Investigation note

Maize genotypes with forage potential for rainfed conditions in the state of Guerrero, Mexico

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Abstract

The development of maize genotypes (*Zea mays* L.) for forage production in rainfed conditions is incipient, because no specific varieties have been disseminated for this purpose. The objective was to identify hybrids with forage potential for rainfed conditions in the state of Guerrero, Mexico. 25 maize genotypes were evaluated under rainfed conditions, under an experimental design of randomized complete blocks with three replications. The experimental unit consisted of four furrows 5 m long, 0.8 m wide between furrows, 0.17 m between plants to obtain a population density of 73 529 ha^{-1} plants. It was fertilized with the formula 120N-60P-00K. The characters studied were: plant height, cob height, plant weight, cob weight, yield of green, grain and dry fodder. The results indicated highly significant differences in the characters studied. Experimental trilinear hybrids H-H562xHCF$_2$-91, H-H565xHCF$_2$-91, H-H516xHCF$_2$-91, simple cross hybrid 329x97 and control H-564C stood out in green forage yield and single cross hybrids 1275x1277, 1278x1276, hybrids Experimental H-H516xHCF$_2$-91 and H-H565xHCF$_2$-91 expressed higher dry forage yield.

Keywords: *Zea mays* L., experimental trilinear hybrids, fodder, grain yield.

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Maize has high forage productivity, low protein content, minerals, dry matter and high energy value (Nuñez *et al*., 2015), its nutritional quality varies depending on the content of protein, fiber, digestibility and dry matter (Cabrales *et al*., 2007). The characteristics of a forage maize are: late cycle, high bearing, lax leaves, high dry matter production, and intermediate hybrids are erect leaves (Montemayor *et al*., 2007). Cuomo *et al*. (1998), reported higher yield of dry matter with 58 000 plants ha^{-1}; Reta *et al*. (2000) with 86 000 plants ha^{-1} reported 70 t ha^{-1} of green forage yield.

In this context, population density greater than 80 000 plants ha^{-1} affects grain yield and forage quality (Peña *et al*., 2010). In the state of Guerrero, farmers do not have genotypes capable of producing fodder and lack accurate information and indicators of biomass yield. Given this problem, the objective of this study was to identify genotypes with forage potential to be recommended in rainfed conditions for the Tropic of Mexico, under the hypothesis that the genotypes under study have genetic potential for forage production.

The research was carried out in two stages: 1) the seed increase of the hybrids and varieties of maize was carried out in the Experimental Fields of Cotaxtla in Veracruz, Bajio in Celaya, Guanajuato and Iguala, Guerrero state; and 2) the crossings were made in the Experimental Fields of Iguala and Guanajuato of the National Institute of Forestry, Agricultural and Livestock Research (INIFAP).

Agronomic evaluation of genetic material and experimental design

25 maize genotypes were evaluated in the spring-summer (S-S) agricultural cycle in rainfed conditions of 2016, in the Experimental Field of Iguala, Guerrero, located at the following coordinates of 18° 21’ 45’’ north latitude and 90° 30’ 05’’ west longitude, at 735 meters above sea level and climate Awo (w) g, the driest of the hottest humid ones with rain in summer, average annual temperature of 26 °C, being May the warmest month with about 44 °C, the average annual rainfall is 977.15 mm (García, 2004).

A randomized complete block design with three repetitions was used, the experimental unit consisted of four 5 m long grooves with 0.8 m wide grooves with one plant every 0.17 m, which produced a population density of 73 529 plants ha^{-1}. The sowing was established in rainfed conditions, the fertilization was with the formula 120N-60P-00K, 50% of N was applied and all the phosphorus in the sowing and the rest of the N at 45 dds. Atrazine + terbutrine was applied in pre-emergency, at a rate of 2 L ha^{-1} to control weeds, 15% G Terfubos at a dose of 7 kg ha^{-1} to control *Phyllophaga* spp. and *Agrotis lineatus*, 5% granulated permethrin at doses of one sack per hectare and monocrotophos at doses of 1 L ha^{-1} to combat *Spodoptera frugiperda Smith* and *Heliothis zea*.

Agronomic characters and statistical analysis

It was measured in cm, plant height (AP) and cob height (AMz), cob position index (IPMz), AMz/AP divided, weighed in kg, plant (PP) and cob (PMz), cob index (IMz), PMz/PP, green forage yield (RFV), grain yield (RGr) was divided, calculated using the cob weight of the useful plot x percentage of grain x moisture percentage x conversion factor to kg ha^{-1}, dry fodder yield (RFS), was carried at constant weight for thirty days, dry fodder index (IFS), RFS/RFV was divided.

In the statistical analysis of the data it included: analysis variance, comparison of means with Fisher's LSD test (with a 5% level of significance) among the measured variables. The Statistical Analysis System (SAS) version 9.0 statistical program was used.

Results Analysis of variance and comparison of means

The analysis of variance (Andeva) indicated that the mean squares of the genotype factor were highly significant ($p \leq 0.01$) in five variables, two were significant ($p \leq 0.05$) and three showed no statistical significance. In experiments conducted in the field, coefficients of variation (CV) have been reported that range from 3 to 10%, 11 to 20% and 21 to 30%, classified as low, medium and high (Pimentel, 1985).

In green forage yield they reported 6.6 to 20.8% (Baghdadi *et al*., 2012), grain yield of 12.4 to 17% (Gómez *et al*., 2008), dry forage yield of 5.06 to 23.2% (Gaytan *et al*., 2009; Peña *et al*., 2010), it has also been suggested that CV greater than 30% should be discarded (Patel *et al*., 2001). In the present investigation the CV ranged from 8.1 to 18.6%, which means that the results are consistent and reliable (Gordon and Camargo, 2015).

The average plant height (AP) was 250 cm and fluctuated from 188.6 to 275.6 cm, results similar to those reported by Shelton and Tracy (2013); Manjarrez *et al*. (2014); Gómez *et al*. (2016). Several researchers consider it important to measure plant height in maize to explore genetic diversity between plants (Nuñez *et al*., 2015).

The HV-65 interverietal hybrid showed a higher cob height (AMz); on the contrary, the synthetic variety VS-535 and the experimental hybrids H-H563xHCF$_2$-91 and H-H516xHCF$_2$-91 exhibited lower values (101, 103 and 104 cm) than the general average (122.2 cm), similar results were reported by Palemón *et al*. (2012) in interserietal maize crosses. In addition to the above, the height of the cob should be located around 92 cm so that the plant is balanced and avoid the stem or root finish due to the height and weight of the cob (Shelton and Tracy, 2013).

In this work, the relative position of the cob was low in genotypes originating in Iguala (0.46), average in Cotaxtla (0.49) and high in Celaya (0.55). The experimental hybrid H-H562XHCF$_2$-91 stood out in plant weight with 35.8 kg and the lowest weight corresponded to the VS-536 (21.8 kg). The experimental hybrids outperformed the commercial control hybrids H-520, H-563, H-516, H-562, HV-65 and the control varieties VS-535, VS-536 and V537C.

In cob weight, ten experimental hybrids matched the H-516 control that produced the highest cob weight (12.58 kg); on the contrary, the HV-65 interval hybrid showed a lower weight (2.16 kg), when contrasting the extreme values, 10.42 kg of variation was found. The commercial hybrid H-516 had a higher position of the cob (0.44), which indicates that 44% of the biomass of the plant is represented by the cob. Unlike the HV-65, it exhibited a lower cob rate (9%).

Commercial control hybrids H-520, H-564C, H-565, H-563, H-562, HV-65 and varieties VS-535, VS-536 and V-537C, were statistically surpassed by 10 experimental hybrids in cob weight.

The green forage yield (RFV) fluctuated from 29 to 46 t ha^{-1}, with an average of 38.8 t ha^{-1}. The commercial hybrid control H-564C produced higher RFV, its cob was positioned at half the height of the plant (IPMz of 0.5) and relatively lower biomass invested in the cob (IPMz of 0.28), it is notorious that it had a low index of dry fodder (6%), this result indicates that its green fodder is heavy and with a higher liquid content; however, its RFV was similar to eight experimental hybrids and commercial hybrids witness H-565 and H-563.

The experimental trilinear hybrids H-H562xHCF2-91 and H-H565xHCF2-91 produced 46 834 and 46 683, kg ha^{-1} and surpassed the commercial hybrids (H-520, H-516, H-562 and HV-65), varieties (VS-535, VS-536 and V-537) and seven experimental hybrids. The RFV of the synthetic variety VS-536 (29 083 kg ha^{-1}) with respect to the H-H562xHCF2-91 hybrid (46 834 kg ha^{-1}), 17 751 kg ha^{-1} of variation was detected at a population density of 75 000 plants ha^{-1}. Mandic *et al*. (2015) reported that with 71 429 plants ha^{-1} they obtained 67.51 t ha^{-1} green forage yield, Sharifi and Namvar (2016) recommend 110 000 plants ha^{-1} to obtain a higher RFV.

The commercial trilinear control hybrids H-563 and H-565 exhibited greater production of green fodder at a population density of 75 000 plants ha^{-1}, which have adapted to tropical climates, with a tortilla dough yield of 1.8 and 1.9 kg per 1 kg of maize (Gómez *et al*., 2013a; 2013b). The H-564C hybrid produced high RFV, good cob coverage, plant and cob health and dough and tortilla quality is good (Sierra *et al*., 2011). Eight experimental hybrids with genetic potential for green forage production were detected and competed with three commercial control hybrids (H-563, H-564C and H565).

The simple 329x97 hybrid produced higher grain yield (7 183 kg ha^{-1}) and was similar to the experimental hybrids H-H562xHCF$_2$-91 and H-H565xHCF$_2$-91 outstanding in RFV and RFS and outperformed the commercial control hybrids (H- 516, H-520, H-562, H-564C, H-565 and HV-65). The synthetic variety VS-536 and the HV-65 varietal hybrid produced lower grain yield, plant weight and cob.

Vázquez *et al*. (2013), reported that with 80 000 plants ha^{-1}, the high quality maize yield components of protein were affected. Lashkari *et al*. (2011) evaluated 70 000 to 80 000 plants ha^{-1}, increased grain yield and decreased the number of grains per row, number of grains per cob and cob length of three hybrids. Mandic *et al*. (2016) evaluated 5.6 to 7.1 plants m^{-2} and reported that grain yield increased 5.94% (790 kg) and decreased the diameter of the cob, number of rows per cob, weight of 1 000 grains, weight of cob (Safari *et al*., 2014).

Haddadi and Mohseni (2014) evaluated 75, 85, 95 and 105 thousand plants ha^{-1}, reported higher grain yield with 75 000 plants ha^{-1}. These studies indicate that forage production is tolerable at a certain level of grain loss to obtain higher yield of green forage with high densities.

The average dry forage yield (RFS) was 2.4 kg and ranged from 2 to 2.9 kg of dry matter. Commercial control hybrids H-520, H-562 and H-564C and eight experimental hybrids produced similar RFS. H-516, H563, H-565, HV-65 hybrids, varieties VS-535, VS-536 and V-537C and eight experimental hybrids were surpassed in RFS by experimental hybrids and three commercial hybrids.

The H-562 control trilinear hybrid is outstanding in grain yield, dry matter production, cob coverage and adapts in warm and semi-solid areas of the states of Tamaulipas, Yucatán, Chiapas, Guerrero and Sinaloa (Gómez *et al*., 2008) H-562 expressed a high rate of dry fodder (8%); that is, the hybrid produces fodder with lower liquid content and higher dry matter content.

Conclusions

Genotypes with acceptable green and dry forage yield were identified in a warm environment of Iguala, Guerrero. In addition to fodder, experimental hybrids with desirable grain yield and which the farmer considers of economic importance were identified. The progenitors that were used as females H-H-516, H-H-562 and H-H-565 when crossing the HCF2-91 line, generated trilinear hybrids with agronomic characteristics, outstanding grain yield and forage components. The trilinear hybrid H-H565xHCF2-91 stood out in most of the variables, it was registered with the SNICS as H-568. The H-563 control showed genetic potential in forage related characteristics. The experimental hybrid HEC-734286, had a favorable response in green, dry and grain forage yield. The hybrids generated in Celaya, Guanajuato with cooler weather responded to the town of Iguala with warmer weather. Commercial and experimental hybrids with forage characteristics were identified.

Cited literature

Baghdadi, A.; Halim, R. A.; Majidian, M.; Noordin, W. N. W. and Ahmad, I. 2012. Forage corn yield and physiological indices under different plant densities and tillage systems. J. Food. Agric. Env. 10(3-4):707-712.

Cabrales, R.; Montoya, R. y Rivera, J. 2007. Evaluación agronómica de 25 genotipos de maíz (*Zea maíz* L.) con fines forrajeros en el Valle del Sinu medio. Rev. MVZ Córdoba. 12(2):1054-1060.

Cuomo, G. J.; Redfearn, D. D. and Blouin, D. C. 1998. Plant density effects on tropical corn forage mass, morphology, and nutritive value. Agron. J. 90(1):93-96.

García, M. E. 2004. Modificaciones al sistema de clasificación climática de Köppen. Instituto Nacional de Geografía-Universidad Nacional Autónoma de México (UNAM). 246 p.

Gaytán-Bautista, R.; Martínez-Gómez, Ma. I. y Mayek-Pérez, N. 2009. Rendimiento de grano y forraje en híbridos de maíz y su generación avanzada. Rev. Mex. Cienc. Agric. 35(3):295-304.

Gómez-Montiel, N. O.; Cantú, A. M. A.; Sierra M. M.; Hernández, G. C. A.; Espinosa, C. A. y González, C. M. 2013b. Maíz híbrido H-565, nueva versión del H-507 para el trópico bajo de México. Rev. Mex. Cienc. Agric. 4(5):819-824.

Gómez-Montiel, N. O.; González-Camarillo, M.; Cantú-Almaguer, M. A.; Sierra-Macías, M.; Coutiño-Estrada, B. y Manjarrez, S. M. 2013a. H-563, híbrido de maíz tropical tolerante a la enfermedad 'Mancha de Asfalto'. Rev. Fitotec. Mex. 36(1):81-83.

Gómez-Montiel, N. O.; Palemón-Alberto, F.; Reyes-García, G.; Hernández-Galeno, C. A.; Cantú-Almaguer, M. A.; Juárez-López, P. y Ascencio-Álvarez, A. 2016. Rendimiento de grano y características fenotípicas de maíz: efecto de ambiente y dosis de fertilización. Rev. Mex. Cienc. Agric. 7(8):1801-1813.

Gómez-Montiel, N. O.; Sierra, M. M.; González, C. M.; Cantú, A. M. A.; Ramírez, F. A.; Wong, P. J. J.; Manjarrez, S. M.; Ramírez, D. J. L. y Espinosa, C. A. 2008. H-562, híbrido de maíz de alto rendimiento para el trópico húmedo y seco de México. Agric. Tec. Mex. 34(1):101-105.

Gordón-Mendoza, R. y Camargo-Buitrago, I. 2015. Selección de estadísticos para la estimación de la precisión experimental en ensayos de maíz. Agron. Mesoam. 26(1):55-63.

Haddadi, M. H. and Mohseni, M. 2014. Effect of the plant density and sowing date on kernel yield in early maturing maize. Int. J. Plant Animal Env. Sci. 4(4):170-175.

Lashkari, M.; Madani, H.; Reza-Ardakani, M.; Golzardi, F. and Zargari, K. 2011. Effect of plant density on yield and yield components of different corn (*Zea mays* L.) hybrids. Amer. Euras. J. Agric. Sci. 10(3):450-457.

Mandic, V.; Bijelic, Z.; Krnjaja, V.; Tomic, Z.; Stanojkovic-Sebic, A.; Stanojkovic, A. and Caro-Petrovic, V. 2016. The effect of crop density on maize grain yield. Biotechnology in Animal Husbandry. 32(1):83-90.

Mandic, V.; Krnjaja, V.; Bijelic, Z.; Tomic, Z.; Simic, A.; Stanojkovic, A.; Petricevic, M.; Caro-Petrovic. V. 2015. The effect of crop density on yield of forage maize. Biotechnol. Animal Husbandry. 31(4):567-575.

Manjarrez-Salgado, M.; Palemón-Alberto, F.; Gómez-Montiel, N. O.; Espinosa-Calderón, A.; Rodríguez-Herrera, S. A.; Damián-N, A.; Hernández-Castro, E. y Cruz-Lagunas, B. 2014. Aptitud combinatoria general y específica de maíces normales y de alta calidad de proteína. Rev. Mex. Cienc. Agric. 5(7):1261-1273.

Montemayor-Trejo, J. A., Olaguer-Ramírez, J.; Fortis-Hernández, M. Sam-Bravo, J. R.; Leos-Rodríguez, A.; Salazar-Sosa, E.; Castruita-López, J.; Rodríguez-Ríos, J. C. y Chavaría-Galicia, J. A. 2007. Consumo de agua en maíz forrajero con riego subsuperficial. Terra Latinoam. 25(2):163-168.

Núñez-Hernández, G.; Anaya-Salgado, A.; Faz-Contreras, R. y Serrato-Medina, H. A. 2015. Híbridos de maíz forrajero con alto potencial de producción de leche de bovino. Agrofaz. 15(1):47-56.

Palemón-Alberto, F.; Gómez-Montiel, N. O.; Castillo-González, F.; Ramírez-Vallejo, P.; Molina-Galán, J. D. y Miranda-Colín, S. 2012. Potencial productivo de cruzas intervarietales de maíz en la región semicalida de Guerrero. Rev. Mex. Cienc. Agric. 3(1):157-171.

Patel, J. K.; Patel, M. N. and Shiyani, R. L. 2001. Coefficient of variation in field experiments and yardstick thereof-an empirical study. Curr. Sci. 81(9):1163-1164.

Peña-Ramos, A.; González-Castañeda, F. y Robles-Escobedo, F. J. 2010. Manejo agronómico para incrementar el rendimiento de grano y forraje en híbridos tardíos de maíz. Rev. Mex. Cienc. Agric. 1(1):27-35.

Pimentel, F. 1985. Curso de estadística experimental. Livraria Nobel SA., São Paulo, Brasil. 240 p.

Reta-Sánchez, D. G.; Gaytán-Mascorro, A. y Carrillo-Amaya, J. S. 2000. Respuesta del maíz para ensilaje a métodos de siembra y densidades de población. Rev. Fitotec. Mex. 23(1):37-47.

Safari, A. R.; Hemayati, S. S.; Salighedar, F. and Barimavandi, A. R. 2014. Yield and quality of forage corn (*Zea mays* L.) cultivar single cross 704 in response to nitrogen fertilization and plant density. Int. J. Bioscs. 4(10):146-153.

Sharifi, S. R. and Namvar, A. 2016. Plant density and intra row spacing effects on phenology, dry matter accumulation and leaf area index of maize in second cropping. Biologija. 62(1):46-57.

Shelton, A. C. and W. F. Tracy. 2013. Genetic variation and phenotypic response of 15 sweet corn (*Zea mays* L.) hybrids to population density. Sustainability. 5(6):2442-2456.

Sierra-Macías, M.; Palafox-Caballero, A.; Rodríguez-Montalvo, F.; Espinosa-Calderón, A.; Vázquez-Carrillo, G.; Gómez-Montiel, N. O. y Barrón-Freyre, S. 2011. H-564: híbrido de maíz con alta calidad de proteína para el trópico húmedo de México. Rev. Mex. Cienc. Agric. 2(1):71-84.

Vázquez, C. M. G.; Mejía, A. H.; Salinas, M. Y. y Santiago, R. D. 2013. Efecto de la densidad de población en la calidad de grano, nixtamal y tortilla de híbridos de maíz de alta calidad proteínica. Rev. Fitotec. Mex. 36(3):225-232.