Tropentag 2017, Bonn, Germany
September 20-22, 2017

Conference on International Research on Food Security, Natural Resource Management and Rural Development
organised by the University of Bonn, Bonn, Germany

Production and Physiological Characters of Soybean Under Drought Stress with Foliar Application of Exogenous Antioxidant

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Abstract

Climate change is a serious threat to the agricultural sector. and it is one of the causes of drought as a major environmental stress factor that affects the growth and development of plants. Drought stress in soybean as one of the food crops of protein sources, will have a serious impact on changes in plant growt and yield, physiological and biochemical aspects of plant cell damage due to oxidative stress caused by increased free radical accumulation in the form of reactive oxygen species in plants. One approach for improving the tolerance of oxidative stress in soybean under drought stress is the application of exogenous antioxidants. The aim of the research was to investigate the effect of foliar application of exogenous antioxidant on production and physiological characters of soybean under drought stress. The research used a factorial randomized block design with 2 factors and 3 replications. The first factor was drought stress treatment, namely 80%, 60% and 40% of field capacity. The second factor was the foliar application of exogenous antioxidant consisted of without exogenous antioxidant application ; salycilic acid (500 ppm), ascorbic acid (500 ppm), α-tocopherol (500 ppm) and chitosan (500 ppm). The results suggest that increased drought stress conditions caused for decreasing of stomatal density, total chlorophyll, total leaf area, relative water content, number of filled pods and 100-seeds dry weight. Effect of ascorbic acid as an exogenous antioxidant increased the chlorophyll total, total of leaf area, number of filled pods and relative water content, while chitosan treatment increased stomatal density. Effect of foliar application of exogenous antioxidants on drought stress showed the important of the role of exogenous antioxidants in reducing the effect of water stress on production and physiological characters of soybean.

Keywords: antioxidant exogenous, drought stress, physiological, production, soybean

Introduction

Climate change is a serious threat to the agricultural sector. and it is one of the causes of drought as a major environmental stress factor that influence plant growth and development. and limit plant production (Bohnert and Jensen, 1996 ; Murshed *et al*., 2013). It is estimated that yield losses in agricultural crops due to drought is 17% (Ashraf *et al*., 2008).

Soybean is very sensitive plant to drought conditions during vegetative and reproductive growth. since soybean is classified as dehydration-sensitive species that require optimum water quantity in the seed germination phase. seed growth and plant growth (Chen *et al*., 2006). Drought stress in soybean may affect plant growth. anatomical. morphological. physiological or biochemical aspects (Manalavan *et al.*, 2009). Drought affects plant growth and development with consequence reductions in the rate of cell division and elongation, leaf area, root and stem growth, interrupted stomatal conductance and water use efficiency, which makes photosynthesis very sensitive to drought (Farooq *et al*., 2009). The detrimental effects of drought on plant growth and development depend on the severity of stress and the crop growth stage. Nutrients require water for uptake and translocation. As water supply decreases, nutrient uptake does (Farooq *et al*., 2012).

Based on the background, the aim of the research was to investigate the effect of foliar application of exogenous antioxidant on production and physiological characters of soybean under drought stress.

Materials and methods

Polybag experiments was conducted in a screen-house at the Faculty of Agriculture. Universitas Sumatera Utara. Medan Indonesia. Analysis of stomatal density and total chlorophyll content was conducted in Physiological Laboratory of the Faculty of Mathematics and Natural Science. Universitas Sumatera Utara Medan.

Seeds of soybean (cv. Wilis) were used. Selection of the cultivar referring to previously experiment conducted by Hasanah (2015). Air-dried soybean seeds were sown along a centre row in each polybag (30 cm in diameter) at a depth of 40 cm, in approx. 10.0 kg of air-dried soil. Before planting liming with dolomite (500 kg/ha) and incubated for 3 weeks. Polybag had previously been covered with plastic. A granular commercial *Rhizobium* sp. was incorporated into the top 30 mm of soil in each pot with the seeds at the time of sowing. Granular of triple superphosphate [46% P_2O_5] was applied at a rate of 100 kg P_2O_5 ha^{-1} and potassium chloride [60% K_2O] applied at a rate 75 kg K_2O/ha into the soil in each poly bag immediately before sowing. Granular of Urea [45% N] fertilizer was applied at a rate of 50 kg N ha^{-1}, was given half the dose of N fertilizer at planting time and the rest at 4 week after planting (WAP).

The research was arranged in a Factorial Randomized Block Design with two factors. Three replicates was used. The first factor is drought stress treatment consisted of 80%. 60% and 40% of field capacity (FC). The second factor is foliar application of exogenous antioxidant consisted of without exogenous antioxidants ; 500 ppm of salicylic acid, 500 ppm ascorbic acid, 500 ppm of α-tocopherol and 1 mg/mL of chitosan. Foliar application of exogenous antioxidant carried out in accordance concentrations on 2 week after planting (WAP) to R6 with an interval of once a week

Determination of soil water content to determine the weight of air-dry soil that will be incorporated into the poly bag carried by the drying method (Foth, 2004), while the determination of water content at field capacity (FC) was conducted using a hydrometer Bouyoucos (Foth, 2004). Treatment 80% of FC done since the time of planting until harvest. In the treatment of 60% and 40% of FC, the application of water initially as much as 80% of FC performed each up to 4 WAP, after that, the plant in poly bag watered with a certain volume once a day to maintain water levels in the poly bag until it reached each treatment of FC by the gravimetri method (Foth, 2004).

Preparation of antioxidant exogenous refered to standard procedures. Autoclaved stock solution of 120^{o}C for 20 minutes. and sterile distilled water to obtain a final concentration of chitosan solution 1 mg/mL. Antioxidant exogenous, salicylic acid, ascorbic acid and α-tocopherol dissolved in distilled water and diluted to concentrations (500 ppm).

Parameters observed was stomatal density, chlorophyll total content, leaf area total, 100-dry seeds weight, number of filled pod and relative water content. Chlorophyll content refers to Arnon (1949) methods for chlorophyll extraction. relative water content refers to the method described by Gonzalez and Gonzalez (2001).

All data were subjected to an analysis of variance (ANOVA) for a factorial randomized block design according to the procedure outlined by Gomez and Gomez (1984). Statistically significant differences between means were separated at $P \leq 0.05$ using Duncan's Multiple Range Test.

Results and Discussion

Based on Table 1 showed that the interaction between exogenous antioxidant and drought stress significantly affected to stomatal density and chlorophyll total content. Increased drought stress (80% - 40% of FC) tends to decrease stomatal density, chlorophyll total content, leaf area total, 100-dry seeds weight, number of filled pod and relative water content. The obtained results are in agreement with those results reported by Heba and Samia (2014) and Qados (2014). It is well known that drought stress conditions cause a biochemical and physiological changes, there by affecting plant growth and development. A decline in plant growth in response to water stress might be due either to decreases in cell elongation resulting from the inhibiting effect of water shortage on growth-promoting hormones which, in turn, lead to decreases in cell turgor, volume and eventually growth. Water-stress conditions cause a marked suppression in plant photosynthetic efficiency, mainly due to the closing of stomata and inhibition of (Rubisco) enzyme ((Boutraa, 2010 ; Lawlor and Cornic, 2002).

Table 1. Physiological and production of soybean with foliar application of exogenous antioxidant under drought stress conditions

Parameter observed	Drought stress (K) (% of field capacity)	Exogenous antioxidant (A)					Mean
		Without exogenous antioxidant (A_0)	Salicilyc acid (A_1)	Ascorbic acid (A_2)	α-tocopherol (A_3)	Chitosan (A_4)	
		………………………… unit ……………………………….					
Stomatal density	80 (K_1)	0.85bcde	0.45f	0.84bcde	1.23ab	1.44a	0.96
	60 (K_2)	0.97bcd	0.88cdef	0.63def	0.88cdef	1.08abc	0.89
	40 (K_3)	1.00bcd	0.52ef	0.61def	0.68def	0.41f	0.64
	Mean	0.94	0.62	0.69	0.93	0.97	0.83
		………………………… mg/L ……………………………….					
Chlorophyll Total	80 (K_1)	4.49a	3.71bcd	3.61bcd	3.61bcd	4.02ab	3.88
	60 (K_2)	3.99ab	3.54bcd	3.94ab	3.41bcd	3.85abc	3.74
	40 (K_3)	3.98ab	3.22cd	3.97ab	3.09d	3.16d	3.48
	Mean	4.15	3.49	3.88	3.37	3.68	
		………………………… cm^2 ……………………………….					
Leaf area total	80 (K_1)	2321.30	1962.95	2746.69	2299.60	2624.54	2044.89
	60 (K_2)	2110.32	1523.64	2314.76	2355.03	2200.72	1992.84
	40 (K_3)	1418.34	910.16	1919.00	1785.34	1456.40	1952.03
	Mean	1949.99	1465.58	2326.82	2146.66	2093.88	
		………………………… g ……………………………….					
100-seeds dry weight	80 (K_1)	9.15	9.86	8.76	9.00	8.71	9.09
	60 (K_2)	8.56	9.29	7.93	9.18	9.28	8.85
	40 (K_3)	9.16	8.38	8.64	8.92	8.40	8.70
	Mean	8.95	9.18	8.44	9.04	8.80	8.88
		………………………… pod ……………………………….					
Number of filled pod	80 (K_1)	41.22	49.89	40.22	42.78	38.11	41.67
	60 (K_2)	38.00	41.33	43.00	39.11	41.78	41.29
	40 (K_3)	37.33	34.56	42.78	40.33	42.56	39.64
	Mean	38.85	41.93	42.00	40.74	40.81	40.87
		………………………… % ……………………………….					
Relative water content	80 (K_1)	32.88	33.61	32.81	34.06	36.92	33.13
	60 (K_2)	32.31	31.36	33.70	30.77	32.32	32.33
	40 (K_3)	29.55	27.93	28.43	26.35	25.62	28.26
	Mean	31.58	30.97	31.65	30.39	31.63	31.24

The numbers followed by the same letters and parameter observed show no significant difference based on Duncan's Multiple Range Test at the level $P \leq 5\%$.

The foliar application of exogenous antioxidant, drought stress and interaction between exogenous antioxidant and drought stress have no significant effect on the leaf area total, 100-dry seeds weight, number of filled pod and relative water content. The foliar application of exogenous antioxidant salicylic acid tends to increase 100-seed dry weight compared to other treatments, while application of ascorbic acid tends to increase number of filled pod compared to other treatments. The effect of 80% drought stress treatment and salicylic acid antioxidant resulted in the highest 100-dry seed weight and number of filled pod. The exogenous antioxidant treatment of ascorbic acid tends to increase the relative water content compared to other treatments. The effect drought stress (80% of FC) and chitosan antioxidants resulted in the highest relative water content.

Conclussion

Increased drought stress conditions caused for decreasing of stomatal density, total chlorophyll, total leaf area, relative water content, number of filled pods and 100-seeds dry weight. Effect of foliar application of exogenous antioxidants on drought stress showed the important of the role of exogenous antioxidants in reducing the effect of water stress on production and physiological characters of soybean.

Acknowledgment

The authors gratefully thank University of Sumatera Utara for financing and supporting this work.

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