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Effect of season of production on storage and production behaviour of potato (*Solanum tuberosum*) mini-tubers

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ABSTRACT

Storage, sprouting and production behaviour of different grades of potato mini-tubers of cv. Kufri Girdhari produced during summer (*Kharif)* and autumn seasons in high hills of north-western Himalaya (9 000 feet amsl) was studied. The study revealed that mini-tubers produced during both the seasons in the high hills store well under ambient conditions till the next potato planting season, i.e. April. Number of sprouts and length of longest sprout per mini-tuber as well as average weight per tuber at the end of storage period was affected significantly by the season of production as well as grade of mini-tubers. However, total physiological loss in weight of mini-tubers from two seasons was almost same but was affected significantly by the grade of mini-tuber. Mini-tubers from both the seasons resulted in same yield and number of tubers per hectare. A gradual and consistent increase in the number of tubers as well as in potato yield with the increasing size of mini-tuber was noticed. Similar field productivity of mini-tubers from two seasons is in total support of the practice of taking two crops of mini-tubers (from in *vitro* plantlets) under protected conditions. The information generated will be helpful in boosting the fast multiplication of elite planting material of potato in the high hills of north western Himalaya.

Key words: Autumn, *Kharif*, Potato, Season, Sprouting, Storage, Tubers, Yield

Seed potato production involving *in vitro* asexual multiplication allows quick and round the year production of disease free good quality seed and thus is a way to supplement the high requirement of quality seed (Sharma *et al.* 2013). *In vitro* propagated potato plantlets are commonly used in potato seed production as a source of healthy propagation material. Knutson (1988) also reported that *in vitro* culture derived crops have improved plant health and environmental stress tolerance characteristics. Mini-tubers are the progeny tubers of in *vitro* derived plantlets (Struik 2007) and production of potato mini-tubers is also a classical way to multiply *in vitro* material before its use in the open field. Mini-tubers are produced by growing micro-propagated plants or micro-tubers *in vivo* under green or screen houses (Ahloowalia 1994). Producing mini-tubers from *in vitro* plantlets reduces the number of field generations needed in seed production (Ranalli 1997) and thus results in better health standards over conventional seed potatoes (Haverkort *et al.* 1991).

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 *et al.* 2000). High hills of north-west India (Himachal Pradesh) are well known for the production of quality seed potatoes on account of natural freedom from virus vectors (aphids) and major soil borne diseases. Among the various physiological and agronomical factors, time of planting and/or season is known to affect the mini-tuber production potential of plantlets to a great extent (Sharma *et al*. 2013). In general, mini-tubers in green or screen houses are produced during main potato season of that area. But, in high hills of north-western Himalaya, potato mini-tubers can be produced successfully during main or *kharif* season (April to August) as well as during autumn (off) season (Septmber – January) by direct transplanting of plantlets under polyhouse conditions (Sharma *et al*. 2013). The mini-tubers produced during these two different seasons are stored in country stores at ambient conditions till planting in the field, i.e. up to next April. On account of differences in season of production, mini-tubers vary considerably in their physiological state on account of length of storage period. The differences in the season of production of mini-tubers may lead to variations in physiological condition, sprouting as well as in the production behavior. Since, no information is available till now on these aspects of mini-tubers produced during two different seasons, the present study was conducted.

MATERIALS AND METHODS

The experiment was conducted in high hills of north

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western Himalaya at Central Potato Research Station, Kufri (Fagu unit), Shimla, Himachal Pradesh during 2012 and 2013 with the mini-tubers of late blight resistant potato cultivar of hills, viz. Kufri Girdhari.

The mini-tubers raised during the main/*kharif* season (April-August) and again during autumn (off) season (mid September-January) under the protected structure (poly-house) without any provision for artificial heating and cooling were used for experimentation. Prior to planting, 3-week old micro-plants were hardened by keeping the test tubes containing the *in vitro* plantlets inside the poly-house for 1-week. For mini-tuber production, planting of micro-plants was done during the first week of April for main season crop and during 2nd week of September for autumn (off) crop at 30 ×10 cm spacing. Haulms were cut upon foliage maturity, i.e. after 120 days in summer (*Kharif*) crop and after 90 days of planting in autumn season crop. Harvesting was done 15 days after the cutting of haulms.

Freshly harvested mini-tubers were cured for 15 days before grading into four grades, viz. >20g, 10-20g, 3-10g and <3g. Graded mini-tubers were packed grade and replication-wise (03 replications) in perforated polythene bags with 0.5% venting area. A uniform sample size (500g) containing the uniform number of mini-tubers within each grade and replication corresponding to both the seasons was taken. Polythene bags containing mini-tubers were kept inside perforated plastic crates (replication-wise) and stored under ambient conditions for storage studies in completely randomized design (CRD, 2f). *Kharif* harvested mini-tubers were put in store on 1 October, while the autumn harvested ones on 1 January. After storage, mini-tubers were taken out on 30 April. The total period of storage was 210 and 120 days approximately for *kharif* and autumn produced mini-tubers, respectively. At the end of storage, data were collected separately for all the replications and grades of mini-tubers for total loss in weight (%) from the first day of storage to end of storage, number of sprouts per mini-tuber, the length of longest sprout and the average weight of mini-tuber at the end of storage.

After storage studies, the effects of season of production and grade of mini-tubers on the production potential were evaluated. Three grades of mini-tubers (3-10g, 10-20g and >20g) of potato variety Kufri Girdhari produced during *kharif* and autumn seasons were planted during last week of April in randomized complete block design (2 factor) in three replications. Planting was done at 50 × 15 cm spacing in 3 × 3 m beds. Standard package of practices for raising the potato crop in hills was followed. Haulms were cut 120 days after planting (DAP). Data were collected on per cent plant emergence at 35 and 50 DAP, plant height, number of shoots and compound leaves per plant at 90 DAP, haulms weight per plant 120 DAP, total number of tubers and yields /ha. Ground cover (%) was estimated after 60, 90 and 105 days of planting with the help of a 50 × 50 cm grid with 100 equal compartments at two locations in each plot as described by Burstall and Harris (1983). Pooling of the data for two years revealed non-significant interactions (Year × Treatment), so the average of two years data was analyzed statistically in RBD (2f) design by applying the technique of analysis of variance (ANOVA) as described by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Per cent loss in tuber weight

The observations recorded on the loss in weight of different grades of potato mini-tubers of cv. Kufri Girdhari produced during *kharif* and autumn seasons during storage under ambient conditions at Fagu (Kufri) reveal that *kharif* produced mini-tubers has slightly higher loss in weight than the autumn mini-tubers but the differences were statistically at par (Table 1). A gradual increase in the loss in weight with the reducing size of mini-tubers was noticed. Loss in weight in all the grades of mini-tubers at the end of storage period as observed in the present study is obvious and can be attributed to the degradative and natural senescence on account of respiration and other metabolic processes in the living tissues of mini-tubers during storage. Significantly higher loss in weight in small mini-tubers than large sized mini-tubers as noticed in the present study can be attributed to the larger surface area per unit weight as well as to the immature state of smaller mini-tubers than larger ones. Higher weight loss in small micro-tubers or tubers of potato than large ones on account of larger surface/ skin area per unit tuber weight has already been reported by earlier workers (Wiersema *et al.* 1987, Seabrook *et al.* 1993, Ranalli *et al.*

Table 1 Loss in weight (%) and average tuber weight at the end of storage in different grades of mini-tubers of potato variety Kufri Girdhari produced during *kharif* and autumn (off) seasons.

Season	Storage duration	Loss in weight(%)					Av. weight/ tuber (g)				
	(days)	>20g	10-20g	3-10g	<3g	Mean	>20g	10-20g	3-10g	<3g	Mean
Kharif (Main)	210	8.6	9.5	10.8	15.0	10.9	47.2	14.6	6.8	2.1	17.7
Autumn (off)	120	8.0	8.6	11.3	14.9	10.7	50.2	17.9	8.2	2.2	19.6
Mean		8.3	9.1	11.1	15.0		48.7	16.2	7.5	2.2	
CD (P=0.05)											
Season (S)			NS							17	
Grade (G)			24							25	
S × G			NS							NS	

1994b, Tabori *et al.* 1999, Sharma *et al.* 2011). The non-significant differences in the weight loss of mini-tubers from *kharif* and autumn seasons during storage under ambient conditions of high hills can be attributed to the prevailing extremely low temperatures due to the snowfall during the major part of the storage period as well as to the specific genotypic response of this particular potato cultivar, which in general retains better integrity of tubers during storage in high hills as compared to other cultivars.

The average weight per mini-tuber at the end of storage was significantly different with the season of production of mini-tubers. Weight per mini-tuber was more in autumn produced mini-tubers than *kharif* ones (Table 1). Comparatively higher tuber weight in autumn mini-tubers can be attributed to the small duration of storage period as compared to *kharif* produced mini-tubers. As obvious, the average weight per mini-tuber at the end of storage was significantly different among the different grades of mini-tubers (Table 1).

Sprouting behaviour of mini-tubers

Sprout length has been used as an indicator of physiological age of seed tubers by Allen *et al*. (1992) and physiologically older tubers were reported to have increased sprout growth (Ezekiel 1994). The physiological age of potato tubers was reported to advance progressively with the increasing chronological age besides depending upon the various other factors like size of individual tuber (Struik 2007). Thus in the present study, with different tuber grades, the results on sprouting pattern and subsequent performance of mini-tubers are discussed on the basis of length of storage period for *kharif* and autumn harvests which has a direct bearing on the physiological conditions of tubers.

A perusal of the data on number of sprouts and length of longest sprout per mini tuber in the present study reveals significant differences in the sprouting pattern of mini-tubers of different sizes and seasons (Table 2). Both, the number of sprouts and length of longest sprout per mini-tuber showed a gradual increase with the increasing size of mini-tubers. Sprouts were maximum (4.7) in large (>20g) and minimum (1.9) in small (<3g) mini-tubers (Table 2). Number of sprouts in *kharif* produced mini-tubers were comparatively less but longer than autumn season mini-tubers (Table 2). More number of sprouts with physiologically young (autumn season) mini-tubers than *kharif* ones can be attributed to the fact that in potato initially (immediately after breaking up of dormancy) more number of eyes turn into sprouts but with time elapse, some of the sprouts don't survive and dry out. The same may have happened with *kharif* produced mini-tubers stored for longer duration than autumn ones. Such a sprouting behaviour is in conformity to the finding of Sharma and Singh (2009) who have also reported a decline in the initial number of sprouts/tuber on account of longer duration of storage in potato cultivar Kufri Giriraj.

Longer sprouts in *kharif* produced mini-tubers may be due to the physiologically older condition of such tubers on account of longer duration of storage (210 days) as compared to autumn produced mini-tubers (120 days). Higher length of sprouts in physiologically older seed tubers of potato has also been reported by Dua and Bhargava (2002), Ezekiel (2004). Whereas, getting more number of sprouts with physiologically young tubers than older ones is in conformity to the findings of Ezekiel (2004) who has also reported more number of sprouts/tuber with physiologically young seed tubers. The season of production and size of mini-tuber interacted significantly for number of sprouts per mini-tuber. Increasing number of sprouts as well as sprout length with the increasing size of mini-tuber as observed in the present study can be ascribed to the already well established fact of more number of eyes in large mini-tubers on account of more surface area. The results are in close conformity with the findings of Tabori *et al.* (1999) and Sharma *et al.* (2011); who have also reported early and higher sprouting with more number of sprouts in larger micro-tubers than smaller ones, whereas Wiersema *et al.* (1987) have also reported an increase in the number and length of sprouts with increasing size of potato tubers.

Non-significant differences in weight loss with normal sprouting in the mini-tubers produced during *kharif* as well as autumn season is indicative of proper viability as well as right physiological stage in mini-tubers of all grades for use in further multiplication. The study indicates that storage behaviour of potato mini-tubers was little affected by the storage environments as well as periods and thus reveals that mini-tubers of potato can be stored for a longer duration

Table 2 Number of sprouts and length of longest sprout in different grades of mini-tubers of potato variety Kufri Girdhari produced during *kharif* and autumn (off) seasons

Season	No. of sprouts/tuber					Length of longest sprout (cm)				
	>20g	10-20g	3-10g	<3g	Mean	>20g	10-20g	3-10g	<3g	Mean
Kharif (Main)	4.1	3.5	2.2	2.1	3.0	1.1	1.0	0.8	0.5	0.9
Autumn (off)	5.3	4.2	3.2	1.7	3.6	0.8	0.7	0.5	0.4	0.6
Mean	4.7	3.8	2.7	1.9		0.9	0.8	0.7	0.4	
CD (P=0.05)										
Season (S)			0.4						0.1	
Grade (G)			0.6						0.2	
S × G			0.8						NS	

Kharif Autumn *Kharif* Autumn

3-10g mini-tubers of Kufri Girdhari 10-20g mini-tubers of Kufri Girdhari

Fig 1 Mini-tubers from *kharif* and autumn season after storage

in high hills provided an adequate sprout condition is maintained.

Field performance of different grades of potato mini-tubers produced during kharif and autumn seasons

Production behaviour of three grades of potato mini-tubers, viz. 3-10g, 10-20g and >20g produced during two different seasons, viz. *kharif* and autumn was studied under field conditions. The salient findings are as under:

Per cent germination

Per cent germination recorded 35 and 50 days after planting was significantly affected by the season of production as well as the grade of mini-tuber. The final crop stand at 75 DAP was similar to the one recorded at 50 DAP (Data not presented). At both the time intervals, viz. 35 and 50 DAP, per cent germination was more in the mini-tubers produced during *kharif* season than autumn season (Table 3). A gradual and consistence increase in the per cent germination was noticed with the increasing size of mini-tubers at both the stages (Table 3). Higher plant emergence in *kharif* mini-tubers can be attributed to the advanced physiological stage of these mini-tubers on account of longer storage period as compared to autumn ones as also indicated by the length of sprouts, while; increasing rate of plant emergence with increasing size of mini-tubers can be correlated to the corresponding tuber vigour (stored food) as well as to the number of sprouts available per mini-tuber as well as to the fact that small mini-tubers are more sensitive to adverse growing conditions than larger ones. Larger as well as physiologically older seed tubers of potato are well known to exhibit early plant emergence (Ezekiel 2000, Dua and Bhargava 2002, Patel *et al.* 2008 and Kumar *et al.* 2009). At 50 DAP, the interaction between season of mini-

Table 3 Germination in different grades of potato mini-tubers of variety Kufri Girdhari produced during *Kharif* and autumn seasons.

Variety	% Germination (35 DAP)				% Germination (50 DAP)			
	3-10g	10-20g	>20g	Mean	3-10g	10-20g	>20g	Mean
Kharif	33.8	54.3	96.1	61.4	96.4	99.3	100.0	98.6
Autumn	30.5	50.5	79.7	53.6	83.7	88.6	98.9	90.4
Mean	32.2	52.4	87.9		90.1	94.0	99.4	
CD (P=0.05)								
Season (S)		6.3				3.4		
Grade (G)		7.7				4.2		
S × G		NS				6.0		

Kharif Autumn

Fig 2 Mini-tubers (>20g) from *kharif* and autumn seasons in the field (45 DAP)

Table 4 Per cent ground cover in different grades of potato mini-tubers of variety Kufri Girdhari produced during *kharif* and autumn seasons

Variety	Ground cover (%)60 DAP				Ground cover (%)90 DAP				Ground cover (%)105 DAP			
	3-10g	10-20g	>20g	Mean	3-10g	10-20g	>20g	Mean	3-10g	10-20g	>20g	Mean
Kharif	43.7	58.0	72.3	58.0	100	100	100	100	99.3	99.7	99.0	99.3
Autumn	44.9	59.2	74.7	59.6	100	100	100	100	100	100	100	100
Mean	44.3	58.6	73.5		100	100	100		99.7	99.8	99.5	
CD (P=0.05)												
Season (S)		NS				NS				06		
Grade (G)		55				NS				NS		
S × G		NS				NS				NS		

tuber production and grade affected the per cent germination significantly. It was found that the per cent germination in smaller sized (<20g) autumn produced mini-tubers was significantly less than others (Table 3).

Per cent ground cover

Per cent ground cover recorded at different crop stages reveals that during the early stages of crop growth (till 90 days after planting), ground cover was not affected with the season of production of mini-tubers. This may be due to the fact that the proportion of sprouts that developed into stems/ shoots was similar in the mini-tubers produced during either of the season as indicated in the Table 5. However, at 105 DAP, ground cover was significantly higher in autumn produced mini-tubers than *kharif* ones (Table 4). Grade of mini-tubers affected the ground cover significantly at 60 days crop stage only and thereafter ground cover was found to be similar in all the grades of mini-tubers. An increase in the ground cover with the increasing size of seed tubers at early stages of crop (50 DAP) have also been reported by Wiersema *et al.* (1987). The higher ground cover during the later stages of crop growth (105 DAP) with autumn produced mini-tubers than the *kharif* ones can be attributed to the differences in their time of germination on account of differences in the physiological status due to the length of storage period and consequently these differences are reflected in the completion of crop cycle accordingly. Maintenance of ground cover for long duration with physiologically young seeds is in conformity to the findings of Ezekiel (2000).

Plant vigour

Vigour of plants raised from mini-tubers from two different seasons reveals that plant height was significantly affected with the season of mini-tuber production, whereas, number of shoots and compound leaves per plant were statistically at par in the mini-tubers from both the seasons. Wiersema *et al.* (1987) have also reported that storage environment of potato does not affect the stem number significantly. Height per plant was higher in autumn produced mini-tubers than *kharif* ones which can be attributed to the better physiological condition on account of shorter period of storage of these mini-tubers over *kharif* ones (Table 5). Ezekiel (2000) also reported that physiologically young seed tubers of potato produce plants having fewer but taller stems. Our results are also in close conformity to these findings. Increasing size of mini-tubers resulted in a gradual and consistent increase in the vigour of plants in r/o plant height as well as the number of shoots and compound leaves per plant (Table 5). Better plant vigour with large sized potato tubers is in conformity with the findings of earlier workers (Wiersema *et al.* 1987, Patel *et al.* 2008, Kumar *et al.* 2009, Singh and Kushwah 2010) and can be attributed to more food reserves as well as the number of sprouts available with larger seed tubers than smaller ones. The interaction between season of production and size of mini-tuber interacted significantly for the number of leaves/plant.

Haulms weight/m²

Haulms weight after 120 DAP was found to be affected significantly with the season of production of mini-tubers

Table 5 Plant vigour from different grades of potato mini-tubers of variety Kufri Girdhari produced during *kharif* and autumn seasons

Variety	Plant Height (cm)				No. of shoots/plant				No. of leaves/plant			
	3-10g	10-20g	>20g	Mean	3-10g	10-20g	>20g	Mean	3-10g	10-20g	>20g	Mean
Kharif	77.2	86.4	92.9	85.5	1.77	2.33	2.77	2.29	32.6	36.9	45.7	38.4
Autumn	84.5	91.6	97.4	91.2	1.53	2.07	3.00	2.20	28.8	35.4	52.1	38.8
Mean	80.9	89.0	95.2		1.65	2.20	2.88		30.7	36.2	48.9	
CD (P=0.05)												
Season (S)		2.6				NS				NS		
Grade (G)		3.1				0.26				4.2		
S × G		NS				NS				5.9		

Table 6 Haulms weight and production behaviour of different grades of potato mini-tubers of variety Kufri Girdhari produced in *kharif* and autumn season

Variety	Haulms weight/m² (Kg)				Total no. of tubers (Lakh/ha)				Total Yield (q/ha)			
	3-10g	10-20g	>20g	Mean	3-10g	10-20g	>20g	Mean	3-10g	10-20g	>20g	Mean
Kharif	2.37	2.77	2.65	2.60	4.50	5.20	5.58	5.09	251.13	281.10	309.36	280.53
Autumn	3.36	3.10	3.27	3.24	4.43	4.89	5.66	5.00	262.07	282.80	318.13	287.67
Mean	2.87	2.93	2.96		4.47	5.05	5.62		256.60	281.95	313.75	
CD (P=0.05)												
Season (S)		0.24				NS				NS		
Grade (G)		NS				0.42				19.96		
S × G		NS				NS				NS		

that were used in planting. Autumn produced mini-tubers had significantly higher weight of haulms over *kharif* ones. With increasing size of mini-tuber from 3g onwards, a gradual but non-significant increase in the weight of haulms was noticed (Table 6). The higher weight of haulms in autumn produced and large sized mini-tubers can be ascribed to the corresponding plant height and ground cover (105 DAP) of such mini-tubers as discussed earlier. Maintenance of larger leaf area index or ground cover for long duration with physiologically young seeds has already been reported by Ezekiel (2000).

Number of tubers and yield

Total number of tubers per hectare was found to be almost same with the mini-tubers from both the seasons. Whereas, yield/ha was though statistically same but otherwise was found to be slightly higher with autumn produced mini-tubers than *kharif* ones (Table 6). Grade of mini-tubers affected the number and yield of tubers significantly. A gradual increase in the number and yield of tubers was recorded with the increasing size of the seed mini-tuber (Table 6). More number of tubers and yields with larger tubers than smaller ones has been reported by many workers (Wiersema 1989, Patel *et al.* 2008, Singh and Kushwah 2010). Statistically, similar production behaviour (in respect to number of tubers and yield/ha) of mini-tubers obtained from two different seasons as observed in the present study can be attributed to the non-significant differences in the vigour of plants in r/o number of shoots and compound leaves per plant as well as to the similar levels of ground cover in the crop raised from these two seed sources. Tuber number is strongly influenced by the stem number (Allen and Wurr 1992). Since, in the present study, there was no significant difference in the number of shoots per plant with the mini-tubers produced during *kharif* and autumn seasons, there was no significant effect on tuber number and yield. Ezekiel (2004), Dua and Bhargava (2002) have also reported similar results on number of tuber and yields with seed tubers of varying physiological ages at optimum dates of harvest. However, the differences in weight of haulms, which indicates delay in maturity of crop with mini-tubers from autumn season, could not be harnessed on account of cutting of haulms in both the treatments on the same date. That is probably the reason that the production behavior of mini-tubers produced during two different seasons was found to be the same.

It can be concluded from the results that the mini-tubers of potato variety Kufri Girdhari produced during both *kharif* and autumn seasons in the high hills store well under ambient conditions till the next potato planting season, i.e. April. During field multiplication, mini-tubers from both the seasons resulted in similar number of tubers and yields. However, increasing size of seed mini-tubers resulted in a gradual increase in the number of tubers and yield. Similar production potential of the mini-tubers grown during two different seasons supports the practice of producing the mini-tubers during both the seasons for faster multiplication of elite planting material of potato in the high hills of north western Himalaya.

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