Journal of Fundamental and Applied Sciences

ISSN 1112-9867

Available online at http://www.jfas.info

Research Article

Special Issue

CHANGES IN YIELD AND ESSENTIAL AMINO ACID COMPOSITION ASSOCIATED WITH AIR TEMPERATURE STRESS IN THAI SOYBEAN SEEDS, SOR JOR 5 CULTIVAR

K. Thanacharoenchanaphas* and O. Rugchati

Faculty of Agriculture, Natural Resources and Environment Naresuan University, Phitsanulok, Thailand

Published online: 24 February 2018

ABSTRACT

This study is aimed at assessing the impacts of high and low air temperature stress on seed yield and essential amino acids composition of Thai soybean (*Glycine max* (L.) Merrill) cultivars: SOR JOR 5. This study was carried out in 2013 to 2014 at Naresuan University, Phitsanulok, Thailand. Soybean were planted and covered with open top chamber (OTC) since seedling through maturing stage. The controlled air temperature in OTC were set into three temperature situations: 25.5±1.3°C (low temperature /LT treatment), 37±3.4°C (high temperature /HT treatment) and 35±1.9 °C (ambient temperature / CT-treatment). The results indicated that number of pod plant^{-1} was not affected by temperature changes, whereas number of seed plant^{-1} and 100-seed weight were negatively and significantly affected under both controlled low and high temperature. Seed yield reductions by 54% and 52 % were found under high temperature and low temperature, respectively. However, the contrast results were found in essential amino acids composition. We observed that both of low and high temperature situations induced the significance increase in 8 amino acids; histidine, arginine, isoleucine, leucine, lysine, phenylalanine , threonine and valine. The highest increase by 6.2% and 8.5% under controlled high temperature and low temperature were recorded in leucine and lysine, respectively.

Author Correspondence, e-mail: kanitat@nu.ac.th

doi: http://dx.doi.org/10.4314/jfas.v10i3s.60

To summarize, the enhanced or decreased surface air temperature situations in growing season could cause yield loss but induced the increases in essential amino acids of Thai soybean, SOR JOR 5.

Keywords: temperature stress, Thai soybean, , yield, amino acid

INTRODUCTION

Temperature stress is becoming the major concern for agricultural sector worldwide because of its well known sensitivity to the changing climate. Physiological processes of plants including crops are largely affected by the alteration of temperature [1]. Temperature stress could have significant impacted on phenology, physiological mechanisms, growth, nutritional value, genetics and yield of crops [2]. Several studies have reported the significant impacts of these changes on yield of crops and seed nutritions in various regions of the world [3,4,5].

The soybean (*Glycine max* (L.) Merrill) is one of the most important economic crops worldwide [6]. Soybean seed is a major source of both protein meal and vegetable oil [7]. Unfortunately, numerous studies have concluded that soybean is sensitive to air temperature changes, especially increased temperature [5,8]. Future climatic change is likely to have substantial impact on soybean production depending upon the magnitude of variation in CO_2 and temperature. Increased temperature significantly reduces the grain yield due to accelerated development and decreases time to accumulate grain weight [9]. Thailand's Department of Meteorology reported that the annual mean temperature in Thailand rose by approximately one degree Celsius from 1981 to 2007 and the mean daily maximum temperature in Thailand will increase by 1.2 to 1.9 °C by 2050 [10]. Studies concerning trends in temperature and its extremes in Thailand from the period of 1970 to 2006 showed that, trends in temperature indices in Thailand reflect an increase in both maximum and minimum temperatures and are consistent with the general global warming trends. Averaged over all stations, the number of warm days and nights significantly increased by 3.4 days/decade and 3.5 days/decade, respectively [11]. 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 during growing season may have effects on soybean production and amino acid. Therefore, this study was set to investigate seed yield and essential amino acids responses of Thai soybean, SOR JOR 5 cultivar to the changes of temperature during growing season.

MATERIALS AND METHODS

A. Field Study

The experiment was done at agricultural crops field at Naresuan University, Phitsanulok, in Lower Northern Thailand in 2013 to 2014. It 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.

B. Air Temperature Changes Control

Soybeans were exposed to 3 controlled temperature levels in open top chambers (OTC). Exposures were carried out in 12 square OTCs were used throughout this 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 Three situations of air temperature change, at an ambient level (CT-treatment or control treatment), lower than ambient level (LT-treatment) and higher than ambient level (HT-treatment) .These were controlled by electronic system. The high temperature and low temperature were controlled by green lamps and air conditioning exposure. The OTCs and temperature controlling of field study were shown in Fig.1.

C. Soybean Planting and Experimental Design

D. Thai Soybean (Glycine max (L.) Merr.) Promising Line, SOR JOR 5 (SJ5) cultivar was selected for the study. This cultivar has been popular and widely cultivated in the northern Thailand for decades. It was planted in controlled air temperature during November 2013 to February 2014. The experiment was Randomized Complete Block Design (RCBD) with 3 temperature levels treatments. Four replications of RCBD were used in this study, therefore treatments were assigned randomly to 12 OTCs.

Fig.1. Square Open Top Chamber (OTC) for temperature controlling for field experiment

Chambers were considered as the experimental units. Soybean seeds were planted in each chamber. At the vegetative growth stage, they were exposed to temperature variability for 9 hr exposure (8.00 am – 5.00 pm) in open top chambers until harvest.

E. Seed Yield Analysis

At the maturing stage (105 days), all soybean seed samples were harvested from the four replications of each treatment. Yield quality was analyzed by determination in yield quantity and amino acid content. The total number of pod plant^{-1}, total number of seeds plant^{-1} and 100-seed weight were observed to estimate seed yield. Amino acid content were analyzed (expresses as mg/100g) by gas chromatography (GC) method based on the procedures described in AOAC official method (1995). Nine types of essential amino acid which were analyzed for this study consist of histidine, arginine, isoleucine, leucine, lysine, methionine, phenylalanin, threonine and valine.

F. Statistical Analysis

The experimental was designed as a Randomized Complete Block Design (RCBD) under 4 replications. Data of amino 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

G. Air Temperature Levels in Open Top Chamber

Air temperature in 12 OTCs were measured daily from the vegetative growth stage to maturing stage. The results obtained show the mean air temperature levels (± S.D) for 9 hr for each treatment. In control treatment (CT), the air temperature was 35°C±1.92°C. The temperature both in below and above ambient level were 25.5±1.3°C and 37±3.4°C in LT-treatment and HT-treatment, respectively. Considering the daily mean temperature, results showed that the highest temperature levels in 3 treatments were recorded at 1.00-3.00 pm.

H. Seed Yield

In this experiment, grain yields of SJ5 cultivar in 3 treatments were examined for total number of pod plant^{-1} , total number of seeds plant^{-1} and 100-seed weight at maturing stage. These are important parameters for estimating the quantity of grain yield. The results showed that the effect of low and high temperature on total number of pod plant^{-1} in SJ5 was not significant compared to CT (Fig.2(a)). Whereas, statistically significant results shown in number of seeds plant^{-1} and 100-seed weight (Fig.2(b,c)). The number of seeds plant^{-1} were 155.42±117.53, 164.56±76.8 and 344.17±38.42, in LT, HT and CT respectively. Whereas, 100-seed weight were 13.79 ± 0.05 g, 14.4±0.06 g, and 16.39±0.83 g in LT, HT and CT respectively. Therefore, the highest number of seeds plant^{-1} and 100-seed weight was recorded in CT whereas the lowest yield was recorded in HT and LT.

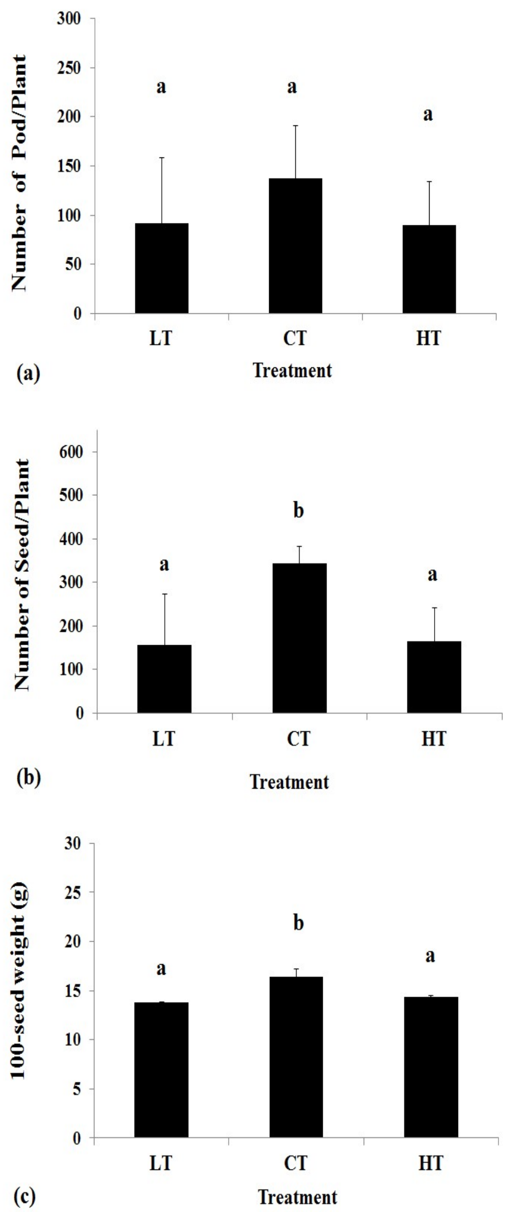

Fig.2. Effects of different air temperature levels on
(a) total number of pods $plant^{-1}$ of soybean, SJ 5 cultivars
(b) total number of seed $plant^{-1}$ of soybean, SJ 5 cultivars
(c) 100-seed weight of soybean, SJ 5 cultivars
(Note: The different letters for each treatment indicate a significant difference at $\rho \leq 0.05$. Error bars above each histogram indicated standard deviations (S.D.) observed from samples of each treatment.)

The results shown that seed yield decreased with both increasing and decreasing air temperature. To compared to CT, the significant ($p \leq 0.05$) reductions in number of seeds $plant^{-1}$ by 54% and 52%, appeared in HT and LT, respectively. Under controlled air temperature at ambient level, the significant ($p \leq 0.05$) reductions in 100-seed weight were 12% and 15.8% in HT and LT, respectively.

The results also indicated that high and low temperature above and below ambient level in growing season could suppress grain filling at reproductive stage (R-stage).

I. Essential Amino Acids content

This part reports the results of the essential amino acids for children and for adults. This is one of the important parameters for estimating the quality of grain yield. The results are reported below.

The nine essential amino acids for infants and children ; histidine, arginine, isoleucine, leucine, lysine, methionine, phenylalanin, threonine and valine; were analyzed to estimate yield quality. Table1. shows the histidine and arginine content of SJ 5 cultivar. Results revealed that the content of histidine were 1310.08±11.45, 1330.68±11.4 to 1382.39±10.23 mg/100g in CT, HT and LT, respectively. The most significant increasing by 5.2% was shown in LT treatment (low temperature). There was no significantly different results ($P \leq 0.05$) in HT compared to CT. The arginine content were 3464.55±35.4, 3689.75±18.99 to 4680.19±14.56 mg/100g in CT, LT and HT, respectively. The results in arginine was similar to the value of histidine described above. Because, the significant ($p \leq 0.05$) increasing were observed at LT (low temperature and HT (high temperature) compared to CT. The increasing percentage by 26% and 6.1 % were shown at HT and LT treatment, respectively.

The results in 7 essential amino acids for adults were also shown in Tabel 1. Responses to temperature changes for individual amino acid for adults (isoleucine, leucine, lysine, methionine, phenylalanine, threonine and valine) were similar to the previous results in histidine and arginine.

Mean values and standard deviation of amino acid shown in HT were 2236.31±20.60 mg/100g, 3761.59±41.2mg/100g,3005.21±38.5 mg/100g, 332.15±6.4 mg/100g, 2548.52±39.8mg/100g, 1979.49±36 mg/100g, and 2180.5±13.5 mg/100g in isoleucine, leucine, lysine, methionine, phenylalanine, threonine and valine, respectively. Whereas, amount of amino acid in LT were 2173.14±19.5, 3666.3±38.5, 3241.75±41.5, 341.99±7.8, 2635.43±49.2, 2047.2±32.25 and 2102.14±12.2 mg/100g in isoleucine, leucine, lysine, methionine, phenylalanine, threonine and valine, respectively.

Enhanced temperature in HT effect on significant ($P \leq 0.05$) increase in isoleucine, leucine, lysine, threonine and valine by 5.04%, 5.87%, 0.57%, 0.16% and 5.6%, respectively when compared HT to CT. We found that, the highest increase under controlled high temperature was recorded in leucine. The consistent results also appeared in low temperature (LT). Under controlled temperature (CT), low temperature influence on significant increase in isoleucine, leucine, lysine, phenylalanine, threonine and valine by 2.3%, 3.42%, 7.82%, 4.8%, 3.5% and 2.1%, respectively. The highest increase under low temperature was shown in lysine.

The results from the experiment, in which Thai soybeans, SJ 5 was grown under temperature changes, reveal that exposure to high temperature and low temperature during growing period led to the significant and obvious reduction in yield. However, we found that high temperature and low temperature evidently increased in 8 essential amino acids in this experiment. The results in seed yield agreed with many previous studies.

Many research have confirmed that temperature is the major environmental factor that influences the vegetative growth processes in plants from the initial stages of development, flower formation, especially during seed filling period when accomulation of the seed chemical components occurs [6,12]. Very low or high temperatures in the growth environment may be detrimental to various metabolic processes in plant tissues such as nutrient uptake, chlorophyll formation, photosynthesis process and damage the plant cell [12]. It was noted that an increase in temperature of 10°C to 15°C above normal growth temperature leads to alteration of photosynthetic pigments and thus limiting photosynthesis [13]. These alterations lead to yield reduction at maturing stage. Hatfield and research team predicted that a 0.8 °C temperature rise would cause a 2.4% decline in soybean yield in the southern USA (current growing season temperature of 26.7°C) [14]. 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 [15].

TABLE 1. AMINO ACID COMPOSITION OF SOYBEAN SEED AS AFFECTED BY DIFFERENT TEMPERATURE LEVELS

Amino acids	**Essential amino acids content (mg/100 g) (average ± SD)**		
	Treatment		
	LT	***CT***	***HT***
Histidine	1382.39±10.23^{b}	1310.08±11.45^{a}	1330.68±11.4^{a}
Arginine	3689.75±18.99^{b}	3464.55±35.4^{a}	4680.19±14.56^{c}
Isoleucine	2173.14±19.5^{b}	2123.5±19.8^{a}	2236.31±20.60^{c}
Leucine	3666.3±38.5^{b}	3540.94±41.02^{a}	3761.59±41.2^{c}
Lysine	3241.75±41.5^{b}	2988.13±29.7^{a}	3005.21±38.5^{b}
Methioni	341.99±7.	333.08±8.	332.145±6

ne	8^{a}	2^{a}	.4^{a}
Phenylalanine	2635.43±49.2^{b}	2510.19±44.8^{a}	2548.52±39.8^{ab}
Threonine	2047.2±32.25^{b}	1976.25±25.80^{a}	1979.49±36^{b}
Valine	2102.14±12.2^{b}	2059.05±14.23^{a}	2180.5±13.5^{c}

Note: The different letters for each treatment in each raw indicate a significant difference at $\rho \leq 0.05$. The average ± SD observed from samples of each treatment.

Low temperature is another major environmental factor that often affects plant growth and crop productivity and leads to substantial crop losses. Low temperature also affect several aspects of crop growth; survival, cell division, photosynthesis, water transport, growth, and finally lead to reduction or crop failure due to direct damage or delayed maturation [16,17]. The results of field study in 2013 at Phitsanulok, Thailand are consistent with these assumptions. Researchers found that soybean seed production, Chiang Mai 60 cultivar is significantly reduced by 40% at temperature above 35°C and below 25°C [5].

Normally, both positive and negative results in amino acid composition associated with temperature stress may occur. These could be explained that the cellular changes induced by either high temperature or low temperature include responses those lead to the excess accumulation of toxic compounds, especially reactive oxygen species (ROS). The end result of ROS accumulation is oxidative stress, then lead to cell death or alterations in nutritional status [7,17]. Some researchers have also reported the effect of temperature on soybean seed amino acid composition. For example, scientists found that higher deposition of sulfur amino acid (methionin and cystine) takes place under elevated air temperature [6]. Normally, heat stress induced oxidative stress to damage membrane properties protein and degradation including reduced amino acids content [18]. However, the results of our experiment were not consistent with the results obtained by those researchers. Results in this experiment showed the increase in essential amino acids content as temperature were increased and decreased. These occurrences can be explained by the fact that under heat stress and cold stress conditions, plants exhibit various mechanisms for surviving which include long-term evolutionary and short-term avoidance mechanisms such as alteration of membrane lipid compositions and biochemical adaptations [7]. Maintenance of stable proteins in a highly organized state is important for proper functions of cells during high temperature stress due to their involvement in metabolic processes and membrane function [18]. These mechanisms can lead to amino acid remaining in plant because proteins are catabolized by proteases into amino acids and derived amino acid [19]. Moreover, there are reports showed that increase in protein are often associated with decreased yield increases in seed protein lead to the amount of sulfur amino acids remaining (Jez, 2008) [19].

CONCLUSIONS

The results reveal that among yield and amino acid parameters examined, the most sensitive component of soybean (under high and low temperature situation) shows in the part of yield as number of seed plant^{-1} and 100-seed weight. High and low temperature stress during growing season strongly reduced seed yield of soybean, SJ 5 cultivar. However, the low and high temperature in this experiment induced the increases in essential amino acids. We conclude that the use of tools which allow for high temperature and low temperature exposure can contribute to assessment of impacts with future temperature changes on yield and some essential amino acids of Thai soybean cultivars.

ACKNOWLEDGMENT

The authors thank Naresuan University, Thailand for the funding supported. This research was also financially supported by the Center for Agricultural Biotechnology, Faculty of Agriculture, Natural Resources and Environment, Naresuan University. We also thank to Office of Agricultural Research and Development, Phitsanulok for soybean seed, SJ5.

REFERENCES

[1] M. Hasanuzzaman, K. Nahar, M.M., Alam, R. Roychowdhury, and M. Fujita, " Physiological, Biochemical, and Molecular of heat stress tolerance in plants," Int J Mol Sci., vol 14(5), pp. 9643-9684, May 2013.

[2] E.M. Bainy, S.M. Tosh, M. Corredding, L. wooddrow and V. Poysa, "Protein subunit composition effects on the thermal denaturation at different stages during the soy protein isolate processing and gelation profiles of soy protein isolates," J Am Oil Chem Soc., vol.85, pp.581-590, 2008.

[3] B. Smitand Cai. Yunlong, "Climate change and agriculture in China," Glob. Environ. Chang., vol. 6, pp. 205-214, 1996

[4] E. Kumagai, and R. Sameshima, “Genotypic differences in soybean yield responses to increasing temperature in a cool climate are related to maturity group,” Agr. Forest Meteorology, vol. 198-199, pp.265-272, November-December 2014.

[5] K. Thanacharoenchanaphas, O. Rugchati, “Impacts of Atmospheric Temperature - Humidity Changes on Yield Quality of Thai Soybean Cultivar,” International Journal of Environmental and Rural Development , vol.6-2, pp. 123-128, September 2015.

[6] C.S. Carrera, C.M. reynoso, G.J. Funes, M.J. Martinez, J. Dardanelli and S.L. Resnik, “Amino acid composition of soybean seeds as affected by climate variables,” Agrometeorology, vol.46. pp. 1579-1587, December 2011

[7] G.L. Hartman, E.D. West and T. K. Herman, “Crops that feed the World 2. Soybean—worldwide production, use, and constraints caused by pathogens and pests,” Food Sec., vol.3, pp. 5–17, January 2011.

[8] J.A. Newman, M. Anand, H.A.L. Henry, S. Hunry and Z. Gedal, Climate Change Biology. Gutenberg Press, Malta, 2011.

[9] R.K. Mall, M. Lal, V.S. Bhatia, L.S. Rathore, and R. Singh, “Mitigating climate change impact on soybean productivity in India: a simulation study,” Agr. Forest Meteorol., vol.121, pp. 113–125, January 2004.

[10] D. Marks, “Climate change and Thailand: Impacts and response,” Contemporary Southeast Asia, vol.33, pp.225-258, August 2011.

[11] A. Limsakul, S. Limjirakan, T. Sriburi and B. Suttamanuswong, “Trends in Temperature and Its Extremes in Thailand,” Thai Environ. Eng. J., vol.25, pp, 9-16, 2011.

[12] S. Nxawe, P. A. Ndakidemi and C. P. Laubscher, “ Possible effects of regulating hydroponic water temperature on plant growth, accumulation of nutrients and other metabolites,” AFR. J. Biochem., vol. 9(54), pp. 9128-9134, December, 2010.

[13] A. K. Tewari, and B. C. Tripathy, “ Temperature-stress-induced impairment of chlorophyll,” Plant Physiol., vol. 117(3), pp. 851-858, 1998.

[14] J.L. Hatfield, K.J. Boote, B.A. Kimnball, L.H. Ziska, R.C.Izaurralde, D. Ort, A.M. Thomson and D. Wolfe “Climate impacts on agriculture: implications for crop production,” Agron. J., vol.103, pp. 351–370, 2011.

[15] D.B. Lobell, and G.P. Asner, “Climate and management contributions to recent trends in U.S. agricultural yields,” Science, vol.299, pp.1032, February 2003.

[16] A. Lukatkin, A. Brazaityte, C. Bobinas and P. Duchovski, “Chilling injury in chilling-sensitive plants: a review,” Žemdirbystė=Agr., vol.99, pp.111-124, 2012.

[17] M. Hasanuzzaman, K. Nahar, and M. Fujita, "Extreme Temperature Responses, Oxidative Stress and Antioxidant Defense in Plants," Chapter 6 in Abiotic Stress - Plant Responses and Applications in Agriculture, http://cdn.intechopen.com/pdfs-wm/43317.pdf. 2013.

[18] Y. He, X. Liu, and B. Huang "Changes in protein content, protease activity, and amino acid content associated with heat injury in Creeping Bentgrass," J.Amer. Soc. Hort. Sci., vol. 130(16), pp. 842-847, 2005.

[19] J. Jez, Sulfur: A Missing link between soils, crops and nutrition, Oxford: American Society of Agronomy, Inc., 2008, pp.238-239.

How to cite this article:
Thanacharoenchanaphas K, Rugchati O. Hanges in yield and essential amino acid composition associated with air temperature stress in thai soybean seeds, sor jor 5 cultivar. J. Fundam. Appl. Sci., 2018, *10(3S), 703-714.*