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Identification of soybean genotypes adaptive and productive to acid soil agro-ecosystem

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Abstract. *Adie MM, Krisnawati A. 2016. Identification of soybean genotypes adaptive and productive to acid soil agro-ecosystem. Biodiversitas 17: 565-570.* Optimalization of acidic land for soybean development can be performed through the provision of soybean variety adapted to low pH. A total of 13 soybean genotypes was identified for its performance on three acid soil sites in Lampung Province, Indonesia, from February to June 2015. Soybean variety adapted to acid soil (Tanggamus and Demas 1) were used as check varieties. The experiment was using Randomized Block Design, 15 traits and four replicates. The concentration of pH (H_2O) in locations L1, L2 and L3 were 5.87, 5.04, and 4.73, respectively. The average yield in L1, L2 and L3 were 1.96 t/ha, 2.17 t/ha, and 1.92 t/ha, respectively. This showed that yield decrease as soil pH value decline. Genotype G4AB was consistently produced highest yield at pH 5.04 as well as at pH 4.73, hence the genotype G4AB was not only adaptive at low pH but also relatively productive. Based on yield in three locations, G4AB categorized as less stable. On the contrary, genotype G115H/Kaba//Kaba///Kaba-8-6 produced average yield of 2.23 t/ha, and categorized as stable in three sites of acid soil. Soybean genotype adaptive to acid soil was characterized by its ability to maintain the plant height, and followed by a high number of node per plant and pod per plant.

Keywords: *Glycine max*, acid soil, pH, yield

INTRODUCTION

Soybean development in acid soils is very potential due to the world-wide availability of acidic land, including in Indonesia. The potential acidic upland in Indonesia reached 148 million hectares, which about 102.8 million ha of the land can be classified into acid soil and the rest of 45.2 million ha as non-acid upland area (Mulyani 2006). The soybean development in acid soil is limited by low pH (< 5.5), low cation exchange capacity (CEC), susceptibility to erosion, poor biotic elements, and high in aluminum (Al) content (Mulyani 2006; Utama 2008). High Al content can cause detrimental effects for soybean plants, such as toxicity and root damage which lead to drought susceptibility and nutritional unbalance (Spehar and Souza 2006). Optimizing the development of soybean in acid soils can be performed through two approaches, by providing soil conditioner to increase soil pH for optimal plant growth, or by using soybean varieties adaptive to low pH. The first approach affects increasing cost of soybean production, and in addition, the application of soil conditioner should be done continuously. Bromfield and Ayamaba (1980) showed that soybean in acid soil which treated without Rhizobium inoculation and liming resulted in fewer number of nodules, nitrogen deficiency and very low seed yield (0.3-0.4 t/ha). Provision of soybean varieties adaptable to dry acid soil conditions are considered more profitable than the use of soil conditioner (Akinrinde et al. 2004; Ezeh et al. 2007). This is possible because of the availability of these varieties do not require additional cost of farming, the effects of adaptive varieties are for long periods, and compatible with other components of soybean cultivation technology.

The strategy on the provision soybean adapted to dry acid soil is initiated by identification of gene source, characterization to obtain morphological characters as tolerance determinant to acid soil, and appropriate selection method. The major constrain of soybean plant in acid soil is Al toxicity which inhibit the cell elongation and division, shorten the root growth, and affected to absorption of water and nutrient (Zheng 2010). Various studies have identified that adaptability in acid soil was determined by plant ability to make morphological changes and root architecture, root symbiosis, activation of high-affinity phosphate (Pi) transporters, enhancement of internal phosphatase activity, and secretion of organic acids and phosphatases into the rhizosphere (Raghothama 1999; Vance et al. 2003; Gahoonia and Nielsen 2004). The soybean root system in acid soil is also important related to the use of phosphor as efficiently. Evaluation on the soybean tolerance to acid soil by Uguru et al. (2012) concluded that root length, root weight and the number of root nodules were as the adaptation characters of soybean in the acid soil; and by using all of these three characters have successfully mapped the level of soybean genotypes tolerance to low pH. Other research revealed that difficult to obtain equality in assessing the soybean tolerance in acid soil based on solution culture than the field screening (Horst and Klotz 1990). This shows that an improvement is still needed in the screening method using solution culture. In the segregated population derived from crossing, Spehar and Souza (2006) performed selection using hydroponic solution in F2 population using characters of root growth, and able to obtain F3 population tolerant to low pH.

Foy et al. (1993) screened soybean germplasm and obtained the range of tolerance to pH 4.0 based on absolute dry shoot weights, relative shoot dry weights, and absolute root dry weights. The evaluation of soybean tolerance to acid soil in Indonesia (with pH H2O 4.3, exchangeable-Al 3.92 me/100 g, and Al saturation 56.48%) which performed by Kuswantoro and Zen (2013) was successfully obtained two soybean lines which produced higher yield than the resistant check variety (1.53 t/ha). A similar result also reported by Uguru et al. (2012) in acid soil of South eastern Nigeria (pH < 5.5), that acid-tolerant soybean was indicated by normal root growth and relatively high yield. However, the tolerance to acid soil is a complex multigenic trait, hence the identification method should be able to produce genotype with high degree of tolerance, productive, and have broad adaptation. The objective of the research was to identify and classify soybean genotypes with high yield and adaptive in acid soil.

MATERIALS AND METHODS

Field experiment

The research material consists of 13 soybean genotypes (11 AB, 13 ED, 14 DD, 19 BE, 25 EC, G4AB, G2BB, G3CB, G5EB, G1DB, G115H/Kaba//Kaba///Kaba-8-6, G511H/Anj//Anj-2-10, G511H/Anj-1-3) and two check varieties adapted to acid soil, i.e. Tanggamus and Demas 1. The field experiment was conducted in three locations of Lampung Province (Indonesia) in 2015, i.e. South Lampung, Pesawaran (dry season 1), and Pesawaran (dry season 2). The experimental design in each location was randomized completely block design with four replicates. The plot size was 2.4 × 4.5 m, 40 cm × 15 cm plant distances, two plants/hill. Fertilizer of 250 kg/ha Phonska and 100 kg/ha SP 36 were applied before sowing time. Seed treatment by the ametoxam. The land used was upland; therefore soil management was optimally performed. Before sowing, a drainage channels was made. Insect and disease were controlled intensively. Weed control was done at two and four weeks after planting. The parameter measured on days to maturity, days to flowering, 100 seed weight, plant height, number of branches, number of nodes, and number of pods per plant.

Characteristics of location

The level of soil acidity in three locations varied from medium acid (pH 5.87) in South Lampung, pH 5.04 (very strong acid) in Pesawaran at dry season 1, and in Pesawaran at dry season 2 categorized as extremely acid (pH 4.73) (Table 1). The availability of P2O5 varied from low to very high in Pesawaran and South Lampung, respectively. The Al-dd concentration only detected in Pesawaran at dry season 2, whereas the H concentration in the soil (H-dd) was from 0.54 up to 1.40. Based on those nutrient characteristics, therefore all three locations were feasible to detect and identify the soybean genotypes adapted to various soil pH.

Data analysis

Data were subjected to analysis of variance using a general linear model. The stability assessment in three environments following Francis and Kannerberg (1978), that is mapping between the coefficient of variation and seed yield from each genotype.

RESULTS AND DISCUSSION

Analysis of Variance

Analysis of variance for yield and yield component as shown in Table 2, location was significantly affect all observed characters, i.e. days to maturity, days to flowering, plant height, number of branches, number of nodes, number of filled pods, 100 seed weight, and seed yield. The effect of genotype was not significant on characters of plant height, number of branches, and number of nodes. The effect of genotype by location interaction was significant on characters of days to maturity, plant height, number of nodes, 100 seed weight, and seed yield (Table 2). The significant effect of genotype by location interaction for seed yield reflecting the availability of adaptation data for each genotype in certain location or specific pH.

Seed yield

The average seed yield of 15 soybean genotypes in South Lampung (pH 5.87) was 1.96 t/ha, in Pesawaran dry season 1 (pH 5.04) was 2.17 t/ha, and pH 4.73 in Pesawaran MK2 reached 1.92 t/ha (Table 3). The seed yield in South Lampung ranged from 1.71 to 2.28 t/ha. Seed yield of two check varieties adapted to acid soil of Tanggamus and Demas 1 were 2.01 and 1.90 t/ha, respectively. Tanggamus variety was released in 2001, whereas Demas 1 was released in 2014. The highest yield at pH 5.87 was genotype 13 ED, which reached 2.28 t/ha, followed by 25 EC, i.e. 2.18 t/ha.

Table 1. Soil analysis of three acid soil locations, in 2015

Code	Location	Actual pH H_2O	Potential pH KCl	P_2O_5 Bray I (ppm)	Concentration	
					Al-dd	H-dd
L1	Hajimena, Natar, South Lampung	5.87 (medium acid)	5.15	19.2 (very high)	0.00	0.54
L2	Masgar, Tegineneng, Pesawaran (DS1)	5.04 (very strong acid)	4.70	14.4 (high)	0.00	0.54
L3	Masgar, Tegineneng, Pesawaran (DS2)	4.73 (extremely acid)	4.20	6.47 (low)	0.43	1.40

Note: DS1 = dry season 1, DS2 = dry season 2.

Table 2. Combined analysis of variance for yield and yield component of 15 soybean genotypes in acid soil, in 2015

Trait	Mean Square				CV (%)
	Location (L)	Replication/R	Genotype (G)	L × G	
DTF	66.6000 **	1.6000 *	10.5095 **	0.4095 ns	2.74
DTM	551.6222 **	0.6685 ns	14.9698 **	8.3901 **	1.49
PHT	2700.8509 **	24.8138 ns	372.0337 **	136.9473 **	15.15
NOB	40.1349 **	2.2280 ns	2.4326 ns	1.2542 ns	39.51
NON	1776.1075 **	11.0981 ns	11.1537 ns	24.2740 *	23.58
NOP	17236.5261 **	228.2982 ns	213.0542 ns	244.0468 ns	36.38
W100	26.8170 **	2.7031 ns	28.5135 **	7.7216 **	13.15
T/H	1.0553 **	1.0167 **	0.4014 **	0.6633 **	17.08

DTF = days to flowering (days), DTM = days to maturity (days), PHT = plant height (cm), NOB = number of branches/plant, NON = number of nodes/plant, NOP = number of filled pod/plant, W100 = 100 seed weight (g). T/H = seed yield (t/ha), CV = coefficient of variation, * = significant at p = 0.05; ** = significant at p = 0.01, ns = not significant.

Table 3. Seed yield of 15 soybean genotypes in acid soil. Lampung, in 2015

Genotype	Yield (t/h)			
	L1	L2	L3	Mean
11 AB	2.05	1.84	2.15	2.01
13 ED	2.28	1.52	2.04	1.95
14 DD	1.83	2.41	2.06	2.10
19 BE	2.05	1.60	2.04	1.90
25 EC	2.18	1.00	1.81	1.66
G4AB	1.97	2.97	2.14	2.36
G2BB	1.93	2.58	1.97	2.16
G3CB	1.76	1.35	2.09	1.74
G5EB	1.71	2.75	2.04	2.16
G1DB	1.94	1.99	1.80	1.91
G115H/Kaba//Kaba///Kaba-8-6	1.91	2.81	1.97	2.23
G511H/Anj//Anj-2-10	2.04	2.53	1.66	2.08
G511H/Anj-1-3	1.85	2.09	1.80	1.91
Tanggamus	2.01	2.80	1.35	2.05
Demas 1	1.90	2.29	1.93	2.04
Mean	**1.96**	**2.17**	**1.92**	**2.02**

Note: L1 = South Lampung, L2 = Pesawaran DS1, L3 = Pesawaran DS2

The seed yield in Pesawaran during dry season 1 at pH 5.04 ranged from 1.35 to 2.97 t/ha. The highest yield at pH 5.04 was G4AB (2.97 t/ha), followed by G115H/Kaba//Kaba///Kaba-8-6 (2.81 t/h). Within two locations, Tanggamus variety produced high yield than Demas 1. The seed yield in Pesawaran at dry season 2 ranged from 1.35 to 2.15 t/ha. The highest yield genotype was 11AB (2.15 t/ha), followed by G4AB (2.14 t/ha). Changing of seed yield superiority within three locations at different pH is a consequence of the interaction between genotype with the environment as stated in Table 2. This means that each genotype has a different adaptation to different environments.

The average seed yield in three locations was 2.02 t/ha, with a range of 1.66-2.36 t/ha. Seed yield of Tanggamus and Demas 1 were 2.05 and 2.04 t/ha, respectively. A total of six genotypes produced yield higher than the best check variety (Tanggamus), and seed yield range of those six genotypes was 2.08-2.36 t/ha. If the selection was based on seed yield increase of 10% higher than the check variety Tanggamus (2.05 t/ha), then it will be obtained only one genotype, i.e. G4AB (2.36 t/ha). A relationship between soil pH, average yield per location, and highest yield of genotype from each location was presented in Figure 1. All the tested soybean genotypes showed adaptability at pH greater than 5, but began to show decreasing yield at pH less than 5. Under a low pH conditions, the aluminium, P fixation, iron, and manganese concentration increases to the toxic level (Keyser and Munns 1979). Furthermore, increase in soil acidity can reduce root growth, reduce nutrient availability and thus, would result in poor crop performance (Ezeh et al. 2007; Duressa et al. 2011). The result agrees with the report of Uguru et al. (2012) that soil pH had strong impact on the soybean root growth, agronomic performance, and yield traits.

The best genotype at pH 5.87 have seed yield differences of 0.32 t/ha with the average yield. Yield differences was showed at pH 5.04, i.e. 0.80 t/ha, and at pH 4.73 was 0.23 t/ha, respectively. Foy et al (1992) conducted a screening of soybean tolerance in the field without liming, and successfully obtained PI248511 (Japan), Perry (USA), PI381674 (Uganda), Amcor (Ohio USA) and Hernon 147 (Zimbabwe, Africa). In this research, genotype G4AB was considered as adaptive to acid soil and as well as productive to be developed in acid soil, followed by genotype G115H/Kaba//Kaba///Kaba-8-6.

Yield stability

Yield stability intended to assess the performance of a genotype which has smallest yield difference between one locations to another. Francis and Kannerberg (1978) combines between the coefficients of variation with yield to map a genotype into four quadrants. Quadrant I is characterized by genotypes which has a relatively stable and high yield at three locations. Quadrant II showed genotypes with high yield but unstable. Quadrants III and IV characterized by seed yield below average, but the genotypes in quadrant IV were considered more stable than the genotypes that were in quadrant III (Figure 2).

Based on those combination, five genotypes were stable and produced high yield, three genotypes produced high yield but less stable. The highest yielding genotype (G4AB) was less stable. On the contrary, G115H/Kaba//Kaba///Kaba-8-6 as a stable genotype in three locations of acid soil.

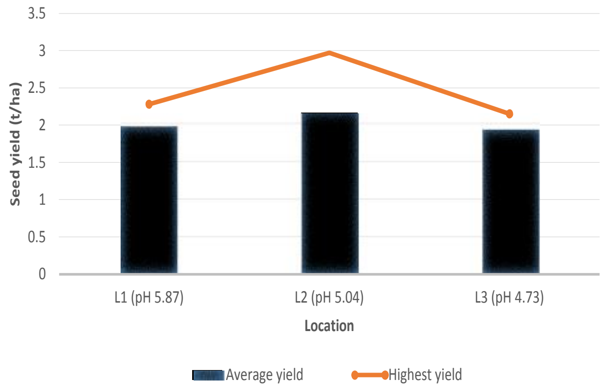

Figure 1. Average yield and the best genotype in three acid soil locations

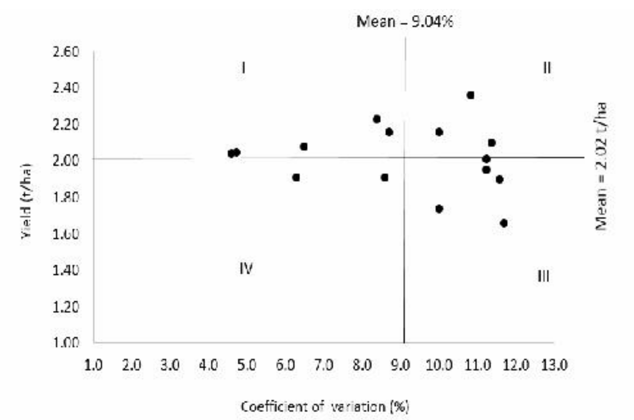

Figure 2. Yield stability of 15 soybean genotypes in three acid soil locations

Yield component

The yield components which consists of days to flowering, days to maturity, plant height, number of branches, number of nodes, number of filled pods, number of empty pods, and 100 seed weight of 15 soybean genotypes in three acid soil were presented in Table 4, Table 5, Table 6, and Table 7; respectively.

Character of days to flowering was more influenced by the genetic factor of each genotype, but for the days to maturity have tendency more influenced by pH. It means that the lower soil pH will tend to extend the plant age. Soybean varieties adapted to acid soil which have been released in Indonesia, have days to maturity over 85 days (Iletri 2012). The current farmers' preferences are soybean with early maturing day (<80 days) and large seed size (>14 g/100 seed). In this study, soybean with early maturing day was not obtained. High yielding soybean in acid soil have 81 days to maturity.

Plant height is often to be used as tolerance indicator of soybean genotype to low pH. Decreasing in soil pH tends to increase plant height. Soybean genotype which has identified producing high yield (G4AB) shows a relatively higher plant height than other genotypes, and followed by high number of branches and number of pods per plant. According to Samac and Tesfaye (2003), aluminium tolerance is a complex multigenic trait, therefore the selection method and selection indicator become something important. In this study, the observed morphological characters were those parts of the plant above ground. Wang et al. (2010) stated that the root system plays an important role in the efficiency of phosphorus in soybean, so it requires root breeding program.

Another interesting point, the best two soybean genotypes (G4AB and G115H/Kaba//Kaba///Kaba-8-6) have high number of empty pods and relatively small seed size, respectively. It seems that those characters have less effect on yield.

Table 4. Days to flowering and days to maturity of 15 soybean genotypes in acid soil, in 2015

Genotype	**Days to flowering (days)**				**Days to maturity (days)**			
	L1	**L2**	**L3**	**Mean**	**L1**	**L2**	**L3**	**Mean**
11 AB	32	31	31	31	78	82	78	79
13 ED	33	32	31	32	78	83	81	81
14 DD	33	31	30	31	79	82	82	81
19 BE	33	32	31	32	79	82	82	81
25 EC	33	32	31	32	79	83	82	81
G4AB	33	32	31	32	79	83	82	81
G2BB	34	33	32	33	78	83	84	82
G3CB	35	34	34	34	80	84	85	83
G5EB	35	34	33	34	79	84	87	83
G1DB	34	33	32	33	79	83	85	82
G115H/Kaba//Kaba///Kaba-8-6	35	33	31	33	79	84	85	83
G511H/Anj//Anj-2-10	34	33	32	33	79	84	85	83
G511H/Anj-1-3	35	33	32	33	78	84	83	81
Tanggamus	34	33	32	33	78	83	88	83
Demas 1	35	34	33	34	78	83	88	83
Mean	**34**	**33**	**32**	**33**	**78**	**81**	**84**	**81**

Note: L1 = South Lampung, L2 = Pesawaran dry season 1, L3 = Pesawaran dry season 2

Table 5. Plant height and branches number of 15 soybean genotypes in acid soil, in 2015

Genotype	Plant height (cm)				Number of branches/plant			
	L1	L2	L3	Mean	L1	L2	L3	Mean
11 AB	49.00	75.25	57.85	60.70	2.25	3.25	2.30	2.60
13 ED	50.50	51.90	52.20	51.53	2.75	3.45	1.45	2.55
14 DD	37.00	55.95	47.00	46.65	2.75	3.90	2.90	3.18
19 BE	43.25	59.55	56.25	53.02	2.25	2.50	2.20	2.32
25 EC	50.00	38.05	41.60	43.22	1.75	3.65	3.75	3.05
G4AB	45.50	64.45	62.95	57.63	2.75	4.35	3.00	3.37
G2BB	45.75	55.75	44.65	48.72	2.50	3.25	3.40	3.05
G3CB	41.75	46.10	48.55	45.47	2.50	4.10	3.10	3.23
G5EB	41.75	57.60	55.05	51.47	2.00	5.75	3.60	3.78
G1DB	42.50	55.35	50.40	49.42	2.50	4.90	2.75	3.38
G115H/Kaba//Kaba///Kaba-8-6	40.50	69.40	66.50	58.80	2.00	3.95	2.45	2.80
G511H/Anj//Anj-2-10	41.75	49.65	49.15	46.85	2.75	4.00	3.10	3.28
G511H/Anj-1-3	37.50	47.05	44.00	42.85	1.50	3.30	1.85	2.22
Tanggamus	36.75	54.80	42.50	44.68	2.50	3.55	2.70	2.92
Demas 1	40.50	62.15	51.00	51.22	2.50	5.05	3.05	3.53
Mean	**42.93**	**49.35**	**51.31**	**47.87**	**2.35**	**3.11**	**2.77**	**2.75**

Note: L1 = South Lampung, L2 = Pesawaran dry season 1, L3 = Pesawaran dry season 2

Table 6. Number of node and 100 seed weight of 15 soybean genotypes in acid soil, in 2015

Genotype	Number of node/plant				100 seed weight (g)			
	L1	L2	L3	Mean	L1	L2	L3	Mean
11 AB	11.25	23.80	12.00	15.68	15.24	15.61	17.63	16.16
13 ED	14.50	21.50	10.45	15.48	15.85	15.86	17.43	16.38
14 DD	11.00	20.15	17.65	16.27	15.85	13.68	15.09	14.88
19 BE	10.75	23.25	14.20	16.07	14.77	15.63	13.12	14.50
25 EC	9.50	17.45	17.30	14.75	15.98	12.54	17.90	15.47
G4AB	10.50	21.20	19.55	17.08	13.05	11.40	16.29	13.58
G2BB	11.50	21.25	13.05	15.27	13.18	15.41	13.96	14.18
G3CB	10.00	22.70	17.95	16.88	12.93	9.84	11.34	11.37
G5EB	9.50	27.75	15.50	17.58	13.38	10.21	12.95	12.18
G1DB	13.50	19.30	14.05	15.62	12.82	12.68	13.44	12.98
G115H/Kaba//Kaba///Kaba-8-6	8.50	22.55	16.55	15.87	13.63	12.51	13.93	13.35
G511H/Anj//Anj-2-10	11.75	19.65	16.25	15.88	12.83	12.64	12.92	12.80
G511H/Anj-1-3	9.00	19.40	12.60	13.67	13.85	15.94	17.48	15.75
Tanggamus	10.50	22.95	13.80	15.75	12.74	12.96	11.53	12.41
Demas 1	11.25	22.20	16.60	16.68	15.05	11.28	12.91	13.08
Mean	**10.87**	**16.10**	**15.17**	**14.04**	**14.08**	**13.66**	**14.53**	**14.09**

Note: L1 = South Lampung, L2 = Pesawaran dry season 1, L3 = Pesawaran dry season 2

Table 7. Number of filled and empty pods of 15 soybean genotypes in acid soil, in 2015

Genotype	Number of filled pod/plant				Number of empty pod/plant			
	L1	L2	L3	Mean	L1	L2	L3	Mean
11 AB	34.50	69.60	24.50	42.87	5.50	9.65	2.25	5.80
13 ED	35.00	45.50	15.30	31.93	6.75	20.85	2.00	9.87
14 DD	28.25	59.90	26.55	38.23	5.00	10.20	5.30	6.83
19 BE	26.50	58.50	28.75	37.92	5.25	6.30	2.95	4.83
25 EC	27.75	45.30	21.40	31.48	5.00	10.15	8.70	7.95
G4AB	28.50	48.45	38.85	38.60	6.50	14.55	2.85	7.97
G2BB	29.00	40.30	20.05	29.78	5.50	10.80	2.10	6.13
G3CB	18.25	60.40	23.55	34.07	6.00	9.60	4.35	6.65
G5EB	24.25	73.15	29.20	42.20	5.50	22.30	2.90	10.23
G1DB	22.75	59.95	23.10	35.27	5.25	9.40	1.25	5.30
G115H/Kaba//Kaba///Kaba-8-6	20.75	46.15	34.40	33.77	4.75	17.25	1.90	7.97
G511H/Anj//Anj-2-10	32.75	45.10	18.60	32.15	4.00	11.20	0.75	5.32
G511H/Anj-1-3	22.25	46.65	17.95	28.95	5.75	8.75	0.45	4.98
Tanggamus	26.75	65.40	13.65	35.27	5.75	12.35	1.45	6.52
Demas 1	20.25	53.30	23.70	32.42	7.50	10.30	3.15	6.98
Mean	**26.50**	**40.05**	**23.97**	**30.17**	**5.60**	**8.81**	**2.82**	**5.75**

Note: L1 = South Lampung, L2 = Pesawaran dry season 1, L3 = Pesawaran dry season 2

From this study, it can be concluded that soybeans are still able to produce optimally on soil acidity to a pH of 5.0. At pH below 5.0, the soybean productivity has declined and suggested to use soybean genotypes adapted to these conditions. Plant height is one of the morphological indicators to identify soybean genotype adaptive to acid soil. Furthermore, genotype G4AB was adaptive and productive to acid soil to a pH of 4.7, and therefore recommended to be developed as high-yielding variety for acid soil.

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