Influence of *Cannabis* Response to Elevated Atmospheric CO_2 on a Pest Insect

Meredith Mitchell
Department of Entomology - Purdue University - West Lafayette, IN 47907

Abstract

As CO_2 levels continue to rise, plants and insects will be affected by these changes. By using an increasingly common agricultural crop, *Cannabis spp.* and a pest species, *Spodoptera frugiperda*, the fall armyworm, we can get an idea of how some other crops will react to these changes in the atmosphere. By growing two varieties of *Cannabis* under ambient CO_2 and the predicted levels in the future, we were able to see how the impacts on plants affect herbivores. We found that higher levels of CO_2 increased the consumption of leaf tissue but decreased the growth rate significantly. This will have impacts on agriculture and how crops are grown.

Introduction

Anthropogenic influences have caused an increase in carbon dioxide (CO_2) in the atmosphere since the industrial revolution. Changes in CO_2 influence plant quality and chemistry, which influence plant-insect interactions, and potentially influence agriculture. Increases in CO_2 cause most plants to be more efficient at photosynthesis as there is less RUBISCO needed. However, there is no increase in protein production. Plant carbon metabolism is impacted by rising CO_2 concentrations and temperatures, but also feeds back to the climate system to help determine the trajectory of future environmental change.

Since 2018, *Cannabis* has become more of a production cropping system in the United States for fiber, seed, and pharmaceutical products. *Cannabis* has many pest insects. Examples are the tobacco hornworm (*Manduca sexta*), corn earworm (*Helicoverpa zea*), spider mites (*Tetranychidae spp*.), aphids (*Aphidoidea spp*.), and the fall armyworm (*Spodoptera frugiperda*). Changes in resource availability and the environment have been shown to alter cannabis quality and in turn, influence cannabis-pest interactions. It is unclear how future predicted levels of atmospheric CO_2 will influence cannabis-pest insect interactions. To address this knowledge gap, we examined the performance of an insect pest on cannabis plants grown under future predicted CO_2 levels. We hypothesized that elevated CO_2 will reduce cannabis quality and reduce insect pest performance.

Methods

2 varieties of Cannabis (CBD and CBG) were grown under controlled environments with different levels of CO_2 concentrations 700 ppm and 400 ppm. It is estimated that 400 ppm CO_2, is approximately what is currently in the atmosphere. The plants were grown in these different conditions for 40 days, leaf tissue was harvested, along with the reproductive parts of the plant. The fall armyworm was used as a pest as it has been recorded on *Cannabis* and is easier to work with than many of the other recorded pests.

The wet weight of *Cannabis* leaves and fall armyworms (before the experiment) were taken. Then, one small, usually 3-5 instar, fall armyworm was placed in a Tupperware box with 2 sets of leaves. The leaves were inside water pits, so they did not dry out. The fall armyworms were left in the containers for 5 days. They were force-fed as they did not get a choice in either variety or CO_2 level. After 5 days, the fall armyworm, frass, and leaves were all dried in the oven and the dry weight was taken.

Results

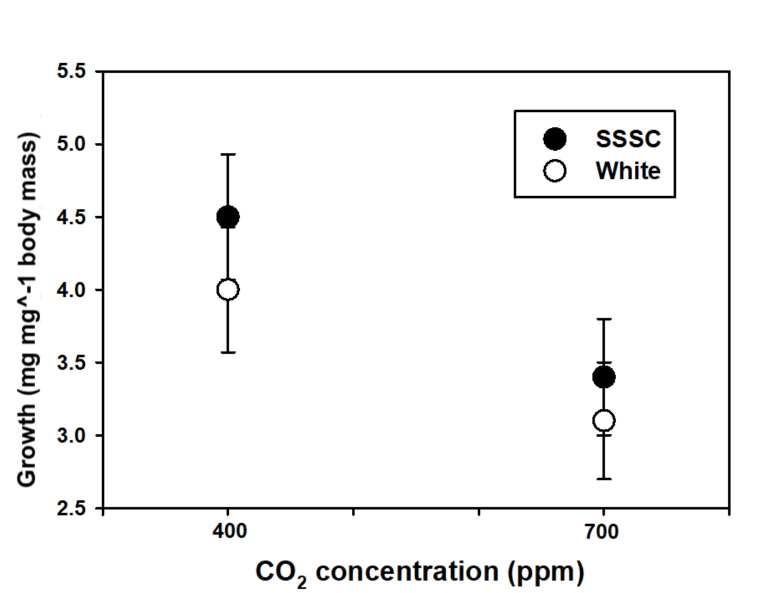

Figure 1: Growth of the insect in mg mg^{-1} body mass for CO_2 and the variety.

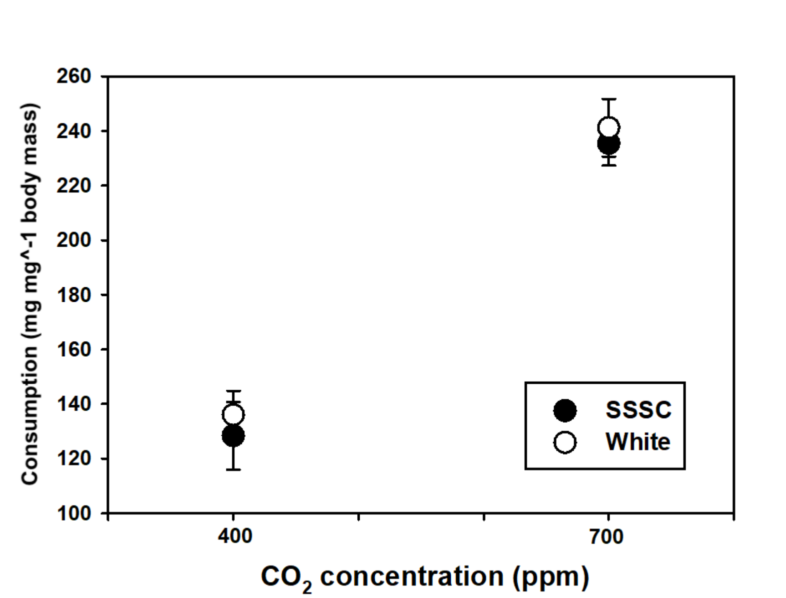

Figure 2: Consumption by insects recorded as mg mg^{-1} body mass for CO_2 concentration and variety.

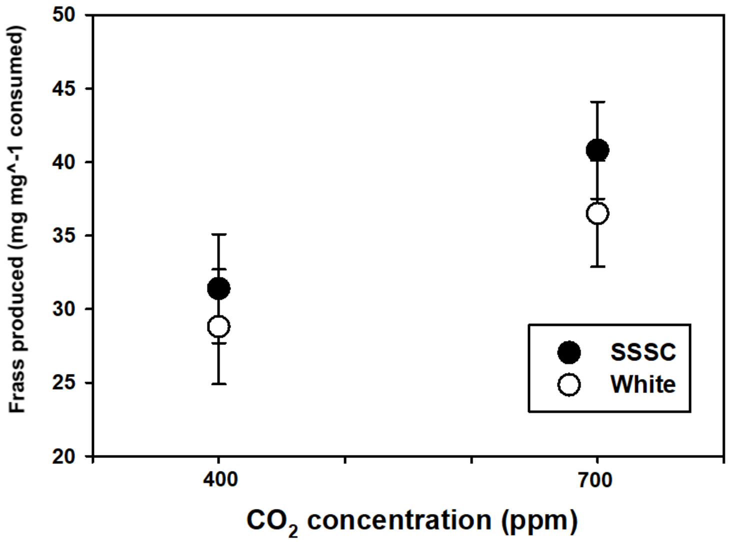

Figure 3: Frass production measured as mg mg^{-1} consumed for the different CO_2 levels and varieties. Frass was tested as approximate digestibility.

	Growth (in mg)	Consumption (in mg)	Frass (in mg)	ECD	ECI
400 ppm, SSSC	6.288125	136.855625	22.87125	5.58588864	4.64786263
700 ppm, SSSC	2.683888889	231.9111111	36.11777778	1.35652166	1.14417558
400 ppm, White	4.219166667	136.7591667	32.2	4.058201	3.06239332
700 ppm, White	1.816428571	235.085	44.34857143	0.95737053	0.77463094

Figure 4: Mean values for growth, consumption, frass, the efficiency of conversion of digested food, and the efficiency of conversion of ingested food under all environments and varieties.

The performance of the pests was measured as consumption rate, digestion rate, nutritional quality, digestibility, and conversion rate. Frass production was used as the measure of approximate digestibility. The efficiency of conversion of digested food and the efficiency of conversion of ingested food is similar to growth. In frass produced, CO_2 levels weren't significantly different, but the variety difference was. There was a 300% decrease in efficiency to both ingest and digest efficiency. The efficiency of conversion of ingested food was different under the difference in CO_2 levels depending on which variety they were feeding on. No real reaction of CO_2 difference on frass production. The ability to digest food varies in different environments depending on the cultivar. The terms of the models were significant. So, for the growth of pests, leaf consumption, and frass produced, the CO_2 and variety were significant. However, the interaction of the CO_2 and the variety were not.

Carbon and nitrogen are indicative of efficiency, the 400 ppm CO_2 C:N ratio is 2.0722:1, and the 700 ppm CO_2 C:N ratio is 3.6967:1. So we saw an increase in carbon, but a decrease in Nitrogen.

Discussion/conclusion

The limiting factor for plants is usually nitrogen. Under high CO_2, plants get bigger, but they don't increase the amount of nitrogen. As CO_2 increases, the rate at which RUBISCO transforms CO_2 becomes more efficient. The plant becomes more efficient, so it doesn't need to increase the amount of RUBISCO it has, it can be up to 50% of the leaf. So, the plants will increase the amount of Carbon that they use but decrease the amount of nitrogen. However, this affects the nutritional quality of the plant as well as the organisms that eat it.

We also measured how efficient fall armyworm was, both post-ingested and post-digested, with handling the plant material. The efficiency of conversion of digested food and efficiency of conversion of ingested food were both negatively impacted by higher levels of CO_2. Approximate digestibility, which is how much nutrients an organism can get from its food, was not statistically significantly impacted by the higher level of CO_2. So, this means that the digestibility of the food itself was not impacted by the growing conditions. Since the insects increased their consumption at higher levels of CO_2, their growth suffered, despite the fact that their ability to digest the food had not changed. Even increased consumption couldn't overcome the exposure to what was impacting the efficiency of ingestion and digestion. Even though the insects that ate the 700 ppm CO_2 leaves ate almost double what the 400 ppm CO_2 ate, they still could not compete growth-wise. The CO_2 reduced the efficiency of digestion, meaning that they had to eat more, less efficient food. As said before, this is not a result of a change in the insect's ability to digest the food. They ate more, so they don't have as much time to digest their food. Even with compensatory feeding, they could not catch up to the amount of nutrients needed to grow at the same rate. Their stomachs can only hold so much, and if they need to eat more, they fill up faster, meaning they must make room, but produce more frass. This is likely the cause of the increased frass production and consumption under higher CO_2, but the decreased growth.

This study is important because it can be used as a projection of what agricultural crops will likely deal with as atmospheric CO_2 increases. Obviously, this is only one study and cannot be used as the basis for what can happen to all agricultural crops. That being said, the influence of future environmental change on future hemp environmental systems will impact fall armyworm as well as all other pests. Based on the consumption and observations during the experiment, there was more damage to the 700 ppm CO_2 leaves than to the 400 ppm CO_2. As CO_2 levels increase, we will see more damage and see a decrease in insect performance. Unfortunately, this is in limited studies, but we do know that they eat more, from this study specifically. This will continue to impact pest management in fields like agriculture and horticulture, and the effects are likely to increase as CO_2 levels rise. This will also mean that the crops will likely be more stressed due to herbivory, causing a decrease in crop production.

In addition to the current problems with insect pesticide resistance steadily growing, this will only add more layers of complication to feeding a rapidly growing world. This problem with larger and less nutritious food will impact humans and our food just as much as it will impact insects. Humans will also need to eat more, and although that is likely not as much of a problem as it is for insects, our food will also need to eat more. Livestock will need to eat more, meaning that they will, like the insects, produce more waste.

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