POTATO BREEDING, MEETING THE CHALLENGES OF CLIMATE CHANGE

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Abstract

Potato, the third most important food crop originates from temperate climatic zone characterised by moderate and even precipitation. Current climatic changes in Central European region mean serious challenges to the potato plant, its growers and breeders as well. The average daily temperature in the growing season is generally above the optimum and the required precipitation is less than needed. The risk of spreading pathogens and pest adapted to warmer climates is increasing, while appearance of new strains of common pathogens like Potato Virus Y and *Phytophtora infestans* means new challenges to the potato production in the Region as well. Potato in general is a sensitive crop to biotic and abiotic stresses due to its numerous pathogens, pest and week root system. Stress sensitivity may manifests in yield decrease and quality loss. Breeding and cultivation of stress resistant varieties is needed to maintain profitability of potato production under stressful conditions. The Potato Research Center at Keszthely runs a specific breeding program since 1960 focusing on the release of varieties suitable for Central European agro-ecological conditions due to their resistance against major biotic and abiotic stress factors. The applied breeding strategy is a complex approach using classical and modern biotechnological methods, such as negative and positive selection based on phenotyping, somatic hybridization, DNA marker based selection for certain traits, use of resistant genotypes as parents and application of a complex parental line evaluation system for breeding value estimation of crossing families. As the results of the consistent selection work several new varieties with complex resistance traits were released from the program recently.

Key words: potato, resistance breeding, climate change

Potato is the third most important staple food worldwide (FAO, 2008). The plant originates from a temperate climatic zone that is characterised by moderate and even precipitation. Current climatic changes in the Central European region, especially in the Carpathian Basin mean serious challenges to the potato and its growers. At the location of Keszthely where our breeding program runs the climatic conditions for potato production are far from the optimal in general. The day time temperature during the vegetation period is generally above the optimum and the required precipitation is less than needed and rather uneven. The frequency of stress full periods in the growing season was increased during the last decades too.

Potato in general is a sensitive crop both to biotic and abiotic stresses (van Loon, 1981). It has many pathogens and pest and a week root system. Stress sensitivity may manifests in yield decrease (lower tuber number and weight/plant) and quality loss (tuber malformations, internal defects, higher sugar or alkaloid content, etc.), (Vayda, 1994; Levy, Veilleux, 2007). Naturally different potato genotypes may dramatically alter in biotic and abiotic stress sensitivity (Hassanpanah, 2010). Among biotic stresses viruses and potato late blight has the highest influence on yield (Salazar, 1996; Forbs, 1998). Moreover it is well-known that virus infected plants are more sensitive to abiotic stresses like heat and drought. Under environmental conditions where abiotic stress and high virus pressure parallel appear their combined negative impact on potato is even more dramatic. According to the last study in Hungary, the virus pressure is extremely high in the country and more than 90% of potato virus Y (PVY) isolates collected from potato fields belong to the economically most aggressive PVY^{NTN} strain These circumstances provides ideal conditions for simultaneous selection for abiotic stress tolerance and virus resistance under field conditions.

The Potato Research Centre at Keszthely deals with resistance breeding since 1960. One of its major duties is the breeding of varieties suitable for Central European agro-ecological conditions due to their resistance against major pests, pathogens and abiotic stresses. The applied breeding strategy is a complex approach to meet these challenges: negative selection of stress sensitive genotypes under natural stressful condition, use of sexually compatible or non-compatible resistant wild species and hybrids as

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parents, positive selection of genotypes under natural field conditions or after artificial infections with pathogens (Polgar *et al*, 2002; Horvath *et al*, 2002), application of DNA markers linked to resistance genes (Cernak *et al*, 2008, Ahmadvand *et al*, 2013), application of complex parental line evaluation system to predict the breeding value of each cross combinations. Recently Polgar et al (2010) reported the release of three varieties coming out of the program exceeding control varieties both in biotic/abiotic stress tolerance and marketable yield. Here we discuss and evaluate the usefulness of the complex breeding approach and introduce the latest results of the program.

MATERIAL AND METHOD

The breeding program operates at Keszthely, Hungary since 1960. Meteorological data were collected at site by Metos weather station of Pressl Instruments, Austria. In the program about 15.000 single hills, 500 “A”, 60 “B”, 40 “C” and 25 “D” breeding clones are evaluated each year under field conditions. Negative selection of stress sensitive genotypes was done based on the recording of visible leaf symptoms during vegetation, for tuber defects and yield at harvest under field conditions. Positive selection for PVY resistance was based on the mechanical infection of genotypes by a local PVY^{NTN} strain according to Cernák et al (2008). DNA markers based selection of positive genotypes for RYsto and Rx1, Rx2 and H1 genes was according to the protocols published by (Cernak at al. 2008, Ahmadvand et al 2013 and Gebhardt et al 1993 respectively). Parental line and crossing family evaluation: characterisation of 100 individuals at single hill stage of each crossing families for average tuber number and average tuber size/plant, general tuber appearance (1 to 3 where 3 is the best), skin colour and the total number of selected genotypes to go for the next generation (clone A) were done at harvest. Collected data were converted into a cumulated file representing the specific combined breeding value of the families of each year.

RESULTS AND DISCUSSIONS

Selected meteorological data in the vegetation period of the last eight years were collected at the site of the breeding program and compared to the 100 years average. The summarized data proves that potato genotypes taking part in the breeding program are under continuous abiotic stress during their vegetation. *Figure 1* demonstrates that in case of excluding the year of 2010 the average precipitation was 14% less than the average (284 mm).

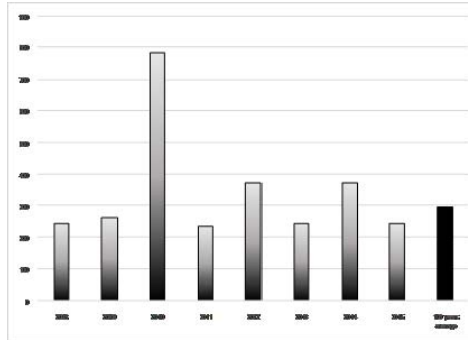

Figure 1 **Average precipitation in May-August (mm)**

The daily average temperatures were above the 100 year average by + 1.4 ^{o}C, while the daily maximums reached or were above of 35^{o}C in each season (*Figure 2*).

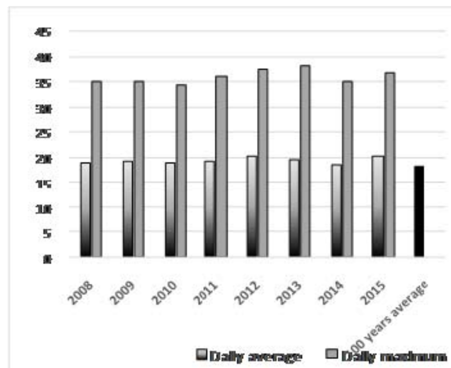

Figure 2 **Daily temperatures in May-August (^{o}C)**

Climatic changes of the region manifested in the increasing frequency of days where the daily maximums were above 25 ^{o}C too. It means in all the evaluated seasons more than 50 % of the days were stressful for potato. From growth chambers experiments of van Dam et al (1996) it is known that haulm growth is fastest between the temperature range of 20˚C - 25˚C while the optimal range of tuberization and tuber development is even lower (15˚C - 20˚C). At a temperature higher than optimal reduction of tuberization and intensified haulm development can take place as recently discussed by Rykaczewska (2013).

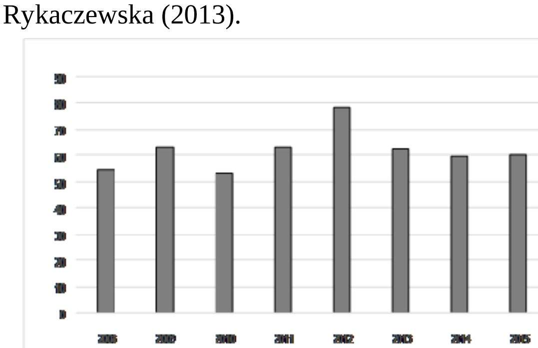

Figure 3 **Percentage of days with + 25ºC daily maximums (%)**

To meet the combined challenges of abiotic and biotic stress conditions our breeding strategy applies a set of tools built on each other. The first is the use of wild potato species and hybrids to incorporate their resistance genes into the genetic background of new varieties. *Tables 1* summarize the most important species utilized in the program. The second is the application of an intensive back crossing program and consistent selection for desired traits. The next steps of the program work under field conditions. Here the applied complex parental line and crossing family evaluation system makes possible to select the best performing parental combinations, families where we could expect potential new varieties from at the highest chance. By the evaluation system more than 300 cross combinations in total were tested during the last 10 years. Based on the cumulated relative breeding value of the families the best 10 to 15 per year were seeded in the next year with higher numbers, 500-2000 seeds/family (*Figure 4*). For the identification of resistant genotypes molecular markers routinely applied for Ry^{sto}, Rx1, Rx2 (own development) and H1 genes from literature adaptation at seedling stage. Genotypes with complex resistance were selected for further steps of the program only.

Table 1

Main wild species used in the program, those by somatic hybridization marked with *

Species	Resistance
S. stoloniferum	PVY, PVA
S chacoense	PVY
S. acaule	PVX
S. tub. ssp. andigenum	PLRV, Nematodes
S. demissum	*Phytopthora*
S. hougasii	PVY, PVS
S. vernei	Nematodes
*S. brevidens**	PLRV, *Erwinia*
*S. bulbocastanum**	*Phytophtora*
S. sparsiphyllum	*Verticillium*
*S. tariense**	Pests
*S. tarnii**	PVY
*S. commersonii**	*Phytophtora*
*S. etuberosum**	PVY

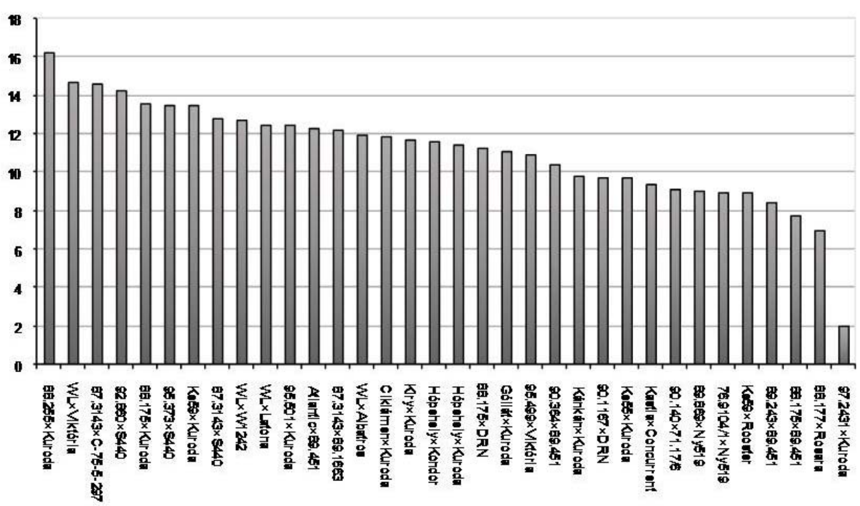

Figure 4 **Sample for comparison of relative cumulated breeding value of tested crossing families**

In these steps at age of clones A, B, C and D commercial evaluation and selection techniques were applied. Here the new variety candidates must reach the yielding potential and culinary quality of standards while must show less problems with tuber malformations and internal defects. *Table 2* summarizes the frequency of tuber disorders of recently released varieties of the program in comparison to standard varieties Desirée and Cleopatra. First year results show that standard varieties are rather sensitive even at virologically healthy status to the ecological conditions being typical for Keszthely location. The frequency of disorders further increased in the second year where seeds were used from the first year harvest for all the tested varieties. However this increase was far less in the case of virus resistant new varieties. The most typical disorders of stress sensitive varieties were tuber malformations and secondary growth reaching 47.5 % for Desiree and 21.1 % for Cleopatra in the second year of the test. Variety Botond showed the least tuber disorders having the highest % 5.5 for malformation and only 1 % for secondary growth.

CONCLUSIONS

The ecological conditions of the site where the selection process of the breeding program takes place has a significant influence on the efficiency and success of the selection process for biotic and abiotic stresses.

By the combination of common and new molecular breeding tools it is possible to increase the efficiency of the breeding program to combine high level of cultural characters with complex resistance to biotic and abiotic stresses.

Potato varieties having complex biotic resistance may meet the challenge of abiotic stresses caused by the climate change for a certain extent.

Table 2

Tuber disorders of the newest varieties originating from the complex resistance breeding program

Cultivar	Generation	Malformation %		Secondary growth %		Tuber cracking %		Index of glassiness %		Internal rust spot index %	
Year		1	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**
Balatoni	1	8.3	15.0	2.3	13.3	0.3	10.7	0	0.2	0.1	0
	2	-	17.7	-	12.0	-	5.3	-	0.2	-	0
Katica	1	11.0	24.0	3.5	14.3	2.0	4.7	0.1	0.5	0	0
	2	-	25.0	-	11	-	4.0	-	0.5	-	0
Désirée	1	**27.0**	**31.7**	**8.5**	**20.7**	**1.5**	**6.0**	**0.1**	**0.4**	**0**	**0.1**
	2	**33.8**	**22.7**	**9.0**	**16.0**	**2.0**	**5.7**	**0**	**0.2**	**0**	**0.1**
Year		**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**
Démon	1	6.0	11.0	2.0	0.4	1.3	2.2	0.1	0	0.2	0
	2	-	15.0	-	0.2	-	1.6	-	0	-	0
Désirée	**1**	**37.0**	**41.3**	**13.8**	**6.2**	**1.3**	**4.0**	**0.2**	**0.1**	**0**	**0**
	2	**-**	**47.5**	**-**	**6.2**	**-**	**3.2**	**-**	**0.1**	**-**	**0**
Year		**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	2
Botond	1	3.0	3.5	1.0	0.5	0.3	1.2	0.3	0.2	0	0
	2	-	5.5	-	0.2	-	1.5	-	0	-	0
Cleopatra	**1**	**35.0**	**24.2**	**18.4**	**12.1**	**5.5**	**10.6**	**0.5**	**1.0**	**0.2**	**0**
	2	**41.2**	**28.7**	**21.1**	**15.6**	**7.8**	**12.2**	**0.7**	**2.3**	**0.2**	**0**

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