Screening for cold tolerant cactus species (*Opuntia ficus indica*) under West Asia conditions

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Introduction

The range-crop-livestock production system is the most vulnerable system to climate change in rainfed agriculture, as it is a very fragile system (Weindl et al. 2015). It harbors the poor sector of the rural communities, whose livelihood rely on agricultural production. In the WANA region the combined effects of overgrazing and cultivation have accentuated the decline in native forage production and the deterioration of the native forage species gene pool, thus threatening biodiversity (McIntyre et al. 2009). The future of the WANA arid region depends on the development of sustainable agricultural systems, and also on the cultivation of appropriate crops. Such crops must be well adapted to withstand water shortage, high temperature, and poor soil fertility (Nefzaoui et al. 2009). Thus, the cultivation of adapted crops such as Opuntia species, especially cactus pear, has the potential to increase productivity in these areas (Pimienta-Barrios and Muñoz-Urias, 1995). Opuntia is a member of the Cactaceae family (Reyes Aguero et al. 2005) that has more than 1500 known species worldwide (Hegwood, 1990). Within Opuntia, cactus pear (*Opuntia ficus-indica*) is the most common species worldwide, in addition to being a drought tolerant fruit crop (Galizzi et al. 2004; Gugliuzza et al. 2000). This species has multiple uses for both humans and animals (Nefzaoui et al. 2009). It can contribute to sustainable food production, especially in countries with large arid and semi-arid lands (Felker and Inglese, 2003).

Cactus pear has developed phenological, physiological, and structural adaptations to the arid areas characterized by drought, erratic rainfall and poor soils. It has gained an important place in the agricultural systems as a fruit, forage and fodder provider, particularly in subsistence agriculture where it can grow with minimal agronomic inputs and its tolerance to drought. Among these adaptation traits, its asynchronous reproduction and its Crassulacean acid metabolism (CAM) stand out. When combined with structural adaptations, such as succulence, these traits allow this plant to continue the assimilation of carbon dioxide during long periods of drought. Added to these benefits, cactus has the following benefits (Gugliuzza et al. 2000; Nefzaoui et al. 2009):

- Biomass generation per unit of water is on average about three times higher than for C_4 plants and five times higher than for C_3 plants,
- While various types of plants can produce similar amounts of dry matter per surface area under optimal conditions, CAM plants are more productive than C_3 and C_4 plants under arid and semi-arid conditions.
- Cactus pear can grow in severely degraded soils, which are inadequate for other crops. It has a great capacity for adaptation and it is ideal for responding to global environmental changes.

- Cactus pear has an asynchronous development of various plant organs, so that even under the worst conditions some parts of the plant are not affected.
- The establishment of sustainable systems of production based on cactus pear may contribute to the food security of populations and to the improvement of soil conservation in agriculturally marginalized areas.
- Cactus pear is one of the most ideal species for rehabilitating arid and semi-arid areas, because they are tolerant of scarce and erratic rainfall, as well as high temperatures.

Nevertheless, despite the great capacity for adaptation and their ability to grow in harsh environments which are not favorable for the production of most common crops, frost risk can be considered as one of the major limitation to cactus growing in the WANA region as well as in many parts of the world (Borrego-Escalante et al. 1990; Le Houérou, 1996a, b; Parish and Felker, 1997). Therefore, the main objective of this study is to screen and evaluate the cold tolerance of cactus accessions acquired from various regions of the world for adaptation to the adverse effects of climate change, particularly night freezing temperature during the winter season.

Materilas and Methods

Using a randomized complete block design (RCBD) with five replicates, 42 accessions of *Opuntia ficus indica* (Cactus inermis), imported from various locations (North Africa, Italy and Mexico), were planted in April 2013 in Muchaqqar Research Station (Jordan, 24°47’30.62”S 29°49’02.27’E), where long term annual rainfall ranges are between 350 and 400 mm. The name and origin of each cultivar are shown in Table 1. The evaluation took place over winter, from 2015, 2016 and 2017, although no frost events were recorded in 2017. Frost damage was recorded visually after each frost event in each year (values ranged from 1, regarded as fully damaged, to 5, regarded as no damage occurred on the cactus cladode). After counting the number of cladodes per plant, five cladodes from each established plant were cut and weighed, to estimate the cladode green biomass weight. The size of each cladode, length and width, was also measured.

Data were analyzed using GLM procedures (SAS, 2009) with the model adopted:

$$Y_{hij} = \mu + B_h + A_i + e_{hij}$$

where Y_{hij} is variable, μ is general mean, B_h is block effect (h = 1–5), A_i is accession effect (i = 1–42), and e_{hij} is residual error. The year factor was considered as the replicate because the experiment was mainly designed to examine variations among accessions due to the seasonal effects. Univariate correlation and regression analyses were used to establish relationship of frost tolerance score, number of cladodes per plant and average weight of each cladode.

Table 1: The name and origin of each cactus accession used for the study.

Origin	Accession name
Italy	15_73063_ Sicile Le folin
Italy	RC Rossa di casttelsardo_SASS
Italy	BB Bianca de Bonacardo_SASS
Italy	Zastron 4
Italy	Trunzara Red San Cono
Italy	Yellow Santa Margherita Belice
Italy	White Santa Margherita Belice
Italy	Red San Cono
Italy	White San Cono
Italy	Red Roccapalumba
Italy	White Roccapalumba
Italy	Seedless Roccapalumba
Mexico	V1
Mexico	F1
Mexico	10
Mexico	9
Mexico	2_21_68
Mexico	2_25_15
Mexico	2_11_85
Mexico	2_26_21
Mexico	2_17_25
Algeria	31_69223_Burbank Azrou_ALG
Algeria	34_69219_Caref 58_ALG
Algeria	3_69200_ALG
Algeria	3_69199_Lanceolata_ALG
Morocco	32_74001_MORO
Morocco	13_74115_Bab Toza_MORO
Morocco	22_75018_El Bouroug_MORO
Tunis	20_74071_ Sbeitla_TUN
Tunis	46_74076_Mornag B_TUN
Tunis	6_96245_Ain Boudriess_TUN
Tunis	27_69242_Matmata_TUN
Tunis	8_74010_Leavis_MEX
Tunis	Zelfeue
Tunis	29_69242_Matmata_TUN
Tunis	30_73952_Mdjez El Bab_TUN
Tunis	33_69246_Oueslatia_TUN

Tunis	41_69242_Sbeitla_TUN
Tunis	42_74077_Mornag_TUN
USA	2_74112_Leavis SP5_USA

Results and disscussion

Significant differences in cold/freezing tolerance, cladode number per plant and cladode fresh weight (g) among tested cactus pear accessions were detected (*$P<0.01$*). COPENA V1, 74115_Bab Toza, and 74001 cultivars produced the highest number of pads per plant, while 3_69199_ Lanceolata and Roccapalumba produced the lowest number of pads per plant (Figure 1).

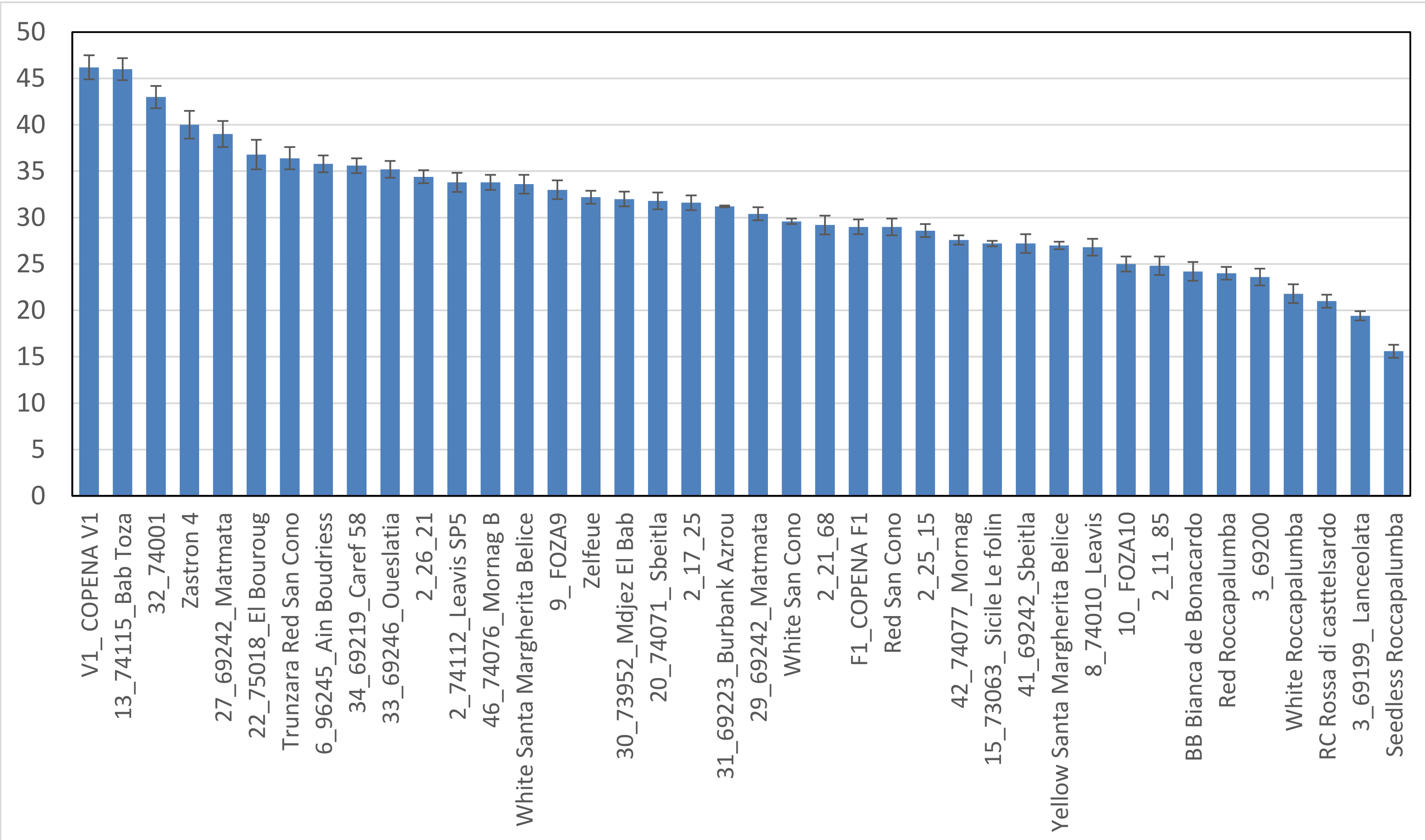

Figure 1. The number of cladodes produced per cactus pear accession

Significant differences (*P<0.01*) were observed among the accessions in terms of tolerance of frost. More than 70 % of accessions showed good tolerance to frost; accessions 69223_Burbank Azrou, 2_25_15 and Bianca de Bonacardo demonstrated the most frost tolerance as evidenced by no apparent frost damage on their cladodes. Seedless Roccapalumba had the lowest number of cladodes and appeared to be highly susceptible to low temperatures (Figure 2).

The average cladode weights differed significantly among the accessions; the average weight of single claddoes varied between 989 – 484 g (Figure 3). Accessions 69242_Matmata, 69246_Oueslatia, and COPENA V1 recorded the highest cladode average weights, while Red Roccapalumba and 10_ FOZA10 had the lowest average cladode weight (Figure 2). The findings of this study showed a significant positive correlation between number of cladodes and the average cladode weights ($r = 0.55$ $P<0.01$). Grouping of 42 cactus pear accessions based on cold/freezing tolerance, cladode number per plant and cladode fresh weight (g) showed that 22_75018_El Bouroug and 13_74115_Bab Toza acessions had the best tolerance for frost, followed by 32_74001, 2_17_25, 20_74071_ Sbeitla and 2_26_21.

Conclusion

The results of this study showed that there is a high number of spineless cactus accessions that exhibited greater cold tolerance, as evidenced by high production in terms of number of cladodes and the cladode average weight. Results from this study are beneficial to the adoption of cactus, in arid regions of West Asia, because a high number of the accessions adapted to the low temperatures in the study site. Therefore, an increasing the distribution and adoption of this important crop will be stimulated due to findings from this study. Consequently, the cold tolerant cactus accessions present significant potential to improve livestock production and create alternative income generation options for resource poor farmers in this region.

Acknowledgments

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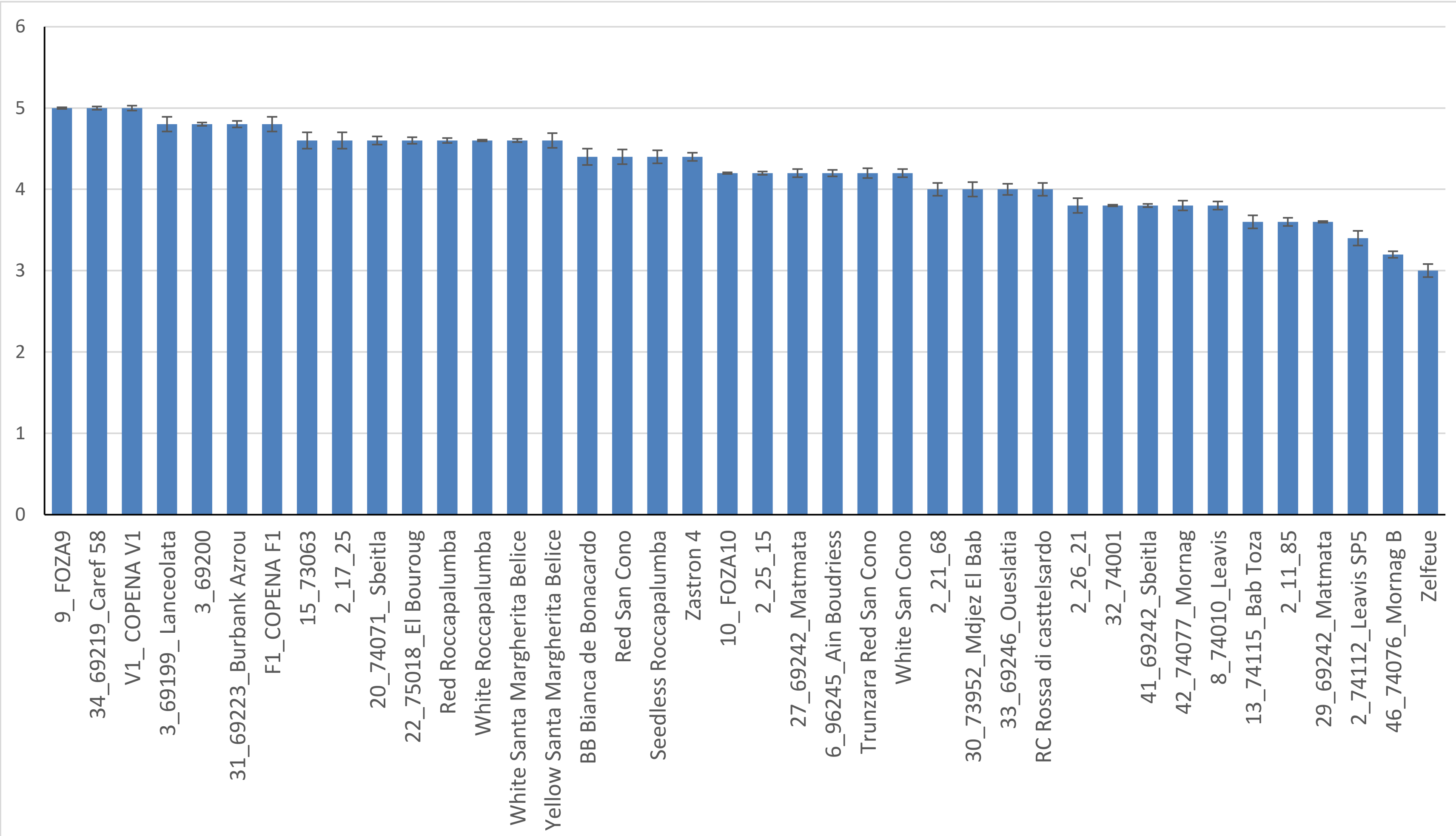

Figure 2. Cactus pear accession performance in terms of frost tolerance.

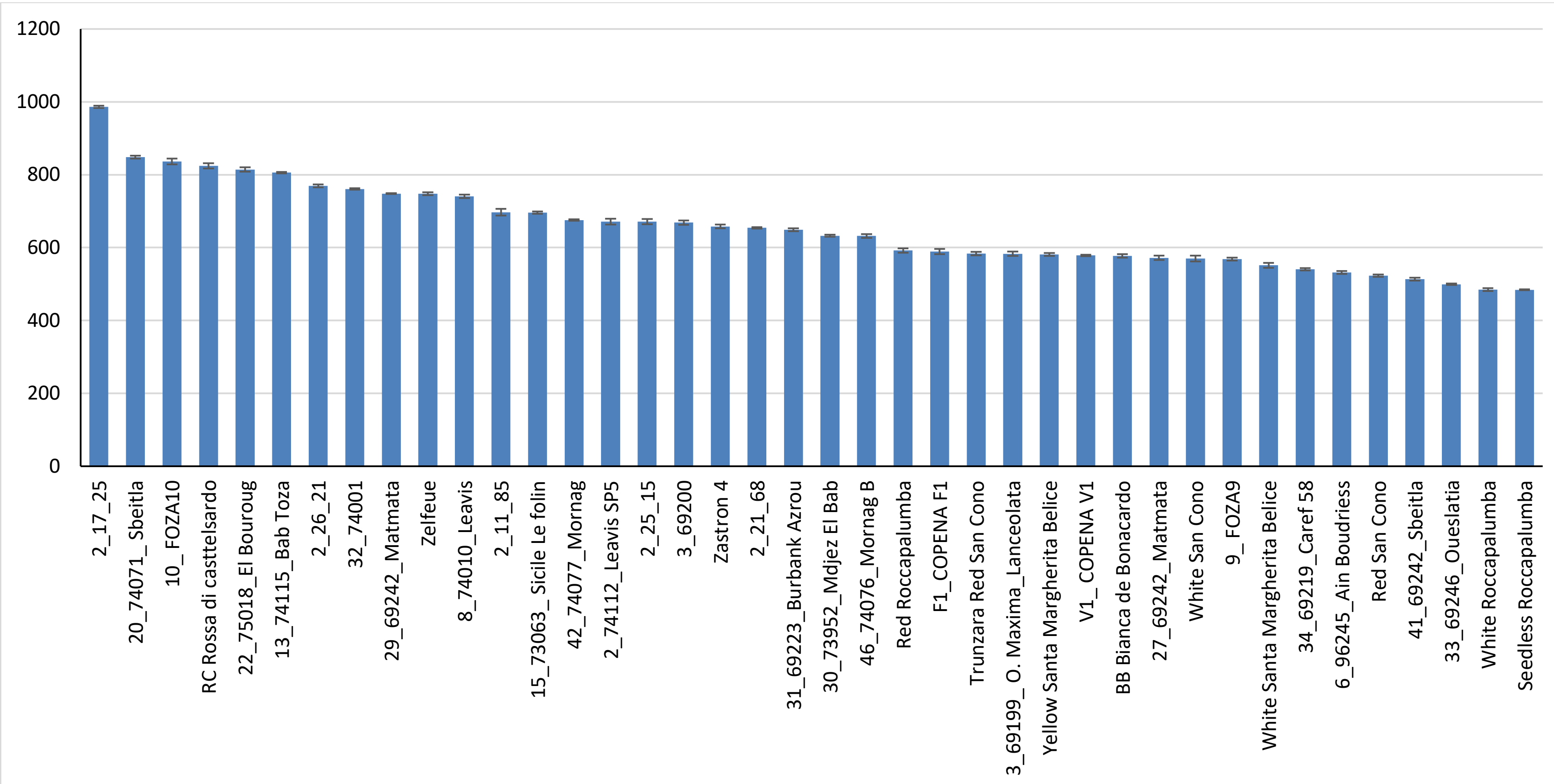

Figure 3. Cactus pear accession cladode fresh weight (g).

Refernces

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