Chapter 7
Studies in the utilization of true potato seeds: Productivity of tubers under subsequent clonal generations

7.1 Introduction

TPS is the botanical term for potato (*Solanum tuberosum* L.) produced through open or artificial pollination for acquiring hybrid seeds between two known parents. Although most potato cultivars do not produce TPS, the International Potato Center (CIP) has developed some cultivars which can produce TPS. In the Netherlands, an epidemic of late blight in 1840's wiped out potato culture that was using imported TPS (Haan, 1953), whereas in China, potato production by using TPS has been practiced successfully since 1967 (Li, 1983). In India, similar studies were carried out in 1960's (Gray, 1979). This technology was also introduced in the 1980's to Bangladesh where it has been standardized. The farmers accepted the technology due to its low transmission of virus diseases, high multiplication rate (1: 750), good tuber yield, etc (Sikka, 1987; Renia and Hest, 1998; Siddique and Rashid, 2000). Only 60 to100 g of TPS is sufficient for planting per hectare instead of using 1.5 to 2.5 t of seed tubers in the conventional system (Renia and Hest, 1998). The use of seed tubers, which generally accounts for 35 to 55% of the total input cost for potato production in the traditional method, can be significantly reduced by the use of TPS (Singh, 1999).

In Bangladesh, this technology has been proven to be highly promising for the marginal farmers (CIP, 1983). Tuber Crops Research Center (TCRC) of Bangladesh recommends a Three-Step Year Production Program for TPS utilization (Anonymous, 1993). It involves sowing TPS in a raised nursery bed at close spacing in the first year to produce seedling tubers (1-35 g), which are then planted at normal spacing to obtaining more seed tubers as well as for consumption in the second year. In the third year, the second year tubers are planted for clonal potato production. This production system has been adapted not only in Bangladesh but also in China, New Zealand, India, Korea, Egypt, Nicaragua, Sri Lanka, Paraguay, and Viet Nam because farmers can reduce the investment for potato production (Malagamba, 1988; Pallais, 1994). In this context, some TPS varieties have been commercially sold at private seed companies (Rashid et al., 1993), but the initial investment for the seed cost is still high for many farmers with small holdings.

Although potatoes generally show low transmission of diseases via TPS (Khurana, 1990), TPS progenies often perform poorly with succeeding clonal generations mainly because of disease infections, such as late blight (Watson, 1970), bacterial wilt (Sunaina et al., 1989), and virus via aphids. The spread is attributed to contact with virus-infected hands and leaves (Hossain et al., 1992). Therefore, the breeding of new TPS cultivars with higher yield, quality, disease tolerance; and inexpensive means of distribution are needed. TCRC has collected some parental lines of TPS from CIP, India, and Bangladesh and has selected some promising male and female parents available for this program (Anonymous, 2001). As a part of this program, we artificially pollinated five pairs of the parental lines and obtained their hybrid TPS since they yield better results because of their hybrid vigor (Pandey and Gupta, 1995). The objectives in our experiment, therefore, are to assess the plant growth, tuber yield, and disease infection under successive clonal potato production by using the hybrid TPS.

7.2 Materials and Methods

Fields trials were conducted at the farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh at $23^{0}41^{'}$N latitude, $90^{0}22^{'}$ E longitude, 8.6 m altitude. The soil type of the experimental plots was clay loam with low organic matter (1.47%). The soil reaction was slightly acidic (pH 5.6).

In 2000 to 2001, twenty-eight parental lines, consisting of exotic germplasm (CIP, 1983) with flowering habits, were planted at the experimental field of TCRC of Bangladesh. Among them, TPS-67 and TS-15 were selected as promising males; MF-I, MF-II, 'Atzimba', and P-364 were selected as promising females. These parents were selected on the basis of flowering intensity, berry setting, berry weight, seeds per berry, 1000-seed weight and proportion of large seeds (Song and Zaag, 1987; Almekinders et al., 1995). Artificial pollinations were performed among these selected male and female parents and progenies from the following 5 hybrids TPS were obtained: MF-II X TPS-67 (released variety named as BARI TPS 1), P-364 X TPS-67, 'Atzimba' X TS-15, MF-I X TS-15, and MF-II X TS-15.

The experiments were conducted in 3 successive years. In the first year, hybrid TPS were sown on 7 November 2001 in raised in 15 cm high nursery beds that were prepared with specially amended soil (soil : sand : well decomposed manure = 1:1:1 (v/v)) (Roy et al., 1997). The nursery beds were fertilized with urea, triple super phosphate (TSP), muriate of potash (MP), gypsum, magnesium sulphate, and boric acid at the rate of 325-220-280-120-14-6 kg ha^{-1}, respectively. Fifty percent each of urea and MP and full dose of other fertilizers were mixed thoroughly and applied to beds 3 days before sowing TPS. Three seeds were sown in each hole at a spacing of 25 x 4 cm; the seedlings were thinned out to 100 plants in a 1 m^2 bed 5 to 7 days after germination (Roy et al., 1999). The nursery beds were watered when necessary. With the growth of the plants, more soil was added. The rest of the urea / MP mixture was applied with extra soil in equal three installments (30, 40, and 50 days after sowing). The tubers were harvested at 107 days after sowing (24 February 2002) and termed as "seedling tubers" (F_1C_0) (F and C mean foliar year and clonal generation, respectively). The F_1C_0 tubers (10-25 g) that were stored at approximately 4ºC from March to mid-October 2002, were transplanted on 10 November 2002 and the second year crop (F_1C_1) was harvested on 13 February 2003. These F_1C_1 tubers were also cold stored and replanted on 15 November 2003; the third year crop (F_1C_2) was harvested on 20 February 2004. In both second and third year tuber productions, the unit plot size was 1x 3 m, and the planting space was 50 x 25 cm. Certified grade seed tubers of 40 to 50 g size of a commercial cultivar 'Diamant' were also grown in the second and third years as a control. For the clonal productions in the second and third years, the crops were fertilized with urea, TSP, and MP at the rate equivalent to 270, 180, and 200 kg ha^{-1}, respectively (Anonymous, 2001). Fifty percent urea and full dose of TSP and MP were applied prior to planting tubers while the rest of the urea was applied 35 days after sowing. Ten plants were randomly selected from each unit plot for measuring the plant growth and yield attributes. Data of late blight, bacterial wilt, and viruses were recorded by observations. Any plants that showed symptom of disease was considered to be infected. Crop maturation was estimated when 40 to 50% leaves in the lower part of stem turned yellow. Total yield and marketable yield (>20 g) were recorded at harvest.

All the 3 year cultivations were set in randomized complete block design with 4 replications. Statistical analysis of recorded data was carried out by MSTAT 5 (Arbin Instruments, TX, USA) computer package. Tukey's honestly significant difference test at 5% level was used to compare differences among the hybrids.

7.3 Results and Discussion

7.3.1 Growth parameters

7.3.1.1 Plant height

In F_1C_0 crops, the plant height of TPS seedlings ranged from 80.1 to 90.2 cm; it was taller than those of F_1C_1 and F_1C_2 (55.3 - 60.6 cm) (Table 7-1) as Kadian et al (1988, 1992) reported previously. This decrease in height is attributed to the closer planting distances. The stem of F_1C_0 seedlings became lanky and formed longer internodes (data not shown). Within a year, the height varied significantly in F_1C_0 crops. Moreover, the plant height of the F_1C_1 and F_1C_2 crops became almost comparable to that of 'Diamant'.

7.3.1.2 Crop duration

Leaf yellowing is used as an indicator for maximum yield of potato tubers because over maturation decreases yield (Beukema and Zang, 1985). In our experiment, F_1C_0 took approximately 107 days to mature which is about 11 to14 days longer than subsequent clonal generations (93-96 days) (Table 7-1). The longer life of the first year crops compared to subsequent clonal generations might be due to application of higher nitrogen and/or different planting spaces.

7.3.1.3 Number of stems plant^{-1}

F_1C_0 seedlings had single stem (Table 7-1), whereas the number of stems in clonal generation crops ranged from 3.6 to 4.8; the values increased with each subsequent generation.

7.3.2 Disease incidence

7.3.2.1 Late blight

Late blight is a serious disease of the potato plant, and the incidence is environment-dependent (Watson, 1970). In F_1C_0 crops, it appeared with a score of 1.8 to 2.3% across the progenies (Table 7-2). The disease appeared at higher rates (3.1 - 9.4%) in all the progenies in the second and third year crops as well as with 'Diamant'. Singh and Bahal (1997) stated that the percentage of late blight incidence in crop raised through TPS progenies was lower than the crop raised through seed tubers. Upadhya (1987) stipulated that hybrid TPS populations that contain recombination products of genes for late blight resistance (integrated both vertically and horizontally, from diverse sources) would give a wide diversity of genotypes. This diversity of genotypes in hybrid TPS, as a multi-line concept, would provide stable protection against late blight damage.

7.3.2.2 Bacterial wilt

No incidence of bacterial wilt was observed in the F_1C_0 crops (Table 7-2). Bacterial wilt is mostly a soil-borne disease, but TPS does not carry any disease organism except some viruses and viroids (Acatino and Malagamba, 1982). In F_1C_0 crops, the TPS was devoid of organism. *Pseudomonas solanacearum* survives in virulent form in tubers, but it does not survive in true seeds of chilies and tomatoes (Sekhawat et al., 1979; Sunaina et al., 1989). Although the disease was manifested in 1.0 to 5.2% of plants in the F_1C_1 and F_1C_2 crops, respectively; the values were still lower than that of 'Diamant'. Seed tubers produce a high number of fibrous roots which easily decompose and rot because of high soil moisture and, thus, allow the pathogen to infect the crops. On the other hand, TPS produces a few fibrous roots which are hard and tough (Singh and Bahal, 1997), that may explain the low wilt infection in the F_1C_0 crops.

7.3.2.3 Virus disease

The major potato viruses are not transmissible through TPS except for a few latent viruses (Acatino and Malagamba, 1982). The latent viruses seldom show symptoms in the growing crops but cause slow degeneration. Basu et al (2003) reported that mild mosaic (PVX), severe mosaic (PVY), leaf roll (PLRV), leaf crinkle (PVX + PVS), and rugose mosaic (PVX + PVY) perpetuate in seed stock and cause degeneration of potato varieties. In F_1C_0 crops, no virus symptom was observed (Table 7-2), but in the F_1C_1 and F_1C_2, PLRV and PVY were recognized in 1.0 to 2.1% and 8.3 to10.4% of the plants, respectively. Although the virus infection increased with succeeding clonal generations as Hossain et al (1992) reported, the infection of all TPS progenies in F_1C_1 crops was significantly lower than those of 'Diamant', both MF-I X TS-15 and MF-II X TS-15, and even in F_1C_2 crops. Virus infection in potato plants usually increases 7 to 10 folds in each clonal generation (Acatino and Malagamba, 1982); a similar trend was also observed in our experiment.

7.3.3 Yield attributes

7.3.3.1 Number of tubers m^{-2}

Although the plant spacing for F_1C_1 and F_1C_2 of 50 x 25 cm is much wider than the 25 X 4 cm of the F_1C_0 crops, the number of tubers $plant^{-1}$ in the three years were almost same (approx. 8) (data not shown). In F_1C_0 crops, the maximum number of tubers m^{-2} was occurred in P-364 X TPS-67 (839) (Table 7-3). In the subsequent clonal generations, the yield of the progenies dramatically decreased, except in that of 'Atzimba' X TS-15 that showed significantly higher values than did 'Diamant' in F_1C_2 generation.

7.3.3.2 Average tuber weight

The mean tuber weight was reverse to the number of tubers m^{-2} in the clonal generations, the F_1C_1 and F_1C_2 crops yielding 32.4 to 38.8 g; that exceeded the higher value of 8.9 to 10.3 g for the F_1C_0 crop (Table 7-3). Pandey et al (1990) reported that average tuber weight of TPS progenies was sustained up to the third clonal generation. Smaller tuber size in F_1C_0 crops is probably because of higher plant density (100 m^{-2}) than in F_1C_1 and F_1C_2 (8 plants m^{-2}). Similar results were reported previously by Nandekar et al (1995).

The mean tuber weights of BARI TPS 1, P-364 X TPS-67 and 'Diamant' were significantly heavier than those of other TPS progenies in F_1C_2.

7.3.3.3 Tuber yield

The yield of F_1C_0 crops was much higher (46.4 – 50.6 t ha^{-1}) than the subsequent clonal generations (Table 7-4). In F_1C_1 and F_1C_2 crops, tuber yields were 28.3 to 34.2 and

25.5 to 30.3 t ha^{-1}, respectively; similar to that of 'Diamant'. These results indicate that under the TPS program, the yield is reduced over subsequent clonal generations probably because of diseases. Among the progenies, tuber yield of BARI TPS 1 and P-364 X TPS-67 were the highest in all the 3 years. Therefore, these 2 TPS progenies are considered as the most promising hybrids.

7.3.3.4 Marketable yield

In Bangladesh, tuber weighing over 20 g are considered as marketable (Pandey et al., 1990), which means that only 9.2 to 10.5% of the F_1C_0 crop was marketable; but it increased to more than 78% in the subsequent clonal generations (Table 7- 4). In all the progenies and 'Diamant', the percentage of marketable yield in F_1C_2 was higher than that in F_1C_1 crops, but total yield decreased probably because of degeneration as Wiersema (1984) pointed out previously. The opposite relation between total yield and marketable yield has also been reported by other researchers (Martin, 1988; Rashid et al., 1990; Siddique, 1995; Singh, 1999).

7.3.3.5 Yield reduction

Yield reduction of potato crop over clonal generation may be attributed to several reasons, such as virus infection, environmental stress, genetic, and their interactions (Jones, 1982). Among those, the virus infection is the most serious (Gerg, 1987). Yield reduction from first to second year was higher than 30% in all the TPS progenies (15.8-18.9 t ha^{-1}) (Table 7- 4). However, the reduction from second to third year was only 4.5 to 12.8% (1.3 - 4.3 t ha^{-1}). Nagalch et al (1974) reported that potato yield decreased to 30% because of mild mosaic viruses. In our experiment, MF-I X TS-15 and MF-II X TS-15 showed significantly lower virus infection and yield reduction than did 'Diamant' (Tables 7-2 and 7-4).

7.3.3.6 Tuber grade

In F_1C_0 crops, more than 82% of tubers were smaller than 28 mm; no tuber bigger than 55 mm was harvested (Table 7-5). The percentage of medium size tubers (28-55 mm), however, increased with succeeding clonal generations, reaching 66.9 to 68.5% and 73.9 to 76.4% in F_1C_1 and F_1C_2 crops, respectively. Percentage distribution of tuber size in the TPS progenies was similar to the range found in 'Diamant' as Singh (1999) reported previously.

7.4 Conclusion

TPS progenies used in the experiment generally maintain their potential yield at least to the second clonal generation. Among the 5 TPS, BARI TPS 1 and P-364 X TPS-67 had the best total tuber yield, but MF-I X TS-15 and MF-II X TS-15 are the more promising hybrids due to their virus tolerance and yield maintenance.

Table 7-1. Plant height, crop duration, and stem number plant^{-1} of hybridized TPS progenies and 'Diamant' in their three subsequent generations

Progeny/cultivar	Plant height (cm)			Crop duration (days)			No. of stem plant^{-1}		
	F_1C_0 2001-02	F_1C_1 2002-03	F_1C_2 2003-04	F_1C_0 2001-02	F_1C_1 2002-03	F_1C_2 2003-04	F_1C_0 2001-02	F_1C_1 2002-03	F_1C_2 2003-04
BARI TPS 1	86.5 b[z]	59.7	55.3	105 b	94 ab	93 a	1	3.7	4.4
P-364 X TPS-67	90.2 a	60.6	56.1	109 a	96 a	95 a	1	3.7	4.5
Atzimba X TS-15	84.9 b	58.6	58.5	106 b	94 ab	94 a	1	4.0	4.8
MF-I X TS-15	85.4 b	59.5	57.0	106 b	93 b	93 a	1	3.7	4.7
MF-II X TS-15	80.1 c	59.8	56.5	107 b	94 ab	94 a	1	3.6	4.8
Diamant	-	59.9	57.6	-	90 c	89 b	-	3.2	4.4
Significance		NS[y]	NS				NS	NS	NS

[z] Different letters within columns show significant difference by Tukey's honestly significant difference test at 5% level.
[y] Non-significance

Table 7-2. Disease infection of hybridized TPS progenies and 'Diamant' in their three subsequent generations

Progeny/cultivar	Late blight (%)			Bacterial wilt (%)			Virus (%)		
	F_1C_0 2001-02	F_1C_1 2002-03	F_1C_2 2003-04	F_1C_0 2001-02	F_1C_1 2002-03	F_1C_2 2003-04	F_1C_0 2001-02	F_1C_1 2002-03	F_1C_2 2003-04
BARI TPS 1	2.3	3.1	9.4	0	1.0 b[z]	2.1 d	0	1.0 c	9.4 ab
P-364 X TPS-67	1.8	3.1	8.3	0	1.0 b	3.1 cd	0	2.1 b	10.4 ab
Atzimba X TS-15	2.3	4.2	8.3	0	1.0 b	4.2 bc	0	1.0 c	9.4 ab
MF-I X TS-15	1.8	3.1	8.3	0	1.0 b	5.2 b	0	2.1 b	8.3 b
MF-II X TS-15	1.8	4.2	9.4	0	1.0 b	4.2 bc	0	1.0 c	8.3 b
Diamant	-	4.2	9.4	-	2.1 a	8.3 a	-	3.1 a	11.5 a
Significance	NS[y]	NS	NS	NS			NS		

[z] Different letters within columns show significant difference by Tukey's honestly significant difference test at 5% level.
[y] Non-significance

Table 7-3. Yield attributes of hybridized TPS progenies and 'Diamant' in their three subsequent generations

Progeny/cultivar	No. of tubers m^{-2}			Average tuber weight (g)		
	F_1C_0 2001-02	F_1C_1 2002-03	F_1C_2 2003-04	F_1C_0 2001-02	F_1C_1 2002-03	F_1C_2 2003-04
BARI TPS 1	829 a[z]	72 a	60 b	10.3	35.2 b	38.8 ab
P-364 X TPS-67	839 a	71 a	56 b	10.3	35.4 ab	38.4 ab
Atzimba X TS-15	754 b	69 a	66 a	8.9	32.4 b	35.8 bc
MF-I X TS-15	789 ab	67 ab	61 ab	10.1	32.6 b	32.0 d
MF-II X TS-15	740 b	64 ab	60 b	10.2	33.8 b	32.4 cd
Diamant	-	56 b	56 b	-	40.1 a	41.7 a
Significance				NS[y]		

[z] Different letters within columns show significant difference by Tukey's honestly significant difference test at 5% level.
[y] Non-significance

Table 7-4. Total and marketable yields of hybridized TPS progenies and 'Diamant' in their three subsequent generations

Progeny/cultivar	Total tuber yield (t ha^{-1})					Marketable yield (%)		
	F_1C_0 2001-02	F_1C_1 2002-03		F_1C_2 2003-04		F_1C_0 2001-02	F_1C_1 2002-03	F_1C_2 2003-04
BARI TPS 1	50.6 a[z]	33.9 a	(33.0b)[y]	29.6 a	(12.8ab)	9.9	78.7	81.3
P-364 X TPS-67	50.2 ab	34.2 a	(31.8b)	30.3 a	(11.5ab)	10.0	80.2	83.4
Atzimba X TS-15	48.4 bc	29.6 b	(38.9a)	26.5 b	(10.4ab)	10.4	80.0	83.8
MF-I X TS-15	46.4 d	28.3 b	(39.0a)	25.5 b	(9.8b)	10.5	79.8	82.7
MF-II X TS-15	47.1 cd	29.2 b	(38.0a)	27.9 ab	(4.5c)	9.2	78.4	81.8
Diamant	-	32.0 ab	-	27.7 ab	(13.3a)	-	80.4	87.8
Significance						NS[x]	NS	NS

[z] Different letters within columns show significant difference by Tukey's honestly significant difference test at 5% level.
[y] Values in parenthesis are percentage reduction of total tuber yield over generations.
[x] Non-significance

Table 7-5. Distribution of tuber grade (% by weight) of hybridized TPS progenies and 'Diamant' in their three subsequent generations

Progeny/cultivar	<28 mm			28-55 mm			>55 mm		
	F_1C_0 2001-02	F_1C_1 2002-03	F_1C_2 2003-04	F_1C_0 2001-02	F_1C_1 2002-03	F_1C_2 2003-04	F_1C_0 2001-02	F_1C_1 2002-03	F_1C_2 2003-04
BARI TPS 1	84.2	19.3	12.8	15.8	66.9	74.0	0	14.1	13.2
P-364 X TPS-67	83.8	17.5	11.7	16.2	68.5	75.5	0	14.0	12.8
Atzimba X TS-15	82.9	17.7	11.3	17.2	67.5	76.4	0	15.1	12.3
MF-I X TS-15	82.1	18.5	12.3	17.7	67.3	75.5	0	14.3	12.2
MF-II X TS-15	85.0	18.9	13.2	15.1	68.4	73.9	0	12.2	13.0
Diamant	-	16.6	10.4	-	70.3	78.1	-	13.2	11.5
Significance	NS[z]	NS	NS	NS	NS	NS	NS	NS	NS

[z] Non-significance

Figure 7-1. Field of experiment 7 for seedling tubers production derived from TPS

Figure 7-2. Field of experiment 7 for potato production derived from seedling tubers

Chapter 8
Storability of tubers derived from true potato seed (*Solanum tuberosum* l.) under ambient storage conditions

8.1 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 to 4 or 8 to10°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; Verma et al., 1974; Bornman and Hammes, 1977; Burton et al., 1992; Devendra et al., 1995). Under ambient conditions in Bangladesh, 20 to 80% of the tubers have been lost (Hashem, 1979). According to Leppack (1979), Sukuamaran (1983), and Ezekiel et al (2003), the monthly loss amounts to 10%, when tubers are stored in ambient conditions in warm countries. The spoilage may be up to 80% in natural storage (Ezekiel et al., 2002). 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 TPS for potato production has increased recently in Europe, North America, and Asia, especially in the developing countries (Devaux, 1984; Song, 1984; Wiersema, 1986a; Burton, 1989). In Bangladesh, this technology has been highly promising (Renia and Hest, 1998; Roy et al., 1999; Siddique and Rashid, 2000) and the TCRC of Bangladesh recommends a Three-Step Year Production Program for TPS utilization (Fig. 8-1). In this 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'.

8.2 Materials and Methods

In 2001 to 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 experimental plots of the TCRC, BARI, Gazipur ($23^0 41^/$ N latitude, $90^0 22^/$ 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).

8.3 Results and Discussion

8.3.1 Climatic conditions during storage

The temperature in the storage room increased gradually from March to May, and decreased slowly thereafter (Table 8-1). The average maximum and minimum temperatures during storage were 32.7 and 24.3°C, respectively. The relative humidity (RH) also increased gradually from March to September. The range of RH varied from 58.0 to 93.6%.

8.3.2 Effects of progeny and tuber size on storage characteristics

9.3.2.1 `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 8-2).

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 8-3). 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.

8.3.2.2 Dormant period

The dormant period of 'Diamant' was 56.1 days (Table 8-2). Singh et al (2002) showed a similar result, in which the dormant period of non-TPS Indian potato cultivars was 50 to 55 days. Bogucki and Nelson (1980) also investigated the dormant period of 10 American non-TPS potato cultivars and reported it to be 56 to 68 days. In our 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 (Leppack, 1979; Hossain et al., 1992).

8.3.2.3 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 8-2). These results also showed the superiority of TPS progenies for storage under ambient conditions.

For the 3 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 8-3) 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.

8.3.2.4 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 8-2). 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 8-3).

8.3.2.5 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 8-3), as Singh (1980); Khan et al (1984) reported for non-TPS potato cultivars.

8.3.2.6 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 8-2).

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 8-3). A similar trend of weight loss was also observed by Butchbaker et al (1973); Booth and Shah (1981); Khuong et al (1987).

8.3.3 Analysis of correlation coefficients

The correlation coefficients among different characters of storability were analyzed for all combinations (Table 8-4). 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 8-2); 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.

Generation 0	1st year Generation 1	2nd year Generation 2	3rd year Generation 3

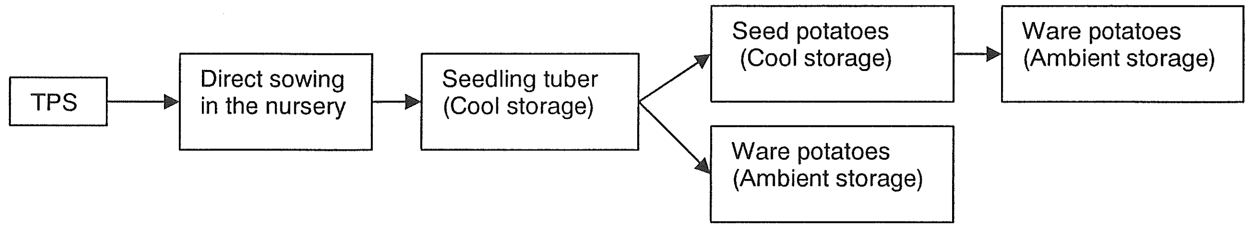

Figure 8-1. Three-Step Year Production Method of TPS utilization

Generation 1 is produced in the nursery, whereas generation 2 and 3 in the open field

Table 8-1. Average monthly temperature and relative humidity of the storage house in 2004

Month	Air temperature(°C)		Relative humidity (%)	
	Maximum	Minimum	Maximum	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 8-2. 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)	Dorman t 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	41.8 d	69.2 b	128.6 d	154.6 b	18.9 a	35.6 bc	60.6 b
TS-7 X TPS-13	47.9 b	73.9 ab	130.7 d	153.3 b	14.7 d	41.3 ab	63.4 a
TS-8 X TPS-67	43.8 cd	73.7 ab	122.9 e	156.4 b	17.7 b	38.1 ab	62.1 a
P-501 X TPS-67	45.9 bc	84.4 a	137.9 bc	160.8 b	13.5 e	42.9 a	60.7 b
TS-9 X TPS-67	51.4 a	84.0 a	132.9 cd	160.3 b	19.0 a	27.3 d	50.8 c
MF-I X TPS-67	53.2 a	85.2 a	139.9 b	158.8 b	14.3 d	42.6 a	60.6 b
P-364 X TPS-67	53.7 a	81.9 a	147.8 a	177.3 a	13.9 de	36.9 ab	57.1 bc
P-364 X TS-9	54.0 a	84.1 a	145.3 a	175.8 a	15.7 c	30.4 cd	50.1 c
BARI TPS 2	51.0 a	75.2 ab	122.4 e	152.8 b	19.1 a	36.6 ab	61.0 b
Diamant	44.3 cd	56.1 c	100.0 f	141.7 c	19.5 a	18.9 e	50.8 c

[z] Tubers were stored for 180 days.
Different letters within columns indicate a significant difference by Duncan's multiple range test at p=0.01

Table 8-3. 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 tubers (%)[y]	Weight loss of healthy tubers (%)[y]
Large (> 45 mm)	44.0 c	69.4 c	138.1 a	165.6 a	16.7 a	64.6 a	79.4 a
Medium (45-28 mm)	48.0 b	76.9 b	135.5 a	162.4 a	17.2 a	36.0 b	56.5 b
Small (28-20 mm)	54.6 a	91.1 a	128.0 b	155.2 b	14.8 b	10.7 c	39.4 c

[z] Tubers were stored for 180 days, [y] Values are the mean of the 9 progenies.
Different letters within columns indicate a significant difference by Duncan's multiple range test at p=0.01

Table 8-4. Correlation coefficients of different storage parameters of 9 hybrid TPS progenies

Parameter	Sprout initiation	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 100% shrinkage					-0.45	-0.65*
Apical sprout length						0.14

*,** Significant at p=0.05 and 0.01, respectively

Chapter 8
General Discussion

TPS technology is a radical alternative to seed tubers for raising commercial crop, and it appears promising in the warm tropics of the developing world, especially where lack of planting materials precludes the expansion of potato production (Ortiz, 1997).

Production of a large quantity of quality TPS at a low cost is of prime importance for the adoption of TPS technology on a commercial scale. Thus selection of parental genotypes that flower over a sufficient length of time and develop into berries with enough seeds is very important. Genotype, day length, and temperature are the main factors that determine flowering and fruiting in potato (Gopal and Ortiz, 2006). A number of other factors, such as inflorescence position (Almekinders and Wiersema, 1991), plant density (Almekinders, 1991), competition for nutrients between flower and tuber (Pallais, 1987), nutrient level (Bamberg and Hanneman, 1988; Otazu and Amoros, 1991), and date of planting (Banik, 2005), are also known to influence production of flowers and fruits in potato.

A number of methods have been suggested to improve flowering and berry setting in potato (Sadik, 1983; Gopal and Rana, 1988). Pallais (1986) produced as many as approximately 117 berries per plant in a potato crop where plants were not hilled, stolons were pruned, and vines were trained on a trellis system.

Potato flower bears a multiovular gynoecium, and an optimum pollen load is therefore necessary for maximum seed set. On average a berry has 150 to 270 seeds, though in certain genotypes fully grown berries may have up to 400 seeds (Upadhya et al., 1984; Sharma and Choudhury, 1985). With an increase in berry weight, the number of seeds increases. Significant variations have been reported in berry and seed characteristics for hybrid seed (Upadhya et al., 1984; Sharma and Choudhury, 1985; Pallais, 1986; Malagamba, 1988; Almekinders et al., 1995). In Chapters 3 and 4, same relationships were observed between berry and TPS characteristics. Hybrid TPS production depends mainly on the pollinating efficiency and the physiological and genetic makeup of the female and male parents (Gopal et al., 2004).

The quality of TPS is determined by genetic constitution of the parents, stage of seed development, nutritional status of mother plant, and biochemical components of the seed. In warm tropical locations, a high level of seed germination, fast emergence, and early vigorous growth of seedlings are required for commercial production (Malagamba, 1988). Seed vigor is a good indicator of the seed quality (McDaniel, 1973). Bold seeds are known to result in vigorous and high- yielding seedlings (Dayal et al., 1984).

Longer on-plant maturation of berries is known to produce more vigorous TPS (Pallais et al., 1989). The formation and growth of the seed are also strongly affected by environmental and climatic conditions such as temperature, water, light, and the kind and quantity of available nutrients (Delouche, 1980; Siddique and Goodwin, 1980; Gray and Thomas, 1982; Pet and Garretsen, 1983; Evenari,1984). Nutrient conditions in the mother plants directly affect the production of quality TPS. Combination of different levels of N and P affects flowering, berry setting, and TPS production (Upadhya et al., 1984). The effects of K are different from those of N and P. With high rate of K application (> 132.6 kg ha^{-1}), the TPS mother plant shows a negative response of TPS characteristics (Kanzikwera et al., 2000). Nitrogen application during and after pollinations is known to result in delayed plant senescence and increased TPS size and weight (Pallais, 1987). The techniques to improve TPS production have involved manipulation of the soil-plant environment. Periodic supplemental N application to the soil during seed development at higher rates than the recommended for tuber production enhanced flowering and delayed plant maturity, thereby prolonging the berry development period (CIP, 1985; Malagamba, 1988). Flower production was increased by more than three times when supplemental N rates up to a total of 240 kg ha^{-1} were applied at weekly intervals. Also, significant increases in weight per 100 seeds were obtained with supplemental applications of N (Pallais, 1986). Considering Chapter 3 and Chapter 4, the combination of 300 kg N, 120 kg P, and 125 kg K ha^{-1} was the most suitable dosages for the commercial production of hybrid TPS. Therefore, N rates greater than those required for tuber production enhance quality TPS production.

Studies by Pallais et al (1986) and Upadhya et al (1984) found a direct relationship between berry size and total weight of seeds produced per berry. A negative correlation between TPS number per berry and 100-TPS weight was more pronounced as berry size decreased (Pallais et al., 1986). Berry size was not correlated with 100-TPS weight, suggesting that seeds from all mature berries have similar sowing quality.

Quality TPS has a high level of germination, and will produce uniform, vigorous seedlings (Dickson, 1980). Uniform emergence and vigorous early growth are of major importance, particularly in warm environments. The genetic constitution of the seed, environmental, and fertilizer conditions acting on the seed before harvest affect performance in field establishment (Harrington, 1971; Siddique and Goodwin, 1980; Ross, 1980). Seed weight and size have been reported to influence uniformity and rate of germination in many crops. Dayal et al (1984) reported a positive correlation between TPS weight and tuber number and yield. At CIP, the amount and rate of germination of TPS of different weights were found to be similar, but plant size at transplanting was significantly larger for heavy seed than light seed (CIP, 1981).

The nutrient levels in TPS affect germination and subsequent seedling growth. Kanzikwera et al (2000) stated that the combination of N_{240} $K_{265.6}$ resulted in low germination rate and less seedling vigor compared with N_{240} $K_{132.8}$. Thus, the quality of TPS also varies significantly according to the different combinations of N and K fertilizers applied to the mother plants, mainly due to the different nutrient levels that are contained in the harvested TPS.

Wheat seeds containing high N germinate faster and develop into larger seedlings than those containing normal N (Lopez and Grabe, 1973). On the other hand, a negative correlation was found between K concentration and germination rate in primrose (*Primula vulgaris* H.) seed (Zerche, 2005).

The size of TPS also affects germination, CoV of germination, seedling growth, and vigor. Almekinders and Wiersema (1991) found that large TPS showed better germination and earlier emergence than small TPS. The results in Chapter 4 concluded that the combination of 300 kg N and 125 kg K ha^{-1} produced the maximum amount of large size TPS and showed better seedling performance in the following season (Table 5-4).

The success of TPS technology depends on the quantity and quality of TPS produced at relatively low cost. Therefore appropriate field practices should be established for the production of quality TPS. The production of high quality TPS is strongly influenced by the application of supplemental N along with basal dose (Pallais et al., 1987; Almekinders and Wiersema, 1991). Planting density (PD) also affects the production of TPS (Almekinders, 1991). Therefore, the best combination of supplemental N and PD, and their economic return must be considered for TPS production. The competition for nutrients between tubers and TPS suggests that N, through its influence on vegetative growth and tuberization, may be of special significance for TPS production (Pallais, 1987). When N is supplied continuously to the potato plant it causes a steady growth of shoots and roots and prevents tuberization; when N application was discontinued, tuberization begins within 2 days (Krauss, 1978). In Chapter 5, supplemental N application was conducted 7 times at 7 days intervals starting from 27 DAP and 2 to 4 haulms $tuber^{-1}$ were allowed to grow. In this Chapter, the combination of $N_{200}PD_{12}$ produced the maximum quantity of marketable TPS and this combination was also found to be more profitable than the other treatment combinations (Table 6-4).

Several alternative systems of using TPS have been developed for tropical areas with different agro economic conditions. A detailed description of the different TPS cultural systems and their applicability under various conditions was made by Monares (1983) and Chaudhury et al (1987). TPS can be used for producing potatoes either for immediate consumption or for seed tubers for planting the following season. Seedling tuber production appears to be the most feasible and economic method of using TPS in developing countries (Acatino and Malagamba, 1982; Sadik, 1983; Malagamba, 1984; Wiersema, 1986a). The high number of seedling tubers produced in each square meter of bed indicates this method is a good alternative to classical seed tuber production, especially in subsistence agricultural areas. Growing conditions in beds can be controlled ensure profuse tuber production and to control diseases, especially those caused by aphid-transmitted viruses. The number of subsequent field multiplications that can be made depends on rate of virus spread, which is usually high in warm areas.

High seedling tuber yields have been obtained from TPS crops in beds 15 to 20 cm raised nursery bed containing sand and peat moss, compost, or soils of high organic matter content (CIP, 1986; Wiersema, 1986). The maximum number of seed tubers per unit area of seedbed is obtained by sowing TPS in the nursery beds. Productivity can reach as high as 1,000 to 1,200 usable seedling tubers m^{-2} under optimal conditions, with a plant population of about 100 plants m^{-2} after thinning (CIP, 1985). In high density seed sowing, seedling tubers of different sizes ranging from 1 g to 30 g are produced in nursery beds. Research results indicate that, seedling tubers of > 1 g sizes are potentially high quality planting material and can be used effectively in seed potato production (Rashid et al., 1993; Anonymous, 1997). Seedling tubers derived from TPS produce higher or equivalent yield with that of standard potato varieties and can maintain better yield potential for at least 2 successive clonal generation of potato production without much reduction in yield (CIP, 1989; Pandey et al., 1990; Hossain et al., 1992; Hossain et al., 1994). In Chapter 7, some TPS progenies were evaluated for successive clonal tuber production. The findings demonstrated that TPS progenies generally maintain their potential yield at least in the second clonal generation (Table 6-4). Yield reduction of TPS progenies over clonal generation may be attributed to virus infection (Gerg, 1987). In this Chapter some TPS progenies showed significantly lower virus infection and yield reduction than 'Diamant' (Tables 7-2 and 7-4).

The purpose of potato storage is to maintain tubers in their most edible and salable condition and to provide a uniform flow of tubers to market. Good storage should prevent excessive loss of moisture, development of rots, and excessive sprout growth.

After harvest potato usually undergoes a rest period of several months during which there is little or no sprout growth regardless of environmental conditions. Following the termination of the rest period sprout growth occurs at temperatures of $4.4^{0}C$ or above (Smith, 1977).

Refrigerated storage remains the best option for the long–term storage of potato. For short-term storage (3-4 months), non-refrigerated, on-farm storage methods are cheap alternatives, particularly in developing countries. Diffused-light storage for seed potato and storage in simple piles or clamps for ware potato have been found to be effective methods in South America (Booth and Shah, 1981). In India, a non-refrigerated store run on passive evaporative cooling was suggested as an alternative storage method (Kaul and Sukumaran, 1984), but it was not adopted by the farmers of Bangladesh owing to its high initial cost compared with the benefits obtained. On-farm storage of potato in heaps and pits is common in some parts of India (Ezekiel et al., 2002).

In Bangladesh, due to high temperature and humidity, the tubers those are stored in ambient conditions, terminate dormancy, begin to sprout, shrink, and rot. In this situation, ultimately 20 to 80% tubers have been damaged (Hashem, 1979; Burton, 1992). In Chapter 8, all the TPS progenies used in this experiment showed a significantly longer dormant period than the non-TPS cultivar 'Diamant' (Table 8-2). Therefore we concluded that the storability of TPS progenies at the clonal generation is superior to that of non-TPS cultivar 'Diamant'.

9.1 Concluding remarks

The different experiments carried out at the Sher-e-Bangla Agricultural University and Tuber Crops Research Center, Bangladesh have revealed that the use of TPS technology seems to be more feasible for Bangladesh where the farm holdings are small and the farmers have scarce resources. On the other hand, most of the farmers are good gardeners and they are familiar with raising vegetables that are transplanted from nursery to the field. It is certainly that the outcome of this study will enable the use of TPS in urban home garden as a low cost alternative method of potato production. Moreover, TPS will also enable the cooperatives and government farms to produce large amount of potatoes.

A number of developing countries involved in TPS research have increased rapidly. This mainly due to high potential for application, great flexibility to suit different agro-economic condition and to recent progress in production of high quality TPS.

Therefore, talking into account the above experiences there is potential in the use of TPS technology to alleviate the increasing food shortage affecting low income people in Bangladesh.

Chapter 10
Summary

Potato production from true potato seed (TPS) is highly promising, and may put remarkable contribution to potato production for marginal farmers of developing countries. But the farmers often face serious problems for the utilization of TPS technology. On this aspect, some agronomic management practices and promotional activities of TPS technology were conducted during 1993 to 2003 to find out the appropriate method of utilization of TPS and to make TPS more attractive to the potato farmers. Thirty one hybrid TPS progenies were evaluated in nursery beds followed by normal planting in field. In nursery beds, among the 31 TPS progenies, the yields of seedling tubers were exceptionally high in P-364 X TPS-67 (73.4 t ha^{-1}). In the following year, the seedling tubers were planted in the field to observe their performance in second generation. Both in nursery bed and field, 3 progenies, TS-7 X TPS-67, MF-II X TPS-67, and P-364 X TPS-67 showed superior performance in respect of tuber uniformity, virus infection, and tuber yield.

An experiment was conducted in order to determine the optimum plant spacing of TPS to obtain the highest seedling tubers yield with maximum economic return. Four TPS progenies were sown at 4 different spacings. Among the TPS progenies and spacings, P-364 X TPS-67 and 25 x 4 cm produced the highest yields (73.8 and 71.9 t ha^{-1}, respectively). For all crop production operations, a plant spacing of 25 x 4 cm was found to be the most economic for the production of seedling tubers.

Ten TPS progenies were evaluated in 3 consecutive years. An average yields of the 10 TPS progenies, obtained in the first, second, and third generations were 65.9, 29.5, and 26.4 t ha^{-1}, respectively. Significant variations were observed among the progenies in respect of yield and other characters providing a basis for selection of superior progenies.

Field performance of 5 different TPS progenies were investigated in their 3 successive generations. The first year crops derived from the TPS were free from virus and bacterial wilt

and yielded 48.5 t ha^{-1}. In the second and third year, the yield decreased to 31.2 and 27.9 t ha^{-1}, respectively, while disease incidence increased. Total tuber yield of BARI TPS 1 and P-364 X TPS-67 in the second and third year were similar to the commercial cultivar 'Diamant' and significantly higher than other TPS progenies. Virus infection of MF-I X TS-15 and MF-II X TS-15 were significantly lower than 'Diamant', especially in the third year.

Storability of tubers obtained from 9 hybrid TPS progenies were compared with that of 'Diamant' under ambient conditions. Among the progenies, P-364 X TPS-67 and P-364 X TS-9 showed better storage performance than 'Diamant'.

Two hybrid TPS progenies, MF-II X TPS-67 and TS-7 X TPS-67, were evaluated at a farmer's field. Both progenies had good seedling tubers yield (about 50 t ha^{-1}) which produced 30 to 35 t ha^{-1} in the following year. Moreover, the use of these TPS progenies resulted in higher yield than that of seed potatoes.

Nutrient conditions in the potato mother plants directly affect the production of quality TPS. Therefore, experiments were conducted during 2004-2007 to examine the effects of combinations of different levels of nitrogen (N), phosphorus (P), and potassium (K) on yield and quality of TPS using crosses of ♀MF-II and ♂TPS-67. Four levels of each of N (0. 150, 225, and 300 kg ha^{-1}) and P (0, 60, 120, and 180 kg ha^{-1}) were applied to MF-II for obtaining better flowering, berry setting, and TPS production. Out of the 16 treatment combinations, the highest 100-TPS weight (84.1 mg) was obtained with 300 kg N and 120 kg P ha^{-1}, while the highest TPS yield (136.1 kg ha^{-1}) was obtained with 225 kg N and 120 kg P ha^{-1}. Considering the findings of the previous study, 2 levels of N (225 and 300 kg ha^{-1}) and a fixed value of P (120 kg ha^{-1}) were selected as promising for TPS production. Twelve combinations of 3 N (0, 225, and 300 kg ha^{-1}, respectively) and 4 K (0, 125, 175, and 225 kg ha^{-1}, respectively) levels were also applied to MF-II to investigate the effects of yield components of TPS. The weight of 100-TPS increased with increasing N rate but decreased with increasing K rate. The highest

100-TPS weight (83.8 mg) and maximum quantity (113.0 kg ha^{-1}) of quality (> 1.18 mm) TPS were obtained with the application of 300 kg N and 125 kg K ha^{-1}, while 225 kg N and 125 kg K ha^{-1} produced the highest TPS yield (145.3 kg ha^{-1}).

TPS that was produced from above mentioned 12 different fertilizer combinations were then used for nutritional analysis, germination tests *in vitro*, and growth performance in nursery beds. Large size TPS (>1.18 mm) produced from 300 kg N and 125 kg K ha^{-1} gave the highest emergence rate (94%), seedling vigor (4.8), and dry matter content (10.5%) of seedling in nursery beds. Considering the present results together with those of the previous studies, it can be concluded that the combination of 300 kg N, 120 kg P and 125 kg K ha^{-1} was the most suitable for the production of high quality TPS.

A field experiment was also carried out to evaluate the relative economic return as influenced by supplemental N (0-250 kg ha^{-1}) and planting density (8-16 haulms m^{-2}) in MF-II. Most parameters showed maximum values when 0 to 150 kg N ha^{-1} was applied, but the values decreased thereafter as supplemental N application increased. Although only the weight of 100-TPS showed a maximum value at 250 kg N ha^{-1}, the value was similar to that at 200 kg N ha^{-1}. A positive effect of higher planting density was detected only in the number of berries $plant^{-1}$ and yield of TPS. The combination effect of supplemental N and planting density on the yield of berries and TPS was significant. Although the total yield of TPS was the highest at the combination of 150 N kg ha^{-1} and 16 stems m^{-2}, the yield of high quality TPS, was the highest at the combination of 200 N kg ha^{-1} and 12 stems m^{-2}. The benefit cost ratio also showed that the combination of 200 kg supplemental N ha^{-1} and 12 stems m^{-2} was the optimal growth conditions to harvest high quality TPS. Therefore, in the commercial aspect, 200 kg N ha^{-1} of supplemental application in 7 separate installments at 7 day intervals starting from 27 DAP along with basal application (150-120-125-120-12-6 kg ha^{-1}, N-P-K-Gypsum-$ZnSO_4$-

Borax, and 10 t ha^{-1} farm yard manure) and 12 stems m^{-2} is the most suitable combination to produce high quality TPS from ♀MF-II X ♂TPS-67.

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