



## Successive double cropping of potato minitubers under insect proof net house for increased seed productivity

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### ABSTRACT

Non-availability of disease-free quality seed material is the most important factor affecting low productivity of potato in India. Successive cropping of disease free minitubers under net house conditions, in the north western plains of India, can be an important intervention for utilizing this expensive vector free space and prevailing potato growing climate of the region in the most sustainable way. A field study was undertaken during 2016–18 to evaluate this hypothesis for its productivity and economics over single crop conventionally taken in the region. Minitubers of six potato varieties were grown in single and successive cropping patterns under net house in the region. The summed yield attributes of their early (DCE) and late planted (DCL) successive crops were compared to single cropping (SC) on per meter square basis. Corresponding observations on morphological traits and yield attributes were quite encouraging. Minituber yield of under size, seed size and combined was 1.99, 1.88 and 1.98 times higher in double crop as compared to conventional single crop. As a result, cost of production declined (2.52 times) and net profit increased (3.15 times) in double crop. Cost of production per tuber was reduced in this technique from ₹ 2.01–1.28 per minituber. Higher profits and productivity under successive planting are achievable and this innovative technology can be easily adopted by the stakeholders for improving multiplication of early generation planting material, which would translate into availability of increased seed material after stipulated multiplications.

**Keywords:** Double crop, Minituber, Minitubers, Net house, Potato, Seed potato, Single crop

India is the second largest producer of potato in the world having increased its production by 6-fold over the past six decades. However, average potato yield (22.3 t/ha) as per estimates of almost half of the reported potential yield of the best Indian potato varieties (FAOSTAT 2016 and Luthra *et al.* 2020) and this is mainly due to the non-availability of disease-free quality planting material. Vegetative propagation of potato seed makes it vulnerable to viral infections (spread by insect vectors) which accumulate and deteriorate seed health over generations leading to major loss of productivity. North-western plains of India are the major potato seed production areas (Singh *et al.* 2019) and potato can be grown from October to March in this region, but the time window of low vector populations for healthy quality seed production is only available from October to January.

Hi tech seed potato production systems evolved in recent years involves climate and insect vector control have much higher rate of seed multiplication. An efficiently managed insect proof net house space holds a zero-vector zone for virus free seed production in the north western plains which can be utilized much better throughout the growing period by planting two successive crops of potato micro-plants/small minitubers. Any technology and strategy to increase productivity at this earliest seed stage will have profound effect on overall seed production (Kaur *et al.* 2019). Thus successive cropping under insect proof net house could extend the seed production window making it more productive and cost effective. Based on these assumptions the field study was undertaken to analyse the feasibility, productivity and economics of two successive mini-tuber crops in a single cropping season in north-western plains of India under net house conditions as compared to single seed crop.

### MATERIALS AND METHODS

The experiment was conducted for two cropping seasons of 2016–17 and 2017–18 in insect-free net houses of ICAR-CPRI, Regional Station, Jalandhar (30°N, 75°E, 237 masl) lying in the north-western plains of India. Scheme of single or double crop followed under net house. The mean

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minimum and maximum temperature during 2016–17 and 2017–18 (period of cultivation October to succeeding next year April) ranged between 11.3–25.0°C and 10.3–25.3°C. While the mean minimum and maximum relative humidity ranged from 56–78.5 and 57–79% respectively for the two consecutive years. The rainfall was 96.9 and 69.3 mm during 2016–17 and 2017–18 respectively.

The experiment comprised 2 treatments single planting designated as single crop (SC) and two successive plantings at the same site in a single season designated as dual crop (DC). The dual crop (DC) further comprised of two crop plantings, viz. dual crop early (DCE) followed by double crop late (DCL). Six potato varieties namely Kufri Khyati, Kufri Surya, Kufri Chandramukhi, Kufri Jyoti, Kufri Badshah and Kufri Himalini comprising 4 replications of three row each, having 20 plants in a single row were planted in a randomised block design. Row spacing of 30 cm and plant to plant spacing of 15 cm were used in the experiment. All recommended cultural practices for net house cultivation in the region were followed with haulm cutting at approximately 90 days after planting in all the treatments. SC was planted in mid-October and haulms were cut by mid-January. DCE was planted in the first week of October with haulm killing in mid-January, while DCL was planted successively on same site of DCE after its harvesting, i.e. first week of January. Similarly, tubers were harvested 15 days after haulm cutting in both SC and DCL but in DCE tubers immediately after haulm cutting for planting DCL at the same site.

Growth parameters (plant height, number of leaves/plant and shoots per plant) and yield attributes (tuber number and weight) were recorded for all treatments. Observations were recorded on 10 plants per replication at 20, 40, 60 and 80 days for evaluating the growth. It was further averaged to derive the respective values for comparison of each treatment for analysis. For taking the yield characters harvested tubers were classified into two categories undersize (below 3 g) and seed size (3–30 g). Category of oversize tubers (>30 gm) was not considered as none of the tubers were found above 30 g due to closer row to row planting of 30 cm. Tuber number and yield of under size and seed size tubers were depicted as NUS (Number of undersize tubers) and WUS (weight of undersize tubers) and NSS (Number of seed size tubers) and WSS (weight of seed size tubers), respectively. Similarly, total number and weight of the tubers were depicted as TT (total tubers) and TW (total weight of tubers). Since the productivity of successive crops was compared with single crop over space and time, the calculations were expressed on per meter square area basis. Tuber yield and numbers obtained in the two plantings of dual crops (DCE and DCL) were summed up to get the final yield on per meter square area basis for the dual crop (DC) treatment and compared with single crop (SC) cropping treatment. Economics of the two crop treatments based on prevailing rates of the various inputs and sale prices was.

The data obtained for different parameters was compiled

and statistically analysed following three-way analysis of variance using Sigma Plot 12.0 and the LS treatment means so obtained were compared using Fisher LSD (0.05).

## RESULTS AND DISCUSSIONS

*Morphological traits:* Morphological parameters recorded for the three crops separately (SC, DCE and DCL) were used to evaluate their growth pattern (Fig 1). It revealed that mean plant height of DCE (78.7 cm) was significantly highest than the single crop (63.3 cm), and DCL (24.2 cm) (Table 1). Similar trend was observed for number of leaves per plant with maximum observation for DCE (15.5) at par to SC (14.4), but statistically superior over DCL (9.78). DCE crop planted in October, recorded rapid growth due to high temperatures, where shoot lengths increased rapidly, with the formation of large number of small sized leaves during the initial phase, followed by a more stabilized growth when the temperatures in its mid-season (November) became cooler and favourable to the potato crop. The crop showed a slower growth in the later part of the season (December) as the crop achieved maturity and temperatures became extremely cold in month of December. The single crop (SC) depicted a more stable growth from the beginning due to its favourable planting in mid-October, followed by a slower pace of growth during the end attributed to the cold climate of December and January and the crop attaining its maturity. The DCL crop had the slowest pace of growth in its initial phase as

Table 1 Morphological traits under study in the different crop types over the varieties and days

Treatment	Plant height (cm)	Number of leaves/stem
Dual crop early (DCE)	78.7	15.5
Single planting (SC)	63.3	14.4
Double crop late (DCL)	24.2	9.78
Sem±	0.397	0.0962
LSD (0.05)	1.106	0.268
Kufri Surya	43.2	12.1
Kufri Khyati	59.8	13.1
Kufri Himalini	59.2	13.2
Kufri Chandramukhi	62.5	14.1
Kufri Badshah	59.7	13.8
Kufri Jyoti	48.1	13.1
Sem±	0.561	0.136
LSD (0.05)	1.564	0.379
20 days	18.8	6.93
40 days	43.5	12.1
60 days	75.3	16.2
80 days	84.0	17.7
Sem±	0.458	0.111
LSD (0.05)	1.277	0.310

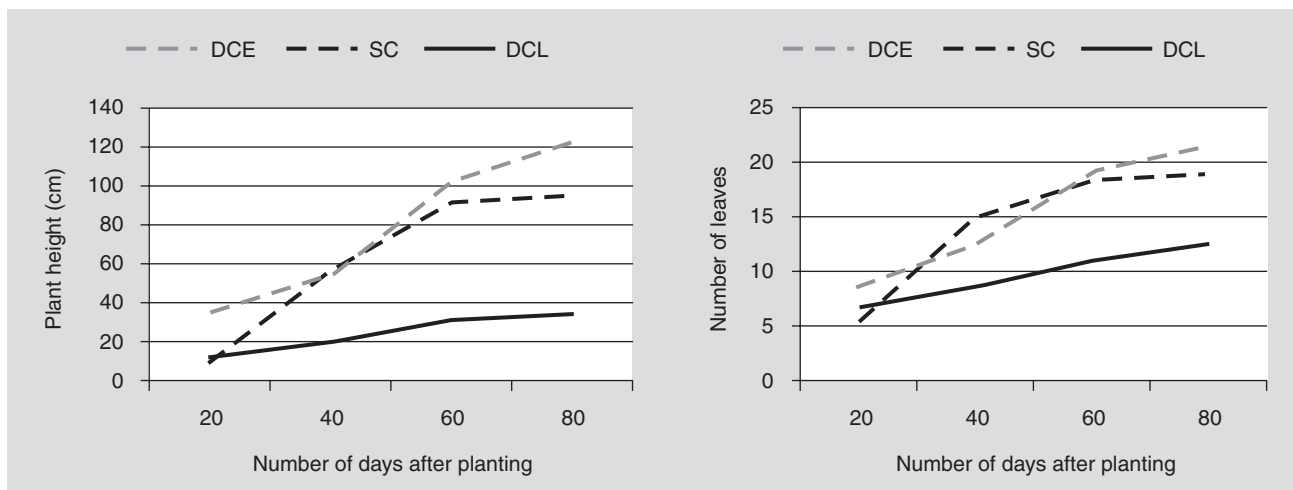


Fig 1 Growth curve for the different crops after 20, 40, 60 and 80 days after planting under DCE, DCL and SC crop types considered in the study.

the crop faced the most adverse cold climate at the time of planting (January), inspite of using well-chitted tubers. However, this could be compensated by providing it a longer growing period extending beyond 90 days up to mid-April. Among the varieties Kufri Chandramukhi had significantly higher plant height (62.5 cm) and number of leaves (14.1) was followed by Kufri Badshah, Kufri Himalini and Kufri Khyati. Minimum plant height (43.2) and leaf number (12.1) was recorded in Kufri Surya.

*Yield attributes and minituber yield:* There was significant variation among the two planting treatments considered in the experiment along with varietal differences for the parameters considered (Table 2). Crop season of 2016-17 was more suitable for potato crop as compared to

2017–18 based upon all yield parameters considered in the study except the weight and yield of undersize minitubers which were observed to be non-significant. The comparison of yield attributes for single cropping (SC) and dual cropping (DC) revealed that the number of undersize and seed size tubers in DC were 2.62 and 2.48 times higher than SC. Overall, total tuber number were 2.52 times higher in DC as compared to SC. Higher number of tubers produced in DC proves greater productivity of this cropping system. Higher productivity in an early seed generation translates into increased number of seed tubers in the advanced seed stages as it increases exponentially during each of the 5 successive seed stages namely two breeder seed stages (G1 and G2), foundation 1, foundation 2 and certified seed.

Table 2 Graded minituber number (number/m<sup>2</sup>) and yield (kg/m<sup>2</sup>) as influenced by different treatments

Treatment	Graded minituber number			Graded minituber weight			
	<3 g (NUS)	3-30 g (NST)	Total (TT)	<3 g (WUS)	3-30 g (WST)	Total (TW)	
Crop Seasons	2016-17	78.4	202.7	281.1	0.25	6.09	6.34
	2017-18	71.5	150.9	222.5	0.24	4.52	4.76
	SE of LS Mean (LSD)	2.76 (7.782)	3.447 (9.716)	4.058 (11.442)	0.028 (0.079)	0.145 (0.410)	0.147 (0.414)
Cropping type	Dual crop (DC)	108.6	252.2	360.8	0.32	7.05	7.38
	Single crop (SC)	41.4	101.4	142.8	0.17	3.55	3.72
	SE of LS Mean (LSD)	2.76 (7.782)	3.447 (9.716)	4.058 (11.442)	0.028 (0.079)	0.145 (0.410)	0.147 (0.414)
Varieties	Kufri Khyati	76.2	183.2	259.5	0.19	5.85	6.04
	Kufri Surya	54.1	157.5	211.6	0.24	5.19	5.44
	Kufri Chandramukhi	78.2	162.8	241.0	0.29	3.94	6.86
	Kufri Jyoti	66.3	158.3	224.6	0.22	5.09	4.23
	Kufri Badshah	72.5	163.3	235.8	0.23	5.18	5.41
	Kufri Himalini	102.5	235.7	338.2	0.31	6.55	5.31
	SE of LS Mean (LSD)	4.781 (13.478)	5.97 (16.829)	7.029 (19.817)	0.0485 (0.137)	0.252 (0.710)	0.254 (0.717)

Thereby, ensuring increased productivity of both seed and ware potato by increased availability of quality seed to potato growers in the country. Tuber weight of undersize and seed size minitubers recorded significant differences in favour of DC and was 1.99 and 1.88 times higher mean tuber yield over SC. This translated into 1.98 times higher total tuber yield under DC as compared to SC.

The available growing season in the north western plains offer an opportunity to enhance potato seed productivity under the vector free net house conditions only. The numbers of tubers formed in these early stages are a better parameter to evaluate productivity as compared to the total yield per se. Also, there is a tendency of formation of undersized tubers due to lesser row to row spacing under net house conditions (Kaur *et al.* 2019, Sadawarti *et al.* 2017). As compared to the seed sized tubers these may be less prolific (shrinkage during storage) but economically more adaptive as they provide more number of planting propagules per

kg of planting material (Kaur *et al.* 2019). The price of the planting material in the early hi tech generations in also therefore fixed on the basis of the cost of a single minituber. In the present study under the dual crop 69% of the total tubers formed were seed sized as compared to the formation of 71% seed size tubers under single cropping, which is quite comparable. Higher density plantings under net house conditions have been reported to increase the number of tubers as compared to low density planting, but there is a corresponding increase in frequency of undersized tubers formed per meter square (Kaur *et al.* 2019, Sharma and Kumar 2014). The technology of high density planting can be superimposed on successive cropping to yield larger number of tubers.

The varietal differences attributed to different genotypic affects were also observed in the yield characters compared over the two cropping treatments and years (Table 2). The variety Kufri Himalini produced significantly higher number

Table 3 Production economics under net house for single and dual planting/season (Net house area: 400 square meter)

S. No.	Details of annual expenses or receipts at farmers' fields	Single crop (₹)	Dual crop (₹)
A	Basis of cost estimation		
	No. of minitubers required as planting material @ 30 cm × 15 cm crop geometry and 10% space for doors, walkways etc.	8900	17800
	Cost of construction of 500 m <sup>2</sup> net-house (10 year life)	500000	500000
	Subsidy available to the farmer (50%)	250000	250000
	Net cost of construction of 500 m <sup>2</sup> net-house (10 year life)	250000	250000
1.	Fixed cost (FC)		
1.1	Depreciation of the net-house	25000	25000
1.2	Annual land rent for 500 m <sup>2</sup> @ ₹ 40000/ acre/year	5000	5000
1.3	Cost of net replacement (adjusted on annual basis)	5000	5000
1.4	Interest on fixed cost @ 10% per annum	11000	11000
	Total fixed cost (including interest on fixed cost and net replacement etc.) per year (1.1+1.2+1.3+1.4)	46000	46000
2.	Variable cost		
2.1	Cost of purchase of minitubers for planting @ ₹ 6 per minituber	53400	106800
2.2	Labour cost @ 20 units per cycle @ ₹ 320/person	6400	12800
2.3	Fertilizer, Chemicals etc.	2000	4000
2.4	Miscellaneous expenses @ ₹ 5000/cycle	5000	10000
2.5	Interest on working capital @ 4%	2672	5344
	Total variable cost (including interest on working capital and miscellaneous expenses) per year (2.1+2.2+2.3+2.4+2.5)	69472	138944
3	Total cost of production ₹/year (Total Fixed Cost + Total Variable Cost )	115472	184944
4	Production		
4.1	Production number of tubers/square meter (mean over all considered varieties based on current study)	143	361
4.2	Total production (No. of tubers from 500 square meter net house) based on spacing and planted area	57200	144400
5	Total sale price of produced tubers @ ₹ 5 per minituber (1 × 5)	286000	722000
6	Profits (Total sale price (5) – cost of production (3))	170528	537056
7	Benefit-cost ratio (5:3)	2.48	3.90

(All costs depicted in Rupees and based on approximate prevailing rates at the time of experiment, 2018)

of undersize tubers (NUS), while Kufri Khyati, Kufri Chandramukhi, Kufri Badshah and Kufri Jyoti performed at par for this character. Similarly, significant differences were recorded for production of seed sized minitubers among varieties Kufri Himalini (235.7), Kufri Khyati (183.2) and Kufri Chandramukhi (162.8) for production of seed sized tubers (NSS), while Kufri Jyoti, Kufri Badshah and Kufri Surya remained at par for this character. The correlated response of tuber numbers formed in the different varieties was observed in the yield characteristics WST, WUS and WT. Kufri Himalini yielded significantly higher (6.55 kg) followed by the other varieties Kufri Khyati, Kufri Jyoti, Kufri Badshah and Kufri Surya. Similar trends were observed for overall yields (TW).

**Economics of production:** A comparative production advantage as well as of economics for seed minituber production under the dual planting system was observed (Table 3). Maximum net return (₹ 537056) and benefit: cost ratio (3.9) was recorded in dual cropping in comparison to single crop which had net return and B: C ratio of ₹ 170528 and 2.48, respectively. Thus, shift from single planting to dual planting resulted into 1.60 times increase in production cost yielding 2.52 times higher profitability due to decline in cost of production from ₹ 2.01–1.28 per tuber.

The duration of a successive cropping is equal to a single late maturing crop planted in the European long-day conditions of up to 160 days. The present proposed successive cropping takes a total time up to 180 days. Double cropping of ware potatoes has been reported from subtropical conditions, Mediterranean region and China (Jansky *et al.* 2009, Levy *et al.* 1986, Solmnik 1961, Susnoschi 1981). However, in consideration for seed potatoes consideration needs to be given to the effect of such successive planting on the increase in incidence of soil borne pathogens, in the second successive crop. The G0 produce of minitubers as utilized in the present study and proposed for planting are quality tested tubers free from soil borne pathogens and therefore their planting in properly managed disease-free well solarized net house soil would license disease free successive cropping. The authors feel that the present technology demonstrating higher productivity of potato seed may therefore be evaluated on case-by-case basis based on the prevalence of soil borne diseases in a particular area. In context to the same efficient management of the soil including seed treatment (Wilson *et al.* 1999), crop rotation, deep ploughing, soil solarisation (Elmore *et al.* 1997 and Singh *et al.* 2012) and incorporation of biocontrol agents like *Trichoderma*, *B. amyloliquefaciens* (Han *et al.* 2005 and Lin *et al.* 2018) have been reported to effectively control soil borne diseases.

From the results it can be inferred that higher profitability of the successive planting scheme is very encouraging and may be adapted by the agencies for increasing the early generation disease free planting material, which will then multiply exponentially in further stages. The study is novel in its kind and depicts the feasibility of carrying out such a cropping. The technology also has a huge potential for

adoption by small farmers for maintaining the quality of their own seed, where a smaller net house will enable them to harvest larger number of tubers, thereby offering more sustainable utilisation of expensive net house space and climatic conditions exclusive to the north western plains. Further utilization of successive cropping under north western plains may be extended to open fields for production of seed in the DCE and ware potato in DCL or both ware potato in DCE and DCL, based on differences in vector pressures.

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