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Performance of edible cactus (*Opuntiaficus-indica*) in saline environments

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ABSTRACT

Edible cactus [*Opuntiaficus-indica* (L.) Mill.] has been used as fruit, vegetable, forage and wide range of commercial purposes in arid regions. It has high efficiency to produce biomass per unit water use due to specialized photosynthetic mechanism. Owing to its tolerance to low input and adverse conditions, it has ample scope for introduction and cultivation in arid and saline parts of world. A field experiment was conducted to standardise planting techniques and irrigation requirements of cactus at Hisar (Haryana) during 2008-2010. Cactus clones 1270, 1271, 1280 and 1287 were planted on ridges, flat beds and furrows with no irrigation, irrigations at one month and two months interval using saline ground water. Raised bed plantations resulted in better survival and plant height. The survival was higher without irrigation but the plant height was higher with monthly irrigation. Clone 1270 sprouted earliest and highest survival was recorded in clone 1271. To assess salinity and alkalinity tolerance, clone 1280, was planted at Karnal. Three soil salinity (ECe) levels and four pH levels were maintained along with no fertilizer, NPK and FYM. This clone was found to tolerate moderate salinity (52 mM) but sensitive to pH and had negligible growth at pH 9.8. Application of NPK and FYM helped in mitigating the effects of salt stress. Raised bed planting was advantageous and once established, *Opuntia* can sustain saline groundwater irrigation for optimum growth and production.

Key words: Alkalinity, Fertilizer, Irrigation, *Opuntiaficus-indica*, Planting methods, Salinity

Drought and salt tolerant alternate crops which can survive in adverse conditions are crucial for sustainability of agriculture in arid and semiarid regions. For such, water scarce marginal soil regions of India, introducing low water requirement species of edible cactus [*Opuntiaficus-indica* (L.) Mill.] also called as prickly pear could be especially advantageous. Edible cactus is a new crop in India, recent attempts to introduce cultivated cactus pear started late in the 1980's (Singh 2006), although it's wild types known as *nagphani*, bearing spiny and small fruits are found in drier areas.

Availability of quite rich literature on physiology of *Opuntiaficus-indica* and its response to the environment points towards its increasing economic importance for fruit, fodder, and industrial uses (Nobel and Zutta 2008). Cactus is a xerophytic plant and has great capability to convert water into dry matter through crassulacean acid metabolism (CAM), photosynthetic pathway. It has been identified as a potential crop for arid and semiarid regions of world (Lahsasni *et al.* 2003). Different parts of the cactus can be used for various purposes (Singh 2006). Plant growth, development and yield are influenced by environmental conditions such as temperature, drought and salinity and cause several changes in plants at molecular level. Recently, Ochoa-Alfaro *et al.* (2012) reported the generation of a cDNA library of *Opuntiastreptacantha* underabiotic stress conditions, where diverse genes such as dehydrins (DHNs), involved in stress response were identified.In recent past, due to inadequate availability of fresh water, there is an appreciable increase in use of saline groundwater in these areas for agricultural purposes. Saline environments limit the plant growth by changing ion accumulation, mineral balances and water availability. Cultivation of *Opuntia* in these salt affected arid environments plays a strategic role due to its adaptation to a wide range of climatic conditions. Application of irrigation and fertilizer may result in its better survival and boost crop yields under such adverse conditions. There are only few field studies reported in literature which describe adaptations of *Opuntia* to water scarcity and also its tolerance to salinity are not well quantified (Pimienta-Barrios *et al.* 2002). So, to realize the full potential of cactus pear in arid regions, there is a need to generate information on the suitable planting methods for proper establishment of the edible clones of *Opuntiaficus-indica*, and appropriate irrigation scheduling,critical limits of salinity and alkalinity tolerance and possibility of mitigating the salt stress with fertilizer application in the crop.

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MATERIALS AND METHODS

The study was conducted at Bir Forest Farm, Hisar (Haryana) of the Central Soil Salinity Research Institute, Karnal during the years 2008-2010. The Hisar farm is situated at 29°10'-N latitude and 75°46'- E longitude and an altitude of 215.2 meter above mean sea level with annual rainfall of 35-40 cm and the ground water used for irrigation is saline. The soil characteristics of experimental site are provided in Table 1. The sand, silt and clay were determined by international pipette method (Jackson 1986), EC and pH (ECe and pHs represent the electrical conductivity and reaction of the solution extracted from saturated paste of soil) were measured by conductivity meter and pH meter, respectively following procedures as described by Page *et al.* (1982); and $CaCO_3$ was measured with rapid titration method (Puri 1930). The average salinity of irrigation water (ECiw) was 38 mM (~4 dS/m).

Table 1 Soil characteristic of experimental field at Bir Forest Farm, Hisar (Haryana)

Soil depth (cm)	Sand (%)	Silt (%)	Clay (%)	pHs	ECe (dS/m)	$CaCO_3$ (%)
0 - 30	62	19	19	8.2	1.7	7.3
30 - 60	61	22	17	8.3	2.6	8.0
60 - 90	60	22	18	8.3	3.4	8.6
90 - 120	59	22	19	8.3	4.6	9.1

The field experiment was conducted in split plot design with three blocks, for standardizing planting methods and irrigation requirements. The clones were planted by three methods, viz, ridge, flat and furrow with three irrigation schedules; as main plot treatment. Clones were planted at 3 × 2 m distance in an area of 18 × 16 m^2 (net plot size). The ridges and furrows were 50 cm wide and 30 cm high. In subplots four clones, viz. 1270, 1271, 1280 and 1287 were planted. One year old cactus cladodes were planted by upright method in which one third portion of the cladode is below the ground and two-third above. Recommended crop management practices and plant protection measures were undertaken (Singh 2006). The clones were irrigated with groundwater of 38 Mm salinity (~4 dS/m). The irrigation was started one or two months after planting depending upon the treatments. The amount of water applied in every flood irrigation was approximately 6 ha-cm, i.e. 600 000 litres per hectare. Observations on days to sprout, plant height, number of cladodes per plant, their length and width were taken at monthly interval for all plants. Total numbers of days were counted for each clone from planting to appearance of sprouts for determining the days taken to sprout. Data on plant height recorded in centimetres (cm) at monthly interval. The number of cladodes, i.e. new cladodes sprouted on planted cladodes was recorded.

Simultaneously, a pot experiment was started at Central Soil Salinity Research Institute, Karnal. Clone 1280 (Fruit) was planted in 30 kg capacity ceramic pots, uniformly filled with sandy loam soil (ECe 0.6 dS/m, pH 7.8, organic matter 2.8 g/kg soil, clay 14%). The experiment was laid out in split plot design. At the upper level, three salinity levels, viz normal (ECe 0.6 dS/m), ECe ~ 4 and 6 dS/m were maintained in 72 pots (12 pots for each treatment with two replications) by mixing NaCl, $MgSO_4.7H_2O$ and $CaCl_2.2H_2O$ in the ratio of 30: 2: 4 on the soil weight basis giving three wetting and drying cycles.In molarity terms, the initial soil EC was 0.6 dS/m when no salt (0 mM) was added (can be expressed as 6 mM NaCl). In case of 4 and 6 dS/m the amount of salt added was 35 and 55 mM/l on NaCl equivalent basis. On actual basis of NaCl, $MgSO_4.7H_2O$ and $CaCl_2.2H_2O$ it comes to be 32 and 52 mM of salts per litre (490 and 775 mM per pot). In further text we use 0, 32 and 52 mM for three salinity treatments. At lower level, three fertilizer treatments, i.e. control, recommended doses of fertilizer NPK (100 kg N, 50 kg P and 100 Kg K/ha/year), and FYM at the rate of 15 tonnes/ ha/year were applied. The NPK were supplied through urea, DAP and MOP. For the evaluation of alkalinity tolerance, four levels of pH, i.e. 7.8, 9.0, 9.4 and 9.8 were maintained (six pots for each treatment in two replications) using $NaHCO_3$ on the basis of sodicity curve drawn earlier for these soils (Singh *et al.* 1992). Observations were recorded on survival, number of cladodes and days taken to sprout,plant height (cm) for each plant.

Data of three years were transformed for homogeneity and analysed by using GenStat, 13^{th} Edition. To determine any significant difference in treatment means, the analysis of variance at 95% confidence interval was determined for all recorded parameters. To determine critical differences, Tukey's test was used. The method of Fisher (1949) was used in order to determine the least significant difference (LSD).

RESULTS AND DISCUSSION

Survival

Edible cactus differed significantly in survival with different planting methods regardless of the state of the available moisture in the soil (P<0.001, LSD, 0.38). Results showed that cactus pear planted on ridges had better survival of 61% (average) than in flat (45%) and furrow (44%) methods of planting. Moreover, flat method of planting has an advantage over furrow method (Fig 1A). The differences in survival among four clones were also significant (P<0.001). Among clones, the highest survival was in clone 1271 (67%) followed by 1270 (65%), 1280 (64%) and the least was in clone 1287(48%) (Fig 1B).

Among, different irrigation schedules, no irrigation, irrigation at two months interval and irrigation at one month interval had 60%, 57% and 53% survival respectively (Fig 1C), though, results were not statistically significant (P<0.540) for irrigation schedules. Again, the differences among clones (P<0.006) were observed to follow the same trend as in planting methods (Fig 1D).

Days to sprout

Clones planted by flat and furrow methods sprouted

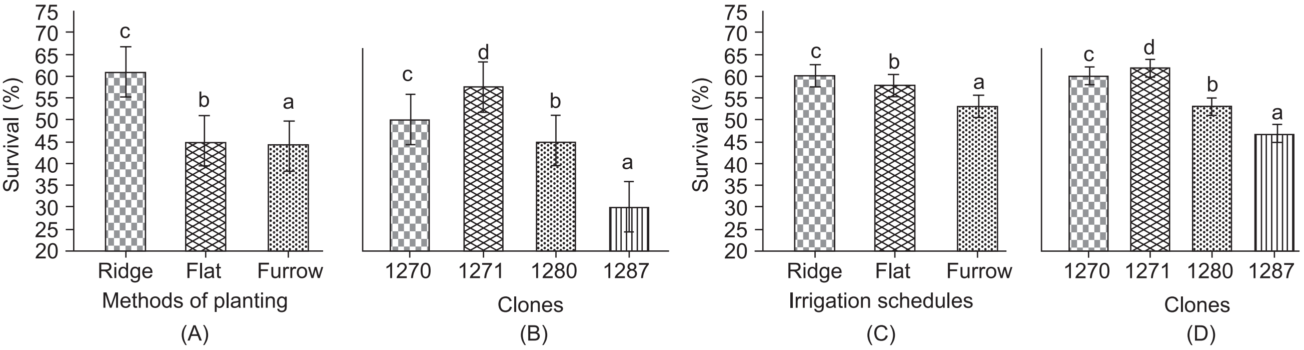

Fig 1 Survival (%) of *Opuntiaficus-indica*, (A) in ridge, flat and furrow methods of planting (LSD $_{0.38}$) and (C) in three irrigation schedules, viz. no irrigation (No Irri), irrigation at two months interval (Irri 2m) and irrigation at one month interval(Irri 1m) (LSD$_{31.12}$); and survival (%) of 1270, 1271, 1280 and 1287 clones of *Opuntiaficus-indica* (B) in different planting methods (LSD$_{0.34}$) and (D) irrigation schedules (LSD$_{12.85}$). Vertical bars are standard errors of means

earlier (P<0.001) (average 88 days) than those planted by ridge method (93 days). It seems that days taken to sprout depend on the clone (P<0.001) irrespective of planting method.Clone 1270 took the least time of 69-72 days to sprout followed by 1271 (85 to 96 days) and 1280 (93 to 98 days) while the maximum timetaken to sprout was found in the case of clone 1287 (97 to 110 days). With regard to irrigation, the clones took less days to sprout when no irrigation was applied followed by irrigation at 2 month interval. Cladodes of all clones with irrigation at one month interval were last to sprout, differences among irrigation schedules were not significant. Different clones in irrigation treatments followed the same trend as in planting methods.

Plant height

Clones planted on ridges attained more plant height (93.2 cm) than in the case of flat (89.0 cm) and furrow (87.7 cm) method of planting.

The average height of clones increased with the increase in frequency of irrigation.The plants irrigated at monthly interval were taller (92.9 cm) followed by those irrigated at two month interval (88.7 cm). Plants with no irrigation recorded least height (87.1 cm). The plant height did not show any consistent trend with respect to planting methods and irrigation treatments. Clone 1271 had significantly larger plant height followed by 1280 under different planting methods, but clone 1270 recorded significantly more plant height followed by 1271 with variable irrigation treatments. Over all clone 1287 was shortest among the four clones.

Salinity

The clone (1280) performed well at all the salinity levels but plant height (P<0.394) and number of cladodes (P<0.408) formation were reduced with increase in salinity (ECe) from normal (0 mM) to 32 mM and then to 52 mM (Fig 2 A and C).

The application of recommended doses of NPK reduced the adverse effect of salinity (P<0.095) (Fig 2B and D). The plant height and number of cladodes increased with the application of NPK at all the salinity levels. Application of FYM did not mitigate the adverse effect of salinity in the first year, however, from second year onwards FYM application also started to reduce the adverse effect of salinity.Data presented in Fig. 2 are average of the both years.

Alkalinity

Plant height reduced significantly (P<0.002) with increase in pH from 7.8 (56.0 cm) to 9.0 (23.5 cm) and then to 9.4 (16.3 cm) and 9.8 (16.0 cm) (Fig 3A). However,the

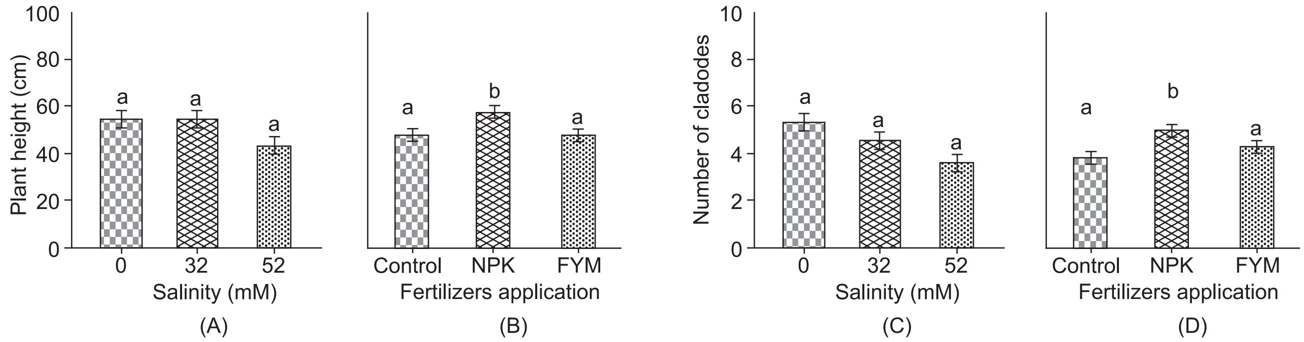

Fig 2 Effect of (A) three levels (0.6, 4.0 and 6.0 dS/m) of salinity (LSD$_{31.46}$) and (B) fertilizer application with no fertilizer (control) recommended dose of NPK and FYM (LSD$_{8.09}$) on plant height (cm) of *Opuntiaficus-indica*. Number of cladodes produced by *Opuntiaficus-indica*, clone 1280(C) in different salinity (LSD$_{4.60}$) and (D) fertilizer treatments (LSD$_{1.41}$). Vertical bars are standard errors of means

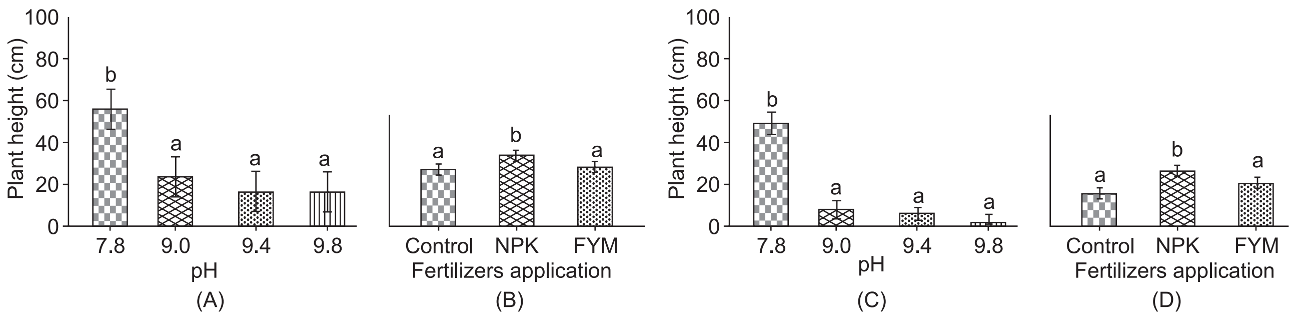

Fig 3 Effect of (A) four levels of pH_2, viz 7.8, 9.0, 9.4 and 9.8($LSD_{8.96}$) and (B) fertilizers application with no fertilizer (control), and recommended dose of NPK and FYM ($LSD_{8.96}$)on plant height (cm) of *Opuntiaficus-indica*. Number of cladodes produced by *Opuntiaficus-indica*, clone 1280(C) in different pH_2($LSD_{1.07}$) and (D)fertilizer treatments ($LSD_{0.47}$).Vertical bars are standard errors of means.

application of NPK reduced the adverse effect of pH and the plant height was significantly higher at every pH level in all treatment pots (Fig 3B). The application of FYM was not found to mitigate the effect of alkalinity rather plant height was reduced in some cases in first year. From second year onwards, it was observed that application of FYM also tended to reduce the effect of alkalinity. The number of cladodes was also reduced ($P<0.002$) with increase in pH and there was no cladode formation at pH 9.8 despite the application of NPK and FYM (Fig 3C). Again application of NPK and FYM reduced the adverse effect of pH ($P<0.010$) (Fig 3D). The beneficial effect of fertilizer was more in case of fertilizer NPK.

Environmental stresses like temperature, drought and salinity influence the plant growth, development and yield. Acclimatization of plants in different environments is a function of soil type, available water and crop management practices. The growth and production of cactus has been affected by environment and plantation design (Garcia de Cortazar and Nobel 1992), planting material (age and number of daughter cladodes) and number of cuttings per planting spot, size, age, and planting methods of cladodes. The cactus pear is highly adapted to a wide range of environmental conditions due to its specialized anatomical, morphological and physiological mechanisms. Therefore, the expression of the genes involved in stress responses such as dehydrins and accumulation of compounds may contribute in plant tolerance to drought, high salt and cold stress (Ochoa Alfaro *et al*. 2012).

All the four cactus clones investigated in this study are fairly adapted in Hisar (Haryana) type, Hyperthermic Typic Ustissaments of semi-arid climate. It was clear that, ridge planting of cactus pear has better survival over flat and furrow planting methods (Fig 1A). Plant height after three years also followed the same trend in response to different planting methods. Ridge planting helped in creating a very loose soil, which helped the roots in faster and better growth and expansion. The higher root growth rate of cactus is associated with higher root respiration rates. This may be an explanation in this case also, where the roots of cactus pear could have grown better when the soil was light and not compacted. The higher survival rate of prickly pear in treatment where no irrigation was applied (Fig 1 C), again proved its ability to proliferate in extremely dry conditions. The lower survival of cactus when irrigated with saline water may be due to its lower tolerance to salt stress at establishment stage. Increase in plant height of cactus pear with increasing frequency of irrigation from no irrigation to irrigation at two months interval and then further to one month interval emphasise the luxurious growth of cactus in better soil water conditions and its extended tolerance to salinity after establishment. In general, the range of salinity tolerance for each plant species is lower during establishment and species become more tolerant to salt stress thereafter (Espinar *et al.* 2005). Cony *et al.* (2006) have not observed any significant reduction in growth and yield of *Opuntiaficus-indica* when irrigated with 50 mM NaCl water. They found that *Opuntiaficus-indica* was suitable for cultivation in arid ecosystems by utilizing poor quality groundwater. Snyman (2006) described that most of the root system of cactus is found in the 0–150 mm of soil depth. The soil moisture content of these upper soil layers is quite heterogeneous and cactus can efficiently utilise the small amount of water available on soil surface due to a light rain and therefore it is one of the potential crop for arid regions.Present study also demonstrated the role of management practices like ridge planting of cactus and its efficiency to utilise poor quality water to optimize production in arid regions.Further, days taken to sprout in this study depended on clone irrespective of planting method and irrigation schedule. Singh and Felker (1998) reported similar results from Karnal (India), where the time of sprouting varied from 57 to 100 days depending on the clone of planted cactus.

The threshold for salinity stress is 40 mM NaCl for most of the salt sensitive plants (Munnsand Tester 2008). The salinity treatments tried in this experiment did not cause any significant difference in performance of cactus pear.Although, there was a reduction in plant height and number of cladodes at salinity of 32 mM and further more at 52 mM (Fig. 2A and C).These results are in agreement with previous reports.Nobel *et al.* (1984) reported the survival of *Cereusvalidus* Haworth (Cactaceae) on temporarily highly saline soils. They advocated that the inward ion retention through the selective ion transport across the roots, and carbon budgeting given by CAM are the possible reasons for cactus to be a productive crop on saline soils. It is due to ability of CAM plants to maintain metabolic activity for a longer period in very saline environments through the internal recycling of respiratory CO_2 as the stomatal conductance is very low. Nerd *et al.* (1991) did not find any significant role of salinity in plant height and fruit yield. Singh (2003) identified edible cactus as a very useful plant which can grow even under high pH soils. He also reported the significant reduction in cactus growth at pH above 8.7. In present study cactus growth was affected significantly by the pH level of the medium. There was significant reduction in plant height and number of cladode and there was no cladode production at pH 9.8 (Fig. 3A and C). Although there was increase in size of planted cladode (plant height), there was no cladode sprout after three years.

The salinity build up adversely affects plant growth and development through osmotic effects and ionic imbalances; however, those could be offset by adequate supply of nutrients. Murillo-Amador *et al.* (2005) described the effect of doses and sources of nitrogen, phosphorus, and potassium and organic fertilization in the production of young cladodes (cladode sprouts) in prickly pear. Nitrogen and potassium were reported to have direct role in mitigating the effect of salt stress. Nitrogen fertilization helps to improve its availability and regulate the nutritional imbalance, whereas potassium has a role in regulation of K^+/Na^+ ratio is well known under salt affected conditions. Similarly, application of phosphorus has been reported to improve yield under salt stress conditions. Results from salinity and alkalinity trials in this study demonstrated the beneficial effect of NPK and FYM application in mitigating the effect of salt stress (Fig 2 and 3). Application of recommended doses of NPK was very effective in ameliorating the salt stress from the beginning; and from second year onwards, FYM also reduced the adverse effect of salinity and alkalinity. Slow release of nutrients in case of FYM may be the reason for this time lag between NPK and farmyard manure.

CONCLUSION

Once established in dry region marginal lands underlain with poor quality groundwater, the edible cactus has good potential to yield fodder and fruit. There is a significant advantage of planting cactus pear on raised beds. Edible cactus has lower tolerance to salinity at establishment and survival stage but can sustain saline groundwater irrigation for optimum growth and production in later stages. Though,plant is moderately tolerant to salinity but sensitive to alkalinity and unable to perform at soil pH 9.8. The adverse effect of salinity and alkalinity could be moderated with application of fertilizers.

REFERENCES

Cony M A, Trione S O and Guevara J C.2006.Macrophysiological responses of two forage *Opuntia* spp. to salt stress. *Journal of the Professional Association for Cactus Development* **8**: 52–62.

EspinarJ L, Garcia L V and Clemente L.2005. Seed storage conditions change the germination pattern of clonal growth plants in Mediterranean salt marshes. *American Journal of Botany* **92**: 1 094–1 101.

Fisher R A. 1949. *The Design of Experiments*. Oliver and Boyd Ltd, Edinburg.

Jackson M L. 1986. *Advanced Soil Chemical Analysis*. Prentice Hall of India, New Delhi.

Lahsasni S, Kouhila M, Mahrouz M and Fliyou M. 2003. Moisture adsorption-desorption isotherms of prickly pear cladode (*Opuntiaficus-indica*) at different temperatures. *Energy Conversion and Management* **44**: 923–36.

Munns R and Tester M. 2008.Mechanisms of salinity tolerance. *Annual Review of Plant Biology* 651–81.

Murillo-Amador B, Garcia-Hernandez J L, Avila-Serrano N Y, Orona-Castillo I, Troyo-Dieguez E, Nieto-Garibay A, Ruiz-Espinoza F H and Zamora-Salgado S. 2005. A multivariate approach to determine the effect of doses and sources of N, P, and K in *Opuntiaficus-indica* (L.) Mill. *Journal of the Professional Association for Cactus Development* **7**: 110–24.

Nerd A, Karadi A and Mizrahi Y. 1991.Salt tolerance of prickly pear cactus (*Opuntiaficus-indica*). *Plant and Soil* **137**: 201–7.

Nobel P S, Luttge U, Heuer S and Ball E. 1984. Influence of applied NaCl on crassulacean acid metabolism and ionic levels in a cactus, *Cereus-validus*. *Plant Physiology* **75**: 799–803.

Nobel P S and Zutta B R. 2008. Temperature tolerances for stems and roots of two cultivated cacti, *Nopaleacochenillifera* and *Opuntiarobusta*: Acclimation, light, and drought. *Journal of Arid Environments* **72**: 633–42.

Ochoa-Alfaro A E, Rodriguez-Kessler M, Perez-Morales M B, Delgado-Sanchez P, Cuevas-Velazquez C L, Gomez-Anduro G, Jimenez-Bremont J F. 2012. Functional characterization of an acidic SK3 dehydrin isolated from an Opuntiastreptacanthac DNA library. *Planta* **235**: 565–78.

Page A L, Miller R H, Kenney D R. 1982. *Method of Soil Analysis*. Parts I and II. American Society of Agronomy, Madison, Wisconsin.

Pimienta-Barrios E, del Castillo-Aranda M E G and Nobel P S. 2002. Ecophysiology of a wild platyopuntia exposed to prolonged drought. *Environmental and Experimental Botany* **47**: 77–86.

Puri A N. 1930.A new method for estimating total carbonates in soils. *Improvements in Agricultural Research.* Pusa Bulletin No. **206**, p 7.

Singh G. 2006. An overview of cactus pear research and development in India. (In) *Proceedings of the Vth International Congress on Cactus Pear and Cochineal, International Society Horticultural Science, Leuven* **1**, pp 43–50.

Singh G. 2003. General Review of *Opuntias* in India.*Journal of the Professional Association for Cactus Development* **5**: 30–46.

Singh G and Felker P. 1998. Cactus: new world foods. *Indian Farming* April: 26–31.

Singh R B, Minhas P S, Chuahan C P S and Gupta R K. 1992.Effect of high salinity and SAR waters on salinisation, sodication and yields of pearl-millet and wheat. *Agricultural Water Management.* **21**: 93–105.

Snyman H A. 2006. Root distribution with changes in distance and depth of two-year-old cactus pears *Opuntiaficus-indica* and *O robusta* plants. *South African Journal of Botany* **72**: 434–41.