Adaptation of Cultivated Potatoes to the Lowland Tropics

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An initial group of 6000 potato clones from various taxonomic groups was screened for adaptation to high temperatures and humidity at a high jungle site. Of these, 34 tetraploid clones were selected for further testing under three tropical environments in Peru. The sites represented a hot, irrigated location; a high, wet jungle; and a low, wet jungle.

The performance of some of the clones, in particular hybrids of *tuberosum* × *neo-tuberosum* and *tuberosum* × *phureja*, was remarkable given the short growing season and the stress imposed not only by the weather but also by weeds, insects, and diseases. The greater genetic diversity of the inter-group hybrids gave the genotypes a greater ability to adapt to conditions of stress than the intra-group hybrids. The results indicate that there is a genetic potential to adapt potatoes to high temperatures, and that for the first time it may be possible to economically grow potatoes in the lowland tropics.

The principal areas of cultivation of the potato are concentrated in zones of the world with cool to medium temperatures during the growing season. This condition is met both at low elevations in medium to high latitude countries as well as at high elevations in many tropical countries.

The type of germ plasm utilized in different production zones also varies with the influence of latitude on daylength and temperature. High latitude countries with medium temperatures and long photoperiods during the growing season use cultivars from the *tuberosum* group, whereas countries with low latitudes, high elevations, and cool temperatures use cultivars from the group *andigenum*, some *tuberosum* × *andigenum* hybrids, and to a lesser extent cultivars from other taxonomic groups.

The response of these various germ plasm groups when moved away from their native ecological niches is in general the same: a very low yield compared to local cultivars. Short day potatoes grown under long day, medium temperature conditions are extremely late, whereas most of the so-called day neutral potatoes grown under the short day and cool temperatures of the low latitude and high altitude environments are in most cases extremely early.

Attempts to cultivate potatoes in the lowland tropics have utilized only cultivars from the group *tuberosum*. Since *tuberosum* cultivars have been selected under higher temperatures than those prevalent at the centre of origin of the potato, they would be expected to have more adaptation to warmer conditions than any other cultivated germ plasm. The stringent conditions that the potato meets in the lowland tropics are rather different to those present in the common areas of cultivation. Therefore, characteristics related to adaptation will have to be given much more emphasis during early stages of selection than certain agronomic characters.

The International Potato Center (CIP) has as one of its objectives to develop heat tolerant clones as a potential to expand the opportunities for potato cultivation in the warm lowland tropics, both dry and wet. This report provides the first data on the progress of the research program.

Materials and Methods

Three testing sites in Peru were used in these experiments. La Molina, an arid area under irrigation that represents a dry, hot lowland tropic. San Ramon, a high jungle location where the common crops are cassava, fruit trees, coffee, and corn. Yurimaguas, a low jungle site in the Amazonian basin where the agriculture is a shifting system that uses cassava, rice, bananas, and tropical forages.

About 6000 clones from various diploid and tetraploid taxonomic groups as well as their intercrosses were evaluated at the San Ramon location during the period June–October 1974. From these, 34 tetraploid clones were chosen for their earliness and yield potential and were grown in replicated trials during December to February 1975 at San Ramon and La Molina. The same set of clones was grown later at Yurimaguas. The taxonomic groups in the pedigrees of the clones utilized in the experi-

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Table 1. Yields of representative clones.

Clone	Taxonomic group	Yield for 10 plants (kg)		
		San Ramon	La Molina	Yurimaguas
N565.1	(T × NT)	14.4	6.4	5.0
N574.1	(T × NT)	14.1	9.0	2.1
DTO-28	(T × P)	13.6	10.1	5.3
DTO-2	(T × P)	11.8	10.7	2.9
DTO-33	(T × P)	11.6	10.0	3.8
N570.5	(T × NT)	11.3	4.4	1.4
Urgenta	(T × T)	10.8	8.8	1.5
N503.162	(NT × NT)	10.7	8.5	1.2
N513.3	(NT × NT)	10.2	5.9	0.7
N545.3	(NT × NT)	9.1	3.8	1.1
ONA	(T × T)	6.7	8.6	1.2
Arran Pilot	(T × T)	6.3	7.8	1.5
Mariva	(T × A)	4.6	2.5	0.1
Revolucion	(T × A)	4.0	3.0	0.8
Inti Sipa	(A × A)	3.6	2.5	0.02
Mean[a]		8.2	6.8	1.7
$LSD_{0.05}$		2.0	2.3	0.8

[a]A general mean per location for all 34 cultivars. LSD values have been calculated from the analysis of variance over all the clones at each site.

ments were: *tuberosum* × *tuberosum*, 4 clones; *tuberosum* × *phureja*, 16 clones; *tuberosum* × *neo-tuberosum* (*andigenum*), 5 clones; *neo-tuberosum* × *neo-tuberosum*, 6 clones; *tuberosum* × native *andigenum*, 2 clones; and native *andigenum*, 1 clone.

The experimental design at each location was a completely randomized block with two replications. Each plot had 10 plants.

Results and Discussion

There was a great deal of variability in yield among clones within each location as shown in Table 1. Each environment represented a different level of stress as measured by differences in the overall means. The growing periods of 60, 75, and 90 days for the testing sites were not purposely chosen but were the length of time at which most of the clones were either mature or dead as a consequence of weather stress, insect and disease damage, or the combined effects of them.

Some of the main environmental components and their effects on or their interactions with the genotypes will be discussed.

Photoperiod

The latitude of the testing sites (6, 11, and 12° for Yurimaguas, San Ramon, and La Molina, respectively) is fairly close. Daylength at San Ramon and La Molina was the same, whereas at Yurimaguas it was about 20 minutes less. The genetic background of all the clones used in this work, except one, was day neutral or hybrids between day neutral × short day types. Any tuber-inducing differences of the photoperiod should either have been minimal or nil.

Temperature and Water Supply

Temperature-wise the two jungle locations placed more stress on the plants than did La Molina. At Yurimaguas, temperatures were high and uniform, whereas at San Ramon it was somewhat cool during the night. However, in these two sites rainfall supplied moisture on a rather regular basis. Despite the fact that at La Molina both the maximum and the minimum temperatures were lower, the yield of most individual clones as well as the overall mean was lower than at San Ramon. Since the crop at La Molina was under surface irrigation, the moisture availability was not uniform and this appears to have had a stress effect on yield.

Diseases and Insects

At La Molina, the principal problem was the attack by tuber moths, *Scrobipalpula absoluta* and *Pthorimaea operculella*, which caused considerable damage in the foliage and later in the tubers. Spraying with insecticides every 7

days did not provide an adequate control. An attack of *Rhizoctonia solani* also affected about 20% of the plants.

At San Ramon, the two major problems were *Rhizoctonia solani*, which attacked about 50% of the plants, and late blight, *Phytophthora infestans*. The damage of late blight was relatively well controlled by fungicides.

At Yurimaguas, a heavy attack of leaf hoppers (*Empoasca* spp.) was recorded and isolated plants were affected by *Pseudomonas solanacearum*. The major disease problem was *Botrytis* sp. which affected the plants at an early stage of growth and killed many of them. Differences in susceptibility were noticeable. Foliage of the most severely affected individuals was practically covered by the mycelium of the fungus. It is interesting to note that no attack whatsoever of late blight was detected during the growing period. The reason could be that the high temperature limits the survival of the fungus. Later experiments were also free from attack by *P. infestans*.

Genotypes

A variety of germ plasm combinations was tried in these experiments to gain insight into their relative abilities to withstand environments. Simmonds (1971) indicated that some main crop or late maturing temperate potatoes can do remarkably well in the subtropics and tropics at medium altitudes. The data in Table 1 support his statement. In fact, the three *tuberosum* cultivars at San Ramon and La Molina yielded significantly better than the Peruvian cultivars used as checks. The failure of the local cultivars was expected because they were all selected under highland conditions (short-day and cool temperatures). On the other hand, *tuberosum* cultivars normally short day types (Mendoza 1974) have a higher critical daylength than Andean potatoes. Also, their adaptation to higher temperatures is a consequence of the conditions under which they were selected in the summers of the northern hemisphere. However, this relative tolerance to higher temperatures appears to be limited and the conditions present at Yurimaguas seemed to be beyond the threshold of adaptation for them.

The NT × NT hybrids at San Ramon and Yurimaguas had a similar behaviour to the T × T cultivars, but at La Molina they were slightly inferior. This would indicate that the selection work made by some northern hemisphere breeding programs for adaptation of *andigenum* to longer and warmer days has made measurable progress (Plaisted et al. 1975). For further selection for adaptation to lowland tropics, the *neo-tuberosum* material may be more responsive than *tuberosum* because it has a broader genetic base (Mendoza and Haynes 1974a).

The performance of some of the "wider" hybrids, T × NT and T × P is encouraging because it shows that the existing potential for adaptation to the lowland tropics might be capitalized upon under a carefully designed breeding scheme. Some clones under the severe environmental conditions of Yurimaguas yielded about 0.5 kg/plant in 60 days. This yield is approximately equivalent to 15 t/ha, which for a short growing period constitutes a remarkable performance. Some of the same hybrid clones also performed very well, in relation to the rest of the materials tested, in the other two locations.

The most promising materials for the lowland tropics, at least at present, have as one parent a *tuberosum* cultivar that provides earliness and relative heat tolerance. To obtain highly heterotic hybrids a *neo-tuberosum* or a *phureja–stenotomum* hybrid that produces 2*n* gametes by first division restitution (Mok and Peloquin 1975) would be suitable as the other parent. To realize the maximum gain from each source of germ plasm, it would be necessary to perform some previous selection for adaptation to tropical conditions (Mendoza and Haynes 1974b). In addition to the widening of the genetic diversity obtained by such combinations of germ plasm, also an adequate level of resistance to diseases must be achieved.

Early maturity is an essential requirement for tropical adaptation. However, this earliness does not necessarily need to be in the absolute sense of time from planting to senescence. A medium maturity cultivar with an early tuber initiation and fast bulking may also be suitable even if the vines do not reach maturity rapidly. A great deal of genetic variability for tuber initiation has been found (Mendoza 1974) and this trait may be rapidly improved under selection. The earliness obtained by genetic means may be increased to some extent using some preconditioning of tubers before planting. Presprouting of tubers and a proper physiological age may help to hasten the crop (Madec and Perennec 1962).

There are some additional problems such as disease resistance, mainly to bacterial wilt and late blight, that have to be solved by breeding to make the potato an economically competitive crop. The impact of introducing the potato to these new areas of cultivation could be tremendous since the high nutritive value of this crop is well known.

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