net return was obtained in S_4 and S_5 treatment, the higher B:C ratio in S_3 is due to lower seed cost, lower labour requirement for harvesting and grading as compared to S_4 and S_5. Although, cost of cultivation remained maximum in paired row bed planting, due to higher seed cost. Higher cost of seed and management practices are main cause of major reason for high cost of potato cultivation (Azimuddin *et al.* 2009). 30th October planting with Kufri Khyati recorded highest gross return of ₹228,900/ha at 90 days harvest (Singh *et al.* 2017). Benefit cost ratio can be again higher as flatbed plantings yielded higher small size tuber which fetches higher price (Kadian *et al.* 2007).

The study signifies that to keep pace with ever increasing demand of potato. Higher potato yield is of utmost important which require good quality seed size tubers. Flatbed paired row 90 cm bed width (two rows at 40 cm × 20 cm plant to plant spacing) with 80 days haulm killing can be an economically viable option for enhancing seed size tuber percent and B:C ratio for formal and informal potato producing organizations.

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