From Forest Nursery Notes, Winter 2012

25. Can environmental variation affect seedling survival of plants in northeastern Mexico? Garcia, J. F. Arch. Biol. Sci., Belgrade 63(3):731-737. 2011.

 DOI:10.2298/ABS1103731G

CAN ENVIRONMENTAL VARIATION AFFECT SEEDLING SURVIVAL OF PLANTS IN NORTHEASTERN MEXICO?

JAIME F GARCÍA

Facultad de Agronomía UANL Unidad La Ascensión, 59577 La Ascensión Aramberri, N.L. México

Abstract - The effects of global warming increase the frequency and intensity of many climate events such as rainfall. We evaluated the effects of environmental conditions on early stage seedling survival of the native thorn scrub species *Caesalpinia mexicana* A. Gray, *Celtis pallida* Torr., *Cordia boissieri* A. DC., and *Ebenopsis ebano* (Berland.) Barneby and J.W. Grimes, during the summer of 2009 and 2010. The experimental design had two factors, two levels of rainfall and three microhabitats of thorn scrub: (i) open interspace, (ii) thorn scrub edge and (iii) under the canopy of dense thorn scrub. In dense thorn scrub, seedling survival was higher for *Caesalpinia mexicana* and *Celtis pallida,* and for *Cordia boissieri* and *Ebenopsis ebano* seedling survival was higher in dense thorn scrub and thorn scrub edge. The effect of rainfall on seedling survival depended on the year. Rainfall in 2010 and dense thorn scrub increased seedling survival of native species. For survival, the limiting factors of microhabitats appear to change across the years. Besides rainfall events, biological aspects like competition and mycorrhiza effects would need to be considered in models of plant establishment.

Key words: *Caesalpinia mexicana*, *Celtis pallida*, *Cordia boissieri*, *Ebenopsis ebano*, microhabitat, native species, rainfall, seedling survival

UDC 504.7:58(72-18)

INTRODUCTION

The early stages of plant growth such as seed germination and seedling survival are most affected by adverse conditions (Harper 1977; Kitajima and Fenner 2000), because survival is strongly affected by biotic and abiotic conditions (Ibañez and Shupp 2001). Water is one of the major factors limiting plant establishment in many ecosystems (Valiente-Banuet and Ezcurra, 1991; Flores et al., 2004). By ameliorating abiotic and biotic stresses, woody plants facilitate the recruitment of plants (García-Moya and McKell, 1970; Franco and Nobel 1989; Tirado and Pugnaire, 2003; Pugnaire et al., 2004), due to microclimatic conditions, including lower evapotranspiration rates and changes in the light quality (Murchie and Horton, 1998; Valladares and Puignaire, 1999; Maestre et al., 2001), and improved soil physical and chemical properties (Cerdá, 1997; Bochet et al., 1999). Global warming can affect rainfall patterns (Hughes, 2000) and thereby plant survival. The objective of this research was to evaluate the effect of yearly variation of rainfall as a limiting factor for seedling survival between contrasting microhabitats: (i) dense thorn scrub; (ii) thorn scrub edge and (iii) open thorn scrub. The hypothesis of this research predicts that yearly environmental variations due to global warming effects are causing yearly differences in microhabitat suitability for seedling establishment.

MATERIALS AND METHODS

Study species

The species chosen for this study are quite common in northeastern Mexico. *E. ebano* (ebano) is a large tree of up to 10 m tall and has a large dense canopy; *C. mexicana* (árbol del potro) grows under 5 m in height and has an upright, low-density canopy (Estrada and Marroquín, 1991); *Cordia boissieri* (anacahuita) is a small tree with a growth of up to 6 m (Estrada et al. 2005) and *C. pallida* (granjeno) is a broadleaf tree of up to 3 m (Benson and Darrow, 1981).

Study site

The study was conducted in an area of thorn scrub near Linares (Nuevo Leon) in northeastern Mexico (24° 51' N, 99° 34' W), from June to September in 2009 and 2010. The climate is sub-humid, semi-tropical with an annual rainfall ranging from 713.3 to 1058 mm that falls mainly in late summer and early autumn. Mean annual temperature is 22.9°C, with a maximum in summer of 45°C and a minimum of -2°C (Cavazos and Molina, 1992). Total rainfall was very different between the two years (Fig. 1); for 2009 it was 154.8 mm and for 2010 i was 716.8 mm.

In the study area, shrubs and trees of *Tamaulipan* thorn scrub such as *Acacia berlandieri* Benth., *Acacia rigidula* Benth., *Caesalpinia mexicana* A. Gray., *Celtis pallida* Torr., *Cordia boissieri* A. DC., *Ebenopsis ebano* (Benth.) Coult., *Havardia pallens* (Benth.) Brintton and Rose, *Flourensia laurifolia* DC., *Leucophyllum frutescens* (Berl.) Johnst., *Porlieria angustifolia* (Engelm.) Gray., *Prosopis laevigata* (Humb and Bonpl. ex. Wild.) M.C. Johnston, and *Randia obcordata* Lindley, are the most frequent and abundant species found.

Treatment of seeds

Seeds of all species were collected in 2008 from the study area from at least 20 mother plants to allow for genetic variation. The seeds were thoroughly mixed; air dried, stored in a site to cool and dry in bottles with silica gel bags for moisture control and left in paper bags for potential after-ripening for 3 months. The seeds were not tested for viability, and no fungal inhibitors were applied to them. All seeds except *Caesalpinia mexicana* were scarified prior to germination. Mechanical scarification with sand paper was preferred as it has been shown be an effective treatment to promote germination for seeds with hard integuments in northeastern Mexico (Foroughbakhch, 1989).

Experimental design

The effects of rainfall limitation and microhabitat for seedling survival were evaluated with two factor ANOVAs. Rainfall exposure was: (1) rainfall of summer 2009 and (2) 2010 (Fig.1). Microhabitats used were: (i) dense thorn scrub, under cover of woody vegetation; (ii) thorn scrub edge and (iii) open thorn

Table 1. Environmental differences among microhabitats. Soil characteristics are from analyses of the surface soil samples from a representative pedon of each microhabitat type. Litter samples are from 30×30 cm samples, *n*=10. Light intensity was measured with a lux meter (LX-1010B) for 5 days at noon in June 2009.

Variable	Microhabitat		
	Open	Edge	Dense
Surface soil characteristics			
Phosphorus (mg/kg^{-1})	3.31	9.95	12.54
Nitrates (mg/kg^{-1})	5.90	20.83	54.13
Organic carbon (%)	1.54	2.35	3.38
Litter dry mass (kg/m^2)	0.15	0.35	0.43
Available water capacity (cm)	3.32	4.56	5.13
Light intensity (lux mean ± S.D.)	225.13±21	553.34 ±78	896.12 ±108

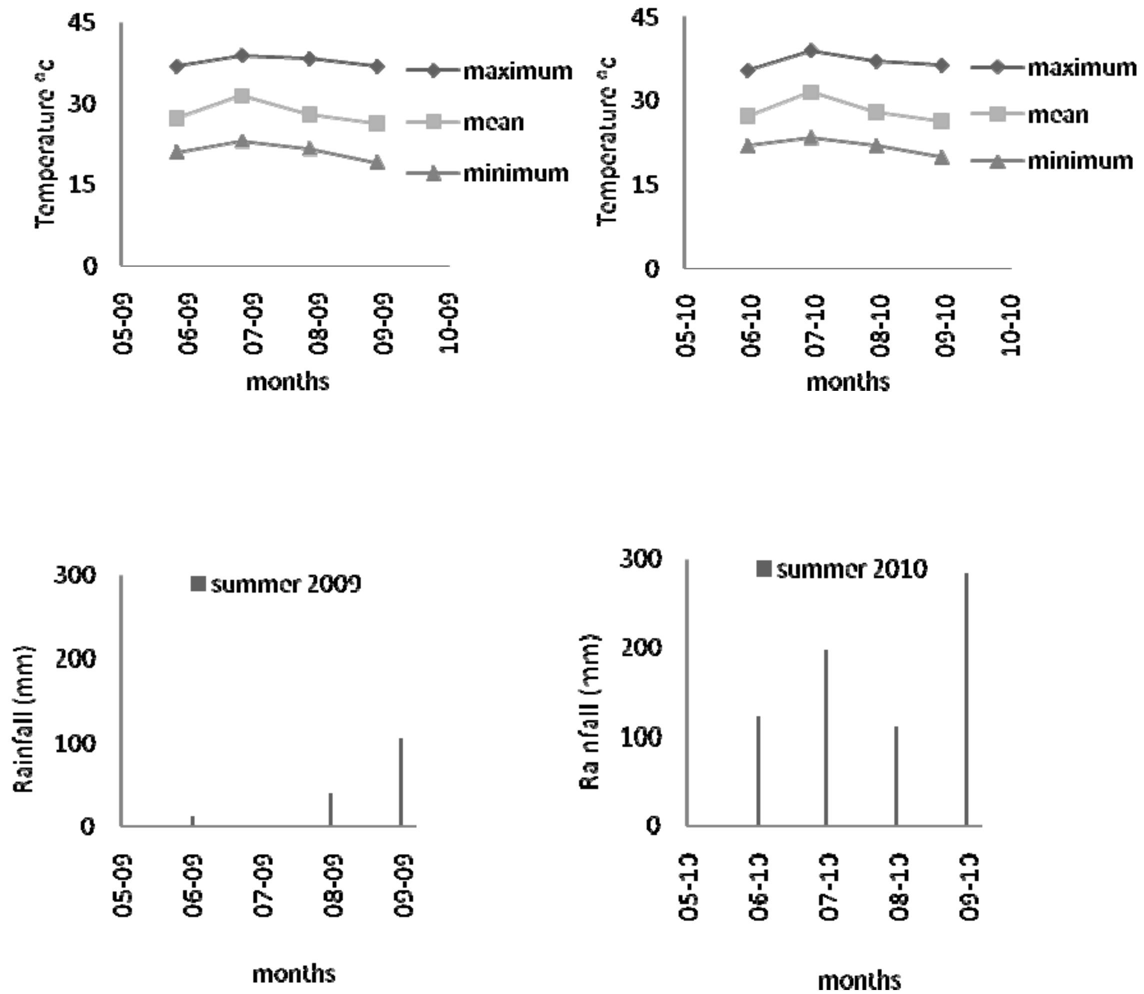

Fig. 1. Mean, maximum, and minimum temperatures; rainfall, during summer (June to September) 2009 and 2010 on microhabitat of thorn scrub in Northeastern México Data provided by the Mexican National Water Commission weather station (CNA).

scrub, without woody vegetation, in a mosaic of herbaceous and bare soil. These three microhabitats differed in important characteristics such as soil characteristics, moisture on the soil surface and light intensity (Table 1). Seeds were germinated on germination trays with the soil of the three microhabitats collected from the study site. At 7 weeks the seedlings were transplanted into each microhabitat (June 15, 2009 and 2010), into holes of 15 cm diameter x 10 cm deep; to avoid stress the transplanted seedlings were supplied with water *in situ*. Transplanted seedlings size (cm) and number of leaves for 2009 and 2010 were: *C. mexicana* 6.5 ± 0.8; 6.8 ± 1.2, 6.9 ± 0.9; 7.1 ± 0.8, (mean ± S.D.). *C. pallida* 4.1 ±.0.3; 4.9 ± 0.6, 4.3 ± 0.7; 4.7 ± 1.1. *C. boissieri* 4.2 ± 0.4; 4.9 ± 0.3, 4.0 ± 0.6; 5.1 ± 0.8 and *E. ebano* 3.9 ±.0.5; 3.6 ± 0.8, 3.7 ±.0.5; 3.5 ± 0.6. For insect protection the seedlings were sprayed with a dilution of synthetic *pyrethrin insecticide once per week*. All environments were within an area of 20 ha, on a deep vertisol. Seedlings in all microhabitats were fenced to avoid predation by small mammals.

There were a total of 2400 seedlings, 600 per species (10 seedlings x 3 microhabitats x 2 rainfall treatment x 10 replicate sites). Seedling survival was monitored each *week*. Percentage of seedling survival was calculated as: percentage of seedling survival (number of live seedlings/total seedlings) * 100. Differences in seedling survival were detected using a two-way ANOVA (α= 0.05). Tukey's *T*-test was used to verify statistically significant differences between the mean values of the examined factors. Prior to analysis of seedling establishment, data were arcsine square-root transformed to obtain a normal distribution (Sokal and Rholf, 1995). Ninety-five percent confidence intervals were used in graphics to highlight differences for each variable.

RESULTS

For all species survival analysis differed between the years of exposure to rainfall (*d.f.*= 1, *P*< 0.001), and according to Tukey's *T*-test (Table 2) all species showed better seedling survival in 2010. Overall 11 and 37% of the seedlings were alive at the end of the summer of 2009 and 2010. During 2009 the mortality rate was greatest through the summer due to high temperatures and lack of rainfall (Fig. 1), while in 2010 rainfall effects increased seedling survival (Table 2; Fig. 2).

For *C. mexicana*, 98 seedlings were alive: 55 in dense thorn scrub (37 in 2010 and 18 in 2009), 28 at the edge (20 in 2010 and 8 in 2009), and 15 under open interspace (11 in 2010 and 4 in 2009). There were 166 seedlings alive from *C. boissieri*: 74 in dense thorn scrub (56 in 2010 and 18 in 2009), 55 at the edge (46 in 2010 and 9 in 2009), and 37 under open interspace (34 in 2010 and 3 in 2009). *E. ebano* had 188 seedlings alive: 86 in dense thorn scrub (66 in 2010 and 20 in 2009), 67 at the edge (54 in 2010 and 13 in 2009), and 35 under open interspace (29 in 2010 and 6 in 2009). Total seedlings alive for *C. pallida* was 119: 60 under dense thorn scrub (45 in 2010 and 15 in 2009), 39 at the edge (29 in 2010 and 10 in 2009), and 20 under open interspace (16 in 2010 and 4 in 2009).

For each species seedling survival was significantly (*d.f.*= 2, *P*< 0.001) associated with environment (*d.f.*= 2, *P*< 0.001). All species showed better seedling survival in dense thorn scrub (Table 2, Fig. 2), while in edge thorn scrub *Cordia boissieri* and *Ebenopsis ebano* also showed higher seedling survivor. The interaction rainfall exposure x microhabitats was significant (*d.f.*=2, *P*< 0.001); dense thorn scrub (Table 2) for all species, and also in edge thorn scrub for *Cordia boissieri* and *Ebenopsis ebano*, (Table 2). The significant two-way interaction demonstrated that the rainfall of 2010 tended to increase survival on edge and dense thorn scrub, while it had virtually no affect on open interspace.

DISCUSSION

In 2009 survival of all species was mainly affected by high temperature and lack of rainfall (Fig. 1), which caused negative effects on seedling growth, yield, physiological processes (Li et al., 2009) and seedling survival (Sánchez-Coronado et al., 2007). Arid areas

Table 2. Mean seedling survivor of for *Caesalpinia mexicana*; *Celtis pallida*; *Cordia boissieri* and *Ebenopsis ebano*. Seedling survivor for all species differed between years (*d.f.*= 1, *P* < 0.001), microhabitat (*d.f.*= 2, *P* < 0.001). The interaction rainfall treatments x microhabitats were significant (*d.f.*= 2, *P*< 0.001). Differences between means (□= 0.05) are indicated using different lowercase letters, according to *Tukey*-test.

Specie	Microhabitats on thorn scrubyear 2010			Microhabitats on thorn scrubyear 2009		
	dense	edge	open	dense	edge	open
Caesalpinia mexicana	3.7^{a}	2.0^{b}	1.1^{b}	1.8^{b}	0.8^{c}	0.4^{c}
Celtis pallida	4.5^{a}	2.9^{b}	1.6^{c}	1.5^{c}	1.0^{c}	0.4^{cd}
Cordia boissieri	5.6^{a}	4.6^{ab}	3.4^{b}	1.8^{c}	0.9^{cd}	0.5^{d}
Ebenopsis ebano	6.6^{a}	5.4^{a}	2.9^{b}	2.0^{bc}	1.3^{c}	0.6^{c}

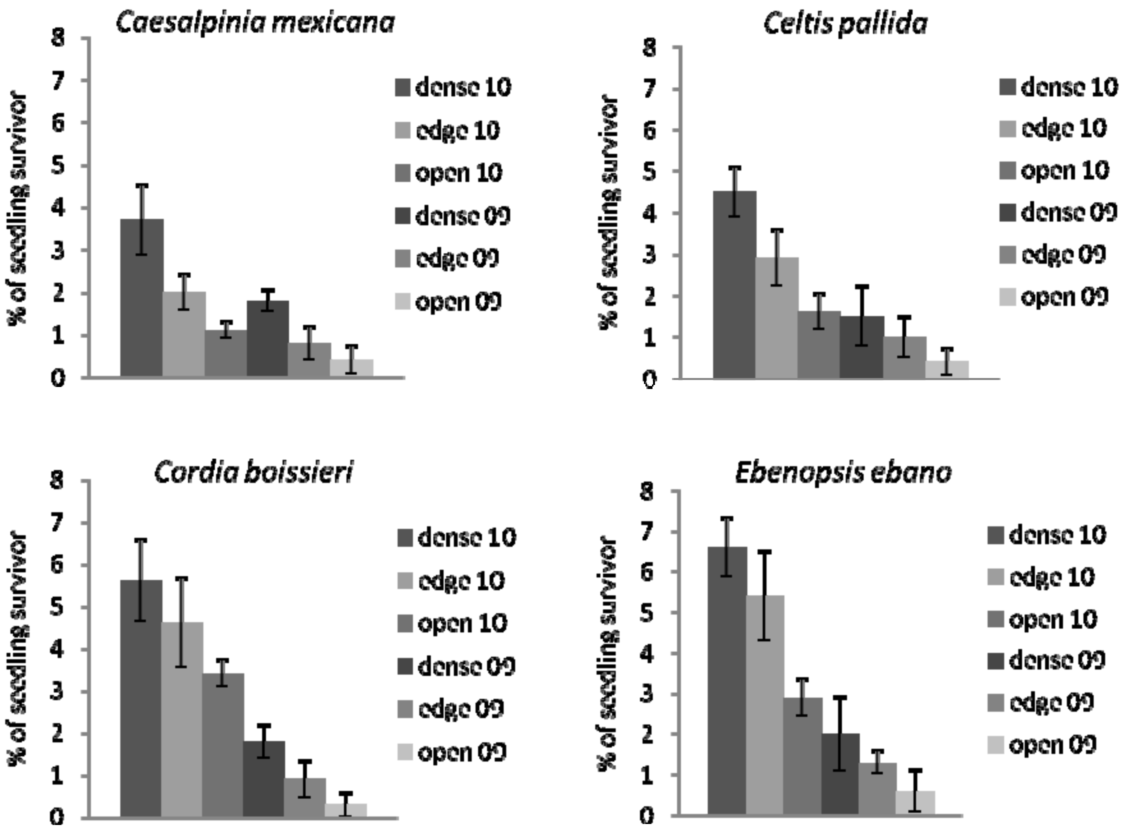

Fig. 2. Percentage of seedling survivor for *Caesalpinia mexicana*, *Celtis pallida*, *Cordia boissieri* and *Ebenopsis ebano*. during summer (June to September) 2009 and 2010 on microhabitats of thorn scrub in Northeastern México. Each point represents the mean of 10 plots. Error bars represent confidence intervals (α= 0.05).

are prone to drought because their rainfall amount critically depends on a few rainfall events (Sun et al., 2006). Moisture due to rainfall in the summer of 2010 in dense and edge thorn scrub had positive effects on seedling survival.

In this study, seedling survivor was limited by water availability in 2009, with high mortality of the species studied here probably caused by the low moisture in the surface of the soil, suggesting an intense environmental selection. Differences found here between species to response stress showed different patterns to ecological stress gradients (Gitlin et al., 2006; Bernal et al., 2011)

The nurse plant in dense thorn scrub appears to exert a crucial positive influence on seedling survival in dry years (Jurado et al., 2006; García and Jurado 2003), or the capacity for resource-sharing through common mycorrhizal networks (Chiariello et al., 1982). However, seedling survival was greater in the wet year 2010 (Table 2; Fig. 2), with dense and edge thorn scrub appearing to enhance the effects of rainfall for 2010.

For thorn scrub species climatic changes could affect seedling abundance (Jurado et al., 2011) due to changes in rainfall (Van der Waal et al., 2009; Kusnierczyk and Ettl., 2002) and temperature (Hughes, 2000; Thomas et al., 2004). In addition to microhabitats, differences in rainfall between years could be the main factor limiting seedling survival; rainfall changes may also affect seedling recruitment by direct effect on survival.

For the thorn scrub ecosystem, changing rainfall patterns caused by climate change can affect the models for establishment of plants.

Acknowledgments - This research was conducted with support from PROMEP/103.5/09/3905; 103.5/10/6646.

REFERENCES

Benson, L. and *R. A. Darrow* (1981). Trees and shrubs of the southwestern deserts. Third Edition. The University of Arizona Press. Tucson, Arizona. Pp. 229-230.

Bernal, M., Estiarte, M., and *J. Peñuelas* (2011). Drought advances spring growth phenology of the Mediterranean shrub *Erica multiflora*. *Plant Biol.* **13**, 252-257.

Bochet, E., Rubio, J. L., and *J. Poesen* (1999). Modified topsoil islands within patchy Mediterranean vegetation in SE Spain. *Catena.* **38**, 23–44.

Cerdá, A (1997). The effect of patchy distribution of Stipa tenacissima L. on runnof and erosion. *J. Arid. Environ.* **36**, 36–51.

Cavazos, M. T., and *V. Molina* (1992). Climatic record for the citrus region of Nuevo León Reporte Técnico Facultad de Ciencias Forestales UANL, vol. 1: pp.1–65.

Chiariello, N. R., Hickman, J. C., and *H. Mooney* (1982) Endomycorrhizal role for interspecific transfer of phosphorus in a community of annual plants. *Science*. **217**, 941–943.

Estrada, E. and *J. Marroquín* (1991). Leguminosas en el centro-sur de Nuevo León. Facultad de Ciencias Forestales. UANL. Rep. Cient. No. 10 (especial), Linares N.L. México, 258 pp.

Estrada, E., Villarreal, J., and *E. Jurado* (2005). Leguminosas del norte del estado de Nuevo León, México. 2005. *Acta Botánica Mexicana.* **73**, 1-18.

Flores, J., Briones, O., Flores, A. and *S. Sánchez-Colón* (2004). Effect of predation and solar exposure on the emergence and survival of desert seedlings of contrasting life-forms. *J Arid Environ.* **58**, 1-18.

Franco, A.C., and *P. S. Nobel* (1989) Effect of nurse plants on the microhabitat and growth of cacti. *J Ecol***. 77,** 870-886.

Foroughbakhch, P. R. (1989). Tratamiento a la semilla de catorce especies de uso múltiple de zonas de matorral y su influencia en la germinación. Rep. Cient. No. 11, Facultad de Ciencias Forestales, UANL, Linares N.L. México. 20 pp.

García, J., and *E. Jurado* (2003). Influence of plant cover on germination in matorral in northeastern Mexico. *Forest Ecol. Manage*. **177**, 11-16.

García-Moya, E,. and *C. M. McKell* (1970) Contribution of shrubs to the nitrogen economy of a desert-wash plant community. *Ecology*. **51**, 81– 88.

Gitlin, A.R., C. M. Sthultz., M. A. Bowker., S. Stumpf., K. L. Paxton., K. Kennedy., A. Munoz., J. K. Bailey, and *T. G. Whitham* (2006). Mortality gradients within and among dominant plant populations as barometers of ecosystem change during extreme drought. *Conserv Biol.* **20**:1477-1486.

Harper, J.L. (1977) Population Biology of Plants. Academic Press, London.

Hughes, L (2000). Biological consequences of global warming: is the signal already apparent? *Trends Ecol Evol*. **15**, 56-61.

Jurado, E., García, J. F., Flores, J. and *E. Estrada* (2006). Leguminous seedling establishment in Tamaulipan thorn scrub of Northeastern Mexico. *Forest Ecol. Manage*. **221**, 133-139.

Jurado, E., García, J.F., Flores, J., Estrada, E and H. González (2011). Seedling abundance in an elevation gradient in northeastern Mexico. *Southwest Nat*, in press.

Kitajima, K., and *Fenner, M.* (2000) Ecology of seedling regeneration. Seeds: the Ecology of Regeneration in Plant Communities, 2nd edn (ed. M. Fenner), pp. 331–359. CAB International, Wallingford.

Kusnierczyk, E. R., and *G. J. Ettl* (2002). Growth response of ponderosa pine (*Pinus ponderosa*) to climate in the eastern Cascade Mountains, Washington, U.S.A.: Implications for climatic change. *Ecoscience* **9**, 544-551.

Li, F.L., W. K. Bao., and *N. Wu* (2009). Effects of water stress on growth, dry matter allocation and water-use efficiency of a leguminous species, *Sophora davidii*. *Agroforest Syst*. **77**, 3: 193.

Maestre, F.T., S. Bautista., J. Cortina., and *J. Bellot* (2001). Potential of using facilitation by grasses to establish shrubs on a semiarid degraded steppe. *Ecol Appl.* **11**, 1641–1655.

*Murchie, E. H., and P. Horton (*1998). Contrasting patterns of photosynthetic acclimation to the light environment are dependent on the differential expression of the responses to altered irradiance and spectral quality. *Plant, Cell Environ.* **21***:* 139–148.

Nobel, P. S. (1980). Morphology, nurse plant, and minimum apical temperatures for young *Carnegiea gigantea. Bot Gaz.* **141**, 188-191.

Pugnaire, F.I., C. Armas., and *F. Valladares* (2004) Soil as a mediator in plant–plant interactions in a semi-arid community. *J Veg Sci*, **15**, 85–92.

Sánchez-Coronado, M. E., R. Coates,, L. Castro-Colina., A. Gamboa de Buen., J. Páez-Valencia., V. L. Barradas., P. A.

Huante., and *A. Orozco-Segovia* (2007). Improving seed germination and seedling growth of *Omphalea oleifera* (Euphorbiaceae) for restoration projects in tropical rain forests. *Forest Ecol. Manage,* **243**, 144-155.

Sokal, R. R. and *J. H. Rholf* (1995). Biometry; the Principies and Practice of Statistics in Biological Research. W.H. Freernan, New York, 887 pp.

Sun, Y., S. Solomon., A. Dai., and *R. Portmann* (2006). How often does it rain? *J Clim*, **19**:916–934.

Tirado, R., and *F. I. Pugnaire* (2003). Shrub spatial aggregation and consequences for reproductive success. *Oecologia*, **136**, 296 –301.

Thomas, C. D., A. Cameron., R. E. Green., M. Bakkenes., L. J. Beaumont., Y. C. Collingham., F. N. Erasmus., M. Ferreira de Siqueira., A. Grainger., L. Hannah., L. Hughes., B. Huntley., A. S. van Jaarsveld,. G. F. Midgley., L. Miles., M. A. Ortega-Huerta., A. T. Peterson., O. L. Phillips and *S. E. Williams* (2004). Extinction risk from climate change. *Nature* **427**, 145-148.

Valiente-Banuet, A. and *E. Ezcurra* (1991) Shade as a cause of the association between the cactus Neobuxbaumia tetetzo and the nurse plant Mimosa luisana in the Tehuacan Valley, Mexico. *J. Ecol.* **9**, 961-971.

Van der Waal, C., H. de Kroon., W. F. de Boer., I. M. A. Heitkönig., A. K. Skidmore., H. J. de Knegt., F. van Langevelde., S. E. van Wieren., R. C. Grant., B. R. Page., R. Slotow., E. M. Kohi, E. Mwakiwa, and *H. H. T. Prins* (2009). Water and nutrients alter herbaceous competitive effects on tree seedlings in a semi-arid savanna. *J. Ecol.* **97**, 430–439.

Valladares, F., and *F. I. Puignaire* (1999). Tradeoffs between irradiance capture and avoidance in semi-arid environments assessed with a crown architecture model. *Ann Bot London* **83**, 459–469.