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Standardization of plant density and intra-row spacing to maximize seed size tubers in two potato cultivars (*Solanum tuberosum*) grown in northern hills

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ABSTRACT

To overcome the problem of oversize tubers, three planting densities (80000, 100000 and 133333 plants/ha) were evaluated at 25, 20 and 15 cm intra-row and 50 cm inter-row spacing, in two late blight resistant potato (*Solanum tuberosum* L.) cultivars, viz. Kufri Himalini and Kufri Girdhari during the *kharif* season under hill conditions. At the maximum plant density (133333 plants/ha) obtained with closer spacing (50 × 15 cm), the proportion of extra large (>150 g) tubers was reduced from 23.5 to 12.4% in cv. Kufri Himalini and from 17.4 to 10.4% in cv. Kufri Girdhari. Besides, an increase in the proportion of seed size (20-80 g) tubers from 33.6 to 43.9% was also recorded. The yield of extra-large tubers (>150g) came down from 43 to 30% along with 10% increase in the yield of seed size (20-80 g) tubers.

Key words: Ground cover, Plant density, Plant vigour, Potato, Seed size, Tubers

Optimizing plant density and seed size is the most important issue of potato production due to its direct effect on seed cost, plant development, yield and quality of the crop. Seed constitutes a major and important input in potato (*Solanum tuberosum* L.) cultivation; non-availability of quality seeds has been reported to be a major factor for low potato productivity in India (Rana *et al.* 2013). On account of vegetative propagation, the requirement of seed potatoes (tubers) is voluminous and accounts for 40-50% of the total production cost (Kushwah and Singh 2008, Sharma and Singh 2010). The production cost may still be higher in the high hills, where, a major proportion of the potato harvest falls in large and extra-large grades on account of long crop season coupled with long day conditions (Sharma and Kumar 2014). Small tubers compared to large ones are highly preferred by the farmers to reduce the seed costs (Horton, 1987). Small tubers are known to reduce the seed requirement by ~50% and consequently, decline the cost of cultivation by about 25% (Arsenault *et al.* 2001).

Late blight is one of the major diseases in the hilly areas, where potato is grown mainly during *kharif* season. To circumvent the problem, development of late blight resistant cultivars is an important approach which also saves the cost of chemicals. On these lines, the ICAR-Central Potato Research Institute, Shimla released two late blight resistant cultivars, viz. Kufri Himalini and Kufri Girdhari during the years 2007 and 2011, respectively. Both the cultivars besides being resistant to late blight have high yield potential over the existing cultivars of potato in the region (Joseph *et al*. 2007, 2011).

Being resistant to late blight, these cultivars are becoming popular amongst the farmers of the hilly areas (Sharma and Pandey 2015). Although, the cultivar Kufri Himalini is performing well in all the potato growing regions of India, due to the longer crop duration in the high hills, a major proportion of the produce falls in large and extra-large grades (Sharma and Pandey 2015). Such, large-sized tubers are not preferred either for seed or for table purpose. Keeping in view the problem of over-sized tubers with late blight resistant cultivars in the hills, an attempt was made to improve the proportion of seed size tubers through the manipulation of planting density/crop geometry.

MATERIALS AND METHODS

A field study was conducted in split plot design with three replications during the *kharif* seasons of 2013 and 2014 at ICAR-Central Potato Research Station, Kufri (Fagu Unit), Shimla, which is located at 2700 m above mean sea level. Seed tubers (40-60 g) of potato cultivars Kufri Himalini and Kufri Girdhari collected from last season (Sept. harvest) were planted at three plant densities, viz., 80000 (D1), 100000 (D2) and 133333 (D3) plants/ha, representing the intra-row spacing of 25, 20 and 15 cm,

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respectively. Row-to-row spacing was kept uniform at 50 cm. The recommended inter and intra row spacing for the hills are 50-60 × 20cm. In both the years of study, planting was done on 29 April in 3×3 m plots. The recommended doses of fertilizers for the region, *i.e.* 120 Kg N, 100 Kg each of P and K were applied for raising the crop. Full dose of P as single super phosphate, K as muriate of potash and 80% N as calcium ammonium nitrate (CAN) were applied at the time of planting. The remaining dose of N (20%) was applied as CAN at the time of earthing up after 50 days after planting (DAP). Standard package of practices was followed for raising a good seed potato crop. Data was collected on frequency of plant emergence (%) at 35 and 50 DAP, whereas, plant height (cm), number of shoots and compound leaves per plant was recorded at 75 DAP. Ground cover (%) was estimated at 60, 75, 90 and 105 DAP with the help of a 50×50 cm grid with 100 equal compartments at two locations in each plot as described by Burstall and Harris (1983). Haulms were cut after 120 DAP and fresh weight was recorded. At harvest, the produce was graded in to four grades, viz., under-size tubers (<20 g), seed-size tubers (20-80 g), large-size (80-150 g) and extra-large tubers (>150 g). Data were recorded on the number and weight (yield) of total and graded tubers. The data was statistically analyzed by following the standard procedures (Gomez and Gomez 1984).

Table 1 Effect of varying intra-row spacings on % germination of potato

Variety	Frequency of germination (%)							
	35 DAP				50 DAP			
	D1	D2	D3	Mean	D1	D2	D3	Mean
K. Himalini	99.9	97.2	97.2	98.1	99.6	98.7	99.9	99.4
K. Girdhari	99.4	99.0	97.2	98.5	99.9	99.4	98.6	99.3
Mean	99.7	98.1	97.2		99.8	99.0	99.2	
CD (P=0.05)								
Cultivar (A)			NS					NS
Spacing (B)			0.8					NS
Factor (B) at same level of A			1.6					1.2
Factor (A) at same level of B			1.6					1.0

RESULTS AND DISCUSSION

Plant emergence

The frequency of plant emergence (%) after 35 and 50 DAP was found to be similar between both the cultivars (Table 1). However, at 35 DAP, plant emergence showed a decreasing trend with the increasing plant density. With the advancement of time (at 50 days crop) the effect of planting density on plant emergence was over, and it was almost same in all the treatments.

Ground cover

At 60 DAP, ground cover was significantly affected by the plant density but was same between the two cultivars (Table 1, 2). With the increase in plant density, a gradual increase in the ground cover was recorded, which could be attributed to more number of plants per unit area.

A similar observation was also reported by Midmore (1988), Singh *et al.* (1997) and Zamil *et al.* (2010). At 75 and 90 DAP, ground cover reached to the maximum (99.9%) and was almost same and statistically non-significant among the treatments as well as between the two cultivars (data for ground cover at 75 DAP not provided). At 105 DAP, the ground cover followed a trend just opposite to the one noticed at 60 DAP, i.e. a gradual decline in the ground cover with increasing plant density. However, at this stage, the ground cover was found to be significantly higher in Kufri Girdhari (99.1%) than Kufri Himalini (94.5%).

Plant growth parameters

Plant height was significantly affected by plant density but not by the genotype (Table 3). Increasing plant density resulted in a gradual increase in plant height. Such a significant increase could be attributed to increased competition among the stems for light and space as already reported by earlier workers (Singh *et al.* 1993, Singh *et al.* 1997).

Number of stems and compound leaves per plant showed a gradual and significant decrease with the increasing

Table 2 Ground cover (%) in potato cultivars as affected by varying plant densities

Variety	Ground cover (%)											
	60 DAP				90 DAP				105 DAP			
	D1	D2	D3	Mean	D1	D2	D3	Mean	D1	D2	D3	Mean
K. Himalini	75.5	78.3	81.3	78.4	99.8	99.8	99.9	99.9	96.6	94.2	92.6	94.5
K. Girdhari	75.8	77.4	80.6	77.9	99.9	99.9	100	99.9	99.1	99.6	98.8	99.1
Mean	75.6	77.8	81.0		99.9	99.9	99.9		97.8	96.9	95.7	
CD (P=0.05)												
Cultivar (A)			NS				NS			0.7		
Spacing (B)			1.1				NS			1.1		
Factor (B) at same level of A			NS				NS			1.7		
Factor (A) at same level of B			NS				NS			1.4		

Table 3 Plant growth parameters of potato as affected by the varying plant densities at 75 DAP

Variety	Plant height (cm)				Number of shoots/ plant				No. of leaves/ plant			
	D1	D2	D3	Mean	D1	D2	D3	Mean	D1	D2	D3	Mean
K. Himalini	63.4	64.5	71.5	66.5	2.5	2.1	2.3	2.3	31.6	29.4	23.7	28.2
K. Girdhari	61.7	65.2	75.2	67.4	2.7	2.3	2.3	2.5	38.0	37.0	30.1	35.1
Mean	62.5	64.9	73.3		2.6	2.2	2.3		34.8	33.2	26.9	
CD (P=0.05)												
Cultivar (A)			NS				NS				0.5	
Spacing (B)			1.9				0.1				1.0	
Factor (B) at same level of A			2.8				NS				NS	
Factor (A) at same level of B			2.4				NS				NS	

Table 4 Production behaviour of potato as affected by varying intra-row spacing

Variety	Haulms weight (g/m^2)				Total number of tubers ('000/ha)				Total yield (tonnes/ha)			
	D1	D2	D3	Mean	D1	D2	D3	Mean	D1	D2	D3	Mean
K. Himalini	155.8	135.3	107.3	132.8	438	471	504	471	40.5	39.9	40.1	40.2
K. Girdhari	272.1	181.6	162.3	205.3	422	473	501	465	37.3	36.5	34.9	36.2
Mean	213.9	158.5	134.8		430	472	503		38.9	38.2	37. 5	
CD (P=0.05)												
Cultivar (A)			4.5				NS				0.5	
Spacing (B)			1.7				06				0.2	
Factor (B) at same level of A			3.8				11				0.5	
Factor (A) at same level of B			4.7				11				0.5	

plant density. Number of stems between the cultivars was found to be almost same but the compound leaves per plant were higher in Kufri Girdhari (35.1) than Kufri Himalini (28.2) (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 (Lal *et al.* 1981, Khurana and Pandita 1982). 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 (Kushwah 1989, Singh *et al.* 1997).

At 120 DAP, increasing plant density resulted in a significant decrease in the weight of haulms/plant (Table 4). Significant reduction in weight of haulms with increase in plant population has also been reported by Zamil *et al.* (2010), and which could be attributed to the increasing competition between plants as space is the major limitation in the development of plant under increased plant densities. Between the cultivars, the haulms weight/plant was found to be higher in Kufri Girdhari (205.3 g/m^2) than Kufri Himalini (132.8 g/m^2) More weight of haulms in Kufri Girdhari could be attributed to the higher ground coverage in this cultivar for the longer period of time (up to 105 DAP and beyond).

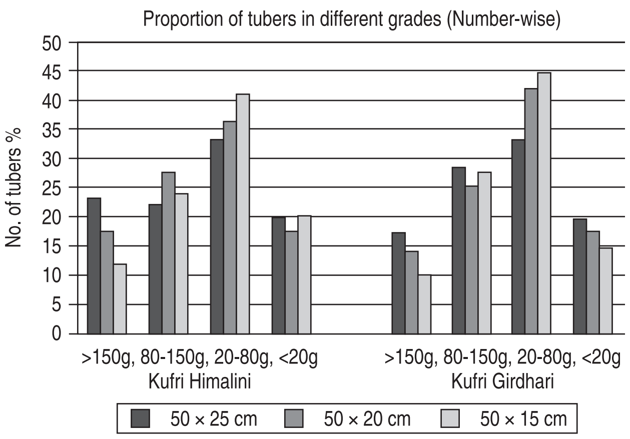
Number of tubers and yield

Increasing plant density resulted in a significant increase in the number of tubers/ha but the yields were affected adversely (Table 4). Increase in number of tubers per unit area with increasing plant population may be due to more number of plants or stems per unit area as tuber number is known to be directly related to stem number (Lal *et al.* 1981, Khurana and Pandita 1982, Kushwah and Singh 2008, Malik *et al.* 1999 and Zamil *et al.* 2010). Reducing tuber yield of potato at high plant density may be due to small size of the tubers obtained on account of increase in number of tubers.

Among the cultivars, total potato yield was more in Kufri Himalini than Kufri Girdhari. Higher tuber yields in Kufri Himalini than Kufri Girdhari have also been reported by the breeders of these cultivars (Joseph *et al.* 2007 and 2011) as well as by Sharma and Pandey (2015). Higher total tuber yield in Kufri Himalini than Kufri Girdhari can be attributed to the fact that the full yield potential of Kufri Girdhari might not have been exploited at the time of cutting the haulms at 120 days of crop age, as indicated by the higher green mass (haulms weight). Increasing the crop duration further, i.e. beyond 120 days in table crop may further increase the yields in Kufri Girdhari.

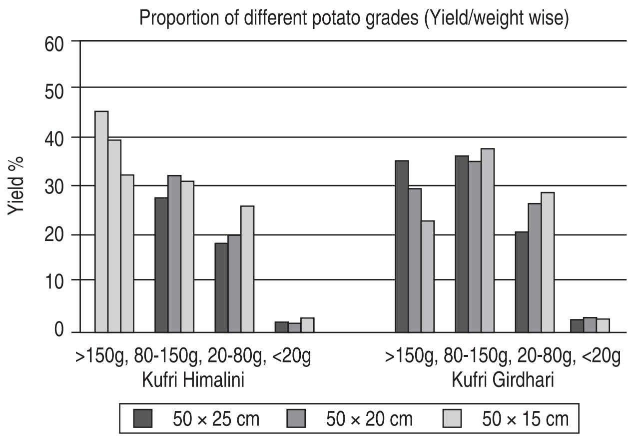
Proportion of different grades of tubers

Increasing plant density resulted in a gradual and significant reduction in the proportion of extra-large (>150 g) tubers, while increasing the proportion of seed size (20-80 g) tubers. The proportion of large (80-150 g) and under-size (<20 g) tubers was found to be unaffected by the varying plant densities. Between the two cultivars, the proportion



CD (P=0.05)	>150g	80-150g	20-80g	<20g
Cultivar (A)	2.0	0.4	NS	NS
Spacing (B)	1.2	NS	0.6	NS
Factor (B) at same level of A	2.2	1.9	1.5	3.2
Factor (A) at same level of B	2.3	1.6	4.6	6.3

Fig 1 Proportion of number of tubers in different grades



CD (P=0.05)	>150g	80-150g	20-80g	<20g
Cultivar (A)	2.7	1.5	1.5	NS
Spacing (B)	1.2	1.1	1.3	0.5
Factor (B) at same level of A	NS	2.0	2.2	NS
Factor (A) at same level of B	NS	1.9	2.0	NS

Fig 2 Proportion of potato yield in different grades

of extra-large tubers was higher in Kufri Himalini, whereas, the proportion of large (80-150 g) tubers was more in Kufri Girdhari. The proportion of other two grades, viz. seed size (20-80 g) and under-size (<20 g) tubers was found to be similar in both the cultivars (Fig 1).

Production of more large-sized tubers in Kufri Himalini can be attributed to the inherent behaviour of this cultivar controlled by genetic traits (Sharma and Pandey 2015). Comparatively higher proportions of extra-large tubers in Kufri Himalini than Kufri Girdhari (with more small tubers) can be attributed to the immature state of plants at haulms cutting in cultivar Kufri Girdhari than Kufri Himalini. On the other hand, the higher proportions of extra-large tubers (>150 g) are not desirable for table or even for seed purpose. Similarly, increase in plant density resulted in a significant reduction in the proportionate yield of oversize (>150 g) tubers, whereas the yield of all the remaining smaller grades, viz. large (80-150 g), seed size (20-80 g) and under-size tuber yield (<20 g) improved at higher plant populations except for 80-150g tuber yield in Kufri Himalini where it was little higher at 50 × 20cm than 50 × 15 cm (Fig 2).

Reduction in over-size tuber yield along with an increase in the yield of lower grades with increase in plant density has also been reported by Guarda and Giulliari (1983), Kumar *et al.* (2001) and Kushwah and Singh (2008). A possible reason for the same was ascribed to be the reduced availability of assimilates for individual tubers to grow on account of reduced number of stems and leaves per plant at higher plant density (Wurr *et al.* 1992). Among the cultivars, the yield of over-size (>150 g) tubers was significantly higher in Kufri Himalini, while, Kufri Girdhari out yielded Kufri Himalini in all the remaining (smaller) tuber grades.

A critical appraisal of tuber grade distribution indicated that at higher plant density of 133333 plants /ha (50×15 cm), the proportion of extra-large tubers (>150 g) in Kufri Himalini can be reduced from 23.5 to 12.4%, and in Kufri Girdhari from 17.4 to 10.4%. It also results in an average gain in the proportion of seed size (20- 80 g) tubers from 33.6 to 43.9%. Similarly, at this higher plant density, the yield of extra-large tubers (>150 g) comes down from 43.0-30.0% along with about 10% increase in the proportion of seed size (20-80 g) tuber yields.

From the results, it can be concluded that to overcome the problem of oversize tubers in the late blight resistant cultivars (Kufri Himalini and Kufri Girdhari) during the *kharif* season in high hills, a plant population of 133333 plants/ha should be adopted by planting the seed tubers at 50×15 cm than 50 × 20 or 25cm to get the maximum proportion of seed size (20-80 g) tubers.

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