



Standardization of planting geometry for aeroponic mini-tuber production in potato (*Solanum tuberosum*)

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ABSTRACT

For optimization of potato (*Solanum tuberosum* L.) mini-tuber production through aeroponics, an experiment was conducted for the standardization of plant density through varying in-row and intra-row spacing's in the aeroponic unit of ICAR-Central Potato Research Institute, Shimla, HP, India. The results revealed that the total number of mini-tubers and yield per plant obtained during all the 14 harvests were in general higher at wider intra-row spacing of 15 cm than 10cm in both the inter-row spacing's, viz. 15 cm as well as 20 cm. On per unit area basis, the number of tubers/m² was maximum at the highest plant density (66 plants/m²) achieved with 15 × 10cm spacing, closely followed and at par with plant density of 44 plants/m² (15 × 15 cm) and minimum with lowest planting density (33 plants/m²) at 20 × 15 cm. Yield/m² was not affected significantly with the varying plant density, however, the average weight per tuber was significantly higher (1.74g) at the lowest planting density (33 plants/m²) obtained with 20 × 15cm spacing and was statistically at par among rest of the treatments.

Key words: Aeroponics, Mini-tubers, Plant density, Potato, Spacing

Potato (*Solanum tuberosum* L.) mini-tuber production through aeroponics is gaining popularity over other methods like direct planting of micro-plants or micro-tubers under net houses etc. The various advantages associated with the aeroponics like higher rates of multiplication, better health standards and size regulation by sequential harvesting of mini-tubers etc. are the major factors behind the wider acceptability of the technique. Beside this, solution recirculation, a limited amount of water use, good monitoring of nutrients and pH are some of the additional advantages associated with aeroponics (Farran and Mingo-Castel 2006). In India, potato mini-tuber production through aeroponics can be successfully practised in all the potato growing areas, viz. hills and plains. Aeroponics under temperate weather conditions has already been reported to substantially improve mini-tuber production (Ritter *et al.* 2001).

Obtaining higher rates of multiplication is always aimed in any seed potato production programme. The crop management practices under aeroponics are altogether different from commercial potato production. Intra-space competition is well known to alter above and below ground

bio-mass partitioning in vegetable crops (Radosevich *et al.* 1997, Roush *et al.* 1989). Karafyllidis *et al.* (1997) have reported that more mini-tubers and yield per unit area are expected in high planting densities in contrast with low planting densities, while, Georgakis *et al.* (1997), and Love and Thompson-Johns (2006) have reported that increasing planting density reduces proportion of large mini-tubers in favour of more small mini-tubers. So, to optimize mini-tuber production in aeroponics, appropriate inter and intra row spacing's and thus plant densities are critical to improve the number and size of mini-tubers. Keeping in view the fact that no such information is available under Indian conditions, the present study was conducted with the objective to standardize the planting geometry and/or plant density in aeroponics.

MATERIALS AND METHODS

An experiment was conducted in the aeroponic unit at ICAR-Central Potato Research Institute, Shimla during the years 2017 and 2018. Three weeks old *in vitro* plantlets of potato variety Kufri Himalini were planted during season II (planting 1st week of Feb.) each year using 04 planting geometries. Two inter and two intra-row spacings, viz. 15 × 10cm, 15 × 15cm, 20 × 10cm and 20 × 15cm (with corresponding plant densities of 66, 44, 50 and 33 plants per sq. meter) were assessed in randomized block design to know their effects on plant growth, rates of multiplication and productivity under aeroponics. Each treatment consisted of 03 replications containing 06 plants each. Data were

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collected on plant establishment at weekly interval up to 04 weeks and on number of primary stolons per plant at 30 and 60 days after planting (DAP). Plant height and root length (cm) were measured at the end of season. Harvesting of mini-tubers was started at 40 DAP and a total of 14 harvestings were done at an interval of 07 days. Data on total number of tubers and yield per plant was collected by making total of all the harvests during the full crop season. Since the year $\times$ year variations were non-significant, the average of two years' data was analyzed statistically by applying the technique of analysis of variance (ANOVA) as described by Gomez and Gomez (1984). Mean values were calculated and separated using F-test at 5% level of significance.

RESULTS AND DISCUSSION

Percent plant establishment

The plant establishment under aeroponics was not affected by any of the planting geometry or plant density and was found to be full (100%) in all the treatment (data not given).

No. of primary stolons

The number of primary stolons per plant after 30 and 60 days of planting (DAP) were though not affected significantly by the varying plant densities obtained through different combinations of inter and intra-row spacing's; but, in general the number of primary stolons per plant were higher at low plant densities than at higher plant densities. Farran and Mingo-Castel (2006) have also reported significant increase in the number of stolons at low plant density under aeroponics. In the present study, the number of stolons were maximum with a plant density of 33 and 44 plants/m². Number of primary stolons at both the stages (30 and 60 DAP) were minimum at the highest plant density (66 plants/m²) obtained through the planting geometry of 15cm $\times$ 10cm. The results indicate that plant density beyond certain optimum is detrimental for the proper development of stolons in the aeroponics production system. Reduction in number of stolons per plant with increasing plant population in aeroponics can be attributed to the availability of limited

space and consequently lower light availability for the proper development of plant (Farran and Mingo-Castel 2006).

Plant height

Plant height in aeroponics was significantly affected by the varying plant densities (Table 1). Contrary to field studies, plant height under aeroponics was in general higher at low plant densities than the higher ones. Higher plant density achieved through reducing the intra-row spacing from 15 to 10cm was more effective in reducing the plant height at both the inter-row spacing's, i.e. 20 cm and 15 cm, respectively. Final plant height was significantly higher (145.2cm) at a plant density of 44 plants/m² obtained through planting geometry of 15 $\times$ 15 cm. Plant height at further low plant density (33 plants/m²) obtained through 20 $\times$ 15 cm geometry was 100.5 cm. These results indicate that it is not only the plant population per unit area but also the method of planting which affects the plant height. In the present study, planting at 15 $\times$ 15cm proved more effective in improving the plant height over 20 $\times$ 15cm and other geometries tested. Increase in plant height with reduction in inter-row spacing from 20 to 15cm at both the intra-row spacing's of 15 and 10cm can be attributed to increased competition between plants for light and space as already reported by earlier workers under field studies (Singh *et al.* 1993, Singh *et al.* 1997).

Root length

Final root length as recorded at end of season was found to be minimum at the maximum plant density of 66 plants per m² obtained through 15 $\times$ 10cm geometry, whereas with all other plant densities, the root length was almost similar and statistically at par. Poor plant development on account of limitation of space may be responsible for the poor development of roots in plants under high density planting.

Number of mini-tubers per plant

The number of mini-tubers per plant obtained during the total number of pickings was found to be affected significantly by the various plant densities. In general, the number of mini-tubers per plant were higher at low plant

Table 1 Effect of plant density/spacing treatments on the growth of potato plants in aeroponics

Treatment	Plant density (No. of plants/m ²)	No. of primary stolons (30 DAP)		No. of primary stolons (60 DAP)		Final plant height (cm)		Final root length (cm)	
		Mean	SE	Mean	SE	Mean	SE	Mean	SE
15 $\times$ 15cm	44	2.50	0.49	2.97	0.33	145.2	1.49	55.9	1.33
15 $\times$ 10cm	66	1.87	0.13	2.40	0.10	84.6	17.95	48.7	4.04
20 $\times$ 15cm	33	2.43	0.30	3.00	0.00	100.5	4.95	58.9	1.53
20 $\times$ 10cm	50	1.97	0.38	2.53	0.12	74.5	9.09	57.1	2.61
CD _{0.05}		NS		NS		28.9		6.18	
SE(m)		0.40		0.19		8.21		1.75	
SE(d)		0.57		0.26		11.61		2.48	
CV		31.9		11.9		14.04		5.49	

Table 2 Effect of plant density/spacing treatments on the production of potato mini-tubers in aeroponics

	Plant density (No. of plants /m ²)	No. of tubers/plant (14 harvests)		Yield (g)/plant (14 harvests)	
		Mean	SE	Mean	SE
15×15cm	44	38.2	1.32	53.2	2.03
15×10cm	66	26.4	2.03	35.3	4.76
20×15cm	33	42.0	0.65	73.2	2.17
20×10cm	50	33.2	0.39	48.5	0.79
CD _{0.05}		4.95		10.0	
SE(m)		1.40		2.84	
SE(d)		0.26		2.48	
CV		11.9		5.49	

densities of 33 and 44 plants/m² (20 × 15cm and 15×15cm, respectively) than the higher plant densities of 50 and 66 plants/m² (20 × 10cm and 15×10cm, respectively). Higher plant densities achieved by reducing the intra-row spacing from 15 to 10cm in both the inter-row spacing's resulted in a significant reduction in number of mini-tubers per plant. The maximum number of mini-tubers (42.0/plant) were obtained at the lowest plant density of 33 plants/m² (20 × 15cm), closely followed and statistically at par (38.2 mini-tubers/plant) with plant density of 44 plants/m² (15×15cm). The number of mini-tubers was minimum (26.4/plant) at the maximum plant density of 66 plants/m² (15×10cm).

Increase in number of mini-tubers per plant with decreasing plant population might be due to better plant vigour at low plant densities as evidenced by the respective plant height and number of stolons per plant. These results are in conformity to the earlier workers who have reported that higher growth vigour of potato plants results in more number of tubers per plant under field conditions (Kushwah and Singh 2008, Malik *et al.* 1999, Kumar *et al.* 2004, Zamil *et al.* 2010). Farran and Mingo-Castel (2006) have also reported that a high plant density resulted in fewer tubers per plant. Similar observations were also described by Struik and Lommen (1990).

Yield per plant

Like number, yield per plant was also significantly affected with the varying plant density (Table 2). In the

present study, total yield of mini-tubers per plant followed a trend similar to the number of mini-tubers per plant. Yield per plant were higher at low plant densities. Reduction in intra-row spacing from 15 to 10cm at both the inter-row spacing's resulted in significant reduction in the yield of mini-tubers on per plant basis. The yield of mini-tubers per plant was maximum (73.2g) at the minimum plant density of 33 plants/m² (20×15cm) and minimum at the maximum plant density of 66 plants/m² (15×10cm spacing). These results are in accordance with the findings of Santos and Rodriguez (2008) have reported that mini-tuber weight per plant increases linearly with increase in in-row distances in the crop raised from *in vitro* seedlings planted directly under field conditions. They suggested that wider in-row distance reduce intra-specific competition therefore causing a significant increase in mini-tuber weight per plant.

Number of mini-tubers/m²

On per unit area basis, the number of mini-tubers followed a trend just opposite to the one noticed for per plant basis, i.e. the number of mini-tubers on per sq meter basis was higher at high plant densities than the low plant densities. The highest plant density of 66 plants/m² resulted in maximum number of mini-tubers (1756 mini-tubers/m²), whereas the minimum plant density (33 plants/m²) resulted in lowest number of minitubers (1397 mini-tubers/m²). Farran and Mingo-Castel (2006) have also reported highest number of minitubers at a plant density of 60 plants/

Table 3 Effect of plant density/spacing treatments on the mini-tuber production behavior of potato in aeroponics

Treatment	Plant density (No. of plants/m ²)	No. of tubers/m ²		Yield (kg/m ²)		Avg. tuber weight (g)	
		Mean	SE	Mean	SE	Mean	SE
15×15cm	44	1,696	11.1	2.364	0.090	1.40	0.077
15×10cm	66	1,756	21.1	2.349	0.079	1.32	0.078
20×15cm	33	1,397	21.6	2.437	0.072	1.74	0.043
20×10cm	50	1,662	19.6	2.424	0.040	1.46	0.040
CD _{0.05}		70.192		NS		0.20	
SE(m)		19.897		0.081		0.058	
SE(d)		28.139		0.114		0.082	
CV		2.117		5.853		6.819	

m². Increase in number of mini-tubers per unit area with increasing plant population might be due to more number of plants or stems per unit area as tuber number is known to be directly related to stem/plant number as reported by many earlier workers during field studies on plant densities of potato (Kushwah and Singh 2008, Malik *et al.* 1999, Zamil *et al.* 2010). Santos and Rodriguez (2008) have also demonstrated that potato plants had differential production and distribution of photosynthates to mini-tubers depending on the in-row distances. At closer in-row spacing, potato plants produce many small mini-tubers, whereas at the larger in-row spacing, the number of mini-tubers are fewer but larger. Farran and Mingo-Castel (2006) have also reported that a high plant density increases the number of tubers per m².

Yield of mini-tubers/m²

Yield/m² was not affected significantly with the variation in planting density as all the plant populations on per unit area basis resulted in almost similar yields of mini-tubers. Non-significant differences between the yield levels of mini-tubers at different plant density treatments in spite of significant differences in the number of mini-tubers on per unit area basis are indicative of variations in the grade of mini-tubers obtained with different plant densities. Almost similar total mini-tuber yields at four plant densities in spite of significant differences in number of mini-tubers might be due to small size of the mini-tubers obtained with treatments resulting in higher number of mini-tubers and vice-versa. A reduction in oversize tubers and an increase in the number of undersize tubers with increase in plant density was also reported by Kumar *et al.* (2001) and Kushwah and Singh (2008) during their studies under field conditions and the possible reason for the same was ascribed to be the reduced availability of assimilates for individual tubers to grow on account of more number of tubers per plant. The results of the present experiment are in agreement with the findings of Karafyllidis *et al.* (1997) and Love and Thompson-Johns (2006). The results revealed that narrow in-row distances and high population densities reduces the proportion of large mini-tubers in favor of more small mini-tubers.

Average weight of mini-tuber

The average weight of mini-tuber obtained under aeroponics was significantly affected by the different plant densities. In general, the average weight of mini-tuber was maximum (1.74g) with the treatment producing the minimum number of mini-tubers per unit area, i.e. with the lowest plant density of 33 plants/m² and vice versa. The average weight per mini-tuber was minimum (1.32g) at the maximum plant density of 66 plants/m² producing the maximum number of mini-tubers/unit area. The possible reason for the same can be ascribed to the reduced availability of assimilates for individual tubers to grow on account of more number of tubers produced per plant. Santos and Rodriguez (2008) have also reported

that mini-tuber weight per unit area steadily decline with increase in in-row distances and the possible reason ascribed was that increasing in-row distances reduces intra-specific competition among potato plants hence causes a major shift on the mini-tuber production pattern from a few large mini-tubers at wider distances to many small mini-tubers at closer in-row spacing.

Conclusion

From the results it can be concluded that for obtaining the maximum number of mini-tubers/m² in aeroponics in the Spring-summer crop (February planting) under Shimla conditions, planting should be done at 15×15cm or 15×10cm spacing. The resultant average wt./mini-tuber will be 1.40 and 1.32g, respectively with same yield/m².

These findings are important for commercial potato mini-tuber production programs under aeroponics as they allow for an increase in mini-tuber numbers per unit area, and thus could prove better economically.

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