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PHYSIOLOGICAL EFFECTS OF HEAT STRESS ON LIMA BEAN (*Phaseolus lunatus*) AND DEVELOPMENT OF HEAT TOLERANCE SCREENING TECHNIQUES

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PHYSIOLOGICAL EFFECTS OF HEAT STRESS ON LIMA BEAN (Phaseolus lunatus) AND DEVELOPMENT OF HEAT TOLERANCE SCREENING TECHNIQUES

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INTRODUCTION

Heat stress reduces yields of May and early June-planted lima beans (*Phaseolus lunatus*) on the Delmarva Peninsula. High temperatures during flowering reduce or delay pod set and can result in later harvest, lower yield and split sets. We are working to develop heat tolerant baby and Fordhook type lima bean cultivars that are adapted to the Mid-Atlantic Region. Both field and greenhouse screening methods have been used to test inbred lines for heat stress response, but greenhouse screening has been particularly useful in determining the physiological effects of heat stress.

METHODS

Eight lima bean inbred lines were grown in two climate controlled chambers inside of the greenhouse under hot and cool night temperature regimes. Experiments were arranged in a randomized complete block design with 5 replications. Target night temperatures were 27 °C in the hot chamber and 18 °C in the cool chamber. For experiment 1, target daytime temperatures were 32-35 °C in the hot chamber and 27-30 °C in the cool chamber. For experiment 2 target daytime temperatures for both chambers were 32-35 °C. Newly opened flowers were collected from plants grown under hot and cool night conditions. The style, with pollen adhering to it, was removed from the flower, stained with acetocarmine, then viewed and photographed under 40x magnification. We later counted stained pollen grains visible in the photograph. We harvested pods from the plants at maturity and noted the number pods, number of seeds per pod, total number of seeds and total weight of seeds for each plant.

RESULTS

Heat Effects on Flower Production - In experiment 1, hot night temperatures reduced time to flowering in all genotypes. On average, plants in the hot chamber began flowering 11 days earlier than those in the cool chamber. Plants in the hot chamber produced many flowers and re-flowered repeatedly on racemes that failed to set pods. Heat stress does not appear to cause yield loss by inhibiting or delaying flowering.

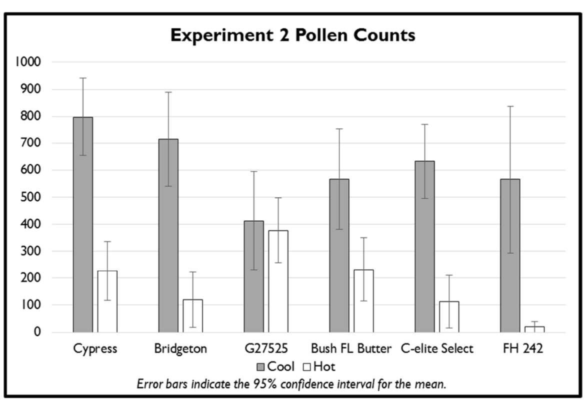

Figure 1. Experiment 2 pollen counts

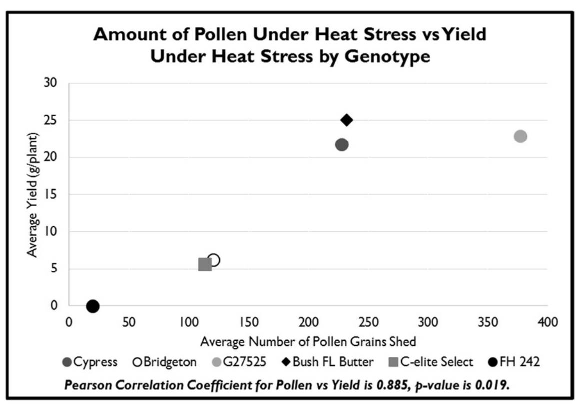

Figure 2. Amount of pollen shed under heat stress vs. yield under heat stress by genotype

Heat Effects on Pollen Production and Release - In both experiments, flowers from plants grown in the hot chamber had less pollen shed onto the stigma and style (Figure 1). In some cases no shed pollen was observed, but in most cases some pollen was present. The maximum number of pollen grains observed was over 1,400. In experiment 2 there was a positive correlation between the amount of pollen shed under heat stress and yield under heat stress (Figure 2).

Heat Effects on Fertilization - The acetocarmine stain used in this assay is reported to be useful as a test for viability. Unstained pollen grains were not counted but were also very rarely observed. Germinated pollen grains were only occasionally seen, but this is not unexpected as flowers were collected only a few hours after opening. We observed that in some flowers the style and stigma were not completely enclosed in the keel. This could interfere with self-pollination. Stigma location was noted for the flowers collected on four different dates in experiment 2. The stigma was located outside of the keel in 47% of the flowers from the hot chamber and 11% of the flowers from the cool chamber (means differ significantly by Student's T-Test p-value=0.0041). Additional experiments are needed to determine if high temperatures affect other aspects of fertilization such as pollen germination, pollen tube growth, stigma receptivity, and egg viability.

Heat Effects on Seed Fill and Maturation - In experiments 1 and 2, yield loss was due to fewer seeds produced per plant. There was not a significant difference in per seed weight. In some genotypes there was not a significant difference in the number of pods set. In all genotypes there were significantly fewer seeds per pod in plants grown in the hot chamber. Fewer seeds per pod indicate heat effects on pollination or fertilization.

Whole Plant vs Localized Effects of Heat Stress - In spring 2015 a vining, heat susceptible genotype (Dr. Martin) was grown inside the hot chamber and trained out into the greenhouse (cool night temperatures) and vice versa. Yield and pollen production were affected by the location of the flower -- either in the hot chamber or in the cooler greenhouse.

Genotype Differences in Heat Tolerance - Under high nighttime temperature conditions, genotypes that were heat tolerant shed more pollen onto the style and set more seed than genotypes that were heat susceptible. A large-seeded genotype, 'Fordhook 242', was the most heat susceptible genotype that was tested. Among the small-seeded genotypes, 'Bridgeton' and 'C-elite Select' are heat susceptible and 'Bush Florida Butter', 'Cypress' and G27525 are more heat tolerant.

CONCLUSIONS

Heat stress related yield loss in lima bean is due, in part, to reduction in the amount of pollen shed onto the stigma and style. The heat effects on pollen production and release are determined by conditions experienced by the flower, not the plant as a whole. Other factors, such as pollen viability, pollen tube growth and location of the stigma inside or outside of the keel may also play a role in heat stress response. By growing in a greenhouse chamber under sustained high nighttime temperature conditions, we were able to identify several heat tolerant genotypes which are now being used as parents in the University of Delaware lima bean breeding program.