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MEASUREMENTS OF INDEX OF GREENERY RELATED TO FOLIAR AREA AND CORN HYBRID PRODUCTIVITY

Mediciones de índices de verdor relacionadas con área foliar y productividad de híbrido de maíz

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ABSTRACT. In human and animal feeding, maize (*Zea mays* L.) is one of the most used, also in the production of biofuel, hence its importance at world level. Nitrogen (N) leaf and chlorophyll contents are positively correlated. This reflects the nutritional status of this important nutrient. For this reason, the goal was to measure the greenery index at different physiological times using the portable Minolta® SPAD 502 chlorophyll meter (fast and non-destructive method) and to relate it to the leaf area index and the productivity of a corn hybrid. The factors under study were related to innovative technological aspects for the cultivation: two fertilizer formulas incorporated in bands parallel to the planting line and three evaluation moments. The variables evaluated were: chlorophyll index, leaf area index and yield. It was found that the indices of greenery and leaf area did not show significant differences with the fertilizer formulations used and it was established in relation to the measurements of greenery index at the beginning of flowering and the production of corn grain at 125 days after emergence (DAE). The innovative contributions allowed to project a training system or social actors, contributing to be more effective the decision making in the productive process.

Key words: chlorophyll, fertilization, incorporated, leaf area index, yield

RESUMEN. En la alimentación humana y animal, el cultivo de maíz (*Zea mays* L.) es de los más utilizados, igualmente en la producción de biocombustible, de ahí su importancia a nivel mundial. El contenido de Nitrógeno (N) foliar y el contenido de clorofila están positivamente correlacionadas. Lo cual refleja el estado nutricional respecto a este importante nutriente. Por esta razón se planteó como objetivo, medir en diferentes momentos fisiológicos el índice de verdor empleando el medidor portátil de clorofila Minolta® SPAD 502 (método rápido y no destructivo) y relacionarlo con el índice de área foliar y la productividad de un hibrido de maíz. Los factores en estudio estuvieron relacionados con aspectos tecnológicos innovadores para el cultivo: dos fórmulas de fertilizantes incorporados en bandas paralelo a la línea de siembra y tres momentos de evaluación. Las variables evaluadas fueron: índice de clorofila, índice de área foliar y rendimiento. Se encontró que los índices de verdor y área foliar no mostraron diferencias significativas con las formulaciones de fertilizantes empleadas y se estableció relación con las mediciones de índice de verdor a inicios de floración y la producción de grano de maíz a los 125 días después de emergido (DDE). Los aportes novedosos permitieron proyectar un sistema de capacitación o los actores sociales, contribuyendo a ser más efectiva la toma de decisiones en el proceso productivo.

Palabras clave: clorofila, fertilización, incorporado, índice de área foliar, rendimiento

INTRODUCTION

Currently, in the process of human and animal feeding, and in the production of ethanol, the cultivation of corn (*Zea mays* L.) is one of the most used, hence its value worldwide.

In Colombia, the cultivation of corn is of great economic importance. It is sown under different environmental conditions of temperature, humidity, rainfall regime, luminosity and soils. The department of Tolima-Colombia sells approximately 23,450 hectares per year of corn for grain production with average yields of 6 t ha^{-1} in technified white maize; being day by day a growing crop in the sowing area and that as a productive system, among the total of its production

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costs, it directs most part (31 %) to the nutritional segment of soil fertilizers (1).

The average yield of corn in Colombia is lower than that observed in other countries, in experimental fields and areas with greater use of technology. Therefore, it is imperative to increase productivity levels to meet the demand for this cereal.

One of the alternatives to increase grain yield is to perform a balanced nutritional program (2). The demands of economic sustainability and production of minimum environmental impacts that currently condition agricultural activity require that the application of mineral fertilizers be calculated and applied with the maximum scientific and technical rigor (3). Nitrogen (N) is the nutrient absorbed in larger quantities by corn and as a result, it is very sensitive to this nutrient, with increases in several characteristics that influence the final production.

The N applied to the soil is subject to loss by leaching, runoff, denitrification, volatilization of ammonia and by immobilization of the microbial biomass (4).

Generally, the nutritional status of the plants is evaluated by chemical analysis of the plant tissue (leaf) and, normally, in its interpretation, critical concentrations or concentration ranges are used. However, these methods have certain limitations due to the time of execution and high cost, which does not allow the rapid correction of nutritional deficiencies (4).

Alternative diagnostic methods to assess the nutritional status of plants, involve the evaluation of biological indicators and the nitrogen status of plants, in real time and in the field itself, using, among others, the index of greenery through of portable chlorophyll meter or Minolta® SPAD 502 (Soil Plant Analysis Development). This equipment allows to indirectly and non-destructively evaluating the chlorophyll content in the leaf by means of the light transmitted through the leaf at 650 and 940 nm (5). It also serves as an auxiliary technique in decision making about nitrogen fertilization, because chlorophyll, pigment that gives the green color of the leaves and it is responsible for absorbing the light necessary to perform photosynthetic activity, has been positively correlated with the N content in the plant. This pigment reflects the nitrogenous condition of the crop (6).

One of the main objectives of crop management is to take advantage of most of the available solar radiation, since it is the source of energy used for the production of dry matter, through photosynthesis (7). The leaf area index (LAI) is a numerical expression that allows estimating the photosynthetic capacity of plants and helps to understand the relationships between biomass accumulation and yield under prevailing environmental conditions of a given region (8).

It is important to adopt systems that allow being efficient in the use of good agronomic practices; Therefore, in the present experimental work, the objective is to measure the green index at different times and relate it to the leaf area index and the productivity of a corn hybrid based on the Greening Index, the idea is to make decisions to correct nutritional deficiencies that arise. This can be done with the application of edaphic fertilizer products or foliar nutrition.

MATERIALS AND METHODS

The experiment was conducted during the months of October 2014 to March 2015 in the Espinal municipality, department of Tolima in Colombia. Located at 4 ° 07'19.37 "N -74 ° 49'40.02" W, with an altitude of 297 m a.s.l, average temperature of 28 °C, average annual rainfall of 1745 mm and relative humidity of 69 %. The soils are from flat to slightly flat topography, with slopes of 0-3 and 3-7 % respectively, mechanized, moderately deep, and well drained, of low fertility and sandy loam texture (9). Prior to sowing and before any fertilization, a soil sample was taken using a drill hole at a depth of 0 to 0,2 m (after 0,2 m, a compacted layer was found).

Eight subsamples were extracted that represented the conditions of the land and together they determined the sample that was sent to the laboratory to evaluate some chemical properties (CE: Electrical Conductivity, CO: Organic Carbon, S: Sulfur, P: Phosphorus, Na: Sodium; K: Potassium, Ca: Calcium, Mg: Magnesium, CICE: Effective Cationic Exchange Capacity, Cu: Copper, Zn: Zinc, Fe: Iron, Mn: Manganese, B: Boron). The experimental area had availability of water for irrigation, for this reason three irrigation by gravity was performed to supply the water needs of the crop (in V10, V13 and in milky grains) maintaining field capacity of the soil. In this area, corn is planted in rotation with rice cultivation.

In the experiment, an experimental randomized block design with three replications was used, with a bifactorial treatment arrangement. The factors under study were two doses of nutrients: 140 $kgha^{-1}$ of Ureic Nitrogen (Urea), 50 kg ha^{-1} of Phosphorus as P_2O_5 and 100 kg ha^{-1} of Potassium as K_2O (fertilization management average farmers of the area from exchange with them), and 175 kg ha^{-1} of Ureic Nitrogen (Urea), 70 kg ha^{-1} of Phosphorus as P_2O_5 and 140 $kgha^{-1}$ of Potassium as K_2O (fertilization suggested by the distributing brand of seeded seed).

Three evaluation moments were carried out: in V5 (five true leaves) average 16 DAE (days after emergence), in V10 (ten true leaves) average 32 DAE and at 52 DAE (beginning of male flowering). The variables evaluated were: green leaf index using SPAD-502, Konica Minolta, Tokyo, Japan[A]. To determine the concentration of chlorophyll in the foliar leaf of the corn, measurements were made in 20 plants per treatment at the three established moments and the average data was obtained. The readings were made in the middle third of the plant, in the leaf 11 and in the middle of the leaf, where the highest chlorophyll contents are found (5).

The leaf area evaluations (cm^2) were carried out according to Montgomery (10), using the formula (leaf length (cm) x leaf width (cm) x 0,75 (correction coefficient for corn)), evaluating the same leaves and moments as the Greenness Index, the performance. The production per parcel was estimated in kg and was carried out at ha^{-1}, evaluating yield variables such as: prolificacy (number of cobs per plant), number of rows per cob, number of kernels per 125 DAE (harvest date). cob, average grain mass. All the factors studied were evaluated in 20 plants randomly, located in the central furrows of each treatment plot. The results obtained from the evaluations at similar phenological moments, were processed statistically through a double classification analysis of variance and the means were applied Duncan's multiple range test (11) in case of significant differences between treatments and simple regression analyzes were performed using STATGRAPHICS® Plus version 5.1 (12).

The fertilizers in all cases were incorporated in bands parallel to the sowing line, using a fertilizer machine that incorporates the fertilizer. They were carried out in three moments: in V0 (to the sowing), in V4 (four true leaves average 13 DDE) and V8 (eight true leaves average 26 DDE).

At planting, 100 % of P was applied, N and K were divided equally (33.33 %) for the three fertilizations. Each experimental unit (treatment) consisted of 72 m^2, with eight rows of planting at 0,8 m distance between rows and 10 m in length. The harvest per plot was made with a density of five plants per linear meter, for a total treatment of 400 plants. The sowing of the corn hybrid (*Zea mays* L.) white P4082WHR was carried out. The treatments were represented as explained in Table I.

Table I. Treatments proposed in three localities to measure greenness indices related to the productivity of a corn hybrid (*Zea mays* L.)

Treatments	Description
T1	Fertilization 140 kg ha^{-1} N, 50 kg ha^{-1} P and 100 kg ha^{-1} K with fertilizer incorporated in all fertilizations (In the sowing (20 % N, 100 % P, 10 % K), in V4 (40 % N, 50 % K) y en V8 (40 % N, 40 % K)).
T2	Fertilization 175 kg ha^{-1} N, 70 kg ha^{-1} P and 140 kg ha^{-1} K with fertilizer incorporated in all fertilizations (In the sowing (20 % N, 100 % P, 10 % K), en V4 (40 % N, 50 % K) and in V8 (40 % N, 40 % K)).

RESULTS

With the analysis of the soil sample, it was determined that in general the initial contribution to the crop by assimilable nutrients of the soil is minimal. The low content of Organic Carbon (0,52 %), Organic Matter (0,9 %) and clays (19 %), reflects the low capacity of cation exchange and aggregate content that define an inadequate structure in the soil, in addition to low fertility which makes it even more necessary to apply fertilizers to increase agricultural productivity, this is further motivated by the intensive use of soil with the rotation of rice, corn (Table II).

[A] La mención de marcas comerciales de los equipos, instrumentos o materiales específicos obedece únicamente a propósitos de identificación, no existiendo ningún compromiso promocional con el (los) autor(es).

Table II. Result physical-chemical analysis of the soil in the experimental area. Before sowing and before any fertilization

Texture			D. Ap.	C. E.	Ph	C.o	S	P	Bases of change				Cice	Minor elements				
									Na	K	Ca	Mg		Cu	Zn	Fe	Mn	B
% A	% L	% Ar	Gr cc^{-1}	uS cm^{-1}		%	Mg kg^{-1}		Cmol kg^{-1}					Mg kg^{-1}				
66	15	19						1,7	0,3	0,32	4,67	1,37	7	0,61	0,38	53	33	0,28
Sandy loam			1,21	229,5	6	0,52	14	Solubles										
								1,7	0,25	0,2	2,12	0,65				0,25		

A: Sand; L: Silt; Ar: Clay; D. Ap.: Apparent Density; C.E .: Electrical Conductivity; C.O .: Organic Carbon; S: Sulfur; P: Phosphorus; Na: Sodium; K: Potassium; Ca: Calcium; Mg: Magnesium; CICE: Effective Cationic Exchange Capacity; Cu: Copper; Zn: Zinc; Faith: Iron; Mn: Manganese; B: Boron

No interaction was found between the fertilizer formulas and the evaluation moments. The results of the greenery index and foliar area are not influenced by the two fertilizer formulas used, showing no significant differences (Table III).

The greenness index at 16 and 32 DAE did not present significant differences, in corn there was little variation in the two seasons. However, the readings made at the beginning of flowering were higher than the other values showing significant differences (Table IV).

The doses140 kg ha^{-1} N, 50 kg ha^{-1} P, 100 kg ha^{-1} K and 175 kg ha^{-1} N, 70 kg ha^{-1} P, 140 kg ha^{-1} K in terms of grain yield did not show significant differences in crop productivity (Table V).

Table III. Influence of fertilizer doses on foliar area and greenery indexes at the start of male flowering (52 DAE)

Dose	$\bar{X}$ Leaf area index (cm)	$\bar{X}$ Green index (SPAD units)
140 kg ha^{-1} N, 50 kg ha^{-1} P and 100 kg ha^{-1} K	739,20	58,31
175 kg ha^{-1} N, 70 kg ha^{-1} P and 140 kgha^{-1} K	742,38	58,65
S$\bar{X}$	4,08 NS	0,11 NS

Table IV. Influence of the different moments of evaluation on the Green Index

Period of evaluation	$\bar{X}$ Green index (SPAD units)
V5 (16 days after emergence (DAE))	49,55 a
V10 (32DAE)	50,98 a
Start of male flowering (52DAE)	58,47 b
S$\bar{X}$	0,88 *

Different letters differ by 1% probability according to Duncan

Table V. Influence of fertilizer doses on corn yields for grain

Dose of fertilizers	$\bar{X}$ Yield t ha^{-1}
140 kg ha^{-1} N, 50 kg ha^{-1} P and 100 kg ha^{-1} K	6,40
175 kg ha^{-1} N, 70 kg ha^{-1} P and 140 kg ha^{-1} K	6,66
S$\bar{X}$	1,48 NS

DISCUSSION

The increase of the levels of chemical fertilization does not show significant differences in production. The technique of incorporating the fertilizer, constitutes an important strategy for the efficient and rational use of the agricultural resources, generates less environmental impacts and improves the characteristics of the crop (3).

The readings of the greenery and leaf area indexes do not show significant differences with the two fertilizer formulas used, which differs with another study that maintains that different applications of mineral fertilizers in the corn crop modify agronomic characteristics between them, the foliar area (13).

The values of greener index found at the beginning of flowering (higher than 50 SPAD units) determine an adequate chlorophyll value for a good yield of corn grain. As a critical value for corn, 35,3 SPAD units are reported (14). This indicates a good availability of N has been found that between 20 and 60 % of the total N of the grain is translocated before the anthesis possibly from the reserves of the stem and mature leaves mainly, where it is stored, and then be used in times of grain filling (15). The N is associated with the chloroplasts responsible for the green color of the leaf and responsible for absorbing the light necessary to perform photosynthetic activity and the N concentration in the leaf indicates the nutritional status of the plant. This is based on the fact that leaves are the organs of the plant that respond most rapidly to changes in the supply of nutrients from soil and fertilizers (16).

A ratio measurements greenness index was established in maize plants at the beginning of flowering and the production of corn grain at 125 DAE, yielding the highest yield from the plants that reported the highest SPAD units. The measurement results of the greenery index are consistent with the nutritional status of corn plants. The greenery index provides increased production, the leaves have a better leaf area index (LAI), gradually covering an available area, gradually increasing the plant's capacity to take advantage of solar energy (17).

Based on the results obtained, to express their yield potential, the corn requires a balanced program of chemical fertilization and be accompanied by good agricultural work during the development of the crop. Therefore, hybrids express greater genetic potential through grain yield (7).

Based on the results achieved, three workshops were held with the social actors involved, based on exhibitions where emphasis was placed on the achievement of the objectives set, which in synthesis constitute proposals for technological innovation.

CONCLUSIONS

- No differences were detected between the measurements of greenery indexes and leaf area using the formulations 140 kg ha^{-1} N, 50 kg ha^{-1} P, 100 kg ha^{-1} K and 175 kg ha^{-1} N, 70 kg ha^{-1} P, 140 kg ha^{-1} K. With the agricultural practice of incorporating the fertilizer in parallel bands to the sowing line, the yield of the grain did not show significant differences in the productivity of the crop.
- As an agricultural practice, the evaluations of greenness index of the plants, in real time, in a non-destructive way and in the field itself, are an alternative diagnostic method that serves as an auxiliary technique in the decision making about fertilization.
- The index of greenery is related to the yield and the foliar area, from this result, it is suggested to make other trials where differences in the analyzed variables are achieved and thus arrive at equations that estimate the performance related to the index of greenery and the foliar area.

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