Research article

Impacts of Atmospheric Temperature - Humidity Changes on Yield Quality of Thai Soybean Cultivar

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Abstract This study aimed to assess the impact of atmospheric temperature and humidity change on yield of Thai soybean, Chiang Mai 60 cultivar. The research experiment was conducted during July - October 2013 at Naresuan University Crops Field, Phitsanulok, Thailand. Soybean seed Chiang Mai 60 cultivars were planted in 16 open top chambers (OTCs) under 4 different temperature and humidity levels. The four simulated climate change situations in OTCs were, lower than ambient temperature, higher than ambient temperature, combined elevated temperature and high humidity and ambient temperature level, which all were controlled by an electrical system. Results indicated that yield loss by statistical significance occurred in all Low-level temperature treatment (25±2.9 °C), High-level temperature treatment (37±2.2°C), and high Temperature-humidity (36±2.8°C/ 81.7±2.2%), compared with ambient-level temperature treatment (31±1.7°C). Exposure to simulated climate change situation in Low-level temperature treatment obviously reduced total pod/plant and total seed/plant by 40.8% and 48.5%, respectively. High-level temperature caused yield loss in total pods/plant and total seeds/plant by 35.6% and 39.5%, respectively. The combined effect of high temperature and humidity on soybean crop reduced total pods/plant and total seeds/plant about 36.4% and 47%, respectively. Finally, low temperature evidently increased in lipid content and all types of fatty acid in experiment, whereas the high temperature treatment could reduce the total mono-unsaturated fatty acids. It was concluded that temperature change situations at above and lower than ambient level in growing season could induce yield loss and some fatty acid in Thai soybean, Chiang Mai 60.

Keywords temperature change, Thai soybean, open top chamber, yield quality

INTRODUCTION

Climate change and variability can have significant impacted on phenology, physiological mechanisms, growth, nutritional value, genetics, and yield of crops (Bainy et al., 2008; Thanacharoenchanaphas and Rugchati, 2011). The "Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC)" conclude that by 2081–2100, the globally averaged surface temperature will be in the range of 2.6-4.8 ˚C in comparison with 1986–2005 and, daily and seasonal high temperature extremes over most land areas will be more frequent in the future (IPCC, 2013). These changes and variability in climate may have significant impacts on yield of crops in various regions of the world (Smit and Yunlong, 1996; Kumagai and Sameshima, 2014).

Soybean is one of the important C3 plants that is sensitive to temperature change (Newman et al., 2011). On the basis of long-term field experiments (1987–2007) in northeastern China, Zheng et al., (2009) reported that soybean seed yield was increased by 6–10% per 1 ˚C rise in mean daily maximum temperature during seed filling. Thailand Department of Meteorology reported that the annual mean temperature in Thailand rose by approximately one degree Celsius from 1981 to 2007. By 2050, the mean daily maximum temperature in Thailand will have been increased by 1.2 to 1.9 °C (Marks, 2011). Hence, current mean temperature during the soybean growing season in Thailand has been changed at meteorological observatories in the northern regions of Thailand. Based on these facts, we hypothesized that the increase/decrease in temperature and humidity during growing season have effects on soybean production. Our data clearly demonstrate the differences in soybean yield responses to the change of temperature – humidity.

OBJECTIVE

This study was set to investigate the differences in Thai soybean yield responses to the changes of temperature – humidity during growing season.

METHODOLOGY

Field Study and Experimental Design

The field study was carried out at Naresuan University in northern Thailand. The experiment was done at agricultural crops field in the university. It is located at coordinates 16 degrees and 44.003 minutes north of the equator, and 100 degrees and 11.810 minutes east of Prime Meridian. The total study area covered about 300 m^2.

Thai Soybean (*Glycine max* (L.) Merr.) Chiang Mai 60 cultivar was selected for the study; this cultivar was widely cultivated in northern Thailand. It was planted in growing season of Thailand during July 2013 to October 2013. Four replications of a Randomized Complete Block Design (RCBD) were used in four treatments with four different levels of air temperature and relative humidity. At the vegetative growth stage, the soybeans in all four treatments were exposed to temperature-humidity variability for 8 hr exposure (9.00 am – 5.00 pm) in open top chambers until harvest.

Temperature - Humidity Control

The square open top chamber was used throughout the study period. The chamber size was 1.5 m (width) x 3 m (length) x 2.5 m (height). It was constructed out of transparent plastic. There were four situations of air temperature-humidity change, at an ambient level (AT-treatment or control treatment), combination of low temperature and humidity at ambient level (LT-treatment), combination of high temperature and humidity at ambient level (HT-treatment), and combination of high temperature and high humidity (HHT-treatment). These were controlled by an electronic system. The high temperature and low temperature system was set up by green lighting and air conditioning exposure, whereas the elevated humidity treatments were set up by electronic water spray. Mean air temperature /humidity levels (± S.D) for 8 hr for each treatment were 25±2.9 °C / 62 ± 9.8 % in LT-treatment, 31±1.7 °C/ 63 ± 7.4 % in AT-treatment, 37 ± 2.2 °C/ 61 ± 5.7 % in HT-treatment, and 36±2.8 °C/81.7±2.2% in HHT-treatment, respectively.

Yield Quality Determination

Soybean seeds were harvested from the experimental field at maturing stage (95 days). Yield quality was analyzed by determination in yield quantity and nutrition value (lipid and fatty acid content). These samples were determined by number of pods/plant, number of seeds/plant and weight of 100 seeds. Lipid content and some important fatty acids were determined by gas chromatography (GC) based on analysis of nutrition content by AOAC (1995) method to estimate grain quality.

Statistical Analysis

The experiment was designed as Randomized Complete Block Design (RCBD) with 4 replications. Data of yield and fatty acids content were statistically analyzed by the analysis of variance (ANOVA). Significant differences of parameters were reported at $p<0.05$ by DMRT.

RESULTS AND DISCUSSION

Yield Quantity

Seed yields were harvested at maturing stage. The yield component, including number of pods/plant, number of seeds/pod and weight of 100 seeds were determined to assess grain quantity. The results are shown in Fig. 1a - Fig.1b. The significant reductions were found in all 3 parameters of yield component. The significant reductions in number of pods/plant and number of seeds/plant appeared in LT treatment, HHT treatment, and HT treatment when compared to control treatment. Exposure to Low-level temperature treatment obviously reduced total pods/plant and total seeds/plant in comparison with control by 40.8% and 48.5%.

We also found that the cumulative effects of high-level temperature caused yield loss in total pods/plant and total seeds/plant by 35.6% and 39.5%, respectively. The combined effect of high temperature and humidity on soybean crop reduced total pods/plant and total seeds/plant by 36.4% and 47%, respectively. The results obviously showed that high level of temperature (plus ambient humidity) reduced the 100 seeds weight when compared to the others (Fig. 2). These results indicated that the higher temperature level and the lower temperature level (above ambient level) in growing season induced high suppression in yield Chiang Mai 60 cultivar soybean.

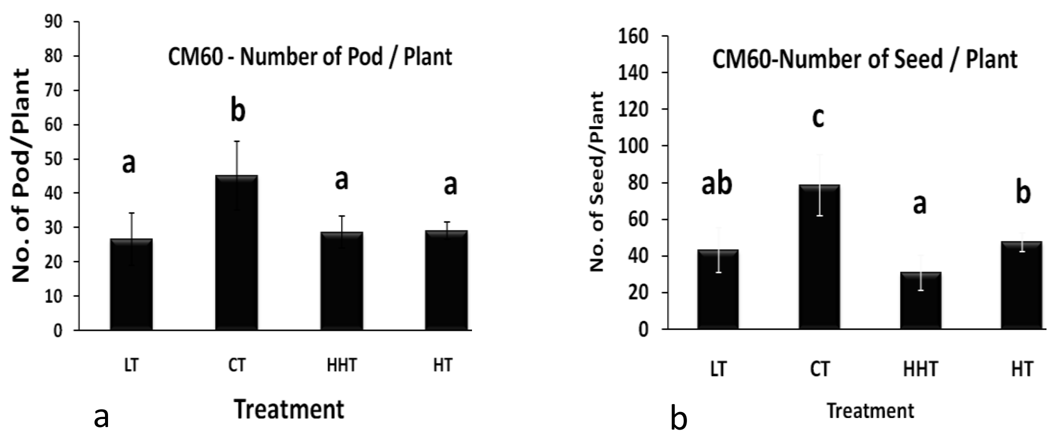

Fig. 1 (a) Effects of different air temperature – humidity levels on number of pod/plant of soybean, Chiang Mai 60 cultivar and (b) Effects of different air temperature –humidity levels on number of seed /plant of soybean, Chiang Mai 60 cultivar

Note: The different letters for each treatment indicate a significant difference at $\rho\leq 0.05$. Error bars above each histogram indicated standard deviations (S.D.) observed from samples of each treatment.

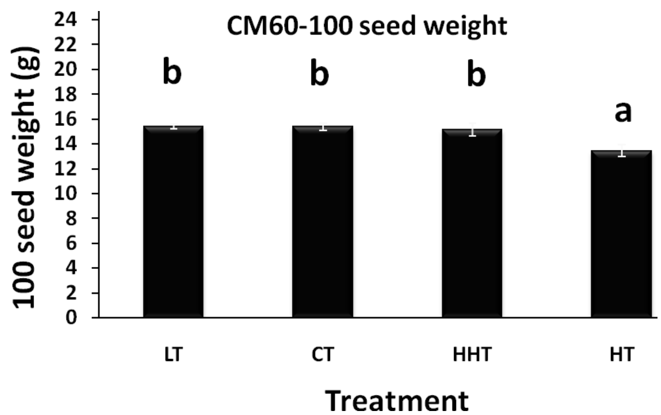

Fig. 2 Effects of different air temperature – humidity levels on 100 seed weight of soybean, Chiang Mai 60 cultivar

Note: The different letters for each treatment indicate a significant difference at ρ≤0.05. Error bars above each histogram indicated standard deviations (S.D.) observed from samples of each treatment.

Nutrition Value in Lipid and Fatty Acid Content

Exposure of soybeans to different air temperature-humidity levels was carried out in an open top chamber. In Table 1, we observed that the LT treatment (at lower temperature level than ambient level) induced high lipid content in the full maturing stage (R8). However, there were no significantly different results found in HT treatment (higher temperature level than ambient level). The significantly different results were also clearly shown in total saturated fatty acids (TSFA), total mono-unsaturated fatty acids (TMUFA), and total poly-unsaturated fatty acid (TPUFA). The results showed the most obvious effects of increasing air temperature (HT treatment) led to the reduction in fatty acid when compared with others. In contrast, the interested results showed that the low temperature treatment (LT treatment) in growing season (than ambient level) led to the significant increase in all 3 types of fatty acid (Table 1).

Table 1 Summary of the results of Lipid content, TSFA, TMUFA and TPUFA of soybean seed, Chiang Mai 60 cultivar grown under four temperature treatments (LT, CT, HHT and HT) in this study

Lipid and Fatty acid	4 treatments under different air temperature levels			
	LT	CT	HHT	HT
Lipid content (g)	21.5 ± 0.3 ^{b}	19.9 ± 0.4 ^{a}	19.8 ± 0.1 ^{a}	19.6 ±0 0.2 ^{a}
TSFA(mg/100g)	2815.7 ± 24.3 ^{c}	2547.6 ± 18.5 ^{a}	2592.8 ± 25.5 ^{ab}	2621.2 ± 34.2 ^{b}
TMUFA (mg/100g)	4680.7 ± 45.8 ^{c}	4498.1 ± 64.3 ^{b}	4753.7 ± 26.5 ^{c}	4414.8 ± 24.8 ^{a}
TPUFA (mg/100g)	11697.9± 67.6 ^{b}	11257.8 ± 61.3 ^{a}	11195.0 ± 78.4 ^{a}	11237.2 ± 87.9 ^{a}

Note: The different letters for each treatment indicate a significant difference at ρ≤0.05.

Many researches that have been investigated for decades showed similar results as this study. For example, Hatfield et al., (2011) predicted that a 0.8 ˚C temperature rise would cause a 2.4% decline in soybean yield in southern USA (current growing season temperature of 26.7˚C). Numerous studies have carried out to understand biochemical reaction taking place in plant's physiology under climate factors change, leading to the inhibition of photosynthesis and yield production. Its photosynthesis is very sensitive to ratio of CO_2 to O_2 in the atmosphere. Increasing in this ratio of CO_2 to O_2 leads to higher rates of photosynthesis (Newman et al., 2011). However, the reaction of photosynthesis is disrupted at high temperatures and inhibit CO_2 fixation (Araus and Slafer, 2011). One of the most temperature-sensitive reactions of carbon assimilation is rubisco activase. Rubisco activase activity is exceptionally sensitive to thermal denaturation. Hence inhibition of the activase at high temperature prevents activation of rubisco in leaves suffering heat stress and leads to inhibition of CO_2 fixation (Crafts-Brandner and Sulvucci, 2000; Salvucci et al., 2001). Heat stress is a serious threat to crop production worldwide. High leaf temperatures reduce plant growth and limit crop yields. Estimates range up to a 17% decrease in yield for each degree Celsius increasing in average growing season temperature (Lobell and Asner, 2003).

CONCLUSION

The results from the experiment showed that Thai soybeans, Chiang Mai 60 were grown under temperature-humidity change and revealed that exposure to high temperature, low temperature, and combination of high temperature-humidity during growing period led to the significant and obvious reduction in yield quantity. Even though low temperature evidently increased in lipid content and all type of fatty acid in experiment, the high temperature treatments could also reduce total mono-unsaturated fatty acids (TMUFA).

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