



## High density planting of potato (*Solanum tuberosum*) minitubers for increased seed productivity

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### ABSTRACT

The experiment was designed to evaluate flatbed planting and density of early potato (*Solanum tuberosum* L.) seed generation of small minitubers produced under net house conditions of North-western plains. Two varieties Kufri Chandramukhi and Kufri Surya were used in the experiments conducted in 2015–17. The flatbed planting at different plant densities (30×10, 20×10, 15×10 and 10×10 cm) was compared with prevalent ridge and furrow method having 30×10 cm row to row spacing as control in net house. Growth characters (plant height, number of leaves) along with yield parameters (yield, total number of tubers, undersize and seed size tubers) were evaluated for the treatments on per meter square basis. The spacing of 10×10 cm on flat bed significantly outperformed the other treatments in yield as well as total number of tubers. On an average the flat bed planting at 10×10 cm provided a benefit of twice the number of tubers and 1.4 times the yield over control ridge and furrow planting, yielding 259.74 tubers and 5.69 kg on per square metre area basis. The economics of this method was compared to the standard ridge and furrow method, where 1.7 times higher net profit was estimated. The adoption of flat bed planting in net house has tremendous potential in doubling the overall seed production and profitability, which would be itself favourable in advanced seed production generations.

**Key words:** High density planting, Minitubers, Net house, Potato seed production

India has emerged as the second largest producer of potato (*Solanum tuberosum* L.) in the world after China with a total production of 46.4 million tonnes (FAOSTAT 2014). Potato has been identified as a future crop for meeting food security issues (Singh and Rana 2013). Based on simulation studies, an estimated production of 122 million tonnes of potatoes is required by 2050 to sustain the increased population (CPRI, Vision 2050). However, owing to limited land resources, the main alternatives for increased crop productivity are developing high-yielding varieties, increasing the availability of disease free planting material and optimizing land resources. The present productivity of the crop in India is 22.9 t/ha (FAOSTAT, 2014); the high yielding potato varieties yield up to 35–40 t/ha on research farms, this yield gap can be explained on the basis of availability of inadequate quality seed and unscientific cultural practices followed by producers. Struik and Wiersema (1999) directly correlated high potato yields with use of high quality, certified seed tubers.

Keeping in view the deteriorating potato seed health

under field conditions, quality seed production can be increased by adopting measures to check seed stock degeneration. Efficient land resource utilization offers a solution to mitigate the effect of declining land resources. Net houses are used in Hi-tech seed production for cultivation of microplants as well as for recycling of small minitubers (<5 g) to get seed size or larger tubers for subsequent field multiplication and channelling into seed production generations. High density planting of small minitubers during recycling in net house in early seed generation offers the ideal opportunity for introduction of the intervention.

Presently potato is grown on ridge and furrows with 30×10 cm geometry in net houses but flat beds have also been reported for potato planting, which are more conducive for higher planting densities to reduce average tuber size (Mundy *et al.* 1999). Flat beds offer benefits of capturing rainfall or irrigation water more efficiently (Robinson 1999), and there are less fluctuations in temperature throughout the bed providing an insulating factor which promotes early emergence of crop (Mundy *et al.* 1999). They also offer scope for manipulating planting densities. Sharma *et al.* (2014) observed significantly higher number of minitubers for flat bed planting during standardization of plant densities and method (flat beds versus ridge and furrow) for microplant establishment under net house conditions of Northern hills. However, with limited work carried out on minitubers,

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the exact spacing, overall benefit of spacing for seed multiplication and its economics for a particular region needs to be worked out before final recommendation to the seed producers. An ideal combination of plant population, row-width, and in-row seed spacing for a particular variety are the major factors for optimizing tuber size and grower's revenue (Rex and Mazza 1989). Besides a major consideration is the acceptable seed size for field multiplication in G-1 which is <5 g, and needs to be reflected in any planting density strategy adopted. The classification of the tubers based on weight is of immense importance as the smaller tubers, tend to develop small and lesser number of sprouts, shoots, tubers, yield, prone to virus incidence and higher weight loss in storage as compared to larger sized tubers reportedly being less vigorous (Wurr *et al.* 1992, Karafyllidis *et al.* 1996). Simultaneously, very large size or oversize tubers are economically prohibitive as seed and also more prone to diseases (Schotzko *et al.* 1983, Rex and Mazza 1989). Differences in vigour have also been reported between undersize tubers and seed/oversize tubers.

The present experiment was conducted with the objective to evaluate planting density in net house using flat beds over the control ridge and furrow method for mintubers (produced from tissue culture microplants or aeronically) for land use optimization and economic viability.

#### MATERIALS AND METHODS

The experiment was conducted in the net house of ICAR-Central Potato Research Station, Jalandhar (31°23'N and 75°79'E, altitude 237 m amsl) with two varieties Kufri Chandramukhi and Kufri Surya during 2015-16 and 2016-17. Minutubers (2–5 g) were withdrawn from the cold store and allowed chitting under diffused light at 25–27°C for 20 days and planted in the 3<sup>rd</sup> week of October. Different row to row spacings of 30 cm (T30), 20 cm (T20), 15 cm (T15) and 10 cm (T10) were used against the control ridge and furrow planting at 30 cm (TC), with uniform plant to plant spacing 10 cm in all the treatments. Each treatment comprised of 3 replications, having 3 rows of 20 tubers each. Standard cultural practices were followed for the management of the crop, using over head sprinkler system for irrigation. The morphological observations on plant height and number of leaves

per stolon were recorded at 45 days after planting (DAP). The crop was terminated at 90 days by cutting haulms. The crop was harvested after allowing skin curing for 15 days. Yield, total number of tubers, tuber grades, viz. undersize, UM (<5 g); oversize, OM (> 30 g) and seed size tubers, SM (5–30 g) were recorded. Different treatment means were compared using two-way analysis of variance for treatment effects, varietal effects and their interactions, by Sigma Plot 12.0 software. Economics of the best planting method yielding highest multiplication rates and control were also worked out. Since the objective of the study was efficient utilization of expensive net house space, all comparisons were done on per square meter basis.

#### RESULTS AND DISCUSSION

The morphological scoring of the crop based on visual observation at 45 DAP did not show any significant differences for planting methods and spacing. The crop was healthy, free from disease and insect pests for the whole crop duration till harvest. Significant differences were observed among different treatments for the various characters (Table 1, 2, Fig 1).

**Total number of tubers/metre square (TM):** Higher mean number of tubers per metre square were obtained in 2015–16 for the variety Kufri Chandramukhi. Among the spacing treatments, maximum number of tubers were seen in T10 treatment which was significantly higher than the other spacing treatments considered in the experiment, showing a 99.23% increase over the control ridge and furrow treatment. The treatments T30 and control ridge and furrow were at par for total number of tubers produced per square metre. Hence, number of tubers observed for the least spacing were significantly more than the larger row spacing used in the experiment. This observation is in agreement to the earlier studies (O'Brien and Allen 1992, Wurr *et al.* 1993, Karafyllidis *et al.* 1996). Increased or

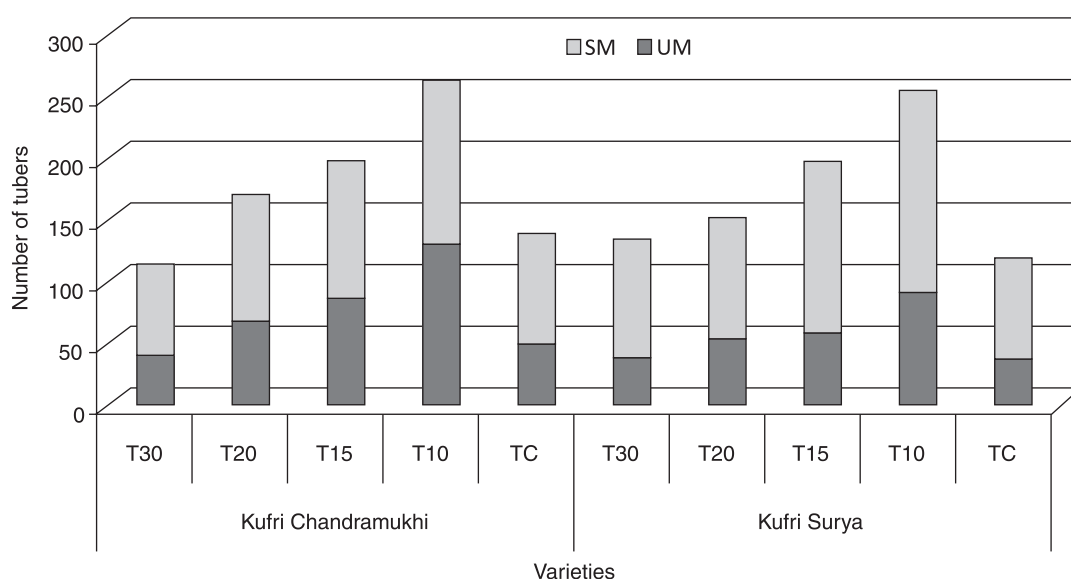


Fig 1 Tubers number in different seed categories out of total tubers produced undersize (UM) and seed size (SM) minutubers on per square meter basis for the two varieties Kufri Chandramukhi and Kufri Surya.

Table 1. Analysis of variance for different characters considered in the experiment and interactions as observed for the year spacing and variety treatments considered in the experiment

| Source of Variation   | df | YM       | TM          | SM         | UM          | NL       | PH         |
|-----------------------|----|----------|-------------|------------|-------------|----------|------------|
| Year                  | 1  | 8.382**  | 18079.954** | 5051.865** | 42245.949** | 47.526** | 1861.494** |
| Variety               | 1  | 16.208** | 445.548     | 2797.541*  | 5475.971**  | 1.601*   | 1895.064** |
| Spacing               | 4  | 11.996** | 37366.085** | 8974.483** | 9907.754**  | 14.951** | 15.356     |
| Year×Variety          | 1  | 0.0617   | 493.285     | 3.581      | 412.808     | 5.891**  | 2279.201** |
| Year×Spacing          | 4  | 1.278    | 902.414     | 470.394    | 1818.531**  | 4.783**  | 73.887**   |
| Variety×Spacing       | 4  | 3.833*   | 809.701     | 1084.245   | 708.726**   | 3.221**  | 23.401     |
| Year×Variety× Spacing | 4  | 1.555    | 710.851     | 370.83     | 148.527     | 0.546    | 17.042     |

YM= yield, TM =Total number of tubers/m<sup>2</sup>, SM= number of seed size tubers/m<sup>2</sup>, UM=number of undersize tubers/m<sup>2</sup>, NL=average number of leaves/plant, PH =average plant height

Table 2. Treatment means, least significant differences for comparison of means and standard error of mean for different characters considered in the experiment

|                    | YT    | SM      | UM      | NL     | PH     | TT      |
|--------------------|-------|---------|---------|--------|--------|---------|
| 2015-16            | 4.927 | 99.398  | 92.916  | 10.757 | 63.83  | 192.314 |
| 2016-17            | 4.179 | 117.75  | 39.847  | 12.537 | 52.69  | 157.596 |
| SEM                | 0.185 | 3.729   | 2.801   | 0.101  | 0.648  | 5.537   |
| LSD (0.05)         | 0.528 | 10.66   | 8.007   | 0.289  | 1.851  | 15.825  |
| Kufri Chandarmukhi | 4.033 | 101.746 | 75.935  | 11.81  | 63.88  | 177.68  |
| Kufri Surya        | 5.073 | 115.402 | 56.828  | 11.483 | 52.64  | 172.23  |
| SEM                | 0.185 | 3.729   | 2.801   | 0.101  | 0.648  | 5.537   |
| LSD (0.05)         | 0.528 | 10.66   | 8.007   | 0.289  | 1.851  | 15.825  |
| T30                | 3.654 | 84.528  | 40.519  | 12.283 | 57.275 | 125.046 |
| T20                | 3.822 | 99.794  | 62.135  | 12.458 | 58.225 | 161.931 |
| T15                | 5.579 | 124.653 | 73.774  | 10.8   | 57.667 | 198.428 |
| T10                | 5.698 | 148.071 | 111.674 | 10.117 | 60.183 | 259.745 |
| TC                 | 4.012 | 85.822  | 43.805  | 12.575 | 57.95  | 129.628 |
| SEM                | 0.292 | 5.897   | 4.429   | 0.16   | 1.024  | 8.754   |
| LSD (0.05)         | 0.836 | 16.855  | 12.66   | 0.458  | 2.927  | 25.022  |

T30, T20, T15, T10 denote the different high density (row to row) spacing for flat-bed used in the present experiment, viz. 30 cm, 20 cm, 15 cm, 10 cm and TC is control ridge and furrow at 30 cm

more number of tubers at high densities may be due to the fact that at low density plantings fewer sinks are produced per unit area and they increase with increasing planting density (Mangani *et al.* 2015)

*Number of undersize mini-tubers per metre square (UM)*: The character number of tubers per square metre showed the maximum and significant variation over the two year period of evaluation, simultaneously also depicting highly significant variations for variety and spacing. The interaction effects of year × spacing and variety × spacing were also significant. The maximum undersize tubers were observed for the T10 treatment which were significantly higher than the other treatment spacings, as observed for total number of tubers per metre square. Similarly, T30 and TC treatments were also observed to be depicting similar trends of being at par. Also T15 and T20 were at par for the character. A comparison of undersize tubers out of the total produced were in the similar range at different spacing as

32.40, 38.37, 37.18, 42.99, 33.79 percentages for T30, T20, T15, T10 and TC respectively. The minimum as expected were for T30 as against the maximum observed for T10. It was therefore observed that higher number of UM are formed at higher density, but their proportion out of total also increases simultaneously. Although, the UM tubers are not preferred as seed but are viable up to a certain lower limit below which the viability of minitubers may be lost due to shrinkage in storage. The UM category though of lower vigour is highly economic as it is first progeny of quality seed, and may be further be multiplied/ recycled. Varietal differences were significant with the variety Kufri Chandarmukhi significantly outyielding the variety K. Surya for number of undersize tubers produced.

*Number of seed size minitubers per square metre (SM)*: Seed size mini-tubers indicate the economically most important class of tubers with respect to seed multiplication and vigour. In the experiment significant differences for

the character over year, spacing treatment and variety were observed. Simultaneously interaction for year  $\times$  spacing was also significant. Similar trends where T10 treatment produced maximum number of seed size treatments as observed previously were obtained for this character as well. Treatments T30, TC and T20 were as par, and T15 was significantly higher than these. Varietal differences were significant with K. Surya producing higher number of seed sized tubers per square meter as compared to Kufri Chandramukhi for this character. Interaction effects were observed to be significant for year  $\times$  spacing.

**Yield per square metre (YM):** The yield is indicative of the total weight of tubers obtained per metre square for different spacing treatments. Significant differences for yield over year, variety, spacing and interaction of variety  $\times$  spacing were obtained. The significantly higher yield was obtained for the variety Kufri Surya as compared to variety Kufri Chandramukhi. Among the spacing treatments included in the study T10 and T15 showed at par yields, which were however significantly higher than the other treatment means of T30, T20 and TC.

**Plant height (PH):** The variety Kufri Chandramukhi showed higher plant height than Kufri Surya. The maximum plant height was obtained in T10, it was significantly tall than all the other treatments included in the study which were all at par. This gives two major inferences; firstly the

plants grew taller in response to higher density in face of competition for more light, secondly the spacings above 15 cm row to row excluded the competition for light among plants, and the treatments T15, T20, T30 and TC showed at par plant heights.

**Number of leaves per plant (NL):** The character showed significant variation for the all the parameters and also their interactions. The significantly higher number of leaves per plant were observed in the variety Kufri Chandramukhi than Kufri Surya. The spacing control treatment TC showed the maximum plant height followed by T30 and T20 which were at par statistically. This was followed by T15, and minimum plant height in T10 treatment. The observation corresponds to more aerial space for growth of canopy in TC and T30 treatments followed by the rest of the others. The interaction effects were observed to be significant for year  $\times$  spacing.

**Economics of planting density:** The economics were worked out for comparison of high-density planting at T10 to the conventionally used ridge and furrow TC (Table 3). On an average the flat bed planting at 10 cm row to row spacing provided a benefit of approximately twice the number of tubers and 1.4 times the yield over control ridge and furrow planting on per meter square basis. Adoption of flat-bed planting in net house has tremendous potential in doubling the overall seed production from net house

Table 3 Economics of planting geometry compared between T10 (flat-bed 10  $\times$  10) and TC (ridge and furrow 30  $\times$  10 cm), from production rates achieved in the present experiment, net house area of 400 square meter has been considered

|      | Cost heads/Others                                                                                 | T10     | TC      |
|------|---------------------------------------------------------------------------------------------------|---------|---------|
|      | No. of mini tubers required @ 20 $\times$ 15 crop geometry and 10% space for doors, walkways etc. | 40000   | 13333   |
| I.   | Fixed cost (A) one time investment (₹)                                                            |         |         |
| A    | Cost of construction of net house                                                                 | 80000   | 80000   |
| II.  | Depreciation, interest and other misc. cost (₹)                                                   |         |         |
| B    | Depreciation @ 10% per year                                                                       | 8000    | 8000    |
| C    | Interest @ 10% per annum                                                                          | 8000    | 8000    |
| D    | Per year cost of repair/ net replacement, net change 4 years                                      | 10000   | 10000   |
| E    | Total fixed cost per year (B+C+D)                                                                 | 26000   | 26000   |
| III. | Variable cost (₹)                                                                                 |         |         |
| F    | Cost of purchase of mini tubers for planting @ ₹ 6/ minituber                                     | 240000  | 80000   |
| G    | Labour cost @ 20 units per cycle @ ₹ 250/unit                                                     | 5000    | 5000    |
| H    | Fertilizer, Chemicals etc.                                                                        | 2000    | 2000    |
| I    | Miscellaneous expenses @ ₹ 5000/cycle                                                             | 5000    | 5000    |
| J    | Total variable cost per year (F+G+H+ I)                                                           | 252000  | 92000   |
| IV   | Total cost of production ₹/year [Fixed Cost B (III D)+ Variable Cost IV E]                        | 278000  | 118000  |
| V    | Production                                                                                        |         |         |
| K    | Production no. of tubers/ square meter (mean over all considered varieties)                       | 259.745 | 129.628 |
| L    | Total production (No. of tubers from 500 squaremeter net house) based on spacing                  | 103898  | 51851.2 |
| VI   | Total sale price of produced tubers @ ₹ 5/minituber (L $\times$ 5) (₹)                            | 519490  | 259256  |
|      | Profits (Total sale price (VI) - cost of production (IV)) (₹)                                     | 241490  | 141256  |

(All costs based on approximate prevailing rates at the time of experiment, 2015)

which would then present itself favourably in advanced seed production generations. An approximate 8 times seed production is projected in G2 on the basis of number of tubers. On working out the economics of implementing the high density flat-bed planting in net house (Table 2), T10 showed an estimated profit 1.7 times more than standard ridge and furrow method (TC). Similarly placing the approximate fixed and variable cost, the profit of ₹ 2.41 lakh under high density and ₹ 1.41 lakh under ridge and furrow have been calculated for a net house of area 400 square meter (purchase price of minituber was kept at ₹ 6/minituber for planting and ₹ 5 for sale of tubers produced) (irrespective of size).

Tuber number is an important character which determines the multiplication rates in potato and is most crucial for seed potato production. However, the size of the tubers is also important as seed size tubers are more prolific than underweight tubers and economically more adaptive than overweight tubers. However, irrespective of the size classification, these are potentially viable, with the smallest minitubers <1 g (constituting a very small component) prone to nonviability due to dehydration in storage. Significantly, higher and economically profitable multiplication rates achieved at higher density flat-bed planting as compared to standard ridge and furrow planting of 30×10 cm, can also be extended to planting outside net houses and for aeroponically developed tubers (2-3 g tubers). Multiplication rates achieved in the early seed multiplication generation has greater implication during subsequent seed multiplication generations. The multiplication of early generation seed upto 6-8 times before supply to farmers is generally practised in India.

Based on the results of the present experiment it can be postulated that a small intervention by increasing planting density under flat-beds in net house in early seed multiplication generations can be used favourably and economically to increase minituber production during recycling of <5 g minitubers in net house. The proposed intervention helps in efficient utilization of expensive net house space besides offering scope for accommodating larger

number of <5 g tubers, produced in early seed generation. The optimizing of plant density has been determined as one of the most important subjects for potato production and can be extended to seed potato production for achieving higher potato production.

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