Introduction

Due to its winter-hardiness, pennycress (Thlaspi arvense) is an oilseed plant being developed to be a cash cover crop planted between rotations of maize and soybeans. In the commercialization of pennycress, the yield drop of soybeans needs to be minimized in order to ensure the economic and environmental benefits of the crop are successful. Cover crops can improve the health of soil by uptake nutrients into their tissue that would otherwise be lost to nutrient leaching when the fields are fallowed for months. Specifically, pennycress has been shown to lower soil nitrogen by up to 19% compared to fields not planted with pennycress (Cubins, 2019). Other environmental benefits of pennycress as a cover crop include: early season pollinator resource; and its ability to suppress weeds with allelopathy, which could potentially lower herbicide use (Cubins, 2019).

What sets pennycress apart is its ability to be a cover crop and a cash cover crop. Currently, ongoing research is being conducted to commercialize pennycress as a novel biofuel and food-grade product. The high viscosity and cold flow properties make the oil a good fit for aviation fuel (Cubins, 2018). Although pennycress contains antinutritional compounds (arsenic and astringent), scientists have made progress on removing them. (Cubins, 2019). Today the largest limiting factor of this cropping system is that it will decrease soybean yield. There are several biotic and abiotic stresses that pennycress impacts onto soybeans including: allelopathy, reduced water, limited nutrients, and shading (Feld, 2011). Specifically, when plants are grown under a canopy they experience shade avoidance syndrome, which causes reduced branching and longer internodes (Martínez-Romero et al., 2018).

This shading stress is caused by the decreased quality and quantity of light. Light quality for plants is measured by the available photosynthetically active radiation (PAR). Light quality is quantified by the red to far-red ratio (R:FR). A reduced R:FR ratio is observed under a pennycress canopy due to plant matter preferentially absorbing red light and reflecting for red light. Soybeans need to be adapted to the biotic and abiotic stresses of this cropping system, and our goal is to develop a soybean genotype with reduced shading stress that will maintain yield penalties. This research tests the ability of different soybean genotypes to tolerate diminished quality and quantity of light, to achieve the goal of releasing varieties adapted for intercropping.

Methods

Research Question
How do reduced R:FR and PAR caused by a pennycress canopy affect the morphology and plant architecture of 10 different soybean genotypes compared to these genotypes experiencing no shading stressors?

Field Methods

Growth chamber and field experiment

- Pennycress and soybeans planted (8/15/2019) and intercropped (8/22/2019)
- Pennycress and soybeans planted (8/15/2019) and intercropped (8/22/2019) in the growth chamber
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- Pennycress and soybeans planted (8/15/2019) and intercropped (8/22/2019) at a ratio of 50:50
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- Pennycress and soybeans planted (8/15/2019) and intercropped (8/22/2019) at a ratio of 100:0
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Pennycress and soybeans planted (8/15/2019) and intercropped (8/22/2019) in the growth chamber

- Pennycress and soybeans planted (8/15/2019) and intercropped (8/22/2019) in the field experiment located in Rosemount, and then replicated in the Growth chamber. The field experiment was conducted in the Growth chamber treatment conditions: No Pennycress Treatment: No Pennycress

Destructive Measurements

- Above Ground Biomass
- Below Ground Biomass
- Leaf Area
- Internode Lengths (L2,3)
- Specific Leaf Area
- Stem Width
- Chl content

Fig. 1 (a) Soybeans growing under a pennycress canopy. (b) in order to quantify internode length and stem width with image J, pictures were taken of each soybean genotype. (c) Setup for measuring biomass and leaf area. (d) The soybean genotype M23-26045S after four weeks in the growth chamber. The treatment conditions are on the right, and the control conditions were on the left.

Discussion

We performed an ANOVA comparing the physiological traits of soybeans between the control and pennycress treatment conditions.

- In the field experiment there was a statistically significant difference between all the physiological traits in the control versus treatment conditions with p-values less than 0.01.
- In the growth chamber experiment, the only physiological traits that had a significant difference between control and treatment conditions with a p-value less than 0.01 were: internode 1 length, internode 3 length, above ground biomass, and below ground biomass.

Pearson’s coefficient of correlation was calculated between all trait combinations. Interestingly, differences were observed between the field experiment and the growth chamber experiment.

- Evidence showed that the shade avoidance response symptoms were more prominent in the growth chamber treatment conditions than the field.
- Growth chamber treatment conditions: Leaf area was found to have a moderate negative correlation with internode 1 (-0.37), and stem width (-0.39).
- In the control growth chamber and both field conditions leaf area did not have a strong correlation with either internode 3 or stem width.
- Reductions of biomass are less correlated with internode 1 elongation in the growth chamber treatment conditions versus the control growth chamber conditions and both field conditions. Thus, denoting that when we isolate shading stress in the growth chamber, it has less of an effect on the reductions of biomass than it would in the field. It is likely another stressor is causing a larger decrease in biomass in the field.
- In the field experiment there was a moderate negative correlation between biomass and internode 1 length (-0.49).
- A decreased in the strength of the negative correlation between biomass and internode 1 length was seen in both the growth chamber conditions and the control field conditions, compared to the growth chamber treatment conditions.

Conclusion

Based on these results, it can be concluded that the quality and quantity of light is not the only factor affecting yield of soybeans grown under pennycress. In the growth chamber, the differences between the internode lengths and biomass are expected responses to shading stress. However, the field experiment showed that there were several physiological differences between soybeans in the control versus treatment conditions that were not generated solely by shading stress. Going forward, it would be interesting to see how the shade stress stimulated by the growth chamber affects the overall yield of soybeans. The limiting factor in this experiment was time. These results account for soybean development during the first 4-6 weeks, limiting us to comparing physiological traits and not their correlation to overall yield. Nevertheless, a good genotype can still be selected for a pennycress intercropping system based on its physical attributes. The ideal soybean genotype in this system would have a shorter internode length to avoid lodging. Finding a soybean genotype resistant to the diminished R:FR rates and PAR, would bring us one step closer to developing improved soybeans for a pennycress intercropping system.

Table 1. R:FR and PAR were measured in the field experiment located in Rosemount, and then replicated in the Growth chamber. The light conditions were replicated in each the control and treatment growth chambers. To ensure reproducibility, R:FR and PAR were measured at the beginning and end of the experiment.

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<tr>
<th>R:FR</th>
<th>PAR (PAR/PAR)</th>
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<tr>
<td>0.123</td>
<td>2548.086</td>
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<tr>
<td>0.432</td>
<td>2647.064</td>
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<tr>
<td>0.342</td>
<td>3403.987</td>
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<td>0.670</td>
<td>304.192</td>
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<tr>
<td>0.360</td>
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Sources


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