Response of Soybean Genotypes to Waterlogging

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ABSTRACT

National demand on soybean can be fullfilled by extending production area including marginal lands. Tidal swamp is one of marginal lands which potentially can be cultivated for soybean production with the use of tolerant varieties to waterlogging. So far, there are only two varieties that are tolerant to tidal swamp condition. This research was conducted to study the response of soybean genotypes to waterlogging and to provide gene resources in breeding for tidal tolerant variety. The research was conducted from October 2007 to February 2008 in the glasshouse of Indonesian Legume and Tuber Crops Research Institute (ILETRI), Malang. The experimental design was split-plot with two replications; where the main plot was waterlogging treatment and the sub plot was soybean genotype (17 genotypes of ILETRI collection). The results showed that soybean genotypes had different responses to different water treatments, shown on the number of branches and reproductive nodes, the number of filled and unfilled pods, and yield (dry seeds) per plant. Waterlogging inhibited plant growth of all traits. Under waterlogging, the highest number of reproductive nodes and filled pods, and yield per plant was from MLGG 0537 i.e. 12.25, 19.25, and 3.13 g plant^{-1}, respectively.

Keywords: germplasms, soybean, waterlogging

INTRODUCTION

Based on the importance of commodity in national consumption, soybean is in the third rank following rice and maize. However the national production cannot fulfill the national demand. Declining agricultural area resulted in low production of soybean. Expanding agricultural area to suboptimal land, for example tidal swamp area, can be conducted to increase soybean production. There are about 33.4 million hectares of tidal swamp in Indonesia (Alihamsyah *et al*., 2003).

Excess water will affect seed yield, because it affects early senescence which impact to chlorosis, necrosis and defoliation of leaf, decreasing of nitrogen fixation, and growth termination (VanToai *et al*., 1994; Linkemer *et al*., 1998; Bacanamwo and Purcell, 1999). The ultimate criterion of waterlogging tolerance is the ability to produce high seed yield in waterlogging fields (Daugherty and Musgrave, 1994), where the most breeding objectives are conducted. The appropriate time frame for waterlogging was 24 to 30 h from beginning of waterlogging to the end of draining (Griffin *et al*., 1985; Heatherly and Pringle, 1991). At least within two days of waterlogging at late vegetative phase of soybean, seed yield decreased up to 18%; while at early reproductive phase, seed yield decreased up to 26% (Scott *et al*., 1989). Different soybean genotypes showed different tolerance to waterlogging and ability to produce yield under waterlogging (VanToai *et al*.,1994).

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MATERIALS AND METHODS

The research was conducted from October 2007 to February 2008 in the glasshouse of Indonesian Legume and Tuber Crops Research Institute (ILETRI), Malang-Indonesia (± 440 m asl). The average daily temperature and relative humidity during research were 23-25 ^{o}C and 73%, respectively. The materials were 17 genotypes of soybean germplasm of ILETRI's collection. The design was split-plot design with two replications. The main plot was watering treatment, consisted of two watering treatments, i.e. (1) capillary watering by adding about 1 cm water higher from pool base, and (2) waterlogging by adding water up to 5 cm upper soil surface and retained for 7 days and followed for 7 days by normal watering. Waterlogging treatment with 7 days waterlogging and 7 days normal watering subsequently was conducted up to two weeks before harvesting. The sub plot was genotype, consisted of 15 land-race genotypes (MLGG 0133, MLGG 0144, MLGG 0231, MLGG 0236, MLGG 0258, MLGG 0470, MLGG 0532, MLGG 0537, MLGG 0553, MLGG 0583, MLGG 0602, MLGG 0714, MLGG 0720, MLGG 0781, and MLGG 0817) and two check varieties (varieties of Panderman and Lawit).

RESULTS AND DISCUSSION

Results

The plant height under waterlogging and control conditions increased as the plant age increased (Figure 1). The increase rates of plant height were high at age

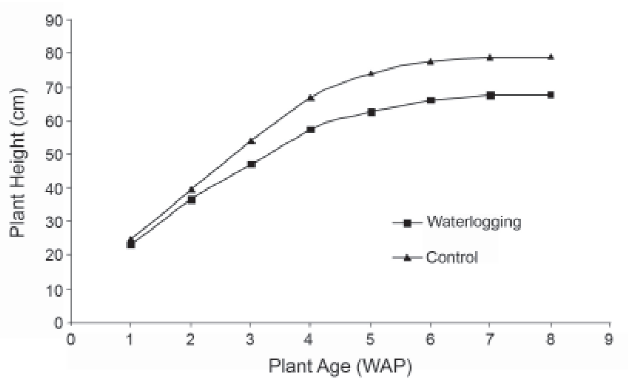

Figure 1. Average of plant height on waterlogging condition and control condition during growing period

of 1-4 weeks after planting (WAP), but after 4 WAP the increase rates of plant height were low. The average growth on waterlogging condition was lower than that on control, where the differences between waterlogging condition and control up to 11.7 cm.

The interaction between genotypes and watering affected the number of reproductive nodes. An advanced test using LSD 5% showed that the number of reproductive nodes of control was 10.9 to 39.9; whilst under waterlogging, the number of reproductive nodes was about 2.8 to 12.3 (Table 1). Genotype MLGG 0532 had the highest number of reproductive nodes in control treatment and significantly different from other genotypes, while MLGG 0537 had highest number of reproductive nodes under water logging condition. Genotypes MLGG 0258 and MLGG 0583 showed the lowest number of reproductive nodes under waterlogging. Sullivan *et al*. (2001) stated that different number of reprodutive nodes at different genotype may due to the diferences at Vegetative-2 growth phase affected by waterlogging

Interaction between genotypes and watering also affected number of filled and unfilled pods. Table 2 shows that the genotype MLGG 0532 had the highest filled pod number in control, i.e. 52.6 pods. Other genotypes that showed non significant different with MLGG 0532 on filled pod number trait was MLGG 0537. Under waterlogging condition, the highest filled pod number was shown by MLGG 0537 as 19.3 pods, while MLGG 0532 reached 11.8 pods lower than MLGG 0537 but higher than the average. Variety of Lawit as a tolerant check cultivar was in the sixth rank under waterlogging and third rank in control, and was higher than the average under both waterlogging and control condition. Variety of Panderman showed lower number of filled pods than Lawit and than the average filled pod number both under control and waterlogging treatments.

Table 2 reveals that there was an effect of interaction between genotypes and watering on unfilled pods. Genotypes of MLGG 0144, MLGG 0258 and MLGG 0714 had the lowest unfilled pod number under control condition; where there was no unfilled pod number for the plant. Under waterlogging condition, all of the three genotypes had unfilled

Table 1. Waterlogging effect on number of reproductive nodes of 17 soybean genotypes

Genotypes	Control	Waterlogging
MLGG 0133	16.0cdef	9.4 efghijkl
MLGG 0144	17.0cde	12.0 defghij
MLGG 0231	16.8cde	6.9 hijkl
MLGG 0236	18.8cd	9.6 efghijkl
MLGG 0258	14.4cdefghi	2.8 l
MLGG 0470	10.9cdefghijkl	7.3 ghijkl
MLGG 0532	39.9a	11.3defghijk
MLGG 0537	22.0bc	12.3defghij
MLGG 0553	11.5cdefghijk	4.6jkl
MLGG 0583	11.9cdefghijk	3.7kl
MLGG 0602	15.4cdefg	5.6jkl
MLGG 0714	15.8cdef	5.6jkl
MLGG 0720	17.0cde	4.6jkl
MLGG 0781	11.4cdefghijk	6.1ijkl
MLGG 0817	14.6cdefgh	11.4defghijk
Panderman	12.0cdefghij	8.1fghijkl
Lawit	28.9b	11.1defghijkl
Average	17.3	7.8
LSD 5%	8.27	

Note: Number folllowed by same notation is not significantly different at LSD 5%

pods. MLGG 0714 had the highest number of unfilled pods than MLGG 0144 and MLGG 0258. The highest unfilled pod number under control condition shown by MLGG 0236 and MLGG 0720, while under waterlogging the highest unfilled pod number showed by MLGG 0231. Panderman showed the highest unfilled pods number on waterlogging up to 5.50, it may due to the tolerance to waterlogging was lower than others.

Seed number was not affected by interaction between genotypes and waterlogging treatments. LSD 5% test showed that MLGG 0537 had highest seed number up to 64.31 (Table 3). But seed numbers of MLGG 0537 was not significantly different with MLGG 0236, MLGG 0532 and Lawit (tidal swamps variety). It indicated that MLGG 0537 had higher tolerance to tidal swamp than Lawit, and it can be used as parent for breeding of waterlogging tolerance. However, seed number character has to be joined with the yield in the analysis to find out tolerant parent. In this research, interaction between genotypes and waterlogging treatments also found on yield per plant; where on control treatment it was about 1.88 to 7.08 g (Table 4), and highest seed yield reached by MLGG 0537 and MLGG 0532. While under waterlogging, seed yield per plant was about 0.26 to 3.13 g and the highest yield reached by MLGG 0537. It confirmed that MLGG 0537 was a waterlogging tolerant genotype.

Table 2. Waterlogging effect on number of filled and unfilled pods of 17 soybean genotypes

Genotypes	Number of filled pods		Number of unfilled pods	
	Control	Waterlogging	Control	Waterlogging
MLGG 0133	20.1bcde	10.5efghijkl	8.3ef	0.5l
MLGG 0144	17.9cdefghi	11.8efghijkl	0.0l	1.9ijkl
MLGG 0231	18.5cdefg	7.0ghijkl	1.4jkl	0.1l
MLGG 0236	24.0bcd	12.4defghijkl	14.1d	4.1fghijkl
MLGG 0258	16.0cdefghij	2.8l	0.0l	0.2l
MLGG 0470	11.5efghijkl	7.5fghijkl	6.0fghij	3.6fghijkl
MLGG 0532	52.6a	11.8efghijkl	2.0hijkl	0.9kl
MLGG 0537	44.8a	19.3cdef	1.9ijkl	0.5l
MLGG 0553	21.9bcde	6.1ijkl	6.8fgh	3.4ghijkl
MLGG 0583	12.9cdefghijkl	6.5ghijkl	7.6fg	1.0kl
MLGG 0602	18.4cdefgh	5.4jkl	1.8ijkl	0.6l
MLGG 0714	24.8bc	3.0kl	0.0l	3.1ghijkl
MLGG 0720	16.4cdefghij	4.9jkl	12.5de	0.9kl
MLGG 0781	14.6cdefghijkl	6.4hijkl	2.4hijkl	0.3l
MLGG 0817	18.0cdefghi	12.4defghijkl	3.3ghijkl	3.0ghijkl
Panderman	15.0cdefghiijk	6.9ghijkl	6.4fghi	5.5fghijk
Lawit	32.0b	11.4efghijkl	3.5fghijkl	0.3l
Average	22.3	8.6	4.6	1.8
LSD 5%	12.12		4.79	

Note: Number followed by same notation is not significantly different at LSD 5%

Discussions

The growth of plants in control and waterloggimg conditions were fast at 1-4 week after planting (WAP), but they were slow after 4 WAP. Waterlogging suppressed soybean growth, where the plant height under waterlogging condition was lower than that under control condition (Figure 1). The decrease of plant height on waterlogging may due to a decrease in oxygen transport (Dennis *et al*., 2000) and nutrition uptake, and resulted in root destruction. During the growing season, waterlogging affects soybean growth and seed production (Stanley *et al*., 1980; Oosterhuis *et al*., 1990). Hence, the ability to produce high seed yield in flooded fields become the ultimate criterion of waterlogging tolerance, where leaf color, plant height, root, and shoot biomass traits have been used frequently as determinants of waterlogging tolerance (Daugherty and Musgrave, 1994). These frequent traits were used because waterlogging causes premature senescence which results in chlorosis, necrosis and defoliation of leaf, decreasing of nitrogen fixation, growth termination and yield decrease (Daugherty and Musgrave, 1994; VanToai *et al*., 1994; Linkemer *et al*., 1998; Bacanamwo and Purcell, 1999). However, soybean is much more tolerant to excess water and lack of oxygen (Boru *et al*., 2003) than previous reports (VanToai *et al*., 1994; Linkemer *et al*., 1998). In this present study, the results showed that non-aerated plants was still alive and there was no effect on plants survival. Boru *et al*. (2003) reported similar results, where soybean plants were very tolerant to excess water and an-aerobic. Heatherly and Spurlock (2000) suggested that either furrow or flood irrigation methods can be used with generally equal results.

The detrimental effect of waterlogging to plant growth leads to the decrease of yield production. Decreasing seed yield depends on plant growth or reproductive stage. Decreasing yield was reported at the late vegetative growth stage and a higher decrease take place at the early reproductive stage (Scott *et al*., 1989). Beside, the effects of waterlogging were much more severe on seed yield than on plant height. Waterlogging treatment for 2 weeks reduced seed yield of Archer (69%), Minsoy (75%), IA2007 (77%) and Noir I (84%) variety (VanToai *et al*., 2001). Filled pod trait had direct effect on seed yield (Linkemer *et al*., 1998), so that traits need to be observed intensively. Every trait related each other in determining soybean seed yield. Usually higher plants have more branches number than the lower plants. Consequently it has higher number of reproductive nodes, filled pods and seeds. Finally, seed yield increases due to the increase of components. Kuswantoro and Arsyad (2002) and Kuswantoro *et al*. (2006) reported that there was a relationship between seed yield trait and plant height, number of branches and pods per plant. Board *et al*. (1999) also reported that number of pods and reproductive nodes had relationship with seed yield.

Table 3. Waterlogging effect on seed number of 17 soybean genotypes

Genotypes	Seed number
MLGG 0133	32.8abc
MLGG 0144	32.3c
MLGG 0231	27.4c
MLGG 0236	35.8abc
MLGG 0258	19.2c
MLGG 0470	19.6c
MLGG 0532	61.3ab
MLGG 0537	64.3a
MLGG 0553	26.6c
MLGG 0583	18.1c
MLGG 0602	22.9c
MLGG 0714	26.2c
MLGG 0720	17.5c
MLGG 0781	24.2c
MLGG 0817	26.5c
Panderman	20.3c
Lawit	40.2abc
Average	30.3
LSD 5%	28.76

Note: Number folllowed by same notation is not significantly different at LSD 5%

Table 4. Waterlogging effect on seed yield of 17 soybean genotypes

Genotypes	Seed yield (g plant^{-1})	
	Control	Waterlogging
MLGG 0133	2.09defghijk	1.29fghijklm
MLGG 0144	2.54defghi	1.48fghijklm
MLGG 0231	2.64defgh	0.98ijklm
MLGG 0236	2.52defghi	1.37fghijklm
MLGG 0258	2.83cdefg	0.42lm
MLGG 0470	2.28defghij	1.42fghijklm
MLGG 0532	5.53ab	1.25ghijklm
MLGG 0537	7.08a	3.13cde
MLGG 0553	2.30defghij	0.45klm
MLGG 0583	1.88efghijklm	0.72jklm
MLGG 0602	2.66cdefgh	0.60klm
MLGG 0714	4.29bc	0.26m
MLGG 0720	2.07efghijk	0.54klm
MLGG 0781	2.26defghij	1.20ghijklm
MLGG 0817	1.99efghijkl	1.15hijklm
Panderman	2.92cdef	1.00jklm
Lawit	3.72cd	1.37fghijklm
Average	3.03	1.10
LSD 5%	1.64	

Note: Number folllowed by same notation is not significantly different at LSD 5%

CONCLUSIONS

Different response in different water treatments was showed by soybean genotypes on the number of branches and reproductive nodes, the number of filled and unfilled pods, and seeds yield per plant. Waterlogging affected plant growth and development by reducing all of the observed traits. In waterlogging, MLGG 0537 had the highest number of reproductive nodes (12.3 nodes plant^{-1}) and filled pods (19.3 pods plant^{-1}), and seeds yield per plant (3.13 g plant^{-1}) and can be served as parent in breeding for waterlogging tolerance.

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