Effects of laser irradiation, organic fertilizer, and adjuvant on corn and cucumber yield.

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Abstract

Laser technologies are not usually associated with farming. This experiment is intended to encourage farmers and producers to try this technology if it can be supported with valid experimental results. Effects of Organic Path fertilizer, adjuvant, and laser irradiation of seed on growth of pepper, cucumber, and corn will be assessed. Treatments are hypothesized to increase the number of fruits, crop biomass and yield.

Objectives

Primary hypothesis: Laser irradiation of seeds increases yield and biomass of corn, cucumber and pepper.

Secondary hypotheses: Laser treatment is more effective when combined with fertilizer and adjuvant application.

Introduction

Laser radiation provides a source of coherent photons, representing an energy input that can have biological effects (Hernandez et al., 2010). The physics of energy distribution inside a crop seed is under-studied. Physical effects culminate in biological effects.

Laser technology could offer a promising alternative to chemical methods of crop improvement. Laser treatments can include pre-sowing seed treatment to stimulate growth, increase germination rate, and improve disease resistance. Laser treatments can be used in conjunction with other agricultural practices at minimal cost.

Light in the visible red region of the spectrum with a wavelength of 632-694 nm is part of the energy of the solar spectrum, which is captured by plant photoreceptors called phytochromes (Hernandez et al., 2010). The light energy captured by phytochromes is converted into chemical energy inside a plant and is used for biological processes (Hernandez et al., 2010). Excitation of these photoreceptors speeds up biological responses in plants (Karu, 1989). Laser radiation as a source of coherent photons causes energy pumping in biological objects (Karu, 1989). In addition to red wavelengths, green and blue wavelengths can also have biological effects. A recent study by Hasan et al. (2020) compared effects of blue, red and green lasers on corn. All of the lasers improved yield, but the blue laser gave the greatest improvement (Hasan et al., 2020).

Wilde et al. (1969) were among the first to research laser technology in agriculture. They found that laser irradiation increased germination rate and plant growth (Wilde et al., 1969). Mitchenko et al. (2008) tested effects of a semiconductor laser on cucumber and wheat seeds, resulting in an increase in germination rate and growth. A similar study was conducted by Mosneaga et al. (2009), who tested laser irradiation on germination rates of beans, corn and wheat. Laser treated crops had a 100% germination rate, compared to 80% in the control group. They found that the germination is faster and growth is more vigorous in lasered varieties than in non-lasered ones (Mosneaga et al., 2009). Shaban et al. (1988) reported that laser irradiation of cucumber seeds positively affects photosynthesis rate and root growth.

Some studies have shown positive associations between laser treatment and plant stress and pathogen resistance. Beans grown from seed treated with He-Ne or CO_2 laser beams had greater resistance to UV-B radiation (Qi et al., 2000).

Laser biostimulation can also have negative results. Yamazaki et al. (2002) tested effects of red laser treatment on rice grown under blue light. The number of spikes decreased by 36% and the total yield was reduced by 60% (Yamazaki et al., 2002). The authors suggested that their technology was not properly optimized before germination trials (Yamazaki et al., 2002). This is one of very few studies with negative results. Most experiments show positive plant responses to laser stimulation.

This remains a relatively under-explored field in agriculture. It is full of grey areas, making it difficult to estimate applicability of existing research. I have chosen the most relevant studies to compare with my own experiment.

I am captivated by the idea of implementing new technologies that have tremendous potential in sustainable agriculture. As the human population keeps growing, it is becoming more and more challenging to sustainably produce food in sufficient quantities. Laser technology in agriculture could help produce larger amount of produce without harming the environment. Increased yields could reduce global food prices and food scarcity. The only known drawback of laser technology is its energy consumption. It could be implemented in association with renewable sources of energy, such as hydro or solar power, to reduce negative environmental impacts.

The main focus of this experiment is not only to test the effects of laser irradiation on crop seeds, but also assess if the effectiveness of such exposure is increased by adding organic fertilizer compounds.

The fertilizer treatment consists of 2 different fertilizers provided by Organic Path Company. "Q-Energy" provides essential nutrients and minerals for plants, while "Q-Algy" supposed to provide the stress resistance, stabilization of hormonal and nutritional balance. The adjuvant compound that was applied with fertilizers is the test product of Organic Path Company. It was assumed that it would increase bioavailability of fertilizer compounds and affect results positively.

The results of this research could interest different groups. Research institutions can use the data for further research, to complement other studies and further develop laser technologies. That could create potential for investments. Food-producing corporations and farmers are potential users of laser technology, and any positive results obtained by this study may encourage them to try this new technology. Implementation by companies and farmers on a global scale could shift world food production.

If application of laser technology brings positive results and people can see its potential then people's perception of "efficient" agriculture may change.

"*You never change things by fighting the existing reality. To change something build a new model that makes the existing model obsolete*." – R. Buckminster Fuller.

Methods

Germination pre-trials

Germination pre-trials were conducted on various crops to identify the optimal laser treatment exposure time for germination. Seeds that are laser treated for the optimal amount of time were chosen for this study.

Sweet corn (*Zea mays* cv. 'Top Hat'), cucumber (*Cucumis sativus* cv. 'Tender Green'), and bell pepper (*Capsicum annuum* 'Rainbow Mix') seeds exposed to laser irradiation for 0, 15, 30, 60 or 120 s were planted in potting soil in plug trays in a greenhouse on 28 May, 2020 (Table 1).

Table 1. Germination trial planting density, replicates, and total seeds per crop.

Crop	Cells/tray	Density (Plants/m²)	Seeds/plot	Replicates	Seeds
Corn	72	518	24	5	600
Cucumber	36	259	4	10	200
Pepper	72	518	24	4	480

Seedlings were treated with foliar fertilizer (Q Algy, Q Energy and adjuvant, each at 3 ml/l, Organic Path, Vancouver, BC), their height and survival rate was recorded on 12 June, 2020.

Bell pepper seeds failed to germinate due to bad batch, so it was decided to test only corn and cucumber plants in this experiment. No statistically significant differences were observed between the treatments (0, 15, 30, 60 or 120 s) in both corn and cucumbers. It was decided to choose the laser exposure with numerically best results that were observed in 15 s treatment for cucumber and 120 s for corn.

Field Study

This study was conducted at Garden City Lands in Richmond, B.C., Canada, in partnership with Kwantlen Polytechnic University and Organic Path Company.

A full-factorial randomized complete block design used in this experiment was conducted to test three independent factors, such as crop (10 corn or three cucumber per plot, transplanted 13 June, 2020), laser pre-treatment (none or 15 and 120 s for corn and cucumber, respectively) and fertilizer (none or weekly foliar applications with or without adjuvant) (Table 3).

The 2 x 2 x 3 factorial structure gives 12 treatments replicated twice in a randomized complete block design, giving 24 plots (Fig. 1).

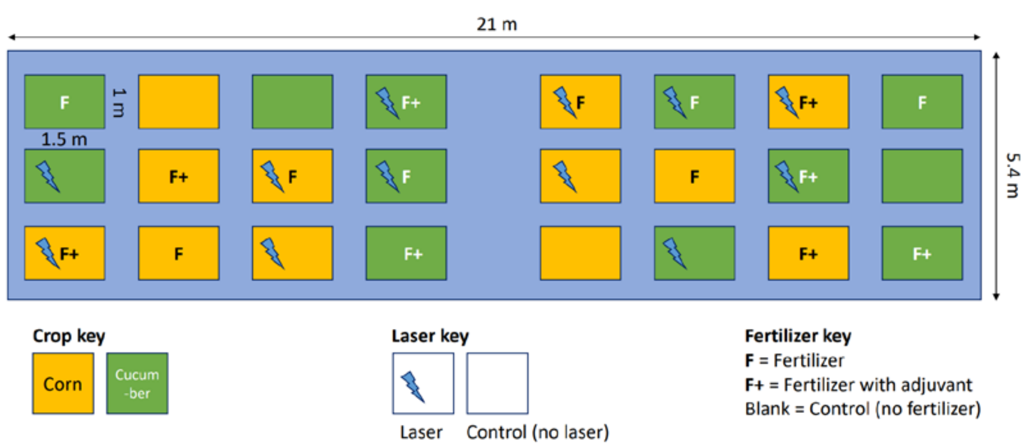

Figure 1. Experimental design and layout, with field plots after transplanting (top) and plot treatment map (bottom).

A single plot area is 1.5 m^2 (~16 ft^2). The total study area is 113 m^2 (1216 ft^2). Plants were spaced according to Table 2.

Table 2. Plant spacing and plant requirements

Crop	In-row spacing (cm)*	Rows per plot	Plants per plot	Total plants
Cucumber	30	1	3	36
Corn	20	2	10	120

*Recommended spacing from BC Vegetable Production Guide, 2020

Experimental space was prepared on June 10. Weeds were removed by hoeing and hand-pulling. Due to high soil compaction, the tillage was done using BCS tractor. 6 drip-lines were installed and connected to water-supply (city water was used) for irrigation.

On June 13, seedlings were transplanted from trays into the field according to the layout in Figure 1. Soil moisture was checked regularly and the watering was performed when required. Weeding was performed weekly in order to eliminate possible competition for tested crops. Fertilizer and adjuvant were applied to the plants according to the protocol provided by Organic Path. (Table 3)

Table 3. Weekly fertilizer application rates by treatment and growth stage.

		Foliar application rate (ml/l)		
Treatment	Growth stage	Q Algy	Q Energy	Adjuvant
None (No)	All	-	-	-
Fertilizer (FERT)	Transplant	4	4	-
	Vegetative	4	3	-
	Reproductive	5	5	-
Fertilizer & Adjuvant (FERT+)	Transplant	4	4	4
	Vegetative	4	3	4
	Reproductive	5	5	5

There were a total of 5 harvests for cucumbers throughout the experiment in July and August. Only the fruits that reached at least 6 inch (15cm) in length were harvested at a time. Each fruit was weighted, and the total yield and number of fruits per plot was recorded.

There was only one harvest of corn at the end of August. All of the ripe fruits were harvested, their count and yield were recorded.

Results

Statistical analysis was conducted by ANOVA with jamovi software (The jamovi project, 2020).

No effect of laser treatment on seedling growth or survival was detected in the germination trial. Pepper seedlings were discarded due to poor germination. Laser irradiation of seeds increased yield of both crops when no fertilizer was added (Fig. 2). Adding adjuvant to fertilizer increased yield of both crops when seeds were not treated with laser irradiation (Fig. 2). The same tendency was observed on a total number of fruits per treatment, more prominent in cucumbers (Fig. 3) Combining fertilizer application with laser seed treatment offered no additional yield or increase in the number of fruits.

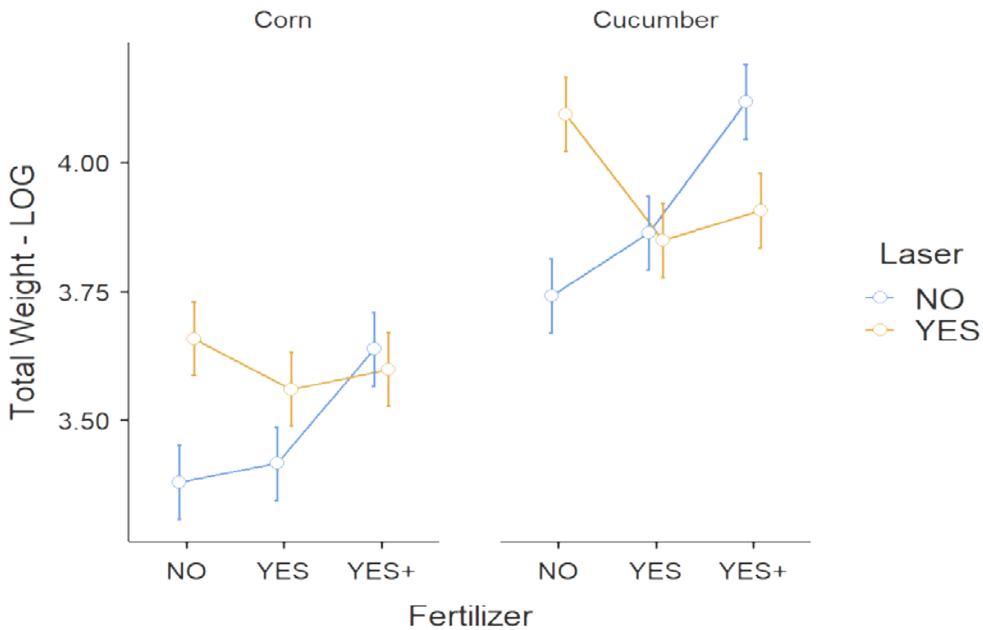

Figure 2. Interaction between laser seed treatment and foliar fertilizer treatment on corn and cucumber fruit number. FERT and FERT+ are foliar fertilizer treatments with and without adjuvant, respectively (Table 2).

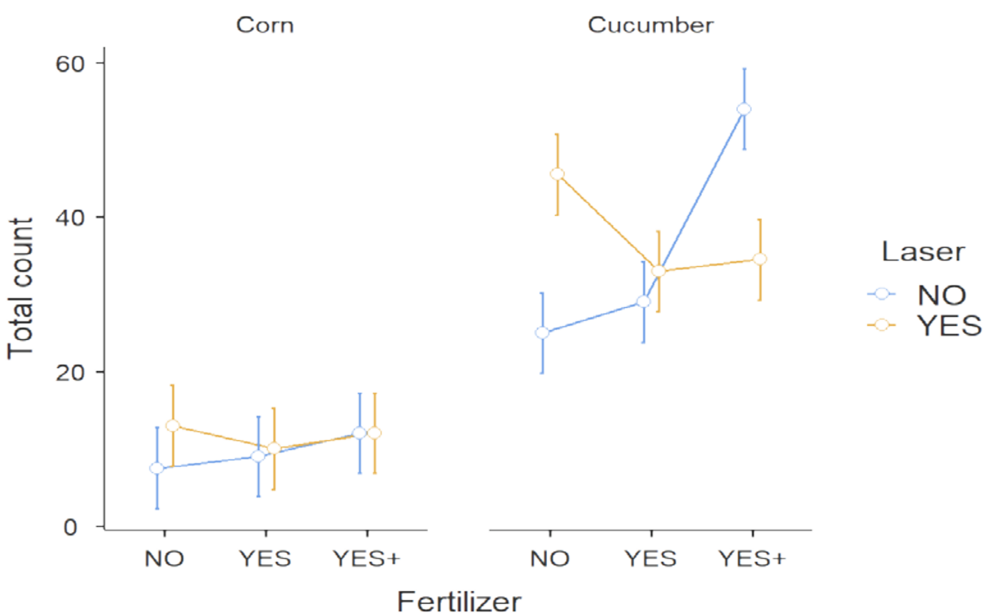

Figure 3Interaction between laser seed treatment and foliar fertilizer treatment on corn and cucumber yield (log transformed). FERT and FERT+ are foliar fertilizer treatments with and without adjuvant, respectively (Table 2).

Conclusion

Laser seed treatment significantly increased yield of both corn and cucumber. Foliar fertilizer treatments combined with adjuvant also increased yields. A negative interaction was observed between laser treatment and fertilizer application, such that no additional benefit was observed when the two treatments were combined. Further research is required in order to understand negative interaction between the laser irradiation treatment and fertilizer application.

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