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Physio-chemical quality of determinate and indeterminate soybean cultivars as influenced by canopy tempreture

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ABSTRACT

The objective of this study was to quantify the effects of canopy temperature on physio-chemical quality of soybean planted on different dates. An experiment was conducted at the Agriculture Research Farm of the NWFP Agricultural University, Peshawar, during 2006 and 2007. Determinate cultivars (Epps, maturity group [MG] V) and indeterminate cultivar, Williams 82 [MG] 111) were planted on May 1st to August 1st at one month interval during both years. Data was recorded on canopy temperature and physio-chemical attributes of soybean. Heat indices were calculated from canopy maximum and minimum temperatures for the periods between growth stages starting from beginning of bloom to physiological Maturity (R3-R7). Physio-chemical attributes were regressed on different heat indices. Canopy temperature during reproductive growth stages of R4-R5, R5-R6 and R6-R7 had pronounced effect on physio-chemical quality of soybean. Increase in mean averaged temperature in the range of 23-30^{o}C during growth stage of R6-R7 improved germination, field emergence, and increase seedling dry weight, protein and oil contents of soybean seed. Whereas, increase in mean temperature averaged in the range of 23 to 30^{o}C during reproductive growth stage of seed beginning to full-seed (R5-R6) reduced germination, field emergence, electrical conductivity, protein and oil contents of soybean seed. Increase in maximum temperature in the range of 32 to 37^{o}C during growth stage of full bloom to seed initiation (R4-R5) decreased seedling dry weight and oil content of soybean seed.

Key words: Seed Quality, Vigor, Varieties, Canopy Temperature, and Reproductive growth stages

INTRODUCTION

Soybean [*Glycine max (L.) Merr.*] is an important crop and is grown across a wide range of agro-geographical regions from China to Brazil and from Oceania to Canada (Bond *et al.*, 1985). Maximum of the cultivated area is in the semi-arid tropics (FAO, 2000). Quality seed is a key component of a successful crop production and is needed to ensure adequate plant populations in a range of field conditions. Unfavorable environmental conditions especially high temperature stress during growth and development in the field causes significant losses in yields of Brassica napus (L.) (Angadi *et al.*, 2000), Lycopersicon esculentum (Mill) (Peet *et al.*, 1998; Sato *et al.*, 2002), Phaseolus vulgaris (L.) (Shonnard and Gepts;1994), Triticum aestivum (L.) (Saini *et al.*, 1983) and Zea mays (L.) (Carlson, 1990). High temperatures reduces seed yield and quality in growth chamber and phytotron experiments (Egli *et al.*, 2005). Temperatures of 35/30°C (day/night) (Gibson and Mullen, 1996) 38/33°C (Spears *et al.*, 1997), and 38/27°C (Egli *et al.*, 2005) during seed filling reduced germination of seed from several cultivars. Reproductive growth periods (R1 to R7) of soybean are more sensitive to high temperature. Temperatures that reduced seed quality in controlled environments (32 to 38°C) could occur in the field during reproductive periods of soybean. It is difficult to extrapolate the results of growth chamber and phytotron experiments to the field.

Temperatures in the field vary diurnally and plants exposed to high temperature stress for the entire photoperiod have harmful effect on various reproductive growth of soybean. The sensitivity of reproductive development in soybean to high temperature stress is not well understood under the agro-climatic conditions of NWFP-Pakistan. Therefore, our objective was to evaluate the relationship between high temperatures during reproductive growth stages on physio-chemical quality of soybean planted on four dates for two connective years under Peshawar environment of NWFP-Pakistan.

MATERIALS AND METHODS

The experiment was carried out at the Agriculture Research Farm of the NWFP Agricultural University Peshawar, during summer 2006 and 2007. The experimental site is located at 34^{o}N latitude and at an altitude of 450 meters above sea level and has a continental climate with very high temperature in summer. Indeterminate variety Williams 82 and determinate variety Epps were planted on May to August at one month interval during both years. The experiment was laid out in randomized complete block design with split plot arrangement having four replications. Twelve combinations of the four planting dates and three plant densities were allotted to main plots and varieties were allotted to sub-plots. A sub plot size of 4m x 5m was established to accommodate 8 rows 50cm apart and hill to hill distance of 10 cm were used. Hills were thinned to leave 1, 2, 3, plants hill^{-1} corresponding to 20, 40, and 60 plants m^{-2} at V2 stage (2nd node with fully developed trifoliate leaf at node above the unifoliate nodes). Normal cultural practices were followed and the plots were hand weeded. Daily maximum and minimum temperatures inside canopies of all the 96 experimental units were recorded by placing maximum and minimum thermometers at 4th node from R3 (the beginning of pods 5 mm long at one of the four upper most nodes on the main stem with a fully developed leaf) onward. Reproductive growth stages (Fehr and Caviness, 1977) were determined at approximately weekly intervals. Canopy mean maximum, mean minimum and mean average temperatures were calculated for the five reproductive growth stages starting from R3-R4, R4-R5, R5-R6, R6-R7 and R7-R8. Germination, vigor and chemical quality of soybean were regressed on 15 canopy heat indices during the above mentioned growth stages to quantify the effect of canopy temperature on physio-chemical quality of soybean varieties (Egli *et al*., 2005). (SAS ProcGLM; 1990) was used for all regression analysis and comparison.

RESULTS AND DISCUSSION

Seed Quality

Four canopy temperatures had significantly affected soybean germination (Table 1). Average canopy temperature in the range of 20-30°C has positive effect on germination of soybean seed during growth stages of full-seed to physiological maturity (R6-R7) and from physiological maturity to harvest maturity (R7-R8), whereas, means minimum canopy temperature during growth stage of full bloom to beginning of seed (R4-R5) showed a slight positive effect on germination of soybean. An increase in germination was observed at the rate of 1.04% per 1^{o}C increase in mean temperature during growth stage of (R6-R7). The improvement in germination during this range of temperature (20-30°C) and growth stages may be due to proper seed development and accumulation of dry matter. Soybean germination was negatively affected by average canopy temperature during growth stage of seed beginning to full-seed formation (R5-R6). Gibson and Mullen (1996) found similar results and stated that high temperature lowered germination and vigor when applied during the first 10 to 30 days of seed development period. Germination and vigor of seed were consistently lowered as days of the high temperature accumulated throughout the seed filling period. Zanakis *et al*; (1994) stated that germination decreased 28%, vigor declined 24mg and seedling^{-1}(38%), when the plants were exposed to high temperature stress (35-43^{o}C) during seed development and maturation periods.

Field Testing

The canopy temperature during growth stage of full-seed to physiological maturity (R6-R7) had the greatest positive effect on seedling dry weight and field emergence of soybean (Table 1).

Table1:Canopy temperature variables selected by SAS stepwise procedure for physio-chemical quality attributes of soybean.

Variable	Growth Stage	Temperature Range (^{o}C)	Parameter Estimate	F-Value
A. Germination				
Intercept MTa.	–	-	1.8169	2.14
MTa.	R7 –R8	20 – 30	0.6176	31.92**
MTa.	R6 – R7	23 – 29	0.6850	47.40**
MTm.	R5 – R6	23 – 30	-0.3405	11.76**
MTm.	R6 – R7	14 – 25	-0.0235	3.17
	R4 – R5	26 – 30	0.0895	8.57**
B. Electrical Conductivity				
Intercept	–	_	3.2043	5.35
MTa.	R6 – R7	23 – 29	1.6084	549.81***
MTa.	R5 – R6	23 – 30	-0.6477	81.68***
TMx.	R3 – R4	32 – 37	-0.0574	3.69***
C. Seedling dry weight				
Intercept	–	_	1.3829	0.10
MTa.	R6 – R7	23 – 29	1.0627	186.12***
MTa.	R4 – R5	26 – 30	0.5338	40.53***
TMx.	R4 – R5	31 – 37	-0.5591	28.82***
D. Field emergence test				
Intercept MTa.	–	_	4.5491	4.43
MTa.	R6 – R7	23 – 29	1.3920	59.97***
MTm.	R5 – R6	23 – 30	-0.8330	23.09***
TMx.	R7 – R8	10 – 24	-0.0446	3.62
	R4 – R5	31 – 37	-0.3349	2.88**

*, **, *** = Means squares significant at the 0.05, 0.01 and 0.001 probability levels, respectively

Seedling dry weight and field emergence improved at the rate of 1.10 and 1.40% per 1^{o}C increase in temperature during R6 to R7 growth stages. Average maximum canopy temperature (31-37°C) negatively affected the seedling dry weight and field emergence of soybean at growth stage of full bloom to seed initiation (R4 to R5). This decrease in field emergence rate during R5 to R6 growth stage may be due to increase in diurnal temperatures which expose the developing seed to high temperature resulting in reduced seed growth rate and duration (Dornbos and Mullen, 1991). Spears *et al*;(1997) interrelated maximum daily temperature during seed maturation with seed germination and field emergence, and found that plants matured during hot, dry conditions produced seeds of inferior quality. Prasad *et al.* (1999) found that vigor reduced in peanut plants when exposed to high temperature stress during the last 40 days of seed growth. Mean maximum canopy temperature during R4 to R5 growth stage decrease seedling dry weight of soybean. The decrease in seedling dry weight demonstrates that soybean is sensitive to high temperature (31 to 37^{o}C) during these growth periods. Keigley and Mullen (1986) stated that high temperature lowered germination and vigor, when applied during the first 10 to 30 days of seed development. The linear relationship of germination and seedling dry weight with increase in high temperature explains most of the variation in seed germination and seedling vigor. The previous studies found that the duration of seed growth in soybean was relatively insensitive to increases in day temperature over a range of 20 to 30^{o}C, but was reduced when day temperatures were 33^{o}C or greater (Dornbos and Mullen, 1991). Seedling dry weight and electrical conductivity decreased with maximum canopy temperature (31-37^{o}C) during R3 to R4 and R4 to R5 growth stages.

Nutritional Quality

The average canopy temperature during growth stage of full-seed to physiological maturity (R6-R7) had positive effect on protein and oil contents of soybean (Table 2).

Table 2: Canopy temperature variables selected by SAS stepwise procedure for protein and oil percentage of soybean.

Variable	Growth Stage	Temperature Range (^{o}C)	Parameter Estimate	F-Value
A. Protein percentage				
Intercept	–	–	4.9657	1.94
MTa.	R6 – R7	23 – 29	1.5265	103.42***
MTa.	R5 – R6	23 – 30	-0.6082	13.22**
MTm.	R6 – R7	14 – 25	0.0733	6.00*
TMx.	R6 – R7	30 – 36	-0.1237	2.94
B. Oil Percentage				
Intercept	–	–	0.0502	0.00
MTa.	R6 – R7	23 – 29	1.4467	188.89***
MTa.	R5 – R6	23 – 30	-0.3595	8.67*
TMx.	R6 – R7	30 – 36	0.3414	34.76**
TMx.	R4 – R5	31 – 37	-0.4295	52.18**

*, **, *** = Means squares significant at the 0.05, 0.01 and 0.001 probability levels, respectively

Abbreviations: MTa = Mean Temperature average
MTm= Mean Temperature minimum
TMx = Temperature maximum

Protein and oil content increased at the rate of 1.5% and 1.4% per 1^{o}C increase in temperature during the said growth period. Mean minimum canopy temperature (14-25^{o}C) during R6 to R7 growth stage exerts a slight positive effect on protein content. Maximum canopy temperature in the range of 30-37 ^{o}C during growth stages of R4 to R5 and R5 to R6 has negatively affected the protein and oil contents of soybean. Thomas *et al*; (2003) reported that protein content of soybean increased as the growth temperature increased up-to 40/30°C and then decreased dramatically. There was a tendency for increase to decrease N concentration in seed, especially at cooler temperatures. The effect of temperature on N concentration was linear (P = 0.001) and quadratic (P = 0.004). Thomas *et al*; (2003) observed that total oil concentration was highest at the 32/22°C temperature treatment in both years and decreased at temperature above 32/22°C. Oil concentration was linearly related to temperature. The concentration of oleic acid increased linearly whereas that of linolenic acid decreased linearly with increase in temperature. There was a slight quadratic temperature effect on oleic acid in both years. Temperature responses for these two fatty acids were generally quite comparable. The concentrations of palmitic, stearic and linoleic acid in the extracted seed oil did not change significantly due to temperature. These results are in line with the published results of (Wolf *et al.*, 1982) and Wu and Wei. (1992) who stated that accumulation of fat in different periods varied depending on temperature, day length and rainfall. Both maximum and average canopy temperatures during R4 to R5 and R5 to R6 had negatively affected the oil content of soybean. Suryavanshi *et al*. (1993) reported similar results and stated that early sowing significantly improve the quality of sesame and gave more oil (%) as compared with late sowing. McGregor (1991) determined that pod abortion increased when later seeding dates delayed anthesis to a warmer part of the growing season.

CONCLUSIONS

Temperature stress in the range of 35-43^{o}C during reproductive development R1-R7 of well watered plants under field conditions were detrimental to physio-chemical qualities of soybean seed and were an important factor in determining the yield and quality of both determinate and indeterminate cultivar. Our results indicate that high temperature stress during flowering and pod development had larger effect on seed set and seed filling duration. Pod formation depends on the stress events occurring before and during flowering but seed development and maturation were highly susceptible to high temperature stress. Avoidance of hot weather during seed development and maturation by optimal planting date for soybean cultivar and management factors that shorten the length of high temperature stress during reproductive growth stages will result in maximum yield and better quality seed. The factors within the seed that influence high temperature deterioration requires further study because soybean seed production areas are often vary in the length and degree of high temperatures during seed development and maturation period.

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