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Studies on the Production of Seed Tubers from True Potato Seed[1]

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Abstract : The health standard and yielding ability of first generation TPS tubers were tested. Comparing to commercial cultivars, TPS families had same disease level of 13%. TPS tubers of Atzimba×DTO-28 and PAS 3064 (Hybrids) gave comparable yield (400 g/pl) to cv. Cardinal (380 g/pl). Open pollinated families yielded lower (240 g/pl) and tended to have more haulm growth than tuber bulking. This indicated that selected TPS family could be used to produce seed tubers with good quality which in turn could produce ware potatoes for fresh consumption.

To determin the proper season to produce seed tubers, four plantings representing early and late half of both October and November were compared in terms of total yields, effective tuber (tuber≥8g) percentage and number. For direct seeding in field, late half of October was better because of cooler temperature. The October 29 planting yields the best of 2.6 kg/m², of which 92% would be good for seed use in number of 90 per square meter. Again hybrid families yielded higher than the OPs.

Under protection in screenhouse, higher TPS tuber yields were generally obtained. The early October sowing resulted in good seedling emergence and growth when shade was provided. The November 11 planting yielded the best, 3.2kg/m² of total tubers and 130 effective tubers/m². Evenly distributed transplants (in density of ca. 13×13cm) in screenhouse tended to produce effective seed tubers smaller in size and more in number than directly field sown seedlings.

The first generation TPS tubers whether produced in open field or in screenhouse had disease rate of no significant difference, being 13.3% vs. 20.8% respectively which again was comparable to that of commercial tuber variety. The screenhouse did not guarantee better protection to TPS seedlings from virus infection by contact or insects. The 2 hybrid TPS progenies gave similar yield to Cardinal tuber (34 t/ha) and most tubers were marketable, being of 150g in size in average.

The use of potato true seed(TPS) for production of tubers as planting material has been practiced on farm level in various countries as Sri Lanka [10,13], Rwanda [5], and mainland China [15], while scientists of more than 20 countries have been involved in

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various aspects related to potential adoption of TPS technology, especially the International Potato Center has concentrated much researches in collaboration with other national scientists to develop the most adaptable agronomic technology and improved TPS progenies[4-13,17]. The advantages of using TPS instead using traditional seed tuber propagation include the low cost for producing TPS, elimination of tuber associated diseases and bulky storage and transport.

In Taiwan, although seed certification and a basic-foundation-certified 3 level production system has been established with in vitro tuberlets as basic seed[1,2,3], some farmers still purchase seed tubers produced through non-certification system. The present study conducted during 1983, 1984 and 1985 was a continuation of a series of agronomic experiments aiming to evaluate the technology of using TPS to produce seed tubers and find the most adaptive method to implement here.

Materials and Methods

Comparison between TPS tubers and commercial cultivars

Four commercial cultivars were used in this experiment. They are Atzimba (Mexican variety), Wu-feng, Cardinal, and Kennebec, with the latter three being current commercial varieties. The TPS tubers used were first generation seedling tubers of 10 different families including 3 open-pollinated (OP) and 7 hybrid ones. All tubers were planted whole on November 15, 1984 in a completely randomized design with unequal number of replications for each entry at TARI experimental farm. For the convenience of using a small cultivator, single rows with row spacing of 90cm and 30cm between hills were used. The size of the TPS tubers used were mostly between 10 and 20g while that of commercial cultivars were above 30g. The plants were investigated visually for tuber borne virus symptoms one month after planting and the diseased plants were discarded then to eliminate further infection. The crops were harvested on February 22, 1984 and fresh weight for both haulm and tubers were recorded.

2. Seasonal effect on the production of seed tubers

To study the seasonal effect on TPS germination, plant growth and final tuber yield, 6 tuber families including 3 OPs and 3 F_1s (Table 1) were used in this experiment which was conducted in both open field and screenhouse. Four sowings were taken at 2 week intervals representing early and later half of both October and November (Table 2). The temperature data for these 2 months are shown in Table 3. TPS were directly sown in field at a spacing of 10×10cm on plots of 2.7×1.3m for each family at each of the 2 replications.

For screenhouse planting, TPS were first sown in plastic flats in greenhouse and then transplanted in completely randomized design at spacing of 12×12cm on 85cm wide bed. The close spacing was aimed to produce numerous small tubers for seed. Plants were harvested at the average maturity for each planting, number and weight of tubers were recorded.

3. Comparison between TPS tubers of different sources

TPS produced either in screenhouse or in open field in 1983—1984 season were

compared in terms of their disease rate and yield ability. Tuberlets of 15—20g each were planted on November 16, 1984 in TARI farm in a RCBD with 3 replications. Three tuber families and 2 sources (screenhouse vs, field) formed 6 treatments. Each plot consisted of 2 double row beds of 1.3×6m with 40 hills on each bed. The number of virus symptomed plants were recorded one month after planting and the diseased plants were pulled out. The crops were harvested on March 25, 1985 with 129 days of growth and the tuber yields were recorded.

Results

1. Comparison between TPS tubers and commercial cultivars

The yielding capacity on plant basis of TPS tuber families ranged between 184g and 427g with average yield of 239g for the OPs and 308g for the hybrids. The yields obtained from 4 commercial cultivars ranged from 299g of Kennebec to 567g of Wufeng with an average of 437g (Table 4). Significant difference existed between cultivars and TPS OP families. Moreover, the OP families produced smaller tubers than either hybrid families or cultivars did, giving only half of the hill being acceptable in terms of tuber size and yield.

Table 1. TPS families used to study seasonal effect.

TPS family	Abbreviation	Genetics
26	26	OP
254	254	OP
475	475	OP
Atzimba × R 128.6	A × R	F_1
DTO-33 × R 128.6	DTO-33 × R	F_1
PAS 3064	3064	F_1

Table 2. Temperature* (C) in October and November of 1983

Date		Max.	Min.	Mean
October	1—10	32.9	22.6	27.8
	11—20	32.0	22.4	27.2
	21—31	29.1	20.2	24.7
November	1—10	29.3	15.6	22.5
	11—20	26.2	14.3	20.4
	21—30	25.3	10.4	17.9

*data taken at TARI, 85m asl.

Table 3. Comparison between TPS tubers and commercial cultivars

Tubers[a]	Hill No.	Disease level %	Tuber yield		avg tuber size (g)
			Per plant (g)	% biological yield	
Cultivar	1960	14.07	437 a[b]	70.5	
Cardinal	1702	9.10	379		68
Kennebec	52	13.52	299		81
F_1 TPS	2445	13.82	308 ab	72.7	
A × DTO-28	1082	12.81	427		64
PAS 3064	334	3.04	382		66
OP TPS	1634	13.10	239 b	64.8	

a. planted on November 15, 1983; harvested on February 22, 1984.

b. Means do not have a letter in common are significantly different at the 5% level according to Ducan's multiple range test.

Selected hybrid TPS families such as A×DTO-28 and PAS 3064 produced tubers comparable to the commercial varieties in size and yield. The morphological uniformity for the above mentioned two TPS families were fairly good in terms of tuber size, skin color (white, except PAS 3064 tubers with red eyes) and shape (mostly oval round). Crops from OP families had vigorous haulm growth but not much of the tuber production in comparison to crops from hybrid families. The average percentage of tuber weight in total biological yield (haulm+tuber) for the OPs, F_1s and commercial cultivars were 64.8, 72.7 and 70.5 respectively (Table 4). Ideal proportion of tuber yield should take at least 70% of the total growth, however, the percentage would be much increased if the haulm was senescent and died down. Tuber weight taking less than 70% of the biological yield probably indicated the unefficient partitioning of photosynthates into tuber bulking which might be of genetic causes or the interaction of genotypes and environment.

2. Seasonal effect on the production of seed tubers

A. Direct seeding in open field

The TPS takes longer time to emerge at earlier sowing date. The percentage of emerged seedlings taken 2 weeks after each planting was shown in Table 5. Sowing on October 12 resulted in the lowest average percentage of emergence, 13%, while later sowing gave more than 40% of emergence. Temperature tended to be major factor for it. The still high temperature in early October slowed and inhibited the seed germination and the gradual decrease in temperature (Table 3) favored the process of germination, resulting faster and more emergence. During growth, natural selection tended to survive the better genotypes by eliminating out weaker seedlings. At young seedling stage, cutworm in soil and damping-off pathogen were main pests. TPS family of PAS 3064 had the earliest maturity since its plants showed first senescence with yellow

leaves at 3½ mo. of planting. However, each planting was harvested according to overall maturity and once for all before all plants turned yellow. The planting of October 29 had the highest tuber yield of 2.61kg/m² of which about 92% would be good for seed tubers since they were larger than 8g (Table 6). Ninty seed tubers were produced per square meter. The 2 plantings in November gave lower but not significantly different tuber yield of 2.04 and 2.40kg/m², respectively. The November 23 planting gave the highest number of tubers of 8g or more in size, being 108 tubers/m². The data indicated the most proper season to direct seed TPS in field for seed tuber production would be from late October on when the temperature was cool enough for germination and still warm enough during the following period for the growth. As for the TPS sources, hybrids generally yield better than the OPs, more than 2.5kg/m² vs. about 1.5kg/m³ (except '254' family) (Table 7).

Table 4. Seasonal effect on TPS emergence % in field[a]

TPS	Oct. 12	Sowing date		Nov. 23
		Oct. 29	Nov. 11	
26	8	43	41	49
254	4	29	47	—
475	11	37	23	47
A × R	23	43	52	53
DTO-33 × R	15	43	38	61
3064	17	54	44	51
average	13	41	41	52

a. Emergenec % was taken 2 weeks of sowing except for Nov. 23 planting which was taken one month of sowing.

Table 5. Seasonal effect on seed tuber production in field

Direct seeding date in 1983	Growing days	Total tuber kg/m²	≧ 8 g tubers		
			kg/m²	%	No./m²
October 12	119	1.96 b[a]	1.76	88.9	70
29	129	2.61 a	2.42	92.0	90
November 11	118	2.04 ab	1.67	78.0	82
23	128	2.48 ab	1.97	77.9	108

Table 6. Seed tuber production of TPS families

TPS family	Total tuber	≧ 8 g tubers		
	kg/m²	kg/m²	%	No/m²
26	1.57 c[a]	1.29 c	80.9 a	65 b
254	2.41 b	2.04 b	82.5 a	96 a
475	1.39 c	1.16 c	81.1 a	59 b
3064	2.53 b	2.20 b	86.2 a	98 a
DTO-33 × R	2.96 a	2.60 a	87.9 a	108 a
A × R	2.78 ab	2.42 ab	86.7 a	98 a

a. Means do not have a letter in common are significantly different at the 5% level according to Duncan's multiple range test.

B. Transplanting in screenhouse

The November 11 planting yielded the highest of 3.22kg/m² and the highest number of 130 tubers/m² of 8g or more in size. All plantings except the Oct. 29 one in screenhouse had better total tuber yield but same useable tuber yield comparing to the plantings in open field. In terms of the number of effective tubers, all planting gave more than 100 per square meter (Table 8). Unlike those directly sown to field, TPS seedlings under protection in screenhouse had less competition from pests, less attack from adverse weather. The-higher density and evenly distributed plants gave slightly higher total yield but smaller tubers and lesser proportion (about 65% by weight) of effective seed tubers compared to field plantings which gave more than 80% of the total yields as seed tubers. The data indicated that sowing of TPS could be as early as early October if shade provided to lower the temperature.

Table 7. Seasonal effect on seed potato production in screenhouse

Seeding (1983)	Trans planting	Growing days	Total tuber kg/m²	≧ 8 g tubers		
				kg/m²	%	No./m²
October 12	November 22	145	2.56 ab[a]	1.66	65.1	105
29	December 2	128	2.27 b	1.53	67.9	103
November 11	December 15	133	3.22 a	2.00	62.1	130
23	January 6, 1984	135	2.60 ab	1.86	71.3	101

a. Means do not have a letter in common are significantly different at the 5% level according to Ducan's multiple range test.

3. Comparison between TPS tubers from different sources

The quality of TPS tubers produced either in screenhouse or in open field was comparable to certified commercial seed tubers of Cardinal in terms of disease rate which was 20.8%, 13.3% and 19.8% for 3 different sources respectively. The tubers of OP family had higher virus infection than those of 2 hybrid families, being 22% vs. 15 % (Table 9). The value was higher than that of previous year. Seasonal effect during seedling growth might be involved. The hybrid families yielded better than OP family with plants being more vigorous along with faster canopy development and probably better partitioning of the assimilates to tuber growth. The tuber yield was 26t/ha for the OPs and 34t/ha for the hybrids, the latter being similar to Cardinal tuber yield. Again, the tuber yields were higher than those obtained in previous year. Both seasonal and soil effects (different field lot) might account for this difference. The tuber uniformity of the hybrid progenies was also acceptable in terms of good tuber size (ca. 150g each), oval round shape and white skin. However, the fairly deep eye in general was inherent defect.

Table 8. Comparison between TPS tubers of different sources[a]

TPS family	Disease rate %			Tuber yield (t/ha)		
	Field	Screenhouse	avg	Field	Screenhouse	avg
A × R	10.0	20.5	15.3	36.1	33.3	34.7
DTO-33 × R	9.2	17.1	13.3	33.6	35.0	34.3
475	20.5	24.6	22.6	26.8	25.5	26.1
avg	13.3	20.8		32.1	31.2	
Cardinal[b]	19.8			33.6		

a. TPS tubers were produced in either screenhouse or open field in 1983—1984 season, they were planted as seed tubers on November 16, 1984.

b. Cardinal tubers were purchased as certified seed and planted in the same field on Nov. 14 with 105 days of growth.

Discussion

Three schemes, proposed for different areas with different situations to use TPS are direct field seeding, transplanting seedlings and producing seedling tubers for proapagtion. Production by seedling tubers and seedling transplants is gegerally better than direct field sowing [5,16,17]. Seedling tubers in turn offer more advantages than transplants by easier to establish, easier management, shorter growing period and large tuders produced with improved homogeneity. It has been successfully used in various countries as a complementary system to national seed program.

Generally TPS tubers are of high health standard, carrying approx. 5% of virus [9]. With optimum environment, they can even be grown for three generations before final

release as seed tubers to large scale farming[7]. In present study the virus incidence of the first generation TPS tuber, although being comparable to commercial seed tubers, is much too high, being more than 13%. However, as low as 3% of virus infection was obtained (Table 4). With seasonal effects being considered more intense disease and insect control will be needed to lower the virus incedence. Hybrid TPS progenies in general outyielded OP progenies. Good yield of 34t/ha (Table 9) was obtained by planting first generation F_1 TPS tuberlets. This result is comparable to that of other countries[5,10] and it is expected that by breeding and selection, tuber uniformity and yield will be further improved especially with hybrid progenies. As high as 1.3kg/pl of population mean tuber yield, equivalent to 54t/ha (42,000pl/ha) from TPS family has been reported[12]. OP progenies with 40t/ha or more of tuber yield has been obtained [11], OP seeds of an India variety had been widely distributed and tested in India, Bangladesh and Sri Lanka for its high yielding ability. The production of seedling tubers in nursery bed has been reported as high as 10kg/m² of total tuber weight and as many as 1,000 or more useable tubers (≥1g)[17]. Comparatively, the yield of 3kg/m² (Table 8) in weight and a few hundred in number (tubers≥1g counted) from the present study was rather low, giving lower multiplication rate in turn. Various studies [4,11,12,17] have shown that the use of regular field soil as nursery substrates gives poor seedling growth and recommended the use of mixture of sand and compost or subsoil and peatmoss in equal parts with low salt concentration. High phosphorus is essential for good seedling growth. Nitrogen and potassium are applied along with irrigation after seedling emergence. The farm soil used in this study is silt loam in structure with low organic matter in fertility. This along with the low hilling (some tuberlets are found near soil surface) might cause the low yield. The TPS seedlings are usually more sensitive to adverse conditions of soil and temperature than tubers. The optimum temperature for TPS germination is 20°C[6] and the temperature in early October is probably inhibitory to TPS emergence, resulting in slower and lower seedling growth (Table 5), while tubers can be planted in late September in central Taiwan[2]. It was therefore recommended to direct seed in late October or earlier seeding should be carri ed out with shade provided to lower the temperature and minimize soil crusting in turn.

The effective tuberlets to be used as seed tuber are 8g or larger in size[1] while tuberlets of 1g are considered useable in other studies[11,17]. The smaller tuberlets can be planted but with slower initial growth, if long season provided along with fertile substrates and intense agronomic management, reasonable yield can still be achieved. If the 1g tubers counted, the number of useable tubers will increase in this study.

The seed tubers produced in open field or in screehouse had disease rate of no significant difference, in fact, the value from the screenhouse was higher than that in the open field. This might be caused by much contact from transplanting operation. The screenhouse did not guarantee better protection to TPS seedling from virus infected by contact or insects as long as there is some isolation from other Solanaceae crops in open field.

In concluding the agronomic experiments conducted through years, there may not be possibility of using TPS in commercial production in the near future here in Taiwan where the domestic market favors large size tuber preferably with high dry matter content for processing products and the export market fluctuates. TPS family can hardly take place of commercial varieties for the time being. However, TPS research offers good potential in breeding work especially for disease resistance incorporation. Selection pressure can be applied at the seedling stage to screen out resistant plants to diseases such as late blight and bacterial wilt and the selected tuberlets can be further multiplied and undergone more accurate evaluation. The breeding work for disease resistance is important yet lacking at this stage.

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利用種子生產馬鈴薯之栽培研究[1]

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摘 要

以馬鈴薯種子來繁殖種薯已在有些國家實行，以彌補健康種薯之不足所造成產量偏低的現象，在本省目前雖由政府支持進行種薯檢疫與生產，但其量仍不足供應每年栽培所需，本所自1980年開始進行由馬鈴薯開花與結種子到各項田間栽培試驗，以探求由種子來生產馬鈴薯在本省的實用性，本研究繼續進行由種子生產小種薯方面的三項栽培試驗，比較栽培品種與實生薯的繁殖程序與產量，比較田間與網室所生產的實生薯，是否在帶病率上有差異，以及最適合生產實生薯的時期。

在不同年度（1983年和1984年）實生薯所帶的病毒率與購自農會的栽培品種採種薯同樣約爲13%，一些雜交族羣的實生薯做爲種薯時可以得到與栽培品種一樣的產量達 34T/ha，同時株間差異小，薯球大，除了芽眼較深外，外觀上相當一致顯示種植實生薯（每個約在 15—20 g）能够獲得很好的產量，這些實生薯種植容易，不再須經切薯。

種子育苗以十月下旬的溫度較適合播種，在此之前田間溫度仍高，影響種子的發芽，或者苗床必須加以遮蔭以降低土壤溫度，只要避開高溫皆適合播種，幼苗經疏苗或以固定距離移植，在每平方公尺面積上最高可得 3.2kg 的薯球，其中選出達 8 公克以上的薯做爲繁殖的薯，可每平方公尺在 100 個以上，而實生薯無論是在田間生產或網室內生產的也都有相同的繁殖率，顯示只要與其他蔬菜作物隔離即可在田間育苗生產實生薯，網室內繁殖實生薯並不一定生產出較不帶病的實生薯。

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