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RESEARCH ARTICLE

Impact of pre-sowing red laser irradiation of corn seeds on quality and quantity of harvest yield

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ABSTRACT

As the population increases, more people need to be fed. In order to find a physical method that influence the corn production, this work is dedicated to evaluating the impact of pre-sowing red laser irradiation of corn (*Zea mays L.*) seeds on harvest yield. The aim was to analyze the influence of red laser radiation on corn seeds, on the quantity and quality of yield, on large-scale and open field production. It is hypothesized that at least one red laser irradiation treatment could improve corn crop yield. In radiation, a red laser diode at 660 nm with a power of 100 mW was used, two radiation densities were used (D1: 2 mW cm^{-2} and D2: 4 mW cm^{-2}), applied during 4 exposure times (T1: 15, T2: 30, T3: 60 and T4: 120 s) and a control group without treatment (C). A random arrangement was used, in a 2 x 4 factorial scheme, totaling 8 treatments and control, with four replications. The data were subjected to an ANOVA and the means were compared with the Tukey test (HSD; $p \leq 0.05$). The D2-T4 treatment produced the most significant impact concerning the control, improving yield by 19±1% (3 t ha^{-1}), cob length 18±1%, cob diameter 22±3%, weight (16±2%) and corn kernels size (14±2%). We also find negative effects on yield, D2-T1 decreased crop yield around 16±1% (2.24 t ha^{-1}). The results show a way to include this technique as a technique that can to increase or decrease corn yield.

Keywords: Cob length; Maize; open field; Thousand kernel weight.

INTRODUCTION

Maize (*Zea mays L.)* is one of the most cultivated cereals in the world and has a high economic and nutritional value (Ai and Jane, 2016). In 2021 the area planted with maize in the world was 201,983,645 hectares, with a world production of 1,162,352,997 tons (FAO-STAT, 2021). Corn is a staple food in many regions of the world and is essential in the industrial area as it is used as a feedstock for the production of biofuels, chemical compounds, pseudo-plastics, and other materials (García-Lara et al., 2019).

Applying physical methods such as laser radiation is an option to improve seed activity and yield (Mohammadi et al., 2012). Physical methods have gained popularity as they are environmentally friendly (Krawiec et al., 2018; Qi et al., 2000). The interaction mechanism between light and seed continues to be the subject of research (Zhao et al., 2022). Some authors attribute the effect of laser treatments on seeds to the fact that low-intensity red laser irradiation can signal phytochrome (Swathy et al., 2021). Phytochrome can regulate morphogenesis, comprising all light-dependent processes involved in plant growth and development (Balcerowicz et al., 2021; Hughes, 2013; Jiao et al., 2007; Quail, 2002; Van Buskirk et al., 2012).

Pre-sowing laser irradiation on seeds, is a technique that can influence the different stages of the plant such as germination, plant growth and development, tolerance to abiotic stress and resistance to diseases (Ali et al., 2020; AlSalhi et al., 2019; Podleśna et al., 2015; Prośba-Białczyk et al., 2013; Thorat et al., 2021). The use of laser irradiation treatments by controlled doses, allows to analyze the effects of different treatments. Laser radiation treatments allow to precisely control the dose of radiation applied and replicate the treatment as many times as necessary. The objective of this research was to evaluate the impact of pre-sowing red laser radiation in corn seeds on harvest yield and the size of cobs and corn kernels.

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MATERIALS AND METHODS

The experiment was conducted in an agricultural field in Sinaloa, Sinaloa, Mexico (25°43'04.4"N 108°39'39.7"W), from August 2020 to May 2021.

Seed lot details

The seeds used were hybrid maize (DK-4050).

Experimental arrangement

The experiment was developed with a random complete block design of 1,000 m^2 (100 m x 10 m) with four repetitions. They were planted in open ground with a population density of 8-9 plants per linear meter and separated between furrows of 75 cm (Fig.1).

Laser radiation process

A laser diode with a power of 100 mW and a wavelength of 660 nanometers continuous mode was used. We tested 8 laser treatments resulting from two surface power densities in the irradiation plane (2 and 4 mW cm^{-2}), and four laser radiation exposure times (15, 30, 60 and 120 s). Laser radiation densities were checked before each treatment with an Ophir power meter model 7Z01560 made in Israel. Laser treatments were applied according to Rivera-Talamantes et al. (2022).

Agronomic management

The crop was developed in open field, as land preparation, a disc plow was applied, then a vertical Tillage followed by another disc plow, then the land was paired with a blade scraper, after that the furrows were marked at 76 cm of distance. The land then received a fertilization preparation based on 300 kg ha-1 of UREA, 100 kg ha-1 of Phosphorus and 100 kg ha-1of ammonium sulfate. After the fertilization period it was irrigated by flood irrigation with a pipe of 1.5 inches in diameter. Nineteen days after finishing the irrigation, the sown take place, planting was carried out with a population of 8-9 plants per meter. Subsequently, CULTIPAK equipment was used to destroy the clods that could obstruct the emergence of corn seedlings. Cultivation was carried out 30 days after planting. For the control of fall armyworm (*Helicoverpa armigera*), 35 days after planting CLAVIS 0.25 liters per hectare was applied (per spray).

Irrigation was applied by 1 ½ in pipe through an irrigation waterway. One irrigation was applied after the land preparation (before of planting), to create conditions that favor germination. After planting (during the crop cycle), three aid irrigations were applied (Table 1). The amount of irrigation was carried out based on the crop's water needs.

During the experiment the following indicators were determined

The production of one hundred linear meter of corn furrow were randomly sampled for the following analysis, with four repetitions.

- Yield of corn produced (t ha^{-1}).

One hundred cobs were randomly sampled for the following analysis, with four repetitions.

- Cob characteristics length and, width (the width measure take care in the middle of the cob).
- Weight of a thousand grains (g).
- Average size of a thousand grains (cm^2).

On corn kernels size calculate, image capture and processing was implemented (Tu et al., 2018). In the capture an EPSON V850 Pro scanner was used, the grains were placed on the scanning area accompanied by a graduated reference object, then the images were captured. For image processing, the IMAGEN J software was used.

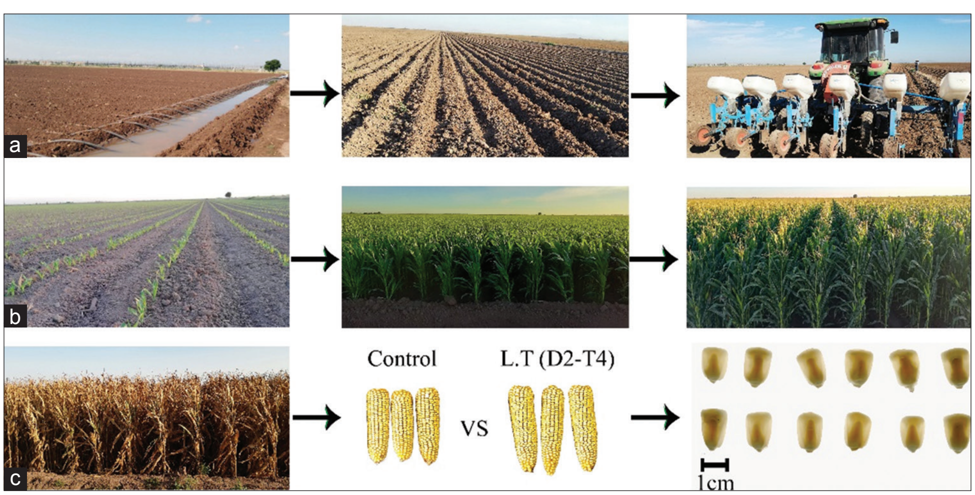

Fig 1. Stages of crop. a) Land preparation and sowing (irrigation, soil preparation and planting). b) Cultivation stages (stage of emergence, stage of growth, flowering). c) Harvest stage (harvested cobs, grain analysis).

Statistical analysis

The experimental design was randomized with 4 replicates per treatment, the following data were statistically analyzed using STATISTICA software, and tests of significant differences ANOVA and Tukey HSD were applied. Significance levels were indicated. There is statistical significance (*P <0.05), there is strong statistical significance (**P<0.01), there is very strong statistical significance (***P <0.001).

RESULTS

Laser radiation treatments were analyzed on the overall yield of their crop, the cobs size, and grains size. Statistical analysis showed significant differences between the different treatments

Crop yield

The effects of laser treatments on crop yield are shown in Fig.2. Pre-sowing laser irradiation during 120 s at 4 mW cm^{-2} significantly increased the yield of the maize crop by 19±1%, increased production by 3 t ha^{-1}. On the other hand, treatment during 15 s at 4 mW cm^{-2} significantly decreased crop yield by 16±1%, reducing production by 2.24 t ha^{-1} (Fig. 2-a).

Table 1: Irrigation dates

Type of irrigation	Date	Days after planting
Pre-sowing	October 16-2021	20 before
1st aid	January 4-2020	60
2nd aid	February 3-2020	90
3rd aid	March 25-2020	140

Cob size analysis

The analysis of cob size reveals that pre-sowing red laser radiation can improve some of the physical properties of the cob. In the cob size, the pre-sowing laser irradiation during 120 s at 4 mW cm^{-2} increased 3.7 cm (18±0.8%) in length and 1.3 cm (22±3%) in width (Fig. 2-b, c), this treatment generates the best results in cobs size. On the other hand, the treatment during 15 s at 4 W cm^{-2} generated a negative effect on the cob size, the width decreased by 10±2% (P<0.001).

The number of kernels rows of each cob was analyzed Fig. 2-d. Pre-sowing laser irradiation during 120 s at 4 mW cm^{-2}, increased by 11±1.5% (P<0. 001) the kernels rows of the cobs concerning to the control group.

Analysis of a thousand corn kernels

The effects of pre-sowing laser treatments on the characteristics of corn kernels are analyzed in Fig. 3. Laser irradiation during 120 s at 4 mW cm^{-2}, increased the mass of the corn kernels by 16%±2, also improved grain size by 14%±2, this treatment recorded the most significant results in grain quality improvement.

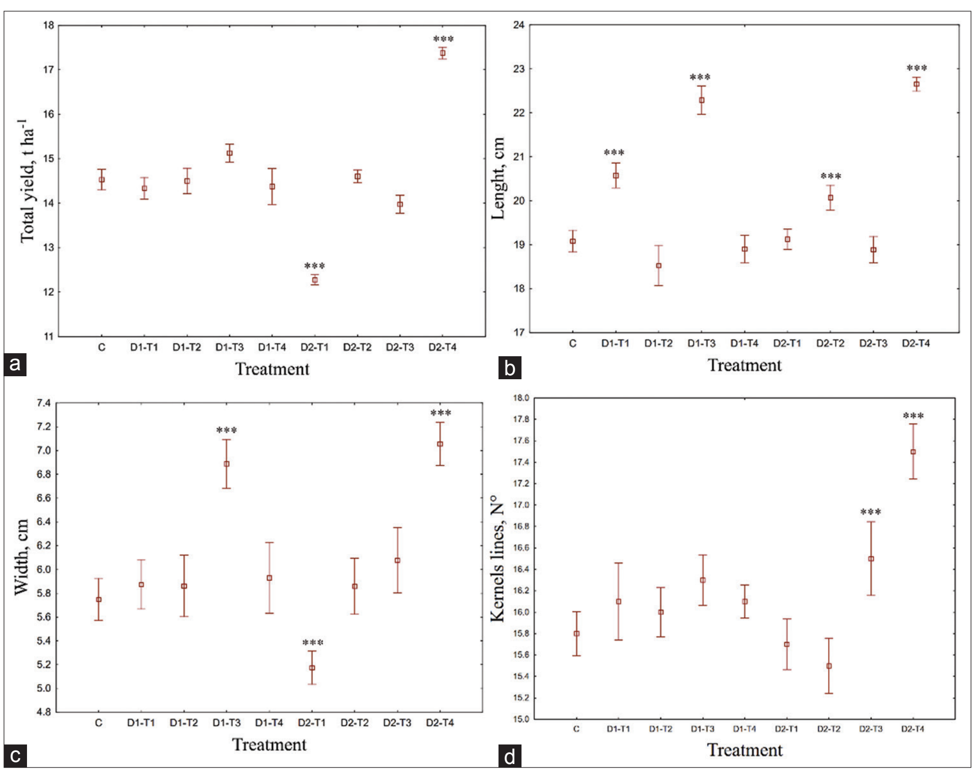

Fig 2. Maize crop yield and Cob characteristics: a) Crop yield t ha^{-1} b) Length, c) Width, d) Corn kernels lines. C: control, D1: 2 mW cm^{-2}, D2: 4 mW cm^{-2}; T1: 15 s, T2: 30 s, T3: 60 s, T4: 120 s, (Mean value ± SD). ***: P<0.001.

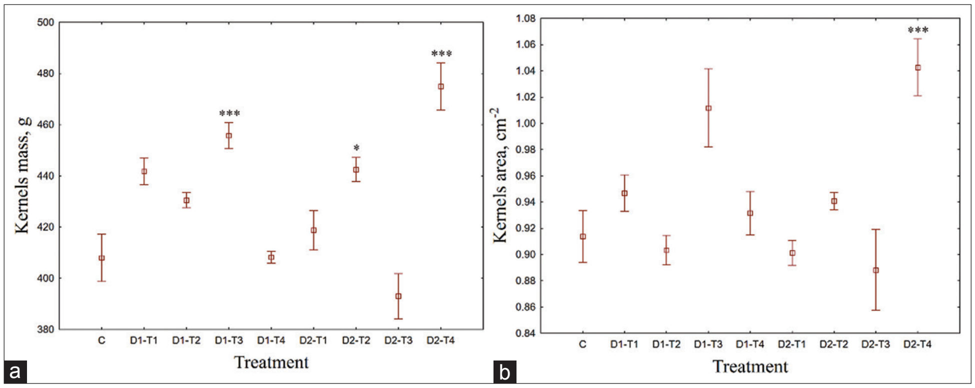

Fig 3. Characteristics of a thousand corn kernels. a) Mass, b) Area. C: control, D1: 2 mW cm^{-2}, D2: 4 mW cm^{-2}; T1: 15 s, T2: 30 s, T3: 60 s, T4: 120 s, (Mean values ± SD). *: P<0.05, ***: P<0.001.

DISCUSSION

In this research, we evaluated the effects of pre-sowing red laser treatments on corn seeds' cultivation in the open field as an additional tool for improving crop yield. Our analyses revealed that it is possible to increase or decrease the yield of the maize crop, including cob size and grain quality. Our evidence suggests that the effect will depend on the treatment applied.

During the development of a plant, the quality of incident light is essential, since light is the main source of energy for photosynthesis and photomorphogenesis, and directly affects the growth and functionality of plants (Li et al., 2021). According to (Paucek et al., 2020), adding red LED light during tomato crop development can increase overall crop productivity. Flores et al. (2021), demonstrated that with red and far-red wavelengths was beneficial for growing endive (*Cichorium endivia*) and lettuce *(Lactuca sativa*) plants by increasing fresh and dry weights compared to the white light spectrum.

Current research indicates that red light treatments on pre-sowing seeds could improve the establishment of a crop. (Samiya et al., 2020), investigated the effects of diode laser irradiation on wheat seeds, and red laser treatment showed significant effects for germination and growth parameters, such as number of roots, number of shoots, percentage of germination, length of shoots, root length, dry and fresh weight.

Some authors attribute the effect to the photosensitivity of the phytochrome present in seeds, that in response to red laser radiation improves the development and performance of plants (Chen et al., 2005; Mardani Korrani et al., 2023; Mathews, 2006). Notwithstanding the recent scientific advances in this area, the precise mechanism on how laser light influences seeds is not yet fully explained.

Our results show that pre-sowing red laser radiation influenced different important parameters of the maize crop yield. The treatment during 120 s at 4 mWcm^{-2} increased the crop yield by 19±1% concerning the control and was the treatment with the best positive results. This treatment increased the physical characteristics of the cobs, on length by 18±0.8% and on width by 22±3%. These results correlate with some research, (Dziwulska-Hunek et al., 2020), found that pre-sowing red light on corn seeds increase the length of corn cobs and consequently increased the mass produced. Similarly, (Hasan et al., 2020), used three types of laser radiation, red (632.8 nm), green (532 nm) and blue (410 nm), in corn cultivation, and found that laser treatment of seeds generates a positive impact on the growth and development of corn plants. There is evidence that He-Ne laser irradiation of scorzonera (*Scorzonera hispanica L*) seeds, generates a positive effect on germination capacity, emergence and on root yield (Krawiec et al., 2016).

Corn kernel size is a feature that could be representative for commercial use. Khan et al. (2005), studied the effect of corn seed size on their crop and found that larger corn seeds improved emergence by m^2, plant height, number of plants by m^2 and lowered mortality percentage. The weight of a thousand grains is closely related to the size of the grain (Swanston, 2011).

This research showed that it is possible to improve the size and weight of a thousand corn grains. The analysis and processing of the images revealed that, laser radiation during 120 s at 4mWcm^{-2}, increased the corn kernel size by 14±2%, and improved the mass of the grains by 16±2%, concerning the control.

On the other hand, our results show that it is possible to generate a significant deterioration in the vigor of the seeds, with short exposure times (15 s) and low radiation densities (4 mW cm^{-2}). Our results can be compared with the results of (Aladjadjiyan, 2012), they used a laser of He-Ne 663.8 nm, at a radiation density of 176 W m^{-2} in carrot seeds (*Daucus carrota L.,* cv. Nantes), they found that with an exposure time greater than 5 minutes probably it introduces too much energy into the cell and, instead of stimulation, leads to inhibition of plant growth. In contrast our exposure time was a short time, which does lead to hypothesizing, it could be a bad phytochrome signaling, that consequently affects the yield of the crop. Sun et al. (2020), on crop rice (*Oryza sativa*) found that, phytochrome (OsmiR530) overexpression significantly decreases grain size and panicle branching, leading to yield loss.

According to (Sacała et al., 2012), the effects of pre-sowing laser stimulation are revealed at all stages of plant development but are especially evident in the early stages of plant development. One way to facilitate the selection of an optimal treatment could be, perform an analysis of the effect of laser radiation during the initial plants development and expect that the effect correlates at the harvest yield.

CONCLUSIONS

This study demonstrated that pre-sowing red laser radiation treatments on corn seeds have the potential to influence the corn crop yield in open fields and on large scale, the effect will correspond to the treatment that is applied, it can increase or decrease the yield of the crop. The increase in crop yield correlated with a significant improvement in the physical characteristics of the cobs and grains, improving the size of the cobs (length and width), the grain produced (size and mass of grain), and the rows of cob kernels, registering the best results for the treatment for 120 s to 4 $mWcm^{-2}$. Nevertheless, the treatment during 15 s to 4 $mWcm^{-2}$ significantly decreased the yield of the crop, this leads us to emphasize that it is possible to decrease the yield of the corn crop by pre-sowing red laser treatments. The results show a path that can include pre-sowing laser radiation treatments in corn seeds as a technique for improving the corn crop, with an accentuation in the correct selection of the treatment to be applied.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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Author Contributions

Carlos Rivera Talamantes conceived and designed the experiments; Carlos Rivera Talamantes, Gabriela González López carried out the experiments; Carlos Rivera Talamantes, Juan Carlos Suarez analyzed the data; Carlos Rivera Talamantes, Alexandre Michtchenko and Gabriela Gonzalez Lopez wrote the article.

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