Agrisost 2016, Vol.22, No.1: pages 1-7 ISSN 1025-0247
Available at: http://www.agrisost.reduc.edu.cu

Agronomical indicators for determination of potato (*Solanum tuberosum* L.) tolerance to drought

Alfredo Morales Rodríguez [1], Alfredo Morales Tejón[2] & Dania Rodríguez del Sol [3]

Received: June, 29, 2015

Accepted: September 13, 2015

ABSTRACT

Lately, water shortage has caused 50% losses in potato yields in several Central American countries. Knowledge and use of more tolerant potato varieties are a critical element to increase production and yields under stressing conditions. The experiments were developed at the Center for Tropical Crops Research (INIVIT), between December 2014, and March 2015. Ten plots were planted, including different varieties. Half of them (5) were not irrigated for 20 days, starting on the 50th day after plantation (drought stress period). Irrigation was resumed on the 70th day. The Stress Susceptibility Index (SSI), Stress Tolerance Index (STI), Tolerance Index (TOL), Mean Productivity (MP), and Yield Stability Index (YSI). The Atlas and Maranca varieties had the lowest values for SSI (0.67 and 0.61, respectively), and the highest values for STI (0.79 and 0.81, respectively). The highest MP (19.92 t/ha) was achieved by Atlas. The highest YSI values were observed in Maranca and Atlas (81.07 and 79.29, respectively).

Key words: Solanum tuberosum, drought tolerance, potato

INTRODUCTION

Water shortage is one of the critical factors that hinder crop growth and production worldwide, more than any other biotic or abiotic factor (Almeselmani et al., 2011, Prabha and Kumar, 2014). It is an ever-growing problem that causes crop losses globally, mainly in the developing world. Plant response to drought stress is complex and depends on several factors, like stage of development, severity, stress duration, and plant genotype (Beltrano and Ronco, 2008).

[1]Agronomy Eng., Junior researcher, Center for Tropical Crop Research: fisiologia@inivit.cu
[2] Doctor in Agricultural Sciences, Senior researcher, Director of Genetics Dept., Center for Tropical Crop Research: genetica@inivit.cu
[3] Agronomy Eng. Specialist, Center for Tropical Crop Research: geneticafer@inivit.cu

In the latest seasons, water shortage has caused losses, accounting for 50% of overall production in several Central American countries (Pino et al., 2012). Drought affects plant growth, inhibits tuber formation, size and quality of the crop. The critical hydric periods of the crop are right after sprouting, and along tuber formation (Balasimbha and Virk, 1978).

Several countries like Chile, Uruguay, Peru and Colombia, are working on identification and characterization of potato varieties capable of withstanding severe water shortage (Pino et al., 2012). Hopefully, it will contribute to important nutritional levels for people, globally.

By 2015, drought had affected 63% of all lands in Cuba (Climate Department at the Weather Center, 2015). Although potato is a technical crop, with permanent irrigation systems, drought has also affected production in several provinces. Moreover, in the 2014-2015 potato season, 100% of productions were lost in more than 50 ha, with water shortage caused by malfunction in the center pivot irrigation systems.

A great deal of methods have been used to identify drought tolerance, but yield losses under water shortage is the main farmer´s concern. Relative variation in yield potential between normal conditions of moisture and water shortage may be used to identify stress tolerant cultivars (Agili et al., 2012). Some of the most commonly used yield-based indexes are the Stress Susceptibility Index (SSI) (Fischer and Maurer, 1978), Stress Tolerance Index (STI) (Fernández, 1992), Tolerance Index (TOL), Mean Productivity (MP) (Rosielle and Hamblin, 1981), and Yield Stability Index (YSI) (Bouslama and Schapaugh, 1984).

To now, no drought-tolerant potato varieties have been identified using the above-mentioned methods in Cuba. Therefore, the purpose of this research was to determine the potato varieties with agronomic drought tolerance features, to be used in genetic breeding programs to achieve varieties that are tolerant to water shortage, or for production in normal conditions.

MATERIALS AND METHODS

The experiments were developed at the Center for Tropical Crops Research (INIVIT), located at 22.5868 north latitude, and 80.2269 west longitude. The experiment was developed between December 2014, and March 2015, on partly washed brown fluffy soil (Hernández et al., 1999). A randomized block design was used to evaluate four potato varieties (Atlas, Armada, Maranca and Everest). The experimental unit was made up of four 5m long furrows, with a planting distance of 0.90 x 0.25 m; each plot had 80 plants (20 per furrow), and 36 were eligible for evaluation.

Ten plots were planted, including different varieties. Half of them (5) were not irrigated for 20 days, starting on the 50th after plantation (drought stress period); irrigation was resumed on the 70th day. The rest of the plots were kept

humid, between 70-80% of the field´s capacity, with a 3-day irrigation interval, and partial net standard of 250 m^3/ha.

The following drought tolerance indexes were determined at harvest:

Stress Susceptibility Index (SSI) (Fischer and Maurer, 1978)
SSI = [1 – (D/C)] / [1 – (Dm/Cm)]

Stress Tolerance Index (STI) (Fernández, 1992)
STI = (Yp * Ys) / Yp^2

Tolerance Index (TOL) (Rosielle and Hamblin, 1981)
TOL = Yp - Ys

Mean Productivity (MP) Tolerance Index (TOL) (Rosielle and Hamblin, 1981)
MP = (Ys + Yp) / 2

Yield Stability Index (YSI) (Bouslama and Schapaugh, 1984)
YSI = Ys/Yp * 100

Where:
D: genotype yield in dry conditions:
C: genotype yield in normal moisture conditions C:
Dm: yield mean of all genotypes in dry conditions
Cm: yield mean of all genotypes in normal moisture conditions
Ys: yield mean in dry conditions
Yp: yield mean in normal moisture conditions

The weather data during the experiment were gathered from a geo-referenced weather station, according to flat rectangular coordinates, between 579532N and 306594E, in the Northern Cuba system.

Table 1. Weather variables during the experiment

Months	Rainfall (mm)	Temperatures (°C)	Relative humidity (%)
December (2014)	1.8	20.5	81.0
January (2015)	29.6	21.1	80.0
February (2015)	14.3	20.4	74.0
March (2015)	18.0	23.9	69.0

RESULTS AND DISCUSSION

Apparently, global weather is changing, and it is the greatest human challenge in the Twenty-First Century. The weather in Cuba might be more severe than

today; therefore, adaptation urges to a more scientifically and technologically based decision making, for which increase of the capacity to adjust is critical. In view of that reality, Cuban agriculture has to implement changes as well, and one of the ways to ensure food safety lies on knowledge and use of more tolerant potato varieties, which are critical elements to increase production and yields under stressing conditions.

Atlas and Maranca had the lowest values for SSI (0.67 and 0.61, respectively), and the highest values for STI (0.79 and 0.81, respectively). Armada, on the contrary, had the highest SSI values (1.55), and the lowest STI (0.52) (Table 2).

Table 2. Stress Susceptibility Index (SSI) and Stress Tolerance Index (STI) in four potato varieties

Varieties	SSI	STI
Atlas	0.67	0.79
Armada	1.55	0.52
Everest	1.03	0.68
Maranca	0.61	0.81

According to the scale suggested by Fernández (1992), for Stress Susceptibility Index (SSI), the varieties with the lowest values are more tolerant to droughts; values closer to 1, they are neutral; and values above 1, they are susceptible. Therefore, Maranca and Atlas are defined as tolerant; Everest, as neutral; and Armada, as susceptible to stress. Hassanpanah (2010) reported potato varieties tolerant to water shortage (SSI, 0.37-0.72), and susceptible varieties (up to 2.23).

According to Rosielle and Hamblin (1981), varieties with high STI, closer to 1, are more tolerant; thus, matching Maranca and Atlas, as drought tolerant. On the contrary, Everest and Armada are susceptible.

Maranca and Atlas showed the lowest TOL (3.89 t/ha and 4.60 t/ha, respectively); whereas Everest and Armada had the highest (7.29 t/ha and 11.06 t/ha, respectively). The highest MP value was observed in Atlas (10.92 t/ha) (Table 3).

Table 3 Tolerance Index (TOL) and Mean Productivity (MP) in four potato varieties

Varieties	TOL (t/ha)	MP (t/ha)
Atlas	4.60	19.92
Armada	11.06	17.80
Everest	7.29	18.87
Maranca	3.89	18.57

TOL shows the relative yield amount not produced by the varieties in stress conditions, compared to others under normal moisture conditions. Maranca and Atlas failed to produce 3.89 and 4.6 t/ha, respectively, making them the

varieties with the lowest tolerance index; whereas Everest and Armada failed to produce 7.29 and 11.06 t/ha, respectively, making them susceptible. Hassanpanah (2010) recorded stress-susceptible potato varieties with yield decreases in more than 7 t/ha, when exposed to severe water shortages, in comparison to treatments in normal moisture conditions. However, the tolerant varieties lower their yields between 2 and 5 t/ha, matching the results shown in this paper.
Mean Productivity (MP) shows the yield mean produced between the treatment with irrigation and the dry treatment, using the same variety. Shi *et al.* (2015) reported potato varieties tolerant to water shortage, and MP of 20 t/ha.

The highest Yield Stability Index (YSI) values were observed in Maranca and Atlas (81.07 % and 79.29%, respectively). The YSI observed in Everest was 67.98%, and the lowest value was observed in Armada, with only 53.59%. (Table 4).

Table 4 Yield Stability Index (YSI) in four potato varieties

Varieties	YSI (%)
Atlas	79.29
Armada	52.59
Everest	67.98
Maranca	81.07

The high values reached for Maranca and Atlas mean that in dry conditions they can guarantee these yield per cents. They have a lower yield variability under stress, which makes them more tolerant to droughts. Armada and Everest have lower values, making them more susceptible to droughts. According to Shi *et al.* (2015) potato varieties with more tolerance to droughts show yield stability values of 80-85%, whereas the susceptible varieties have values ranging around 60%.

According to Spitters and Schapendonk (1990), the potato varieties more tolerant to droughts keep their stomas open under severe water shortages, thus they are able to make photosynthesis, leaf and tissue damages are lower, and yields are high. According to Morales et al., (2015) high drought tolerance shown by some potato varieties owes mainly to anatomical and physiological features that help the plant adapt to stress conditions; such as, lower stoma density, smaller stomas, minimal reduction of relative water content, and greater cell-membrane stability.

CONCLUSIONS

1. Not all potato varieties respond to water shortage in the same way; there are susceptible and tolerant varieties.

2. Maranca and Atlas are drought tolerant; Everest is neutral; and Armada is susceptible.
3. The lowest effect on yields was observed in Maranca and Atlas, with 3.89 and 4.6 t/ha, respectively.

RECOMMENDATIONS

1. The current changing weather conditions require the use of potato varieties that can adapt to the new conditions, in present and future plantations in Cuba.
2. Further research on potato drought recovery mechanisms must be done.

BIBLIOGRAPHY

Agili, S., Nyende, B. y Ngamau, K. (2012). Selection, Yield Evaluation, Drought Tolerance Indices of Orange-Flesh Sweet potato (*Ipomoea batatas* Lam.) Hybrid Clone. *Journal of Nutrition and Food Sciences* 2(3): 1-8.

Almeselmani, Met al., (2011). Effect of drought on different physiological characters and yield component in different Syrian durum wheat varieties. *Journal of Agriculture Sciences*, 3(1): 127-133.

Balasimha, D. and Virk, M. (1978). Effects of water stress on tuber yield and metabolism in potato. *Journal of Indian Potato Association*, 2(1): 104-107.

Beltrano, J. and Ronco, G. (2008). Improved tolerance of wheat plants (*Triticum aestivum* L.) to drought stress and rewatering by the arbuscular mycorrhizal fungus *Glomus claroideum*: Effect on growth and cell membrane stability. *Brazilian Journal Plant Physiology*, 20(1): 29-37.

Bouslama, M. and Schapaugh, W. (1984). Stress tolerance in soybean, Evaluation of three screening techniques for heat and drought tolerance. *Crop Science*, 24(1): 933–937.

Centro del Clima del Instituto de Meteorología. (2015). Estado de la sequía, Available at: http://www.met.inf.cu/asp/genesis.asp?TB0=PLANTILLAS&TB1=sqCLIMA&TB2=/CLIMA/sequia/sqJulio2015.htm (Consulted: August 31, 2015).

Fernandez, G. (1992). Effective selection criteria for assessing stress tolerance. Proceedings of the international Symposium on "Adaptation of Vegetables and other Food Crops in Temperature and Water stress". Taiwan. Available at: www.idosi.org/mejsr/mejsr9(1)11/11.pdf (Consulted: March 26, 2015).

Fischer, R. and Maurer, R. (1978). Drought resistance in spring wheat cultivars, Grain yield responses. *Australian Journal of Agriculture Research*, 29(1): 897–912.

Hassanpanah, D. (2010). Evaluation of Potato Cultivars for Resistance Against Water Deficit Stress Under In Vivo Conditions. *Potato Research,* 53(1): 383–392.

Hernández, A., Pérez, J., Bosch, D., Rivero, L. (1999). Nueva versión de clasificación genética de los suelos de Cuba. Instituto de Suelos: AGRINFOR. La Habana, 64 pp.

Morales, R.A., Morales, T.A. and Rodríguez, S.D. (2015). Identificación de variedades de papa (*Solanum tuberosum* L.) tolerantes a sequía y altas temperaturas, mediante métodos anatómicos y fisiológicos. *Revista Agrotecnia de Cuba*, 39(1): 8-20.

Prabha, D. and Kumar, N. (2014). Seed Treatment with Salicylic Acid Enhance Drought Tolerance in Capsicum. *World Journal of Agricultural Research*, 2(2): 42-46.

Pino, M., Inostroza, F., Kalazich, B., Gutiérrez, R. and Castro, M. (2012). El desafío de lograr variedades de papa y trigo tolerantes al cambio climático. Curso teórico-práctico: "Evaluación de la Tolerancia a Factores Abióticos". Cusco, Perú. Available at: http://platina.inia.cl/ftg_cluype (Consulted: April 2, 2015)

Rosielle, A. and Hamblin, J. (1981). Theoretical aspects of selection for yield in stress and non-stress environments. *Crop Science,* 21(1): 943-946.

Shi, S., Fan, M., Iwama, K., Lic, F., Zhang, Z. and Jia, L. (2015). Physiological basis of drought tolerance in potato grown under long-term water deficiency. *International Journal of Plant Production,* 9(2): 305-320.

Spitters, C., Schapendonk, A. (1990). Evaluation of breeding strategies for drought tolerance in potato by means of crop growth simulation. *Plant and Soil 123, 193-203.*