DEVELOPMENT OF HYBRID AND OPEN POLLINATED TRUE POTATO SEED IN NWFP.

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ABSTRACT

True Potato Seed were developed and compared with seed tubers of two commercial varieties in Malakand division of NWFP. The study comprised four experiments. In first experiment, reproductive biology of fourteen potato genotypes was studied. The results indicated highly significant (P= 0.01) variation among the potato genotypes for all the characters under investigation. Data ranged from 53.0 to 81.7 days to flowering, 84.2 to 107.0 days to flower completion, 12.2 to 41.2 days for flowering duration, 17.75 to 43.0% pollen viability, 26.7 to 75.5 flowers plant^{-1}, 4.5 to 25.8 berries plant^{-1} and 16.8 to 43.5% fruit set. Berry diameter, average berry weight, number of seeds berry^{-1} and 100 seed weight ranged from 1.5 to 2.3cm, 3.1 to 4.8, 88 to 355 and 66.9 to 97.7mg, respectively. True potato seed yield ranged from 0.2 to 4.2 g plant^{-1}. Five hybrid TPS viz., SH 103 x 9743, SH 176 x 396239-76, SH 53 x 396258/24-22, SH 5 x 9813 and 9805 x SH 9 were developed. In experiment 2, F_1C_1 seedling tubers were produced and open pollinated and hybrid TPS, were compared. Significant differences were observed for all the characters studied. Data ranged 64.5 to 84.5% for germination, 5.5 to 7.5 for seedling vigor, 45.0 to 62.25cm for plant height, 112.5 to 129 days for days to harvest, 589 to 209 for number of seedling tubers m^2, 7.93 to 3.8 kg m^2 for seedling tuber yield m^2. Hybrids showed maximum vigor, seedling tubers m^2 and seedling tuber yield m^2 in comparison to OP. In experiment 3, the F_1C_1 seedling tubers produced from TPS genotypes in experiment 2 were evaluated for yield and yield components. Significant differences were recorded among F_1C_1 TPS progenies for all the characters, except percent germination. 80% ground cover ranged from 40 to 50.5 days. Statistically lower diseases were observed on TPS progenies. Days to harvest ranged from 116 to 122 days. Main stems plant^{-1} ranged from 2.9 to 1.8. Number of tuber plant^{-1} ranged from 6.0 to 13.2. Average tuber weight ranged from 48.0 to 85.3g. Tuber yield ha^{-1} was 26.6 to 11.3 tons. As a group, hybrids had maximum mainstems plant^{-1}, tuber plant^{-1}, average tuber weight and yield ha^{-1}. In experiment 4, F_1C_1 seedling tuber progenies were compared with seed tubers of two commercial varieties at three different locations. Locations were significantly different for percent germination, disease incidence, days to harvest, tubers plant^{-1}, average tuber weight and yield ha^{-1}, whereas plant height was non significant. Among location, Kalam was best for germination, average tuber weight and tuber yield per ha^{-1} while, Pallai surpassed for diseases and tubers plant^{-1}, whereas, Mingora was best for days to harvest. Among genotypes, significant variations were observed for all the characters studied. Among genotypes maximum germination, plant height, tubers plant^{-1}, average tuber weight and yield ha^{-1} were recorded in #9805, 9805xSH9, SH 5 x 9813 and SH 176 x 396239-76, respectively. Whereas, minimum disease incidence and days to harvest were recorded in 9805 and SH5, respectively. Genotype x location interaction revealed significant differences for percent germination, disease incidence, days to harvest, number of tubers plant^{-1}, whereas non-significant differences were observed for plant height. As a seed source, hybrid TPS were found better than OP and seed tubers for various economical traits, whereas, OP and seed tubers were at par.

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List of Abbreviations

%	Percent
Asl	Above sea level
ARS	Agriculture Research Station
ARSS	Agriculture Research Substation
°C	Degree Celsius
CIP	International Potato Center Lima, Peru
cm	Centimeter
Cv	Cultivar
DAP	Di-ammonium phosphate
g	Gram
GA_3	Gibberellin
F_1C_1	First clonal generation
ha^{-1}	Per hectare
kg	Kilogram
LSD	Least significant difference
mg	Milligram
MINFAL	Ministry for Food Agriculture and Livestock
NARC	National Agriculture Research Center
NWFP	North West Frontier Province
OP	Open pollinated
SOP	Sulfate of Potash
TPS	True Potato Seed

CHAPTER 1

INTRODUCTION

Introduction

The potato plant belongs to Family *Solanacea*, genus *Solanum* and Section *petota*. There are about 200 wild and eight cultivated species in the section petota, with a ploidy level ranging from diploid (2n = 2x = 24) to hexaploid (2n = 2x = 72). Most potato species originated in South and Central America, however, only the tetraploid *Solanum tuberosum*, subspecies *tuberosum* is grown worldwide for potato crop production. The potato is so adaptable that it grows from below sea level behind Dutch dikes to almost 4,500 meter up in the chilly Andes and Himalayas, from the Arctic Circle to Strait of Magellan, and in the scorching heat of Australia and Africa. Through the efforts of breeders and agronomists, the potatoes are now being grown in more than 180 countries under a variety of climates and cultivation techniques. Nevertheless, in general, potatoes are best adapted to the cool temperate zones of the high altitudes of Andes (2000 to 3500 m), at sea level in temperate region of North America, Europe, Southern Chile and Argentina and at appropriate altitudes in intermediate latitudes.

Potato is a highly productive and nutritious crop, being fourth after wheat, corn and rice in world production, and because of short growing season, it yields more energy and proteins per unit area as compared to these crops. The harvest index of potato is 75-85% of total dry matter in tubers and it yields quick nutritious food even under unfavorable climatic conditions. The potato contains high quality protein and substantial amounts of vitamins B, C, and iron, but no fats.

In Pakistan, the combination of climate and irrigation facilities allows three crops in a year; spring, summer and autumn. Autumn and spring crops are planted in plains and the summer crop is planted in the high hill valleys. During 2000-2001, potatoes were planted on nearly 0.1052 million hectares with a total production of about 1.72 million tons and an average yield of 16.9 tones ha $^{-1}$. During the same year in the North West Frontier Province (NWFP), potatoes were planted on about 0.0094 million hectare which produced nearly 0.11 million tons, with an average yield of 12.3 tons ha.$^{-1}$ which were 25% lower than the national average (MINFAL, 2002). In NWFP, the low potato productivity is often associated with the non-availability of quality seed to the small farmers for sowing.

Seed is the most important and costly input in potato crop production, accounting upto 60% of the total production cost. Potatoes can be multiplied both vegetatively (i.e., from seed tubers or plant tissue culture techniques) and sexually from True Potato Seed (TPS). However in most countries commercial potato crops are vegetatively produced from seed tubers. To grow one hectare of land depending on the size, 2-3 tons of seed tubers are required, which represent food that is being buried in the field instead of human consumption. In NWFP, to grow 9400 hectare of land, about 23500 tons seed potatoes are buried back in the field to grow next season crop. Seed tubers are an expensive planting material, often imported from developed countries and are the main carriers of different insect/pest and diseases. Seed tubers are perishable and bulky and are difficult to transport to remote areas for cultivation. Mostly, seed tubers require costly refrigerated storage facilities to keep them in desirable physiological condition until the next planting season.

Sexual potato production by TPS is relatively a new technological alternative that offers farmers an option to overcome the perceived weaknesses of clonally propagated seed tubers as a source of planting material. Most degenerative plant viruses are not transmitted through true seed. As compared to seed tubers, TPS is also a low cost planting material that can reduce the production cost of potatoes. To plant one hectare of potatoes, farmers need only 100 grams of TPS compared to 2-3 tons of seed tubers. TPS can also be stored conveniently and inexpensively by farmers from one planting season to another or for several years. Moreover, TPS is also easy and economical to transport to remote production areas (CIP, 1983).

TPS can be obtained either through "Open" or "Controlled" pollination. In open pollination, plants are left in the field to set fruits naturally. In such cases, most of the seed will result from self pollination. In genotypes with shorter style than the anther cone, self pollination is about 100%, while in other genotypes it is about 50 to 60%. The remaining 40 to 50% caused by out crossing is mainly through insects. The resultant seed is called "open pollinated (OP) seed as only the female parent is known. Without taking any special measures, the OP seed of some genotypes can be produced in large amount under normal field conditions at higher altitudes in cool summer seasons. In controlled pollination, artificial crosses are made on known parental lines, and the resulting TPS is called "hybrid" TPS. In both cases, superior TPS progenies, developed mostly from the local cultivars, are selected for desirable traits including tuber yield from seedlings as well as from the subsequent tuber generations.

Potato crop can be grown either by transplanting TPS seedling directly into the field or planting mini seedling tubers produced from TPS seedlings. In transplantation method, seedlings are first raised on a nursery bed and then transplanted to the field at a certain stage just like tomatoes or other vegetables. In the later method, F_1C_1 seedling tubers (the first clonal generation tubers) are produced in a nursery bed, which are then used as seed tubers to grow a commercial crop. This method also combines the advantages of TPS with those of planting seed tubers.

In several Asian countries like China, India, Bangladesh, Indonesia and Sri Lanka, research has provided enough evidence to adapt TPS technology as an alternative to the costly seed tubers, especially for poor farmers with cheap labor and small farm holdings. In Pakistan too, TPS can be developed as a seed source for potato crop production, which will increase net farm income particularly for resource-poor farmers of NWFP where farm size is mostly small. Keeping in view these facts, the present study was under taken to investigate the production, utilization and prospects of TPS as a seed source for potato crop production in NWFP.

OBJECTIVES

1). To study the Reproductive biology of different potato genotypes and to produce hybrid and OP TPS.

2). To identify superior TPS genotypes (including Hybrids and OP's) for commercial seedling tuber production (F_1C_1 generation).

3). Evaluation of selected F_1C_1 seedling tuber genotypes for crop yield and its components.

4). Yield multi-location comparisons of the most desirable F_1C_1 generation genotypes against seed tubers of commercial varieties across different agro-ecological conditions of NWFP.

5). The overall objective of this study is to develop and introduce most suitable TPS as a seed source for potato crop production in NWFP.

CHAPTER 2

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Botanical or TPS were used thousands of years ago by the Incas of Central America to renew their seed stock and improve production. Modern scientists discovered it less than 30 years ago and during the last two decades, extensive studies conducted worldwide on its use for potato crop production has brought the fact that it reduced the production cost and increased net profit to the farmer. Currently more than 30 countries are using TPS. In China and India it is seen as a solution to the serious difficulty of acquiring seed tubers of certified quality, and to deal with the growing demand of planting material.

Salomon et al. (2002) studied 15 TPS hybrid progenies procured from CIP. Seeds were put in beds on a compacted red ferralitic soil. Progeny behavior in presence of *Altemaria solani* and *Phytophthora infestans* fungi was evaluated 65 days after seedling. The experiment was harvested 100 days after seedling. Tuber number/m^2 and yield (Kg/m^2), skin color, shape and uniformity were evaluated. They selected five hybrid progenies, i.e., HPS 1/13, Serrana x IS-5, MFI x XY-13, Serrana x XY-13 and TS-6 x IPS-67 for their nice tuber yield per m^2 and appropriate performance in presence of fungi and a good tuber quality.

Castillo et al. (2001) studied the intraspecific variability among six crosses of potato i.e., 3 cultivars (Desiree. Atlantic and Kondor) crossed with 4 clones (CIP-23, CIP-110, CIP-114 and CIP-115) under green house condition. They used two isoenzyme electrophoresis analysis, i.e. Esterase and Peroxidase systems to evaluate the similarity among bands in leaf samples from parents and crosses. The two analysis methods showed different results. Electrophonesis peroxidase diagrams determined a higher number of hybrid off springs in Desiree x CIP-23, Desiree x CIP-110 and Desiree x CIP-115, with 4 different progenies. Esterase electrophoretic diagrams on the other hand determined a larger number of hybrid of off springs in the most variable crosses i.e., Desiree x CIP 23 and Desiree x CIP-115, with 8 and 7 new genotypes, respectively. The greatest variability was observed in each cross than among crosses. Considering the results of the 2 isoenzyme electrophoretic systems., the greatest variability was found in Desiree x CIP-23. Desiree x CIP-15 and Desiree x CIP-110.

Gopal et al. (2001) evaluated 31 early bulking tuberosum accessions as females and 8 accessions as males for their suitability in TPS production at Central Potato Research Station, Kufri (HP), India. On the basis of %pollination success, number of seeds per berry, number of seeds per flower pollinated, average berry weight and 100 seed weight, they identified 6 female parents and 3 male parents suitable for utilization in TPS program.

Patel et al. (2000) planted male and female parents of two hybrid TPS populations on six different dates in a field experiment conducted in Deesa, Gujarat, India, during two rabi seasons. They recorded data on flowering duration of female parent (number of days), total number of branches plant^{-1}, % berry setting, berry weight plot^{-1}, number of seeds berry^{-1}, and TPS plot^{-1} (g) were recorded. They reported 50% flowering in the second week of December, when the average minimum and maximum values for temperature were below 10 and 30°C and for relative humidity were below 25 and 75%, respectively. The period between 25 October and 15 November was observed to be the optimum for flowering of the TPS parents. With the exceptions of branches plant^{-1} and % berry setting, there were significant differences for the characters studied between the 2 female parental lines, viz. MF-1 and JTH/C-107, and between the different planting dates. The optimum date for planting TPS parents for maximum production of berries and seeds was 15 November.

Salahuddin (2000) reported the release of potato varieties from different sources in Bangladesh including, introductions, locally grown germplasm and TPS progenies. He reported that thirty varieties released so far included, 25 from exotic cultivars, 3 from native germplasm and 2 from hybrid TPS progenies. He also reported that 6 superior genotypes selected from germplasm and 3 exotic cultivars are awaiting approval of the National Seed Board (NSB) for release. Moreover, 25 promising genotypes and 3 hybrid TPS progenies are also in the pipeline for approval.

Sharma (1999) assessed 59 TPS populations to get information on the magnitude of genetic variability, estimates of heritability and genetic advance for tuber yield and its components. He found that variability of tuber yield and its component characters appeared mainly due to genotypic differences, however, stems plant^{-1} and tuber yield plant^{-1} were considerably influenced by the environment. The broad sense heritability and genetic advance as a percentage of means were high for fresh foliage weight plant^{-1}, tubers plant^{-1} and main stem height plant^{-1}. Genetic variability was low for dry matter and harvest index, however, heritability in broad sense was high for these characters. Among the hybrid TPS populations or families, Kufri Lauvkar x Q-63, K-2500 x Kufri Jyoti, Kufri Lalima x Kufri Jyoti and JL-2520 x Kufri Jyoti were high tuber yielder with high performance for other yield contributing characters.

Arevalo-Miranda (1999) reported that many sanitary problems are transmitted through seed tuber due to the scarcity of certified seed in Colombia. He evaluated the TPS of varieties Parda Pastusa and ICA Narino (*Solanum tuberosum* subsp. *andigena*), for yield and the quality of its clones in comparison with farmer's tuber seed. TPS was obtained from ripe fruits and clones were compared by a t-test in the preliminary comparison. He observed that TPS was superior as compared to farmers' seed. He found that variety Parda Pastusa TPS yielded 3.51 kg plant^{-1}, significantly higher (1% probability) than farmers' seed with 1.85 kg plant^{-1}. For ICA Narino, yields were 3.34 and 1.14 kg plant^{-1} for TPS and the farmer's seed, respectively. The highest quantity of tubers plant^{-1} was 53 tubers with ICA Narino TPS and the maximum average tuber weight was 137.81 and 110.0 g with Parda Pastusa TPS and basic seed, respectively. ICA Narino farmers' seed tested positive for the viruses PVY and PVS, with 20% of potato yellow vein virus and 60% misshapen tubers.

Madalageri (1999) evaluated seven TPS (hybrid and OP) populations as seedling transplants with two seed tuber-planted commercial varieties (Kufri Chandramukhi and Kufri Badshah) under rainfed conditions during kharif seasons in 1992 and 1993. He reported that raising a potato crop by growing TPS genotypes JEX/C-166 and HPS-7/67 was more economical, with high net production values of 4.7 and 4.1, respectively, than the tuber-planted commercial varieties due to the considerably low input cost of seed/planting material.

Chilver et al. (1999) assessed on-farm profitability of TPS-related technologies in several agro-ecologies in Egypt, India, Indonesia, and Peru, based on results of on-farm research conducted in the mid-1990s. Of nine generalized locations, TPS was substantially more profitable than clonal propagation at three locations and marginally more profitable at one location. TPS seedling tubers gave heavy yields, but the productivity level of clonally propagated materials greatly exceeded expectations. The lowest average yield of conventional tuber seed was 12 tons ha^{-1}. They proposed that TPS technologies are reasonably good when the cost of planting material in the conventional system exceeds 22% of the value of production.

Golmirzaie et al. (1998) studied the effect of inbreeding and open pollination in TPS. They used ten *Solanum tuberosum* subsp. *andigena* clones as parental material to derive hybrid (S_0), inbred (S_1 and S_2), and open-pollinated (OP_1 and OP_2) generations. Significant differences among generations were found for pollen production, pollen viability (as determined by its stainability with acetocarmine glycerol), number of flowers and berries $plant^{-1}$, number of seeds $berry^{-1}$, 1000 seed weight, and tuber yield $plant^{-1}$. The parental populations were significantly different for most of the traits, but not for flower production and berry weight. The interaction of population x generation was significant for pollen and seed production as well as for 1000 seed weight. All the traits evaluated except seed weight showed a strong inbreeding depression, while the OP progenies had intermediate values between the S0 and the S1. They reported that open pollination in potatoes is not exclusively the product of selfing; it also results from out-crossing.

Khan (1998) reported that potato cultivation based on TPS technology was successful in mid hill conditions of Uttar Pradesh. He observed that TPS families namely HPS 1/13, HPS 7/13 and HPSI/III can be commercially cultivated in the mid hill region of Pithoragarh. He recorded the highest yield of seedling tubers for HPS 1/3 (4.25 kg/m^2), followed by HPS I/III (3.970 kg/m^2) and HPS 7/13 (3.650 kg/m^2). He also reported that yield of TPS families from seedling tubers in the first and second clonal generations was statistically superior than Kufri Jyoti. Seedling tubers can also be used as seed tubers for at least two years for commercial production.

Lama et al. (1998) conducted on-farm studies to compare potato production from TPS technology and conventional seed tubers. They reported that mean tuber production was about 3 times higher with TPS technology as compared to seed tubers.

Abera (1997) evaluated eight CIP potato genotypes for flowering, fruiting and tuber yield during the main and off seasons of 1995-96, at Bako. He reported that all genotypes flowered but only four produced berries in the main season while all except CIP 382173.12 flowered and fruited in the off season. Seeds were stored for two months and sown in December. Although CIP 383032.15 and CIP 381376.15 had the strongest seedling emergence, the vegetative growth of all genotypes was promising. Three and a half months after transplantation, tubers were harvested and best performance for yield was shown by CIP 787894.2. However, tuber uniformity (size, shape and color) was better in CIP 381376.15. He indicated that TPS genotypes could produce yields comparable to seed tuber genotypes.

Carputo et al. (1997) evaluated hybrid families from different groups of crosses involving 4X clones, 2X *Solanum phureja-tuberosum* haploid hybrids, 2X *S. tuberosum* haploid *S. chacoense* hybrids as well as OP families in Brusciano and Camigliatello Silano, S. Italy, for TPS production. TPS families were grown both by transplanting seedlings to the field (transplants), and by planting tubers derived from seedlings grown in the screen house (seedling tubers). The results obtained in both locations indicated that families from seedling tubers had higher total and marketable yield than families from transplants. The hybrid families always produced higher tuber yield than OP families. In particular, families from 4X x 2X crosses were the highest yielding, and also had the best uniformity.

Love et al. (1997) compared nine commercially available TPS hybrids at Aberdeen Research and Extension Center during 1992-93. They planted TPS hybrids using second vegetative generation tubers derived originally from botanical seed. Ten plants from each plot were individually evaluated for plant height, vine maturity, early blight (*Alternaria solani*) symptoms, and verticillium wilt (*Verticillium dahliae*) symptoms. Following harvest, yield was determined and the tubers were rated or measured for appearance, shape, specific gravity, and French fry color. TPS hybrids had significant mean values for all tuber and foliar traits, except plant height, that were not significantly different from those of one or more of the cultivars; generally, values for the hybrids fell amid those of the cultivars. Two of the hybrids were taller on average than any of the 4 cultivars. They reported that for many market uses, the TPS hybrids appeared to possess the tuber yield and quality characteristics needed to compete with standard clonally propagated cultivars.

Singh et al. (1997) tested sixteen hybrid TPS progenies with one local OP progeny and seed tubers of cv. Kufri Jyoti during the summer season (April-August) of 1991 and 1992 to select suitable TPS progenies for the North-East hilly region of India. TPS progenies JTH/C 107 x OP-2, QB/A-9-120 x PH/F 1545, JTH/C 107 x OP-4 and JR-465 x CP-2289 gave 19.5 19.0 8.8 and 5.1% higher tuber yields, respectively, than Kufri Jyoti. Seed tubers of Kufri Jyoti gave significantly higher yields of large size tubers whereas medium size tuber production was significantly higher with good yielding TPS progenies. Percentage of bacterial wilt/field rot (*Pseudomonas solanacearum*) and late blight (*Phytophthora infestans*) incidence in crops raised through TPS progenies was conspicuously lower than in the crops raised through seed tubers. Late blight disease build-up in the TPS progenies was far lower than in the tuber crop of Kufri Jyoti. TPS progeny tubers showed a short dormancy period during storage, but higher weight loss and rot was recorded in standard cultivar tubers.

Subrata and Upadhaya (1997) evaluated TPS families, TPS-2 (OP), TPS-1/13, TPS-1/67, TPS-7/13 and TPS-7/67 for seedling tuber production, and for ware potato production from the seedling tubers, at three sites in West Bengal (Hooghly, 24 Parganas (N) and Nadia). They reported the average seedling tuber yield in a range of 3.39 to 3.86 kg/m^2 with TPS 7/13 giving the highest yield of 4.98 kg/m^2 at location, Hooghly. The mean ware potato yield from the seedling tubers was highest from TPS-1/13, which gave a yield of 36.7 tons ha^{-1}, reaching 41.2 tons ha^{-1} at Hooghly. Ware tuber yields from planting seed tuber cv. Kufri Jyoti and Kufri Badshah were lower (average yield 27.9 tons ha^{-1}) with the highest yield of 30.9 tons. They reported that the cost of using TPS was lower than seed tubers.

Kadian et al. (1996)) compared seedling tuber production from TPS in spring and autumn seasons. They reported a good seedling performance in autumn than in spring with average yields of 4.74 to 5.89 kg/m^2 and 2.34 to 2.61 kg/m^2, respectively. Numbers of seed tubers produced followed the same trend. In spring, a higher proportion of stolons were converted into aerial stems, reducing yields. Production of seed tubers in both spring and autumn reduced the area required to produce seed tubers for 1 ha. (from 178 to 264 m^2 to 121 to 161 m^2. Total and marketable yield (>35 mm size) of all families except cv. HPS-

II/13 from seedling tubers produced in the autumn and spring seasons were equivalent.

Almekinders et al. (1996) reviewed TPS technology for potato tuber production, TPS breeding and production. They reported that TPS competes successfully with clonal cultivars in Egypt and India. In other developing countries higher yields and better adaptation are needed to make the TPS technology economically attractive. In developed countries, well-organized seed tuber programs, productivity and legislative restrictions are difficult to be surpassed by TPS, however, the use of TPS can be economically attractive where disease pressure is high. They concluded that TPS has a place within potato systems where agroe-cological conditions for seed tuber systems and steady supply of good quality tubers from a formal seed program are most constrained. They reported that further genetic improvement would increase the area under TPS as it provides better and cheaper planting material.

Carputo et al. (1996) studied the effect of varying plant density (35, 70 or 100 plants/m2) on the production of tubers from potato seedlings. They found that increasing plant density significantly increased the number of tubers produced, however, there was no significant difference between the plant densities of 70 and 100 plants/m^2. They tested different sized seedling tubers produced in the nursery beds for commercial crop production in the field and observed best performance for the seedling tubers of 30 to 40 mm sizes. They also significant differences among the seven TPS families for tuber yield.

El-Amin et al. (1996) reported that three TPS crosses raised in a seedbed (soil mixture of clay, sand and dry leaves) produced about 3.1 kg of seedling tubers m^2 in the growing season of 1988/89 and between 4.3 and 5.1 kg m^2 in 1989/90. The seedling tubers produced were stored and their use as seed tubers was subsequently compared with the locally popular cv. Alpha. The mean tuber yield of hybrids ranged between 9.4 and 11 tons ha^{-1} in 1990/91 and between

21.9 and 22.9 tons ha^{-1} in 1991/92. Mean tuber yields of cv. Alpha were 14.3 tons ha^{-1} in 1990/91 and 24.1 tons ha^{-1} in 1991/92, showing that tuber yields comparable to those of imported seed tubers could be obtained from seedling tubers of TPS origin.

Verma and Singh (1996) evaluated seven TPS progenies at Faizabad, India, in 1991-92 and 1992-93. They reported that HPS 7/67 produced the highest number of minitubers (389/m2) followed by 83P47 x TPS/B-57 (332/m^2) with maximum minituber yields of 32.59 and 31.01 tons ha^{-1}., respectively. They observed that the production cost of mini-tubers ranged from Rs. 1559 ton^{-1} for HPS 7/67 to Rs. 1909 ton^{-1} for the lowest yielding progenies.

Alacho et al. (1995) presented data from field studies in Uganda on tuber production from TPS using both transplants and seedling tubers. Mean tuber yields from transplants (from 3 progenies) was 26.8 tons ha^{-1} in 1992/93 and 21.7 tons ha^{-1} (from 12 progenies) in 1993/94 compared with 20.5 tons ha^{-1} from clonal seed tubers. TPS raised in nursery beds of 3 m^2 produced many seedling tubers, averaging 224 and 119/m^2 in 1992/93 and 250/m^2 in 1994, with mean tuber weights of 20, 27 and 23 g, respectively. Studies on the degeneration of seed tubers derived from TPS showed that there was no consistent decline in tuber yields as the number of generations increased. They observed that tuber yields from TPS in the third and fourth generations were similar to those of the first generation. Extensive on-farm trials in the mid and low altitudes showed that seed tubers derived from TPS had mean yields of 24.6 tons ha^{-1} compared with 26.2 tons ha^{-1} from established cultivars.

Berga et al. (1995) reviewed research on TPS in Ethiopia. They reported that the use of TPS for commercial potato crop production can be an effective alternative to the seed tubers.

Carputo and. Frusciante (1995) compared the effect of planting method on tuber yield of hybrid families from 4X x 4X and 4X x 2X crosses. Results obtained in two years indicated that families from seedling tubers had a significantly higher tuber yield than families from transplants and reported that it could be the result of better early vigor of plants grown from seedling tubers. The 4X x 2X families as a group always performed better than the 4X x 4X group in terms of mean tuber yield, confirming the benefits of heterozygosity on tuber yield itself.

El-Bedewy et al. (1995) reported research on potato production from TPS, including screening of several TPS progenies, seedling tuber production with promising progenies at different locations and performance of seedling tubers. They reported that tuber yields from TPS progenies Serrana x DTO-28 and Serrana x LT-7 at 2 sites during 1990-92 was in the range 23.7-32.3 tons ha^{-1} compared with 23.2-31.5 t from 5 cultivars (seed tubers) from Europe.

Elias et al. (1995) investigated genotype x environment interaction for tuber yield of 12 TPS progenies along with a control cultivar, Diamant, at 4 locations. Their results showed that the genotypes interacted significantly with the environments. Eight progenies out yielded overall mean. Of these, Serrana x DTO-33 and HPS-1/13 were stable, HPS-7/13, HPS-2/67 and HPS-25/67 performed well in better environments, while HPS-2/13 and Diamant were adapted to poor environments.

Sangar (1995) evaluated 14 TPS progenies on the basis of survival of transplanted seedlings and their yield. Of these, 9 progenies were found promising. He reported the highest yield for hybrid HPS-2/III (26.65 tons ha^{-1}), TPS-2 (20.12 tons ha^{-1}) and HPS-II/13 (25.36 tons ha^{-1}) during 1985-86, 1986-87 and 1987-88 seasons, respectively. Average yield of all TPS progenies was higher than the average potato yield in India (16 tons ha^{-1}) and Madhya Pradesh (11 tons ha^{-1}). He also observed a yield variation among all of the TPS progenies. Tuber yields obtained were higher from the hybrid TPS families than OP ones.

Sathiyamoorthy and Nakamura (1995) studied the effect of potassium nitrate (KNO_3), potassium dihydrogen phosphate (KH_2PO_4) or gibberellins (GA_3 and GA_4) to eliminate dormancy in freshly harvested seeds and enhance the emergence performance of aged seeds. Both GA_3 and GA_4 eliminated seed dormancy in fresh seeds when applied in emergence media. Priming with gibberellins did not overcome dormancy in fresh seeds, whereas in aged seeds the emergence percentage was increased by 16-26% over control. Presoaking for 24 or 48 h in GA_3 (1000 ppm) enhanced emergence in fresh and aged seeds, but in fresh seeds the mean emergence time was not reduced. Seeds soaked for 4 days either in 1.0% KNO_3 or 2.0% KH_2PO_4 or 1.0% KNO_3 plus 1.0% KH_2PO_4 and dried back for 2 days eliminated dormancy and reduced the mean emergence time in both fresh and aged seeds more effectively than the seeds primed for 24 or 48 h.

Souibgui et al. (1995) reported data of field studies conducted in 1988-93 in Tunisia evaluating seedling tuber production from TPS hybrids and OP progenies, and tuber production from seedling tubers. Their studies indicated that potato production from TPS is technically feasible in Tunisia.

Swamy and Krishnappa (1995) in a field trial at Bangalore, Karnataka, compared potato cv. Kufri Jyoti tubers and 9 TPS genotypes. The highest A and B grade yield and total tuber yields, leaf area and LAI were obtained from TPS genotype HPS-1/13.

Abeytunge (1992) studied flowering and berry production of 583 potato lines derived from several crosses under field conditions at Sita Eliya, Sri Lanka, during 1984-86, to select suitable OP lines for TPS production. From studies conducted over 4 seasons, 4 promising lines 27/40, 12/34, 16/17 and 260/39 were identified. He reported a seasonal difference for flowering and fruit production among the lines. A high degree of flowering and berry production was observed during the yala (spring) season. A planting date experiment conducted with 8 selected OP lines showed that plantings during mid-February were the best for maximum berry production. TPS quality studies involving 19 lines showed a positive correlation between mean berry weight and seed number/berry and a negative correlation between number of seed berry^{-1} and 100-TPS weight.

Dabas et al. (1994) reported seedling tuber yields of 5.1 and 4.8 kg/m^2 from TPS of HPS 1/13 and HPS 1/67, respectively, during 1990-91, and 6.2 and 4.7 kg/m^2 from HPS 1/13 and C-3, respectively, during 1991-92. The average number of seedling tubers per kg for these cultivars was 104 and 96 during 1990-91 and 141 and 136 during 1991-92, respectively. The main crop yields were 34.4 and 30.9 tons ha^{-1} during 1990-91 for HPS 1/13 and HPS 1/67, respectively, which were 36 and 26% higher than those obtained with the traditional method of using seed tubers of cv. Kufri Bahar.

Hossain and Mondal (1994) conducted field trial on a silt loam soil to evaluate seedling tubers of TPS progenies, Atzimba x R-128.6, Atzimba x DTO-28, Serrana x DTO-28, Serrana x DTO-33, with cv. Cardinal as a check. The Atzimba progenies had similar yields to Cardinal, which were significantly higher than those of the Serrana progenies.

Hossain and Rashid (1994) used different seedbed media for TPS progeny Atzimba x R-1286. Their study indicated that emergence was best (99.3%) and seedling height (11.27 cm), number of leaves and fresh weight of seedlings greatest in the 1:1:1 soil, sand and cow dung mixture.

Sangar (1994) compared seedling tubers of seven TPS hybrids with potato cv. Kufri Badshah as a check. Percentage survival and average tuber yield of all TPS hybrids were not significantly different from the local check. However, the tuber yield of sex hybrids was between 2 and 9 tons ha^{-1} greater than that of Kufri Badshah. Hybrid TPS-C 3 produced the highest tuber yield of 29.19 tons followed by HPS-II/III (27.35 tons). He reported that the hybrids produced a larger percentage of small tubers (<30 g).

Khurana and Bhatia (1994) compared seven TPS families for seedling tuber production in nursery beds. Five sizes of seedling tubers, between 3 and 40 g in weight, from these nursery beds, were sown in the field at a range of spacings. In 1989-90, 30-70g seed tubers of cv. Badshah, and in 1990-91, of cv. Kufri Bahar were also planted. Tubers produced from all the TPS families were marketable. Marketable tuber yield increased with increase in seedling tuber size. They concluded that with the use of seedling tubers from TPS families, seed tuber planting rate may be reduced by >50% without loss in the yield.

Sangar and Upadhya (1994) reported that percentage survival and average yield of seedling tubers (F_1C_1) of 5 TPS families were similar to the commercial cv. Kufri Chandramukhi. However, hybrid HPS7/13 gave the highest yield and produced the most seed-size tubers (below 50 g). The tubers of this hybrid family were also the most uniform in shape, size and colour.

Sikka et al. (1994) from an experiment reported the mean yield of 10 TPS progenies 8.1 kg/m^2 (range 3.9 to 12.6 kg), while the number of tubers averaged 367/m^2 (range 222 to 533) in the long rainy cropping season. Similar results were obtained in the following short rain season. Tuber yields as transplants in 9 TPS progenies averaged 57 tons $ha.^{-1}$ (range 18.2-95.3 tons). Their mean tuber FW was 36-90 g (mean 45 g) and was comparable to that of improved potato cultivars raised conventionally. TPS progenies were uniform phenotypically for foliage and tuber characters with negligible segregation. The average OP tuber yields were equal to yields of the best hybrid progenies. Seedling tubers derived from TPS were as productive as those raised from seed tubers.

Singh et al. (1994) reported the selection of an OP line from a field of commercial TPS crop, which fulfilled the basic requirements of a TPS parent. The line had profuse flowering (6-8 inflorescences of 8-10 flowers each) and abundant seed production; 90% of flowers set berries with 150-200 seeds berry^{-1}, thus producing about 3 g TPS plant^{-1}. They observed that this line produces a morphologically uniform crop with acceptable tuber shape. The commercial crop raised from seedling tubers gives yields similar to those of other hybrid lines and commercial varieties.

Upadhya (1994) reported that research on the use of TPS for potato production is being carried out at more than 20 locations in India, in collaboration with Indian National Program. The results from the locations showed that yield performance of first generation (F_1C_1) seedling tubers of most of the hybrid TPS families is either better or comparable with the certified tuber seeds of the prominent cultivars. There are several studies that advocate the superiority of F_1C_1 seedling tuber in terms of yield. He stated that yield alone cannot be the sole indicator for the superiority or otherwise of a new source of seed over existing one. He reported the results of a socio-economic study conducted on evaluation of TPS technology in comparison to seed tubers in four different agro-ecological zones of India. The results showed that the estimated cost of producing seedling tubers required for planting per unit area was lower than the cost of tuber seed available in the respective areas during planting time, thus saving in terms of total cost were quite substantial. Furthermore, high degree of resistance to late blight in TPS families eliminated the use of fungicides, thus on one hand the saving on purchase of fungicides and on the other, reduction in environmental pollution.

Sikka and Kanzikwera (1993) reviewed the major production constraints for extension of potato production and the role of potato as an important food crop. They reported that TPS both as seedling tubers and transplants seems to be a promising alternative to the costly seed tubers. TPS progenies exhibited better resistance to both late blight and bacterial wilt than the conventional seed tubers.

Abeytunge (1992) conducted a series of field evaluations at Sita Eliya, Sri Lanka, during 3 consecutive yala seasons (1987-89) to select productive OP and hybrid parents of potato. In his experiment, estimates of general combining ability (GCA) effects for seedling tuber yields showed that male, OP parent 260/39 and female parents Sita, Atzimba and 25/40 had significantly high GCA effects. In general, 4X x 4X progenies were significantly higher yielding than OP and 4X (4X x 2X) progenies. Locally developed 4X x 4X progenies of Sita x 260/39, Atzimba x 260/39 and 25/40 x 260/39 were identified as promising with respect to seedling vigor, high tuber yield and acceptable tuber uniformity.

Elias et al. (1992) evaluated TPS progenies (three hybrids and six OP) at the Regional Agricultural Research Station, Jamalpur, during 1987-88 and 1988-89. They reported that hybrids performed better than the OP progenies. Among the hybrids, Atzimba x R-128-6 was the highest yielder (49.1 tons ha^{-1}), early maturing, had desirable plant and tuber characteristics and therefore, can be used on commercial basis for potato production under the present local edaphic and climatic conditions in Jamalpur, Bangladesh.

Chaudhury (1991) evaluated potato production through TPS in field trials from 1984-85 to 1988-89 at Joydepur, Bogra and Munshiganj, Bangladesh. Three methods of production from TPS (i.e., direct sowing in nursery beds, transplanting in the field and planting seedling tubers produced from TPS) were investigated in 4 hybrids obtained from CIP, 3 OP genotypes produced locally, and seed tubers from varieties Patrones and Lal Pakri:. He reported the highest yield for the TPS progenies of hybrids Atzimba x R128.6 and Atzimba x DTO-28 (31.1 and 10.6 tons ha^{-1}, respectively).

Shonnard and Peloquin (1991) studied the effect of planting method on performance of TPS families from 4X x 2X hybrids and open self pollinated families. Families from seedling transplants and seedling tubers and their 4x parental clones were compared for tuber yield and specific gravity. Families from tubers had substantially higher yields and significantly more uniform specific gravity than families from transplants. Hybrid seedling tuber families had a higher mean yield than the parental clone and did not differ from them in specific gravity. They proposed that selection in the seedling generation could further improve both OP and hybrid families from transplants and from seedling tubers

Gisela et al. (1990) selected twelve potato clones in preliminary trials for low pollen stainability but high fruit and seed set which initially seemed promising for inexpensive production of mostly hybrid OP TPS. However, In subsequent tests, pollen stainability of these clones appeared to be highly variable and fruit and seed set were not as high as expected. Bumblebees favored the most fertile clones, especially during periods when pollen stainability was the highest. Amounts of OP fruit and seed set correlated with maximum observed pollen stainability levels of the clones. Most of the OP seeds produced by these clones were probably the result of self-pollination therefore, they concluded that other methods must be used to obtain hybrid TPS.

Devaux (1989) proposed that the selection of a superior OP progeny would increase the potential of TPS use in Pakistan because, TPS from an OP can be produced easily in large quantity at low cost, even by farmers themselves. He suggested that in hilly areas true seed should be sown by farmers every 3-5 years to renew their seed stock or to introduce a better line, the following season they could use the seed tubers produced from TPS as seed. When farmers would have covered their own need of seed tubers, surplus could be sent to the plains as seed for the spring crop. In the plains, farmers would produce seedling tubers in nursery during the autumn crop and multiply them the following years through autumn to autumn cycle. New nursery could be raised every year to increase the quantity of seed tubers to multiply.

Rahimi and Garter (1989) reported that abscission of flowers in *Solanum tuberosum* L., cv. Katahdin immediately after pollination and probably before fertilization was a barrier to crossing between *S. tuberosum* and *S.chacoense* Bitt. in their greenhouse. They evaluated a new method for improving flower retention. Treatment of flower buds at an early stage with silver thiosulphate (STS) was compared to the cut stem technique. Flower retention on STS. Treated Katahdin was greater than on untreated plants, and better than that on cut stems. Advantages of STS over the cut stem method include ease of application and reduced maintenance requirement of the plant material.

Vander Zaag et al. (1989) evaluated TPS progenies from diverse genetic backgrounds in three different environments in the Philippines. In their study, first generation seed tubers had superior yields than transplants, especially at the high and low elevation locations and gave yields similar to the local cultivars.

In Pakistan, research on the development of TPS as a potential seed source for potato crop production was initiated in mid Eighties with collaboration from International Potato Center, Lima, Peru. Shah and Jan (1987) studied the possibilities of growing potatoes from TPS at Kalam, Swat. They compared the performance of a hybrid TPS (Atzimba X R 806, procured from CIP, Peru) with the seed tubers of a commercially cultivated variety, Cardinal. The seed germinated within 8-10 days with good success. The seedlings also survived well from the transplanting stocks. However, the yield of the potato crop raised from true seed was slightly less (16 tons ha^{-1}) than from seed tubers (18.5 tons ha^{-1}). They reported that with the selection of suitable hybrid progenies/genotypes and appropriate crop management practices can produce better yields through TPS technology.

Lozoya-Saldana and Miranda-Velazquez (1987) studied the effect of 25 ppm gibberellicacid (GA_3). 7.500 ppm Gapol® (0.4%), molybdate: 0.42% cobalt:

0.5% tungstate: 2.84% borax: 4 ppm indoleancetic acid:4 ppm naphthyltalamic acid ; and 2 ppm ethyelediaminetetracetic acid) over two photoperiods (12 and 18 h daily) on flowering of potato cv. Marijke. They reported that GA_3 specifically reduced the number of days required for flowering and Gapol® or long days favored bud retention. When combined, only a slight additive effect was observed. In most case spraying the products on plants subjected to long days resulted in an increase in the number of floral buds, but their attachment on the plant was mainly influenced by the presence of Gapol®.

Song Bofu et al. (1987) reported that in China, pioneer work on TPS was initiated in 1959. Their experience shows a good potential in the improvement of potato production through TPS technology.

Upadhya et al. (1986) evaluated the development of TPS technology in India. In one experiment, populations from two TPS hybrids were compared with a commercial variety. They reported that hybrid populations raised from TPS showed a degree of late blight resistance as compared to the commercial variety. The hybrid populations were homogenous in plant and tuber characters and gave better yields than the seed tubers of a commercial variety.

Kidane-Mariam et al. (1985) evaluated four different sets of TPS families at three different locations in Peru. They reported significant difference among families in tuber yield, uniformity and transplant survival rate in the field. Hybrid TPS families gave higher tuber yields and more uniform tubers than families from open-pollination. Because of family-environment interaction for tuber yield, they suggested that locally adapted cultivars or advanced selections should be used as parents to generate TPS progenies for specific areas

Malagamba (1983) studied the TPS yield at Huancayo, Peru (high altitude, cool conditions) and estimated that it is about 28 kg or 36,000,000 seeds ha^{-1}, enough for the seeding of 360 hectares.

CHAPTER 3

AN INVESTIGATION INTO THE REPRODUCTIVE BIOLOGY OF 14 POTATO GENOTYPES AND OPEN POLLINATED AND HYBRID TPS

An Investigation into the reproductive biology of 14 potato genotypes and development of hybrid seed.

3.1. MATERIALS AND METHODS.

Seed tubers of fourteen potato genotypes from three different categories, including five TPS hybrids in 2nd clonal generation from CIP origin (i.e., 9743, 9805, 9813 and 88008), two CIP potato lines (i.e., 396239-76 and 396458/22-24) five Sialkot potato selections (i.e., SH-5, SH-9, SH-53, SH-70, SH-103 and SH-176), and a commercial cultivar Desiree were procured from National Potato Program, NARC, Islamabad, through Potato Botany section, Agricultural Research Station (N), Mingora (ARSNM). These were planted at ARSNM, substation Kalam (2075 m above sea level) on May, 15, 2000. The experiment was laid out in an RCB design, replicated 4 times in a 3 x 1.4 meter plot, having 2 rows of 70 cm row to row spacing and 20 cm plant to plant spacing. Fertilizer was applied @ 200:150:75 kg N:P:K ha^{-1} from Urea, DAP and SOP fertilizer sources. Half of the nitrogen and all of the phosphorous and potash were applied at the time of seedbed preparation, whereas, the remaining half nitrogen was applied at the earthing-up stage. Recommended crop management practices (i.e. weeding, hoeing, irrigation etc.) and plant protection measures were followed to raise a good crop. For open pollinated TPS, berries were collected at maturity from open pollinated flowers. For the development of hybrid TPS, crosses were made between randomly selected parental lines in a Partial Diallel Mating design (Fehr, 1987). For making crosses, mature flower buds were emasculated in the afternoon and then pollinated next morning with bulk pollen of the desirable parent. For pollen collection, freshly opened flowers were harvested in the morning, the anthers separated and sun-dried in a closed petri dish for about an hour to enhance anther dehiscence. TPS from both hybrid and OP berries were extracted by keeping the berries in polythene bags under room temperature upto three weeks for softening. The softened berries were transferred to small plastic jars containing water and left for another week for further softening. When the berries were fully softened, the surplus water was drained and the berries were smashed with fingers to release the seeds. The remaining water and inert matter (debris from berries) were removed and the seeds were air-dried in a glass house for one more week.

Data were recorded for the following parameters.

1. Days to flowering.

Days to flowering were counted from the date of planting to the appearance of first flowers in the plot.

2. Days to flower completion.

Days to flower completion were counted from the date of sowing to the complete cession of flowering.

3. Flowering duration.

The number of days for flowering duration was counted by subtracting days to flowering from days to flower completion.

4. Pollen viability (%).

For pollen viability data, ten freshly opened flowers were collected, anthers separated and placed in a petri dish and covered for about an hour to stimulate anther rupture. Pollens were extracted from the anthers, placed on a slide and stained with acetocarmine glycerol. The total number of pollen grains and fully stained pollen grains were counted under a powerful microscope and percent viability calculated, using the following formula.

$$\text{Pollen viability (\%)} = \frac{\text{Total number of fully stained pollen grains}}{\text{Total number of pollen grains}} \times 100$$

5. Number of flower plant^{-1}.

The number of flowers plant^{-1} data were recorded by counting the total number of flowers produced in 5 randomly selected plants in each plot, and their means computed.

6. Number of berries plant^{-1}.

The total number of berries produced in 5 randomly selected plants were counted in each plot and their means computed.

7. Fruit set (%).

Fruit set data (percent) for each plot were recorded on five randomly selected plants using the following formula.

$$\text{Fruit set (\%)} = \frac{\text{Total number of berries}}{\text{Total number of flowers}} \times 100$$

8. Berry diameter (cm).

The berry diameter data were recorded following taking measurements with a Vernier caliper on five matured berries randomly collected from five plants in each plot

9. Average berry weight (g).

Five random berries were collected from each plot at harvesting time, weighed in grams and mean berry weight was calculated.

10. Number of seeds berry^{-1}.

At maturity the berries were collected and stored at room temperature for 3 to 4 weeks to enhance softening. Four softened berries were randomly collected from each genotype in each replication, their seeds extracted, counted and average number of seeds computed.

11. 100 Seed weight (mg).

After air drying, a sample of 100 seeds was counted from each genotype in each replication, weighed with a sensitive electronic balance and data were recorded in mg.

12. TPS yield plant^{-1} (g).

True potato seeds were extracted from the total berries of 3 randomly selected plants in each plot, air-dried, weighed and their means computed to record TPS yield plant^{-1} in grams.

The data was analyzed using MSTATC computer software for the estimation of variance.

3.2. RESULTS.

The analysis of variance tables have been compiled in appendices from table 1.1 to 1.14.

3.2.1. Days to flowering.

Statistical analysis of the data for days to flowering revealed highly significant ($P \leq 0.01$) mean squares for 14 potato genotypes (Appendix 1.1). Genotype, 396258/22-24 was the earliest in flowering and took 53.00 days to flowering, followed by commercial cultivar Desiree (58.25 days). Genotype, 9802 took the maximum days of 81.75 to flowering. Five genotypes, viz., SH-176, SH-70, SH-53, 88002 and 9743 were statistically at par and took 70.25 to 71.75 days to flowering (Table 3.1).

3.2.2. Days to flower completion.

Fourteen potato genotypes showed significant variation at 1% probability level for the number of days to flower completion (Appendix 1.2). Cultivar Desiree completed flowers earlier and took 79.7 days, followed by genotypes 396239-76 and 9813 which took 83.95 and 87.25 days, respectively, to flower completion. Genotype SH-103 took the maximum days (107.00) to flower completion, followed by 104.00 days for genotype 88002 (Table 3.1).

3.2.3. Flowering duration.

Analysis of variance showed highly significant ($P \leq 0.01$) mean squares for flowering duration (Appendix 1.3). Genotype, SH-103 had the maximum flowering duration of 41.20 days, followed by genotype 396258/22-24 (37.70 days). The minimum flowering duration of 12.25 days, followed by 17.70 days were recorded for genotypes, 9802 and 396239-76, respectively. Genotypes 9813, SH-9, SH-53 and SH-70 completed flowering phase at par with cv., Desiree (Table 3.1).

Table 3.1. Means of days to flowering, flower completion and flowering duration of 14 potato genotypes, planted at ARSS Kalam, during summer, 2000.

Genotype	Days to flowering	Days to flower completion	Flowering duration(days)
9743	70.75	101.75	31.00
9802	81.75	94.00	12.25
9805	69.00	103.50	34.50
9813	63.25	87.25	24.50
88002	71.25	104.00	32.70
396239-76	66.25	83.95	17.70
396258/22-24	53.00	90.75	37.70
SH-5	60.75	89.70	29.00
SH-9	65.50	89.25	24.20
SH-53	71.25	96.20	24.75
SH-70	70.75	95.20	24.50
SH-103	67.00	107.00	41.20
SH-176	70.25	101.50	31.20
Desiree	58.25	79.70	21.50
LSD (P 0.01)	**2.20**	**3.29**	**4.70**

3.2.4. Pollen viability (%).

Analysis of variance showed highly significant ($P \leq 0.01$) mean square due to pollen viability of 14 potato genotypes (Appendix 1.4). Genotype SH-103, had the maximum pollen viability of 43.50%, followed by genotypes 9805 and 88002 with pollen viability of 39.50 and 38.5%, respectively. The minimum pollen viability of 17.7% was recorded for genotypes, SH-5, followed by 20.2, 20.3, 21.2 and 21.7% for genotypes SH-70, SH-9, 9743 and 9802, respectively. However, the pollen viability of the commercial cultivar Desiree was in a medium range of 27.0% (Table 3.2).

3.2.5. Number of flowers plant $^{-1}$.

Statistical analysis of the data revealed highly significant ($P \leqslant 0.01$) mean squares for the number of flowers plant $^{-1}$ (Appendix 1.5). The highest number of flowers plant^{-1} (75.5), were observed for genotype SH-103, followed by 9813 and 396239-76 (71.7 and 71.0 flowers, respectively). The minimum number of flowers plant^{-1} (26.7) were observed for genotype, SH-9, followed by 35.7 flowers plant^{-1} for genotype, 9802. Genotype SH-70 and cv., Desiree produced approximating number of flowers (36.2 and 36.3 respectively) plant $^{-1}$ (Table 3.2).

3.2.6. Number of berries plant^{-1}.

Fourteen potato genotypes exhibited highly significant mean square ($P \leqslant 0.01$) for number of berry plant^{-1} (Appendix 1.6). The highest number of berries plant^{-1} (25.80) was recorded for genotype 9805, followed by SH-176, SH-5 and SH-103, with 24.30, 24.30 and 23.30 berries plant^{-1} respectively. Genotype SH-9 produced the lowest number of berries plant $^{-1}$ (4.50), followed by 6.30, 7.50, 8.00 and 8.50 berries plant^{-1} for genotypes 9802, Desiree, 88002 and SH-70, respectively (Table 3.2).

Table 3.2. Means for pollen viability (%), flowers $plant^{-1}$ and berries $plant^{-1}$ of 14 potato genotypes, planted at ARSS Kalam, during summer, 2000.

Genotype	Pollen viability (%)	Flowers $plant^{-1}$	Berries $plant^{-1}$
9743	21.2	45.0	11.5
9802	21.7	35.7	6.3
9805	39.5	66.5	25.8
9813	34.2	71.7	14.0
88002	38.5	40.5	8.0
396239-76	32.7	71.0	15.0
396258/22-24	36.2	54.2	9.5
SH-5	17.7	60.5	24.3
SH-9	20.3	26.7	4.5
SH-53	27.5	52.0	14.8
SH-70	20.2	36.2	8.5
SH-103	43.5	75.5	23.3
SH-176	36.5	56.2	24.3
Desiree	27	36.3	7.5
LSD (P 0.01)	**7.2**	**5.3**	**3.8**

3.2.7. Fruit set (%).

Variation in fruit setting percentage of 14 potato genotypes was significant at 1% probability level (Appendix 1.7). The highest fruit set of 43.50% was observed for genotype SH-176, followed by 40.10% and 38.80% for SH-5 and 9805, respectively. Genotype SH-9, had the lowest mean fruit set of 16.80%, followed by 396258/22–24, 9802 and 88002 with17.50%, 17.60% and 19.80% fruit set, respectively. The fruit set percentage of Desiree was statistically at par with genotype 396239-76 (Table3.3).

3.2.8. Berry diameter (cm).

Analysis of variance showed highly significant ($P \leq 0.01$) mean square for 14 potato genotypes (Appendix 1.8). The maximum berry size of 2.37 cm was recorded for commercial cultivar Desiree, followed by 2.13 cm for genotype SH-176. The minimum berry size of 1.58 cm was recorded for genotypes 396258/22-24, followed by 1.74, 1.74 and 1.75 cm for genotypes 9743, SH-9 and 9802, respectively (Table 3.3).

Table 3.3. Means for percent fruit set, berry diameter and average berry weight of 14 potato genotypes, planted at ARSS Kalam, during summer, 2000.

Genotype	Fruit set (%)	Berry diameter (cm)	Av. berry weight (g)
9743	23.70	1.74	4.09
9802	17.60	1.75	3.16
9805	38.80	1.96	3.78
9813	19.50	1.98	3.88
88002	19.80	1.82	3.25
396239-76	21.20	1.89	3.80
396258/22-24	17.50	1.58	3.48
SH-5	40.10	1.84	3.84
SH-9	16.80	1.74	3.89
SH-53	28.50	2.01	3.79
SH-70	23.30	1.97	4.85
SH-103	30.80	1.85	3.30
SH-176	43.50	2.13	4.72
Desiree	21.40	2.37	4.64
LSD (P 0.01)	**7.80**	**0.26**	**0.15**

3.2.9. Average berry weight (g).

Highly significant ($P \leq 0.01$) mean squares were observed for the average berry weight of different potato genotypes (Appendix 1.9). Average berry weight was highest for SH-70 (4.85 g), followed by SH-176 (4.72 g), and cv. Desiree (4.64 g). The lowest average berry weight of 3.16 g was observed for genotype 9802 (Table 3.3).

3.2.10. Number of seeds berry^{-1}.

Fourteen potato genotypes differed significantly at 1% probability level for number of seeds berry^{-1} (Appendix 1.10). Genotype SH-103 produced the maximum number of seeds berry^{-1} (355.0), followed by genotype 396239-76 (330.5 seed berry^{-1}). The minimum number of seeds berry^{-1} (i.e, 88.0) was recorded for cv. Desiree. The genotypes 9813 with SH-70 and 9802 with SH-53 produced nearly matching number of seeds berry^{-1} (Table 3.4).

3.2.11. 100 seed weight (mg).

Analysis of variance for 100 seed weight showed highly significant ($P \leq 0.01$) differences among fourteen potato genotypes (Appendix 1.11). The maximum 100 seed weight was recorded for genotype SH-103 (97.00 mg), followed by 396239-76 (91.30 mg). The minimum 100 seed weight of 46.90 mg was observed for cv. Desiree, followed by genotype, SH-9 (53.00 mg). The 100 seed weight of genotypes SH-53 (54.10 mg) and 9743 (54.20 mg) were nearly similar (Table 3.4).

3.2.12. TPS yield plant^{-1}(g).

Statistical analysis of the data revealed a highly significant ($P \leq 0.01$) means square for TPS yield plant^{-1} of 14 potato genotypes (Appendix 1.12). Genotype, SH-103 produced the highest TPS yield of 4.20 g plant^{-1}, followed by genotypes SH-176 (4.00 g) and 396239-76 (3.50 g). The lowest yield of 0.20 g was produced by genotype SH-9, followed by 0.30, 0.58, 0.83 and 0.90 g plant^{-1} for cv., Desiree, 9802, SH-70 and 396258/22-24, respectively (Table 3.4).

Table 3.4. Means for number of seed berry^{-1}, 100 seed weight and TPS yield plant^{-1} of 14 potato genotypes, planted at ARSS Kalam, during summer, 2000.

Genotype	Seeds berry^{-1}	100 seed wt. (mg)	TPS yield plant^{-1} (g)
9743	175.00	54.20	0.98
9802	129.20	80.70	0.58
9805	267.50	85.30	3.10
9813	150.00	74.50	1.45
88002	242.50	60.30	1.14
396239-76	330.50	91.30	3.50
396258/22-24	122.20	82.70	0.90
SH-5	217.00	80.10	3.20
SH-9	98.70	53.00	0.20
SH-53	132.20	54.10	1.04
SH-70	154.70	61.60	0.83
SH-103	355.70	97.00	4.20
SH-176	301.20	82.10	4.00
Desiree	88.00	46.90	0.30
LSD (P 0.01)	**21.50**	**5.70**	**0.74**

3.3. DISCUSSION.

The use of true seed as a mean of propagation for the potato, gives interest to the study of its flowering, fruiting and seed set behavior. In potato, these sexual reproductive traits are governed by a multitude of factors including photoperiod (Patterson, 1953; Sadik, 1983), temperature (Marinus and Bodlaender, 1975; Bienz, 1958), humidity (Buhr, 1961; Ahmad, 1977), plant nutritional status (Thijn, 1954) and variety (Pushkarnath, 1976). However, most of these factors can be fulfilled either in a controlled green house or natural field condition with long photoperiod (14 to 16 hours) and cool temperatures (18 to 22°C). In NWFP, natural field condition for potato flowering and fruit set can be obtained at higher altitudes in cool summer season. The location of Agricultural Research Station, Kalam has high altitude (2075 m), longer photoperiod due to summer season and moderate low temperature which is favorable to investigate the reproductive biology of potato and development of OP and hybrid TPS. Moreover, the occurrence of berries on certain potato varieties grown commercially by local farmers at Kalam encourages researchers for carrying out such studies. The data collected on various parameters are discussed below.

Days to flowering.

In all plants grown for sexual seed production, flowering is an important characteristic and is related to crop maturity. Early flowering genotypes mature earlier as compared to late flowering genotypes. Highly significant differences were observed for days to flowering of the potato genotypes. Genotype, 396258/22-24 flowered in the 2nd week of July and took the minimum of 53 days to flowering, as compared to the late flowering genotype 9802, which flowered in the last week of August and took 81.76 days to flowering. Patel et al. (2000) reported 50% flowering in four parental lines of TPS in the 2nd week of December, when the mean minimum and maximum values for temperature were 10^{o} C and 30^{o} C respectively and relative humidity 25% and 75% respectively. Similarly, Gopal (1994) screened 344 accessions from *Solanum tuberosum*, subspecies *tuberosum* for flowering under short day conditions but none of the genotypes flowered in his experiment.

Days to flower completion.

Fourteen potato genotypes showed significant variation for days to flower completion. Cultivar Desiree completed flowers earlier and took 79.70 days followed by genotypes, 396239-76 (84.25 days) and 9813 (87.25 days). The maximum days of 107.00 followed by 104.00 to flower completion were observed for genotypes SH-103 and 88002, respectively. Abeytunge (1992) reported seasonal differences for flowering and days to flower completion for different potato lines in his study.

Flowering duration.

Flowering and fruit set in potatoes are regulated by genetic as well as environmental factors. For OP TPS production, genotypes with long flowering duration are needed to compensate for weather fluctuation under field conditions.

Significant variations were observed among different genotypes for flowering duration. The range of flowering duration was 12.25 to 41.20 days (2 to 6 weeks) for various genotypes. Similar results have been reported by Gopal (1994) when he evaluated 30 potato accessions for flowering duration. In his experiment, flowering duration ranged from 3 to 8 weeks for different genotypes. He also reported that flowering and fruiting are important characteristics for evaluating, describing and classifying the potato genotypes.

Pollen viability (%).

Male sterility observed through pollen viability occurs quite frequently in potato, which depends partially on environmental factors. The main reason for male sterility is the abnormal division of pollen mother cells due to higher temperatures, resulting in the formation of abortive pollen grains (Stow, 1927).

A significant variation in percent pollen viability of different potato genotypes was observed. The range for pollen viability was 17.70 to 43.50% for genotypes under study. Gisela, et al. (1990) evaluated 12 potato clones with low pollen fertility, under different locations and pollen collection dates. He reported significant variation in pollen viability due to locations and date of pollen collection. He reported 0-33% pollen viability in his study.

Number of flowers plant^{-1}.

Flowering intensity and subsequent fruit set are important characteristics for the selection of TPS lines, as well as breeding potatoes. In most potato genotypes, flowering is profuse under long day photoperiod and cool environment. The range of 26.70 to 75.50 flower plant^{-1} shows significant variation among different genotypes for number of flowers plant^{-1}. Singh et al.

(1994) reported 6 to 10 inflorescences of 8 to 10 flowers each for an OP TPS line, MST-1. Gopal (1994) reported that genetic as well as environmental factors interfered with the developmental process leading to flower production in different potato genotypes.

Number of berries plant^{-1}.

Flowering can be followed by fruit set only if the stigma is pollinated by fertile and compatible pollen. Berry drop is a common phenomenon in S. *tuberosum* cultivars and a frequent cause of the inability of a profusely flowering variety to set fruit. In a fertile flowering variety, lack of fruit set may be the result of anyone of the three reasons, namely; lack of pollinators in cases where these are necessary, unsuitable temperatures for pollen emergence and pollen tube growth or flower abscission before berry set. Our results showed significant variation among the potato genotypes for the number of berries plant^{-1} and the values ranged between 4.5 to 25.8 berries plant^{-1} the minimum being for genotype SH-9 and the maximum for 9805. Singh et al. (1994) reported 28 to 58 berries plant^{-1} in an OP TPS line MST-1, under extended photoperiod (16 to18 hours).

Fruit set (%).

In potato fertilization has been reported to take 36 to 45 hours from the time of pollen germination (Williames, 1955), however, it is also temperature dependent. Bienz (1958) reported 15-20° C optimum, whereas below 10° C and above 25° C inhibitory for potatoes. Fruit setting varied significantly among the 14 potato genotypes. The highest fruit set of 43.5% was observed for genotype SH-176, whereas the lowest (16.8%) for genotype SH-9.

Berry diameter.

Highly significant variations among the 14 potato genotypes were observed for berry diameter. The maximum berry diameter was recorded for cv. Desiree (2.37 cm) and the minimum berry diameter was recorded for 396258/22-

24 (1.58 cm). Almekinders and Wiersema (1985) reported that increase in the number of berries/inflorescence resulted in a decrease in the average berry size.

Average berry weight.

Potato genotypes varied significantly for average berry weight. The maximum berry weight of 4.85 gm was observed for SH-70 and the minimum berry weight of 3.16 gm was observed for genotype 9802. Singh et al (1994) reported 5 to 10 gm average berry weight for an open pollinated TPS line under long day conditions.

Number of seeds berry^{-1}.

Number of seeds berry^{-1} is an important trait that directly influences the production of hybrid and OP TPS. Significant variations were observed among 14 potato genotypes for the number of seeds berry $^{-1}$. Upadhya (1994) proposed that a good parental line for TPS production should have more than 250 seed berry^{-1}. This was confirmed by the genotype SH-103 that produced the highest number of seeds berry^{-1} (355.0). The range of 88.00 to 355.00 was observed in the present investigation which is near to the CIP (1983) report, according to which the number of TPS berry^{-1} could range from 50 to 500, with an average of usually about 200.

100 seed weight.

100 seed weight is one of the important yield components in TPS production. Significant variability was observed among the potato genotypes for 100 seed weight. A range of 46.90 to 97.70 mg was recorded in the present study which is similar to the results of Almekinders and Wiersma (1985) who reported a range of 57.1 to 82.7 mg for 100 seed weight in 3 potato varieties.

TPS yield plant^{-1}.

TPS yield is the most important characteristic in the development and adaptation of TPS technology. TPS yield varied significantly among 14 potato genotypes. The yield of TPS in present investigation was 0.20 g (SH-9) to 6.1g (SH-103) plant^{-1} in the high altitude and cool environment of Kalam. Malagamba (1983) reported estimated TPS yield at Huancayo, Peru (high altitude, cool condition) to be 28 kg ha^{-1}. Singh et al. (1994) reported a range of 2.2 to 4.8g TPS yield plant^{-1} in a potato variety under extended potato period. This shift from the present study could be due to difference in genotypes and environment.

CHAPTER 4

PRODUCTION OF F_1C_1 SEEDLING TUBERS FROM HYBRID AND OPEN POLLINATED TPS AT ARS, MINGORA.

Production of F_1C_1 seedling tubers from hybrids and open pollinated TPS, at ARS, Mingora

4.1. MATERIALS AND METHODS.

TPS from nine OP genotypes (viz., 9743, 9805, 9813, 88002, 396239-76, SH-5, SH-53, SH-103 and SH-176,) and five hybrids (viz., 9805 x SH-9, SH-5 x 9813, SH-53 x 396258/24-22, SH-103 x 9743 and SH-176 x 396239-76) developed in experiment 1 were treated with 1500 ppm GA_3 to break seed dormancy. The treated TPS were planted in an RCB design with four replications, in a 1 x 1 meter raised nursery beds on February 15, 2001, at ARS (N), Mingora. Each nursery plot was thoroughly prepared by mixing 1:1:1 ratio sand, soil and Farm yard manure. The TPS from hybrids and OP genotypes were sown in rows with 10 cm row to row distance. After sowing, the nursery beds were covered with a piece of old cotton gunny bags and frequently sprinkle irrigated to keep the plots in moist condition. At initial germination, the gunny bag pieces were removed and sprinkle irrigation continued until maximum germination was observed. All the recommended cultural practices were followed to raise a good crop. The following data were recorded.

1. Germination percentage.

Germination percentages for nine OP and five hybrid genotypes were calculated using the following formula.

$$\text{Germination (\%)} = \frac{\text{Total number of plants germinated}}{\text{Total number of TPS sown}} \times 100$$

2. Seedling vigor (0-9 scale).

The seedling vigor data were recorded 45 days after emergence on a 0-9 visual scale. Different statured seedlings were observed which were then grouped according to their vigor. Very week seedlings were grouped as 0 and very vigorous seedlings were categorized as 9.

3. Plant height (cm).

Plant height data in cm were recorded on 5 randomly selected plants in each plot at the time of harvest. Measurement was made from the soil surface to the tip of the plant.

4. Days to harvest.

Days to harvest data were recorded from the date of planting to the date of harvest (in days).

5. Number of seedling tubers plot^{-1}.

The number of seedling tubers larger than 1 gram in a 1 x 1m plot was counted to record the production of seedling tuber plot^{-1}.

6. Seedling tuber yield m^2 (kg).

After harvesting seedling tubers from each plot separately, tubers larger than I gram were sorted out, weighed and seedling tuber per 1 x 1 m plot were recorded.

4.2. RESULTS.

4.2.1. Germination percentage.

Analysis of variance showed highly significant (P 0.01) mean squares for percent germination of 14 potato genotypes grown from TPS (Appendix 2.1). All the genotypes, except 396239-76, 88002 and SH-103 x 9743 had the highest emergence percentage ranging from 76.75% to 84.50% (Table 4.1.a). The lowest emergence of 64.50% was observed for genotypes 396239-76.

Comparison of plots grown from OP TPS and hybrid TPS showed a non-significant difference for germination percentage. However, combined mean for nine OP TPS was 76.66%, as compared to that of 78.50% by five hybrid TPS, (Table 4.1.b).

4.2.2. Seedling vigor.

Potato genotypes means squares for seedling vigor showed a highly significant difference at 1% probability level (Appendix 2.2). The highest seedling vigor of 7.85 was recorded for hybrid SH-176 x 396239-76 followed by 7.75 by hybrids SH-5 x 9813, SH-53 x 396258/22-24 and OP genotype 9743. OP genotype SH-53 had the lowest seedling vigor of 4.50 (Table 4.1.a).

Hybrids vs. OP TPS comparisons were also highly significant at 1% probability level (Appendix 2.2) Hybrids had a mean seedling vigor of 7.72 as compared to that of 6.95 by OP TPS (Table 4.1.b).

Table 4.1.a. Percent germination, seedling vigor and plant height of nine OP and five hybrid TPS, planted at ARS, Mingora, during Spring, 2001.

Genotype	Germination (%)	Seedling vigor (0-9)	Plant height(cm)
9743	78.25	7.75	36.25
9805	80.25	7.25	55.25
9813	80.25	6.50	39.25
88002	66.25	6.75	52.00
396239-76	64.50	5.50	32.00
SH-5	80.00	6.75	45.00
SH-53	84.50	4.50	45.25
SH-103	77.25	6.75	46.25
9805 x SH-9	76.75	7.05	53.00
SH-176	78.75	6.50	33.25
SH-5 x 9813	82.75	7.75	62.25
SH-53 x 396258/22-24	80.25	7.75	59.00
SH-103 x 9743	76.00	7.50	60.50
SH-176 x 396239-76	76.75	7.85	51.75
LSD (P 0.01)	**N.S.**	**1.381**	**4.695**

Table 4.1.b. Mean comparisons of nine OP and five hybrid TPS genotypes for percent emergence, seedling vigor and plant height, planted at ARS, Mingora, during spring, 2001.

Genotype	Germination (%)	Seedling vigor (0-9)	Plant height (cm)
Open Pollinated	76.66	6.95	42.72
Hybrids	78.50	7.72	57.30
Significance	N.S.	**	**

N.S. = non significant; ** Significance at $P \leq 0.001$.

4.2.3. Plant height.

Statistical analysis of the data revealed highly significant ($P \leq 0.01$) mean squares for 14 potato genotypes, including hybrid and OP TPS (Appendix 2.3). The maximum plant height of 62.25 cm followed by 60.50 and 59.00 cm were recorded for hybrid genotypes SH-5 x 9813, SH-103 x 9743 and SH-53 x 396258/22-24, respectively (Table 4.1.a). Minimum plant height of 32.0cm was observed for OP genotype, 396239-76.

Hybrid vs. OP comparison was also highly significant (P 0.01) for plant height. The overall mean plant height of five hybrid genotypes was 57.30 cm as compared to 42.72 cm by nine OP genotypes (Table 4.1.b).

4.2.4. Days to harvest.

Analysis of variance showed highly significant ($P \leq 0.01$) mean squares for days to harvest among 14 potato genotypes (Appendix 2.3). OP genotype, SH-5 matured earlier and took 112.50 days to harvest, whereas the hybrid SH-176 x 396239-76 took the maximum days of 129.00 to harvest (Table 4.2.a).

Hybrid vs. OP comparison for days to harvest was non significant (Appendix 2.3). However, the means showed that nine OP genotypes matured in 122.69 days, as compared to 124.30 days for five hybrid genotypes (Table 4.2.b).

4.2.5. Number of seedling tubers (m^2).

The total number of seedling tubers larger than 1 gram were significantly different ($P \leq 0.01$) for 14 potato genotypes (Appendix 2.5). The highest number of 589.50 seedling tubers/m^2 followed by 565.25 seedling tubers/m^2 were recorded for hybrids SH-103 x 9743 and SH-176 x 396239-76, respectively. The lowest numbers of 209.25 seedling tubers/m^2, followed by 233.75 and 238.75 seedling tubers/m^2 were observed for OP genotypes, 396239-76, SH-53 and 88002, respectively (Table 2.2.a).

Group comparison of hybrid vs. OP genotypes also showed a highly significant ($P \leq 0.01$) mean square (Appendix 2.5). The hybrids produced 517.9 seedling tubers/m^2 as compared to 315.91 seedling tubers/m^2 by OP genotypes (Table 4.2.b).

4.2.6. Seedling tuber yield (m^2).

As shown in appendix 2.6, the yield of seedling tubers larger than I gram was highly significant at 1% probability level. The highest yield of 7.93 kg/m^2 was recorded by hybrid SH-103 x 9743, followed by 7.47 and 7.43 kg/m^2, by hybrids SH-176 x 396239-76 and SH-5 x 9813, respectively. OP genotypes, 9743, produced the lowest yield of 3.82 /m^2 (Table 4.2.a).

Hybrid vs. OP comparison also showed a highly significant difference (P 0.01) for seedling tuber yield m^2 (Appendix 2.6). The mean of 5 hybrids was 6.7 kg/m^2 as compared to 4.5 kg/m^2 by 9 OP genotypes (Table 4.2.b).

Table 4.2.a. Means for days to harvest, number of seedling tubers/m^2 and yield/m^2 of nine OP and five hybrid TPS, planted at ARS, Mingora, during Spring, 2001.

Genotype	Harvest (days)	Seedling tubers/m^2	Yield/m^2 (Kg)
9743	124.50	248.50	3.82
9805	125.50	343.00	4.72
9813	122.00	275.75	4.53
88002	122.25	238.75	4.08
396239-76	120.00	209.25	4.24
SH-5	112.50	410.75	5.02
SH-53	128.50	233.75	4.24
SH-103	122.50	504.00	5.01
SH-176	123.50	379.00	4.82
9805 x SH-9	121.50	410.00	5.45
SH-5 x 9813	125.25	529.00	7.41
SH-53 x 396258/22-24	120.25	500.75	5.24
SH-103 x 9743	125.50	589.50	7.93
SH-176 x 396239-76	129.00	565.25	7.47
LSD ($P \leq 0.01$)	**3.516**	**29.94**	**0.445**

Table 4.2.b. Mean comparison of nine OP and five hybrid TPS progenies for days to harvest, number of seedling tubers/m^2 and seedling tuber Yield/m^2, planted at ARS, Mingora, during spring, 2001.

Genotype	Harvest (days)	Seedling tubers/m^2	Yield/m^2 (Kg)
Open Pollinated	122.69	315.91	4.5
Hybrids	124.30	517.90	6.7
Significance	N.S.	**	**

N.S. = non significant; ** Significance at $P \leq 0.001$.

4.3. DISCUSSION.

Raising seedlings from TPS is an indispensable basic step in potato breeding as well as true potato seed programs. Using true seed, potatoes can be grown either by transplanting seedlings to the field or planting seedling tubers. In the first method, seedlings are raised on a nursery bed and then transplanted to the field at a certain stage like tomato or other *Solaneceous* vegetables. In the 2nd method similarly seedlings are raised in a nursery bed and allowed to grow until maturity. At maturity small seedling tubers are harvested which are then subsequently used to grow commercial potato crop. Research has shown that commercial potato crop grown from seedling tubers is more productive than crops grown from transplanting seedlings to the field (Upadhya et al. 1986 and Shonnard & Peloquin, 1991).

Germination percentage.

The results indicated significant variation among the potato genotypes for TPS germination. The germination ranged from 64.5 to 84.5%, however, a non-significant difference for hybrid vs. OP TPS was observed. Sadik (1983) in a series of experiments with non-dormant seed reported 70 to 85% germination in a temperature range of 13 to 22°C. Upadhya et al. (1986) also reported 66.4 to 95.4% germination for five hybrid TPS. Josep et al. (1994) reported 34.5 to 82.5% emergence for one year old GA_3 treated and untreated true potato seed on three different substrates. Clarke and Stevenson (1943) mentioned a number of factors that influence the germination of true potato seed.

Seedling vigor.

The seedling vigor of potato is rather weaker as compared to other *Solanaceous* crops like tomato, Chili and peppers etc., and, its seedlings are also very susceptible to drought, adverse temperatures, insect attack or other stresses. The results revealed significant differences for 14 potato genotypes and ranged between 4.5 and 8.5 on the scale. Hybrids vs OP comparison was also significant. The hybrids were more vigorous as compared to seedlings of OP TPS. Similar results for hybrid vigor in potatoes were reported earlier by Kidane-Mariam et al. (1985).

Plant height.

The plant height is an important characteristic and has its significance, both for farmers as well as breeders. Burton (1966) quantified potato plant height as short (>45 cm) medium (45-60 cm) and tall (<60 cm). Significant variation was recorded among the genotypes and short genotypes (i.e., 396239-76, SH-176, 9743 and 9813), medium genotypes (i.e., SH-5, SH-53 and SH-103 etc.,) and one tall genotype (i.e., SH-5 x 9813) were observed. Hybrids vs. Op comparison showed significantly greater plant height for hybrids as compared to plant grown from OP TPS. Similar findings were reported by Love et al. (1997), that hybrids were taller than cultivars.

Days to harvest.

Cropping intensity is high in a vegetable based cropping system and the growers prefer early maturing varieties to vacate their fields for next crop sowing. Days to harvest differed significantly for the potato genotypes under study. The minimum days of 112.5 were recorded for OP genotype SH-5 as compared to the maximum of 129.0 days by hybrid SH-176 x 396239-76. Hybrid vs. OP comparison was non-significant.

Number of seedling tubers/m^2.

Significant variations were observed among the potato genotypes for number of seedling tubers/m^2 larger than 1 gram. The highest number of 589 seedling tubers/m^2 were observed for hybrid SH-103 x 9743 as compared to 209 seedling tubers/m^2 by OP genotype, 396239-76. As a group, hybrids produced significantly more seedling tuber/m^2 as compared to OP genotypes. Wiersema (1986) reported 200 to 976 seedling tubers/m^2 under various plant population

CHAPTER 5

EVALUATION OF SEEDLING TUBERS (F_1C_1) FOR WARE POTATO CROP AT ARS, MINGORA.

Evaluation of seedling tubers (F_1C_1) for ware potato crop at Agriculture Research Station (N), Mingora.

5.1. MATERIALS AND METHODS.

The F_1C_1 seedling tubers from nine OP (viz., 9743, 9805, 9813, 88002, 396239-76, SH-5, SH-53, SH-103 and SH-176,) and 5 hybrids (viz., 9805 x SH-9, SH-5 x 9813, SH-53 x 396258/24-22, SH-103 x 9743 and SH-176 x 396239-76) produced in experiment 2 were planted for ware potato production at ARS, Mingora, during autumn, 2001. The experiment was laid out in an RCB design, replicated 4 times in a 4 x 1.4 meter plot, having 2 rows of 70 cm row to row and 20 cm plant to plant spacing. Fertilizer was applied @ 200:150:75 kg N:P:K ha^{-1} from Urea, DAP and SOP fertilizer sources. Half of the nitrogen and all of the phosphorous and potash were applied at the time of seedbed preparation, whereas, the remaining half nitrogen was applied at the earthing-up stage. Recommended crop management practices (i.e., weeding, hoeing, irrigation etc.,) and plant protection measures were adopted to raise a good crop.

The following data was recorded.

1. Emergence percentage.

Emergence percentage for the 9 open pollinated and 5 hybrid genotypes were calculated using the following formula.

$$\text{Emergence (\%)} = \frac{\text{Total number of plants emerged}}{\text{Total number seedling tubers sown}} \times 100$$

2. Plant height (cm).

Plant height data in cm were recorded on 5 randomly selected plants in each plot at the time of harvest.

3. Days to 80% ground cover.

Data on days to 80% ground were recorded by placing a 1 x 0.8m plastic marker divided equally into 80 cells of 1 x 1cm area, and days were calculated from sowing until the foliage covered 80% cells of the marker.

4. Disease (0-9 scale).

Data for disease were recorded on a 0-9 scale, 0 being for no disease and 9 being for maximum disease. Data were recorded on the incidence of three major potato diseases, i.e., Late blight (*Phytophthora infestans*), Bacterial wilt (*Pseudomonos solanacearum*) and Early blight (*Alternaria solani*) under natural field condition.

5. Days to harvest.

Days to harvest data were calculated for the number of days from sowing to harvest.

6. Number of main stems plant^{-1}.

The number of main stems plant^{-1} data were recorded by counting main stems on five randomly selected plants, in each plot.

7. Number of tubers plant^{-1}.

The numbers of tubers plant^{-1} were calculated by counting tubers in five randomly selected plants in a plot and their means computed.

8. Average tuber weight (g).

Ten tubers were randomly collected in each plot, weighed and average tuber weight computed.

9. Yield ha.$^{-1}$ (tons).

Yield data was recorded by weighing all tubers produced in a 4 x 1.4m plot and then converted to per hectare using appropriate formula.

5.2. RESULTS.

5.2.1. Percent emergence.

Analysis of variance showed non-significant mean squares for percent emergence of 14 potato genotypes (Appendix 3.1). However, mean emergence ranged from 82.0% (for OP TPS progenies, SH-5 and 9813) to 89.3% (for hybrid progeny, SH-5 x 9813), Table 5.1.a.

Hybrid vs. OP TPS comparisons for percent emergence was also non significant (Appendix 3.1). However, hybrids had a mean emergence of 85.68% as compared to 83.25% for OP progenies (Table 5.1.b).

5.2.2. Days to 80% ground cover.

A highly significant mean square (P $\leq$0.01) was observed for 14 potato genotypes grown from F_1C_1 seedling tubers (Appendix 3.2). All the hybrids and three OP progenies (viz., SH-53, SH-5 and 9805) took the minimum of 40 to 43 days to 80% ground cover. Genotype SH-103 took the maximum of 50.5 days to 80% ground cover (Table 5.1.a).

Hybrid vs. OP comparison was also highly significant (P $\leq$ 0.01) for days to 80% ground cover (Appendix 3.2). Hybrid genotypes took 42.4 days to 80% ground cover as compared to 45.6 days by OP genotypes (Table 5.1.b).

5.2.3. Plant height.

Analysis of variance showed highly significant mean square (P$\leq$0.01) for plant height (Appendix 3.3). The maximum plant height of 70.0 cm, followed by 65.0 and 64.8 cm were observed for OP progeny, 88002 and hybrid progenies, SH-103 x 9743 and SH-53 x 396258/22-24, respectively. The minimum plant height of 36.8 cm followed by 40.5 cm were observed for OP progenies, SH-176 and 396239-76, respectively (Table 5.1.a).

Group comparison of hybrid vs. OP progenies was also highly significant for plant height (P $\leq$0.01), Appendix 3.3. Five hybrids had the maximum mean plant height of 57.90 cm as compared to the lowest of 50.2 cm by nine OP progenies (Table 5.1.b).

Table 5.1.a. Means for percent emergence, plant height and days to 80% ground cover of nine OP and five hybrid F_1C_1 TPS progenies, planted for ware potato crop at ARS, Mingora, during autumn, 2001.

Genotype	Emergence (%)	80% ground cover (days)	Plant height (cm)
9743	84.5	45.0	55.0
9805	84.0	41.3	60.0
9813	82.0	47.0	55.0
88002	83.0	50.0	70.0
396239-76	82.3	48.5	40.5
SH-5	82.0	43.0	57.3
SH-53	83.5	40.8	51.5
SH-103	85.0	50.5	50.5
SH-176	83.0	44.3	36.8
9805 x SH-9	83.0	43.0	61.8
SH-5 x 9813	89.3	40.0	60.0
SH-53 x 396258/22-24	84.0	41.3	64.8
SH-103 x 9743	87.3	47.8	65.0
SH-176 x 396239-76	84.8	40.0	48.0
LSD ($P \leq 0.01$)	**N.S.**	**3.80**	**7.19**

Table 5.1.b. Mean comparison of nine OP and five hybrid F_1C_1 progenies for percent emergence, plant height and days to 80% ground cover, planted for ware potato crop at ARS, Mingora, during autumn, 2001.

Genotype	Emergence (%)	80% ground cover (days)	Plant height (cm)
Open pollinated	83.25	45.6	50.7
Hybrids	85.68	42.4	57.9
Significance	**N.S.**	**	**

N.S. = non significant; ** Significance at $P \leq 0.001$.

5.2.4. Disease.

Statistical analysis of the data revealed highly significant ($P \leq 0.01$) mean squares for disease incidence on 14 potato progenies (Appendix 3.4). No diseases were observed for SH-176 x 396239-76, 9805 and 9743. The maximum disease incidence of 2.0, was recorded for OP progeny 88002, followed by 1.8 for another OP progeny, SH-53 (Table 5.2.a).

Hybrids vs. OP comparison showed a non-significant difference for disease incidence (Appendix 3.4). However, mean comparison revealed 0.94 for OP and 1.0 for the hybrid progenies (Table 5.2.b).

5.2.5. Days to harvest.

A highly significant mean square ($P \leq 0.01$) was observed for 14 potato progenies for days to harvest (Appendix 3.5). The OP progeny, 396239-76 took the minimum (116.0) days to harvest followed by 117.0 days each to harvest by the progenies of SH-103, 9805 and hybrid progeny SH-53 x 396258/24. The maximum 122.0 days to harvest were recorded each for 9743, 88002, SH-103 x 9743 and 9805 x SH-9 (Table 5.2.a).

Hybrids vs. OP comparisons were also highly significant ($P \leq 0.01$) for days to harvest (Appendix 3.5). Five hybrid progenies took 120.0 days as compared to 117.0 days by five OP progenies (Table 5.2.b).

5.2.6. Number of main stems plant^{-1}.

Statistical analysis for the number of main stems plant^{-1} revealed significant differences at $P \leq 0.05$ only (Appendix 3.6). The maximum number of 2.9 main stems plant^{-1} each were recorded for hybrid progenies of SH-176 x 396239-76, SH-5 x 9813, followed by 2.8 main stems plant^{-1} by hybrid SH-53 x 396258/22-24. The minimum stem density of 1.9 followed by 2.0 stems plant^{-1} were recorded for SH-103 and 88002, respectively (Table 3-2.a).

Hybrid vs. OP comparisons was highly significant ($P \leq 0.01$) for stem density (Appendix 3.6). Five hybrids had 2.71 main stems plant^{-1} as compared to 2.22 by nine OP progenies (Table 3.2.b).

Table 5.2.a. Means for days to harvest, disease incidence and number of main stems plant^{-1} for nine OP and five hybrid F_1C_1 progenies, planted for ware potato crop at ARS, Mingora, during autumn, 2001.

Genotype	Disease (0-9)	Harvest (Days)	Number of main stems plant^{-1}
9743	0.0	122.0	2.3
9805	0.0	117.0	2.3
9813	1.0	112.0	2.5
88002	2.0	122.0	2.0
396239-76	1.0	116.0	2.3
SH-5	1.0	111.0	2.5
SH-53	1.8	121.0	2.4
SH-103	0.8	117.0	1.9
SH-176	1.0	119.0	2.3
9805 x SH-9	1.5	122.0	2.5
SH-5 x 9813	1.0	119.0	2.9
SH-53 x 396258/22-24	1.5	117.0	2.8
SH-103 x 9743	1.0	122.0	2.5
SH-176 x 396239-76	0.0	121.0	2.9
LSD ($P \leq 0.01$)	**1.10**	**2.8**	**0.8**

Table 5.2.b. Mean comparison of nine OP and five hybrid F_1C_1 progenies for days to harvest, disease incidence and main stems $plant^{-1}$, planted for ware potato crop at ARS, Mingora, during autumn, 2001.

Genotype	Disease (0-9)	Harvest (days)	Number of main stems $Plant^{-1}$
Open pollinated	0.94	117	2.22
Hybrids	1.0	120	2.71
Significance	**N.S.**	**	**

N.S. = non significant; ** Highly significant.

5.2.7. Number of tubers $plant^{-1}$.

Analysis of the variance showed highly significant ($P \leq 0.01$) mean square for number of tubers $plant^{-1}$ (Appendix 3.7). The highest number of tubers $plant^{-1}$ (13.20) were recorded each for hybrid SH-176 x 396239-76 and OP 88002. They were followed by OP SH- 5 (12.60 tubers $plant^{-1}$) and hybrid 9805 x SH-9 (12.30 tubers $plant^{-1}$) and OP SH-53 (12.30 tubers $plant^{-1}$). The lowest number of 6.00 followed by 7.60 tubers $plant^{-1}$ was recorded for OP progenies, 396239-76 and 9813, respectively (Table 5.3.a).

Comparison of hybrid vs. OP progenies was also highly significant at 1% probability level (Appendix 3.7). Hybrid genotypes had the maximum number 11.50 of tubers $plant^{-1}$ as compared to 9.48 tubers $plant^{-1}$ by OP genotypes (Table 5.3.b).

5.2.8. Average tuber weight.

Means of 14 potato progenies showed a highly significant differences ($P \leq 0.01$) for average tuber weight (Appendix 3.8). The maximum average tuber weight of 85.30 g followed by 82.60, 80.30, 80.20 and 77.90 g were recorded for hybrid progenies, SH-5 x 9813, SH-103 x 9743, SH-53 x 396258/22-24 and OP progenies, 9805 and SH-103, respectively. The minimum average tuber weight of 48.00 g followed by 50.00 g was observed for OP progenies, 88002 and 9743, respectively (Table 5.3.a).

Comparison of hybrid vs. OP progenies for average tuber weight was also highly significant at 1% probability level (Appendix 3.8). Five hybrids had a mean tuber weight of 79.50 g as compared to 63.10 g by nine OP progenies (Table 5.3.b).

Yield ha.$^{-1}$ (tons).

Highly significant mean square ($P \leq 0.01$) was observed for yield ha.$^{-1}$ of 14 potato progenies (Appendix 3.9). The highest yield of 26.66 tons ha^{-1} followed by 25.33, 23.50, and 22.88 tons ha.$^{-1}$ were recorded for hybrid progenies SH-53 x 396239/22-24, SH-176 x 396239-76, SH-5 x 9813 and 9805 x SH-9, respectively. The lowest yields of 11.30 tons ha^{-1} followed by 13.55 and 15.33 tons ha.$^{-1}$ were observed for OP progenies 396239-76, 9813 and 9743, respectively (Table 5.3.a).

Hybrid vs. OP comparison was also highly significant at 1% level probability level (Appendix 3.9). Five hybrids had the average yield of 23.39 tons ha.$^{-1}$ as compared to 17.35 tons ha.$^{-1}$ by nine OP progenies.

Table 5.3.a. Number of tubers plant^{-1}, average tuber weight (g) and yield tons ha.$^{-1}$ for 14 F_1C_1 seedling tuber progenies planted at ARS, Mingora, during autumn, 2001.

Genotype	Number of tubers plant^{-1}	Av. Tuber wt.(g)	Yield ha.$^{-1}$ (tons)
9743	7.80	50.00	15.33
9805	10.30	80.20	18.66
9813	7.60	59.30	13.55
88002	13.20	48.00	19.77
396239-76	6.00	58.10	11.33
SH-5	12.60	62.40	21.56
SH-53	12.30	60.30	21.55
SH-103	7.80	77.90	17.77
SH-176	7.80	72.00	16.88
9805 x SH-9	12.30	74.30	22.88
SH-5 x 9813	9.90	85.30	23.55
SH-53 x 396258/22-24	11.80	80.30	26.66
SH-103 x 9743	10.30	82.60	18.66
SH-176 x 396239-76	13.20	75.30	25.33
LDS at ($P \leq 0.01$)	**2.40**	**10.20**	**4.20**

Table 5.3.b. Mean comparison of nine OP and five hybrid F_1C_1 seedling tuber progenies for number of tubers plant^{-1}, average tuber weight (g) and yield ha,$^{-1}$(tons), planted for ware potato crop at ARS, Mingora, during autumn, 2001.

Genotype	Number of tubers plant^{-1}	Av. tuber weight (g)	Yield ha.$^{-1}$ (tons)
Open pollinated	9.48	63.10	17.35
Hybrids	11.50	79.50	23.39
Significance	**	**	**

N.S. = non significant; ** Significance at $P \leq 0.001$.

5.3. DISCUSSION.

There are several studies that advocate the superiority of first generation (F_1C_1) seedling tubers as a seed source for potato production (Shonnard and Peloquin, 1991; Dabas et al. 1994). Carputo and Frusciante (1995) reported that early better vigor of plants grown from seedling tubers could be the reason for this superiority over transplants. The F_1C_1 generation seedling tubers produced in experiment 2 were evaluated as a seed source for ware potato production and the results are discussed below.

Percent emergence.

Emergence plays a pivotal role in the overall crop stand, yield and yield contributing traits. No significant differences in emergence percentage of different TPS progenies, including OP and hybrids were observed, however, the mean values ranged between 82.0 and 89.3%.

Hybrid vs. OP comparison was also non significant. The hybrid progenies had an average emergence of 85.68% as compared to 83.25% by OP progenies,

Plant height.

Potato progenies grown from seedling tubers showed significant mean square variation for plant height. OP progeny, 88002 attained the maximum plant height of 70.0 cm whereas the minimum plant height of 38.8 cm was recorded for another OP progeny, SH-176.

Hybrids vs. OP comparison for plant height also revealed significant difference. The mean plant height of five hybrid progenies was higher as compared the mean plant height of nine OP progenies. The increased plant height of hybrids may be due to hetrosis. Cho et al. (1994) also reported taller plants for hybrid progenies as compared to their parents.

Days to 80% ground cover.

Growth of the potato plant canopy as determined by ground cover is an important trait. Early canopy growth in potato is essential for several reasons, including weed suppression and increased photosynthate production for plant growth and tuberization. Significant variations were observed for days to 80% ground cover among the TPS progenies grown from seedling tubers. The minimum of 40 days to 80% ground cover was recorded for hybrid progeny, SH-176 x 396239-76, whereas, the maximum of 50.50 days to 80% ground cover were recorded for OP progeny, SH-103.

Hybrid vs. OP comparison was also highly significant for days to 80% ground cover. As a group, hybrids took the minimum days to 80% ground cover and were about three days earlier as compared to OP TPS progenies.

Disease.

The potato plant is prone to more than 100 diseases caused either by bacteria, fungi, viruses or mycoplasms, but fortunately few reach serious proportions in any growing area (Harris, 1992).

Comparatively low, but statically significant disease incidence was observed for different potato progenies. No diseases were observed on three progenies, including two OP (viz., SH-176 and 9805) and one hybrid, SH-176 x 396239-76.

Non-significant group comparison was observed for disease incidence on hybrid vs. OP progenies. CIP (1983) reported that potato propagation through TPS minimizes the problem associated with tuber-transmitted diseases, as TPS carries few pathogens especially viruses, from season to season. Shah and Jan (1987) also reported resistance to late blight in a TPS hybrid progeny grown at Kalam.

Days to harvest.

Highly significant mean square was observed for different potato progenies for days to harvest. The minimum days of 116 to harvest were recorded for OP progeny, 362936-76 whereas the maximum days of 122 were recorded for two hybrids and two OP progenies

Hybrid vs. OP comparison was also highly significant for days to harvest. Hybrid progenies took comparatively more days to harvest and matured three days latter as compared to OP progenies.

Number of main stems plant^{-1}.

Although the interest in stems as the unit of plant density in potatoes is of recent origin, several earlier researchers reported that increase in stems per hill gave increases in total and graded yields (Arthur, 1892, Bates, 1935).

Significant variations were observed for the number of main stems plant^{-1} for 14 potato progenies grown from seedling tubers. The highest number of main stems plant^{-1} was recorded for hybrid SH-176 x 399239-76, whereas the lowest value of 1.9 stems plant^{-1} was recorded for OP progeny, SH-103. Hybrids vs. OP comparison showed that hybrids had significantly more number of main stems plant^{-1} as compared to OP progenies.

Number of tubers plant^{-1}.

Significant variations for tuber plant^{-1} were observed among the TPS progenies grown from first generation seedling tubers. The maximum of 13.2 tubers plant^{-1} was recorded both for OP progeny, 88002 and hybrid SH-176 x 396239-76. The minimum of 6.0 tubers plant^{-1} was recorded for OP progeny, 396239-76. Hybrid vs. OP comparison was also highly significant for the number of tuber plant^{-1}. The hybrids as a group produced more tubers plant^{-1} as compared to OP progenies, Similar, results were reported earlier by Elias et al. (1992), who evaluated 6 OP and 3 hybrid TPS progenies for potato production in Bangladesh. He reported 7.4 to 14.0 tubers plant^{-1} in his study.

Average tuber weight.

Average tuber weight varied significantly among the TPS progenies. The maximum average tuber weight of 85.30 g was recorded for hybrid TPS progeny, SH-5 x 9813, whereas the lowest average tuber weight of 50.00 g was recorded for OP TPS, 9743. Hybrid vs. OP comparison was also significant for the average tuber of weight of 14 TPS progenies grown from seedling tubers. The hybrids had a higher mean tuber weight value as compared to OP progenies. Similar results have been reported earlier by Sikka et al. (1994) who observed 36 to 90 g average tuber weight for 10 TPS progenies grown from seedling tubers.

Yield ha.$^{-1}$ (tons).

Yield is the most important characteristic, determined by variety, seed quality and environmental factors. Significant variation was observed for yield ha.$^{-1}$ among TPS progenies grown from seedling tubers. The maximum yield of 26.66 tons ha.$^{-1}$ was recorded for hybrid TPS progeny, SH-53 x 396258/22-24. The minimum tuber yield of 11.33 tons ha.$^{-1}$ was recorded for OP TPS progeny, 396239-76. As a group, hybrids performed significantly better and give 25.80% more yield as compared to OP TPS progenies. Our results confirmed the findings of several earlier researchers who reported higher yields for hybrid TPS progenies as compared to OP TPS (Sangar and Upadhya, 1994; Love, 1997; Macaso-Khwaja and Peloquin, 1983). The lower tuber yields of OP progenies may be attributed to inbreeding depression, since they may be the result of self-pollination.

CHAPTER 6

PERFORMANCE OF SELECTED HYBRID AND OPEN POLLINATED F1C1 SEEDLING TUBERS AGAINST SEED TUBERS OF COMMERCIAL CULTIVARS ACROSS DIFFERENT AGRO-ECOLOGICAL ZONES OF NWFP.

Performance of selected hybrid and OP F_1C_1 seedling tubers against seed tubers of commercial cultivars across different agro-ecological zones of NWFP.

6.1. MATERIALS AND METHODS.

Eight F_1C_1 seedling tubers from the best progenies selected in experiment 3 (viz., 9805, SH-5, SH-53, SH-103, 9805 x SH-9, SH-5 x 9813, SH-53 x 396258/24 and SH-176 x 396239-76) were planted for evaluation against seed tubers of two commercial potato cultivars, Desiree and Cardinal, at three locations [viz., ARS, Mingora (950m asl), ARSS, Kalam (2075m asl) and Pallai (700m asl)] of NWFP. At Mingora, the experiment was planted as a spring crop on January 21, 2002; at Kalam the experiment was planted as a summer crop on May 18, 2002; and at Pallai the experiment was planted as an autumn crop on October 15, 2002. At all locations, the experiments were conducted in an RCB design with 4 replications. Each plot measured 4 X 1.4 m, having 2 rows with 70 cm row to row spacing and 20 cm plant to plant spacing. Fertilizer was applied @ 200:150:75 kg N:P:K ha^{-1} from Urea, DAP and SOP fertilizer sources. Half of the Nitrogen and all of the phosphorous and potash were applied at the time of seedbed preparation, whereas, the remaining half nitrogen was applied at the earthing-up stage. Recommended crop management practices (i.e., weeding, hoeing, irrigation etc.,) were followed to raise a good crop.

The following data was recorded at each location.

1. Emergence percentage.

Emergence percentages for the 10 potato genotypes/cultivars were calculated using the following formula.

$$\text{Emergence (\%)} = \frac{\text{Total number of plants emerged}}{\text{Total number of seedling tubers sown}} \times 100$$

2. Plant height (cm).

Plant height data in cm were recorded on 5 randomly selected plants in each plot at the time of harvest.

3. Disease (0-9 scale).

Data for disease incidence were recorded on a 0-9 scale, 0 for no disease and 9 being for 100% disease. Data were recorded on the incidence of three major potato diseases, i.e., Late blight (*Phytophthora infestans*), Bacterial wilt (*Pseudomonos solanacearum*) and Early blight (*Alternaria solani*) under natural field condition.

4. Days to harvest.

Days to harvest data were calculated for the number of days from sowing to harvest.

5. Number of tubers plant^{-1}.

The number of tubers plant^{-1} were recorded by counting number of tubers in five randomly selected plants in each plot and their means were computed.

6. Average tuber weight (g).

Ten tubers were randomly collected in each plot, weighed and average weight per tuber computed.

7. Yield ha.$^{-1}$ (tons).

Yield data was recorded by weighing all tubers produced in a 4 x 1.4 m plot and then converted to ha.$^{-1}$ using appropriate formula.

The data collected at various locations was pooled for a combined ANNOVA over locations to study genotype x environment interactions for various traits.

6.2. RESULTS.

6.2.1. Percent emergence.

Analysis of variance showed significant ($P \leq 0.05$) mean squares for locations and genotypes, whereas location x genotype interaction was significant at $P \leq 0.01$ (appendix 4.1). Among locations, the highest emergence of 84.05% was recorded at ARSS, Kalam, followed by 83.62% at ARS Mingora. The lowest emergence of 82.55% was recorded at Pallai (Table 6.1).

Table 6.1. Percent emergence of eight F_1C_1 TPS progenies and seed tubers of two commercial cultivars, planted at three different agro-ecological zones of NWFP.

Genotype	Location			Mean
	Mingora	Kalam	Pallai	
9805	85.25	87.00	83.25	**85.17**
SH-5	80.75	85.50	83.00	**83.08**
SH-53	82.75	82.25	85.50	**83.50**
SH-103	80.75	84.00	85.00	**83.25**
9805 x SH-9	84.25	82.75	86.00	**84.33**
SH-5 x 9813	83.25	82.50	80.50	**82.08**
SH-53 x 396258/22-24	83.25	85.00	84.00	**84.08**
SH-176 x 396239-76	84.25	86.00	82.75	**84.33**
Desiree	78.00	82.25	84.75	**81.67**
Cardinal	83.00	83.25	81.50	**82.58**
Mean	**82.55**	**84.05**	**83.62**	

LSD for location 1.03 ($P \leq 0.05$)
LSD for genotype 2.02 ($P \leq 0.05$)
LSD for G x L 2.03 ($P \leq 0.01$)

Among genotypes, the highest emergence of 85.17% followed by 84.33, 84.33 and 84.08% were recorded for the seedling tubers of 9805, SH-176 x

396239-76, 9805 x SH-9 and SH-53 x 396258/22-24, respectively. Seed tubers of cv., Desiree had the lowest emergence of 81.67% (Table 6.1).

Genotype by location interaction revealed the highest emergence of 87.0% and 86.0% for the seedling tubers of OP progeny, 9805 at Kalam and hybrid progeny, 9805 x SH-9 at Pallai, respectively. The lowest emergence of 78% was observed for cv., Desiree at Pallai (Table 6.1).

6.2.2. Plant height.

Statistical analysis of the data revealed non-significant differences among locations while genotypes and genotype x location interaction were highly significant (Appendix 4.2).

Mean plant height revealed the lowest value of 58.90 cm at Pallai and the maximum value of 59.77 cm, at Mingora (Table 6.2).

Among genotypes, the maximum plant height of 67.00 cm was recorded for OP 9805 followed by 64.92, 64.83 and 64.42cm, for hybrids SH-5 x 9813, 9805 x SH-9 and OP progeny SH-5, respectively. The minimum plant height of 52.58, was recorded for cv. Cardinal (Table 6.2).

Location by genotype interaction revealed the maximum plant height of 70.50 cm for OP genotype 9805 at Pallai, followed by 67.75, 67.00, 66.75 and 66.50 cm for OP progeny 9805 and hybrid SH-5 x 9813 at Kalam; hybrid progeny 9805 x SH-9 at Pallai and OP progeny SH-5 at Mingora, respectively. The minimum plant height of 50.25 cm was recorded for OP progeny, SH-103 at Pallai (Table 6.2).

Table 6.2. Plant height (cm) of eight F_1C_1 TPS progenies and seed tubers of two commercial cultivars, planted at three different agro-ecological zones of NWFP.

Genotype	Location			Mean
	Mingora	Kalam	Pallai	
9805	62.75	67.75	70.50	**67.00**
SH-5	66.50	61.50	65.25	**64.42**
SH-53	54.75	52.00	51.75	**82.83**
SH-103	55.00	57.00	50.25	**54.08**
9805 x SH-9	65.55	62.50	66.75	**64.83**
SH-5 x 9813	62.75	67.00	65.00	**64.92**
SH-176 x 396239-76	55.75	58.50	52.25	**55.50**
SH-53 x 396258/22-24	60.50	61.75	63.00	**61.75**
Desiree	55.50	55.45	52.00	**54.42**
Cardinal	51.50	54.00	52.25	**52.58**
Mean	**59.02**	**59.77**	**58.90**	**2.826**

LSD for location Non significant.
LSD for genotype 2.82 ($P \leq 0.01$)
LSD for G x L 4.82 ($P \leq 0.01$).

6.2.3. Disease.

Statistical analysis of the data for disease incidence showed significant mean square for location, highly significant mean square for genotypes and a non-significant mean square for location x genotype interaction (Appendix 4.3).

Among locations, the lowest disease incidence (0.55 on the scale) was recorded at Pallai, whereas high disease incidence of 1.05 and 0.85 were recorded at Kalam and ARSNM, respectively (Table 6.3).

Among genotypes all the TPS progenies, including hybrids and OP, had the lowest disease incidence and remained at par to each other. For TPS progenies, disease varied from 0.17 (OP 9805) to 0.75 (hybrid SH-5 x 9813). The highest disease incidence of 2.42 was recorded for cv. Cardinal followed by 1.75 by cv. Desiree (Table 6.3).

Genotype x location interaction was non-significant. However, mean comparison showed that some of the TPS progenies (viz., OP SH-5, OP 9805 and hybrid SH-176 x 396239-76 at ARSNM) developed no disease symptoms (0.0 on the scale). The highest disease incidence of 2.75 was observed for cv., Cardinal at Kalam (Table 6.3).

Table 6.3. Disease incidence (0-9 scale) of eight F_1C_1 TPS progenies and seed tubers of two commercial cultivars, planted at three different agro-ecological zones, NWFP.

Genotype	Location			Mean
	Mingora	Kalam	Pallai	
9805	0.00	0.25	0.25	**0.17**
SH-5	0.00	1.25	0.25	**0.50**
SH-53	0.75	0.25	0.50	**0.50**
SH-103	0.75	0.75	0.50	**0.67**
9805 x SH-9	0.25	1.00	0.25	**0.50**
SH-5 x 9813	1.00	1.00	0.25	**0.75**
SH-53 x 396258/22-24	1.00	0.25	0.25	**0.50**
SH-176 x 396239-76	0.00	1.00	0.25	**0.42**
Desiree	2.25	2.00	1.00	**1.75**
Cardinal	2.50	2.75	2.00	**2.42**
Mean	**0.85**	**1.05**	**0.55**	**0.627**

LSD for location 0.25 ($P \leq 0.05$)
LSD for genotype 0.63 ($P \leq 0.01$)
LSD for G x L Non significant

Days to harvest.

Analysis of variance for days to harvest revealed highly significant differences among locations, genotypes and location x genotype interaction (Appendix 4.4).

Among locations, the minimum days to crop harvest were recorded at Mingora (115.68 days). The maximum days to crop harvest were recorded at Kalam (121.45 days), Table 6.4.

Among genotypes, the minimum of 115.58 days to harvest were recorded for OP progeny SH-5 followed by 116.58, 116.67 and 116.75 days to harvest for hybrids SH-5 x 9813, SH-53 x 396258/22-24 and OP genotype SH-103, respectively. Hybrid, SH-176 x 396239-76 took the maximum of 122.42 days to harvest (Table 6.4).

Genotype by location interaction revealed the minimum days to harvest for OP SH-5 (111.50 days) at Mingora followed by OP SH-5 SH-5 x 9813 (112.75) at Kalam. The maximum of 124.24, days were recorded for OP 9805 at Kalam (Table 6.4).

Table 6.4. Days to harvest of eight F_1C_1 TPS progenies and seed tubers of two commercial cultivars, planted at three different agro-ecological zones of NWFP.

Genotype	Location			Mean
	Mingora	Kalam	Pallai	
9805	120.00	124.25	120.00	**121.42**
SH-5	111.50	113.25	122.00	**115.58**
SH-53	119.00	116.00	122.00	**119.00**
SH-103	114.25	117.00	119.00	**116.75**
9805 x SH-9	115.00	113.00	123.00	**117.00**
SH-5 x 9813	112.75	115.00	122.00	**116.58**
SH-53 x 396258/22-24	114.00	116.00	120.00	**116.67**
SH-176 x 396239-76	120.00	123.25	124.00	**122.42**
Desiree	115.25	118.25	120.00	**117.83**
Cardinal	115.00	115.00	122.50	**117.50**
Mean	**115.68**	**117.10**	**121.45**	

LSD for location 0.67 ($P \leq 0.01$)
LSD for genotypes 1.22 ($P \leq 0.01$)
LSD for G x L 2.12 ($P \leq 0.01$)

6.2.5. Number of tubers plant^{-1}.

Analysis of variance for the number of tubers plant^{-1} revealed significant ($P \leq 0.05$) mean square for locations and highly significant ($P \leq 0.01$) mean square for genotypes and location x genotype interaction (Appendix 4.5).

Among location, the highest number of tubers plant^{-1} were recorded at Pallai (9.86 tuber plant^{-1}) and followed by Kalam (9.60 tuber plant^{-1}). The lowest number of tubers plant^{-1} (8.86) was recorded at Mingora (Table 6.5).

Table 6.5. Number of tuber plant^{-1} for eight F_1C_1 TPS progenies and seed tubers of 2 commercial cultivars, planted at three different agro-ecological zones of NWFP.

Genotype	Location			Mean
	Mingora	Kalam	Pallai	
9805	7.20	8.75	9.38	**8.44**
SH-5	9.43	9.23	8.63	**9.09**
SH-53	10.57	9.50	10.19	**10.09**
SH-103	5.28	6.32	7.38	**6.32**
9805 x SH-9	10.70	11.15	11.68	**11.18**
SH-5 x 9813	8.07	10.65	10.25	**9.66**
SH-53 x 396258/22-24	10.30	11.00	11.32	**10.88**
SH-176 x 396239-76	11.50	9.93	10.45	**10.63**
Desiree	8.48	10.25	9.87	**9.53**
Cardinal	7.10	9.25	9.48	**8.61**
Mean	**8.86**	**9.60**	**9.86**	

LSD for location 0.65 ($P \leq 0.05$)
LSD for genotype 1.59 ($P \leq 0.01$)
LSD for G x L 1.80 ($P \leq 0.01$)

Among genotypes, all the four hybrid TPS progenies viz., 9805 x SH-9, SH-53 x 396258/22-24, SH-176 x 396239-76, OP progeny SH-53 and hybrid SH-5 x 9813 had the higher number of 11.18, 10.88, 10.63, 10.09 and 9.66 tuber plant^{-1}, respectively. The minimum (6.32 tubers plant^{-1}) was recorded for OP SH-103 (Table 6.5).

Genotype x location interaction revealed the maximum of 11.68 tuber plant^{-1} for hybrid 9805 x SH-9 at Pallai. The minimum of 5.28 tubers plant^{-1} was recorded for OP progeny, SH-103 at Mingora (Table 6.5).

6.2.6. Average tuber weight.

Statistical analysis of the data revealed highly significant ($P \leq 0.01$) mean squares for locations, genotypes and location x genotype interaction (Appendix 4.6).

Among locations, the maximum tuber weight of 80.27 g was recorded at Kalam. The minimum average tuber weight of 73.13 g was recorded at Pallai (Table 6.6).

Among genotypes, hybrids SH-5 x 9813 had the maximum average tuber weight of 84.12 g, followed by SH-53 x 396258/22-24 (82.52 g) and 9805 x SH-9 (80.3 g). The minimum tuber weight of 65.20 g was recorded for OP TPS progeny, SH-53, (Table 6.6).

Genotype x location interaction revealed the maximum average tuber weight of 86.95 for hybrid SH-5 x 9813followed by SH-53 x 396258/22-24 (85.15 at Kalam, respectively. The lowest tuber weight of 60.07 g was recorded for OP progeny SH-53 at Pallai (Table 6.6).

Table 6.6. Average tuber weight (g) of eight F_1C_1 TPS progenies and seed tubers of two commercial cultivars, planted at three different agro-ecological zones of NWFP.

Genotype	Location			Mean
	Mingora	Kalam	Pallai	
9805	75.27	83.02	78.12	**78.81**
SH-5	75.07	67.95	61.30	**68.11**
SH-53	63.15	72.37	60.07	**65.20**
SH-103	60.15	82.25	71.07	**71.15**
9805 x SH-9	80.20	82.05	78.67	**80.31**
SH-5 x 9813	83.15	86.95	82.25	**84.12**
SH-53 x 396258/22-24	82.15	85.15	80.25	**82.52**
SH-176 x 396239-76	83.15	82.25	72.10	**79.17**
Desiree	72.00	82.82	73.42	**76.08**
Cardinal	69.95	77.95	74.02	**73.97**
Mean	**74.42**	**80.27**	**73.13**	

LSD for location 1.12 ($P \leq 0.05$)
LSD for genotype 2.20 ($P \leq 0.01$)
LSD for G x L 3.81 ($P \leq 0.01$)

Tuber Yield ha.$^{-1}$(tons).

Analysis of variance revealed highly significant ($P \leq 0.01$) mean squares for locations, genotypes and location by genotype interaction (Appendix 4.7).

Among locations the highest yield of 21.77 tons ha.$^{-1}$ was recorded at Kalam. The lowest yield of 20.51 tons ha.$^{-1}$ were recorded at Mingora (Table 6.7).

Among genotypes, the maximum yield of 25.55 tons ha^{-1} followed by 24.66 and 24.04 tons ha^{-1} were recorded for hybrids SH-176 x 396239-76, SH-5 x 9813 and SH-53 x 396239-76, respectively. The lowest yield of 18.35 tons ha.$^{-1}$ was recorded for OP progeny SH-103 (Table 6.7).

Location x genotype interaction revealed the highest yield 26.66 tons ha^{-1} followed by 25.66 and 25.55 tons ha.$^{-1}$ for hybrid progenies, SH-176 x 396239-76 and SH-53 x 396258/22-24 at Kalam and SH-176 x 396239-76 at Mingora, respectively. The minimum yield 15.60 tons ha.$^{-1}$ was recorded for OP TPS progeny, SH-103 at ARS, Mingora.

Table 6.7. Yield ha.$^{-1}$ (tons) of eight F_1C_1 TPS progenies and seed tubers of two commercial cultivars, planted at three different agro-ecological zones of NWFP.

Genotype	Location			Mean
	Mingora	Kalam	Pallai	
9805	18.33	18.60	19.26	**18.73**
SH-5	19.11	19.55	19.37	**19.35**
SH-53	19.48	20.82	15.88	**18.73**
SH-103	15.60	17.67	21.82	**18.35**
9805 x SH-9	22.55	24.44	23.22	**23.40**
SH-5 x 9813	24.44	25.37	24.18	**24.66**
SH-53 x 396258/22-24	23.88	25.66	22.55	**24.04**
SH-176 x 396239-76	25.55	26.66	24.44	**25.55**
Desiree	18.26	19.00	19.22	**18.82**
Cardinal	17.78	20.00	17.77	**18.51**
Mean	**20.51**	**21.77**	**20.77**	

LSD for location 0.84 ($P \leq 0.01$)
LSD for genotypes 1.50 ($P \leq 0.01$)
LSD for G x L 2.68 ($P \leq 0.01$)

6.3. DISCUSSION.

Percent emergence.

Significant variation for percent emergence was observed for locations, genotypes and location by genotype interaction. The highest emergence of 84.05% was recorded at Kalam, as compared to the lowest of 82.55% at Mingora. Among genotypes, the highest emergence of 85.17% was recorded for the seedling tubers of OP TPS, 9805. The lowest emergence of 81.67% was observed for the seed tubers of cv. Desiree.

Genotype x location interaction revealed that emergence varied significantly for different genotypes at different locations. The maximum emergence of 87.0% was observed for the seedling tubers of OP genotype, 9805 at Kalam, whereas the lowest emergence of 78.0% was recorded for the seed tubers of cv. Desiree at Kalam. The variation in percent emergence of the potato genotypes can be attributed to the genetic as well as environmental factors at 3 different locations.

Plant height.

Non-significant differences for plant height were observed among locations; however, genotypes as well as genotype x location interactions were highly significant. Among genotypes, the maximum plant height of 67.0 cm was recorded for the seedling tubers of OP TPS progeny, 9805. The minimum plant height of 52.58 cm was observed for the seed tubers of cv. Desiree. Location x genotype interaction showed the maximum plant height of 70.5 cm for OP progeny 9805 at Kalam, whereas the minimum plant height 50.25 cm was recorded for OP progeny, SH-103 at Pallai. Similar results were reported earlier by Love et al. (1997) who observed taller TPS hybrids than cultivars. Elias et al. (1992) also reported significant variation in plant height of different TPS progenies, however a non-significant difference for two growing seasons.

Days to harvest.

Location, genotype and location x genotype interaction varied significantly for days to harvest. Collectively all the genotypes matured earlier at ARS, Mingora, followed by Kalam. Among genotypes, the OP progeny, SH-5 was earliest in maturity and took 115.58 days to harvest as compared to the maximum days of 122.42 by hybrid TPS progeny, SH-176 x 396239-76. Location x genotype interaction revealed the minimum of 111.50 days to harvest for OP

TPS progeny, SH-5 at ARS, Mingora, as compared to the maximum days of 124.25 by OP progeny 9805 at Kalam. Elias et al. (1992) reported 88.7 to 107.6 days to harvest for various hybrid and OP TPS, grown under two seasons.

Disease.

Significant variations for disease incidence were observed for locations and genotypes whereas location x genotype interaction was non significant. Minimum disease incidence was observed at Pallai, as compared to the other two locations. Among genotypes lower diseases were observed for crops grown from TPS as compared to crops grown from seed tubers. Genotypes x location interaction revealed no disease symptoms for OP progenies SH-5, 9805 and hybrid progeny SH-176 x 396239-76 at Mingora, The highest disease incidence was observed for the seed tubers of cv. Cardinal at Kalam. Upadhya et al. (1986) and Singh et al. (1997) reported similar results, which observed lower incidence of bacterial wilt and late blight on crops raised from TPS. Solomon et al. (2002) also reported resistance to fungi in 15 TPS progenies.

Number of tubers plant^{-1}.

Locations, genotypes and location x genotype interaction showed significant variations for the number of tubers plant^{-1}. Among locations, higher values for tuber plant^{-1} were observed at Kalam and Pallai as compared to Mingora. Among genotypes, the maximum number of tubers (11.18 tubers plant^{-1}) were recorded for the hybrid TPS progeny 9805 x SH-9, whereas, the minimum number of 6.32 tuber plant^{-1} were recorded for OP TPS progeny, SH-103. Genotype x location interaction revealed the highest (11.68 tuber plant^{-1}) for hybrid TPS progeny, 9805 x SH-9 at Pallai, whereas the lowest (5.28 tubers plant^{-1}) were observed for OP TPS progeny SH-103 at ARS, Mingora. Arevalo-Miranda (1999) reported higher tubers plant^{-1} for TPS ICA Narino of *andigena subsp* as compared to farmer's seed.

Average tuber weight.

Highly significant variations were observed for locations, genotypes and location x genotype interaction. Among locations, the maximum average tuber weight of 80.27 g was observed at Kalam, whereas the minimum average tuber weight of 73.13 g was observed at Pallai. Among genotypes, hybrid SH-5 x 9813 had the maximum (84.12 g) average tuber weight and OP SH-53 had the minimum average tuber weight (65.20 g). Genotype by location interaction revealed the maximum average tuber weight of 86.95 g for hybrid TPS progeny, SH-5 x 9813 at Kalam and the minimum average tuber of 60.15 g for OP TPS progeny, SH-103 at Mingora. Similar results were reported by Singh et al. (1986) who reported significant genotype x location interaction for average tuber weight of 15 potato varieties evaluated in 4 different environments.

Yield ha^{-1}.

The yield is a highly variable character and is influenced by location, Soil type, fertility and the genotype. Therefore, stability of a variety over a wide range of environments has considerable importance in potato crop improvements. Locations, genotypes and location x genotype interaction revealed significant differences for yield ha^{-1}. Among locations, the highest yield of 21.77 tons $ha.^{-1}$ was observed at Kalam as compared to the lowest yield of 20.51 tons $ha.^{-1}$ at Mingora. Among genotypes, the maximum yield of 25.55 tons $ha.^{-1}$ was observed for hybrid progeny, SH-176 x 396239-76, as compared to the minimum yield of 18.35 tons $ha.^{-1}$ for OP progeny, SH-103. On average, hybrids produced significantly more yield $ha.^{-1}$ as compared to OP progenies and seed tubers of cvs. Desiree and Cardinal. No significant differences in the yield of OP TPS progenies and seed tubers were observed. Similar results have been reported by Sangar, (1994); Dabas, et al (1994); Singh et al (1997); Subrata Upadhya, (1997) and Arevalo- Miranda (1999) who observed better yield performance for hybrid TPS progenies as compared to OP TPS and seed tubers.

Genotype x location interaction revealed the maximum yield of 26.66 tons ha^{-1} for hybrid progeny SH-176 x 396258-76 at Kalam and the minimum of 15.60

tons ha.-1 for OP progeny SH-103 at Mingora. Earlier researchers who observed significant genotype x location interaction for yield and yield contributing parameters in potato have reported similar results (Sawant and Mandlor, 1974 and Pandita and Siddhu, 1981). Kidane-Mariam et al. (1985) reported superior performance of TPS families at high altitudes (3300 m asl) as compared to lowers altitudes. The better performance of TPS progenies at Pallai as compared to Mingora may be due to the more favorable environment at Pallai during the sowing season. At Pallai, the experiment was planted in October-Feb. when nights are cool and days comparatively warm.

CHAPTER 7

SUMMARY

VII. Summary

The potato (*Solanum tuberosum L*) is planted on more than 105200 hectare in Pakistan and 9400 hecatre in NWFP. Our National as well as provincial potato yields are substantially less than developed countries and comparatively less than the other developing countries in the region. Seed is the most important input in potato production and accounts upto 60% of the total production cost. In NWFP, the limited availability of quality seed tubers to the small farm holders is a major reason for lower potato productivity. Keeping in view these facts, the present study was under taken to investigate the possibility of utilizing True Potato Seed as a seed source for commercial potato crop production in NWFP. To achieve these objectives a series of four experiments were conducted at different agro-ecological zones of NWFP, during 2000-2003.

Experiemnt 1 was conducted at ARSS, Kalam. Fourteen different potato genotypes were planted in a two row plot, replicated 4 times, during summer, 2000. Data on flowering phenology, reproductive biology and TPS production were recorded. The results indicated highly significant variation among the potato genotypes for all 12 characters under investigation. Days to flowering varied significantly from 53 days for 396258/22-24 to 81.75 for genotype, 9802. Days to flower completion ranged from 84.25 days for 396239-76 to 107 days for genotype, SH-103. Days to flowering duration ranged from the minimum of 12.25 days for genotype 9802 to 41.25 days for genotype SH-103. Pollen viability (%) ranged from17.75% for genotype SH 5 to the 43.0% for SH-103. Flower number plant^{-1} varied from 26.7 for SH-9 to 75.5 for SH-103. Number of berries plant^{-1} varied from the minimum of 4.5 for genotype SH-9 to 25.8 for genotype 9805. Percent fruit set data varied from the minimum of 16.8% for SH-9 to the maximum of 43.5% for SH-176. Berry diameter ranged from the minimum of 1.58 cm for genotype 396258/22-24 to 2.37 cm for cv. Desiree. Average berry weight varied from the minimum of 3.16 g for genotype 9802 to the maximum of 4.85 g for SH-70. The minimum of 88 seeds berry^{-1} were observed for cv. Desiree as compared to the maximum of 355 seeds berry^{-1} for SH-103. 100 seed weight

varied from the minimum of 66.9mg for cv. Desiree to the maximum of 97.7mg for SH-103. True potato seed was the maximum for SH-103 (4.20 g plant^{-1}) and minimum for genotype SH-9 (0.20 mg plant^{-1}). Five hybrid TPS viz., SH-103 x 9743, SH-176 x 396239-76, SH-53 x 396258/24-22, SH 5 x 9813 and 9805 x SH-9 were developed.

Experiment 2 was conducted to produce F_1C_1 seedling tubers from the true potato seed collected in Experiment 1. In spring 2001, the OP and hybrid TPS, were planted in a 1 x 1 m raised seedbed in an RCB design, at ARS, Mingora. Data were recorded on six parameters and individual mean comparison as well as group comparison of OP vs, hybrids were computed. Significant differences were observed for all the characters. TPS emergence was maximum for SH-103 (84.50 %) and minimum for 396239-76 (64.50 %), whereas hybrid vs. OP comparison was non significant. Seedling vigor ranged from 5.50 to 7.50 for 396239-76 and SH-176 x 396239-76, respectively, as a group hybrids were significantly more vigorous than OP TPS. Plant height varied significantly from the minimum of 45.00 cm for SH -5 to the maximum of 62.25 cm for SH 5 x 9813. In group comparison, hybrids were significantly taller than OP TPS. Days to harvest were minimum for SH-5 (112.50 days) and maximum for SH-176 x 396239-76 (129 days), whereas hybrid vs. OP TPS comparison was non significant. The maximum number of seedling tubers plot^{-1} was recorded for SH-5 x 9813 (589) as compared to the minimum of 209 seedling tubers plot^{-1} for 396239-76. Hybrid vs. OP comparison revealed significantly more seedling tuber plot^{-1} for hybrids than OP TPS. Seedling tuber yield m^2 was maximum for SH-5 x 9813 (7.93 kg m^2) and minimum for 9743 (3.82 kg m^2). For group comparison, hybrids produced significantly more yield plot^{-1} than OP TPS.

In experiment 3, the F_1C_1 seedling tubers produced from 14 TPS genotypes in experiment 2 were used as the planting material. The experiment was conducted in an RCB design with 4 replications. Recommended cultural practices for growing a ware potato crop were adopted. Analysis of the data revealed significant differences among F_1C_1 TPS progenies for all the characters, except percent germination. The minimum of 40 days to 80% ground cover were recorded for two hybrids and one OP genotype, where as the maximum of 50.50 days were recorded for SH-103. Group comparison revealed less days to 80% ground cover for hybrids than OP progenies. The maximum plant height of 70 cm was recorded for 88002 and the minimum of 38.80 cm for SH-176. For group comparison, hybrids were significantly taller than OP progenies. Statistically significant but lower diseases were observed on TPS progenies. Hybrid vs. OP comparison was non significant for disease. Days to harvest were minimum (116 days) for 396239-76 and maximum (122 days) for two OP and two hybrid progenies. As a group, OP progenies matured earlier than hybrid progenies. The maximum number of main stems plant^{-1} was observed for SH-176 x 396239-76 (2.92) and the minimum of 1.88 main stems plant^{-1} for SH-103. Group comparison revealed significantly more main stems plant^{-1} for hybrid progenies than OP progenies. Number of tuber plant^{-1} was maximum (13.20) for hybrid SH-176 x 396239-76 and minimum (6.00) for 396239-76. In group comparison, hybrids had significantly more tubers plant^{-1} than OP progenies. The maximum average tuber weight of 85.37g was recorded for SH 5 x 9813 and the minimum (48.00 g) for 88002. As a group, hybrids had significantly higher average tuber weight than OP progenies. The maximum yield of 26.66 tons ha^{-1} was recorded for SH-53 x 396258/22-24 and the minimum yield of 11.33 tons ha^{-1} was recorded for 396239-76. In group comparison, significantly higher yield was recorded for hybrids than OP genotypes.

In experiment 4, the high yielding F_1C_1 seedling tuber progenies evaluated in experiment 3 and seed tubers of two commercial varieties, Desiree and Cardinal were planted in an RCB design for ware potato crop at three different agro-ecological zones of NWFP. viz., Mingora, Kalam and Pallai. Locations were significantly different for percent germination, disease incidence, days to harvest, tubers plant^{-1}, average tuber weight and yield ha^{-1}, whereas plant height was non significant. Among location, emergence was maximum (84.05%) at Kalam and minimum (82.55%) at Pallai. Disease was maximum (1.05) at Kalam and minimum (0.55) at Pallai. Days to harvest were maximum (121.45 days) at Pallai and minimum (115.60 days) at Mingora. Number of tuber plant^{-1} were maximum

(9.86) at Pallai and minimum (8.36) at Mingora. Average tuber weight was maximum (80.27 g) Kalam and minimum (73.13 g) at Pallai. Tuber yield per plot^{-1} was maximum (9.80 kg) at Kalam and minimum (9.23 kg) at Mingora. Among genotypes, significant variations were observed for all the characters studied. Maximum emergence (85.17%) was observed for 9805 and minimum (81.67%) for Desiree. Maximum plant height (67.05cm) was observed for 9805 and minimum (52.58 cm) for Cardinal. Maximum disease incidence (2.42) was observed for Cardinal and the minimum (0.17) for 9805. Days to harvest were maximum (122.42 days) for SH-176 x 396239-76 and minimum (115.50 days) for SH 5. Number of tuber plant^{-1} was maximum (11.18) for 9805 x SH-9 and minimum (6.32) for SH-103. Average tuber weight was maximum (84.12g) for SH 5 x 9813 and minimum (62.20 g) for SH-53. Yield ha^{-1} was highest (25.50 tons) for SH-176 x 396239-76 and lowest (18.35 tons) for SH-103. Genotype x location interaction revealed significant differences for percent germination, disease incidence, days to harvest, number of tubers plant^{-1}, whereas non-significant differences were observed for plant height.

LITERATURE CITED

Literature Cited

Abera, G. 1997. True potato seed: a low cost alternative technology for potato production in the Bako area. IAR Newsletter of Agricultural Research. 12: 9-10.

Abeytunge, S. 1992. Selection of open pollinated lines for true potato seed production. Tropical Agriculturist. 148: 23-26.

Abeytunge, S. 1992. Comparison of open pollinated and hybrid true potato seed progenies for tuber yield and uniformity. Tropical Agriculturist. 148: 37-52.

Ahmad, K. U. 1977. Potatoes for the Tropics. Mumtaj Kamal, Dacca, Bangladesh, pp240.

Alacho, F.O., R.M. Kajuhanzire, R.C. Kanzikwera, and L.C. Sikka. 1995. Experiences in TPS research and development in Uganda. True potato seed in the Middle East and Africa. Proceedings of an international workshop held at Cairo, Egypt. pp. 83-93.

Almekinders, C. and S. Wiersema. 1985, TPS production: true potato seed. Letter, International potato centre, Lima, peru. 6: 1-2

Almekinders, C.J.M., A.S. Chilver, and H.M. Renia. 1996. Current status of the TPS technology in the world. Potato Research. 39: 289-303.

Arevalo-Miranda, A. C. 1999. New technique for production of seed potatoes of high sanitary quality. Fitopatologia Colombiana. 23: 1-2, 95-100.

Arthur, J.C. (1892). The relation of number of eyes on the seed tubers of potatoes to the product. Indiana Sta. Bulletin. 42. 105-118

Bates, G.H, 1935. A study of the factors influencing size of the potato tubers. J.Agric.Sci., Camb, 297-313.

Bienz, D.R. 1958. The influence of environmental factors and pollinating techniques on the success of potato pollination in the green house. Am. Potato J. 35:377-385.

Berga, L., G. Endale, K. Bekele, B. Lemaga, E. Gebre, B. Kassa, B. Hardy, P. Malagamba, and C. Martin. 1995. True potato seed research in Ethiopia and future trends. True potato seed in the Middle East and Africa. Proc. of an international workshop held at Cairo, Egypt. pp. 35-52.

Buhr, H. 1961. Biologie and Oklogie met Beruch-sichtigung phsiologischer Fragen. In R. Schick and M. Klinkowski (eds) Die Kartofell vol., Berlin. pp. 47-189.

Carputo, D., and L. Frusciante. 1995. Comparison between two agronomic systems in potato production from true potato (Solanum tuberosum L.) seed in southem Italy. Rivista-di-Agronomia. 29: 42-47

Carputo, D., M. Pentimalli, and L. Frusciante. 1996. Production and use of seedling tubers from true potato seed (TPS) for potato cultivation in Italy. Potato Research. 1996, 39: 3-10.

Carputo, D., A. Barone, T. Cardi, P. Garreffa and L. Frusciante 1997. True potato seed (TPS) as an alternative technique for potato production in the Mediterranean area. Annali della Facolta di Scienze Agrarie della Universita degli Studi di Napoli, Portici. 31: 29-37.

Castillo, J., A. Estevez, M.E. Gonzalez, M. Florid, R.M. Lara, and J.L. Salomon 2001. Intraspecific variability in tetrabloid varieties (4x) of potato *tuberosum*. Cultivos Tropicales. 22: 37-41.

Chilver, A., T. Walker, V. Khatana, H. Fano, R. Suherman and A. Rizk. 1999. On-farm profitability of true potato seed (TPS) utilization technologies.

Chaudhury, E.H. 1991. Methods of potato production through true seed in Bangladesh. Proc. of the First National workshop on tuber crops (Quasim, A. eds.)

Cho, M.H., S.Y. Ahu, H.Y. Kim-Lee and I.J. MOK. Genetic diversification through interspecific crosses between *solanum tuberosum* haploids and Wild species in potatoes. Proceeding of the Fourth APA Triennial conference. (Raso, E.T., F.B. Aromin and C.H. Balatero eds.) Vol. 2:137-139.

CIP, 1983. True Potato Seed: an Alternative Method for Potato production. International Potato Center Slide Training Series III-I P.O. Box 5969, Lima Peru

Clarke, A.E. and F.J. Stevenson 1943. Factors effecting the emergence of seeds of the potato. Am. Potato J, 20:247-258.

Dabas, J.P.S., N. Hira, M.S. Kadian, and H. Nand. 1994. Performance of true potato seed under lab to land on-farm demonstrations in Meerut. Potato: present & future. Proc. National Symposium held at Modipuram. (eds. G.S. Shekhawat, S.M.P. Khurana, S.K. Pandey and V.K. Chandla)pp. 74-72.

Devaux, A. 1989. Potential for potato production from true seed in Pakistan. Published by Pak-Swiss Potato Development Project, Pakistan Agricultural Research Council Islamabad. pp 112-122.

El-Amin, S.M., B. Adam, E. Varis, and E. Pehu. 1996. Production of seedling tubers derived from true potato seed and their use as seed tubers in the Sudan. Experimental-Agriculture. 32: 419-426.

El-Bedewy, R., B. Hardy, P. Malagamba and C. Martin. 1995. Seedling tubers and potato production from true potato seed: a new technique for the crop in Egypt. True potato seed in the Middle East and Africa. Proc. of an international workshop held at Cairo, Egypt, pp. 25-34.

Elias, M., S. Sarker, M.G.S. Torofder and R.U. Miah. 1992. Evaluation of true potato seed (TPS) progenies for the potato production in Jamalpur, Bangladesh. Pak. J. Agri. Res. 13: 255-259.

Elias, M. S. Sarker, and B.R. Banik. 1995. Genotype X environment interaction of true potato seed (TPS) progenies. Indian J. Agri. Res. 29: 79-82.

Fehr, R. W., 1987. Principles of Cultivar Development. Macmillan Publishing Company, New York, USA. Pp,145-146.

Gisela, C., J.L. Arndt, H.M. Rueda, Kidane-Mariam. And S.J. Peloquin. 1990. Pollen fertility in relation to open pollinated true seed production in potatoes. Am. Potato J. 67: 499-505.

Golmirzaie, A.M., R. Ortiz, G.N Atlin, and M. Iwanaga. 1998. Inbreeding and true seed in tetrasomic potato. I. Selfing and open pollination in Andean landraces (*Solanum tuberosum* Gp. *Andigena*). Theoretical and Applied Genetics. 97: 1125-1128.

Gopal, J. 1994. Flowering behavour, male sterility and berry setting in Tetraploid *Solanum tuberosum* germplasm. Emphytica. 72:133-142

Gopal, J. 1994. Genetic resources of potato: Flowering and fruiting behavior in North-Western plains of India. J. Indian Potato Assoc. 21: 211-215.

Gopal, J., S.S. Thakur, and V. Kumar. 2001. Evaluation of potato germplasm for characters important in TPS production. J. Indian Potato Assoc. 28:11-12.

Harris, P.M. 1992. The potato crop: the scientific basis for improvement. Chapman & Hall. PP. 403

Hossain, M.M., and M.M. Rashid. 1994. Raising of seedlings from true potato seed (TPS) as affected by different growth media. Bangladesh J. Sci. & Ind. Res. 29: 162-165.

Hossain, M.M., and M.A.A. Mondal. 1994. On farm trial with seedling tubers derived from true potato seed (TPS). Bangladesh J. Sci. & Ind. Res. 29: 193-197.

Joseph, T.A, R.K. Birhman, H.S. Chuhan and J. Gopal 1994. Effect of substrate and Gibberllic acid treatment on emergence of true potato seed. In Potato: Present to future (Eds. GS Shekwat, SM Paul Khurnana, SK Pandey & V.K Chandla), Indian Potato Asso, Shinld. (India).

Kadian, M.S., P.K. Patel, M.D. Upadhya and K.C.Thaem 1987. Evaluation of TPs progenies for the potato production in Dessa (Gujrat). J. India potato Assoc. 14:57-59.

Kadian, M.S., P.C. Pande, and M.D. Upadhya. 1996. Production and utilization of autumn and spring TPS (true potato seed) seedling tubers. J. Indian Potato Assoc. 23: 62-67.

Kidane- Mariam, H.M., H.A. Mendoza and R.O. Wissar. 1985. Performance of true potato seed derived from intermating tetraploid parental lines. Am Potato J. 62:643-651.

Khan, I.A. 1998. Studies on the performance of various TPS families and suitability of seedling tubers as seed tubers in potato cultivation. Progressive Horticulture. 30: 3-4, 211-213.

Khurana, S.C., and A.K. Bhatia. 1994. Performance of TPS families at Hisar. J. Indian Potato Assoc. 21: 243-246.

Lama,T. M.P. Chaturvedi, R.L. Mandal, S.P. Dhakal, and M.S. Kadian 1998. On-farm true potato seed (TPS) technology in Nepal. J. Indian Potato Assoc. 25: 131-133.

Love,S.L., B.K. Werner, H.I. Groza, and J.A. Thompson. 1997. Performance of commercially available true potato seed hybrids grown from tubers. HortScience 32: 728-732.

Lozoya-Saldana, H., and I. Miranda-Velazquez. 1987. Growth regulators photoperiod and flowering in potatoes. Am. Potato J. 64: 377-382.

Macaso-Khwaja, A.C. and S.J. Peloquin. 1983. Tuber yields of families from open pollinated and hybrid true potato seed. Am. Potato. J. 60:645-651.

Madalageri, M.B. 1999. True potato seed (TPS) technology for rainfed vertisols. V. Economics of crop production from TPS transplanting method vis-a-vis seed tuber planting method. Advances in Plant Science Research in India. 10: 29-32.

Malagamba, P. 1983. Reducing the effect of stress during the establishment and growth of potatoes from true seed in hot climates. In W.L. Hooker (Eds.). Research for the potato in the year 2000. CIP, Lima, Peru.

MINFAL. 2002. Agricultural Statistics of Pakistan. Published by Ministry of Food, Agriculture and Livestock (MINFAL), Economic Wing, Govemment of Pakistan, Islamabad.

Marinus, J. and Bodlaender, K.B.A. 1975. Response of some potato varieties to temperature. Potato Research. 18:189-204.

Pande, P.C., M.S. Kadian, M.D. Upadhya, J. Singh, and J. Singh. 1994. Production and utilization of true potato seedling tubers. Potato: present & future. Proceedings of the National Symposium held at Modipuram, India, March 1-3, 1993 [edited by Shekhawat, G. S.; Khurana, S. M. P.; Pandey, S. K.; Chandla, V. K.].

Pandita, M.L. and A.S. Siddhu. 1981. Genotype environment interaction, heritibility and genetic advanced for yield and other quantitative characters in potato. H.A.U.J. Res. 11.540-541.

Patel, P.K., L.D. Parmar, J.B. Patel, S.K. Pandey, and SMP. Khurana. 2000. Optimum planting period of parental lines for production of hybrid TPS in Northern Gujarat. J. Indian Potato Assoc. 27: 65-67.

Patterson, C.F. 1953. A method of obtaining fruits in the potato variety Russet Burbank. Am. Potato J. 30:89-91.

Pushkarnath. 1976. Potato in sub-tropics. Orient Longman, New Delhi, pp.289.

Rahimi, F.R., and C.D. Garter. 1989. Preventation of flower abscission after pollination in *Solanum tuberosum* cv. Katahdin. Am. Potato J. 66: 47-51.

Sadik, S. 1983. Potato production from true seed-present and future. In W.J. Hookers (ed.) Research for the potato in the year 2000. International Potato Center, Lima, Peru. pp.18-25

Salahuddin, A.B.M. 2000. The progress of research on potato and its status in Bangladesh. Potato Global Research and Development: Proceedings of the Global conference on potato, New Delhi, India. (S.M.P. Khurana, G.S. Shekhawat, B.P. Singh and S.K. pandey eds.),pp.156-162.

Salomon, J.L., A. Estevez, M.E. Gonzalez and J.G. Castillo. 2002. Performance of potato (*Solanum tuberosum L.*) hybrid progenies derived from true seed. Cultivos Tropicals. 23:59-61.

Sangar, R.B.S. 1994. Potato production from TPS tuberlets in central India. Orissa J. Horticulture. 22: 22-25.

Sangar, R.B.S. 1995. Performance of TPS progenies in central India. Orissa J. Horticulture. 1: 108-111.

Sangar, R.B.S., and M.D. Upadhya. 1994. HPS-7/13: a promising TPS hybrid for potato production in northern hill region of Chhatisgarh, Madhya Pradesh. J. Indian Potato Assoc. 21: 122-124.

Sathiyamoorthy, P., and S. Nakamura. 1995. Effect of gibberellic acid and inorganic salts on breaking dormancy and enhancing emergence of true potato seed. Seed Research. 23: 5-7.

Sawant, A.R. and K.K. Mandbi –1974. Genotype x environment interaction, heritibility and genetic advance for yield of potato (*Solanum tuberosum* L). Indian J. Agri. Sci. 44:159-164.

Shah, S.M.A., and N. Jan. 1987. Preliminary investigations on growing potatoes from true potato seed. Pak. J. Agri. Res. 8:211-213.

Sharma, Y.K. 1999. Studies on genetic variability and performance of true potato seed populations. Crop Research Hisar. 18: 412-418.

Shonnard, G.C., and S.J. Peloquin. 1991. Performance of true potato seed families. 2. Comparison of transplants vs. seedling tubers. Potato Research. 34:409-418.

Sikka, L. and R. Kanzikwera. 1993. Recent advances in *solanum* potato improvement in Uganda. Uganda-J. Agricultural Sci. 1: 29-35.

Sikka, L.C., A.S. Bhagari, J.M. Ssebuliba, and R. Kanzikwera. 1994. Potato production from true potato seed. Acta-Horticulturae. 380: 484-489.

Singh, J., P.C. Pande, J.S. Grewal, and J. Singh. 1994. 'MST-1' - a potential open-pollinated TPS line. Potato: present & future. Proceedings of the National Symposium held at Modipuram, India. (Shekhawat, G. S.; Khurana, S. M.P.; Pandey, S. K.; Chandla, V. K. eds.).

Singh, K., V.K. Bahal and K. Singh. 1997. Performance of TPS progenies for ware potato production in North-East hills. J. Indian Potato Assoc. 24: 148-153.

Song Bofu, Qu Dong Yu, and P. Vander Zaag. 1987. True Potato Seed in China: Past, Present and Future. Am Potato J. 64:321-327.

Souibgui, M., B. Hardy, P. Malagamba, and C. Martin. 1995. Performance of TPS in Tunisia. True potato seed in the Middle East and Africa. Proceedings of an international workshop held at Cairo, Egypt. pp. 57-73.

Stow, I. 1927. A cytological study on pollen sterility in *Solanum tuberosum* L Jap. J. Bot. 3:217-237.

Subrata, M., and M.D. Upadhaya. 1997. True potato seed in potato production in West Bengal. Environment and Ecology. 15:646-649.

Swamy, H.N.S., and K.S. Krishnappa. 1995. Studies on growth yield of TPS genotypes in Southern Karnataka. South Indian Horticulture. 43: 5-6.

Thijn, G.A. 1954. Observations on flower induction with potato. Euphytica. 3:28-34.

Upadhya, M.D., T.R. Dayal, R. Chandra, and A.N. Singh. 1986. Potential of true potato seed (TPS) for producing commercial crop in India. J. Indian Potato Assoc. 13:29-34.

Upadhya, M.D. 1994. True Potato Seed: Propagule for potato production in 21st Century. Potato: present & future. Proc. National Symposium held at Modipuram. (eds. G.S. Shekhawat, S.M.P. Khurana, S.K. Pandey and V.K. Chandla)pp. 15-22.

Vander Zaag, P., B. Susana, Z. Ganga and S. Gayao. 1989. Field evaluation of True Potato Seed Progenies in the Philippines. Am Potato J. 66:109-117.

Verma, R.B., and R.D. Singh. 1996. Performance of TPS progenies for seedling tuber production in nursery beds. J. Indian Potato Assoc. 23: 59-61.

Wiersema, S.G. 1986. The effect of density on tuber yielding in plant grown from TPS in seedbeds during two contrasting seasons. Amer. Potato J. 63: 465-471.

Wiliams, E.J. 1955, Seed failure in the Chippewa variety of Solanum tuberosum. Bot. Gaz, 117: 10-15.

APPENDICES

Appendix 1.1. Analysis of Variance for days to flowering of 14 potato genotypes planted at Agricultural Research Substation, Kalam, during summer, 2000.

Source	DF	SS	MS	F Value	Significance
Replication	3	4.86	1.62	1.22	
Genotype	13	2499.21	192.25	145.18	**
Error	39	51.64	1.32		
Total					

Coefficient of variation = 1.72%

Appendix 1.2. Analysis of Variance for days to flower completion of 14 potato genotypes planted at Agricultural Research Substation, Kalam, during summer, 2000.

Source	DF	SS	MS	F Value	Significance
Replication	3	19.48	6.49	2.20	
Genotype	13	3488.80	268.37	90.80	**
Error	39	115.27	2.96		
Total	55	3623.55			

Coefficient of variation = 1.82%

Appendix 1.3. Analysis of Variance for flowering duration of 14 potato genotypes planted at Agricultural Research Substation, Kalam, during summer, 2000.

Source	DF	SS	MS	F Value	Significance
Replication	3	1.86	0.62	0.11	
Genotype	13	3194.86	245.76	43.14	**
Error	39	222 14	5.70		
Total	55	3418.86			

Coefficient of variation = 8.63%

** Significant at $P \leq 0.01$

Appendix 1.4. Analysis of Variance for percent pollen viability of 14 potato genotypes planted at Agricultural Research Substation, Kalam, during summer, 2000.

Source	DF	SS	MS	F Value	Significance
Replication	3	12.48	4.16	0.29	
Genotype	13	8191.37	630.11	44.41	**
Error	39	553.27	14.19		
Total	55	8757.12			

Coefficient of variation = 9.75%

Appendix 1.5. Analysis of Variance flowers plant^{-1} of 14 potato genotypes planted at Agricultural Research Substation, Kalam, during summer, 2000.

Source	DF	SS	MS	F Value	Significance
Replication	3	16.34	5.45	0.70	
Genotype	13	12751.73	980.9	126.29	**
Error	39	302.91	7.77		
Total	55	13070.98			

Coefficient of variation = 5.36%

Appendix 1.6. Analysis of Variance for berries plant^{-1} of 14 potato genotypes planted at Agricultural Research Substation, Kalam, during summer, 2000.

Source	DF	SS	MS	F Value	Significance
Replication	3	5.00	1.67	0.4262	
Genotype	13	2882.21	221.71	56.69	**
Error	39	152.50	3.91		
Total	55	3039.71			

Coefficient of variation = 14.05%

** Significant at $P \leq 0.01$

Appendix 1.7. Analysis of Variance for percent fruit set of 14 potato genotypes planted at Agricultural Research Substation, Kalam, during summer, 2000.

Source	DF	SS	MS	F Value	Significance
Replication	3	41.70	13.90	0.83	
Genotype	13	4246.20	326.63	19.53	**
Error	39	652.38	16.73		
Total	55	4940.28			

Coefficient of variation = 15.79%

Appendix 1.8. Analysis of Variance for berry diameter of 14 potato genotypes planted at Agricultural Research Substation, Kalam, during summer, 2000.

Source	DF	SS	MS	F Value	Significance
Replication	3	0.006	0.002	0.1222	
Genotype	13	1.956	0.150	8.519	**
Error	39	0.689	0.018		
Total	55	2.651			

Coefficient of variation = 6.99%

Appendix 1.9. Analysis of Variance for berry weight of 14 potato genotypes planted at Agricultural Research Substation, Kalam, during summer, 2000.

Source	DF	SS	MS	F Value	Significance
Replication	3	0.009	0.003	0.483	
Genotype	13	14.383	1.106	187.562	**
Error	39	0.230	0.006		
Total	55	14.622			

Coefficient of variation = 1.98%

** Significant at $P \leq 0.01$

Appendix 1.10. Analysis of Variance for seeds berry^{-1} of 14 potato genotypes planted at Agricultural Research Substation, Kalam, during summer, 2000.

Source	DF	SS	MS	F Value	Significance
Replication	3	156.62	52.21	0.41	
Genotype	13	507104.30	39008.02	309.36	**
Error	39	4917.62	126.09		
Total	55	512178.55			

Coefficient of variation = 5.53%

Appendix 1.11. Analysis of Variance for 100 seed weight of 14 potato genotypes planted at Agricultural Research Substation, Kalam, during summer, 2000.

Source	DF	SS	MS	F Value	Significance
Replication	3	21.66	7.22	0.81	
Genotype	13	14599.40	1123.03	125.56	**
Error	39	348.81	8.94		
Total	55	14969.88			

Coefficient of variation = 4.15%

Appendix 1.12. Analysis of Variance for days to TPS yield plant^{-1} of 14 potato genotypes planted at Agricultural Research Substation, Kalam, during summer, 2000.

Source	DF	SS	MS	F Value	Significance
Replication	3	2.56	0.85	5.70	
Genotype	13	332.92	25.61	171.12	**
Error	39	5.84	0.15		
Total	55	341.31			

Coefficient of variation = 15.90%

** Significant at $P \leq 0.01$

Appendix 2.1. Analysis of Variance for percent emergence of 5 hybrid and 9 OP potato genotypes planted for seedling tuber production at Agricultural Research Station, Mingora, during spring, 2001.

Source	DF	SS	MS	F Value	Significance
Replication	3	11.21	3.74	0.21	
Genotype	13	1624.71	124.98	7.02	**
(*Hyb vs. OP*)	(*1*)	(43.21)	43.21	2.51	N.S.
Error	39	694.28			
Total	55	2330.21			

Coefficient of variation = 5.46%

Appendix 2.2. Analysis of Variance for seedling vigor of 5 hybrid and 9 OP potato genotypes planted for seedling tuber production at Agricultural Research Station, Mingora, during spring, 2001.

Source	DF	SS	MS	F Value	Significance
Replication	3	0.48	0.16	0.31	
Genotype	13	36.80	2.83	5.45	**
(*Hyb vs. OP*)	(*1*)	(19.37)	19.37	37.25	**
Error	39	20.27	0.52		
Total	55	57.55			

Coefficient of variation = 10.07%

Appendix 2.3. Analysis of Variance for seedling plant height of 5 hybrid and 9 OP potato genotypes planted for seedling tuber production at Agricultural Research Station, Mingora, during spring, 2001.

Source	DF	SS	MS	F Value	Significance
Replication	3	18.57	6.91	1.03	
Genotype	13	5182.71	398.67	66.32	**
(*Hyb vs. OP*)	(*1*)	(2732.29)	2732.29	454.62	**
Error	39	234.43	6.01		
Total	55	5435.71			

Coefficient of variation = 5.12%

N.S. on significant; ** Significance at P $\leq$0.01.

Appendix 2.4. Analysis of Variance for days to harvest of 5 hybrid and 9 OP potato genotypes planted for seedling tuber production at Agricultural Research Station, Mingora, during spring, 2001.

Source	DF	SS	MS	F Value	Significance
Replication	3	2.77	0.92	0.27	
Genotype	13	882.73	67.90	20.14	**
(Hyb vs. OP)	*(1)*	(33.16)	33.16	8.93	**
Error	39	131.48	3.37		
Total	55	1016.98			

Coefficient of variation = 1.49%

Appendix 2.5. Analysis of Variance for number of seedling tubers per M^2 of 5 hybrid and 9 OP potato genotypes planted for seedling tuber production at Agricultural Research Station, Mingora, during spring, 2001.

Source	DF	SS	MS	F Value	Significance
Replication	3	357.34	119.11	0.48	
Genotype	13	924985.30	71152	291.03	**
(Hyb vs. OP)	*(1)*	(509007.6)	509007	2081.9	**
Error	39	9534.91	244.48	5	
Total	55	934877.55			

Coefficient of variation = 4.03%

Appendix 2.6. Analysis of Variance for seedling tuber yield $plot^{-1}$ of 5 hybrid and 9 OP potato genotypes planted for seedling tuber production at Agricultural Research Station, Mingora, during spring, 2001.

Source	DF	SS	MS	F Value	Significance
Replication	3	0.385	0.13	2.38	
Genotype	13	93.38	7.18	133.19	**
(Hyb vs. OP)	*(1)*	(62.41)	62.41	115.74	**
Error	39	2.10	0.05		
Total	55	95.87			

Coefficient of variation = 4.40%

** Significance at P ≤ 0.01.

Appendix 3.1. Analysis of Variance for percent emergence of 5 hybrid and 9 OP potato genotypes planted for ware potato production at Agricultural Research Station, Mingora, during spring, 2001.

Source	DF	SS	MS	F Value	Significance
Replication	3	12.21	4.07	0.37	
Genotype	13	216.36	16.64	1.53	N.S.
(Hyb vs. OP)	*(1)*	(-)			
Error	39	422.78	10.48		
Total	55	651.36			

Coefficient of variation = 3.91%

Appendix 3.2. Analysis of Variance for days to 80% ground cover of 5 hybrid and 9 OP potato genotypes planted for ware potato production at Agricultural Research Station, Mingora, during spring, 2001.

Source	DF	SS	MS	F Value	Significance
Replication	3	8.05	2.68	0.67	
Genotype	13	718.09	55.24	13.84	**
(Hyb vs. OP)	*(1)*	(130.29)	130.29	32.63	**
Error	39	155.70	3.99		
Total	55	881.84			

Coefficient of variation = 4.50%

Appendix 3.3. Analysis of Variance for Disease incidence of 5 hybrid and 9 OP potato genotypes planted for ware potato production at Agricultural Research Station, Mingora, during spring, 2001.

Source	DF	SS	MS	F Value	Significance
Replication	3	0.36	0.12	0.35	
Genotype	13	20.43	1.57	4.66	**
(Hyb vs. OP)	*(1)*	(0.041)	0.041	0.21	N.S.
Error	39	13.14	0.34		
Total	55	33.93			

Coefficient of variation = 35%

N.S. non significant; ** Significant at P ≤0.01.

Appendix 3.4. Analysis of Variance for plant height of 5 hybrid and 9 OP potato genotypes planted for ware potato production at Agricultural Research Station, Mingora, during spring, 2001.

Source	DF	SS	MS	F Value	Significance
Replication	3	14.14	4.71	0.33	
Genotype	13	5617.43	432.11	30.65	**
(*Hyb vs. OP*)	(*1*)	(662.41)	662.41	46.96	**
Error	39	549.86	14.10		
Total	55	6181.43			

Coefficient of variation = 7.05%

Appendix 3.5. Analysis of Variance for stem density of 5 hybrid and 9 OP potato genotypes planted for ware potato production at Agricultural Research Station, Mingora, during spring, 2001.

Source	DF	SS	MS	F Value	Significance
Replication	3	0.57	0.19	1.09	
Genotype	13	5.12	0.39	2.26	*
(*Hyb vs. OP*)	(*1*)	(4.90)	4.90	28.2	**
Error	39	6.77	0.17		
Total	55	12.46			

Coefficient of variation = 17.36%

Appendix 3.6. Analysis of Variance for days to harvest of 5 hybrid and 9 OP potato genotypes planted for ware potato production at Agricultural Research Station, Mingora, during spring, 2001.

Source	DF	SS	MS	F Value	Significance
Replication	3	15.34	5.11	2.33	
Genotype	13	689.08	53.01	24.20	**
(*Hyb vs. OP*)	(*1*)	(106.06)	106.06	48.43	**
Error	39	85.41	2.19		
Total	55	789.84			

Coefficient of variation = 1.25%

* Significant at $P \leq 0.05$; ** Significant at $P \leq 0.01$

Appendix 3.7. Analysis of Variance for number of tubers plant^{-1} of 5 hybrid and 9 OP potato genotypes planted for ware potato production at Agricultural Research Station, Mingora, during spring, 2001.

Source	DF	SS	MS	F Value	Significance
Replication	3	6.74	2.45	1.38	
Genotype	13	388.66	26.05	16.02	**
(*Hyb vs. OP*)	(*1*)	(24.35)	24.35	14.97	**
Error	39	63.43	1.63		
Total	55	408.83			

Coefficient of variation = 12.78%

Appendix 3.8. Analysis of Variance for average tuber weight of 5 hybrid and 9 OP potato genotypes planted for ware potato production at Agricultural Research Station, Mingora, during spring, 2001.

Source	DF	SS	MS	F Value	Significance
Replication	3	49.48	16.49	0.58	
Genotype	13	7975.69	613.51	21.51	**
(*Hyb vs. OP*)	(*1*)	(3412.95)	3412.95	119.66	**
Error	39	1112.28	28.52		
Total	55	9137.46			

Coefficient of variation = 7.74%

Appendix 3.9. Analysis of Variance for yield plot^{-1} of 5 hybrid and 9 OP potato genotypes planted for ware potato production at Agricultural Research Station, Mingora, during spring, 2001.

Source	DF	SS	MS	F Value	Significance
Replication	3	2.56	0.85	0.89	
Genotype	13	203.43	15.65	16.47	**
(*Hyb vs. OP*)	(*1*)	(95.39)	95.39	100.41	**
Error	396239.7	37.04	0.95		
Total	55	243.04			

Coefficient of variation = 11.09%

** Significant at P ≤0.01

Appendix 4.1. Analysis of Variance for percent emergence of 8 TPS progenies and 2 seed tuber cultivars, planted at 3 different locations of NWFP.

Source	DF	SS	MS	F Value	Significance
Location	2	47.82	23.91	6.06	*
Error	9	35.47	3.94		
Genotypes	9	130.41	14.49	2.32	*
L X G	18	254.52	14.14	2.27	**
Error	81	504.78	6.23		
Total	119	972.99			

Coefficient of variation = 2.99%

Appendix 4.2. Analysis of Variance for plant height of 8 TPS progenies and 2 seed tuber cultivars, planted at 3 different locations of NWFP.

Source	DF	SS	MS	F Value	Significance
Location	2	17.92	8.96	2.62	N.S.
Error	9	30.75	3.42		
Genotypes	9	3672.3	408.03	59.26	**
L X G	18	490.75	27.26	3.96	**
Error	81	557.75	6.89		
Total	119	4769.47			

Coefficient of variation = 4.43%

Appendix 4.3. Analysis of Variance for days to harvest of 8 TPS progenies and 2 seed tuber cultivars, planted at 3 different locations of NWFP.

Source	DF	SS	MS	F Value	Significance
Location	2	724.03	362.02	144.33	**
Error	9	22.57	2.51		
Genotypes	9	535.07	59.45	46.00	**
L X G	18	411.95	22.88	17.71	**
Error	81	104.67	1.29		
Total	119	1798.32			

Coefficient of variation = 0.96%

N.S. non significant; * Significant at P ≤0.05;** Significant at P ≤0.01

Appendix 4.4. Analysis of Variance for disease incidence of 8 TPS progenies and 2 seed tuber cultivars, planted at 3 different locations of NWFP.

Source	DF	SS	MS	F Value	Significance
Location	2	5.06	2.53	4.85	*
Error	9	4.70	0.52		
Genotypes	9	53.30	5.92	14.85	**
L X G	18	10.60	0.58	1.47	N.S.
Error	81	32.30	0.39		
Total	119	105.96			

Coefficient of variation = 25.6%

Appendix 4.5. Analysis of Variance for number of tubers plant^{-1} of 8 TPS progenies and 2 seed tuber cultivars, planted at 3 different locations of NWFP.

Source	DF	SS	MS	F Value	Significance
Location	2	21.36	10.68	4.50	*
Error	9	21.36	2.37		
Genotypes	9	155.29	17.25	7.94	**
L X G	18	113.51	6.30	2.90	**
Error	81	175.91	2.17		
Total	119	487.45			

Coefficient of variation = 15.61%

Appendix 4.6. Analysis of Variance for average tuber weight (g) of 8 TPS progenies and 2 seed tuber cultivars, planted at 3 different locations of NWFP.

Source	DF	SS	MS	F Value	Significance
Location	2	1159.34	579.67	217.94	**
Error	9	23.94	2.66		
Genotypes	9	4216.08	468.45	111.57	**
L X G	18	1473.17	81.84	19.49	**
Error	81	340.09	4.19		
Total	119	7212.61			

Coefficient of variation = 2.70%

N.S. non significant; * Significant at P ≤0.05; ** Significant at P ≤0.01

Appendix 4.7. Analysis of Variance for yield plot^{-1} of 8 TPS progenies and 2 seed tuber cultivars, planted at 3 different locations of NWFP.

Source	DF	SS	MS	F Value	Significance
Location	2	7.33	3.66	24.94	**
Error	9	1.32	0.15		
Genotypes	9	194.29	21.58	51.31	**
L X G	18	31.16	1.73	4.11	**
Error	81	34.08	0.42		
Total	119	268.19			

Coefficient of variation = 6.86%

N.S. non significant; * Significant at P ≤0.05; ** Significant at P ≤0.01