Article

Plastic padding for the production of corn (*Zea mays* L.) forage in the Comarca Lagunera

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Abstract

In the Comarca Lagunera that includes part of the states of Coahuila and Durango, Mexico. The main dairy basin of the country is located. Therefore, the establishment of forage crops exerts the greatest pressure for the exploitation of water resources in this region. The above, generates the constant need to adapt and modify the current production systems. The objective of this research was to evaluate the production of fodder maize through the use of quilted plastics in a belt irrigation system. Three colors of quilting were evaluated: white, silver, black and as a control the soil without quilting in a block design with arrangement in strips. The work was developed in the small property Esmeralda in the municipality of Gomez Palacio, Durango. In the spring-summer cycle of 2012. The variables evaluated were: plant height, stem diameter, diameter and length of corn, fresh and dry weight of the plant and leaf area index (IAF). The results obtained show that there was no significant difference ($p \leq 0.05$) between the colors of padding for the production of dry matter, but there was difference with respect to the soil without quilting. An IAF growth model was obtained as a function of the days after sowing quadratic type $Y_{ca}= -0.002x^2 + 0.294x -5.8183$, $R^2= 0.97$ para acolchado and $Y_{sa}= -0.0017x^2 + 0.259x -5.503$, $R^2= 0.94$ without quilting and a dry matter production model based on the IAF linear type $Y_{ca}= 86.295x -110.84$, $R^2= 0.92$ and $Y_{sa}= 65.761x -55.764$, $R^2= 0.91$ both for the system with and without padding. It is concluded that the use of plastic mulches for the production of fodder maize increased the yields up to 25% more with respect to the system without quilting.

Keywords: plastic covers, leaf area index, production models.

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Introduction

The plastic films for quilting in agriculture, constitute the second application in importance after greenhouses. The world surface under this modality is 4 530 000 ha, with countries such as China with 2 000 000 ha, Japan with 150 000 ha, France and Spain with 100 000 ha each. In Latin America this application has been developed mainly in Central America and Mexico, surpassing the latter 9 000 ha. Its importance is very varied and consists of: increase and quality of production, precocity in the harvest, greater efficiency in the use of water, increase in soil temperature and control of weeds among others (Feng *et al*., 1999; Munguía *et al*., 2003; Kasirajan and Ngouajio, 2012).

The techniques to modify the microclimate in crops such as plastic mulch favor greater profitability (Rodríguez *et al*., 2000). They prevent the development of weeds by not allowing the photosynthetic light to pass through and they allow saving the water that they could consume, from the thermal point of view the padding behaves like a double effect filter, which accumulates heat in the soil during the day and leaves part of it during the night, this prevents or reduces the risk of frost due to low temperatures (Robledo and Martín, 1988). In Mexico, over-exploitation of aquifers and low water productivity of only 1.6 kg of dry matter per cubic meter of water applied at the district level (CONAGUA, 2010) and the low availability of water observed in some dams in the country in recent years, make urgent the establishment of strategies to make a rational and efficient use of this resource.

In the Comarca Lagunera that includes part of the states of Coahuila and Durango, the main dairy basin of the country is located; It is estimated that there is a cattle operation of 248 812 heads, with a daily demand of 3 732 tons of dry matter (El Siglo de Torreon, 2013). To satisfy these needs are established mainly the crops of alfalfa (*Medicago sativa* L.), corn (*Zea mays* L.) and sorghum (*Sorghum vulgare* H.) these are established in the spring-summer cycle and oats (*Avena sativa*), mixtures of clover (*Trifolium pratenese* L.) and triticale (X. Triticosecale Wittmack) as winter fodder. The main factors that reduce the productivity and profitability of the agricultural production systems are: the limitation and high cost of irrigation water, the degradation of soils due to salinity problems and the low diversity of crops.

This causes problems of commercialization, increase of pests and diseases (Santamarina *et al*., 2006). The forage maize in the Comarca Lagunera for the Spring-Summer cycle of 2012 represented an area of 33 215 ha and its average yield was 46 697 kg ha^{-1} (El siglo de Torreon 2013). However, this crop has been shown to have a potential of 70 000 kg ha^{-1} of green forage (Montemayor *et al*., 2007). The above has been achieved by incorporating new technologies derived from plastics such as sub-surface drip irrigation. The objective of the present investigation was to evaluate the effect of plastic mulch with different colors in the production of fodder maize, in a belt-type drip irrigation system.

Materials and methods

The Comarca Lagunera comprises part of the states of Coahuila and Durango, Mexico. It is located between the meridians 101° 41’ to 104° 61’ west longitude and between the parallels 24° 22’ and 26° 23’ north latitude, it has an area of 47 887 km^2 with an average altitude of 1 100 meters above sea level, with a mountainous extension and a flat surface where the agricultural area is located. Its climate is dry desert, with rain in summer and cool winter, the average annual rainfall is 258 mm and the annual average evaporation is 2 000 mm, for which the precipitation-evaporation ratio is 1:10; The average annual temperature is 21 °C with maximum of 33.7 °C and minimum 7.5 °C. The period of low temperatures or frosts of crops are presented from November to march, although in some cases they occur early in October and late in April (García, 1973).

The investigation was carried out during the Spring-Summer cycle of 2012, in the small property Esmeralda located in the municipality of Gomez Palacio, Durango. The texture of the soil is sandy loam with a moisture retention capacity of 0.2 cm^3 cm^{-3}. Planting was carried out in dry soil during the first days of May of the year, this was done manually with the Pioneer 30A60 hybrid, this hybrid is classified as intermediate cycle with a cut-off duration of 100 to 110 days for the production of forage.

Prior to sowing, plastic mulch was established on seed beds separated by 1.5 m, an irrigation tape was installed for each bed at an expense of 3 liters per hour per linear meter. The irrigation sheet applied throughout the crop cycle was 50 cm. The configuration of the sowing was of two rows of plants per each bed with a separation of 50 cm between rows and 13 cm between plants, the estimated population was 101 508 plants ha^{-1}. The plastic was perforated at the time of sowing and one seed was placed for each hole made. The padding evaluated was white, silver and black padding.

The soil without quilting was considered as a witness. The experimental design was in complete blocks with arrangement in strips and four repetitions. The response variables were: plant height (cm), stem diameter (mm), diameter and length of corn, fresh and dry weight of the plant and leaf area index (IAF), the variables of fresh and dry weight were measured in weekly form and the procedure was to take four plants of each experimental unit to obtain the fresh weight and later by drying in an oven, obtain the weight of dry matter.

Plant height, stem diameter, diameter and length of corn were measured 98 days after sowing (DDS). The leaf area index was measured every week during the period from 25 to 98 DDS, the readings were taken with the LAI 2000 Plant Canopy Analyzer (LI-COR, Inc. Lincoln, Nebraska, EE. UU). The behavior model of the leaf area index based on the days after sowing and the dry matter production model as a function of the IAF were obtained using the simple linear regression method.

Results and discussion

Production of dry matter, height of plant, diameter of stem, length and weight of cob

The dry matter produced by plant was greater in the systems of quilting with respect to the system without quilting, in the silver colored plastic the greater weight was obtained, followed by the black and later the white. However, no statistical difference was found between the different colors of the plastic padding. The difference in dry matter produced between the silver-colored mulch *vs* non-quilted plants was 89 g, equivalent to 25.7%. Easson and Fearnehough (2000) found an 18.3%

increase in dry matter when comparing a non-quilted and non-quilted corn cultivar; they conclude that in plastic mulch 15% less heat units were required to reach the pollination stage and 33% more heat units were available from pollination to harvest. Zhang *et al.* (2011) report increases of 8 to 24% in plastic mulch systems vs. traditional corn handling. Bakhiar *et al*. (2009) indicates that the mulches affected all the studied parameters such as plant height, leaf area index among others.

In the height of the plant (Table 1) no statistical differences were obtained between the colors of the quilting plastics. However, there is a trend of higher plant height in the white plastic, followed by the color silver and then the color black. The plant was on average 0.4 m higher in mulch systems compared to non-quilted plants. In the stem diameter the highest value was in the white color, followed by the color silver and later the black color, although in the latter there were no statistical differences. The maximum difference between white and non-quilted quilting was 0.33 cm which corresponds to 13.4% of larger diameter in the plants produced with white quilting. In the length and diameter of the ear, no statistical differences were detected. However, the highest values of ear weight were found in the padding. Kwabiah (2004) mentions that plastic mulches improve the phenological characteristics of corn and found an increase in production of 8 to 17%.

Table 1. Comparison of dry matter, height of plant, diameter of stem and diameter, length and weight of cob.

Treatment padded	Dry matter (g plant^{-1})	Plant height (m)	Stem diameter (cm)	Cob diameter (cm)	Cob length (cm)	Cob weight (g)
White	291 ab	2.9 a	2.45 ab	5.25 a	18.2 a	138 a
Silver	346 a	2.8 a	2.32 b	5.05 a	16.7 a	114 a
Black	323 ab	2.7 a	2.3 b	4.8 a	15.7 a	114 a
Without padded	257 b	2.4 b	2.12 c	4.82 a	18.2 a	111 a
√CME	38.3	0.1	0.07	0.31	1.95	18

Values with the same letter are statistically equal, Tukey< test 0.05; CME= mean square of the error.

Leaf area index

The Figure 1 shows the behavior of the leaf area index with respect to the days after sowing, the models found in both production systems were of the second order polynomial type, that is, a linear effect and later a quadratic effect. Jean-Claude *et al.* (2013) mentions that IAF has a typical behavior, this starts with a slow growth, followed by a rapid growth (vegetative stage), until reaching a maximum value and later decreases by the senescence of the leaves, and because the crop reaches maturity physiological. Similar behaviors are reported by Guevara *et al*. (2005); Montemayor *et al*. (2012).

In both production systems, the highest of IAF coincides with the stage of flowering of the crop, the estimated values of IAF were five for padding and four for the system without quilting. A good estimate of the IAF is important to estimate the interception of light by cultivation, transpiration and biomass accumulation; therefore, it has a great influence on the growth and production of the crop (Birch *et al*., 1988; Setiyono *et al*., 2007). Guevara *et al.* (2005) reports maximum IAF values of five for separate lines at 1.1 m and six for separate lines at 0.4 m at a planting density of 133 000 seeds ha^{-1}. Andrew and Shashi (2009) report maximum IAF values of 4.9 to 6.4 for a maize under irrigation conditions with an average evapotranspiration of 548 mm over a five-year study period.

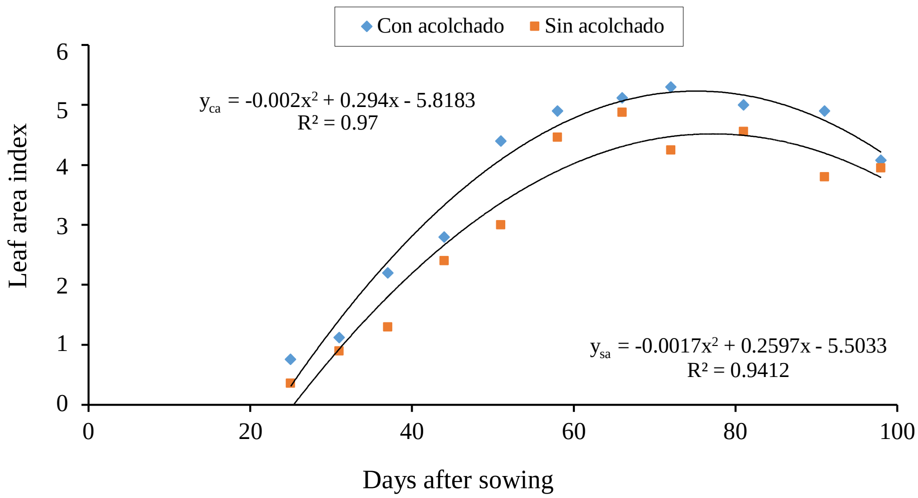

Figure 1. Behavior of the leaf area index with respect to the days after sowing of the forage maize grown with and without plastic mulch.

In dry conditions the same authors report a maximum IAF of 3.1 to 4.4 with an evapotranspiration of 482 mm. Giaveno *et al*. (2002) reports IAF values of 4.4 to 5.5 for irrigated and fertilized maize and values below three under rainfed conditions. In the model found in the quilting system it has a daily linear growth of IAF of 0.294, while without quilting this value is 0.259, which represents 12% less growth with respect to the quilting system. Montemayor *et al*. (2012) found values of 0.251, 0.155 and 0.106 for irrigated maize with sub surface irrigation, central pivot and gravity.

It concludes that the decrease in the IAF is mainly due to a greater hydric stress in the plant, this induces a lower transpiration of the crop, less CO_2 absorption and reduction in the photosynthesis process; The above, is reflected in the phenological variables of the crop such as: plant height, dry matter weight and stem diameter.

Dry matter production and leaf area index

The Figure 2 shows the relationship between the IAF and the production of dry matter in the quilting system and without quilting. The models found were linear with coefficients of determination (R^2) of 0.92 and 0.91 respectively. Reta *et al.* (2007) evaluated separations between rows of maize in two years and found linear models of dry matter production as a function of the IAF with R^2= 0.86 and 0.79 respectively, it concludes that the increase in dry matter is due to the higher index of leaf area develops in the early stages of cultivation. Zhang *et al.* (2011) indicates that a higher leaf area index provided a larger accumulation of biomass and consequently higher grain production (7 251 kg ha^{-1}) and an efficiency of water use of 2.41 kg m^{-3}.

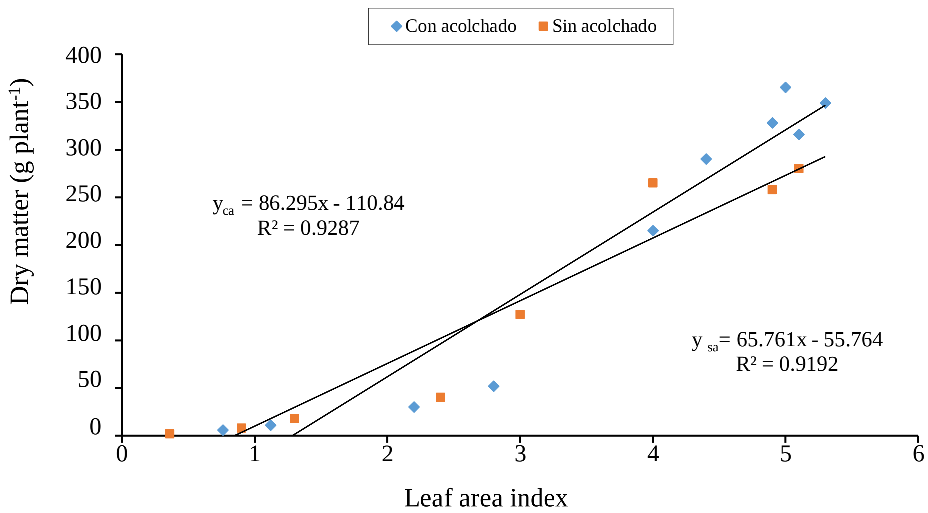

Figure 2. Production of dry matter based on the leaf area index of the forage maize grown with and without padding.

Adekayode and Olojugba (2010) report a correlation of 0.97 in grain production and leaf area index, mention that the IAF and the leaf distribution angle are important parameters for estimating the exchange of energy and gases in the canopies of the crop. The distribution and quantity of leaf area as well as the angle of the leaves are factors that control light interception within the maize canopy (Elings, 2000; Stewart *et al.*, 2003). Subedi and Ma (2005) reported that by removing all the leaves found in the lower part of the ear leaf after the anthesis, it reduced grain production from 17 to 25%.

The slope obtained in the models of the IAF and the dry matter produced by the plant was 86.29 g plant IAF^{-1} in the system of padding and 65.76 g plant IAF^{-1} in the system without quilting. The above represents an increase of 23.8% of dry matter produced in the quilting system with respect to the system without quilting. Renquist and Martin (1982) point out that, with polyethylene mulch during the summer, one third of the water is required compared to that needed when it is grown without padding, they conclude that padding improves the efficiency of water use and expresses in a higher fruit yield, this because of the better conservation of soil moisture and indirectly by the higher recorded soil temperatures. Zribi *et al.* (2011) indicates that the plastic mulch favors the structural stability and fertility of the soil, reduces the salinization of the soil that manifests itself in a greater production of dry matter.

Conclusions

No statistical differences were found in the production of dry matter between the quilting colors. However, the highest production was obtained in silver plastic, followed by black and then white. The use of plastic mulches to produce fodder maize increased the yields up to 25% more with respect to the system without quilting. The growth of the leaf area index as a function of the days after sowing was described by a linear quadratic model and the production of matter as a function of leaf area index was described by a linear model.

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