Physiological traits and yield of three soybean (*Glycine max* (L.) Merr.) genotypes as affected by water deficiency

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SUMMARY

Soybean is a very important legume; it has the highest protein content, and it is a very important source of vegetable oil. Soybean is drought-susceptible, and drought is one of the major abiotic stresses that has been increasing over the past decades as a result of the global climatic changes. To evaluate the influence of drought stress, three soybean genotypes were grown under rainfed conditions, and compared to irrigated controls. The obtained results showed that the chlorophyll content, leaf area index and plant height decreased under drought stress conditions, which led to noticeable and sometimes significant yield reduction. Our results suggest more specific studies on the physiological changes of the local soybean genotypes under drought stress to better select the adopted ones.

Keywords: Soybean, drought stress, yield, chlorophyll content, leaf area index

INTRODUCTION

Soybean (*Glycine max* (L.) Merr.) is a very important crop for both human consumption and animal feeding because of its high content of protein and oil (Liu et al. 2008). Compared to other legumes, soybean seeds have the highest protein concentration, and are one of the highest in oil concentration, they also contain carbohydrates, minerals and other components (Miransari 2016). Soybean is mostly sown under rainfed conditions, and the current global climatic changes have put this crop under many abiotic stresses with drought stress being the most influencing hazard, because soybean is known to be drought-susceptible crop (Liu et al. 2004, Oh and Komatsu 2015). Drought restrains soybean growth and leads to yield reduction by around 40% (Manavalan et al. 2009). Moreover, Ishibashia et al. (2011) reported that flowering stage is the most sensitive to drought stress; Ohashi et al. (2006) recorded 20% yield reduction when soybean was subjected to drought stress during the vegetative stages, whereas the reduction reached about 46% in the flowering stage; similar results were introduced by Cui et al. (2013). Turner et al. (2005) reported yield reduction by 20% under drought conditions during seed filling.

Many physiological changes in soybean plants occur as a result of drought stress; these changes lead to growing and development confictions (Reynolds and Tuberosa 2008). The leaf area index (LAI) is the canopy density of a crop population, and has an important effect on the final yield (Liu et al. 2008). Dong et al. (1979) reported a positive correlation of (LAI) with grain yield of eight cultivars; however, each cultivar had a different leaf size, leaf shape and leaf development (Chang 1981). Shading happens to the lower leaf levels and consequently reduces the (LAI), but still, drought stress decreases the (LAI) more than mutual shading does (Liu et al. 2008).

Chlorophyll content is one of the most important physiological traits, as it reflects the potentials of plant photosynthesis, and consequently, the yield potential. Drought stress influences the chlorophyll content and reduces its value as presented by many researchers; Makbul et al. (2011) recorded significant reduction in chlorophyll content by 28% in drought-stressed soybean, whereas Hao et al. (2013) found it to be 31% compared to control plants. Similar results were previously provided by Atti et al. (2004).

Plant height shows the ability of the soybean plants to produce more nodes, and consequently more flowers, pods and seeds. Navari-Izzo et al. (1990) reported a reduction by 4.3% of soybean seedling height when subjected to drought stress; later, other papers reported similar conclusions at different stages of soybean lifecycle (Atti et al. 2004, Hao et al. 2013, Mak et al. 2014).

It is normal, taking into consideration the above-mentioned traits, that the final seed yield will be affected by drought stress; all the previous studies on soybean, under water deficit, reported significant yield loss (e.g. Sadeghipour and Abbasi 2012, Li et al. 2013) regardless of the stage when the drought stress was applied (for example, during pod formation (Sionit and Kramer 1977), or during seed filling (Maleki et al. 2013). The different soybean genotypes were reported to show different yield reductions under drought stress conditions (Bellaloui and Mengistu 2008, He et al. 2016).

The aim of this paper was to study the changes in chlorophyll content, leaf area index, plant height and yield of three different soybean genotypes under certain drought stress conditions.

MATERIALS AND METHODS

Three soybean genotypes, *ES Mentor*, *ES Gladiator* and *Pannonia kincse*, were sown in Debrecen University’s experimental site (Látókép) (N. latitude 47°33’, E. longitude 21°27’) on April 26th, whereas the harvest was on September 1st for *ES Mentor*, and on September 15th, 2017 for both *ES*.
RESULTS AND DISCUSSION

Leaf Area Index (LAI) was lower for the drought stressed plants of the three genotype, compared to the well-watered plants. Moreover, the difference was significant during the flowering stage for both genotypes ES Mentor and ES Gladiator (Figure 2). Sinclair and Serraj (1995) reported drought stress to cause a reduction in leaf area, and thus reduced protein synthesis and led to yield reduction (Purcell and King 1996). Drought stress reduces the active photosynthetic leaf area and the interception of radiation by the crop canopy, which decreases seed yield (Sinclair et al. 1981, Monteith and Scott 1982). Dong et al. (1979) reported a positive correlation between LAI and grain yield, which was noticed in our experiment, as the non-stressed plants of the three genotypes had higher LAI in all three studied stages, and also higher yields. Jin et al. (2004abcd) concluded that increased LAI during reproductive stages was correlated with increased soybean yield, which was previously reported more specifically as soybean yield was positively related to LAI at R5 (beginning of seed filling) stage (Wells et al. 1982, Kumudi 2002). Regardless of the maturity group, LAI value was the highest during the seed filling stage for both the drought-stressed and the control plants, which is consistent with the findings of Liu et al. (2005) who concluded that genotypes of different maturity groups during the reproductive stages revealed similar LAI tendency; LAI was the highest during seed filling stage (R5) and then it gradually decreased.

For the three studied genotypes, chlorophyll content wasn’t affected by drought stress very much during the vegetative and flowering stages; it was even higher sometimes for the drought-stressed plants than for the well-watered ones with no significant differences. This could be understood as the precipitation was fairly high during that stages (Figure 1). However, when plants reached the seed filling stage, the chlorophyll content was considerably lower under drought stress, and the difference was significant for both genotypes (ES Mentor and Pannonia kinse) during the flowering stage for both drought-stressed and the control plants, which is consistent with previous studies (Cui et al. 2004, Pagter et al. 2005). Makbul et al. (2011) recorded a significant decrease in chlorophyll content by 28% and Hao et al. (2013) by 31% of drought-stressed soybean compared to control plants. Similar results were provided by Atti et al. (2004), Chang (1981) concluded that high yield could be achieved by an increased LAI.

When well-watered, Chlorophyll content during the seed filling stage for the three genotypes seemed to affect the yield, as the yield was higher when the chlorophyll content was higher (Figure 2).
Water stress affected the plant height, as the plants of the three genotypes showed greater value when not subjected to water stress; the difference was insignificant for genotype ES Gladiator (Figure 1), which is consistent with the results of Sionit and Kramer (1977) who reported no significant differences in plant height under drought stress, whereas it was significant for both ES Mentor and Pannonia Kinca genotype, which is consistent with many previous studies (e.g. Kadhem et al. 1985, Demirtas et al. 2010). Hossain et al. (2014) reported that progressive drought stress significantly decreased plant height of soybean genotypes, but the drought-susceptible genotype response to drought stress was more obvious and plant height was about 44% of the control plants, whereas the drought tolerant genotypes reached about 58% (Hossain et al. 2014).

The yield was higher for the well-watered plants compared to the drought stressed ones in the three studied genotypes; moreover, the difference was significant for the genotype ES Monitor, whereas it was not significant for the other two studied genotypes (Figure 1). All the previous studies reported a yield reduction under drought stress, although different timings of drought stress application were suggested to have different yield loss amounts (e.g. Turner et al. 2005, Demirtas et al. 2010, Maleki et al. 2013).

**CONCLUSIONS**

Water deficit has noticeable effects on the soybean physiology and yield. Different soybean genotypes show different reactions against water deficit, but they all tend to have less chlorophyll content, less leaf area index, less plant height under drought stress conditions, which leads to considerable yield losses. Although a one-year experiment is not enough to conclude precise results, it still gives an initial idea on how water deficit may affect the studied soybean genotypes; more demonstrative conclusions can be made after two or three years of experiments. Further studies should also be carried out to detect the most sensitive stage of the current soybean genotypes to drought stress.
REFERENCES


