International Journal of Plant & Soil Science
3(5): 448-456, 2014; Article no. IJPSS.2014.002

SCIENCEDOMAIN *international*
www.sciencedomain.org

SCIENCEDOMAIN

Use of Electrical Conductivity as a Tool for Determining Damage Index of Some Mango Cultivars

Omayma M. Ismail[1*]

[1]*Horticultural Crop Technology, National Research Centre (NRC), Giza, 12311, Egypt.*

Author's contribution

This whole work was carried out by the author OMI.

Original Research Article

Received 4th December 2013
Accepted 1st February 2014
Published 25th February 2014

ABSTRACT

Four Mango (*Mangifera indica* L.) cultivars: 'Ewais', 'Sidik', 'Fajrikalan' and 'Zebda' were investigated to study the electrical conductivity as a tool for determining damage index of mango cultivars and their relationship with the index of injury (Id), the Relative Water Content (RWC), Soluble Solid Content (SSC) and total phenols. 'Ewais' had the highest cold tolerance whereas 'Fajrikalan' had the lowest cold tolerance. EC and Id values were highest at -4°C and there was a direct proportional among: cold injury, exposure time and the decreasing of temperature. Cold temperature increased the accumulation of SSC with time. Total phenols of 'Ewais' and 'Fajrikalan' were lower than in 'Zebda' and 'Sidik'. The relationship between the RWC and the Id was not clear from this experiment.

Keywords: Mango; electrical conductivity; injury index and relative water content.

1. INTRODUCTION

A change in the Egyptian climate has already been observed during the last decades, and this is expected to continue throughout this century. This change in climate affects the behavior of fruit trees and their productivity. In 2008, Egypt was exposed to a wave of frost that caused severe damage to mango trees; hence, there is a need to know which cultivars are resistant to winter cold.

**Corresponding author: E-mail: omaymaismail@yahoo.com;*

Low temperatures decrease the biosynthetic activity of the plants, disturb the normal function of physiological processes and may results in permanent injuries that finally bring about the plants death. Therefore, the ability to estimate the degree of cold hardiness in plants is of great value for both basic and applied studies [1].

The ultimate survival of woody plants is dependent not only on the maximal capacity of cold hardening, but also on the timing and rate of both cold acclimation and deacclimation, [1,2,3]. The electrolyte leakage test is well suited for measuring freeze-induced damage as it is based on alterations in cell membranes. Recording the amount of leakage will thus provide an estimate of tissue damage. The Electrolyte leakage tests involve measuring of the electrical conductivity of pure water in which detached tissue samples have been placed after a freeze-thaw cycle [1].

Cold acclimation is a complex process associated with physiological and biochemical changes in the plants, including modifications in membrane lipid composition; increases in soluble sugars, amino acids, and organic acids; synthesis and accumulation of antioxidants and protective proteins; changes in hormone levels; and alterations in gene expression [4,5].

However, the role of phenolic compounds in plant abiotic stresses particularly low temperature stress, has received much less attention. The structural chemistry of polyphenols predicts their potential role as free radical scavengers (antioxidants) and this has been well documented [6].

The principle of increased permeability and electrical conductivity of injured tissue is a familiar one in plant physiology, while the method of electrical conductance as a measure of changing electrolyte concentration has been more or less standard for many years [7].

The aim of this experiment is to study the electrical conductivity as a tool for determining damage index of some mango cultivars and to detect the index of injury (Id) and its effect on: the leaves relative water content (RWC), soluble solid content (SSC) and total phenols content, also on the exposed time to the cold.

2. MATERIALS AND METHODS

2.1 Sampling Technique

Leaf samples were collected from the mature terminal leaves and brought to the laboratory where they were washed with tap water then with distilled water and toweled dry.

2.2 Electrical Conductance Measurements (EC)

The Electrical conductivity of water extracted from the frozen leaves, was used to determine the cold injury [8] and the electrolyte leakage was used to assess membrane competence in plant tissues, [9] .As there may be a considerable variation in the total amount of electrolytes between different samples, [10] introduced the idea of expressing the amount of leakage as a percentage of total electrolytes released from the sample after heat killing.

Six replicates for each treatment of each sample was 2 g. leaf discs at 1.5 cm diameter prepared with cork borer from leaf blades and put in glass tube. Samples distributed at three controlled cool rooms temperature were adjusted at 4°C, -4°C and 20°C. Mango seedling

Freezing at temperatures above -3.0°C occurred on 2 occasions as reported [11]; Seedling turpentine mango in pots growing in Gainesville were killed at less than -3°C on February 9 and August 10, 1983, -4.5°C on April 29 [12] for three tested durations (1,2,3 hours) , after each duration of the test at each temperature the samples were taken out and left to thaw then 20 ml distilled water was added for each tube, and the samples were put into the cool room at 20°C for 24 hours then measured EC u mhos (before boiling or EC initial) by using water conductivity and soil activity meter (HANNA -HI 99331). The samples tubes were covered and placed in a water path until boiling point (20-25 min.) to kill the tissue then cooled and back up to the initial volume (20 ml.). Then, the samples were returned to cool room at 20°C for 24 hours then measured EC u mhos (after boiling or EC total).

The percentages of electrolytes were calculated as follows:

% electrolytes = EC u mohs before boiling / EC u mohs after boiling *100

The index of injury was calculated by Whitlow et al. [9] according to the following equation:

The "Index of Injury" (Id) = 100 (Rt-R0) / (1-R0)

Where:-

Rt = EC initial/ EC total for stressed tissues.
R0 = EC initial/ EC total for non stressed tissues.
EC initial = Conductivity of the bathing solution following a given period of leakage.
EC total = Conductivity of the bathing solution following heat killing to release all ions from tissues.

2.3 Relative Water Content (RWC)

Relative Water Content (RWC) has often been used to measure internal water stress. It is useful because it expresses the absolute amount of water required for full saturation. A given value for RWC may have different physiological significance for different species or even for different parts of one plant [13].

Discs of leaves prepared as previously described, 10 replicates each one had 15 discs pre-weighted immediately to obtain fresh weight then put discs in Petri dish and added 20 ml distilled water until it became fully turgid (4 hours) at 2°C in dark cool room. After it quickly blotted to remove surface moisture by paper towel and reweighted to obtain turgid weight. Discs put in paper pages and put in the oven at 70 °C for 24 hours then reweighted to obtain the dry weight.

Measurement of RWC of plant tissue was determined as:

RWC = (fresh weight – dry weight) / (turgid weight – dry weight)

2.4 Soluble Solid Content (SSC)

After the leaves were exposed to "4°C, -4°C and control (20°C room temperature)" for 1,2 and 3 hours, the pieces of the leaves were crushed in a mortar and the SSC of leaves juice were measured by digital Refractometer (ATAGO Pr-32).

2.5 Total Phenols

After the leaves of the mango cultivars were exposed to 4°C and -4°C for 1, 2, and 3hours the total phenols were measured by spectrophotometer at 730 wavelength, according to [14].

2.6 Experimental Design

A complete randomized design was applied with six replicates per treatment except the Relative Water Content (RWC) which was represented by 10 replicates.

2.7 Data Analysis

The means of the two seasons were subjected to ANOVA and were evaluated by MSTATC program. The differences between the means were compared using LSD test at 5% level of significance.

3. RESULTS AND DISCUSSION

Data in (Fig. 1) showed that, the EC had the highest value of 'Fajrikalan' at -4°C after 3 hours, followed by 'Zebda' then 'Sidik' and 'Ewais', where the EC values increased by time duration. In general, the EC was higher at -4°C than at 4°C for all cultivars at three different time durations. There was no trend of EC values at 4°C among cultivars or time durations.

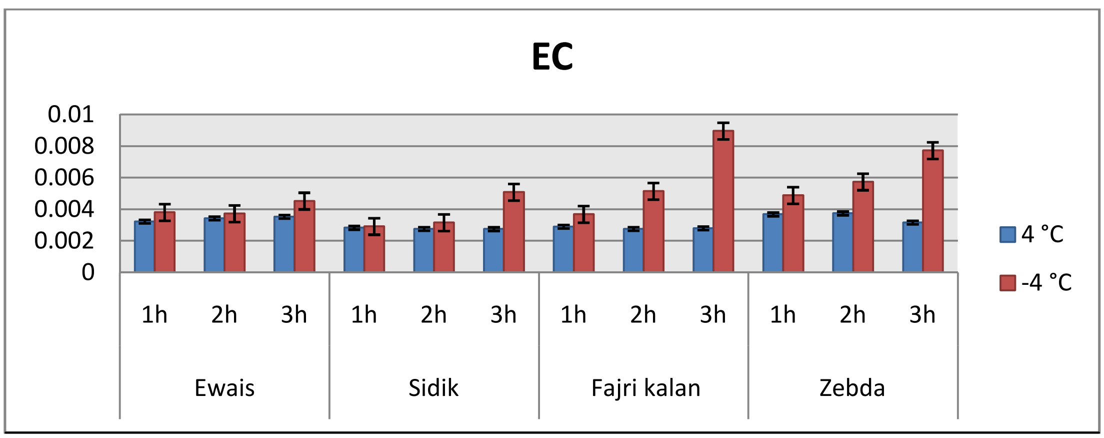

Fig. 1. Conductance of diffused electrolytes of 'Ewais', 'Sidik', 'Fajrikalan' and 'Zebda' mango discs leaves exposed to different temperature for various periods.

The Id values were shown in (Fig. 2) where in all cultivars, Id values at -4°C were higher than those values at 4°C and increased by time durations, also 'Fajrikalan' had the highest Id value after 3 hours followed by 'Zebda' , 'Sidik' and 'Ewais' respectively. At 4°C Id values varied without specific trend.

The mean values of RWC were shown in (Fig. 3) where 'Fajrikalan' and 'Zebda' had the highest values, whereas 'Sidik' had the lowest value, but there were insignificant differences of relative water contents among all the cultivars, therefore the cold tolerant of 'Sidik' and

'Ewais' may be due to the low content of RWC. The reduced water content is commonly related to the increased hardiness [15].

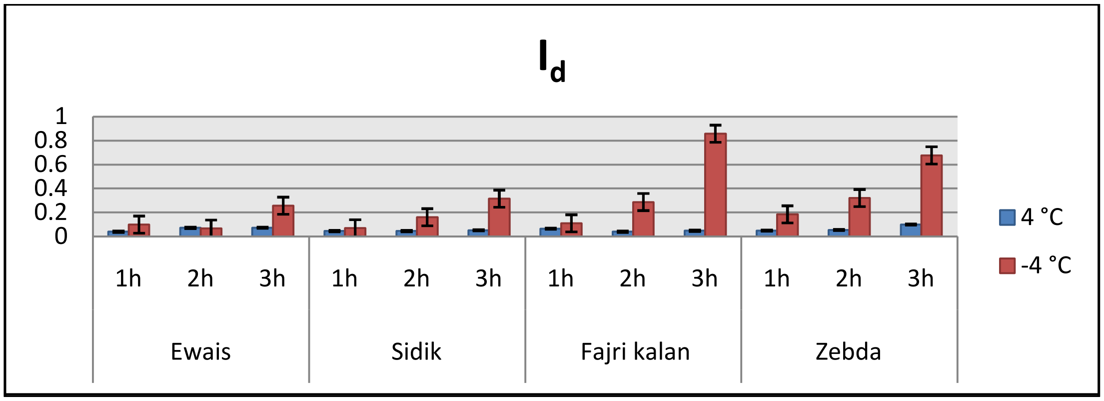

Fig. 2. Conductance of diffused electrolytes of I_d Ewais', 'Sidik', 'Fajrikalan' and 'Zebda' mango discs leaves exposed to different temperatures for various periods.

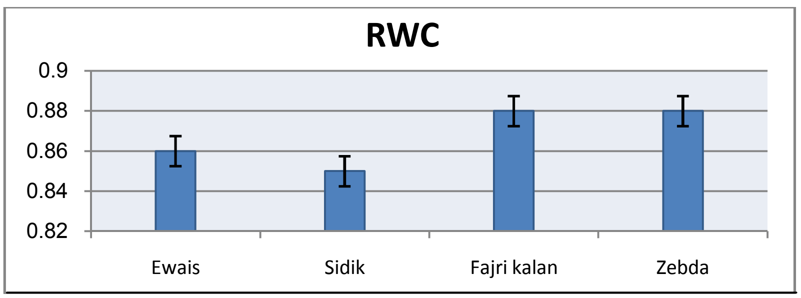

Fig. 3. RWC of Ewais', 'Sidik', 'Fajrikalan' and 'Zebda' mango.

The water status may also have an indirect effect on cold hardiness mediated by a decreased respiratory consumption of cryoprotective sugars in dehydrated tissues [16]. Exposure to drought can increase cold hardiness of woody plant stems and of leaves by several degrees [1,17,18,19].

An increase in freezing tolerance at minimum temperatures above 0°C is accompanied by a decrease in tissue water contents with a further increase in freezing tolerance at temperatures below 0°C occurred without a commensurate change in tissue water content .The results suggest that the proportion of a very weakly bound water in crown tissue is reduced during cold acclimation and increased under snow cover. The critical amount of water necessary to avoid desiccation may vary with genotype.

The changes in both the amount and physical state of water are perhaps dependent on the accumulation of hydrophilic substances such as proteins and carbohydrates. Plants may develop the capacity not only to retain water in tissues but also to protect cell structures against desiccation by accumulating substances that bind water molecules, which leads to a reduction in free water and to an increase in bound water [20].

The SSC values are shown in (Fig. 4), these values decreased by increasing the time at different temperatures for all cultivars. Also noticed that the SSC values of 'Zebda' followed by 'Sidik' were higher than those for 'Fajrikalan' followed by 'Ewais'. As a general the SSC values at -4°C were higher than their values at 4°C after 2 and 3 hours of all cultivars. During cold acclimation, plant cells and tissues undergo a wide range of changes that allow cell functioning at low temperatures and enable survival of freezing stress. Cold acclimation is accompanied by both reduced water content of tissues and an accumulation of putative cryoprotective compounds, such as soluble carbohydrates and proteins [21,22].

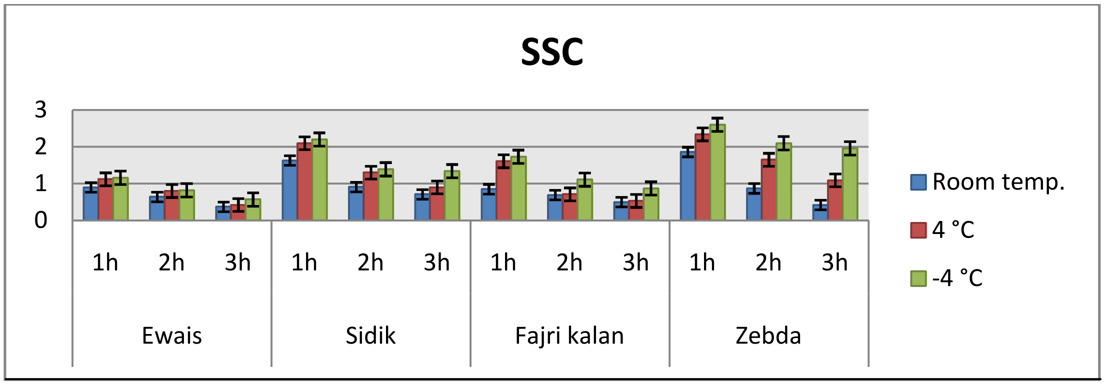

Fig. 4. SSC contents of Ewais', 'Sidik', 'Fajrikalan' and 'Zebda' mango.

Fig. 5 shows The total phenols content values where the phenols content values of 'Ewais' and 'Fajrikalan' were lower than 'Zebda' and 'Sidik' at 4°C and -4°C. In general, the phenols content values were lower at -4°C than at 4°C without significant differences in most cases. Also the phenols values were increased over time at -4°C. [23] found that there was a positive linear (R^2=0.9022; P=0.002) relationship between total phenolic content and the total antioxidant capacity of cold acclimated plants.

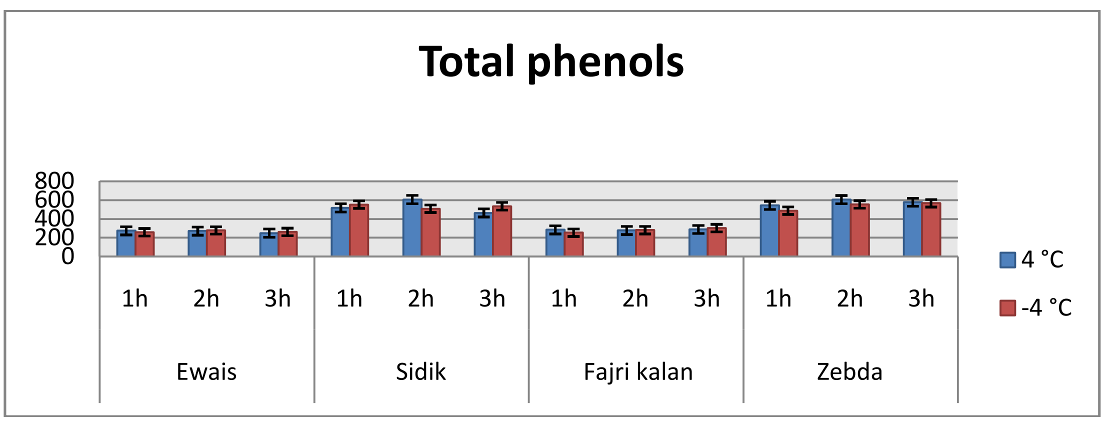

Fig. 5. Total phenols contents of 'Ewais', 'Sidik', 'Fajrikalan' and 'Zebda' mango.

The electrolyte leakage technique allows for simultaneous spectrophotometric measurement of leached phenolic compounds, which can also be used as a measure of freezing injury [1,24,25,26].

Increase of phenolic compounds in tissues during chilling treatments may be partially due to chilling adaptation as defense mechanisms for scavenging ROS and also to mediate these stresses [27,28,29].

However, the mechanisms of chilling stress tolerance is complex and may act in concert with other biochemical and physiological mechanisms to maintain normal physiological functions under chilling conditions [27].

Mango trees show high susceptibility to cold injury. Young trees are damaged by temperatures of -0.5°C. Variability among cultivars is apparent after a cold spell, but precise information on this subject is non-existent [11], nor is it known if mangos can acclimate to cold [12].

4. CONCLUSION

The conclusion was that the EC and Id values were the highest at -4°C and that there are directly proportional among: cold injury, exposure time and the decreasing temperature. ‘Fajrikalan’ was the highest Id value after 3 hours followed by: ‘Zebda’, ‘Sidik’ and ‘Ewais’ respectively. Therefore the ‘Fajrikalan’ was the most sensitive cultivar to the cold injury whereas the ‘Ewais’ was the lowest sensitive. ‘Fajrikalan’ and ‘Zebda’ had RWC values higher than ‘Sidik’ and ‘Ewais’ values. Therefore the cold tolerance of ‘Sidik’ and ‘Ewais’ may be due to the low content of RWC, but the values were insignificant so the relationship between the RWC and the Id was not shown in this experiment. In addition the SSC was the lowest value with ‘Ewais’ where the ‘Zebda’ ‘Zebda’ was the highest , Also notice that the cold temperature increased the accumulation of SSC over time. Total phenols of ‘Ewais’ and ‘Fajrikalan’ were lower than ‘Zebda’ and ‘Sidik’ Our results suggest that ‘Ewais’ had the highest tolerance to damage index whereas ‘Fajrikalan’ was the most sensitive of cold after 3 hours followed by ‘Zebda’ and ‘Sidik’ respectively. The author recommends applying this study on the other mango cultivars and fruit crops.

COMPETING INTERESTS

Author has declared that no competing interests exist.

REFERENCES

1. Lindén L. Measuring cold hardiness in woody plants.University of Helsinki, Department of Applied Biology. Publication 2002; no. 10. Helsinki 57 p. Electronic publication at http://ethesis.helsinki.fi/
2. Larcher W. Die Temperaturresistenzals Kostitutionsmerkmal der Pflanzen. Deutsche Akademiefür Landwirtschaftswissenschaft, Berlin, Tagungsberichte. 1968;100:7-21.
3. Fuchigami LH, Weiser CJ, Kobayashi K, Timmins R, Gusta LV. A degree growth stage (ºGS) model and cold acclimation in temperate woody plants. In: Li, P.H. & Sakai, A. (eds.). Plant cold hardiness and freezing stress. Vol. 2. New York, Academic Press. 1982;93-116.
4. Thomashow MF. Plant cold acclimation: Freezing tolerance genes and regulatory mechanisms. Annu. Rev. Plant Physiol. Plant Mol. Biol. 1999;50:571–599.
5. Xin Z, Browse J. Cold comfort farm: the acclimation of plants to freezing temperatures. Plant Cell Environ. 2000;23:893–902.

6. Rice-Evans CA, Miller NJ, Paganga G. Antioxidant properties of phenolic compounds. Trends Plant Sci. 1997;2:152–159.
7. Osterhout WJV. Injury, recovery, and death, in relation to conductivity and permeability. Philadelphia and London; 1922.
8. Shawky I, El-Nabawy S, Desoky I, Riad M Electrical conductivity as a tool for determining winterhardiness of banana plants. Egypt, J. Hort. 1983;10(1):21-26.
9. Whitlow H, Bassuk L, Ranney G, Reichert L. An Improved Method for Using Electrolyte Leakage to Assess Membrane Competence in Plant Tissues.Plant Physiol. 1992;98:198-205.
10. Stuart NW. Comparative cold hardiness of scion roots from fifty apple varieties. Proceedings of the American Society for Horticultural Science. 1939;37:330-334.
11. Carmichael WW. Observations of cold damage to mangos in Dade Countyand the Lower West Coast. Proc. Fla. State Hort. Soc. 1958;71:333-335.
12. McKellar MA, Buchanan DW, Campbell CW. Cold hardiness of two cultivars of avocado and a mango Proc. Fla. State Hort. Soc. 1983;96:212-215.
13. Joly Robert J. Techniques for determining seedling water status and their effectiveness in assessing stress. 1960; Duryea M.L.(ed) proceeding: Evaluating seedling quality : principles, procedures, and predictive abilities of major testes; 1985. ISBN 0-87437-000-0.
14. AOAC. Association of Official Agricultural Chemists Official Method. 1970;1(4):74.
15. Guy CL. Freezing tolerance of plants: current understanding and selected emerging concepts. Can J Bot. 2003;81:1216–1223.
16. Ögren E. Premature dehardening in Vacciniummyrtillus during a mild winter: a cause for winter dieback. Functional Ecology. 1996;10:724-732.
17. Chen PM, Li PH, Burke MJ. Induction of frost hardiness in stem cortical tissues of *Cornus stolonifera Michx*. by water stress. I. Unfrozen water in cortical tissues and water status in plants and soil. Plant Physiology. 1977;59:236-239.
18. Yelenosky G. Water-stress-induced cold hardening of young citrus trees. Journal of the American Society for Horticultural Science. 1979;104:270-273.
19. Anisko T, Lindstrom OM. Cold hardiness and water relations parameters in Rhododendron cv. Catawbiense Boursault subjected to drought episodes. Physiologia Plantarum. 1996b;98:147-155.
20. Yoshida M, Abe J, Moriyama M, Shimokawa S, Nakamura Y. Seasonal changes in the physical stateof crown water associated with freezing tolerance in winter wheat. Physiol. Plant. 1997;99:363-370.
21. Levitt J. Responses of plants to environmental stresses. Vol. 1. Chilling, freezing and high temperature stresses. 2nd ed. New York, Academic Press. 1980;497.
22. Guy CL. Cold acclimation and freezing stress tolerance: role of protein metabolism. Annual Review in Plant Physiology and Plant Molecular Biology. 1990;41:187-223.
23. Joyce C. Pennycooke, Cox S., Stushnoff C._ Relationship of cold acclimation, total phenolic content and antioxidant capacity with chilling tolerance in petunia (Petunia × hybrida) Environmental and Experimental Botany. 2005;53:225–232.
24. Dexter ST, Tottingham WE, Graber LF. Investigations of the hardiness of plants by measurement of electrical conductivity Plant Physiol. 1932;7(1):63–78.
25. Chalker-Scott L, Fuchigami LH, Harber RM. Spectrophotometric measurement of leached phenolic compounds as an indicator of freeze damage. Journal of the American Society for Horticultural Science. 1989;114:315-319.
26. Dunning CA, Chalker-Scott L, Scott JD. Exposure to ultraviolet-B radiation increases cold hardiness in Rhododendron. Physiologia Plantarum. 1994;92:516-520.

27. Anisko T, Lindstrom OM. Applying the Richards function in freezing tolerance determination with electrolyte and phenolic leakage techniques. Physiologia Plantarum. 1995;95:281-287.
28. Christie PJ, Alfenito MR, Walbot V. Impact of low temperature stress on general phenylpropanoid and anthocyanin pathways: enhancement of transcript abundance and anthocyanin pigmentation in maize seedlings. Planta. 1994;194:541–549.
29. Mansour AM, Mobrami Z, Sajedi RH. Bioactive compounds and antioxidant capacities in the flavedo tissue of two citrus cultivars under low temperature Braz. J. Plant Physiol. 2011;23(3):203-208.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sciencedomain.org/review-history.php?iid=442&id=24&aid=3825