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ESTABLISHMENT ATTRIBUTES OF *Bouteloua curtipendula* (Michx.) Torr. POPULATIONS NATIVE TO MEXICO

ATRIBUTOS DE ESTABLECIMIENTO DE POBLACIONES DE *Bouteloua curtipendula* (Michx.) Torr. NATIVAS DE MÉXICO

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SUMMARY

Large areas of arid and semi-arid grasslands in Mexico are severely damaged. Large areas of high-risk rainfed crops have been abandoned. These problems are the result of constant overgrazing, extraction of firewood, overutilization of valuable species, fire and the practice of subsistence agriculture. The aim of this study was to measure the initial performance of the seedlings, as well as forage production and survival in the second year of nine *Bouteloua curtipendula* populations native to Mexico in comparison with El Reno, a commercial variety from the US. Plant development was visually estimated and dry matter (DM) production was estimated one year after the establishment. Survival was assessed at the end of the growing season in the following year. The experiment was carried out using a complet randomized blocks experimental design, and differences in vigor between genotypes were analyzed by a permutation test. Significant differences in DM production and plant establishment (P ≤ 0.05) were observed between genotypes. The US commercial variety was the least productive population, exhibiting less vigor during the first year than the rest of the genotypes evaluated. Large diversity in seedling establishment capacity, DM yield and survival was observed in the second year. The Mexican populations 241, NdeM-303, 47 and NdeM-5 were superior for plant establishment and DM production.

Index words: Forage production, seedling establishment, transplanting, vigor.

RESUMEN

Grandes áreas áridas y semiáridas de pastizales en México están gravemente deterioradas. Superficies extensas de cultivos de temporal de alto riesgo han sido abandonadas. Estos problemas son resultado del sobrepastoreo constante, extracción de leña, utilización excesiva de especies valiosas, incendios y la práctica de agricultura de subsistencia. El objetivo del presente estudio fue medir el desempeño inicial de plántulas, así como la producción de forraje y la supervivencia durante el segundo año de nueve poblaciones de *Bouteloua curtipendula* nativas de México, en comparación con El Reno, una variedad comercial de Estados Unidos de América. El desarrollo de la planta se estimó visualmente y se estimó la producción de materia seca (MS) un año después del establecimiento. La supervivencia se evaluó al final de la temporada de crecimiento en el año siguiente. El experimento se llevó a cabo utilizando un diseño experimental de bloques completos al azar y las diferencias en vigor entre los genotipos se analizaron mediante un ensayo de permutación. Se observaron diferencias significativas entre algunos genotipos (P ≤ 0.05) para producción de MS y establecimiento de las plantas. La variedad comercial estadounidense fue la menos productiva, exhibiendo menor vigor durante el primer año que el resto de los genotipos evaluados. Se observó elevada diversidad en la capacidad de establecimiento de plántulas, rendimiento de MS y supervivencia en el segundo año. Las poblaciones mexicanas 241, NdeM-303, 47 y NdeM-5 fueron superiores con respecto al establecimiento de las plantas y producción de MS.

Palabras clave: Producción de forraje, establecimiento de plántulas, trasplante, vigor.

INTRODUCTION

In Mexico, arid and semi-arid zones comprise 60 to 70 % of the total surface area of about 196 million hectares of the country (Challenger and Caballero, 1998). Climate and topography are the most important factors that determine the spatial and temporal patterns of vegetation in these areas, which are characterized by annual precipitation of less than 450 mm (Valentín *et al.*, 1999). Large areas of arid and semi-arid grasslands in Mexico are severely deteriorated, and many areas previously cultivated under rainfed conditions have been abandoned (Esqueda, 2014). These problems are the result of constant overgrazing, extraction of firewood, over-utilization of valuable species, fires and subsistence agriculture (Monroy-Ata *et al.*, 2007); therefore, partial replanting in 5.7 million hectares and complete replanting in 32.4 million hectares are required in Mexico (Gutiérrez and Echavarria, 2005). Replanting of open areas is an option for the reversal of desertification caused by high-risk agriculture and overgrazing; however, research is needed to identify quality forage and establishment characteristics in native materials that are beneficial for use in grassland improvement.

The successful establishment of pastures under arid conditions requires that seeds are able to germinate and

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seedlings display root elongation rates equal to or greater than the rate of water loss from the soil facing drought or weed competition; other important factors for the establishment include site characteristics, species involved, quality and selection of seeds, preparation of the soil, sowing season, sowing method, fertilization and weed control (Faría, 2005; Quero-Carrillo *et al.*, 2014). The establishment stage of a pasture is the period comprised between seed sowing and the first use (Faría, 2005), with the most critical period occurring at the beginning of the growing season (Quero-Carrillo *et al.*, 2016). Esqueda *et al.* (2005) reported a survival rate of 20 % for sideoats grama (*Bouteloua curtipendula* [Michx.] Torr.) in sandy/clay soils, but up to 40 % in clay soils. Ries y Svejcar (1991) indicated that adventitious roots must be long enough and of sufficientlarge diameter to ensure that photosynthetic area receives enough water and nutrients before seedlings are considered as established. These authors considered two stages for seedling establishment: 1) germination and emergence, followed by seedling growth, and 2) survival. The species selection, sowing time and rate, fertilization, grazing, intentional fire and herbicides as well as management options may improve seedling establishment (Cook, 1980); however, after germination, the resulting plants are very vulnerable as they are exposed to biotic factors (*e.g.* herbivores, competition, allelopathy) and abiotic factors (*e.g.* soil drying, radiation levels and inadequate temperature) that limit survival (Padilla, 2008; Quero-Carrillo *et al.*, 2014).

Re-vegetation of arid and semiarid zones is a complicated practice (Carrillo *et al.*, 2009). It is possible to obtain plant survival rates larger than 90 % by transplanting seedlings, even with precipitation as low as 50 mm after transplanting. The expected forage production of native grass species in Mexico is 800 kg of dry matter (DM) per hectare, and it reaches 2000 kg ha^{-1} for introduced grasses (Esqueda, 2003, Com. Pers.[1]).

In desert shrublands, with ditches as humidity catching devices, the establishment of alkali sacaton grass [*Sporobolus airoides* (Torr.) Torr.] has reached up to 90 % with two rain events of 25 mm after transplanting, indicating that the combination of ditches and transplanting enables re-establishment of forage production in areas where it has decreased because of both overgrazing and drought; this technology increased grassland production from 75 to 600 kg ha^{-1} (Royo *et al.*, 2003, Com. Pers.[2]).

El Reno variety was released in 1944 by the former US Soil Conservation Service. The original seed was collected close to El Reno, in Oklahoma, USA in 1934. The material is outstanding in terms of forage production and vitality. It also displays good seed production and resistance to disease and winter conditions. It is widely used and is adapted to environmental conditions in Kansas, Oklahoma and Texas (NRCS, 2011). In Mexico, it has been outstanding in comparison with 277 genotypes; however, Morales *et al.* (2009) reported that more than half of Mexican genotypes displayed a better growth performance than El Reno. The aim of this study was to measure the initial performance of seedlings, as well as forage production and second-year survival of plants of nine native Mexican genotypes in relation to an introduced commercial variety.

MATERIALS AND METHODS

Locations and site conditions

The study was conducted from 2011 to 2012, at ejido Tuitán, municipality of Nombre de Dios, Durango at 24º 01' 11" North latitude and 104º 15' 51" West longitude, and an altitude of, 1883 m a.s.l. (Figure 1). An *ejido* is a local community of common landowners. Vegetation at the site is a medium-size grassland (COTECOCA, 1979). The soil is reddish brown, of volcanic origin, sandy texture and well drained. The mean annual precipitation is 450 mm and the annual mean temperature is 18 ºC. During the first growth period, the following temperatures were observed: maximum 26 ºC; minimum 13.8 ºC; mean 19.1 ºC. The accumulated precipitation between the sowing date (July) and the date of yield sampling (September) was 354 mm.

Genotypes used and plantation management

Nine populations of sideoats grama native to Mexico were identified from the collection of genetic resources of this species (genotypes 5, 47, 62, 125, 181, 241, 303, 357, 417) (Morales *et al.*, 2009); some of those were registered as varieties in 2017 by the Mexican National Service for Seed Inspection and Certification (SNICS), preserving the original number: NdeM-5 (SNICS 1728), NdeM-303 (SNICS-1729), NdeM-417 (SNICS-1727), NdeM-125 (SNICS 1730), and El Reno variety was used as a control. Seeds were sown in trays under greenhouse conditions, they were sown in a peat moss seedbed, covered with fine vermiculite and watered daily. Twenty days after sowing, seedlings were transplanted into individual trays containing soil from the experimental area, and they were maintained in the greenhouse and watered as required. The seedlings were fertilized with triple 17 fertilizer (3 g L^{-1} of water, 0.5 L applied per tray).

[1]**Esqueda C. M. H. (2003)** Trasplante de gramíneas para la rehabilitación de pastizales degradados. Ficha de Transferencia de Tecnología. Campo Experimental La Campana, INIFAP. Aldama, Chihuahua.
[2]**Royo M. M. H., J. S. Sierra y R. Carrillo (2003)** Trasplante de zacatón alcalino en matorrales desérticos en obras de conservación de agua. Ficha de Transferencia de Tecnología. Campo Experimental La Campana, INIFAP. Aldama, Chihuahua.

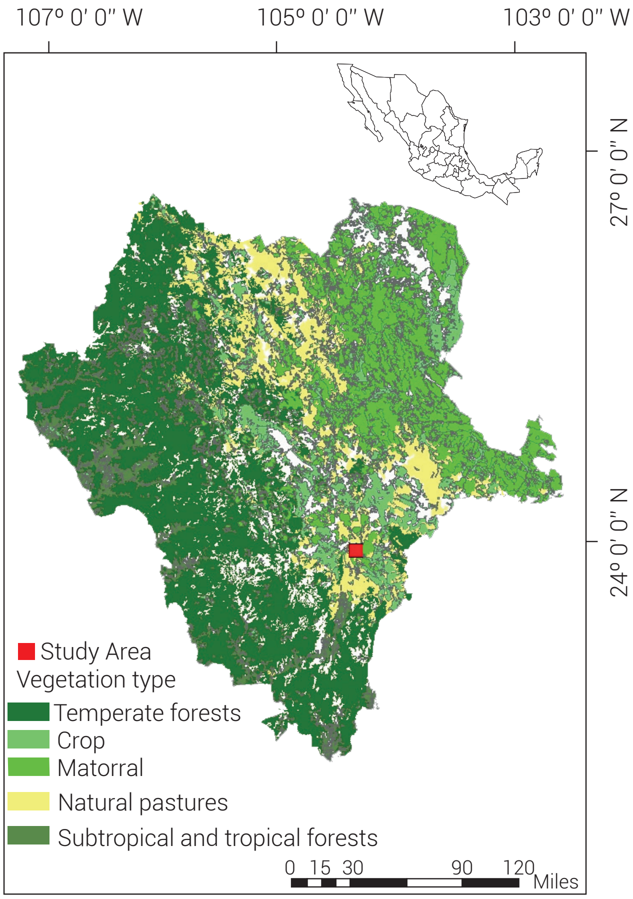

Figure 1. Location of the experimental plot planted to native sideoats grama (*Bouteloua curtipendula*) genotypes.

Fifty-six days after sowing the plants were pulled out and placed into soil previously watered to field capacity. During transportation, the plants were protected against air convection and solar radiation. The planting bed was prepared by tilling and cross-furrowing with a heavy blade to cover the soil. Plants were transplanted as follows: 1) plants were taken from the trays, with no watering for 24 hours, 2) the plants were planted in the soil with the root-crown exactly at ground level, 3) the roots were covered with soil, and 4) the soil was firmly compacted.

Under a complete randomized blocks design, three blocks were established. Each block included ten plots (corresponding to ten genotypes per block and three replications per genotype) (Figure 2). Each plot consisted of five rows containing 25 plants of the same genotype each with 80 × 50 cm of distance among rows and plants (4.4 × 12.5 m per plot). Five central plants in each plot (randomly taken) were considered as the experimental unit. The estimated initial plant density was 23,530 plants ha^{-1}.

Assesment of genotypes

Biomass production in dry matter base was estimated by cutting and weighting 15 plants of each genotype (the three plots of each experimental unit of five plants) at the end of the reproductive stage in the same year of transplantation. Forage production per hectare was calculated on the basis of 300,000 plants ha^{-1} as a pasture in good condition may contain 30 plants m^{-2} during the establishment year (Quero *et al.*, 2014).

Due to the nature of fibrous roots, growing habit in grasses and the challenging environment facing by transplants, plants were examined three times to evaluate establishment: i) 13 days after transplantation, ii) 32 days after heavy rainfall, and iii) 47 days after the first harvest.

An establishment index was determined 47 days after transplanting by two scorers who visually examined the plants by considering vigor, color and general forage morphology as characteristics of vitality. An ideal plant was considered as well nourished, with a greener color and good growth, taking into account that growth is the expression of all internal and external features and a bright green color is a reflection of nitrogen availability (Deputy, 2000).

Thus, genotype establishment was classified as follows: A) Excellent, B) Very good, C) Good and D) Regular (Olivera *et al.*, 2007). Plants evaluated as Excellent were vigorous, robust and dark green; plants that were considered as Very good had minor limitations, such as lack of vigor and a less intense green color; plants classified as Good displayed important limitations such as decreased vigor, less basal coverage and lower robustness; plants categorized as Regular, had less basal cover, less vigor and strength, and a yellowish color indicating lack of nitrogen (*i.e.* plants generally appeared weak and unhealthy) (Figure 3).

Using the three replications of the experimental unit (15 plants per genotype), the survival rate was evaluated one year after transplantation, at the end of the growing season in the following year.

Data analysis

A permutation test based on randomly chosen reassignments (Manly, 2006) was used to check whether the observed differences in the average values of establishment index, yield index and survival rate for the different genotypes, were generated solely by random events or by directed forces. This test constitutes a non-parametric approach, which enables comparison of two groups by the mean value of a variable; however, unlike the *t* test, the data do not

Block	Plots									
1	5	417	241	47	357	125	303	62	181	RENO
2	303	241	125	417	RENO	357	5	47	181	62
3	47	181	417	RENO	303	5	241	62	357	125

Figure 2. Spatial arrangement of the ten genotypes in the three blocks at the experimental site.

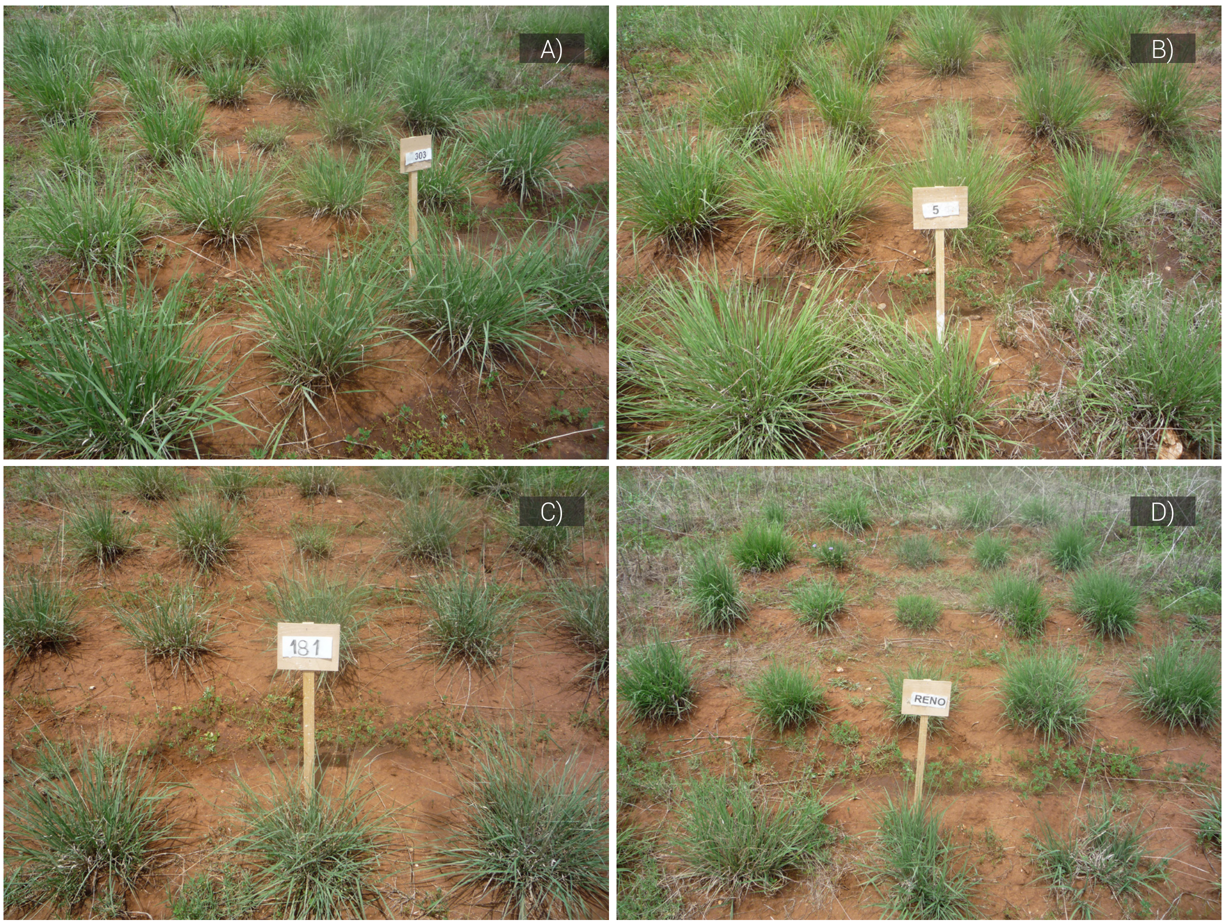

Figure 3. Establishment index of individuals of *Bouteloua curtipendula*. A) Excellent, B) Very good, C) Good and D) Regular.

need to satisfy the assumptions of normality and equality of variances.

The method essentially involves the generation of a large enough number of reassignments (permutations) of individuals of the genotypes and computing the values of the establishment index, yield and survival for each reassignment. The percentage of the estimated differences in the establishment index, yield index and survival rate (*Diff*) that are greater than or equal to the respective observed differences in the establishment index, yield and survival percentage (P (Z ≥ *Diff*)-values) was calculated. If the P (Z ≥ *Diff*) is not significant (for example P > 0.05), random differences are expected; otherwise, directed forces between two genotype expressions are declared (Wehenkel *et al.*, 2009).

RESULTS

Visual scoring of the populations indicated that establishment of NdeM-303 and population 241 was excellent (P < 0.05, Figure 4), while NdeM-125 and El Reno were poorly adapted (Table 1).

Population 241 displayed the best average in DM yield (2.48 g DM/plant), followed by population NdM-303 with 2.11 g/plant. NdeM-125 and El Reno displayed the lowest DM yields, 0.59 and 0.53 g/plant, respectively (P < 0.05, Figure 4).

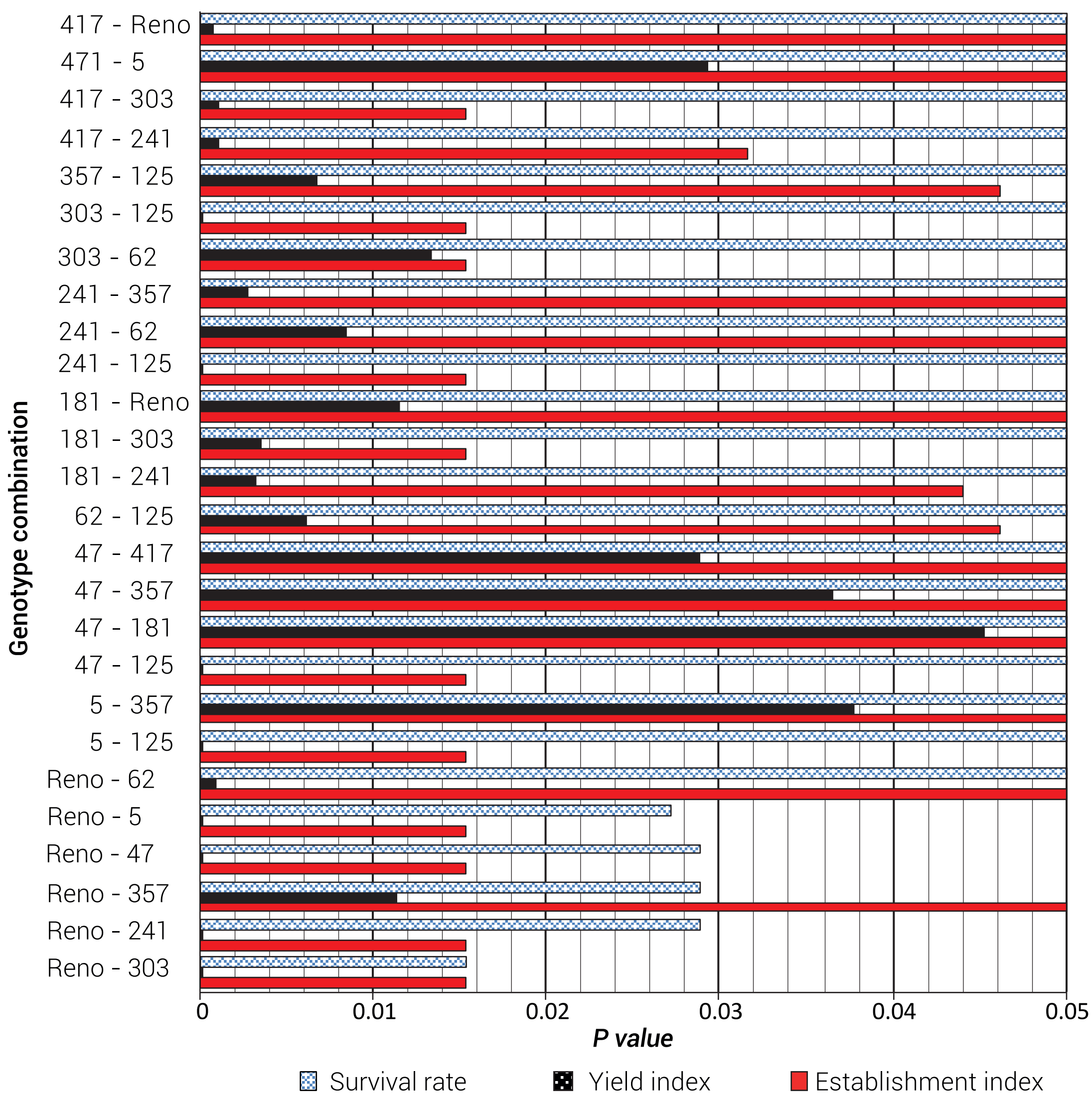

Figure 4. Probability of error (*P*(*Z* ≥ *Diff*)) that the differences in the survival rate, establishment index, and yield index between two genotypes are random (only comparisons with P ≤ 0.05 between genotypes are shown).

The survival rate of Mexican variety NdeM-303 was 100 %, whereas that of El Reno was 87 %. Populations 241, 47, NdeM-5, 62, and 357 displayed survival rates of up to 99 %, while genotypes 181, NdeM-417, and NdeM-125 displayed survival rates of 91, 95 and 97 %, respectively. Further analysis revealed that the survival of El Reno and variety NdeM-125 were significantly different from those of other populations (Figure 4). This can be corroborated by observation of the mean values of the variables (Table 1).

In six instances, population 241 differed significantly from other genotypes in establishment index, while NdeM-303 and population 47 differed from the other in five instances, and NdeM-5 differed from the other in four instances. Populations NdeM-303, NdeM-5, 47 and 241 differed significantly from the control in establishment index (P = 0.015). Populations NdeM-303, NdeM-5, 47, 241, 62 and 357 differed significantly from NdeM-125 for the same index (P ≤ 0.05). Local variety NdeM-303 was significantly different (P ≤ 0.015) from populations NdeM-417, 181, and 62. Finally, population 241 differed significantly from genotypes NdeM-417 and 181 (P ≤ 0.05) with respect to the establishment index values (Figure 4).

Regarding yield index, El Reno was registered in eight combinations with significant difference (P ≤ 0.05), except for population NdeM-125, which indicates its inferiority in yield; however, when El Reno was compared with populations NdeM-303, NdeM-5, 47, 241, NdeM-417 and 62, the differences in yield were highly significant (P ≤ 0.001). The differences in yield index between El Reno genotype and populations 357 and 181 were significant (P = 0.011 and P

Table 1. Mean values of establishment, dry matter yield index and survival in transplanted genotypes of sideoats.

Genotype	Establishment visual evaluation (1-4)†	Yield index		Survival (%)
		(g/plant)	(kg ha^{-1})	
303	1.00	2.11	633.99	100
241	1.25	2.47	743.61	99
47	1.75	1.75	526.71	99
5	1.75	1.74	522.99	99
62	2.25	1.57	427.20	99
357	2.25	1.19	359.79	99
125	3.50	0.59	177.39	97
417	2.75	1.16	349.80	95
181	2.75	1.20	361.20	91
El Reno	3.25	0.52	157.80	87

†: 1) Excellent, 2) Very good, 3) Good, 4) Regular, see the statistics in Figure 4.

= 0.012, respectively). Populations NdeM-303, NdeM-5, 47, 241 and 357 were significantly different (P ≤ 0.05) from El Reno genotype in relation to plant survival rate (Figure 4).

DISCUSSION

The observed production values were lower than 51.1 g/plant for El Reno, 1213 g/plant for population 20, and 13.7 g/plant for population 328; these values represent the mean production of three years (Morales *et al.*, 2009). The plants had relatively large root crowns and stems number per root-crown unit evaluated. Johnson and Aguayo (1973) observed a DM yield of 14 g m^2 with 14 sideoats plants after the first year of the establishment; however, all the plants were lost during the second year due to low precipitation and its inadequate distribution in the State of Sonora, Mexico. Due to the harsh conditions for seedling establishment into rain-fed semiarid rangelands, the use of transplanting is a valuable strategy to establish strategic seed sources for natural recovering of rangeland. Quero-Carrillo *et al.* (2016) reported an extremely low rate of plant establishment (0.02 %) in two localities of the Chihuahuan desert using seeds.

Population 241 yielded 743.61 kg DM ha^{-1} per year (for a plant density of 300,000 plants ha^{-1}), which is lower than the yield reported by Veneciano *et al.* (2004) of 2043 kg DM ha^{-1} for the Vaughn variety; however, the plants in the latter study were mature, fertilized and the plant density was higher than that in the present study, with no fertilizer applied. Medina *et al.* (2001) reported yields for sideoats grama of 1000 to 1500 kg DM ha^{-1} in temperate arid and semi-warm semi-arid zones of the state of Zacatecas, Mexico, depending on management and precipitation.

There are several possible reasons for the low yields observed in the present study, which may have reflected a delay in establishment in the field before sampling: weakening of the plants from changing to individual trays, stress from transplantation, damage caused by flooding, low density of planting (1/8 to 1/12 of the recommended density for grazing prairies), and such factors as age of the prairie, which determines the size of the root-crown and the number of blades per root-crown unit. A density of 300,000 individuals per hectare in the first year can be considered as excellent; however, this may decrease to 60,000, with wider root crowns three years after prairie establishment and it may be considered as an excellent plant density (Quero-Carrillo *et al.*, 2014).

The survival rates were similar to the 100 % survival reported for Vaughn sideoats plants, following a winter season in sandy soil with high permeability (Medina *et al.*, 2001). This type of soil is comparable to that of the present study area; however, the survival rates in the present study were higher than those observed in a similar study (Esqueda *et al.*, 2005), in which survival of common sideoats was 67 %. The plant survival rates observed in the present study were also higher than those observed by other authors (Carrillo *et al.*, 2009), who obtained 69 % living transplanted sideoats plants after application of a biofertilizer; without inoculation the survival rate was 40 %. In another study, García-Sánchez (2005, Com. Pers.[3]) reported 0 % survival rate of *B. curtipendula* one year after transplantation, and argued that plants were damaged by wildlife. The results of the latter study were consistent with those of another study in which 177 genotypes of sideoats were evaluated

[3]**García-Sánchez R. (2005)** Restauración de la Cubierta Vegetal de los Matorrales Semiáridos del Valle del Mezquital, Hidalgo, México. Laboratorio de Zonas Áridas, Unidad de Investigación en Ecología Vegetal. FES Zaragoza, UNAM. México.

(Morales *et al.*, 2009), including those evaluated in the present study.

CONCLUSIONS

Differences among populations were observed in regard to plant vitality, dry mass production and survival percentage in the second year after plant establishment. Varieties of *Bouteloua curtipendula* native to Mexico showed better establishment and production traits compared to the control variety from USA.

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