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Response of soybean genotypes introduced from South Korea to drought stress during reproductive stage

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Abstract. *Purwantoro, Suhartina, Nugrahaeni N, Sulistyo A. 2017. Response of soybean genotypes introduced from South Korea to drought stress during reproductive stage. Biodiversitas 18: 15-19.* Soybean is mostly planted in wetland (paddy field) during dry season. The plant is frequently suffered from drought which lead to low productivity. Cultivar tolerant to drought is needed in an attempt to increase productivity. Instead of high productivity, short duration and large seed size are soybean characteristics preferred by soybean farmers in Indonesia. Research aimed to assess response of soybean introduction genotypes to drought stress during reproductive phase were conducted during dry season of 2012. Genotypes used in the study were twenty soybean genotypes introduced from South Korea and three check cultivars (Mutiara, Grobogan, and Dering 1). The trials were conducted in the field at Kendalpayak Experimental Farm and under rain-shelter in Kendalpayak, Malang, East Java, Indonesia. Each genotype was planted in a single row of 2 m length, with no replication. Plant spacing was 40 cm x 15 cm. Fertilizers i.e. 100 kg ha^{-1} of Urea, 100 kg ha^{-1} of SP36, and 75 kg ha^{-1} of KCl were applied entirely at planting time. The plants were irrigated twice, at planting and at flowering time, and then subjected to drought stress during reproductive phase. Observations included days to flowering, days to maturity, plant height, number of branches, number of fertile nodes, number of pods, number of empty pods, weight of 100 seeds, and seed weight per plant. Results showed that five out of the 20 tested genotypes were resistant to drought stress during reproductive phase comparable to the check cultivar Dering 1. Four of them, i.e. Daewon, Ilmi, Jangmi, and Mausu, including large seed size and short duration. Those characteristics can be used to improve seed size and plants maturity of the existing drought tolerant cultivar.

Keywords: *Glyine max,* introduction, genotype, drought stress, reproductive phase

INTRODUCTION

Soybean in Indonesia is mostly planted in the dry season (July-October) and is frequently experience of drought stress during reproductive phase. Flowering, pod formation, and seed filling phases are critical periods of soybean plants to drought stress. Drought stress during flowering phase causes flowers and young pods abortion. If the drought continues through pod formation and seed filling phases, it will lead to yield decrease through decreasing number of pods per plant (Whigham and Minor, 1978). Drought that occurred during the two phases also cause imperfect seed filling and poorly-filled seeds. Those stresses cause smaller seeds and yield decrease (Momen et al. 1979).

Soybean yield decrease due to water deficit range between 11.7% and 44.9% depending on levels and time of drought stress (Saitoh et al. 1999; Sincik et al. 2008). The stress during generative phase can reduce soybean yield by 34% (Suhartina and Arsyad 2005). Higher yield decrease was found under green house study and the plant was imposed to drought stress during the generative phase (Suhartina 2001; Suhartina et al. 2002).

Dering 1 is the first soybean cultivar released officially in Indonesia as tolerant to drought stress during reproductive phase. The cultivar was released in 2014, and is classified as medium maturity (82 days), medium seed size (12 g/100 seeds), and provides 2.0 t/ha yield average. Improvement of the drought tolerant soybean variety needs to be done, especially for seed size and maturity days. However, existing soybean germplasm for improving the characters are limited, therefore we were introducing germplasm South Korea in an attempt to broaden the diversity of the two characters. Introduced of soybean genotypes that have high adaptability with good agronomic characters and a higher yield than the check varieties has the potential to be released as a new high yielding varieties. In addition, the genotypes can be used as a source of genes or parent in improved varieties.

Drought stress tolerance assessment can be based on the plant characters, both morphological and physiological, such as pattern of rooting depth, number of stomata, osmotic adjustment, and changing of cell wall elasticity (Sammons et al. 1980; Ku et al. 2013; Devi et al. 2014). However, several studies showed that there was no consistent correlations between those characters' changes and yield. Therefore, yield and yield stability are still the main basis of drought tolerance assessment. Several studies have concluded that selection of drought stress tolerance would be more efficient when is done on reproductive period (Hura et al. 2007). It is suggested that selection for soybean tolerance to drought and high yield should be done under optimal and drought stress conditions and was based on grain yield (Nalampang et al. 1989).

The purpose of this study was to assess the adaptation of soybean genotypes introduced from South Korea under drought stress during reproductive phase .

MATERIALS AND METHODS

Two experiments were conducted during the dry season of 2012, i.e. field experiment and rain-shelter experiment. Both of the experiments were conducted at Kendalpayak, Malang, East Java, Indonesia. Material used in the study were 20 soybean genotypes introduced from South Korea (Cheongdu 1, Cheongja 3, Daehwang, Daemang, Daemang 2, Daepung, Daewon, Danweon, Geomjeong, 3, Geonjeongsaeol, Jangmi, Ilmi, Jinpumkong 2, Mansu, Punsan namul, Saonyu, Shinpaldakong 2, Sodam, Songhak, Taekwang) and three check cultivars, i.e. Mutiara used as large seed size check cultivar, Grobogan used as a check of sensitive genotype with early maturity and large seed size, and Dering 1 used as drought resistant check.

Each genotype was planted in a single row of 2 m length and without replication. Plant spacing was 40 cm x 15 cm. Fertilizers i.e. 100 kg ha^{-1} of Urea, 100 kg ha^{-1} of SP36, and 75 kg ha^{-1} of KCl were applied entirely at planting time. Irrigation was only given at planting and flowering time, and for drought stress condition during the reproductive phase. Observations included days to flowering, days to maturity, plant height, number of branches, number of fertile nodes, number of pods, number of empty pods, weight of 100 seeds, and weight of seeds per plant. Supporting data collected were pF curve and soil water content. The pF curves made at pF 0; 2.0; 2.5; 3.0; and 4.2, while the soil water content was observed with an interval of 7 days during the reproductive phase.

The soil water content during reproductive phase ranged from 24-31% under rain-shelter and 22-25% in the field. Based on pF curve at the location of the trial, field water capacity is equivalent to 40% soil moisture content. Thus, the water content of the soil during the reproductive phase was under field capacity. This indicates that soybean plants experienced drought stress during the trial.

Wilting as plant response to drought stress was rated visually on 1-5 scale following De Rosario et al. (1992) scoring method. The observation was started at R2 (flowering phase) to R5 (seed filling phase). Wilting scores used were as follows:

Score 1 : all leaves were green and fresh,
Score 2 : > 50% of the leaves were still turgid and no brown leaves,
Score 3 : > 50% of the leaves were started to wilting and < 50% of the leaves were started to brown,
Score 4 : > 50% of the leaves were started to wilting and > 50% of leaves were started to brown, there was no dead plant,
Score 5 : > 50% of the leaves were started to wilting, > 50% of the leaves were started to brown, and the plants were starting to die.

The data obtained from both the trials were analyzed for t-test using SAS v.9 software (SAS Institute Inc., NC) to test the difference between the two stress conditions for the respective traits.

RESULTS AND DISCUSSION

The first drought stress symptom that appear was canopy wilting, and it was noticed earlier on the field trial. The same symptom was observed by Carter et al. (2006) on soybean that experienced water deficit especially for the genotypes that susceptible to drought stress. Therefore, delay wilting under drought conditions is important trait in evaluating soybean response to drought stress (Pathan et al. 2014). In this study, the symptoms appear at 60 days after planting (dap) or two weeks after the last irrigation. At the beginning of symptoms of dryness, the average score was 2.1 and the wilted rose to 3.6 at 70 dap. The same symptoms appeared in 70 dap on trial in rain-shelter, but directly with an average score of 3.3 in the range 2-5 (Table 1, Figure 1).

Based on the wilting scores both in the field and under rain-shelter, there were five genotypes that showed drought tolerance equal to the drought tolerant check Dering 1 cultivar, namely Daewon, Ilmi, Jangmi, Mausu, and Sodam (Table 2). Daewon and Ilmi are South Korean drought tolerant cultivars. These results indicated that the two cultivars were consistently showed tolerant both in Indonesia and in South Korea, their origin country. According to London et al. (2012), drought-tolerant soybean genotypes, indicated by delay wilting, are able to save the use of water by limiting transpiration. Sinclair et al. (2007) found that the delayed wilting canopy followed by continuous nitrogen fixation in drought conditions would increase yield under water deficit conditions.

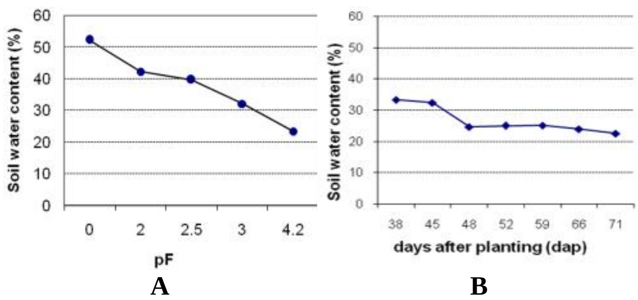

Figure 1. Soil water content at various pF (A) and the dynamics of soil water content since the flowering stage until physiological maturity in field experiments (B)

Table 1. Average and range of soybean wilting scores at 60, 67, and 70 dap in the field and rain-shelter trials

Information	Plant wilting score in the field			Plant wilting score under rain-shelter		
	60 dap	67 dap	70 dap	60 dap	67 dap	70 dap
Average	2.1	3.6	3.6	1	1	3.3
Min.	1	1	1	1	1	2
Max.	5	5	5	1	1	5

Table 2. Days to flowering, days to maturity, weight of 100 seeds, weight of seeds per plant, and wilting score of five soybean genotypes introduced from South Korea that resistant to drought stress in field and under rain-shelter

Genotypes	DF (dap)		DM (dap)		WS (g)		WSP (g)		Wilting Score Field			Wilting Score Rain-shelter		
	Field	Rain-shelter	Field	Rain-shelter	Field	Rain-shelter	Field	Rain-shelter	60	67	70	60	67	70
Mausu	31.0	25.0	76.0	78.0	22.2	24.2	6,0	7,9	1	1	2	1	1	2
Jangmi	29.0	25.0	76.0	76.0	17.5	23.2	4,4	8,7	1	1	2	1	1	2
Daewon	28.0	24.0	79.0	72.0	17.0	22.1	4,6	4,7	1	1	2	1	1	2
Ilmi	29.0	25.0	84.0	78.0	18.6	19.4	6,5	7,0	1	1	2	1	1	2
Sodam	31.0	26.0	74.0	80.0	5.4	10.4	3,2	3,3	1	2	3	1	1	2
Grobogan	31.0	29.0	74.0	69.0	18.6	16.8	5,8	3,3	1	2	4	1	2	4
Mutiara	33.0	34.0	82.0	79.0	23.8	16.4	11,9	4,4	1	1	4	1	1	3
Dering 1	33.0	34.0	83.0	80.0	10.1	11.5	11,3	3,4	1	1	2	1	1	2

Notes: DF=days to flowering, DM=days to maturity, WS=weight of 100 seeds, WSP=weight of seeds per plant

Table 3. Agronomic traits of introduced soybean genotypes in the field and under rain-shelter in drought stress condition during the reproductive phase

Characters	Field	Rain-shelter	t-test
Days to flowering (dap)	30.2	26.3	9.54**
Days to maturity dap)	76.4	74.5	2.08*
Plant height (cm)	29.1	37.4	-9.6**
Number of branches	2.5	1.7	4.20**
Number of fertile node	11.9	8.7	4.27**
Number of pods	14.9	13.8	0.51 ns
Number of empty pods	1.6	3.5	-5.96**
Weight of 100 seeds (g)	15.9	20.4	-3.05**
Seed weight per plant (g)	5.3	4.7	0.82 ns

Note:* and ** = significantly different at 5% and 1% respectively, ns = not significant

Soybean plants under rain-shelter received more severe stress because of the shade in addition to drought.. The rain-shelter construction caused reduction of solar radiation intensity, and it was approximately 75.2% of full radiation (ranged between 72.0-79.5%). The radiation intensity difference received between the plants in the field and rain-shelter trials caused differences in plant growth. . Soybean plant under rain-shelter grew higher than those in the field (Table 3). Polthanee et al. (2011) also found the same that differences in the intensity of solar radiation affected soybean stem elongation. Soybean grows in height between 10% and 24% under low light. According to Zhang et al. (2011), plants grow taller under shade conditions caused by increased hormone indole-3-acetic acid (IAA).

On the contrary in terms of number of branches, number of fertile nodes, and number of pods. Observations on plants under rain-shelter showed that those three agronomic traits were less compared to those observed on field trial (Table 3). These results are in line with research found in Japan (Kurosaki and Yumoto 2003; Kakiuchi and Kobata 2006), and in Thailand (Polthanee et al. 2011) that low light intensity led to a reduction in the pod number per plant. Although the number of pods reduced, soybean plant under rain-shelter produced larger seed size than those in the field. That phenomena caused average of seed weight per plant became insignificant between the two conditions (Table 3). According to Ghassemi-Golezani et al. (2015), maximum seed weight under low light condition is due to long duration of seed filling under shade condition, and the condition leading to a 15.8% increase in seed weight.

Drought stress that occurred during this study both in the field and under the rain-shelter was also affected number of pods, number of seeds and seed size. Desclaux et al. (2000) reported that soybean plant would reduce the number of seeds per pod when water deficit occurs at the beginning of pod filling, and reducing the weight of the seed if water stress occurs at the end of seed filling. Oya et al. (2004) adds that the drought stress that occurs during the initiation of flowering will reduce the number of pods per plant, and causes a decrease in the number of seeds.

Days to maturity is one of the characters that plan to be improved on Dering 1 cultivar. In general, soybean genotypes introduced from South Korea shorter and matured earlier compared to the check cultivars, both in the field and under rain-shelter (Table 4). This means that there is an opportunity to improve the maturity of Dering 1 by utilizing those early maturing genotypes. Days to maturity in soybean is reported to have a high heritability indicates that these trait can be inherited to the offspring (Costa et al. 2008; Osekita and Olorunfemi 2014). In term of water scarcity, adaptation of plants to drought stress can be through drought escape, dehydration postponement, and dehydration tolerance (Turner et al. 2001). Soybean genotypes introduced from South Korea with early maturity potentially improve drought resistance of Dering 1 through drought escape mechanisms.

On the other hand, results also showed that seed size of soybean genotypes introduced from South Korea has a wider range under both the environments (Table 4). It is suggested that the soybean genotypes from South Korea could be used as gene sources for seed size improvement. This result was more interesting compared to the previous studies when planting F5 populations derived from crosses among Indonesia soybean. Sulistyo et al. (2016) reported that there were only 14 lines out of 85 lines with a medium seed size (11-13 g/100 seeds) and larger than Dering 1 (10.76 g/100 seeds). In this study, Grobogan cultivar is one of the check varieties with large seed size. Four out of the 20 soybean genotypes tested had large seed size (> 14 g/100 seeds). Those four genotypes were Mausu, Jangmi, Daewon, and Ilmi (Table 2).

Table 4. Performance of agronomic characters of soybean genotypes introduced from South Korea in the field and rain-shelter in drought stress conditions during reproductive phase

Character	Genotypes	Field			Rain-shelter		
		Average	Min.	Max.	Average	Min.	Max.
Days to flowering (dap)	Introduced	29.9	28.0	32.0	25.4	24.0	29.0
	Check	32.3	31.0	33.0	32.3	29.0	34.0
Days to maturity (dap)	Introduced	75.9	69.0	84.0	74.3	69.0	80.0
	Check	79.7	74.0	83.0	76.0	69.0	80.0
Plant height (cm)	Introduced	25.6	18.7	44.5	34.6	26.6	47.8
	Check	52.7	37.6	70.6	56.8	47.7	67.1
Number of branches	Introduced	2.5	1.3	3.6	1.7	0.0	3.6
	Check	3.0	1.8	3.7	1.6	1.2	2.1
Number of pods	Introduced	12.1	6.8	21.2	13.9	7.0	23.4
	Check	33.8	14.4	54.4	13.0	10.4	14.5
Number of empty pods	Introduced	1.5	0.2	3.5	3.8	1.4	5.4
	Check	2.7	1.1	4.8	2.1	1.6	2.6
Weight of 100 seeds (g)	Introduced	15.7	5.4	25.6	21.2	10.4	30.3
	Check	17.5	10.1	23.8	14.9	11.5	16.8
Weight of seeds per plant (g)	Introduced	4.6	2.7	7.2	4.9	2.2	8.7
	Check	9.7	5.8	11.9	3.7	3.3	4.4

Table 5. Coefficient correlations among agronomic characters of drought-tolerant soybean genotypes

Characters	DF	DM	PH	NB	NFN	NP	NEP	WS
DM	0.34**							
PH	0.16ns	0.26ns						
NB	0.41**	0.27ns	-0.06ns					
NFN	0.47**	0.36*	0.28ns	0.71**				
NP	0.18ns	0.25ns	0.47**	0.41**	0.77**			
NEP	-0.57**	-0.07ns	0.26ns	-0.29ns	-0.18ns	-0.01ns		
WS	-0.37*	-0.04ns	0.01ns	0.03ns	-0.04ns	0.00ns	0.43**	
WSP	0.14ns	0.34*	0.37*	0.53**	0.71**	0.78**	0.03ns	0.24ns

Notes: DF=days to flowering, DM=days to maturity, PH=plant height, NB=number of branches, NFN=number of fertile nodes, NP=number of pods, NEP=number of empty pods, WS= weight of 100 seeds, and WSP=weight of seeds per plant

Correlation studies showed that seed weight per plant were positively correlated with days to maturity, plant height, number of branches, number of fertile nodes, and number of pods (Table 5). The highest seed yield per plant was found within the late maturity genotypes, taller plants, higher number of branches, higher number of fertile nodes, and higher number of pods. These results are in line with Akram et al. (2011) report that seed weight per plant had highly significant and positive correlation coefficients with days to maturity, plant height, number of branches, and number of pods. According to Oz et al. (2009), and Valencia-Ramirez and Ligarreto-Moreno (2012) number of pods and number of nodes gave direct positive effect to seed weight per plant. Malik et al. (2007) and Sitompul et al. (2015) suggested that number of pods may be used as one of selection criteria in soybean breeding for high yield. Additionally, the highest yield per plant in this study was found on genotypes with large and medium seed size. The correlation profile between these characters indicates that there were early maturity and large seed size genotypes among genetic material tested. However, among the five genotypes resistant to drought stress, Daewon, Ilmi, Jangmi, and Mausu genotypes have large seed size and early maturing (Table 2).

Based on the results it can be conclude that genotypes which showed tolerance to drought stress as indicated by low wilting score were not necessarily found on high seed yield genotypes. Tolerant genotypes have advantages in seed size character. Four of the five genotypes resistant to drought (Daewon, Ilmi, Jangmi, and Mausu) have larger seed size than Dering 1 cultivar.

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