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Storability of Tubers Derived from True Potato Seed (*Solanum tuberosum* L.) under Ambient Storage Conditions

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Abstract: Storability of tubers obtained from 9 hybrid True Potato Seed (TPS) progenies were compared with that of non-TPS cultivar 'Diamant' under ambient conditions (22.0-34.8°C and 58.0-93.6% RH). Dormant period, days to start shrinkage and days to 100% shrinkage of all TPS progenies were significantly longer than those of 'Diamant', especially in P-364 X TPS-67 and P-364 X TS-9. The results of correlation analysis among these parameters also indicated that the storability of the TPS progenies was superior to that of 'Diamant'. The rate of rotten tubers of all the TPS progenies, however, was significantly higher than that of 'Diamant' because of their high susceptibility to infectious diseases, indicating the importance of the selection of TPS progenies with high disease resistance during storage under ambient conditions. Tuber size also affected the storability of TPS progenies; small tubers were preferable to medium and large ones, except for their high shrinkability.

Key words: Ambient conditions, storability, true potato seed

INTRODUCTION

Storage of potato (*Solanum tuberosum* L.) tubers is an important technique for keeping not only the marketability of the tubers but also their potential as seed potatoes. Improvement of storability using several techniques such as refrigerated storage at 2-4 or 8-10°C (Burton *et al*., 1992), utilization of passive evaporation by cooled water (Kaul and Mehta, 1988), application of sprouting inhibitors such as malic hydrazide, tetracholoro-nitrobenzene and isopropyl-N-3-cholorophenyl carbamate (Mehata and Kaul, 1991), or natural substances such as salicylaldehyde, benzaldehyde, cinnamaldehyde, cuminaldehyde and thymol (Sukuamaran and Verma, 1993) and irradiation using ^{60}Co gamma-rays (Storey and Shackley, 1987) has been attempted. In developing countries such as Bangladesh, however, these techniques are not necessarily available, especially for farmers, mainly for economic reasons. As a result, more than half of the produced tubers have been stored at ambient temperature (Kaul and Mehta, 1999; Ezekiel *et al*., 1999). In Bangladesh, potatoes are generally harvested in February to March, when both temperature and humidity begin to rise sharply. Under such conditions, the tubers terminate dormancy and begin to sprout, which results in a decrease of their quality due to changes such as shrinkage, weight loss and rot (Lindblom, 1970; Burton *et al*., 1992; Devendra *et al*., 1995; Bornman and Hammes, 1977; Verma *et al*., 1974). Under ambient conditions in Bangladesh, 20 to 80% of the tubers have been lost (Hashem, 1979). According to Leppack (1979) and Sukuamaran (1983), the monthly loss amounts to 10%. The growers, however, still prefer to store the tubers at home even during the hottest period (April-August) in order to sell them gradually and consequently at a higher price.

The use of True Potato Seed (TPS) for potato production has increased recently in Europe, North America and Asia, especially in the developing countries (Burton, 1989; Devaux, 1984; Song, 1984; Wiersema, 1986). In Bangladesh, this technology has been highly promising (Renia and Hest, 1998; Roy *et al*., 1999; Siddique and Rashid, 2000) and the Tuber Crops Research Center of Bangladesh recommends a Three-Step Year Production Program for TPS utilization (Fig. 1). In this

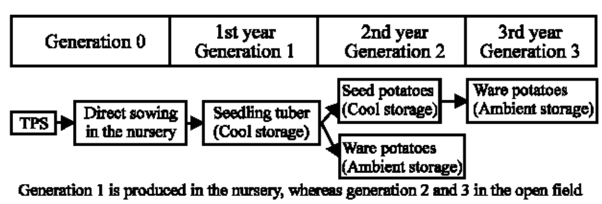

Fig. 1: Three-step year production method of TPS utilization

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program, the seedling tubers (generation 1 or G_1) derived from TPS are stored in a refrigerator for planting the next year as seed potatoes because of the short dormant period. On the other hand, the 2nd generation (G_2) tubers are generally stored under ambient conditions, especially when the tubers are utilized as table potatoes, because the dormant period of G_2 tubers is longer than that of G_1 tubers. A large fraction of the G_2 tubers, however, is still lost during storage under ambient conditions, as is also the case for non-TPS tubers (Anonymous, 2003). Therefore, the selection of G_2 tubers with higher storability than non-TPS cultivars under ambient conditions is very important. In the present study, we collected G_2 tubers from 9 promising hybrid TPS progenies and stored them for 180 days under ambient conditions to compare the storability with that of a non-TPS commercial cultivar, 'Diamant'.

MATERIALS AND METHODS

In 2001-2002, artificial pollination was performed among male (TPS-13, TPS-67 and TS-9) and female TPS parents (MF-II, MF-I, TS-7, TS-8, P-364 and P-501) in nursery beds of the Tuber Crops Research Center (TCRC), Gazipur (23°41′N latitude, 90°22′ E longitude and 8.1 m altitude), Bangladesh and progenies from the following 9 TPS hybrids were obtained: MF-II X TPS-13, TS-7 X TPS-13, TS-8 X TPS-67, P-501 X TPS-67, TS-9 X TPS-67, MF-I X TPS-67, P-364 X TPS-67, P-364 X TS-9 and TS-7 X TPS-67 (released variety named "BARI TPS 2"). In the following season (2002-2003), the hybrid TPS were sown and produced G_1 tubers (1-35 g). The G_1 tubers were planted on 11 November 2003 to obtain G_2 tubers at TCRC, as described previously (Roy *et al*., 2005). A non-TPS commercial cultivar, 'Diamant', was also planted for comparison. All the tubers were harvested 90 days after sowing and kept in heaps at ambient temperature for 10 days for proper curing of the skin. The tubers were classified into three sizes: large (> 45 mm), medium (45-28 mm) and small (28-20 mm), put into netted boxes to avoid insects and then stored in a well-ventilated room. This storage study was conducted at the laboratory of TCRC, Gazipur during March to August, 2004. Sprouting of the tubers was recorded weekly during storage. The breaking of dormancy was regarded to occur when 80% of the tubers had a sprout longer than 2 mm (Van Ittersum and Scholte, 1992). Tuber weight was recorded at 30-day intervals up to 180 Days After Storage (DAS). The number of rotten tubers during storage was counted and then the rotten tubers were discarded. The apical sprout length per tuber was recorded at 180 DAS. Shrinkage of the tubers was evaluated by visual observation. When shrunken tubers per progeny/cultivar were initially observed and when all tubers had shrunk was termed as "start shrinkage" and "100% shrinkage", respectively. The experiment was conducted according to a Completely Randomized Design following a 2-factor (progeny X tuber size) design with 3 replications. Thirty tubers were used for each progeny for each replication. All data were analyzed using MSTAT 5 (Freed *et al*., 1987).

RESULTS AND DISCUSSION

Climatic conditions during storage: The temperature in the storage room increased gradually from March to May and decreased slowly thereafter (Table 1). The average maximum and minimum temperatures during storage were 32.7 and 24.3°C, respectively. The RH also increased gradually from March to September. The range of RH varied from 58.0 to 93.6%.

Effects of progeny and tuber size on storage characteristics

Sprout initiation: Sprout initiation of all the TPS progenies except MF-II X TPS-13, TS-8 X TPS-67 and P-501 X TPS-67 occurred significantly later than that of 'Diamant' (47.9-54.0 vs. 44.3 days) (Table 2).

The storage characteristics of G_2 tubers were influenced by the tuber size, but the trends were similar for all the TPS progenies (data not shown). Therefore, the results are shown as the mean value of the 9 progenies (Table 3). The sprouting of the small tubers took significantly longer than that of the medium and large ones (54.6 vs. 44.0-48.0 days). Small potato tubers at harvest often show juvenility (Leppack and Stentyler, 1988), suggesting that the delayed sprouting of the small tubers in our experiment may have been due to the immaturity of the tubers.

Dormant period: The dormant period of 'Diamant' was 56.1 days (Table 2). Singh *et al*. (2002) showed a similar result, in which the dormant period of non-TPS Indian potato cultivars was 50-55 days. Bogucki and Nelson

Table 1: Average monthly temperature and relative humidity of the storage house in 2004

Month	Air temperature (°C) Maximum	Air temperature (°C) Minimum	Relative humidity (%) Maximum	Relative humidity (%) Minimum
March	32.3	22.0	87.6	58.0
April	32.8	22.4	90.0	67.8
May	34.8	26.3	91.4	61.4
June	32.1	24.6	91.8	74.8
July	31.8	25.8	92.4	75.8
August	32.5	25.1	93.5	75.2
September	30.6	24.1	93.6	78.8
Average	32.7	24.3	91.5	70.3

Table 2: Storability of 9 hybrid TPS progenies at G_2 generation as compared with non-TPS cultivar 'Diamant' under ambient storage conditions

Progeny/ cultivar	Sprout initiation (Days)	Dormant period (Days)	Days to start shrinkage	Days to 100% shrinkage	Apical sprout length (mm)	Rotten tubers (%)[z]	Weight loss of healthy tubers (%)[z]
MF-II X TPS-13	41.8d	69.2b	128.6d	154.6b	18.9a	35.6bc	60.6b
TS-7 X TPS-13	47.9b	73.9ab	130.7d	153.3b	14.7d	41.3ab	63.4a
TS-8 X TPS-67	43.8cd	73.7ab	122.9e	156.4b	17.67b	38.1ab	62.1a
P-501 X TPS-67	45.9bc	84.4a	137.9bc	160.8b	13.5e	42.9a	60.7b
TS-9 X TPS-67	51.4a	84.0a	132.9cd	160.3b	19.0a	27.3d	50.8c
MF-I X TPS-67	53.2a	85.2a	139.9b	158.8b	14.3d	42.6a	60.6b
P-364 X TPS-67	53.7a	81.9a	147.8a	177.3a	13.9de	36.9ab	57.1bc
P-364 X TS-9	54.0a	84.1a	145.3a	175.8a	15.7c	30.4cd	50.1c
BARI TPS 2	51.0a	75.2ab	122.4e	152.8b	19.1a	36.6ab	61.0b
Diamant	44.3cd	56.1c	100.0f	141.7c	19.5a	18.9e	50.8c

[z]Tubers were stored for 180 days, Different letter(s) within columns indicate a significant difference by Duncan's multiple range test at, $p \leq 0.01$

Table 3: Storability of tubers at G_2 generation under ambient storage conditions as influenced by the tuber size[z]

Tuber size	Sprout initiation (Days)	Dormant period (Days)	Days to start shrinkage	Days to 100% shrinkage	Apical sprout length (mm)	Rotten tub (%)[y]	Weight loss of healthy tubers (%)[y]
Large (>45 mm)	44.0c	69.4c	138.1a	165.6a	16.7a	64.6a	79.4a
Medium (45-28 mm)	48.0b	76.9b	135.5a	162.4a	17.2a	36.0b	56.5b
Small (28-20 mm)	54.6a	91.1a	128.0b	155.2b	14.8b	10.7c	39.4c

[y]Values are the mean of the 9 progenies, [z]Tubers were stored for 180 days, Different letter(s) within columns indicate a significant difference by Duncan's multiple range test at $p \leq 0.01$

(1980) also investigated the dormant period of 10 American non-TPS potato cultivars and reported it to be 56-68 days. In this experiments, however, the dormant period of all the TPS progenies was significantly longer (69.2-85.2 days) than that of 'Diamant'. These results strongly suggest that the storability of TPS progenies under ambient conditions will be better than that of non-TPS cultivars.

The dormant period was also affected by the tuber size. The small tubers had a significantly longer dormant period than medium and large ones (91.1 vs. 69.4-76.9 days), as reported previously for some non-TPS potato cultivars (Hossain *et al*., 1992; Leppack, 1979).

Shrinkage: Both days to start shrinkage and days to 100% shrinkage of all the TPS progenies were significantly longer than those of 'Diamant' (122.4-147.8 vs. 100.0 days and 152.8-177.3 vs. 141.7 days, respectively), especially in P-364 X TPS-67 and P-364 X TS-9 (Table 2). These results also showed the superiority of TPS progenies for storage under ambient conditions.

For the three sizes of tubers, both days to start shrinkage and days to 100% shrinkage of the small tubers were significantly reduced compared to those of the medium and large ones (128.0 vs. 135.5-138.1 days and 155.2 vs. 162.4-165.6 days, respectively) (Table 3) as Hossain *et al.* (1995) reported for some non-TPS British potato cultivars. Thus, small tubers are not preferable for storage under ambient conditions when evaluated by shrinkability.

Apical sprout length: The longest sprout length at 180 DAS was recorded in 'Diamant' (19.5 mm), which showed no significant difference from that for BARI TPS 2, TS-9 X TPS-67 and MF-II X TPS-13 (18.9-19.1 mm); whereas the shortest was recorded in P-501 X TPS-67 and P-364 X TPS-67 (13.5 and 13.9 mm, respectively) (Table 2). Thus, the sprout growth under ambient conditions largely depends on the progeny.

For the tubers of different sizes, the apical sprout length of the large and medium tubers was significantly longer than that of the small ones (16.7-17.2 vs. 14.8 mm) showing the advantage of the small tubers for storage under ambient conditions (Table 3).

Rotten tubers: Tuber rot under ambient conditions is mainly caused by bacteria such as those causing soft rot (*Erwinia* sp.) and fungi such as those causing dry rot (*Fusarium* sp.) (Hooker, 1981). In our experiments, the rate of rotten tubers increased gradually as the storage period progressed (data not shown), irrespective of whether they were from TPS progenies or cultivars. The percentages of rotten tubers of all the TPS progenies during storage were significantly higher than those of 'Diamant' (42.9-27.3 vs. 18.9%), showing a disadvantage of TPS progenies for storage under ambient conditions.

Among the 3 sizes, the highest rotten rate was recorded in the large tubers (64.6%) followed by the medium (36.0%) and small ones (10.7%) (Table 3), as Khan *et al.* (1984); Singh (1980) reported for non-TPS potato cultivars.

Weight loss of healthy tubers: Weight loss of healthy tubers during storage was largely influenced by the type of the TPS progeny and tuber size. The maximum weight loss was observed in TS-7 X TPS-13 and TS-8 X TPS-67 (63.4 and 62.1%, respectively), whereas the minimum was in P-364 X TS-9 and TS-9 X TPS-67 (50.1 and 50.8%, respectively) which were comparable to those for 'Diamant' (50.8%) (Table 2).

Table 4: Correlation coefficients of different storage parameters of 9 hybrid TPS progenies

Parameter	Sprout initiation shrinkage	Dormant period	Days to start shrinkage	Days to 100% shrinkage	Apical sprout length	weight loss (%)
Rotten tubers (%)	-0.27	0.40	-0.60*	-0.34	-0.59*	0.85**
Sprout initiation		0.72*	0.63*	0.61*	-0.31	-0.56
Dormant period			0.73*	0.59*	-0.52	0.57
Days to start shrinkage				0.87**	-0.75*	-0.51
Days to					-0.45	-0.65*
Apical sprout length						0.14

*,** Significant at $p \leq 0.05$ and 0.01, respectively

The weight loss of healthy tubers at 180 DAS increased with increasing tuber size: the weight loss was minimal for the small tubers (39.4%) followed by the medium and large ones (56.5 and 79.4%, respectively) (Table 3). A similar trend of weight loss was also observed by Khuong *et al.* (1987); Booth and Shah (1981); Butchbaker *et al.* (1973).

Analysis of correlation coefficients: The correlation coefficients among different characters of storability were analyzed for all combinations (Table 4). Rotten tubers (%) showed a significantly positive correlation with weight loss (R = 0.85), but a negative correlation with days to start shrinkage and apical sprout length (R = -0.60 and-0.59, respectively). Days to start shrinkage showed positive and negative correlations with days to 100% shrinkage and apical sprout length (R = 0.87 and-0.75, respectively). A significantly negative correlation (R = -0.65) was found between weight loss and days to 100% shrinkage. These results indicate that rapid apical sprout growth during storage induces shrinkage, followed by weight loss of the tubers and then finally results in rot. Therefore, the collection of TPS hybrids with a low sprouting habit is one of the most important parameters for improving the storability of the G_2 tubers under ambient conditions.

Sprout initiation showed significantly positive correlations with dormant period, days to start shrinkage and days to 100% shrinkage (R = 0.72, 0.63 and 0.61, respectively). The dormant period also showed significantly positive correlations with days to start shrinkage and days to 100% shrinkage (R = 0.73 and 0.59, respectively). Thus, the results of correlation analysis emphasized again the importance of the selection of TPS progenies with a long dormant habit.

All the TPS progenies used in our experiments showed a significantly longer dormant period than the non-TPS cultivar 'Diamant' (Table 2); they are also probably longer than those of other non-TPS cultivars (Bogucki and Nelson, 1980; Singh *et al*., 2002). Therefore, we conclude that the storability of TPS progenies at the G_2 generation is superior to that of non-TPS cultivars when it is evaluated by the dormant period. Although other parameters of storability depend largely on the progenies, P-364 X TPS-67 and P-364 X TS-9 showed comparatively better results than the other TPS progenies. Therefore, these two TPS progenies will have the best storability. Among the 3 sizes of tubers, the small tubers (28-20 mm) were the most suitable for storage under ambient conditions, but their shrinkability needs to be improved. Although many parameters indicated the advantages of TPS progenies, the tuber rot caused by infectious diseases still remains a problem. Therefore, the selection of TPS progenies with high disease resistance during storage under ambient conditions is strongly needed in future studies.

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