

# Performance of Acid-Tolerant Soybean Promising Lines in Two Planting Seasons

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## Abstract

Phenotypic performance of a genotype is not similar from season to season depends on the environment condition such as amount and time of water availability. Objective of this study was to identify soybean promising lines with high yield on acid soil in two planting seasons. The research was conducted in rainy season 2009 and 2010 at Sitiung Research Station, West Sumatera, Indonesia. The soil of the experimental field is Ultisols with pH (H<sub>2</sub>O) 4.3, exchangeable-Al 3.92 me/100 g, and Al saturation 56.48%. The experiment was arranged in randomized completely block design with four replications. Result showed that the average of seed yield in RS 2010 was higher than that in RS 2009. Water supply was very important in pod filling period, plant height, filled pod, flowering and maturity days that may lead the seed yield performance. Based on the average of yield in two planting seasons, there were two genotypes having seed yield higher than the highest check variety, i.e. genotypes of SC5P2P3.23.4.1-3-28-3 and SC5P2P3.23.4.1-5. Therefore, these two genotypes are possibly to be released as new acid-tolerant varieties or can be served as new genetic materials for developing acid-tolerant variety.

**Keywords:** acid soil, flowering stage, soybean, yield

## 1. Introduction

Approximately 69% of dryland in Indonesia are acid soils (Mulyani, 2006), and an estimated 30-40% of the world's total land area consists of acid soils (Haug, 1983; Uexkull & Mutert, 1995). Many problems soil are found in these soils, and they can be divided into two groups i.e. micronutrient toxicity and macronutrient deficiency. However, of many problems soil, Al toxicity is the most important in acid soil and being a major constraint for crop production on 67% of the total acid area (Esawaran et al., 1997). Al toxicity causes hindering plant growth and development due to the inhibition of root elongation lead by the destroying cell structure of the root apex (Zheng, 2010).

For improving crops production, minerals toxicity can be ameliorated by surface application of lime, but this is not economically feasible for the poor farmers (Uguru et al., 2012). Hence, an alternative strategy should be provided for improving crops production on acid soils. A less costly complementary approach can be implemented by the improvement of the genetic Al resistance and it can be the most effective strategy for improving crop production on acid soils. Many research activities have been conducted to provide acid soil tolerance varieties from developing screening technique (Ferrufino et al., 2000), germplasm screening (Foy et al., 1992; Foy et al., 1993); inheritance (Kuswanto et al., 2011), segregating population selection (Spehar & Souza, 2006) and cultivars response (Board & Caldwell, 1991).

Genotypic expression of a phenotype is environmentally dependent because gene expression is subject to modification by the environment (Kang, 1998). Therefore, under diverse agro-ecological conditions, phenotypic performance of a genotype is not necessarily the same (Ali et al., 2003). To ensure that selected genotypes have acceptable performance in variable environments within the target region, testing over diverse environment is very important (Ashraf et al., 2010). Planting season is one of the environment factors causing different

genotypic expression of a specific genotype. Principally the weather condition at a planting season, especially rainfall, is a prime factor rather than soil type and fertility causing that phenomenon. Water deficit at flowering stage would affect soybean performance, and indicated by decreasing yield and yield components (Kobraee et al., 2011; Kobraee & Shamsi, 2011a).

The objective of this study was to identify soybean promising lines that maintained high yields on acid soil in two planting seasons.

## 2. Materials and Method

Two experiments were conducted during rainy season of 2009 and 2010 at Sitiung Research Station, West Sumatera, Indonesia. Ten promising lines and two checks of acid-tolerant soybean varieties (Tanggamus and Wilis) were used in this study. Planting dates were September 3, 2009, and December 9, 2010. Soil type is Ultisols, and the soil properties are pH (H<sub>2</sub>O) 4.3, P<sub>2</sub>O<sub>5</sub> (Bray II) 1.65, Ca 1.09 me/100 g, Mg 0.25 me/100 g, Na 0.8 me/100 g, K 0.19 me/100 g, CEC 6.94, Al dd 3.92, and Al saturation 56.48%. The genotypes were arranged in a randomized completely block design with four replications. Each genotype was planted in 6 rows plot of 4.5 m long, planting space was 40 cm x 15 cm. Fertilizers were applied at rates equivalent to Urea:SP36:KCl = 75:100:100 kg/ha.

In rainy season (RS) 2009 and 2010 the irrigation were applied by using the rainfall. The rainfalls in RS 2009 from September to December were 153.1, 53.0, 170.1 and 270.0 mm; while in RS 2010 from January to April were 193.6, 186.1, 283.2, 121.9 mm (Table 1). From each genotype in all of the four replications, observations were recorded on ten randomly selected plants for plant height (cm) and filled pods per plant; while observation were recorded on plot for days to 50% flowering, days to maturity and seed yield (t/ha). The data were statistically analyzed using analysis of variance and continued with least significant difference (LSD) for mean comparison.

Table 1. Distribution of rainfall in two planting seasons, RS 2009 and RS 2010

Month	Rainfall (mm)
September 2009	153.1
October 2009	53
November 2009	170.1
December 2009	270
January 2010	193.3
February 2010	186.1
March 2010	283.2
April 2010	121.9

## 3. Results and Discussion

Analysis of variance showed that genetic x environment (GE) interaction of all of observed characters were significant, except seed yield (Table 2). It is suggested that there was no ranking change for seed yield performance if the genotypes grown in rainy season 2009 and rainy season 2010 in that area. This made genotypes selection was easier compare to that in the present of GE interaction; as stated by Uguru et al. (2012) that only in the absence of GE interaction, crop performance across environments was a useful indicator of genotypic performance.

Average seed yield in RS 2010 was higher than that of RS 2009 (Table 3). The different rainfalls during the two planting seasons (Table 1) affected water supply for the soybean growth and development, where the soybeans encountered drought stress on flowering stage in RS 2009. It caused plants in lower water supply having lower seed yield (Daneshian et al., 2011; Kobraee et al., 2011). Related study also reported by Demirtas et al. (2010) where drought stress significantly affected seed yield. Dry matter production was restricted by soil moisture before flowering period causing stronger effect after flowering (Oya et al., 2004). Further, Oya et al. (2004) found significant correlation between seed yield and crop growth rate during the drought stress period at early reproductive growth; and stated that a key for high seed yield under drought condition was the maintenance of a

high crop growth rate during drought stress period. In this research, significant correlations between yield and filled pods were found on both of RS 2009 and RS 2010 (Table 6).

Table 2. Analysis of variance of soybean promising lines and the check varieties in two planting seasons. RS 2009 and RS 2010

Source	Df	Yield	Height	Pod-f	Flower	Maturity
E (season)	1	24.39**	15.611**	148.04**	4.095**	276.76**
Rep*E	6	0.61**	196.06**	481.98**	5.33**	3.29ns
G (genotype)	11	0.32**	81.31**	401.73**	19.71**	85.85**
G*E	11	0.16ns	89.00**	214.24**	11.25**	12.58**
Error	66	0.12	18.41	33.06	1.19	4.33
CV (%)		19.85	8.31	7.62	3.42	2.50

ns = non significant, \*\* = significant at 0.01%, Yield = seed yield per plot (t/ha), Height = plant height (cm), Pod-f = filled pods per plant, Flower = days to 50% flowering, Maturity = days to maturity.

In RS 2010 genotype SC5P2P3.5.4.1.5 had the highest seed yield followed by genotype of SC5P2P3.23.4.1-3-28-3 and the check variety of Wilis, while in RS 2009 there were no differences among genotypes (Table 3). Based on the average of the two seasons, there were two genotypes having seed yield higher than the highest check variety, i.e. genotypes of SC5P2P3.23.4.1-3-28-3 and SC5P2P3.23.4.1-5. Some researchers also reported similar results that responses of soybean genotypes to water deficit stress lowering seed yield (Daneshian et al., 2011; Kosturkova et al., 2008; Oya et al., 2004).

Table 3. Seed yield of soybean promising lines and the check varieties in two planting seasons, RS 2009 and RS 2010

Genotypes	Yield (t/ha)		
	RS 2009	RS 2010	Average
SC2P2.99.5.4.5-1-6-1	1.21ab	1.64d	1.42d
SC2P2.151.3.5.1-10	1.30ab	2.25a-c	1.77a-c
SC5P2P3.23.4.1-3-28-3	1.51a	2.46a	1.99a
SC5P2P3.5.4.1.5	1.25ab	2.51a	1.88ab
SC5P2P3.23.4.1-5	1.54a	2.44a	1.99a
MLGG 0758	0.99b	2.40ab	1.70a-d
SJ-5/Msr.99.5.4.5-1-6-1	1.08ab	2.15a-c	1.61b-d
Msr/SJ-5.21.3.7-3-27-1	1.26ab	2.05a-d	1.66a-d
Msr/SJ-5.23.4.1-3-28-3	0.97b	1.83cd	1.40d
Msr/SJ-5.23.4.1-5	0.99b	2.42ab	1.70a-d
Tanggamus	1.10ab	1.95b-d	1.53cd
Wilis	1.27ab	2.47a	1.87ab
Average	1.20b	2.21a	1.705

Number in the same column and followed by the same letter was not significantly different at LSD 5%.

Plant height among soybean genotypes in RS 2009 and in RS 2010 had the differences among the genotypes (Table 4). The highest plant height was shown by both of Msr/SJ-5.21.3.7-3-27-1 and Msr/SJ-5.23.4.1-5 genotypes in RS 2010. Tanggamus as a check variety had the lowest plant height in RS 2009. Plant height average in RS 2009 was lower than that in RS 2010. Water deficit lead the plant height lower than in optimal condition (Demirtas et al., 2010; Zhang et al., 2011).

Table 4. Plant height of soybean promising lines and two check varieties in two planting seasons. RS 2009 and RS 2010

Genotypes	Plant height (cm)	
	RS 2009	RS 2010
SC2P2.99.5.4.5-1-6-1	45.60f	59.90de
SC2P2.151.3.5.1-10	43.05fg	65.60b-d
SC5P2P3.23.4.1-3-28-3	39.10gh	57.90e
SC5P2P3.5.4.1.5	38.95gh	64.80b-d
SC5P2P3.23.4.1-5	37.30gh	54.50e
MLGG 0758	37.35gh	68.45ab
SJ-/Msr.99.5.4.5-1-6-1	37.55gh	66.20bc
Msr/SJ-5.21.3.7-3-27-1	38.90gh	73.15a
Msr/SJ-5.23.4.1-3-28-3	37.15gh	60.30c-e
Msr/SJ-5.23.4.1-5	38.00gh	72.90a
Tanggamus	35.75h	60.20c-e
Wilis	38.00gh	68.85ab
Average	38.9b	64.4a

Number followed by the same letter was not significantly different at LSD 5%.

Table 5. Filled pods characters of soybean promising lines and check varieties in two planting seasons, RS 2009 and RS 2010

Genotypes	Number of filled pod/plant	
	RS 2009	RS 2010
SC2P2.99.5.4.5-1-6-1	45.05h	103.65e-g
SC2P2.151.3.5.1-10	33.45j-m	121.50a-c
SC5P2P3.23.4.1-3-28-3	45.75h	116.15cd
SC5P2P3.5.4.1.5	40.10h-j	122.10a-c
SC5P2P3.23.4.1-5	42.25hi	127.95a
MLGG 0758	29.60lm	119.30bc
SJ-/Msr.99.5.4.5-1-6-1	31.20k-m	105.50ef
Msr/SJ-5.21.3.7-3-27-1	35.85i-l	101.50fg
Msr/SJ-5.23.4.1-3-28-3	25.80m	96.95g
Msr/SJ-5.23.4.1-5	29.75lm	111.13de
Tanggamus	36.25i-l	127.10ab
Wilis	38.80h-k	123.50a-c
Average	36.2b	114.7a

Number followed by the same letter was not significantly different at LSD 5%.

Filled pod is the main yield component that supported the yield. In RS 2009, the highest filled pods was achieved by SC5P2P3.23.4.1-3-28-3 (Table 5). This genotype consistently produced high filled pods up to 116 pods in RS 2010. The lowest genotype Msr/SJ-5.23.4.1-3-28-3 in RS 2009 also consistently had the lowest filled pods in RS 2010. However, the check varieties i.e. Tanggamus and Wilis, having 36 and 38 filled pods respectively in RS 2009, showed the highest filled pods up to 127 and 123 pods as many as genotype of SC5P2P3.23.4.1-5 with 128 filled pods. Drought induced pod abortion during the critical pod development, where the critical stage for

pod abortion was 3-5 days after anthesis and severe drought stress significantly decreased pod set up to 40% (Liu, 2004). The number of pods was largely dependent on the number of floral buds that initiate pods (Desclaux et al., 2000).

Days to flowering was determined when the 50% plants in a plot were flowering. Days to flowering in RS 2009 were similar among the genotypes, while in RS 2010 days to flowering were vary and longer than that in RS 2009 (Table 6). Tanggamus had the highest days to flowering in both planting seasons (27 days in RS 2009 and 42 days in RS 2010). Flowering stage is one of the most sensitive growth stages (Kobraee & Shamsi, 2011a). In RS 2009, there was no rainfall up to 9 days before flowering date and 15 days after flowering date (data not shown). It shortened flowering date than when the genotypes were cultivated in relatively optimal condition in RS 2010. The water supply in this stage had an extreme effect on pod per plant and finally it effected on seed yield (Demirtas et al., 2010; Kobraee & Shamsi, 2011b). In this study, although the seed filling period was longer under water deficit in RS 2009 than in RS 2010 due to the shortening of flowering stage affected by the water deficit, the production was lower due to the flower abortion (Liu et al., 2003). Hamayun et al. (2010) stated that drought stress at pre and post flowering stage significantly affected to soybean growth and yield attributes.

Table 6. Days to 50% flowering and days to maturity of soybean promising lines and two check varieties in two planting seasons. RS 2009 and RS 2010

Genotypes	Days to flowering (day)		Days to maturity (day)	
	RS 2009	RS 2010	RS 2009	RS 2010
SC2P2.99.5.4.5-1-6-1	25.50fg	43.50a	87.50ab	89.50a
SC2P2.151.3.5.1-10	25.00fg	37.50b-d	80.25fg	84.50c-e
SC5P2P3.23.4.1-3-28-3	25.00fg	38.00bc	80.25fg	84.75b-e
SC5P2P3.5.4.1.5	24.75fg	37.25cd	83.00ef	84.00c-e
SC5P2P3.23.4.1-5	25.25fg	38.50bc	83.00ef	84.00c-e
MLGG 0758	24.75fg	33e	77.50g	78.75g
SJ-/Msr.99.5.4.5-1-6-1	25.50fg	38.75bc	83.00ef	89.50a
Msr/SJ-5.21.3.7-3-27-1	24.25g	38.50bc	78.25g	85.00b-e
Msr/SJ-5.23.4.1-3-28-3	24.75fg	38.00bc	79.00g	86.00b-d
Msr/SJ-5.23.4.1-5	24.75fg	39.00b	80.25fg	83.50de
Tanggamus	27.75e	42.00a	86.50bc	90.25a
Wilis	26.25ef	36.25d	78.75g	78.25g
Average	25.3b	38.4a	81.4b	84.8a

Number followed by the same letter was not significantly different at LSD 5%.

Genotypes of MLGG 0758 and Wilis had lowest days to maturity than other genotypes in RS 2009 and RS 2010. In both planting seasons, the highest maturity was showed by SC2P2.99.5.4.5-1-6-1 and Tanggamus. However, in RS 2010 SJ-/Msr.99.5.4.5-1-6-1 also showed the longest maturity. The lower water supply in RS 2009 caused lower maturity than RS 2010. It was caused by phenological avoiding as a drought tolerance mechanism. Similar result also reported by Acosta-Diaz et al. (2009) that drought treatment reduced days to maturity. Increasing relative maturity lead plant height increased (Shonjani, 2002).

Significant positive correlation found on yield and filled pod in both of RS 2009 and 2010, and on flowering and maturity in RS 2010 (Table 7). It suggested that performance of seed yield was supported by yield components such as plant height, numbers of filled pods, and both of flowering and maturity days. However, relationship among these components has shown to be inconsistent (De Bruin & Pedersen, 2009). On another hand, significant negative correlation was found on yield and both of flowering and maturity in RS 2010. It suggested that in these genotypes the longevity of flowering and maturity will decrease seed yield.

Table 7. Relationship of yield and yield components of soybean promising lines and the check varieties in two planting seasons, RS 2009 and RS 2010

	Flower	Maturity	Height	Pod-f
Yield	-0.036	0.108	0.227	0.810**
	-0.677*	-0.696*	0.199	0.613*
Flower		0.571	-0.229	0.185
		0.841**	-0.359	-0.225
Maturity			0.297	0.471
			-0.389	-0.341
Height				0.405
				-0.237

Yield = seed yield per plot (t/ha), Height = plant height (cm), Pod-f = filled pods per plant, Flower = days to 50% flowering, Maturity = days to maturity. Upper = RS 2009, Lower = RS 2010.

#### 4. Conclusion

In two planting seasons, water stressed and unstressed at flowering stage lead the lower average of seed yield in RS 2009 than in RS 2010. The water stressed at flowering stage condition in RS 2009 also lead similar flowering day among the genotypes in RS 2009, while the unstressed flowering stage in RS 2010 lead the days to flowering varied and longer. Even though the days to flowering were similar in RS 2009, the days to maturity varied in both of the two seasons. Genotypes MLGG 0758 and Wilis had earliest days to maturity than the other genotypes in RS 2009 and RS 2010. In two planting seasons, the longest maturity was showed by SC2P2.99.5.4.5-1-6-1 and Tanggamus. There were two genotypes having seed yield higher than the highest check variety in two planting seasons, i.e. SC5P2P3.23.4.1-3-28-3 and SC5P2P3.23.4.1-5. These two genotypes need to be tested under diverse acid soil areas to be released as new acid-tolerant varieties or can be served as new genetic materials for developing acid-tolerant variety.

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