Screening for Cold Tolerant Cactus Species (*Opuntia ficus-indica*) for West Asia Region

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Keywords: barbary fig, prickly pear cactus, livestock feed, freezing tolerance, semi-arid ecosystem, environmental adaptation

Abstract

The identification of the cold tolerant *Opuntia* species to increase their cultivation in West Asia region where the cold winter conditions limit their adaptation is the primary yet the most critical step. The International Center for Agricultural Reserach in the Dry Areas (ICARDA) imported a total of 40 accessions of *Opuntia ficus-indica* from various regions of Latin America, North Africa, and Southern Europe. The mother cladodes from each accession was transplanted to the field at Tel Hadya research station in Aleppo (Syria) either on the 10 November 2011 (fall) or on the 14 April 2012 (spring) and their pad production and survival rates were recorded in 2012 and 2013. Significant differences in cold/freezing tolerance and pad production among tested *Opuntia ficus-indica* accessions were detected. Three accessions from the top five were those imported from Italy: "Trunzara yellow San Cono", "RSS Rossa San spate" and "M1 Gialla di Macomer". On the other hand, "CARTHA-73058" that was imported from Tunisia and "Conlea Rubescens, Conlea-L19" from Algeria had severe tissue damages. Averaged across the years, the accessions that were planted in spring produced 8.7 more pads compared to those were planted in autumn indicating that spring planting provides more conducive conditions for more successful establishment of cactus in West Asia region.

INTRODUCTION

Roughages from the degraded natural resources are the main source of livestock feed in West Asia and North Africa (WANA) region where large number of small ruminants have been reared under nomadic and semi-nomadic grazing systems (Ben Salem and Smith, 2008). This region is characterized by high population growth rate, low and variable rainfall, and water scarcity (Mulas and Mulas, 2004). Most of this area is overgrazed, and over 50% of the arid rangeland may have lost its vegetation since the 1950s (Le Houérou, 1992; Nefzaoui and Ben Salem, 2001). In some areas the damage has been irreversible leading to desertification (Sanlaville, 2000). Furthermore, the region is considered as one of the most susceptible to climate change impacts as significant increases in temperature and reductions in precipitation are expected (IPCC, 2007). The high dependence of resident communities on natural resources for their livelihoods and the poverty in many parts of the region will increase the vulnerability of affected people to respond to an increased incidence of drought and floods which will renders them less resilient to the impact of higher temperatures and lower and more variable precipitation (Seo and Mendelsohn, 2006).

Cacti that are adapted to seasonally hot (up to 50-55°C) and drought conditions, contribute to the feed base and increasingly attracting to the livestock farmers in the arid and semiarid regions of the world. In particular, Opuntia species and in particular *O. ficus-indica* have been successfully grown in the marginalized areas for fodder as a standing buffer feed for drought periods, fruit and cochineal production of dye (carminic acid) and are widely used to prevent soil erosion and to combat desertification (Le Houérou 1996a; Gugliuzza et al., 2000; Felker and Inglese, 2003). It has been suggested that cacti as a CAM plant can be a significant part of the low input production systems in the semiarid zones of the developing countries where the productivity of C3 and C4 crops is restricted by the amount and the distribution of rain (Mondragon-Jacobo, 1999; Nefzaoui 2004). The increased use of cacti for forage and fruit will high likely to help reducing the feed gap for livestock and contribute to the food security and diversify the income source of resource poor farmers in marginalized areas of the West Asia region (Nefzaoui and Ben Salem, 2000). In addition, due to its ability to store carbon dioxide as organic acids through its unique CAM metabolism, greater potential exist for cacti than C3 crops to respond to the increased levels of atmospheric CO_2 concentration (Nobel, 2002).

Despite their great capacity for adaptation and their ability to grow in degraded, infertile soils which are not favourable for the production of most common crops, cacti do not appear to be widely cultivated in West Asia where probably its distribution is restricted primarily by the freezing events that occur during winter seasons (Le Houérou, 1996b). Cacti are not usually native to the cold regions that often experience sub-zero temperatures (Levitt, 1980) that limits their latitudinal and elevational distribution as most cacti species have been reported to have irreversible tissue damage when being exposed to air temperature below -5 to -10°C, exceeding 1 h (Nobel, 1988; Goldstein and Nobel, 1994). However, Loik and Nobel (1993) reported that cold hardy species of cacti with varying in freezing tolerance such as *Opuntia fragilis* can withstand the negative impacts of sub-zero temperatures for several weeks in North America indicating that some cacti species can be successfully grown in the areas of the world that experiences harsh winter conditions. This suggests that genotypes that may have the traits of cold tolerance may provide opportunities to increase the cultivation of cacti in the colder regions or at higher elevations. Therefore research and adaptation studies, including germplasm exchange and evaluation should be undertaken to identify the adaptability of the cacti lines that may successfully adapt to cold temperatures in West Asia.

Thus a screening study to evaluate the cold tolerance of cacti accessions acquired from various regions of the world was conducted with the main objectives to explore genetic resources with potential genes for adaptation to the adverse effects of climate change particularly night freezing temperature during winter season and to evaluate agronomic practices such as date of transplantation on cactus establishment and vigour.

MATERIAL AND METHODS

Study Site

The experiment was carried out in the research station of the International Center for Agricultural Research in the Dry Areas (ICARDA) (36°01'N, 36°56'E, 284 m a.s.l.) located at 30 km south of Aleppo, northern Syria. The soil contains 20-30 % calcium carbonate, the pH range of 7.9-8.2. The parent material is limestone. The clay content, at nearly 65% of the total soil texture, is a smectite mineral. Soil has relatively low soil organic matter, less than 2%. The average maximum daily air temperatures ranged from 10.5°C in winter 2012 to 39.6°C in summer 2012 while the average minimum daily air temperatures were between 0.5°C in winter 2011 and 23.1°C in summer 2011 (Table 1). The lowest daily air temperature recorded was -5.6°C in December 2011. The air temperature went down below -5°C only in one day in December 2011 and one day in March 2012 (Table 2).

Plant Materials

A total of 40 accessions of *Opuntia ficus-indica* (OFI) pads were imported from various regions of Latin America, Africa, and Europe to ICARDA's research station, Aleppo, Syria in 2011. Mother cladodes from each accession were transplanted to the field gene-bank during the fall of 2011 and spring of 2012. The pads were stored under shade for 15 days prior to planting in spring. The remaining pads were planted in pots and preserved in the greenhouse for 90 days before planting them in autumn. The row space and the distance between each pad were 3 × 2 m. The pads were irrigated as needed during the establishment phase.

Measurements and Statistical Analyses

Cladodes were naturally subjected to ambient temperature and freezing events during the experimental period (Fig. 1). Assessment of frost damage (survival of new cladodes) was conducted by means of visual symptoms (color turned brown) during the month of August 2012 and 2013. During the same time, the growth of the accessions was assessed by counting the number of new cladodes. General linear model procedure was used for statistical analysis through SAS software (SAS, 2009), using completely randomized design. For the purpose of comparison between the two transplanting dates, paired t-test were employed. Duncan's multiple tests were applied for comparison of means.

RESULTS AND DISCUSSION

Opuntia ficus-indica is the cactus species with the highest economic importance worldwide. The *Opuntia ficus-indica* accessions also differed significantly ($P < 0.01$) in their inherent cold/freezing tolerance in both years (Fig. 1). Three accessions from the top five were those imported from Italy: "Trunzara yellow San Cono", "RSS Rossa San sperate" and "M1 Gialla di Macomer". On the other hand, "CARTHA-73058" that was imported from Tunisia and "Conlea Rubescens, Conlea-L19" from Algeria had severe tissue damages (Fig. 1). It was also observed that the young cladodes were more vulnerable in all accessions.

Results of the independent sample t-test analysis for evaluation of the planting date (fall versus spring) revealed significant differences (Fig. 2) for the pad production of *Opuntia ficus-indica* accessions. Pad production of cacti accessions in spring planting (13.7 ± 5.9) was significantly higher ($P < 0.01$) than fall planting (5.6 ± 7.3) in 2012; $t(39) = 5.43$. Similar results were obtained in 2013 when spring planting (15.3 ± 7.2) resulted in significantly more ($P < 0.01$) number of newly produced pads compared to fall planting (6.1 ± 8.2); $t(39) = 5.34$. These results indicates that spring planting may provide conditions more conducive for successful establishment and higher chance of survival for cacti in West Asia region. In addition, cactus pads that were planted in the fall were probably more susceptible as their root system has not been fully developed to withstand the cold winter conditions.

CONCLUSION

The genus *Opuntia* is probably the most successful cactus genus according to its distribution, dispersal traits and multiplication processes. Cactus is an important forage option to semi-arid regions. Fiting the right plant to the semi-arid environment makes more sense than changing the environment. Thus assessing adaptation of cactus accessions across a wide range of climates and agro-ecosystems is needed. In order to have more representative sites covering main agro-ecological production systems in West Asia, additional sites were selected in Jordan and Lebanon.

It is concluded that a number of *Opuntia ficus-indica* accessions that were used in this study have shown promising resistance to cold in Syria. These preliminary results should be used with cautions until further testing is complete. The success of establishment of cold tolerant *Opuntia ficus-indica* accessions may be increased through spring planting. The trials established so far have looked only at the adaptation of *Opuntia ficus-indica* based on the phonological traits. Future research will focus on key traits responsible for resistance to cold (frost damage) using biotechnology techniques.

ACKNOWLEDGEMENTS

This work was sponsored by the CGAIR Agriculture and Food Security (CCAFS) and the Center for Agricultural Research in the Dry Areas (ICARDA). We are grateful to the support of the FAO-ICARDA Cactusnet for facilitating provision of plant materials.

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Tables

Table 1. Monthly rainfall, maximum and minimum mean daily air temperatures at Tel Hadya, Aleppo, Syria (2011-2013).

	Mean of maximum daily air temperatures (°C)				Mean of minimum daily air temperatures (°C)				Rainfall (mm)			
Month	2011	2012	2013	LTM*	2011	2012	2013	LTM*	2011	2012	2013	LTM*
January	13.0	10.5	13.1	11.7	2.5	2.6	1.6	1.6	40.8	120.3	47.9	31.0
February	14.9	13.0	15.8	13.8	3.1	1.3	4.7	2.2	42.1	104.8	58.2	28.3
March	19.3	16.1	20.0	18.2	4.0	2.8	5.0	4.3	24.4	33.5	10.2	31.0
April	23.5	26.6	24.7	24.1	7.8	8.6	8.3	8.0	44.6	3.2	36.0	30.0
May	28.6	29.3		30.1	12.2	13.4		12.1	10.1	4.6		31.0
June	34.6	37.4		35.0	18.5	19.2		17.7	0.5	2.5		30.0
July	38.9	39.6		37.8	22.1	22.8		21.7	0.0	0.0		31.0
August	38.2	38.4		37.9	23.1	22.8		21.9	0.0	0.0		31.0
September	35.0	36.1		34.5	19.8	19.5		17.6	0.7	0.0		30.0
October	27.2	28.8		28.3	10.9	14.1		12.4	21.6	32.7		31.0
November	15.8	21.0		19.5	3.3	7.7		6.0	96.1	30.7		30.0
December	12.8	14.5		13.0	0.5	4.2		2.8	68.6	140.0		31.0

LTM*: Long term means of air temperature and rainfall are for the period 1985-2012.

Table 2. Minimum air temperatures and number of days when the temperature was lower than ≤ 0 and -5 at Tel Hadya, Aleppo, Syria (2011-2013).

	2011		2012				2013		
	Nov	Dec	Jan	Feb	Mar	Dec	Jan	Feb	Mar
Minimum air temperature (°C)	-3.3	-5.6	-5	-3	-5.5	-2.5	-3.2	-0.3	-4.5
Number of days ≤ 0°C	6	15	8	14	7	6	13	2	4
Number of days ≤ -5°C	0	1	0	0	1	0	0	0	0

Figures

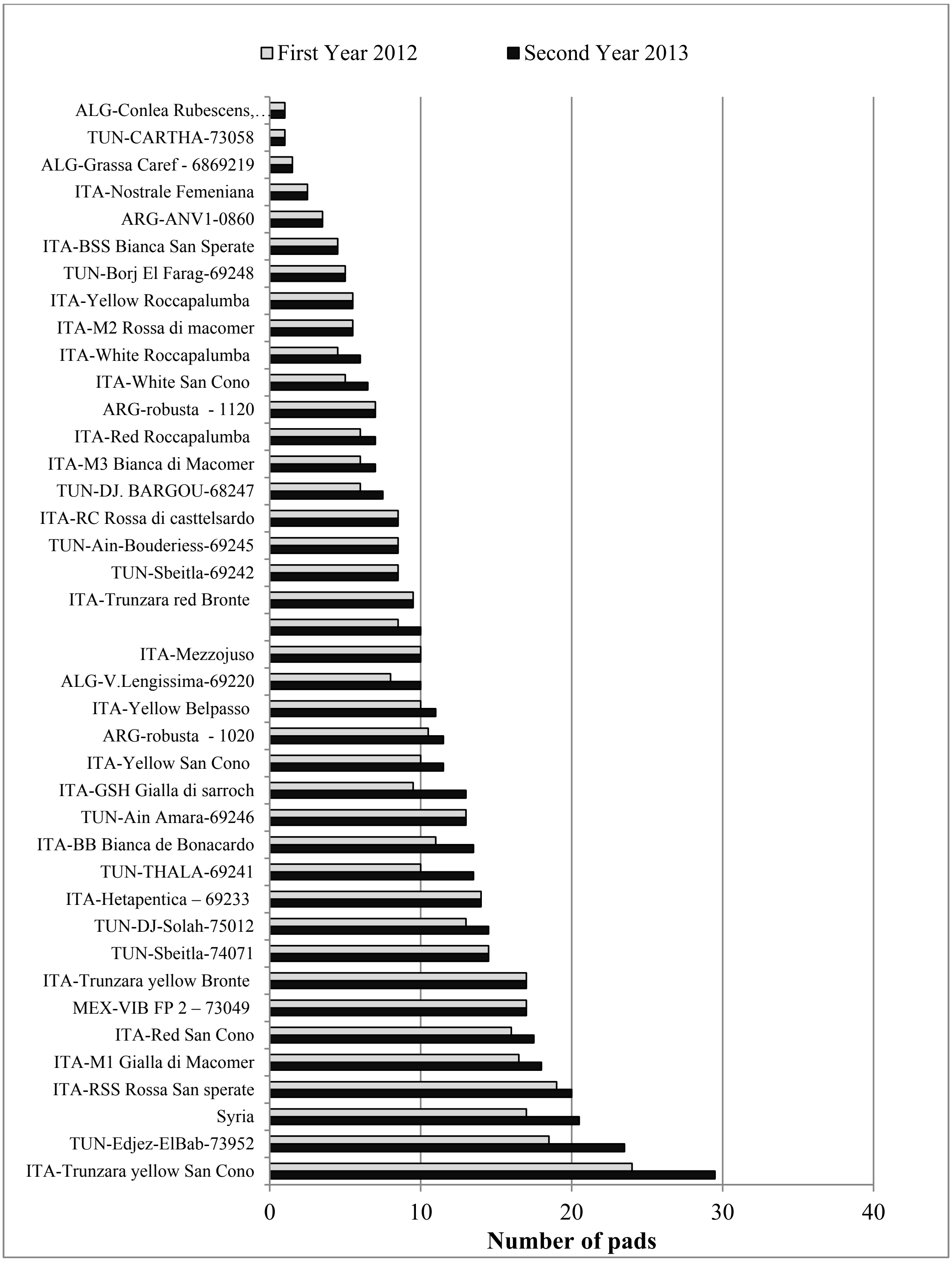

Fig. 1. Number of pads produced per accession in two growing seasons (2012, 2013).

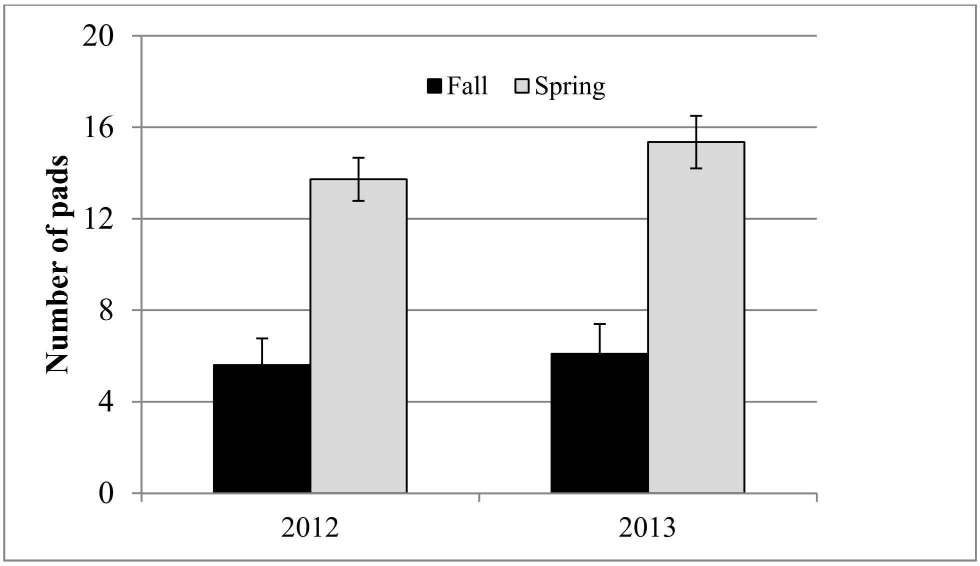

Fig. 2. Number of pads in fall and spring transplanting dates in two groing seasons 2012 and 2013.