Colegio de Postgraduados

Extraction of nitrogen and distribution of dry matter in forage corn (*Zea mays* L.) in a clayey soil

Mendoza-Gómez, Alejandro[1]; **Figueroa-Viramontes, Uriel**[2]; **Ochoa-Martínez, Esmeralda**[2]; **Mendoza-Gómez, Aurelia**[3*]

[1] Universidad Autónoma Agraria Antonio Narro, Departamento de Fitomejoramiento, Buenavista, Saltillo, Coahuila, México. C.P. 25315.
[2] Instituto Nacional de Investigaciones Forestales Agrícolas y Pecuarias, Campo Experimental La Laguna, Matamoros, Coahuila.
[3] Universidad Autónoma de Baja California, Instituto de Ciencias Agrícolas, Mexicali, Baja California, México.
* Correspondence: aurelia.mendoza@uabc.edu.mx

Citation: Mendoza-Gómez, A., Figueroa-Viramontes, U., Ochoa-Martínez, E., & Mendoza-Gómez, A. (2024). Extraction of nitrogen and distribution of dry matter in forage corn (*Zea mays* L.) in a clayey soil. *Agro Productividad*. https://doi.org/10.32854/agrop.v17i11.3144

Academic Editor: Jorge Cadena Iñiguez
Associate Editor: Dra. Lucero del Mar Ruiz Posadas
Guest Editor: Daniel Alejandro Cadena Zamudio

Received: May 12, 2024.
Accepted: September 23, 2024.
Published on-line: December XX, 2024.

Agro Productividad, 17(11) supplement. November. 2024. pp: 263-268.

ABSTRACT

Objective: To analyze nitrogen extraction in forage maize (*Zea mays* L.) and its distribution in the plant's stems, leaves, ears, and husks under different fertilization rates, and to determine the total dry matter (DM) yield in the plant and in each of its organs.

Design/methodology/approach: Plots of forage maize were established to evaluate treatments with different nitrogen fertilization rates in a randomized complete block design with four replications in clay-textured soil.

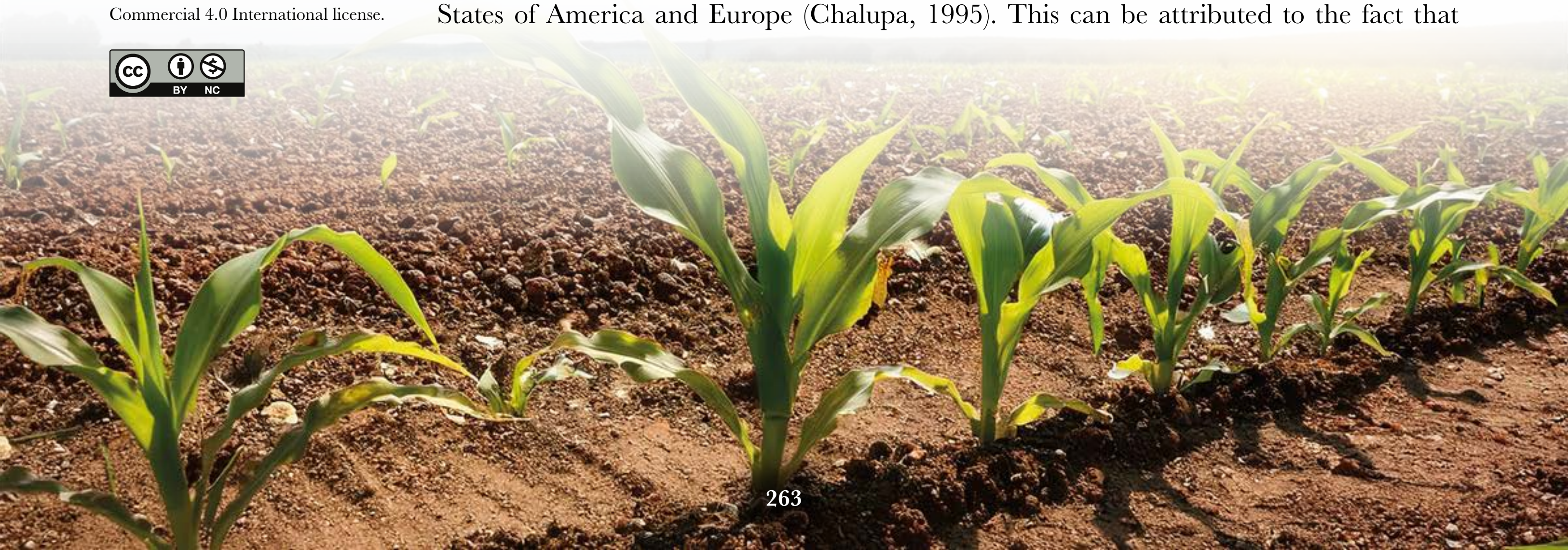
Results: The behavior of nitrogen extraction in forage maize production on clay soil was observed. No significant differences were found among the treatments. The DM yield was very low, ranging from 13.72 to 16.52 t ha^{-1}. The percentage of DM distribution was higher in the ear and lower in the husks, and the same pattern was observed for N extraction.

Findings/conclusions: The dry matter yield in forage maize was not significantly affected by the applied nitrogen rates, and the yield was very low. The percentage of dry matter in the ear did not reach the 45% that the crop should have.

Keywords: N rates, yield, plant organs.

INTRODUCTION

Maize (*Zea mays* L.) is one of the most widely used forages in the world, as it grows quickly, produces a large amount of biomass, has a good nutritional level, and adapts to a wide variety of climates and regions. In Mexico, maize silages have a low net energy value for lactation (<1.5 Mcal kg^{-1} of dry matter) compared to maize silages in the United States of America and Europe (Chalupa, 1995). This can be attributed to the fact that



in the past, the emphasis was primarily on yield per hectare in maize silage production, without considering its nutritional value, as there was no available information regarding the importance of this aspect (Núñez *et al.*, 2006). In the Comarca Lagunera, dairy farming is intensive or technified, with an intensive use of inputs and a high degree of mechanization. In milk production in the Lagunera Region, it is very important to analyze forage production as it is the nutritional support for regional livestock (Rector Plan 2001-2006). The production of forage maize is one of the most important agricultural activities in the Comarca Lagunera, as it is the second source of forages that meet the growing demand of Mexico's main dairy basin (Salazar *et al.*, 2003).

Absorption studies aim to quantify, in some way, the requirements, extraction, or consumption of nutrients by a crop to complete its production cycle. These studies quantitatively contribute to strengthening the recommended fertilization programs, as they specifically allow us to know the amount of nutrients absorbed by the crop (Bertsch F., 2003). Fertilization is an important component of forage maize production technology. Soil and plant analyses are also important tools for making appropriate decisions on what and how much to fertilize. Nitrogen is the nutrient that forage maize requires the most and is the one that most commonly limits yield. The nitrogen taken up by plants from the soil can come from fertilizers, manure, or residual nitrogen in the soil. However, when nitrogen is applied in excess, what the plant does not absorb can be lost from the soil through various processes, such as ammonium $\left(NH_4^+\right)$ volatilization and nitrate $\left(NO_3^-\right)$ leaching, which can contaminate the aquifer. The extracted nitrogen is the nitrogen removed by the crop in its above-ground parts; research has estimated that forage maize extracts an average of 14 kg of nitrogen per hectare per ton of dry matter produced (Núñez *et al.*, 2006).

The yield of a crop is determined by its ability to accumulate biomass (fresh and dry matter) in the organs designated for harvest, and a proportional increase in the biomass allocated to these organs ensures an increase in yield. Thus, the distribution of dry matter among the different organs of the plant plays a fundamental role in crop production (Peil *et al.*, 2005). Dry matter yield per hectare and digestibility are important because they largely determine the potential for milk production (Núñez *et al.*, 2003). Other studies also highlight the contribution of the nutritional characteristics of leaves and stems to the digestibility of maize hybrids. The objective of this study was to determine the total dry matter (DM) yield and its distribution in stems, leaves, ears, and husks in forage maize according to different nitrogen fertilization rates; additionally, to evaluate the total nitrogen (N) extraction in each of the plant's organs.

MATERIALS AND METHODS

The study was conducted at the La Laguna Experimental Field (CELALA, by its acronym in Spanish) of the National Institute of Forestry, Agricultural and Livestock Research (INIFAP) in Matamoros, Coahuila, located in the Comarca Lagunera, which has an average annual rainfall of 243.5 mm, an elevation of 1,355 meters above sea level, and an average annual temperature of 24 °C. In the spring-summer cycle, plots were established with forage maize to evaluate treatments with different nitrogen fertilization rates. The treatments were distributed in a completely randomized block design with four replications. The soil where the crop was established is clayey, with the properties noted in Table 1.

For the data collection of the variables, plant sampling was conducted, and the samples were divided by organs (stems, leaves, ears, and husks). The samples were dried and ground to analyze total N in the laboratory using the Kjeldahl method (Jones, 2001). Statistical analyses were performed using SAS version 9.1 (SAS Institute, 2003) with Duncan and Tukey methods. These analyses allow determining if the explanatory variables are associated with the applied N treatments, and in what way this association occurs, *i.e.*, whether the values of each dependent variable tend to increase or decrease as the N dose levels of the treatments increase. The fertilization doses were applied in fractions as described in Table 2. The sowing date was May 19, 2008, and the variety used was SB-302. The N source was ammonium sulfate (20.5% N), which was diluted in water before each application.

A pre-sowing irrigation or flood irrigation was applied to moisten the soil, ensuring good seed germination; subsequently, four supplemental irrigations were given at 23, 44, 60, and 78 days. The harvest took place on September 1 of the same year, 105 days after sowing.

RESULTS AND DISCUSSION

Researchers from the forage program at the La Laguna Experimental Field of INIFAP mention that the selection criteria for forage maize hybrids are based on the expected yields and the nutritional quality of the forage. For this reason, a practical way to select maize hybrids is that they should have a potential yield of more than 18 tons per hectare of dry matter, more than 45% ear, less than 55% neutral detergent fiber, or less than 28% acid

Table 1. Soil properties where the crop was established.

Parameter	Unit	Value
pH		8.14
Electrical conductivity	dS m^{-1}	0.42
Texture		Clayey
Sand	%	20.4
Clay	%	48.6
Nitrate	mg kg^{-1}	13.4
Ammonium	mg kg^{-1}	12.4

Table 2. N dose and percentage applied in sowing and relief irrigation.

N dose (kg/ha^{-1})	Soeing	1er Irrigation	2^{o} Irrigation	3er Irrigation
	Applied % of N rate			
70	15	85	--	--
190	15	45	40	--
310	15	40	35	10
430	15	40	35	10

detergent fiber (INIFAP, 2004). In the results obtained from the variables analyzed in this study, there were statistically no significant differences in any of the applied treatments; however, there are differences among the means of each treatment, which are explained below. The total dry matter yield varied from 13.72 to 16.52 t ha^{-1}, with the highest DM yield occurring in treatment four, showing very little difference compared to the other treatments depending on the fertilizer dose applied (Table 3).

In terms of dry matter yield by organs, we observed that the highest yield occurred in the ears, while the lowest was in the husks across all treatments. Overall, the DM yield is low, as other research conducted in the same region has reported yields ranging from 19.145 to 22.368 t ha^{-1} (Reta *et al.*, 2000). Our low yield may be attributed to the fact that planting was not done within the recommended spring date range for the Lagunera Region, which is from March 20 to April 30, as most hybrids decrease their forage production when planted late (Núñez *et al.*, 2006). Our planting date was 19 days late outside the mentioned range. In treatment three, the lowest DM yield (13.72 t ha^{-1}) was obtained, despite the nitrogen application dose being higher than that of treatments one and two. The percentage distribution of DM by organs was highest in the ears across all fertilization treatments applied (Table 4).

Regarding the total nitrogen extraction, there were no statistically significant differences in any of the treatments, nor in the amount of nitrogen extracted from each of the plant organs (Table 5).

N extractions of 7.2, 9.07, 8.25, and 9.4 kg N/ha per ton of DM were obtained in treatments 1, 2, 3, and 4, respectively. The highest N extraction occurred with the application of 430 kg N ha^{-1}, but it is still very low compared to the average N extraction that the plant should have. In treatment 3, lower N extraction was observed than in treatment 2, despite the fact that the N application rate was much higher, which suggests

Table 3. Dry matter yield obtained with the different treatments.

Dose (kg ha^{-1}) N	Dry matter yield (t ha^{-1})				
	Stem	**Leaf**	**Cob**	**Bract**	**Total**
70	4.36	2.67	5.79	1.04	13.86
190	3.88	3.07	6.14	1.37	14.46
310	4.81	2.41	5.23	1.27	13.72
430	5.12	2.79	7.26	1.35	16.52

All differences are non-significant according to the analysis of variance, Duncan and Tukey test, 0.05.

Table 4. Dry matter distribution percentage.

Dose (kg ha^{-1}) N	dry matter distribution (%)			
	Stem	**Leaf**	**Cob**	**Bract**
70	31	19	42	8
190	27	21	42	10
310	35	18	38	9
430	31	17	44	8

Table 5. Nitrogen extraction.

Dose (kg ha^{-1}) (N)	Nitrogen extraction (kg ha^{-1})				
	Stem	Leaf	Cob	Bract	Total
70	15.03	17.67	63.08	4.01	99.79
190	12.33	34.41	78.43	6.04	131.21
310	17.06	26.75	64.41	5.00	113.22
430	20.89	36.75	92.26	5.42	155.32

All differences are non-significant according to the analysis of variance, Duncan and Tukey test, 0.05.

a significant loss of N. These low N extraction may be due to the residual N content in the soil; in the 0-30 cm extract alone, there are 25.8 mg kg^{-1} of inorganic N, which is approximately equivalent to 100 kg ha^{-1}. The amount of N taken up by the plant organs was higher in the ear in all treatments, and lower in the husks.

CONCLUSIONS

The dry matter yield in forage maize was not significantly affected by the applied N doses, and the yield was very low, as in the Lagunera region, a good potential yield should exceed 18 tons per hectare of dry matter. The dry matter percentage in the ear did not reach the 45% that the crop should have. The fertilizer doses had no statistically significant influence on the distribution of dry matter in the plant organs. Similarly, there were no statistically significant differences in nitrogen extraction across any of the treatments analyzed. Average extractions of 7.2, 9.07, 8.25, and 9.4 kg N/ha per ton of dry matter were obtained in treatments 1, 2, 3, and 4, respectively. These values are very low compared to the average nitrogen extraction that forage maize should achieve.

REFERENCES

Bertsch Hernández, Floria. (2003). Absorción de nutrimentos por los cultivos. 1ª ed. San José, Costa Rica. ACCS. p. 6.

Chalupa, W. (1995). Requerimientos de forrajes de vacas lecheras. Primer ciclo internacional de conferencias sobre nutrición y manejo. Gómez Palacio, Durango. LALA. p. 19-28.

INIFAP (2004). Alternativas para el maíz forrajero. El Siglo de Torreón. Consultado en 2009. http://www.elsiglodetorreon.com.mx/noticia/79582.alternativas-para-el-maiz-forrajero-agropecua.html

Jones, J.B. (2001). Laboratory guide for conducting soil tests and plant analysis. CRC Press. New York.

Núñez, H.G., González, C.F., Faz, C.R. y Figueroa, V.U. (2006). Fertilización de maíz forrajero. En: Tecnología de producción de maíz forrajero. Folleto Técnico Num. 13. Campo Experimental La Laguna. INIFAP. p. 10-13.

Núñez H.G., Faz C.G. y Faz C.R. (2003). Características agronómicas y químicas importantes en híbridos de maíz para forraje con alto valor energético. *Técnica Pecuaria en México. Vol. 41* Núm. 1 p. 37-48.

Núñez, H.G., González, C.F., Faz, C.R. y Figueroa, V.U. (2006). Fechas de siembra recomendadas. En: Tecnología de producción de maíz forrajero. Folleto Técnico Num. 13. Campo Experimental la Laguna. INIFAP. p. 8.

Núñez, H.G., Peña, R.A., González, C.F. y Faz, C.R. (2006). Características de híbridos de maíz de alto rendimiento y calidad nutricional de forraje. En: maíz forrajero de alto rendimiento y calidad nutricional. Libro Científico No. 3. Campo Experimental La Laguna. INIFAP. p. 45.

Peil, M.R., Galvez, L.J. (2005). Reparto de materia seca como factor determinante de la producción de las hortalizas de fruto cultivadas en invernadero. R bras. *Agrociencia, v.11*, n. 1, p. 05-11.

Plan Rector del Sistema Producto Bovino-Leche (2001-2006). p. 4, 6 y 8.

Reta S.D.G., Cueto W.J.A., Gaytán M.A. y Santamaría C.J. (2000). Rendimiento y extracción de nitrógeno, fósforo y potasio de maíz forrajero en surcos estrechos. *Agricultura Técnica en México Vol. 33* Núm. 2 Mayo-Agosto 2007 p. 145-151.

Salazar, S.E., Beltrán, M.A., Fortis, H.M. (2003). Mineralización de nitrógeno en el suelo y producción de maíz forrajero con tres sistemas de labranza. *TERRA Latinoamericana, Vol. 21*, Núm 4, octubre-diciembre 2003, p.569-575.

SAS Institute. (2003). SAS/STATuser's guide. Release 9.1 ed. SAS Inst., Cary, NC.