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Hi-tech planting materials performance under *in vivo* conditions for potato breeder seed production

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Abstract
The present study was conducted at ICAR-Central Potato Research Institute, Regional Station Gwalior during 2007-08 to 2016-17 for 10 years on micro-propagted material multiplied at the station to identify suitable tissue culture/ hi-tech based seed potato production systems using micro-plants, micro-tubers and mini-tubers and performance of seven popular cultivars *viz* Kufri Lauvkar, Kufri Chandramukhi, Kufri Surya, Kufri Bahar, Kufri Chipsona-1, Kufri Chipsona-3 and Kufri Sindhuri planted during 10 years under these three hi-tech systems for potato breeder seed production. Variation in performance among different varieties for establishment/emergence, mean tuber weight and seed multiplication rate (both by number and weight), percent <3 g tuber (both by number and weight) and tuber yield (m^2) were recorded during the study. Kufri Sindhuri, Kufri Bahar and Kufri Surya under micro-plant based, Kufri Bahar and Kufri Surya and Kufri Chipsona-1 under micro-tuber and mini-tuber based multiplication system performed better than other varieties under G-0 conditions for yield attributing parameters. Seed multiplication rate by number was higher in micro-plant system of seed production (5.50) followed by micro-tuber systems (5.31) and mini-tuber (4.43) based system of seed production. Mean tuber weight was higher for mini-tuber system of seed production (22.46 g) followed by micro-plant (15.59 g) and micro-tuber systems (14.62) and showed higher tuber yield *i.e* 130 tuber/m^2 and 3.10 Kg/m^2 in mini-tuber based system followed by111 tuber/m^2 and 1.74 kg/m^2 in micro-plant based system and by 86 tuber/m^2 and 1.16 kg/m^2 in micro-tuber based seed potato production system. Hence performance of Kufri Sindhuri, Kufri Bahar and Kufri Surya under micro-plant based, Kufri Bahar and Kufri Surya and Kufri Chipsona-1 under micro-tuber and mini-tuber based seed multiplication system was better in 10 years of the study.

Keywords: Micro-plant, micro-tuber, mini-tuber, potato and breeder seed production system

Introduction
The key problems of conventional seed potato production systems are the stumpy growth rate, accumulation of viral, bacterial, or fungal diseases over a period of field multiplications (Hossain *et al.*, 2017) [10]. Meristem culture provides a reproducible and economically viable method for producing pathogen free plants. (Jha and Ghosh, 2005) [12] which are commonly used for production of *in vitro* tubers, greenhouse production of mini-tubers. (Özkaynak and Samanci, 2005) [20]. Therefore, hi-tech seed production system is the only alternate to overcome the limitations of conventional seed potato production system in which the multiplication steps are speeded up first by using *in vitro* plantlets, micro-tubers, and mini-tubers (Hossain *et al.*, 2017; Sharma *et al*., 2008 and Venkatasalam *et al.*, 2011) [31 and 40] to improve the quality of seed (Singh *et al*., 2011) [33] as well as to supplement the ever increased demand of quality seed (Mohapatra *et al.*, 2017) [18]. *In vitro* produced disease-free potato clones combined with conventional multiplication methods have become an integral part of seed production in many countries including India (Naik and Karihaloo, 2000) [19].
Micro-tubers are produced in laboratory conditions with the result of tuberization in controlled conditions on *in vitro* plantlets (Ranalli, 2007) [23] and constitute base material for the production of mini-tubers. Micro-tubers are miniature seed potatoes and considered as the intermediate stage between *in vitro* plantlets and mini-tubers and overcome the problems of transplanting of tender vegetative plantlets from *in vitro* condition to *in vivo* condition to produce mini-tubers (Nistor *et al.*, 2010; Liljana *et al.*, 2012; Husain *et al.*, 2017) [11,17, 20]. Micro-tuber can be basic source of high quality disease free seed to supplement or even replace the traditional method of breeder seed production of potato by following the check testing of material at the initial stage (Somani and Venkatasalam, 2012) [36], hence mass

production of micro-tuber is likely to revolutionize the world potato production (Kanwal and Shoaib, 2006; Dessoky *et al.*, 2016) [5, 13].

Mini-tubers produced after acclimatization from plants propagated *in vitro* or micro-tubers and planted at high density in the glasshouse in seed beds or aphid-proof net houses/ glass house using different substrate mixtures (Sharma *et al*., 2008; Altindal and Karadogan, 2010; Nistor *et al.*, 2010; Wróbel, 2014; Srivastava *et al.*, 2015) [31, 2, 20, 41, 37]. Direct *in vivo* planting of micro-plants in a soil medium under aphid proof net/polyhouses is a well established method for the production of potato mini-tubers (Kumar *et al*., 2011, Sharma and Pandey, 2013, 2014 and 2017) [16, 28, 29, 30]. However, transplanting of tender micro-propagated plantlets from *in vitro* condition to external environment has a high failure rate in some varieties (Chandra *et al*., 1992) [13] and usually only one to two minitubers are formed on each plantlet (Garner and Blake, 1989) [8].

Mini-tubers can be principally used for the production of pre-basic or basic seed by direct field planting (Özkaynak and Samanci, 2005) [21] or further multiplied as Generation-1 and Genration-2 in fields (Sharma *et al*., 2008; Somani and Venkatasalam, 2012) [31, 36]. From one *in vitro* plantlet or micro-tuber it is possible to obtain 2-10 mini-tubers (Struik and Wiersema 1999) [39]. The size of mini-tubers is from 5-25 mm and their weight range is from 0.1-10 g or even more (Struik 2007) [38]. The introduction of micro and mini-tubers reduced the field time necessary to supply the seed materials to the commercial growers and greatly improved seed tuber quality (Donnaly *et al.*, 2003, Nistor *et al.*, 2010 and Wróbel, 2014) [7, 20, 41]. ICAR-CPRI, the nodal agency in India for the production and supply of breeder seed of potato and planning to switchover 100% breeder seed production through micro-propagation (Sharma *et al.*, 2011) [27].

It has been observed that when micro-plants or micro-tubers are grown in net house, large number of <3g mini-tubers are produced which is valuable material but cannot be planted in open fields directly because of their small size and need to be recycled for one more under protected condition to improve the tuber size for their effective utilization in the field (Singh *et al*., 2008; Sadawarti *et al.*, 2017) [26, 34]. Therefore, an attempt was made to study the production potential of different micro-propagated material *viz.* micro-plants, micro-tuber and <3g mini-tubers (obtained from micro-plants/micro-tuber) of seven popular varieties multiplied under basic seed production (G-0) under protected aphid proof net house conditions.

Materials and methods

The micro-propagated material of potato *viz.*, micro-plants, micro-tubers received from ICAR-CPRI, Shimla and <3g mini-tubers obtained from micro-plants/micro-tubers were planted during crop season of 2007-08 to 2016-17 (for 10 years) under aphid proof net house conditions at ICAR-Central Potato Research Institute, Regional Station Gwalior. Above mentioned three category of hi-tech planting materials of seven varieties *viz.*, Kufri Lauvkar, Kufri Chandramukhi, Kufri Surya, Kufri Bahar, Kufri Chipsona-1, Kufri Chipsona-3 and Kufri Sindhuri under seed production system were planted and taken under study. Details of planting years, variety wise average area and number of hi-tech planting material is given in table 1.

Micro-propagated materials were planted on well prepared beds during last week of October to second week of November in different years. Seed bed was prepared after addition of one inch thick layer of well decomposed farm yard manure and sand in the ratio of 1:1 on the top of the bed. Two micro-plantlets and one micro-tuber and <3g mini-tuber were planted at inter and intra row spacing of 30x10 cm in 2 m wide strip. The micro-plantlets were properly washed to remove the media if any and excess roots were trimmed-off before planting. Well sprouted micro-tubers and <3g mini-tubers were planted as per availability in different years. A light irrigation was given with the help of rose cane just after planting and subsequent irrigation was given as per the requirement and other packages of practices were followed as per the recommendation to seed potato crop. After 85-90 days after plating, haulms were pulled d manually and after 10-12 days of de-haulming the crop was harvested manually. The data on the performance of micro-plants, micro-tubers and <3g mini-tubers over the years were compiled and mean was calculated. The data recorded during the study are plant emergence (25-30 DAP) Establishment/ emergence (%), mean tuber weight (g), seed multiplication rate both by number and weight, > as well as <3g, tuber yield both by number and weight per m^2 and percentage of < 3 g mini-tuber both by number and weight.

Results and discussion

Effect of different planting materials on establishment/ emergence%

Establishment/ emergence (%) varied among varieties in different type of planting materials used under the study. The establishment (%) of micro-plants ranged from 51.41% to 40.57% in the cultivars Kufri Surya and Kufri Sindhuri respectively) and highest was recorded K. Surya (51.41%) table 2. Under Gwalior conditions, Kufri lauvkar (67.50%) and Kufri surya (65.83%) recorded significantly higher mean establishment in comparison to Kufri sindhuri (56.67%) under micro-plants study (Sadawarti *et al.*, 2017) [25]. The difference in survival of micro-plantlets under poly house conditions were earlier reported by Kumar *et al.*, 2011 at Modipuram,Venkatasalam *et al.*, 2011at Shimla and Sharma *et al.*, 2014 at Kufri-Fagu [16, 40, 30].

In micro-tuber, emergence (%) ranged from 83.11 to 30.37 (%) in Kufri Bahar and K. Chipsona-3 respectively. Similarly the emergence (%) of mini-tuber ranged from 95.83 to 65.20

Table 1: Variety wise area and number of hi-tech planted material.

Micro-plant			Micro-tuber			Mini-tuber		
Variety	**Area (m^2)**	**Nos planted**	**Variety**	**Area (m^2)**	**Nos planted**	**Variety**	**Area (m^2)**	**Nos planted**
Kufri Lauvkar (5)*	13.2	441	Kufri Lauvkar (6)	142.0	4742	Kufri Lauvkar (5)	53.7	1791
Kufri Chandramukhi (2)	5.5	185	Kufri Chandramukhi (3)	80.0	2666.	Kufri Chandramukhi (3)	48.2	1606
Kufri Sindhuri (4)	17.3	576	Kufri Sindhuri (5)	102.3	3411	Kufri Sindhuri (5)	27.6	919
Kufri Surya (3)	4.9	163	Kufri Surya (1)	51.0	1700	Kufri Surya (5)	15.7	525
Kufri Bahar (3)	5.6	187	Kufri Bahar (1)	88.2	2940	Kufri Bahar (1)	23.4	978
Kufri Chipsona -1 (1)	1.8	60	Kufri Chipsona -1 (1)	6.3	210	Kufri Chipsona -1 (1)	9.7	322
Kufri Chipsona -3 (1)	3.8	128	Kufri Chipsona -3 (1)	8.8	293	Kufri Chipsona -3 (1)	8.4	280

*Value in parenthesis indicates number of year planted

Kufri Bahar and Kufri Surya respectively (Table 2). Somani and Venkataselam, 2012 [36], also reported the emergence percent of micro-tubers from 27.4 to 73.6 in Kufri Kanchan and Kufri Lauvkar with an overall average of 64.6% in 10 cultivars over a period of 9 years under Gwalior conditions. Difference in micro-tuber survival due to genetic background were reported under NE conditions (Gupta *et al.*, 2003; Srivastava *et al.*, 2015) [9, 37] and under Bangladesh conditions (Hoassain *et al.*, 2017) [10].

Among micro-propagated material mean establishment/emergence (%) was highest in mini-tuber (81.91) followed by micro-tuber (50.42) and micro-plant (45.67). Significantly higher germination/establishment was reported in <3 g mini-tubers (95.15) followed by micro-tubers (76.3%) over micro-plants (48.1%) in cultivar K. Lauvkar under Gwalior conditions (Sadawarti *et al.*, 2017) [26]. The percent survival/establishment was significantly influenced by potato cultivar and type of planting material and their interaction under *in vivo* conditions (Vekatasalam *et al.*, 2011) [40]. Higher germination in <3 g mini-tubers may be due to higher vigor than micro-plant and micro-tubers (Sadawarti *et al.*, 2017) [26].

Effect of different planting materials on mean tuber weight (g)

Mean tuber weight is the result of tuber yield and number of tubers produced. Varietal difference was recorded in various micro-propagated materials in terms of mean tuber weight. In micro-plants, it ranged from 28.44 g in Kufri Bahar and 7.25 g in Kufri. Chandramukhi (Table 2). Significantly highest mean tuber weight was observed in cv. Kufri Sadabahar (15 g) followed by cvs. Kufri Bahar and Kufri Surya and lowest in Kufri Anand (6.83g) when nine varieties were tested under Modipuram conditions (Kumar *et al.*, 2011) [16]. Kufri Bahar reported biggest mini-tuber weight under Modipuram conditions under micro-plant multiplication and could be due to the fact that cv. Kufri Bahar had less number of mini-tubers per plant (Kumar *et al.*, 2007, 2011) [15, 16]. This confirms the present study where Kufri Bahar reported highest mean tuber weight.

In micro-tuber mean tuber weight ranged from 26.50 g to 7.77 g and was highest in Kufri Surya (26.50 g). In mini-tuber it ranged from 27.39 g Kufri Chandramukhi and 15.85 g in Kufri Sindhuri. Cultivar Kufri Giriraj produced maximum average weight of mini-tubers (14.3 g) followed by Kufri Chipsona-2 (13.9 g) where as the minimum in Kufri Sindhuri (3.5 g) under micro-tuber multiplication study (Somani and Venkatasalam, 2012) [36] and this supports the present findings. Singh *et al.*, (2007) [35] also reported variations in mean tuber weight among varieties in micro-tuber multiplication study. Among micro-propagated material mean tuber weight was highest in mini-tuber (22.46 g) followed by micro-plant (15.59 g) and micro-tuber (14.62 g). Higher mean tuber weight may be due to higher vigour in mini-tuber.

Table 2: Mean morphological and yield attributing parameters in different varieties and micropropagated materials

Variety	Establishment / emergence %			Mean tuber weight (g)			Seed multiplication rate					
							by number			by weight (g)		
	Micro-plant	Micro-tuber	Mini-tuber	Micro-plant	Micro-tuber	Mini-tuber	Micro-plant	Micro-tuber	Mini-tuber	Micro-plant	Micro-tuber	Mini-tuber
Kufri Lauvkar	47.23	48.92	71.86	15.28	15.70	16.44	3.11	4.15	4.18	47.44	65.22	68.80
Kufri Chandramukhi	42.61	43.89	94.00	7.25	11.15	27.39	5.11	3.94	3.00	37.04	43.93	82.22
Kufri Sindhuri	40.57	59.35	89.50	8.54	7.77	15.85	6.93	8.08	4.79	59.14	62.73	75.84
Kufri Surya	51.41	35.00	65.20	28.24	26.50	24.58	6.35	4.95	4.75	188.56	131.09	116.65
Kufri Bahar	40.86	83.11	95.83	28.44	15.30	27.15	3.09	4.20	2.72	131.79	64.22	73.93
Kufri Chipsona-1	50.00	52.30	89.00	10.91	10.84	26.93	9.16	5.94	6.21	100.00	64.44	167.23
Kufri Chipsona-3	47.00	30.37	68.00	10.45	15.12	18.89	4.78	5.94	5.35	49.87	89.90	101.10
Mean	45.67	50.42	81.91	15.59	14.62	22.46	5.50	5.31	4.43	87.69	74.50	97.97

Rate of multiplication based on number

Variation in seed multiplication rate by number also recorded among varieties in different micro-propagated material. In micro-plant, it ranged from 9.16 to 3.09 and highest was recorded in Kufri Chipsona-1, but in micro-tuber it ranged from 8.08 in Kufri Sindhuri and 3.94 in Kufri Chandramukhi. In mini-tuber multiplication it ranged from 6.21 to 2.27 and highest was recorded in Kufri Chipsona-1 and lowest in Kufri Bahar. Venkatasalam *et al* (2011) [40] reported significantly higher multiplication rate in potato cultivars Kufri Chipsona-1 (11.8) and Kufri Anand (11.5) raised from micro-plants. However, crop raised from micro-tuber recorded higher multiplication rate in Kufri Badshah (9.2), Kufri Himalini (8.4) and Kufri Kanchan (8.0). Mean seed multiplication rate by number was highest in micro-plant (5.50) followed by micro-tuber (5.31) and mini-tuber (4.43). However, Sadawarti *et al.*, 2017 [26] reported significantly higher multiplication in micro-tuber (3.8) followed by mini-tuber (3.1) and micro-plant (2.7).

Rate of multiplication based on weight

In micro-plant, seed multiplication rate ranged from 188.56 g in Kufri Surya to 37.04 g in Kufri Chandramukhi. In micro-tuber it ranged from 131.09g in Kufri Surya to 43.93g in Kufri Chandramukhi. In mini-tuber multiplication it ranged from 167.23g in Kufri Chipsona-1 to 68.80g in Kufri Bahar. The rate of multiplication of micro-plants and micro-tubers was almost similar in the cultivars Kufri Bahar, Kufri Chandramukhi, Kufri Giriraj, Kufri Himalini, Kufri Kanchan, Kufri Lauvkar and Kufri Sutlej (Venkatasalam *et al.*, 2011) [40]. *In vitro* growth rate and subsequent productivity has been reported to be genotype specific (Danielle *et al*., 2008) [4]. Mean seed multiplication rate by weight was highest in mini-tuber (97.97 g) followed by micro-plant (87.69 g) and micro-tuber (74.50 g).

Tuber yield <3 and >3g (Number/m^2)

On the basis of different year of study, mean yield/m^2 was calculated for each variety for different type of planting materials. By number <3g mini-tubers/m^2 were maximum in Kufri Sindhuri (142 and 83) in micro-plant and micro-tuber produce respectively and 96 in Kufri Bahar from mini-tuber produce and lowest were in Kufri Lauvkar (28 and 26) in micro-plant and mini-tuber produce and in Kufri Surya in micro-tuber (21). Among micro-propagated materials highest <3 g by number was recorded in micro-plant (58) followed by mini-tuber (52) and micro-tuber (43) (Table 3). Plantlets derived plants produced more percentage of <28mm size of mini-tuber over Micro-tuber derived plants under Bangladesh conditions (Hoassain *et al.*, 2017) [10]. This confirms the present finding. Varied trend was reported in >3g mini-tuber /m^2 by number among varieties of different micro-propagated materials. It was highest in Kufri Sindhuri (80) in micro-plant, in Kufri Bahar (74) in micro-tuber and in Kufri Chipsona-1 (109) in mini-tubers. Among micro-propagated materials highest >3 g by number was recorded in mini-tuber (78) followed by micro-plant (55) and micro-tuber (43).

Total tuber yield (Number/m^2)

Total tuber by number/m^2 was recorded highest in K. Sindhuri (222 and 128) in microplant and micro-tuber and in K. Bahar (204) in minituber and lowest was recorded in Kufri Chandramukhi (72) in microplant and in Kufri Surya (58 and 90) in micro-tuber and minituber. Significantly higher number of tubers/ m^2 was recorded from cv. Kufri Chipsona-1 followed by Kufri Surya, Kufri Sutlej and Kufri Pukhraj due to variation in the survival of *in vitro* plants under Modipuram conditions (Kumar *et al.*, 2011) [16]. In the present study also Kufri Chipsona -1 and Kufri Surya reported higher 153 and 107 mini-tuber/m^2 after Kufri Sindhuri under microplant multiplication and variations also reported in establishment/ emergence percent among cultivars in present study.

Among micro-propagated materials highest tuber number/m^2 was recorded in minituber (130) followed by micro-plant (111) and micro-tuber (86) table 3. Mean tuber number/ plant were significantly higher in micro-plant (14.61) over micro-tuber (12.59) multiplication of three varieties under Bangladesh conditions (Hoassain *et al.,* 2017) [10]. The *in vitro* plantlet group had higher tuber number (9.9) than the micro-tuber group (9.5) in 2007 but had lower mean in 2008, confirming variation in performance of potato plantlets between years, planting seasons, growing conditions, plant densities and potato cultivars (Özkaynak and Samanci, 2005) [21] confirms the present study.

Tuber yield <3, >3g and total (Kg/m^2)

Similar trend like minituber number/ m^2 was reported in terms <3g, >3g and total tuber weight (Kg/m^2) in micro-plant, micro-tuber and mini-tuber respectively. Kufri Sindhuri reported 0.39 Kg/m2 in microplant and 0.19 Kg/m2 in micro-tuber and Kufri Chipsona-1 in 0.34 Kg/m2 in mini-tuber <3g tuber yield. Kufri surya (2.67 and 2.92 Kg/m2) in microplant, Kufri Bahar (1.65 and 1.78 Kg/m2) in micro-tuber and Kufri Chipsona-1 (4.64 and 4.98 Kg/m2) in mini-tuber recorded significantly higher >3g and total tuber yield (Table 3). Under *in vitro* plant multiplication, mini-tubers yield per plant as well as per unit area (kg/m^2) was recorded highest but reverse trend was reported in terms of mini-tuber number per unit area (Kumar *et al.*, 2011) [16]. This trend has been reported in present study also in some of varieties *viz* Kufri Bahar, Kufri Surya and Kufri Lauvkar. Mini-tuber production is affected by genotype (Powell *et al*., 1989) [22]. Cultivars differ widely in their capacity to produce mini-tubers, some being much more prolific than others (Venkatasalam *et al*., 2011; Sharma, *et al*., 2013) [40, 28]. A tenfold difference in the yield of mini-tubers between the highest and lowest yielding varieties has been reported by Ahloowalia (1994) [1]. The variation in different varieties under different micro-propagated material in this study also confirms above findings.

Total tuber yield was higher in mini-tuber (3.10 Kg/m^2) followed by microplant (1.74 Kg/m2) and micro-tuber (1.16 Kg/m2) in the present study (Table 3). IP group had long time for tuber development and bulking so the IP group had high means for yield related traits than those of the MT group. (Oztaruk and Yilidrim, 2010) [21]. Differences in the production potential can be attributed to the variable genetic base of the varieties evaluated as well as to the corresponding growth vigour (Shrivastava *et al.*, 2015, Dimante, 2013 and Sharma and Pandey, 2013) [37, 6, 28].

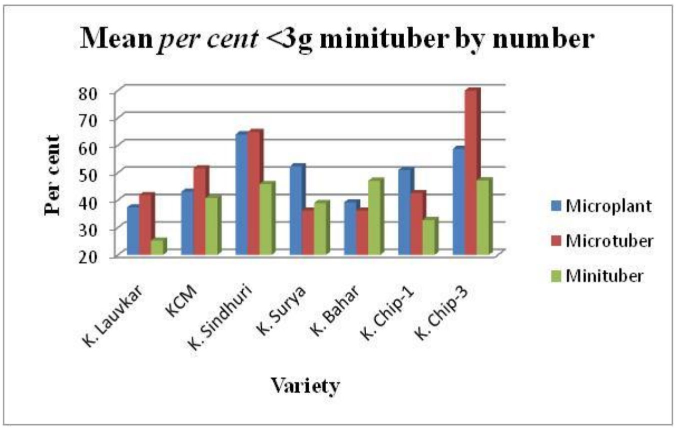
Table 3: Mean yield attributing parameters in different varieties and micropropagated materials

Variety	Minituber yield by number/ m^2									Minituber yield by weight(Kg)/ m^2								
	<3g			>3g			Total			<3g			>3g			Total		
	Micro-plant	Micro-tuber	Mini-tuber	Micro-plant	Micro-tuber	Mini-tuber	Micro-plant	Micro-tuber	Min-ituber	Micro-plant	Micro-tuber	Mini-tuber	Micro-plant	Micro-tuber	Mini-tuber	Micro-plant	Micro-tuber	Mini-tuber
Kufri Lauvkar	28	28	26	47	39	77	75	67	103	0.10	0.09	0.09	1.32	0.94	2.24	1.42	1.03	2.34
Kufri Chandramukhi	31	33	46	42	31	67	72	64	113	0.05	0.07	0.17	0.46	0.64	2.18	0.51	0.71	2.34
Kufri Sindhuri	142	83	61	80	45	72	222	128	133	0.39	0.19	0.21	2.39	0.80	2.18	2.78	0.98	2.39
Kufri Surya	56	21	35	62	37	55	107	58	90	0.25	0.07	0.10	2.67	1.46	3.05	2.92	1.53	3.15
Kufri Bahar	29	42	96	45	74	108	74	116	204	0.14	0.13	0.32	1.99	1.65	4.07	2.13	1.78	4.40
Kufri Chipsona-1	78	45	53	75	62	109	153	107	162	0.28	0.11	0.34	1.39	1.05	4.64	1.67	1.16	4.98
Kufri Chipsona-3	44	48	50	31	12	56	75	60	106	0.16	0.11	0.14	0.63	0.80	1.96	0.78	0.91	2.10
Mean	58	43	52	55	43	78	111	86	130	0.20	0.11	0.20	1.55	1.05	2.90	1.74	1.16	3.10

Production of small (<3g) size tuber in micropropagated material

Percent <3 g minituber by number were calculated from total number of minituber produced. In microplant, Kufri Sindhuri (63.96%) recorded highest <3 g mini-tuber and in micro-tuber and mini-tuber produce Kufri Chipsoan-3 (80.00 and 47.17%) recorded highest <3 g minituber by number and lowest was in Kufri Lauvkar (37.33 and 25.24%) in microplant and minituber produce and in Kufri Surya and Kufri Bahar (36.31%) in micro-tuber produce. Among micro-propagated materials highest total tuber by number was recorded in micro-tuber (50.54%) comparable in micro-plant (49.36%) and very low in mini-tuber (39.66%) fig 1. Sadawarti *et al.* (2017) [26] reported non significant difference in terms of percent <3g by number among microplant, micro-tuber and minituber.

Percent <3 g mini-tuber by weight was highest in Kufri Chipsona-3 (20.51%) in microplant and in Kufri Sindhuri in micro-tuber (19.39%) and mini-tuber (8.79%). Variation in production of small size tuber among cultivars were reported by Özkaynak and Samanci (2005) [21] and Kianmehr *et al.* (2012) [14]. Among micro-propagated materials highest total tuber by weight was recorded in microplant (11.90%) followed by micro-tuber (10.20%) and mini-tuber (6.26%) fig 2. Significantly higher <3 g mini-tuber by weight were reported in micro-tuber and micro-plant over mini-tuber (Sadawarti *et al.*, 2017) [26]. This confirms the present study.



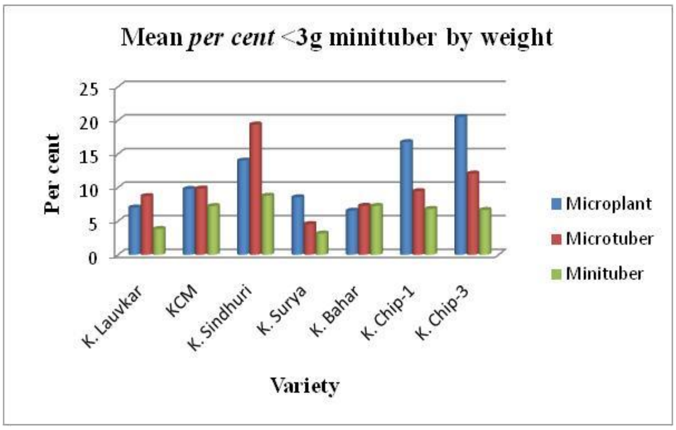


Fig 1 **Fig 2**

Fig 1 and 2: Mean percent <3g mini-tuber by number and weight

It can be concluded that there was variation in performance among different varieties for establishment/emergence, mean tuber weight and seed multiplication rate (both by number and weight), percent <3 g tuber (both by number and weight) and tuber yield (m^2). Kufri Sindhuri, Kufri Bahar and Kufri Surya under microplant Kufri Bahar and Kufri Surya and Kufri Chipsona-1 under micro-tuber and mini-tuber multiplications performed better under G-0 conditions. Among hi-tech production system, mini-tuber system of seed production followed by micro-plant and micro-tuber systems was better for most of the yield attributing traits.

References

1. Ahloowalia BS. Production and performance of potato mini-tubers. Euphytica 1994; 75:163-72
2. Altindal D, Karadogan T. The effect of carbon sources on *in vitro* microtuberization of potato (*Solanum tuberosum* L.). Turkish Journal of Field Crops. 2010; 15:7-11.
3. Chandra R, Randhawa GJ and Chaudhary DR. Use of ordinary sugar in *in vitro* production of potato mictotubers. Potato J. 1992; 19(1-2):87-89
4. Danielle JD, Warren KC and Shirlyn EC. Potato microtuber production and performance: A review. Am J Potato Res. 2008; 80:103-15
5. Dessoky El, Dessoky S, Attia OA, Ismail A, Ehab El I. *In vitro* Propagation of Potato under Different Hormonal Combinations. International Journal of Advanced Research. 2016; (4)1:684-89
6. Dimante I. Evaluation of potato breeders' seed material (minitubers) production in State Priekuli PBI). Jelgava Latvija. 2013; 150:37-40.
7. Donnelly, Danielle J, Coleman K, Warren E, Coleman S. Potato microtuber production and performance: A review, American J Potato Research. 2003; 80(2):103-15
8. Garner N, Blake J. The induction and development of potato micro-tubers *in vitro* on media free of growth regulating substances. Ann Bot. 1989; 63:663-74
9. Gupta VK, Kumar S, Baishya LK, Kumar M. Effect of planting density on mini-tuber production from micro-propagated plants. Potato J. 2003; 30:43-44
10. Hossain MS, Hossain MM, Haque MM, Haque MM, Sarkar MD. Varietal Evaluation of Potato Microtuber and Plantlet in Seed Tuber Production. International Journal of Agronomy. 2017, 1-5.
11. Husain S, Shah SAH, Asghar S, Hussain N, Ali N, Hussain I *et al.* Micro-Tuberization of Four Potato (*Solanum tuberosum* L.) Cultivars through Tissue Culture. Research & Reviews: Journal of Botanical Sciences. 2017; 6(3):35-40
12. Jha TB, Ghosh B. Plant Tissue Culture: Applied and Basic. Universities Press (India) pvt. Lit, 2005
13. Kanwal A, Shoaib K. *In vitro* Microtuberization of Potato (*Solanum tuberosum* L.) Cultivar Kuroda: A New Variety in Pakistan. International Journal of Agriculture and Biology. 2006; 8(3):337-40.
14. Kianmehr B, Otroshy M, Parsa M, Mohallati MN, Moradi K. Effect of Plant Growth Regulation during *in vitro* Phase on Potato Minituber Production. Intl J Agri Crop Sci. 2012; 4(15):1060-67
15. Kumar D, Singh V, Singh RP, Singh BP, Naik PS. Performance of *in vitro* plantlets for production of mini-tubers in vector free environment. Potato J. 2007; 34:131-32
16. Kumar D, Singh V, Singh BP. Growth and Yield of potato plants developed form *in vitro* plantlets in net house. Potato J. 2011; 38(2):143-48
17. Liljana KG, Sasa M, Trajkova F, Ilievski M. Micropropagation of Potato *Solanum tuberosum* L., Electronic Journal of Biology. 2012; 8(3):45-49
18. Mohapatra PP, Poonia M, Batra VK, Kajla S, Poonia A. Efficient Protocol for Mini-tuber Production in Potato (*Solanum tuberosum* L.) Cultivar Kufri Frysona. Int. J Curr. Microbiol. App. Sci. 2017; 6(4):889-92
19. Naik PS, Karihaloo JL. Micro propagation for production of quality potato seed in asia-pacific. Asia-Pacific Consortium on Agricultural Biotechnology (APCoAB) C/o ICRISAT, NASC Complex, Dev Prakash Shastri Marg, Pusa Campus, New Delhi-110012, India. 2007, 1-44
20. Nistor A, Campeanu G, Atanasiu N, Chiru N, KarácsonyI D. Influence of potato genotypes on "*in vitro*" production of micro-tubers. Romanian Biotechnological Letters 2010; 15(3):5317-314.
21. Özkaynak E, Samanci B. Yield and yield components of greenhouse, field and seed bed grown potato (*Solanum tuberosum* L.) plantlets, akdeniz üniversitesi ziraat fakültesi dergisi. 2005; 18(1):125-29.
22. Powell W, Brown J, Caligari PDS. Variability in response of potato cultivars to micro-propagation II. Subsequent field performance. Ann Appl Biol. 1989; 115:123-28.
23. Ranalli, P. The canon of potato science: 24. Microtubers. Potato Res. 2007; 50:301-304

24. Rykaczewska K. Wpływ różnych wielkości minibulw na plon sadzeniaków i współczynnik rozmnażania wybranych odmian ziemniaka. (In Polish) In: Nasiennictwo i Ochrona Ziemniaka –Abstracts of Papers and Posters, Conference, Kołobrzeg, March19– 20, ZNiOZ IHAR Bonin Poland. 2007, 101-03.
25. Sadawarti M, Pandey KK, Venkatasalam EP, Somani AK, Singh SP. Effect of MS Medium Gel on Potato Micro Plants Performance Under *In Vivo* Conditions of Central India. Environment & Ecology. 2017; 35(2D):1415-419.
26. Sadawarti M, Pandey KK, Somani AK, Venkatasalam EP. Minituber Production Potential of Different Micro Propagated Material Under *in vivo* Conditions of North Central India. Environment & Ecology. 2017; 35(2A):820-23.
27. Sharma AK, Venkatasalam EP, Singh RK. Micro-tuber production behaviour of some commercially important potato (*Solanum tuberosum* L) cultivars. Indian Journal of Agricultural Sciences. 2011; 81(11):1008-13.
28. Sharma AK, Pandey KK. Potato mini-tuber production through direct transplanting of *in vitro* plantlets in green or screen houses – a review Potato J. 2013; 40(2):95-103.
29. Sharma AK, Singh RK, Buckseth Tanuja. Effect of method of planting of *in vitro* plantlets on potato mini-tuber production under protected conditions. Potato J. 2017; 44(2):135-38.
30. Sharma AK, Venkatasalam EP, Kumar V. Effect of plant growth promoting bio-agents (Bacillus sp) on the production of potato (*Solanum tuberosum* L) mini-tubers in north-western Himalaya. Indian Journal of Agricultural Sciences. 2014; 84(4):473–78.
31. Sharma AK, Singh V, Singh RP. Minitubers for potato seed production. Indian Hort. 2008; 53:25-27.
32. Sharma AK, Venkatasalam EP, Kumar V. Potato minituber production during main and off crop seasons in high hills of north-western Himalaya. Potato J. 2013; 40(1):29-37.
33. Singh BP, Pandey KK, Venkatasalam EP. Potato seed production system in India. In Production of disease-free quality planting material propagated through tubers and rhizomes. (ed), Central Potato Research Institute, Shimla (H.P.), 2011, 1-16.
34. Singh S, Venkatasalam EP, Kang GS, Rai RP, Singh DB, Singh RP, Singh V *et al*. Effective utilization of potato minitubers in Indo-Gangetic plains- A success story. Abstract in Global Potato Conference. Opportunities and Challenges in the New Millennium, 9-12 December, New Delhi, India, 2008, 60.
35. Singh V, Kumar D, Singh RP, Singh BP, Singh S. Performance of microtubers of various potato cultivars in net house. Potato J. 2007; 34(1-2):133-34.
36. Somani AK, Venkatasalam EP. Microtuber propagation for breeder's seed production of potato. Potato J. 2012; 39(1):98-100.
37. Srivastava AK, Yadav SK, Diengdoh LC, Raiand R, Bag TK. Effect of cultivars and seed size on field performance of potato micro-tubers in North Eastern Himalayan region in India. Journal of Applied and Natural Science. 2015; **7**(1):335-38.
38. Struik PC. The canon of potato science: Minitubers. Potato Res. 2007; 50:305-08
39. Struik PC, Wiersema SG. Seed potato technology. Wageningen Press, 383, 1999.
40. Venkatasalam EP, Latawa J, Sharma S, Sharma S, Sharma AK, Sharma S *et al*. *In vitro* and *in vivo* performance of potato cultivars for different seed production systems. Potato J. 2011; 38(2):149-54.
41. Wróbel S. Assessment of Possibilities of Microtuber and *in vitro* Plantlet Seed Multiplication in Field Conditions. Part 1: PVY, PVM and PLRV Spreading, Am. J Potato Res. 2014; 91:554-65.