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Review Article

Producing Potato from True Seed, Review

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Abstract

The International Potato Center (CIP) and its partners undertook a 25-30-year study on using potato's botanical seed as a substitute technique of developing potato harvest. The benefits of using botanical or 'true' potato seed (TPS) instead of the seed tubers are several. TPS has the potential to appeal to small-scale farmers in underdeveloped nations particularly. In numerous ways, using TPS instead of seed tubers forced developing a new chain of the crop-commodity, needing research in seed processing, breeding, marketing, and agronomy. Through addressing some critical limits in TPS variety uniformity and earliness, along with seed physiology, this study enabled commercial-scale potato production from TPS. Experimentation and farmer adoption in various regions demonstrated that the technical benefits related to TPS just translated into cost savings over tuber seed, which has been either unavailable or too expensive. TPS is a possible alternative because the economic efficiency of the seed tubers is projected to fluctuate in future. Researchers may be able to learn more about the factors which stimulate or inhibit the innovation of the crop technology by looking at how TPS is used in many nations. The study provides an overview of the variety of the disciplines of TPS researches in the CIP, along with information on how the TPS technology is used in a number of advanced nations.

Keywords: Potato; True Seed; Plant Breeders; Diseases

Introduction

Potatoes (*Solanum tuberosum* L.) are a vegetatively propagated species with breeding programs aimed at producing superior clones. Those procedures begin with poly-crossings or hybridizations between many pairs of parents to acquire true seeds from which numerous clones have been obtained. In first generations, clones are chosen (visually) for features with high heritability, like eye depth and tuber shape, and undesired clones are removed [1]. Potato, a tetraploid (2n = 4 x = 48) field crop of great commercial significance all over the world, belongs to the Solanaceae family. After wheat, maize, and rice, it is the 4th most widely grown food crop [2]. Potato production in the humid tropical areas is hampered by a scarcity of high-quality, low-cost seeds. Potato seeds are responsible for 10-20% of the total value of the crop. Furthermore, because farmers typically plant potato tubers preserved from past harvests, illnesses develop over time, reducing productivity. Seed is the most expensive input for potato producers for such reasons, and having an excellent supply of high-quality seed is important to potato profitability and productivity. In spite of its significance, the best seed approach for potato development in tropical nations remains unclear. To meet local demands, several nations have depended significantly on verified seed imports from temperate areas.

Real seeds are used in potatoes for breeding purposes, and interest in this technology began since the late seventies, especially in New Zealand, at the Potato Institute in Peru and in the United States of America. It is transmitted through seed and that reproduction by seed method is intended to resort to sexual embryos that are on a high degree of genetic homogeneity, as the potato plant is one of the genetically mixed plants [3].Potato seeds are characterized by being small in size and the weight of one seed does not exceed 0.6 mg, and one fruit contains 200 seeds and each plant produces an average of 20 fruits and only a few potato viruses are transmitted by seeds, for example (T, X, Y virus) and spot virus annular, but all potato diseases are transmitted through tubers [4].The technology of producing potatoes based on real seeds, whether using seedlings resulting from direct seed cultivation or using seedling tubes, is an ideal system for planting potatoes for farmers in developing countries (third world countries) [5].

Plant breeders direct their interests towards selecting strains of potatoes to produce true seeds, which are characterized by their high ability to combine for the characteristics of the crop, earlyness and flowering in high temperature conditions and resistance to major diseases while having the desired characteristics for the tubers, and the selection of flowers and fruit set in high temperature conditions helps to improve Production of seeds in areas where there is no moderate weather during the growing seasons in which the photoperiod is long. Plant breeders are also interested in selecting strains whose seeds produce strong and healthy seedlings and have the ability to withstand seedling shocks. High temperatures during the period after transplanting reduce root growth and persist in weak plant growth [6]. Among the important wild species that form tubers of the genus Solanum and its seeds germinate well and give strong seedlings and produce highly efficiently in hot weather.

- *Solanumjamessi*
- *S.Commersonii*
- *S.pinnatisectum*
- *S.kurtzianum*
- *S.polytrichon*

Plant breeders are attempting to transmit crucial sexual reproductive features from such species to cultivated potatoes [7]. Imported seed, on the other hand, remains prohibitively expensive for farmers, limiting their options of the varieties to these available in countries that export the seeds. Other nations have attempted to mimic the certified seed systems of advanced nations in order to produce potato seed, frequently with international financial and technical aid. Unfortunately, a lot of such programs did not have a solid track record regarding sustainability when the support for theproject had ended [8]. In addition to that, formal seed certification norms employed in temperate regions of developed nations might not be acceptable for the developing nations in tropical climates [9]. Others say that significant progress could be made through gradually improving farmer-based, informal seed systems [10] or by completely discarding clonal seed in favor of botanic seed, sometimes referred to as “True Potato Seed” [11]. In Nepal, almost all farmers have long used left small seed tubers, and occasionally even slice pieces with just 1 eye as seed to grow the potato crop, in order to cover as much area as possible with least amount of seed input possible with the use of smaller seed pieces or extremely small seed tubers. This habit could be a factor that contributes to the low output. TPS is the best option in this case because it has a higher yield potential and a cheaper seed cost. Approximately 18% of total edible potato production in advanced nations might be conserved with using TPS as planting material [12]. Furthermore, bacterial, viral, and other plant pathogens might be passed from generation to generation via tubers, lowering plant productivity and health. Since no percentage of the useable harvest must be diverted for seed, and diseases are significantly less prevalent in the botanical seed than in vegetative propagated materials, TPS decreases both of such restrictions [13]. Those TPS characteristics are of particular significance to resource-poor farmers in emerging nations such as Nepal. The increased utilization of the seedling tubers grown from TPS at farmer’s level was caused by true seed potato propagation [14]. TPS is typically utilized in order to generate little seedling tubers (less than 20g/tuber) for use as seed in ware potato crops. Seeding TPS at high plant density in the nursery [15,16] or planting seedlings directly in the field might produce high-quality first-generation seedling tubers (F1C1). The harsh conditions could be better managed in small nursery beds compared to a field. Potatoes might be grown from seedling tubers larger than 1g. [17,18] found that tubers larger than 5 g increased yield significantly. It was extensively observed that the seed tuber size influences both the yield and growth of individual stems [19]. The International Potato Center (CIP) developed a substitute to cultivating the potatoes from the seed tubers in the second half of the 1970s. Till then, there had been indications of the infrequent utilization of the botanical seed in Bolivia and Peru, and a case of Inca descendents employing this technology in Cuzco area [20,21]. Many researchers in advanced nations investigated the application of TPS [22], yet no link could be found between large-scale potato processing and botanical seed. TPS technique was developed as a result of a change away from conventional potato vegetative propagation and toward sexual propagation (Table 1). This meant that practically each aspect of potato production had to be altered, such as seed management, breeding, agronomy, and sowing. The organization of the many participants in the potato production chain, like demand and service supply with regard to novel variety growth, marketing, and seed production, was frequently considered when developing an efficient TPS technology. Consumers were also significant players since TPS varieties had different tuber skin color, scale, and culinary consistency than clonal types. In actuality, putting TPS technology into practice necessitated the creation of a whole crop-commodity chain.

CIP was in the forefront of all aspects of the technology's experimentation and research, despite the fact that a wide range of other research groups in industrialized and emerging nations experimented with elements of TPS system [22]. In the year 1974, Rowe proposed a breeding approach for using TPS in the production of potato. TPS research at CIP started in the year 1977 with the breeding as well as the agronomic experimentations. Also, the first studies on this issue have been published in Proceedings of 28thConference of Planning at the CIP about the 'Innovative Approaches for Propagating Potatoes' in 1983-1984 [23] and the Proceedings of 'Researches for Potato in 2000' [23,24]. In 1984, TPS was tested in over 34 nations, with farmers in five of them using it. TPS's broad use in China, piqued CIP circles' curiosity in the breakthrough technology. The TPS initiative, which started at CIP, concentrates on the implementation and study of the program in farmers' fields. The writers underline that all decisions they make are their own interpretations of the data they present, and most of the data is based on informal correspondence. The cultivation of potato from true seeds allows for an economic outlay of 3 - 3.50 tons of the potato seeds stock per hectare [25-27]. Aside from that, the costs of tuber storage and transportation have been reduced. It is advised that healthy seed material be created depending on experiments conducted in our republic [28] for the growing of virus-free seed breeding from botanical seeds under Uzbekistan's conditions. Recently, the creation of healthy initial material from true seeds has been exploited as a potato-growing approach in our country [26,29,30], with exports to India, China, and the Philippines expected. The effectiveness of this strategy is also determined by how resistant the plants are to bacterium, fungal, and virus illnesses. Its cause, according to researchers, is linked to disease-causing agents that are not transmitted to progenies during the sexual reproductions. However, low-rate virus infection of plants occurs throughout their vegetation stage or as a result of seed surface infection.

No.	Traits	Main
1	100 seed weight	75
2	No. of seeds per berry (number /berry)	200
3	Flower production (number/stem	50-100
4	TPS production (kg/ha.)	200
5	TPS weight sown per 1m2 nursery bed in mg (50-100 stems/m2)	50-75
6	TPS weight sown per ha. in mg (20 stems/m2)	150-200
7	Seedling tuber weight (kg/ha.; 14 stems/me; 5-10g tubers)	700
8	Seed tuber weight (kg/ha.; 14 stems/m2; 40-60 g tubers)	2000

Table 1: Main traits of TPS.

CIP's engagement origin

Before the 1970s, potato breeders generally utilized sexual propagation for creating new varieties through crossing stock material to select clonal variations and, on infrequently, to eradicate virus. TPS became a key point after the CIP has been founded in 1972. The TPS has been started and propelled by Dr. R. Sawyer, CIP's first director, and Dr. O. Page, CIP's first director and director of science, respectively. They anticipate that by using TPS, small-scale farmers will be capable of consuming or selling tubers that they might otherwise have to acquire or store for the next planting. Therefore, the expression "a handful of seed can replace two tons of tubers" was coined. TPS was also, and perhaps most importantly, not bulky; it might be carried in one's pocket into hills of Philippines or Nepal. TPS didn't require refrigeration as well and didn't transmit soil-borne diseases or viral infections between generations. Those benefits have been compared with the possibility of setting up national programs ofpotato seedsin industrialized nations, in which potato has been or could be a more valued crop for the small-scale producers. The potato has been an intriguing income-generating crop in the majority of such nations, yet the high costs of high-quality planting content discouraged poor small-scale farmers from pursuing potato agriculture. TPS, in contrary to seed tubers, might offer a labor [14,15,1,32]. Potato harvesting that is both intensive and low-capital intensive, making it excellent for farmers of small scale. Because those farmers have been the focus of

CGIAR-associated centers in first place, and no other organization has been possible to commit resources in creating the technology, it has been a wise decision to give CIP top significance in creating such alternative technology [33]. In addition, CIP and its collaborators performed a thorough study campaign for the next 20 years. The incidents reached a pinnacle towards the middle of 1990s. In 1996, CIP projected to spend roughly $1.1 million on TPS research, in comparison with $1 million on standard seed systems and $2.60 million on late blight tolerance, largest research attempt of the CIP at the time [34]. TPS-related spending has significantly fallen since then, and CIP is allegedly considering eliminating all TPS-related employees.

Agronomic research and breeding

It is critical in any breeding operation to produce a cultivar quickly for cutting costs. Propagation strategies that grantee quick generation of commercially valuable tubers from TPS are often favoured in potato breeding. This offers the benefit of guaranteeing that the resulting crop is in good health. In the case when too many field multiplications are used, this benefit is readily lost. The utilization of nurseries or other well-regulated conditions to grow seedlings and seedling tubers is one strategy to preserve acceptable health standards of early TPS-derived product generations. Ware potato crop might be produced in order to produce a commercial potato crop from real potato seeds through

- Direct TPS sowing in the area for seed or ware tuber production (35; 36),
- Raising seedlings from the TPS in a green-house or a seedbed and transplanting them after that to the field for producing seed or ware tubers in same season; and
- Direct TPS sowing in seedbeds at close spacing for the seedling tubers' production for the production of a commercial crop in the following season [37,38]. Throughout the 1980s, seedling tubers were the most popular of the three propagation approaches in Peru. Experience with producing seedlings from TPS created through breeders served as the agronomic starting point. TPS was used in two different ways, which were compared and contrasted:
- Growing ware potatoes from the botanical seed, either by spreading seed or transplanting seedlings into the field.
- Direct seeding to nursery beds or sowing in trays and transferring to nurseries produce seedling tubers in the nursery beds to be utilized as seed tubers in following planting (Figure 1).

The TPS researchers' agenda was defined by the experiments on these two methods of cultivating potatoes, which revealed a number of technological obstacles. Seed production, agronomy, breeding, and physiology were all obstacles.

Figure 1: The whole potato plant.

Figure 2: The flowers of potato plant.

Agronomy

Sowing Directly

The following methods could be used for growing a commercial potato crop from TPS: direct TPS sowing in field for the seed or ware tuber production; raising seedlings from the TPS in a seedbed or green-house and transplanting them later into field for seed or ware tuber production in same season; and direct TPS sowing in seedbeds at close spacing for seedling tuber production for the production of commercial crop the following season. Every one of the propagation approaches has its own set of benefits and drawbacks. In light of this, a research was done with the goal of comparing the efficacy of seedling transplants and seedling tubers in the generation of potato crop from TPSs. The CIP physiology department researcher›s initial challenge was to grow potato plant from botanical seeds and create an economically and commercially viable yield. The first and most obvious drawback was the prolonged growth time of a TPS-based crop. Slower germination and weak growth of less strong seedlings might result in crop tube rise too early in contrast to a crop grown from seed tubers, extending the growing season by at least one month. Small potato seeds appeared to have strict germination requirements, and emergence in field circumstances has been frequently poor. Crop germination has been inconsistent, and nothing has been known regarding seed physiology, germination, or factors that affect it. Early seedling growth has been slow, and germination of potato seeds is measured in the laboratory by placing 100 seeds on filter paper in a Petri dish and moistening them (Table 2). When put to comparison with plants grown from tuber seed or tuber generations of the TPS, seedling transplants frequently have a higher tuber set, longer growth duration, and smaller tuber size [39,40].

No.	Hybrid populations and varieties	Germination (%)	Survival (%)	Vegetative period, days Plant height (cm)	Biometric indexes		Phonologic uniformity of tubers, ball Productivity (gr/bush)	Productive indexes		
					Number of leaves, piece on plant			Number of tubers piece/bush	Average weight one tuber	
1	Vir-8	58	83	130	55.2	121	2	312.5	9.4	33.2
2	IIone	78	91	118	66.4	125	3	386.4	10.5	36.8
3	K7115	48	74	134	43.5	104	1	145	4.9	29.6
4	Deva	84	95	127	78.2	159	4	450.2	10.8	41.7
5	Triumf	76	90	128	76.3	118	4	355.5	8.7	40.9
6	Assol	68	85	123	48.5	125	2	390	11	35.5
7	Vilona	69	74	119	56.2	136	2	250.8	8.8	28.5
8	Zolushka	60	78	132	65.4	142	3	365.2	9.2	39.7
9	N2670	65	68	129	49.5	110	1	245.6	7.5	32.7
10	Nevskiy	71	79	125	69.2	128	3	364.5	9.3	39.2
11	Pikasso	73	80	131	74.1	112	3	396.3	10.5	37.7
12	Santa (st) Tuganak	--	--	72	68.5	196	5	573	9.8	58.5
			*5 ball –the best, Iball –the worst							

Table 2: Growth, development and productivity indexes of plants from [41].

Low harvest indices, early tuberization, and low yields were all caused by physiological stress. TPS-grown field crops have been fragile and responsive as a result of such qualities, which explains why realized yields were rarely higher compared to potential yields. Thus, direct sowing was quickly dismissed as an unrealistic option by many individuals. To reduce the growth cycle, early maturing parental clones have been utilized in crosses, although seedlings cultivated in the nursery beds might potentially decrease the crop's field duration. Seedlings could also be raised in a nursery bed before being transplanted to the production area to improve growing and germination conditions. Then, under carefully regulated shading and irrigation circumstances, thorough testing of different substrates and transplanting regimens was conducted.

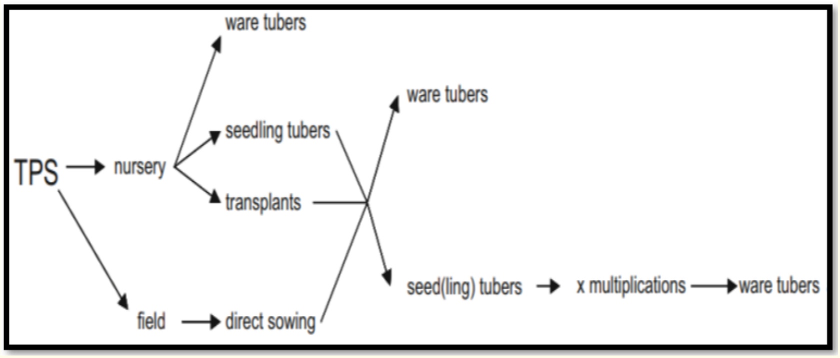

Figure 3: The technology of production seed from true seeds of potato.

By efficiently boosting the early growth period in nursery, the role of bottle-neck in next process, in other words, in the case where seedlings have been transplanted to field, the function of bottle-neck in the next process, in other words, when the seedlings have been transplanted to field, was revealed. Potato seedlings responded better to transplanting and soil conditions compared to seedlings from other vegetable crops. Seedlings damping off has been considered as a common occurrence. Early tuberisation was hampered by drought stress, resulting in extremely early maturation and low yielding harvest. Soil preparation, timely irrigation, and weeding were all critical. Potato cultivation from generated seeds is conducted according to methodological guidelines for cultivating potatoes from seeds. Each sample was planted in nursery of green-house soils previously prepared at an equal ratio of three parts, which are: black sand, soil, and humus in the first half of February (8-10.02) at a depth of 0.5cm-1cm on area of 2m2. Systems for utilizing potato seeds [31]. The vulnerability of potato seeds to germination conditions, sluggish seedling development, and transplant shock, spurred interest in a new seedling tuber production approach in nursery beds. In constrained locations, using especially prepared substrates, intensive methods ofwatering, and shading to relieve tension and permit the seedling development to continue uninterrupted was easy.

It can be utilized in the off-season and in screen houses for keeping aphids out of seedling tubers and assure virus-free seedling tubers which are well-suited for seed multiplication. Seedling leaves have been more tempting to aphids and more susceptible to virus infections compared to tuber-grown potatoes, according to experiments with seedling crops. With diligent monitoring, spectacular yields were produced 7 kg-10 kg of 1g tubers may be created with a 100-seedlingdensity for each square meter and meticulous care, and one trial yielded 1.365 tubers, totaling 13. 1kg.m2. Seedling tubers were gathered and processed before being planted to develop either a ware potato crop or seed potato crop. Because of their small size, seedling tubers have high sprout-to-tuber weight ratio, making them particularly inexpensive for usage and storage as seed tubers. In addition, lower density of the plant in the nursery beds led to extremely desired ware potato yields; tubers were little yet can be used in soups and curries.

Seed production and breeding

Crop physiologists in the CIP employed true seed from the crossings of the clonal female and male parents that have been chosen depending on seemingly reasonable factors important to flowering and other tuber and crop traits to evaluate potential forms where TPS could be used. (Atzimba DTO 33, Serrana LT 7) However, researchers realized early on that in order for TPS to be a success, they needed to cultivate well-adapted varieties and produce significant quantities of botanical seed. As a result, breeders updated their conclusions and choices for TPS tetraploid potato varieties. The primary difficulty, of course, was to achieve optimal tuber uniformity. Different methods were followed, with co- researchers Hermsen and Peloquin in the Netherlands and Wisconsin, respectively, providing significant feedback [22,24,42].

Figure 4: Potato fruit, seed inside potato berries.

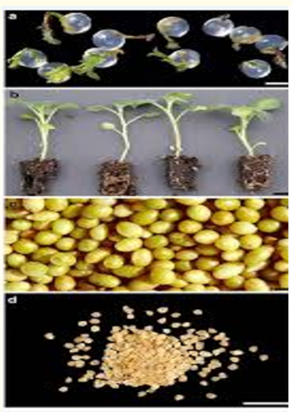

Figure 5: The fruit, seed, and seedling from true seed of potato.

OP. vs. hybrid varieties

Chinese farmers first utilized seed from the open pollination (OP) kinds which flowered excellently and produced berries with their own seeds. In contrast, the 4x4xO.P. types showed extensive division in almost all of the cases, leading to an extremely varied seedling communities. Enhanced uniformity was investigated using hybrid varieties [43] had suggested hybrid seed plan of 4 x 2 x cross that had produced vigorous, uniform and offspring of high-yield. This approach promised as well to boost heterozygozity and the capability to obtain hybrid seed without requiring hand pollination. Yet, because the 4 x 2 x crosses produced a poor seed set, the varieties of the OP and hybrid seeds from 4 x 4 x crosses have been explored first. A large seed collection will be needed for the development of the commercial seeds. Due to the fact that the OP seed has been quickly discovered to be inferior to the hybrid seeds with regard to tuber yield and consistency of plants and tuber agronomic parameters, the study's attention moved to hybrid types. The potato business considered generating inbred lines, yet it was deemed unfeasible [22]. The use of male sterile 4 x parents in 4 x 4 x crosses was thought to be a solution to avoid the emasculation costs. It was reasoned that emasculating female crops might make seed development very expensive for technology to be commercially-feasible. Parallel to Lima breeders' attempts to identify viable TPS types, Mahesh Upadhya, a breeder with India's National Potato Program and a CIP collaborator, established his own TPS breeding program. He took into account the culinary consistency of TPS-grown tubers, tetrad sterility, TPS embryo type, and flower and berry development stability [32].

Tetrad male sterility was discovered to be beneficial and stable. The selection of very consistent 4x4xprogenies included a male sterile 4xfemale parent. When igena (ADG) and Tuberosum (TBR) hybrids were employed, heterosis was detected, and the 4 x TBR 4 x ADG system, which utilized male sterile female relative, had become CIP normal. Upadhya was transferred to the CIP Headquarters' Physiology Department in Lima, where he finished his studies. Serrana TPS13 and MFII TPS67, for instance, are crossed with more profusely flowering Solanum and igenamale parents and comparatively early male sterile *Solanum tuberosum* female parents. This type of cross can still be found these days. The major breeding aim of CIP breeders has not been to select TPS progenies for direct sowing, in part since it was immediately apparent that the optimum approach to use TPS was to develop seedling tubers in secure nurseries. There have been as well no responses to the selection for the enhanced seedling transplant tolerance. Extreme diversity in seedling stand was due to this, which was most possible resulted from transplanting shock. Seedling tuber selection was focused in the 1stgeneration of the tubers that have been grown from the seedling tubers. The seedlings' extreme sensitivity to day length and temperature made seedling selection much more difficult. This meant that maturity, tuberisation, and yield of the varieties of the TPS have been highly location-specific, making screening for target locations with varying temperatures and day length regimes at the CIP Peru difficult. The breeding program has been influenced by other aspects of TPS technology. Based on how the seed was used, there is going to be complicated options for discovering superior genotypes in community [18].

The most extensively used procedures were culturing plants with poor productivity, spraying plant with the gibberellic acid, watering best-performing seedlings, and extending photo-period with more artificial light (i.e. bulbs) in the midst of night or at the end of day. The initial approaches have been appealing to breeders since they have been dependable and provided well-regulated conditions for their cross-breeding technique, which typically required only a small number of the inflorescences from different types. At the same time, TPS manufacturing necessitated the bulk manufacture of botanical seed and, which is why, the mass flower production. It was a good idea producing the TPS under the conditions of the long day. Which indicated the fact that in the case when TPS has been to be utilized in the tropical nations with day lengths varying from 12 to 13 hours (see 6), it might have to be developed elsewhere by an entity in a country where days are long. Because hybrid types were initially supposed to require hand pollination and emasculation, the site might also required to be a place with fairly affordable labor. Instead of concentrating on industrialized nations in the north, CIP searched for developed nations in the south in order to promote the TPS projects that might give seed to developing country potato programs. CGIAR's Technical Advisory Committee, which pushed for TPS manufacturing to be handed over, has already questioned CIP's actual position as a producer of the hybrid TPS to a wide spectrum of consumers worldwide. Lastly, it was decided that any seed supply might have to come from the commercial sector, yet as a foreign institution, engaging explicitly with the private sector was challenging. Chile has emerged as a prospective TPS producer. Seed processing began at Osorno, at a 40°Slatitude, as a result of connections with potato program at the Instituto National de Investigacion Agropecuaria (INIAnational). Personnel training in mother crop management (pruning and training, seed extraction, pollination, and storage), along with technology help, opened the path for consistent TPS provision. In addition to resolving the flowering day length dilemma, the CIP wanted a politically acceptable response to the question of what type of organization they should sponsor for developing into a respectable true seed supplier. Seed extraction, pollination, and processing approaches for tomatoes were largely adapted and coped. Emasculation was frequently duplicated at first, yet tuber lets from highest-producing 1stgeneration might be kept for future multiplications, etc. Both of these approaches have potential to reduce success variation and enhance progeny genetically. These would allow uniformity less of a conditional consideration in breeding scheme, leading to speculations on how farmers might use these mechanisms to pick disease-resistant seedlings, resulting in farmer varieties. This also raised the issue of the need to emasculate, which would theoretically be a significant cost factor in commercial TPS processing. However, there are already certain areas of TPS genetic enhancement that can be improved [11,32].

Seed production technology

Botanical seed output requires well-flowering mother plant for obtaining high seeds outputs. Due to 200 years of selection for the below-ground production of the tuber instead of the above-ground shoot growth, effective potato cultivars were identified as weak flowering crops in developing nations. Due to the longer growing season of TPS crops compared to seed tuber crops, early-maturing clones, and early clones predominated, produced less flowers [31]. Among the variants which had yielded high-yielding TPS progenies were DTO and subsequently LT, materials chosen for adapting to low-land tropics and to create mature crops in 90-100 days. Those clones, at the same time, only produced some flowers per plant under natural day length conditions of Peru (Table 1), making them only valuable as male parents' pollen might be utilized for pollinating many female flowers.

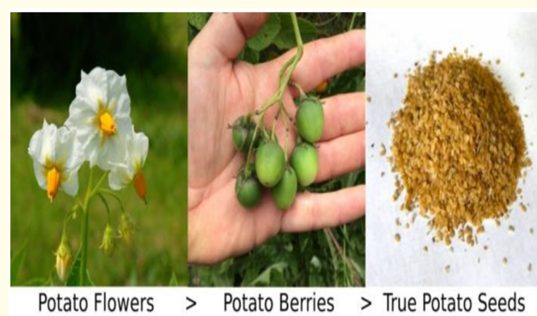

Figure 6: Three stages of potato for true seed production.

Production of flowers

Potato breeders had to figure out how to get around the fact that their plants didn't flower. For getting the potato plants to bloom, many methods were utilized. All of them were reliant on tuber formation delays or limitations. Planting the plant on top of a brick for allowing tuber milking, grafting on tomato, removing inflorescences and storing them in bottle of claim gained traction, claiming that genetic differences in TPS types, along with the way TPS has been utilized, did not demand the same strict purity as in the tomatoes. Due to the fact that larger potato seeds boosted germination and seedling development in tests, it was required to look at how the mother crop can be managed for increasing the seed size. Seed size was controlled by stem density, lateral stem trimming, the number of inflorescences for each vine, and the number of pollinated flowers for each one of the inflorescences [31]. In addition, crop dormancy was a major stumbling block to TPS adoption. TPS has a lifespan of 8-10-years, however it is inactive for 6-12 months at a period. This entailed either adequately keeping seed prior to selling and utilizing it or developing methods for breaking the dormancy. The two choices had drawbacks. TPS must be stored for one year by dependable seed providers who are prepared to keep their money tied up in storage seeds. In the case when users sell too soon, they face the danger of poor germination. The breeders' other option was to use gibberellic acid for treating the TPS, yet this led in seedlings that were chlorotic, elongated, and non-vigorous. Pallais and his colleagues indicated that storing TPS at low levels of humidity (i.e.,3.50-4%) and a fairly high temperature (30° Celsius) for roughly 6 months following harvest breaks dormancy, led to uniform germination (Table 3). Adapted from [44].

Temperature (oC)	**SMC (%)**	**Storage (months)**					
		1	2	3	4	5	6
15	3.4	1	2	0	2	0	1
	5.1	2	4	4	5	6	20
	7.3	3	3	7	13	17	52
30	3.4	2	3	5	6	12	38
	5.1	4	21	55	63	72	81
	7.3	9	21	50	59	67	87
45	3.4	2	45	74	79	78	92
	5.1	14	69	61	63	34	50
	7.3	22	15	0	0	0	0

Table 3: Effects of the temperature of storage, storage time and seed moisture content (SMC) on the germination (%) at 27°C.

(From Pallais and Flacon, 1997).

TPS treated and processed in this manner displayed over 75% germination after 8 years [44,45]. This study represents foundation for the CIP's current seed management and storage procedures, allowing for the processing of relatively large quantities of seed which may be strategically processed and utilized, such as after a catastrophe where small-scale farmers require assistance in order to rapidly restart potato development, as in case of Chacasina in Peru in 1995-1996. (see below). importance of seed size was further emphasized by this research group's work. Large seeds do even higher, to the point that direct field sowing has resurfaced as a viable method of utilizing TPS to produce a ware harvest.

Pests and diseases

Concerns over TPS's use have also highlighted the future advantage of TPS in terms of virus infections. TPS has the benefit of the viruses not being spread by botanical seeds, while seed tuber programs try to maintain viral infection to a low. Although the potato spindle tuber viroid was considered as an outlier, it didn't offer a significant technological difficulty because it was monitored easily. Resistance to significant fungi diseases like the *Phytophthorain festans* might be crossed into the TPS types by choosing resistant or partly resistant clonal kin. It was also looked into if TPS technology could be used for selecting disease tolerance in seedling tuber generation or later. At the same time, natural selection for disease tolerance at farmer levels proved ineffectual. It took a lot of money and time to set up and maintain nurseries, because seedling survival rates after a serious infection were extremely low. One of the reasons why technology remains alive and strong in Nicaragua is because of the resistance of TPS-derived materials. According to [46], when seedling tubers weight was raised relative to whole and half cut Desiree seed tubers, plant height, percent emergence, stems/plant, ground cover by foliage, marketable and total yields, and number of tubers per plant all improved considerably. TPS crops had a lower incidence of late blight (*Phytophthorain festans* L.) compared to Desiree. Desiree seed tubers produced considerably high average per tuber weight in both half cut and whole forms. Tubers taken from various seedling tubersizes have been statistically similar in uniformity, and Desiree tubers have been statistically uniform when put to comparison with seedling tubers. The three-year results imply that seedling tubers larger than 1 g might be efficiently employed for potato production in the same way that seed tubers from any standard variety can. Pesticides are administered once a week during the first (2-4) weeks following planting. In the case where plants reach the age of 30-70 days, pesticides are administered at least two times a week, based on the severity of the pest/disease infestation. For avoiding pest resistance, contact and systemic insecticides (like Marshal, Curacron, Decis, Spontan, Kalikron, Padan, Pounce, and Arrivo) and fungicides (like Trineb, Redomil, Preficur, Daconil, Dithane, Curci, Polyram andVandozeb) are alterately applied for avoiding pest resistance [47].

Economic evaluations and other controversies

TPS progenies competed favorably with clonal check in 4 diverse Indianagro-ecologies, yielding 3.4 Mg/ha more on average, according to an economic study of TPS-derived materials of planting that have been focused on the adaptability trials. This resulted in a net profit of USD415 per hectare. Based on those findings, a conservative estimate of 78000 hectares under the TPS in India by 2015 was created [48]. Further research revealed that northeastern hills of India are profitable, while the northeastern plains are marginally profitable. In mid-1990s, CIP conducted on-farm research in Egypt, Indonesia, India, and Peru for comparing the TPS against clonally propagated range. This exposed a far less rosy vision for TPS. In comparison to clonal variety, study discovered a crucial trade-off between the lower TPS cost and lower crop harvest value. In three of the locations, cost reductions from the TPS were equivalent to 50%. Ware potatoes produced from the TPS seedling tubers were priced similarly to clonal check per kilo per size grade, however, the yield has been lower and there has been a higher proportion of smaller tubers in most areas [49]. Both of those data indicate that the TPS usage entails high labor cost for growers, and that economic appeal of TPS is highly dependent on relation to seed tubers. Cost and efficiency of the seed tubers, latter of which is primarily dictated by degeneration and resulting yield reduction, characterize TPS technology's opportunities. Based on success of the current clonal scheme, findings of on-farm research contributed to establishment of an analytical rule- of-thumb to define a sufficient indicator of the profitability of the TPS. TPS is more likely to be successful when seed costs account for 22% or more of the value of tuber supply, according to this rule of thumb. The assumption is that the TPS is not suitable for all processing conditions, but it is a cost- effective alternative in certain areas where clonal seed is difficult to obtain and costly [49]. TPS technology's performance is moderate when assessed by region currently cultivated under TPS or TPS-derived products [35].

Aspects of plant health legislation

The Commission informed the experts on the plant health provisions applicable to True Potato Seed (TPS) and the necessary procedures to allow their movement within the EU. While Annex 4, Section 2, point 18.3 lists the viruses and viroids that need to be tested in the case of TPS, any additional risks are unknown. Therefore, the Netherlands was requested to provide a Pest Risk Assessment (PRA) as soon as possible. Such a PRA will be discussed in the Standing Committee for Plant Health and, if the Member States decide so, an EFSA-opinion might be requested. If subsequently any amendments to the Annexes of the plant health legislation are necessary, the entire process might only be concluded by the end of 2016.

Marketing pathways

[50,52] write some requirements for producing true seed of potato. The expert group discussed the most likely marketing pathways for potato varieties produced from TPS. Given the climatic conditions in Europe it is considered to be most likely that tubers, and not TPS, will be marketed to final users. The most realistic pathway is thus: TPS → plants for planting → 1st generation hybrid tubers → 2nd generation hybrid tubers [51]. As the potato is an agricultural crop, the propagating material needs to be certified and certification requirements need to be developed [52]. If TPS are to be imported from 3rd countries, an equivalence decision will be required. The issue of an appropriate terminology for the two tuber generations was discussed. It was agreed that the first generation corresponds to basic and the second generation to certified seed potatoes. The names of the two generations should reflect this, but also signal the specific mode of propagation through TPS. A decision concerning the naming of the TPS derived tuber generations was not taken.

Requirements

Uniformity requirements for variety acceptance TPS varieties are less uniform than vegetatively propagated varieties. The current uniformity requirements in the relevant CPVO protocol might thus be too strict for TPS varieties and a temporary experiment should also derogate from the existing uniformity standards. It was agreed to compile information on the uniformity that can be achieved by TPS varieties in order to develop an appropriate standard for this type of propagation.

Requirements for seeds.

The experts agreed that appropriate requirements need to be developed for the parental lines:

- Uniformity
- Purity
- Trueness to type

- Percentage of off-types
- Inspection at suitable growth stage
- Certain plant health requirements;

for the crop (for production in field or greenhouse):

- Isolation (maybe not applicable if produced in greenhouses)
- Varietal purity
- Species purity
- Plant health requirements
- Inspections; and for lots:
- Germination
- Varietal purity,
- Analytical purity
- Moisture content
- Lot size (maximum lot size)
- Sample size
- Plant health requirements.

FR informed that ISTA protocols exist for the testing of TPS. Requirements on propagating material Small plants might be an intermediary production stage and therefore official checks on seedlings are necessary, especially with regard to traceability and sanitary risks. Requirements for 1st and 2nd generation hybrid tubers. The experts agreed that in general the requirements as for basic and certified seed potato tubers in Annex I of the basic directive 2002/56/EC should apply. The possibility that certain requirements, such as external defects, are not needed should be taken into account. Other requirements. Further requirements that need to be determined concern

- Requirements on producers of TPS tubers.
- Labelling and packaging.
- Quantitative restrictions; reporting requirements for the temporary experiment.

Conclusion

Exploring promise of TPS in a variety of countries resulted in several fascinating results. first experimental findings in different countries revealed exciting possibilities and positive extrapolations. However, finding details on actual state of TPS usage, and, most specifically, information that may justify why the TPS did not take off and expand further, has proved challenging. simple inference is that tuber seed technology did not outperform economic viability. This, though, ignores valuable lessons that may come from more rigorous studies in different countries on other influences that could have affected. Although it is possible to believe that the use of the TPS as a popular method of growing potato in developed countries is too innovative to become commonplace, it has significant niche applications, like restoring genetic diversity or ensuring food protection after. Moreover, as shown by hundreds of the journal publications on TPS in potato, the study has contributed to expertise on different aspects of potato crop morphology, breeding and agronomy. Finally, it remains to be seen if this is what there is to tell regarding TPS. The technology could be developed further, especially by breeding and seed quality, to make it more stable. It's still a viable potato technology in areas and times where seed tubers are scarce and costly.

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