Agronomical Characters of Some Soybean Germplasm under Waterlogging Condition

Heru Kuswantoro
Indonesian Legume and Tuber Crops Research Institute, Indonesian Agency for Agricultural Research and Development, Jl. Raya Kendalpayak Km. 8, Malang, Indonesia

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 ant 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...
ethylenes 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 (Kuswantoro, 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 has a variety for tidal swamp area. These two varieties were used to study wether 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 Khairstulina 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\textsuperscript{ab} | 101.09\textsuperscript{ab} |
| MLGG 0076 | 53.13\textsuperscript{b}  | 97.50\textsuperscript{bd}  |
| MLGG 0077 | 51.75\textsuperscript{bc} | 97.75\textsuperscript{bd}  |
| MLGG 0078 | 36.88\textsuperscript{a}  | 89.00\textsuperscript{a}  |
| MLGG 0081 | 54.50\textsuperscript{a}  | 101.00\textsuperscript{abc} |
| MLGG 0083 | 47.13\textsuperscript{deh} | 96.13\textsuperscript{d}  |
| MLGG 0084 | 51.88\textsuperscript{ab} | 99.38\textsuperscript{abcd} |
| MLGG 0086 | 44.75\textsuperscript{f}  | 98.38\textsuperscript{f}  |
| MLGG 0088 | 47.00\textsuperscript{g}  | 96.38\textsuperscript{f}  |
| MLGG 0089 | 50.75\textsuperscript{bcd} | 99.75\textsuperscript{abcd} |
| MLGG 0091 | 39.25\textsuperscript{g}  | 86.38\textsuperscript{e}  |
| MLGG 0096 | 45.75\textsuperscript{g}  | 100.75\textsuperscript{abcd} |
| MLGG 0103 | 43.50\textsuperscript{e}  | 103.50\textsuperscript{a}  |
| MLGG 0104 | 49.50\textsuperscript{gh} | 101.38\textsuperscript{abc} |
| Sinabung  | 45.50\textsuperscript{gh} | 97.63\textsuperscript{bcd} |
| Lawit     | 45.50\textsuperscript{gh} | 97.63\textsuperscript{bcd} |
| Average   | 47.61                     | 97.90                    |
soybean and wild soybean in waterlogging of soil during the entire growth period, this study found lengthening interstage period.

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  | 1.5b                    | 2.3c                                |
| MLGG 0076  | 2.6b                    | 2.1b×d                             |
| MLGG 0077  | 3.0b                    | 2.2c×d                             |
| MLGG 0078  | 2.0b                    | 2.13bc                             |
| MLGG 0081  | 3.2c                    | 2.09bc                             |
| MLGG 0083  | 3.6e                    | 9.1c                               |
| MLGG 084   | 2.5b                    | 8.4c                               |
| MLGG 0086  | 2.6b                    | 8.1b                               |
| MLGG 0088  | 2.5bc                   | 5.3bc                              |
| MLGG 0089  | 3.5e                    | 10.3c                              |
| MLGG 0091  | 2.3c                    | 5.5b                               |
| MLGG 0103  | 2.6b                    | 7.3e                               |
| MLGG 0096  | 3.4e                    | 7.9b                               |
| MLGG 0104  | 2.5c                    | 3.8c                               |
| Sinabung   | 3.0b                    | 8.9c                               |
| Lawit      | 3.5e                    | 8.8c                               |
| Average    | 2.8                     | 7.1                                |

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 MLGG 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 0084, as many as 3 unfilled pods. Similar to the number of filled pods, the lowest number of unfilled pods per plant was also achieved by MLGG 0071 where there was no unfilled pod. 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 MLGG 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 (Kobraee 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

| Genotype   | No. of unfilled pods per plant |
|------------|-------------------------------|
| MLGG 0071  | 0.00e                         |
| MLGG 0076  | 1.7e×d                        |
| MLGG 0077  | 2.2c×d                        |
| MLGG 0078  | 2.13bc                        |
| MLGG 0081  | 2.09bc                        |
| MLGG 0083  | 0.63c×d                       |
| MLGG 0084  | 3.00e                         |
| MLGG 0086  | 1.80b×d                       |
| MLGG 0088  | 1.67b×d                       |
| MLGG 0089  | 0.50e                         |
| MLGG 0091  | 0.50e                         |
| MLGG 0103  | 1.50b×d                       |
| MLGG 0096  | 1.50b×d                       |
| MLGG 0104  | 1.50b×d                       |
| Sinabung   | 0.84b×e                       |
| Lawit      | 1.50b×de                      |
| Average    | 8.09                          |

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

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.
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 (Suyamto 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 tolerated 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).

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

| 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**

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.

REFERENCES

Ahmed, S., E. Nawata and T. Sakuratani, 2002. Effects of waterlogging at vegetative and reproductive growth stages on photosynthesis, leaf water potential and yield in mungbean. Plant Prod. Sci., 5: 117-123.

Ariffin, 2002. Water Stress and Plant Life. Publishing Unit of Agriculture Faculty, University of Brawijaya, Malang, Pages: 97, (In Indonesian).

Bacanamwo, M. and L.C. Purcell, 1999. Soybean dry matter and N accumulation responses to flooding stress, N sources and hypoxia. J. Exp. Bot., 50: 689-696.

Balitkabi, 2012. Description of superior varieties of legume and tuber crops. Indonesian Legume and Tuber Crops Research Institute. (In Indonesian).

Daugherty, C.J. and M.E. Musgrave, 1994. Characterization of populations of rapid-cycling Brassica rapa L. selected for differential waterlogging tolerance. J. Exp. Bot., 45: 385-392.

Griffin, J.L., R.W. Taylor, R.J. Habetz and R.P. Regan, 1985. Response of solid-seeded soybeans to flood irrigation. I. Application timing. Agron. J., 77: 551-554.

Heatherly, L.G. and H.C. Pringle, 1991. Soybean cultivar’s response to flood irrigation of clay soil. Agron. J., 83: 231-236.

Jitsuyama, Y., 2013. Responses of Japanese soybeans to hypoxic condition at rhizosphere were different depending upon cultivars and ambient temperatures. Am. J. Plant Sci., 4: 1297-1308.

Khairulina, T.P. and P.V. Tikhonchuk, 2012. Growth and development of soybean under the effect of water stressor. Russian Agric. Sci., 38: 364-366.
Kobraee, S. and K. Shamsi, 2011. Sink-source relationships in Soybean. Ann. Biol. Res., 2: 334-342.
Kuswantoro, H. and F.C. Indriani, 2012. Yield and Yield Components of some Soybean Varieties in Lowland. In: The Role of Agriculture in Supporting Food Security and Energy for Strengthening Nasional Economics Based on Local Resources, Suwarto, P.H. and S. Rochdianto (Eds.). Faculty of Agriculture, University of Jenderal Soedirman, Indonesia, (In Indonesian).
Kuswantoro, H., 2011. Response of soybean genotypes to waterlogging. J. Agron. Indonesia, 39: 19-23.
Linkemer, G., J.E. Board and M.E. Musgrave, 1998. Waterlogging effects on growth and yield components in late-planted soybean. Crop Sci., 38: 1576-1584.
Marashi, A.K. and M. Mojaddam, 2014. Adventitious root and aerenchyma development in wheat (Triticum aestivum L.) subjected to waterlogging. Int. J. Biosci., 5: 168-173.
Miura, K., A. Ogawa, K. Matsushima and H. Morita, 2012. Root and shoot growth under flooded soil in wild groundnut (Glycine soja) as a genetic resource of waterlogging tolerance for soybean (Glycine max). Pak. J. Weed Sci. Res., 18: 427-433.
Morita, S., J. Abe, S. Furubayashi, A. Lux and R. Tajima, 2004. Effects of waterlogging on root system of soybean. Proceedings of the 4th International Crop Science Congress, September 26-October 1, 2004, Australian Society of Agronomy, Brisbane, Australia.
Rhine, M.D., G. Stevens, G. Shannon, A. Wrather and D. Sleper, 2010. Yield and nutritional responses to waterlogging of soybean cultivars. Irrigat. Sci., 28: 135-142.
Riche, C.J., 2004. Identification of soybean cultivars tolerance of waterlogging through analyses of leaf nitrogen concentration. Master’s Thesis, The Department of Agronomy and Environmental Management, Louisiana State University, USA.
Rodiah and Sumarno, 1994. Yield performance of soybean genotypes on soil with water saturation condition. Proceeding of Food Crops Research 1994, Indonesian Legume and Tuber Crops Research Institute, Malang, (in Indonesian).
Salisbury, F.B. and C.W. Ross, 1995. Plant Physiology 2. Institute of Technology Bandung, Indonesia, (In Indonesia).
Scott, H.D., J. DeAngulo, M.B. Daniels and L.S. Wood, 1989. Flood duration effects on soybean growth and yield. Agron. J., 81: 631-636.
Suyamto and Musalamah, 2010. Flowering capacity, level of flower falling and potential yield of some soybean varieties. Buletin Plasma Nutfah, 16: 38-43, (In Indonesian).
Tamang, B.G., J.O. Magliozzi, M.A.S. Maroof and T. Fukao, 2014. Physiological and transcriptomic characterization of submergence and reoxygenation responses in soybean seedlings. Plant Cell Environ., 37: 2350-2365.
Tampubolon, B., J. Wiroadmodjo and J.S.B. Soedarsono, 1989. Effect of flooding at various growth stages of soybean (Glycine max (L.) Merr) on growth and yield. Forum Pascasarjana, 12: 17-25, (In Indonesian).
VanToai, T.T., A.F. Beuerlein, S.K. Schmitthenner and S.K. St.Martin, 1994. Genetic variability for flooding tolerance in soybeans. Crop Sci., 34: 1112-1115.
VanToai, T.T., T.T.C. Hoa, N.N. Hue, H.T. Nguyen, J.G. Shannon and M.A. Rahman, 2010. Flooding tolerance of soybean [Glycine max (L.) Merr.] germplasm from southeast asia under field and screen-house environments. Open Agric. J., 4: 38-46.