Breeding for heat tolerance and disease resistance for the warming potato growing environments

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Abstract

The potato is normally adapted to grow under cool to mild temperature regimes. However, in the recent years the climate of many potato producing areas is warming up and rainfall distribution is becoming erratic and scarce. These trends may continue in the foreseeable future, as a result of the global weather change.

Breeding potatoes for heat tolerance, earliness and disease resistance started at the International Potato Center (CIP) in 1974 aiming to extend the potato crop to warmer; humid and arid areas of the developing world. At present, the importance of these potatoes has been boosted by the gradual global weather warming that has started to affect its production areas. CIP evaluated large populations genetically diverse and selected clones in two arid and warm and two humid and hot locations in Peru with further testing in African an Asian countries.

Within *Solanum tuberosum* L. ssps *tuberosum* and *andigena* adapted to grow under long days (Neo-*tuberosum*) and to a lesser extent in the diploid *S. phureja – S. stenotomum* populations, some heat tolerant and early maturing genotypes (80 to 90 days growing period) were selected. Intercrossing them produced a rapid increase of heat tolerance and early maturity. Next step was introducing resistances particularly to virus diseases. As a result CIP developed clones that could maintain the crop where warming climate may limit potato production.

Keywords: Earliness, Heat tolerance, Disease resistance, Combining ability.

Introduction

An important part of potatoes produced in developing countries concentrate in rainy hilly areas of variable altitude with cool to mild temperature. Under the global warming these areas are being affected and the expected increase of 4 to 5°C would alter tuberization, extend the growing period and enhance susceptibility to pests and diseases. Erratic rainfall patterns already observed are causing water stresses. In such a scenario, probably many of the presently grown varieties may suffer significant yield reduction and will need to be replaced.

Since 1974 the International Potato Center (CIP) headquartered in Peru, started a breeding program to improve potato adaptation and increase food production in the humid warm tropics as well as in semi arid areas of the tropics and subtropics of the developing world which are densely populated by people of scarce resources and great need of food.

This paper reports the work developed at CIP for adaptation to these environments emphasizing its genetic aspects and resources, its breeding philosophy and strategy and its outputs as new varieties released in Peru and other countries.

Genetic aspects of potato adaptation to hot environments

Daylength and temperature responses are basic factors for adaptation to changing environments. Research results showed that long day reaction for tuberization was recessive to short day reaction (Mendoza and Haynes, 1977). Also, it was suggested that adaptation to hot and warm conditions would be recessive to that to cool environments. The critical daylength concept established that each genotype has its own value, *i.e.*, 13 hours, above which tuberization stops and below which it takes place normally (Mendoza and Haynes, 1976). Likewise, each genotype would have a critical temperature, *i.e.*, 16C°, above which tuberization stops and below it takes place normally. Daylength and temperature responses appeared correlated as long days and high temperatures act in the same direction as did response to short days and low temperatures. For instance, under a mean temperature of 24°C and a 13 hour photoperiod, a clone with a critical day length of 15 hours, would tuberize better than other with a critical day length of 12 hours. Recessiveness of heat tolerance was confirmed as intercrossing selected heat tolerant genotypes produced a steady increase in the frequency of clones showing that attribute (Mendoza, 1976, Mendoza and Estrada, 1979).

Genetic resources for the breeding work

The initial material for evaluation and selection under short day hot environments was formed by a large number of US and European *S. tuberosum* ssp. *tuberosum* varieties and breeding lines, *S. tuberosum* ssp. *andigena* (neo-tuberosum) adapted to long days and warmer temperatures than those of the Andean region and with immunity to PVX and PVY and late blight minor gene resistance (Plaisted, 1980) and a diploid S. *stenotomum* – S. *phureja* population adapted to long days (Mendoza and Haynes, 1977). Also, diploid hybrids of the wild species *S. sparsipilum*, *S.chacoense*, *S. bulbocastanum* and *S. berthaultii* were included as sources of disease resistance (Mendoza and Estrada, 1979).

Breeding philosophy

Mendoza and Haynes, 1974; proposed that heterosis for tuber yield would be maximized by increasing allelic diversity, provided that parental materials besides a wide genetic background would have a proper level of environmental adaptation. This was demonstrated by further experimental research results (Amoros and Mendoza, 1979; Mendoza, 1980).

Mendoza and Estrada, 1979; proposed that the yield of a genotype (**X**) may be expressed as the function **X = f(A + Y + R)** where **A**, are genes controlling adaptation to temperature and daylength, mayor factors in potato growth and development; **Y**, are the genes controlling yield *per se* related to the plant's capacity and efficiency to use light energy and transform it into chemical energy in the form of plant material, including tubers and **R**, are the genes controlling resistance or tolerance to diseases, pests and environmental stresses.

At present, many developing countries still grow cultivars selected under temperate and favorable conditions that may not adapt and perform under warm or hot environments. Therefore, breeding potatoes for developing countries where growing conditions might have more severe environmental constraints and more damaging pest and diseases, required selecting robust cultivars with the **A**, **Y** and particularly **R** genes to ensure an increased and stable yield to provide a greater food security.

Stepwise breeding strategy

First step: Evaluation of a large number of genetically diverse clones to select for heat tolerance in Peru in two semi arid and warm sites, La Molina and later Tacna, and two humid and hot, San Ramon and Yurimaguas.

Second step: Intercrossing selected clones to build a base population to apply recurrent selection for general combining ability for heat tolerance, earliness and agronomic attributes. These materials were later evaluated in hot and humid African an Asian countries

Third step: After progressing in heat tolerance, resistances to viruses X, Y and PLRV, bacterial wilt and early blight were introduced using resistant and adapted progenitors,

Fourth step: Increase testing and selection in warm environments of African and Asian countries to identify potential new varieties.

Fifth step: Use heat tolerant and high yielding clones to improve earliness of materials of other CIP programs as late blight resistance and use of true seed for commercial production.

Breeding results

Heat tolerance

Progress in heat tolerance had a slow starting but speeded up as early maturing heat tolerant clones were identified and intercrossed to produce new populations for the recurrent selection with progeny testing scheme. Results confirmed that heat tolerance was a recessive character.

This early work lead to selection of a few clones such as: DTO-33, DTO-28, DTO-2, LT-1, LT-2, LT-3, LT-4, LT-5, LT-6, LT-7, Maria Tropical, and others that showing heat tolerance. Selected clones were tested for general combining ability and a few like LT-1. LT-7, DTO-2, Maria Tropical among others proved to be excellent progenitors transmitting their attributes to a large number of progenies. The testing process continued identifying new heat tolerant progenitors like B71.240.2, Serrana, Katahdin, Atlantic, AVRDC-1287.19, TS-2, TS-4, 866.1, WRF-1923.1, 377888.8, 378015.3, 378015.13, 7XY.1, R128.6 etc., were used to combine their attributes with resistance to viruses and other diseases. **LT-5** resistant to late blight became the variety **MEVA** in Madagascar and **LT-8** released as **COSTANERA** in Peru.

Combining heat tolerance and virus resistance

With improved adaptation, the next step was to introduce resistances to the most common pathogens of the hot environments, the viruses PVX, PVY, and PLRV. LT-1 was a parent of the two first heat tolerant PVX and PVY immune clones: LT-8 and LT-9 that besides their good attributes were excellent progenitors. These two progenitors became the foundation of CIP's virus resistance breeding program leading to selection of excellent PVX and PVY immune progenitors as XY.4, XY.8, XY.13, XY.16, XY.20, etc Later these were used to breed *multiplex* XY immune and combine PVX and PVY immunities with PLRV resistance.

Combining heat tolerance and Phytophthora infestans late blight resistance

Several heat tolerant clones derived from *S. tuberosum* ssp. *andigena* adapted to long days (*neo-tuberosum*) were minor gene resistant to late blight. Several late blight resistant clones released in developing countries had as male progenitor a mixture of pollen from heat tolerant material (bulk early) or the clones 7XY.1, R128.6, 377888.8 and N551.12 (Table N° 1)

Combining heat tolerance and Alternaria solani early blight resistance

Since early blight could be a serious problem in several warm environments screening for resistance were carried out in Peru (San Ramon) and Brazil (Brasilia) finding several resistant clones such as Maine-28, Maine-47, NDD-277.2 and Atlantic. Crosses of these to heat tolerant material were evaluated in Brazil and 30 clones were selected as resistant and listed as CNPH/CIP. Numbers 001 and 006 [(377888.7 (N-565.2 x DTO-28) x NDD-277.2], 002. 004 and 005 (Serrana x NDD277.2), 014, 015, 016, and 017 (Atlantic x 378015.16), 018, 019, 020, 021 (Maine 28 x 378015.16), 022 and 023 (Y84.011 x LT-7), 024 (AVRDC-1287.19 x Y011), 025 (C83.633 x EB Bulk), 026, 027 and 028 (378015.16 x Y84.011), 029 (CFS-69.1 x Y84.011) and 031 (Y84.004 x WNC-521.22). Research on inheritance of resistance to early blight permitted to obtain heritability estimates of $h^2 = 0.7$ and $h^2 = 0.8$ that explains the fast transfer of resistance to heat tolerant clones (Mendoza *et al*, 1987)

Combining heat tolerance and Ralstonia solanacearum, bacterial wilt resistance

This resistance is complex due to existence of races 1 and 3 that interact with the environment and complicated by latent tuber infection. Moreover, heritability of resistance is low, $h^2 = 0.19$ determining that response to selection is slow (Anguiz and Mendoza, 1997). Resistance in cultivated materials is rare but despite of this, CIP identified some resistant clones: Cruza-148, BR-63.65, BR-63.74, BR-63.76, MS-35.22 and MS-1C.2. These were crossed to heat tolerant material and the following clones were selected in Peru and Philippines.

Several heat tolerant and bacterial wilt resistant clones were identified in Peru: BW-1 (BR-63.65 x Katahdin), BW-2 and BW-3 (BR-63.65 x Atlantic), BW-10 (BR-63.74 x DTO-28) BW-11 and BW-12 (BR-65.74 x WRF-1923.1). **BW-11** released as **KINGA** in Madagascar.

Later, in Philippines the resistant clones FBA-1 [(377835.11 (BR-63-65 x Atlantic) x BW Bk.], FBA-2 {381064.3 [(BR-63.74 x WRF-1923.1) x AVRDC-1287.19] x BW Bk., FBA-3 {[379673.17 (377847.4 x Maria Tropical)] x BW Bk.} and the full sibs FBA-15, FBA-16 and FBA-17 {381064.10 [(BR-63.74 x WRF-1923.1) x AVRDC-1287.19] x 7XY.1}

Table 1. Diseases resistant new varieties derived from heat tolerant progenitors developed from CIP's breed material released in Asia, Africa and Latin America

Variety	Country	Female	Male	L. blight	B. wilt	Viruses
DHeera	Bangladesh	Maine-53	377888.8	MR	---	---
Heera	Bangladesh	377831.1	M. Tropical	MR	---	---
Chamak	Bangladesh	Serrana	LT-7	MR		Imm.PVY
Ingabire	Burundi	378493.915	Early Bk.	R	---	---
Muruta	Burundi	CFK-69.1	14XY.1	MR	R	---
Muziranzara	Burundi	65-ZA.5	DTO-28	R	---	---
Ruzinko	Burundi	378493.915	Early Bk.	R	---	---
Babungo	Cameroon	379703.3	7XY.1	MR	---	---
IRA- 92	Cameroon	Renska	7XY.1	MR	---	Imm.PVY
Cipira	Cameroon	378493.915	Early Bk.	R	---	---
Baseko	Congo	Serrana	Atzimba	R	---	---
Enfula	Congo	65-ZA.5	CFK-69.1	MR	---	---
Floresta	Costa Rica	I-959 x XY Bk.	866.1 x P_2C_6.25	R		
Cooperation	China	Serrana	XY.4	MR	MR	Imm. X+Y
Kinga	Madagascar	BR-63.74	WRF-1923.1	MR	R	---
Meva	Madagascar	Snow Flake	N551.12	R	---	---
Amarilis	Peru	376724.1	Early Bk.	R	---	---
Raniag	Philippines	Y84.025	378015.16	R	---	---
Kinigi	Rwanda	65-ZA.5	YY.1	MR	---	Imm.PVY
Mabondo	Rwanda	Murca	378676.6	R	R	---
Mizero	Rwanda	BL-2.9	R128.8	R	---	---
Yayla Kizi	Turkey	Serrana	15XY.4	MR	---	Imm.PVY
Victoria	Uganda	378493.915	Early Bk.	R	---	---
Kisoro	Uganda	378493.915	Early Bk.	R	---	---

MR = Moderate resistant, **R** = Resistant, **Imm**. = Immune

Selection of high general combining ability progenitors derived from heat tolerant material for use in potato production from true seed (TPS)

The progenitors DTO-28, LT-7, LT-8, R-128.6, 378015.3, 378015.16, the TS clones numbered from 1 to 15, and the varieties Serrana and Atlantic were either breed or identified within the heat tolerance breeding work.

Conclusions

All the materials described provide an excellent genetic foundation to face the weather warming that will accentuate in the forthcoming years that will particularly affect food production in the developing world.

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