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## Agronomical Characters of Some Soybean Germplasm under Waterlogging Condition

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### ABSTRACT

Waterlogging is one of environmental stresses that can affect the growth and yield, because on that condition the plant will be injured due to the anaerobic environment. The objective of the research was to study the variability of agronomic characters in soybean germplasm under waterlogging condition. The study was conducted in the greenhouse of Indonesian Legume and Tuber Crops Research Institute in Malang. A total of 16 soybean genotypes including two check varieties (Lawit and Sinabung) were used as research materials. The design was a randomized complete block design. Waterlogging was started at 21 days after planting until harvesting by applying water level about 5 cm above the soil surface. Observations were made on the days to flowering, days to maturing, number of filled pods, number of unfilled pods, number of reproductive nodes, number of grains and grain yield per plant. The results showed that soybeans could grow and produce grains even in a waterlogging condition in almost throughout its life cycles. A significant difference was found in all observed characters. Genotype MLGG 0096 had the highest grain yield equivalent to varieties of Sinabung and Lawit. Those three genotypes were supported by the number of pods per plant.

**Key words:** Soybean, germplasm, waterlogging

### INTRODUCTION

Water excess at the early seedling stage is a common environmental constraint for soybean production throughout the world (Tamang *et al.*, 2014). In planting areas of lowland rainfed, waterlogging can occur due to the high rain precipitation. The excess water condition (waterlogging) in the field is difficult to be managed and usually it can occur intensively, seasonally, permanently or temporarily (Tampubolon *et al.*, 1989). Those conditions lead the plants experiencing water excess stress that occur if the water availability in the soil is more than plant's requirement. In this condition a plant will experience root organ damage and it can be toxic to the plant because of anaerobic condition (Ariffin, 2002).

The main problem in waterlogging is hypoxic that can damage the plant. The process of hypoxic damages can be divided to sudden death symptom and biomass decreasing (Jitsuyama, 2013). Every plant has a mechanism to remain

survive in disadvantage condition. Soybean is classified as a plant that resistant to waterlogging and able to make adventitious roots and root nodules. The mechanisms of hypoxic tolerance is absolutely controlled by the genetic background (Jitsuyama, 2013) and waterlogging effect will disappear when adventitious root is formed (Morita *et al.*, 2004). Adventitious roots increased under waterlogging stress (Marashi and Mojaddam, 2014). In waterlogged soybean plant, it will form new roots that appear over the soil surface (adventitious root). The adventitious root is used by soybean to replace main root located in the soil that may be damage because of waterlogging. According to Riche (2004), adventitious root will develop over the water surface in order to increase aerobic respiration and root oxidation. Beside adventitious root formation, plant also increases ethylene to accelerate aerenchyma tissue formation (Marashi and Mojaddam, 2014) lead surviving plant. In waterlogging condition, ethylene gas concentration of the plant increases than in normal condition. Salisbury and Ross (1995) stated that

ethylene is a result of chemical compound changing in plant organ namely aminocyclopropane-1-carboxylate (ACC) that occurs in anaerobic media. In plant that is not resistant to waterlogging, it can be toxic because of ethanol accumulation.

Water excess affects senescence initiation causing chlorotic, necrotic and defoliation of the leaves, decreasing nitrogen fixation, growth termination and yield losses (Bacanamwo and Purcell, 1999; Linkemer *et al.*, 1998; VanToai *et al.*, 1994). Soybean capability to face waterlogging stress varies among genotypes, but in waterlogging for 48-96 h soybean still survives without any damages (Rhine *et al.*, 2010). However, waterlogging occurring in early vegetative phase (V2) and early reproductive phase (R1, R2 and R3) are the most sensitive phases (Linkemer *et al.*, 1998). Yield loss can reach up to more than 60% in soybean applied with periodically waterlogging (Kuswanto, 2011). There is no study that reported waterlogging treatment continuously from vegetative phase to harvesting. In this article, the continuously waterlogging treatment was applied to study the agronomical characters of some soybean germplasm.

## MATERIALS AND METHOD

**Research site:** Research was conducted at the screen house of Indonesian Legume and Tuber Crops Research Institute (ILETRI) Malang, East Java, Indonesia. The altitude is ±400 m above sea level, with daily temperature of 23-25°C and relative humidity of 73%.

**Soil preparation:** Before soil was used in the experiment, soil was dried under the sunshine to eradicate soil borne diseases that carried in the soil. After dried for two weeks, soil was destructed manually and then sieved by using 1 cm sieve. The sieved soil was entered in the pot, 5 kg per pot.

**Plant materials:** The materials were sixteen soybean genotype germplasm including two check varieties (Sinabung and Lawit). Sinabung is a variety for lowland field after rice while Lawit is a variety for tidal swamp area. These two varieties were used to study whether distinct varieties respond differently in waterlogging.

**Maintaining water level:** The design was randomized complete block design. Waterlogging treatment was applied continuously from 21 days after planting (DAP) until harvesting by applying water level about 5 cm above the soil surface. Water level was checked everyday and water was added if the level decreased due to the evapotranspiration.

**Observation:** Observations were recorded for days to flowering, days to maturing, plant height, number of branches per plant, number of reproductive nodes per plant, number of filled pods per plant, number of unfilled pods per plant, number of grains per plant and yield per plant.

## RESULTS AND DISCUSSION

Based on the least significant difference on soybean agronomical characters, all of observed characters were significantly different. However, the differences on number of branches and number of grain per plant among genotypes were less than other agronomical characters. This indicated that the tested genotype had variability or different response to waterlogging. But on those two characters the variability were lower than other characters. VanToai *et al.* (1994) stated that different genotype also has role in soybean tolerance difference to waterlogging and the production capability.

Days to flowering of the tested genotype under waterlogging condition were longer than in optimal condition, where the average of days to flowering was 47.6 days ranging from 39-53 days. Varieties of Sinabung and Lawit showed days to flowering 46 and 49 days, respectively under waterlogging condition (Table 1), while in optimal condition were 35 and 40 days, respectively (Balitkabi, 2012). Days to flowering became longer probably due to the plant attempt to survive by maintaining vegetative growth, such as adventitious roots formation. High energy was needed in adventitious root formation causing energy used for flowering initiation decreases or not available longer days to flowering longer.

Similar to days to flowering, days to maturing under waterlogging condition was also delayed. Usually, Sinabung and Lawit has days to maturing about 88 and 84 days respectively, but in this study the both varieties had days to maturing of 98 and 100 days (Table 1). The delay in days to maturing as a consequence of the delay in days to flowering. In addition, delay days to maturing are also supposed to be caused by lack of nutrients that could not be absorbed by plants as a result of the death of roots in the soil. Plant growth relies on adventitious roots to absorb nutrients. Unfortunately, there are poor nutrients content in the water area compare to the soil. Dissimilar to Khairulina and Tikhonchuk (2012) that reported shortening length of interstage periods of cultivated

Table 1: Days to flowering and days to maturing of some soybean germplasm under waterlogging condition

Genotype	Days to flowering (days)	Days to maturing (days)
MLGG 0071	52.09 <sup>abc</sup>	101.09 <sup>ab</sup>
MLGG 0076	53.13 <sup>ab</sup>	97.50 <sup>bcd</sup>
MLGG 0077	51.75 <sup>abc</sup>	97.75 <sup>bcd</sup>
MLGG 0078	36.88 <sup>h</sup>	89.00 <sup>e</sup>
MLGG 0081	54.50 <sup>a</sup>	101.00 <sup>abc</sup>
MLGG 0083	47.13 <sup>defg</sup>	96.13 <sup>d</sup>
MLGG 0084	51.88 <sup>abc</sup>	99.38 <sup>abcd</sup>
MLGG 0086	44.75 <sup>g</sup>	98.38 <sup>bcd</sup>
MLGG 0088	47.00 <sup>efg</sup>	96.38 <sup>cd</sup>
MLGG 0089	50.75 <sup>bcd</sup>	99.75 <sup>abcd</sup>
MLGG 0091	39.25 <sup>h</sup>	86.38 <sup>e</sup>
MLGG 0096	45.75 <sup>fg</sup>	100.75 <sup>abcd</sup>
MLGG 0103	43.50 <sup>g</sup>	103.50 <sup>a</sup>
MLGG 0104	49.50 <sup>bcd</sup>	101.38 <sup>ab</sup>
Sinabung	45.50 <sup>fg</sup>	97.63 <sup>bcd</sup>
Lawit	48.50 <sup>cdef</sup>	100.38 <sup>abcd</sup>
Average	47.61	97.90

Table 2: Number of branches and number of reproductive nodes per plant of some soybean germplasm under waterlogging condition

Genotype	No. of branch per plant	No. of reproductive nodes per plant
MLGG 0071	1.5 <sup>b</sup>	2.3 <sup>c</sup>
MLGG 0076	2.6 <sup>ab</sup>	6.8 <sup>ab</sup>
MLGG 0077	3.0 <sup>ab</sup>	5.6 <sup>ab</sup>
MLGG 0078	2.0 <sup>ab</sup>	8.1 <sup>a</sup>
MLGG 0081	3.2 <sup>a</sup>	7.0 <sup>ab</sup>
MLGG 0083	3.6 <sup>a</sup>	9.1 <sup>a</sup>
MLGG 0084	2.5 <sup>ab</sup>	8.4 <sup>a</sup>
MLGG 0086	2.6 <sup>ab</sup>	8.1 <sup>a</sup>
MLGG 0088	2.5 <sup>ab</sup>	5.3 <sup>ab</sup>
MLGG 0089	3.5 <sup>a</sup>	10.3 <sup>a</sup>
MLGG 0091	2.3 <sup>ab</sup>	5.5 <sup>ab</sup>
MLGG 0103	2.6 <sup>ab</sup>	7.3 <sup>ab</sup>
MLGG 0096	3.4 <sup>a</sup>	7.9 <sup>a</sup>
MLGG 0104	2.5 <sup>ab</sup>	3.8 <sup>bc</sup>
Sinabung	3.0 <sup>ab</sup>	8.9 <sup>a</sup>
Lawit	3.5 <sup>a</sup>	8.8 <sup>a</sup>
Average	2.8	7.1

Table 3: Number of filled pods and unfilled pods per plant of some soybean germplasm under waterlogging condition

Genotype	No. of filled pods per plant	No. of unfilled pods per plant
MLGG 0071	2.25 <sup>d</sup>	0.00 <sup>e</sup>
MLGG 0076	7.01 <sup>abc</sup>	2.17 <sup>abcd</sup>
MLGG 0077	5.25 <sup>cd</sup>	2.25 <sup>ab</sup>
MLGG 0078	11.63 <sup>a</sup>	2.13 <sup>abc</sup>
MLGG 0081	6.88 <sup>abc</sup>	2.09 <sup>abc</sup>
MLGG 0083	9.25 <sup>abc</sup>	0.63 <sup>cde</sup>
MLGG 0084	9.38 <sup>abc</sup>	3.00 <sup>a</sup>
MLGG 0086	8.38 <sup>abc</sup>	1.80 <sup>abcd</sup>
MLGG 0088	5.38 <sup>abc</sup>	1.67 <sup>abcd</sup>
MLGG 0089	11.80 <sup>a</sup>	0.50 <sup>de</sup>
MLGG 0091	7.88 <sup>abc</sup>	0.50 <sup>de</sup>
MLGG 0103	10.25 <sup>ab</sup>	1.50 <sup>abcd</sup>
MLGG 0096	9.25 <sup>abc</sup>	1.50 <sup>abcd</sup>
MLGG 0104	4.50 <sup>bcd</sup>	1.50 <sup>abcd</sup>
Sinabung	9.63 <sup>ab</sup>	0.84 <sup>bcd</sup>
Lawit	10.88 <sup>ab</sup>	1.50 <sup>abcde</sup>
Average	8.09	1.47

Table 4: Number of grains per plant and yield per plant of some soybean germplasm under waterlogging condition

Genotype	No. of grains per plant	Yield per plant (g)
MLGG 0071	3.3 <sup>b</sup>	0.09 <sup>e</sup>
MLGG 0076	10.5 <sup>ab</sup>	0.21 <sup>de</sup>
MLGG 0077	10.4 <sup>ab</sup>	0.30 <sup>cde</sup>
MLGG 0078	15.0 <sup>a</sup>	0.52 <sup>abc</sup>
MLGG 0081	12.6 <sup>a</sup>	0.32 <sup>cde</sup>
MLGG 0083	15.3 <sup>a</sup>	0.56 <sup>abc</sup>
MLGG 0084	18.4 <sup>a</sup>	0.52 <sup>abc</sup>
MLGG 0086	13.4 <sup>a</sup>	0.41 <sup>abcd</sup>
MLGG 0088	9.6 <sup>a</sup>	0.31 <sup>cde</sup>
MLGG 0089	21.0 <sup>a</sup>	0.34 <sup>bcd</sup>
MLGG 0091	12.0 <sup>a</sup>	0.37 <sup>abcd</sup>
MLGG 0103	15.6 <sup>a</sup>	0.63 <sup>a</sup>
MLGG 0096	17.4 <sup>a</sup>	0.52 <sup>abc</sup>
MLGG 0104	8.6 <sup>ab</sup>	0.36 <sup>bcd</sup>
Sinabung	18.4 <sup>a</sup>	0.63 <sup>a</sup>
Lawit	17.3 <sup>a</sup>	0.59 <sup>ab</sup>
Rerata	13.7	1.47

soybean and wild soybean in waterlogging of soil during the entire growth period, this study found lengthening interstage period.

Numbers of branches per plant of some genotypes were significantly different while most of the genotypes were not significantly different among them (Table 2). It is because waterlogging suppressed branches formation causing less number of branches per plant. Linkemer *et al.* (1998) also reported a significant decline in branch number after 7 days of flooding at various vegetative and reproductive growth stages. However, Miura *et al.* (2012) reported waterlogging treatment at flowering stage for 21 days resulting number of branches about 7.5±0.6 and control 7.0±0.6. Flowering stage is a reproductive phase in a plant, when usually plant has completed the branches formation.

The highest number of reproductive nodes per plant were shown by MLGG 0089 followed by MLGG 0083 and the both check varieties Sinabung and Lawit while the lowest number of reproductive nodes were shown by genotype MLGG 0071 and MLGG 0104 (Table 2). When compared to the optimal conditions, the number of reproductive nodes in this study is lower. In optimal conditions the amount of reproductive nodes of Sinabung reach 30 nodes (Kuswantoro and Indriani, 2012) and Lawit reach 29 nodes (Kuswantoro, 2011). The number of reproductive nodes in this study was similar to the number of reproductive nodes in previous studies (Kuswantoro, 2011) in which the waterlogged conditions performed for 7 days and 7 days until the optimum plant enters maturing age.

The highest number of filled pods indicated by genotype MLGG 0089 and MLG 0078 (12 pods) followed by Lawit (11 pods) and MLGG 0103 and Sinabung (10 pods) while the lowest number of filled pods indicated by MLGG 0071 (2 pods) followed by MLGG 0104 (4 pods) and MLGG 0077 (5 pods) (Table 3). Lawit is a variety that released for adaptive tidal swamp. In this study, Lawit was classified as having the highest number of pods. However, when compared to the optimal conditions, the number of filled pods was very low, where in the optimal condition Lawit had 41 filled pods (Suyamto and Musalamah, 2010). The least number of filled pods allegedly due to the low nutrients absorption because the roots are in the water area with poor nutrients instead in soil with rich nutrients.

The highest number of unfilled pods was shown by MLG 0084, as many as 3 unfilled pods. Similar to the number of pods, the lowest number of unfilled pods per plant was also achieved by MLGG 0071 where there was no unfilled pod. Under these conditions the number of unfilled pods may be equivalent to the optimal conditions (Suyamto and Musalamah, 2010), but the most important is the ratio of the number of unfilled pods increased than optimal conditions.

Grain is the most important component because grain is closely related to grain yield per plant, where variation of soybean yield is affected by grain per plant (Kobrae and Shamsi, 2011). The average number of grains in this study was 13.7 grains per plant. The highest number of grains was achieved by MLGG 0089 where not significantly different to other genotypes except MLGG 0071 (Table 4). It is because the flooding treatment was carried out continuously lead the plant could not produce grains perfectly, as a result of the lack

Table 5: Correlation among agronomical characters of some soybean germplasm under waterlogging condition

Characters							
Characters	Flowering	Branch	Node	Pod-f	Pod-u	Grain	Yield
Flowering	0.657**	0.187	-0.175	-0.447	0.170	-0.222	-0.423
Maturing		0.342	-0.015	-0.166	0.085	0.043	0.026
Branch			0.683	0.513	0.007	0.644	0.434
Node				0.917**	0.153	0.933**	0.638**
Pod-f					0.107	0.929**	0.706**
Pod-u						0.134	0.090
Grain							0.710**

\*\*Significant at 1%, Flowering: Days to flowering, Maturing: Days to maturing, Branch: Number of branches, Node: Number of reproductive nodes, pod-f: Number of filled pods, pod-u: Number of unfilled pods, Grain: Number of grain, Yield: Grain yield

of nutrients that can be taken up by the roots. It can be seen through the less grains number, when compared to the ratio of grains/pods. In general, the pod can be filled by two or three grains. However, in this study the pods were filled by one or two grains which indicated the grains formation did not performed well.

The main criteria of waterlogging tolerance is the ability of plants to produce grain yield (Daugherty and Musgrave, 1994). The highest soybean grain yield was shown by MLGG 0096 which is equivalent to the grain yield of Lawit and Sinabung varieties while the lowest grain yield was shown by MLG 0071 (Table 4). In this study, the highest grain yield was only 0.6 g per plant which extremely different compared to the results in optimal conditions (Suyanto and Musalamah, 2010). This occurs because the formed pods number was extremely low due to disturbing pod formation that triggered by less nutrient uptake. Some authors suggested the waterlogging that can be tolerate by soybean was about 24-30 h from the beginning to the end waterlogging treatment (Griffin *et al.*, 1985; Heatherly and Pringle, 1991). Phases of plant growth also plays a role in decline grain yield, where waterlogging for two days at the end of the vegetative phase could decrease yield up to 18%, whereas at the beginning of the reproductive phase can be decreased to 26% (Scott *et al.*, 1989). Longer waterlogging also lead higher decline yields, where waterlogging in the vegetative phase until the pod filling period decrease grain yield by 47% and when the plants were waterlogged since early pod filling period, yield reduction reached 51% (Rodiah and Sumarno, 1994). In this study, waterlogging was longer than the ability of plants to tolerate or forming plant organs other than to survive resulting very low grains that can be formed. Ahmed *et al.* (2002) reported the higher decrease at reproductive stage than vegetative stage.

Relationship among agronomical characters of some soybean under water logging condition showed that grain weight significantly correlated to number of reproductive nodes, number of filled pods and number of grains per plant, number of grain significantly correlated to number of reproductive nodes and number of filled pods per plant, number of filled pods significantly correlated to number of reproductive nodes and maturing days significantly correlated

to flowering days (Table 5). Grain weight is the resultant of other agronomical characters. The most important characters supporting grain yield were number of pods per plant. VanToai *et al.* (2010) reported significant correlation between grain yield with number of branches, number of nodes and number of total grain in flooding treatment. However, this correlation is not consistent among the three tested genotypes. It indicates that the different genetic background resulting different response to waterlogging (Jitsuyama, 2013).

## CONCLUSION

Soybean was still able to grow and produce grains even in a waterlogging condition almost throughout its life cycle. Genotype MLGG 0096 had the highest grain yield equivalent to Sinabung and Lawit varieties. Genotypes had the highest grain yield was supported by a many number of pods per plant. Further research is needed on the amount of flower that is formed and the amount of flower that fall due to waterlogging. The nutrient content in surface water need to be analyzed due to adventitious roots cannot absorb nutrients from the soil that have rich nutrients.

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