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Response of Acid-Adaptive Soybean Genotypes Grown in Associated Entisols-Inceptisols and Vertisols Soil Types

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ABSTRACT

Response of plant grown on different soil types will be different depending on the nature of the soil. Acid-adaptive soybean genotypes that normally grown in Ultisols, may have higher yield potential when grown in optimal soil types such as associated Entisols-Inceptisols and Vertisols. A total of 10 soybean (*Glycine max* (L.) Merrill) genotypes, consisted of nine acid-adaptive soybean genotypes and one released variety (Tanggamus/G10), were grown on both locations. A randomized complete blocks design with three replications was applied in this study. Results showed that interaction between the genotypes and the environments was found on five characters of seven observed characters. The check variety Tanggamus that released as acid-adaptive soybean variety showed the highest grain yield in both soil types indicating that Tanggamus is potential to be grown in Vertisols and associated Entisols-Inceptisols soil types. Shrink-swell in Vertisols might lead detrimental effect on soybean roots and caused growth and developing restriction. Consequently, grain yield in Vertisols was lower than in associated Entisols-Inceptisols. However, there were three genotypes with higher grain yield in Vertisols than in associated Entisols-Inceptisols, i.e., G2 (Tgm/Anj-833), G5 (Tgm/Anj-846) and G6 (Tgm/Anj-847).

Key words: Associated Entisols-Inceptisols, vertisol, soybean

INTRODUCTION

Indonesia has very wide acid soil up to 69% of the total dryland (Mulyani, 2006), leads agriculture development addressed to this area. Soybean grown in this area is different than that in the optimal land. It is because soybean grown in acid soil faces growth constraint due to macro nutrient deficiency such as N, P, K, Ca and Mg and micro nutrient toxicity such as Al and Mn. In optimal land conditions, there is no nutrients constraints, resulting better growth and development for acid-adaptive plants.

In optimal land, the differences of environments growth such as soil type, rain fall, humidity and temperature, also affect plant growth and development. Generally, a genotype has different response from an environment to other environments, even though in the optimal land condition. It relates to the stability of a genotype to the different environments. In the present of G×E interaction, the superiority of individual genotypes across the range of environments is determined by using stability parameter traits Ulker *et al.* (2006). The G×E interaction also describes the interplay between genetic and environmental factors on plant growth and development (Cucolotto *et al.*, 2007).

Soil type is an environmental factor that is difficult to change and any type of soil has different characteristics than other soil types. Entisol is a newly developing soil. However, this soil is not only soil parent material but it has experienced soil formation processes that produce ochric

epipedon (Hardjowigeno, 2003). Inceptisols is an immature soil with weaker growth profile compared to mature soil and much resembles the parent material properties (Hardjowigeno, 2003). Therefore, associated Entisols-Inceptisols soil property is a combination of the two soil types. Unlike associated Entisols-Inceptisols soil type, Vertisols is a soil with heavy structures and have a capacity to swell and shrink. The wetting and drying of the soil mass lead the swell-shrink behaviour. The high content of expanding clay minerals, called smectites, is the important cause of the shrink-swell processes (Anderson, 2010). The swell-shrink behaviour induces cracks in the upper parts of the soil. The cracks in Vertisols with a depth of 50 cm down may exhibit at least 1 cm wide (Dengiz *et al.*, 2012).

A plant grown on a soil type with different fertility levels will produce different performance. Similarly, a plant grown on different soil types will perform different response, depending on the nature of the soil. In this research, acid-adaptive soybean genotypes that normally grown on Ultisols were studied on Vertisols and associated Entisols-Inceptisols soil types.

MATERIALS AND METHODS

The study was carried out at Jambegede Research Station and Ngale Research Station from June to September 2011 (Fig. 1). All of the two locations are in East Java Province. Jambegede Research Station is located on Malang Regency, while Ngale Research Station is located on Ngawi Regency. The most importance of the two locations is the soil type because, Jambegede Research Station has associated Entisols-Inceptisols soil type, while Ngale Research Station has Vertisols soil type. The altitude also important, because Jambegede is located at 335 m above sea level (asl) while Ngale Research Station at 168 m asl. The climate type of both environments is C3 according to Oldeman (1975).

A total of 10 soybean (*Glycine max* (L.) Merrill) genotypes, consisted of nine acid-adaptive soybean genotypes and one check variety (Tanggamus), were grown on both locations. A randomized complete blocks design with three replications was applied in this study. Every genotype was grown in 1.6×3.0 m with plant spacing of 0.4×0.15 m, two plants per hill (Table 1). The fertilizers were 50 kg urea, 75 kg SP36 and 75 kg of KCl ha⁻¹ and applied at sowing time. The weed control was carried out manually at 14 and 28 day after planting (dap). Insecticides with 5 days interval were applied to control the pest. Harvesting was carried out after the plant

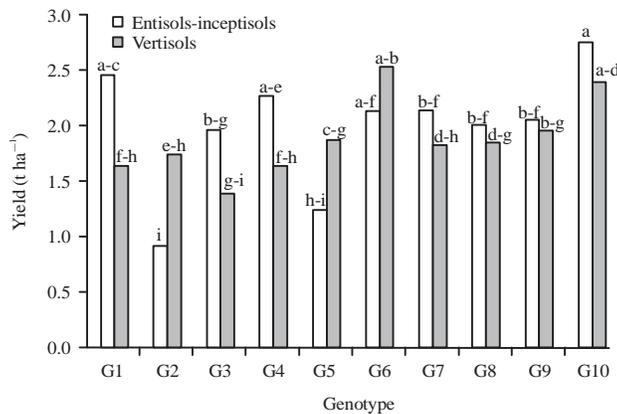


Fig. 1: Genotype×environment interaction on grain yield of acid-adaptive soybean genotypes in associated Entisols-Inceptisols and Vertisols soil types, dry season 2011

Table 1: Code and genotype name

Codes	Genotypes
G1	Tgm/Anj-784
G2	Tgm/Anj-833
G3	Tgm/Anj-834
G4	Tgm/Anj-844
G5	Tgm/Anj-846
G6	Tgm/Anj-847
G7	Tgm/Anj-856
G8	Tgm/Anj-871
G9	Tgm/Anj-889
G10	Tanggamus

was physiologically matured, where most of the leaves yellowing/browning and fallen. Agronomical data such as grain yield per hectare, 50% days to flowering, days to maturity, plant height, number of branches per plant, number of pods per plant and 100 grains weight were observed.

RESULTS

Combined analysis of acid-adaptive soybean genotypes in two optimal soil conditions showed genotype×environment interaction on flowering days, maturity days, plant height, number of branches per plant and grain yield. Even though genotype and environment of 100 grain weight was significantly difference but there was no genotype×environment interaction shown by this character. There was no genotype×environment interaction on number of pods per plant but the genotypes were significantly different (Table 2). It means that based on that character at least one genotype has a good performance in certain environments but not good on other environments.

Differences of planting environment affected different performance of tested genotypes. These differences planting environment caused changes of the genotypes rank in other environment. In Entisols-Inceptisols, G10 variety showed the highest grain yield. The G10 also remained showed a high grain yield after G6 in Vertisols. There were three genotypes with higher grain yield in Vertisols than in Entisols-Inceptisols, i.e., G2, G5 and G6, whereas the other genotypes showed the same or higher grain yield in Entisols-Inceptisols rather than in Vertisols.

Genotype×environment interaction was significant on flowering days (Table 2). The longest flowering days was shown by G3 in Entisols-Inceptisols, while the earliest was shown by G1 in Vertisols. Flowering days of G1 increased when grown in Entisols-Inceptisols but the flowering days of G3 was also consistently longest with G5 and G7 in Vertisols. There were six days different on flowering days between the two soil types for G3. G10 as check variety had similar flowering days to G5 and G7 in Entisols-Inceptisols (Table 3).

Similar to the flowering days, maturity days of ten tested genotypes were also affected by genotypes×environment interaction (Table 2). In this character, the longest maturity was achieved by G3 and G1 in Entisols-Inceptisols, whilst the earliest was achieved by G2 and G7 and in vertisols. G3 also showed the longest maturity days in Vertisols, together with G4 and G6. For G1, there was six days different between the two soil types (Table 3). The maturity days of the check variety G10 were not different between two soil types.

The highest plant height was achieved by G3 in Entisols-Inceptisols, whilst the lowest plant height was achieved by G2 also in Entisols-Inceptisols. When grown in Vertisols, G2 increased plant height up to 56.2 cm. The G1 showed similar plant height in two soil types. The check variety G10 also showed similar plant height in two locations with higher plant height than G1 (Table 4).

Table 2: Combined analysis of acid-adaptive soybean genotypes in associated Entisols-Inceptisols and Vertisols soil types, dry season 2011

Source	df	Flower	Maturity	Height (cm)	Branch	Pod	100 GW	Yield
E	1	173.4**	79.35**	299.09**	1.67	1601.67	35.64**	0.18
G	9	20.49**	18.63**	291.78**	1.41**	593.18**	12.50**	0.79**
G×E	9	4.18**	6.35**	147.74**	1.04**	88.00	1.15	0.46**
Error	36	0.39	0.66	25.76	0.45	137.25	0.77	0.13

** : Significant at 1%, Flower: Flowering days, Maturity: Maturity days, Height : Plant height (cm), Branch: No. of branches per plant, Pod: No. of pods per plant, 100 GW: 100 grains weight, Yield: Yield per hectare (t ha⁻¹), df: Degree of freedom

Table 3: Flowering days and maturity days of acid-adaptive soybean genotypes in associated Entisols-Inceptisols and Vertisols, dry season 2011

Genotype	Flowering days		Maturity days	
	Entisols-Inceptisols	Vertisols	Entisols-Inceptisols	Vertisols
G1	34.7 ^{fg}	31.0 ^k	86.7 ^a	81.3 ^{d-f}
G2	34.3 ^{gh}	33.0 ^j	80.3 ^{efg}	78.0 ^h
G3	41.0 ^a	35.0 ^{fg}	88.0 ^a	82.0 ^{b-d}
G4	36.7 ^{de}	33.0 ^j	83.0 ^{bc}	82.0 ^{b-d}
G5	39.3 ^b	35.0 ^{fg}	81.0 ^{d-f}	80.0 ^{fg}
G6	33.3 ^{hi}	32.0 ^{jk}	81.3 ^{d-f}	82.0 ^{b-d}
G7	37.7 ^{cd}	35.0 ^{fg}	81.3 ^{d-f}	79.3 ^{gh}
G8	35.7 ^{ef}	32.0 ^k	81.3 ^{d-f}	80.0 ^{fg}
G9	34.7 ^{fg}	33.0 ^{ji}	83.3 ^b	80.0 ^{fg}
G10	38.7 ^{bc}	33.0 ^{ji}	83.0 ^{bc}	81.7 ^{c-e}
LSD (5%)	01.03	01.35		

Value followed by the same letter was not significantly different at LSD 5%, LSD: Least significant difference

Table 4: Plant height and number of branches per plant of acid-adaptive soybean genotypes in associated Entisols-Inceptisols and Vertisols soil types, dry season 2011

Genotype	Plant height (cm)		Number of branches/plant	
	Entisols-Inceptisols	Vertisols	Entisols-Inceptisols	Vertisols
G1	49.9 ^g	49.1 ^g	3.3 ^c	3.7 ^{bc}
G2	40.1 ^h	56.2 ^{d-g}	3.3 ^c	4.0 ^{a-c}
G3	77.1 ^a	56.1 ^{d-g}	4.7 ^{ab}	4.7 ^{ab}
G4	52.4 ^{fg}	61.0 ^{c-e}	3.3 ^c	5.0 ^a
G5	62.4 ^{cd}	71.6 ^{ab}	5.0 ^a	5.0 ^a
G6	55.5 ^{d-g}	62.5 ^{cd}	3.3 ^c	4.0 ^{abc}
G7	54.4 ^{d-g}	62.3 ^{cd}	3.7 ^{bc}	5.0 ^a
G8	52.9 ^{e-g}	60.7 ^{c-f}	4.0 ^{a-c}	4.0 ^{a-c}
G9	48.7 ^g	55.4 ^{d-g}	3.7 ^{bc}	3.7 ^{bc}
G10	65.0 ^{bc}	68.2 ^{bc}	4.7 ^{ab}	3.3 ^c
LSD (5%)	08.41	01.11		

Value followed by the same letter was not significantly different at LSD 5%, LSD: Least significant difference

Number of branches per plant also showed genotype×environment interaction (Table 2). Genotype with the highest number of branches per plant was G5 in both soil types and G4 in Vertisols. However, G4 showed low number of branches per plant in Entisols-Inceptisols. Similar to G4, the check variety G10 also showed different number of branches on two soil types, where G10 showed high number of branches per plant in Entisols-Inceptisols but showed low number of branches per plant in Vertisols. Yield per plant was primarily regulated by changes in branch dry matter per plant, where greater branch dry matter per plant created more branch nodes, branch reproductive nodes and branch pods.

Number of pods per plant was significantly different among genotypes but was not significant different between the two soil types. Beside, there was no genotype×environment interaction (Table 2). Genotype with the highest number of filled pods per plant was G3 and G5, whilst the

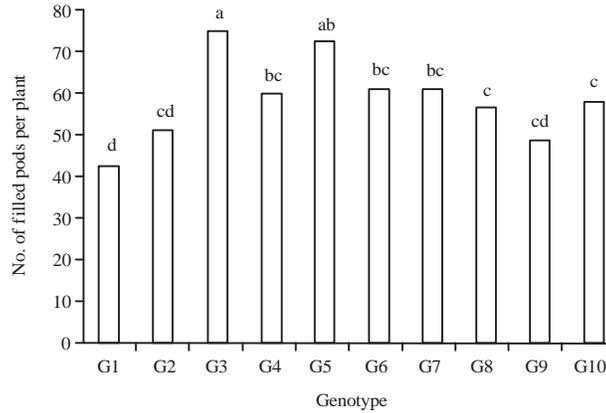


Fig. 2: Average of filled pods of acid-adaptive soybean genotypes in associated Entisols-Inceptisols and Vertisols soil types, dry season 2011

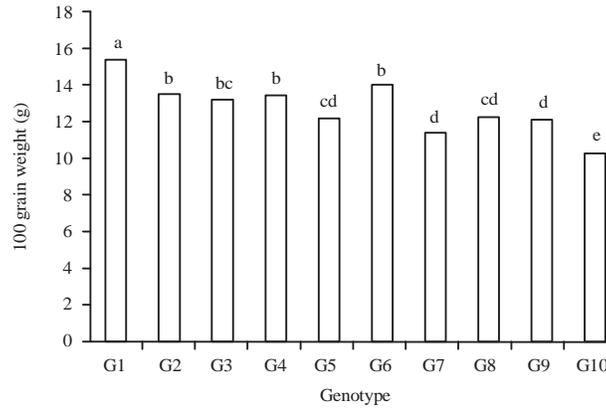


Fig. 3: One hundred grains weight of acid-adaptive soybean genotypes in associated Entisols-Inceptisols and Vertisols soil types, dry season 2011

lowest was G1 (Fig. 2). However, the lowest genotype G1 was not significantly different to G2 and G9. The check variety G10 was in the middle rank among the tested genotypes. Number of pods is often associated with the grain yield (Egli, 2013).

Seed size is described by 100 grain yield. The largest seed size was shown by G1, while the smallest was shown by the check variety G7 (Fig. 3). Environment affected 100 grains weight but there was no genotype×environment interaction. It means that increasing or decreasing seed size due to the environmental changes did not change the rank of the genotypes in those two soil types. The average of 100 grain yield in Vertisols (13.57 g/100 grains) was higher than in Entisols-Inceptisols (12.05 g/100 grains).

DISCUSSION

Genotype×environment interaction was found on flowering days, maturity days, plant height, number of branches per plant and grain yield, it means that based on one or all of those characters at least one genotype had a good performance in certain environment but not good on other environments. In genotype×environment interaction, genotype and environment have a role in

expressing the performance of a character. However, the role of the genotype is not always equal to the environment on a character. Genotype×environment interaction on those five characters also indicated that the expression of plant's genes can be influenced by the environment, where the plant was grown. The abiotic environment has two components, i.e., climate and soil, which determine the plant evolutionary adaptability and representing a set of surrounding physical, chemical and sometimes limiting traits, that can determine the availability of nutrients and energy (De la Vega, 1996).

In this study, the role of the environments in expressing the performance of a character was caused by different soil types. The chemical properties of Vertisols are better for growing plant than Entisols-Inceptisols. On the other hand, physical properties of Entisols-Inceptisols are better than Vertisols. The disadvantage of Vertisols in dry season leads possibility to shrink when the water availability was low and swell in high water availability. Shrink-swell in Vertisols may lead detrimental effect on soybean roots and causes growth and developing restriction (Mandal *et al.*, 2013). The crop growth in Vertisols is dominantly affected by the available soil water storage capacity and moisture stress (Wakode *et al.*, 2011).

The significantly difference on flowering days and maturity days beside genotype×environment interaction revealed that genotype and environment had the similar effect on those two characters. Khan *et al.* (2011) reported that various soybean genotypes affected flowering days and maturity days. In soybean, maturity days may be more important than flowering days because usually the difference between maturity days is longer than flowering days. However, the most important among phenological characters is the duration between flowering days and maturity days, because it describes seed filling period. This duration also has significant correlation to grain yield (Ghodrati *et al.*, 2013).

Environment was not significantly different on number of pods per plant but genotype was significantly different. It indicated that genotype had important role in expressing number of pods per plant but environment had no role. Genotype of G3 and G5 had the highest number of pods per plant, indicated that those two genotypes genetically capable to perform many number of pods per plant. Even in the acid soil, the check variety G10 (Tanggamus) is able to reach number of pods per plant up to 127 pods per plant (Kuswantoro and Zen, 2013). In this study Tanggamus had lower number of pods per plant than in acid soil, it might be due to the low water availability and the high solar radiation in dry season. It seemed that weather condition at the planting season was a prime factor rather than the soil type and fertility causing this phenomenon (Kuswantoro and Zen, 2013).

Grain size was measured through 100 grains weight. This character was affected by the environment and the genotype separately, where there was no genotype×environment interaction even though genotype and environment were significantly different. Grain size in Vertisols was higher than in Entisols-Inceptisols because the nutrient in Vertisols is higher than in Entisols-Inceptisols (Nursyamsi and Suprihati, 2005). For pod filling process, it is needed nutrients as the raw materials. If the raw materials are limited, the process can not perform normally. The grain size decreases when soybean grown in a soil with low fertility, especially in low phosphorus (Soares *et al.*, 2013). Presumably, phosphorus in Entisols-Inceptisols was lower than Vertisols because soil parent material of Entisols-Inceptisols in Jambegede Research Station is originated from volcanic material.

Soybean genotypes have different response to the different soil types because of the physical and chemical properties. In this research, physical properties seemed to be more dominant than

chemical properties. In Vertisols, the swell-shrink potential is not conducive for crop production purposes and the grain yield is also low at the less rainfall (Mandal *et al.*, 2013). It leads the crop yield to be largely proportional to moisture availability (Wakode *et al.*, 2011). In associated Entisols-Inceptisols, there is no swell-shrink phenomenon as Vertisols. Therefore root damages do not occur in this soil type but other physical stress can occur such as water deficit stress. Usually the water deficit due to the dry season leads suppressing plant growth and development. However, the crop water requirement of soybean decreases as the increasing water deficit levels (Ahmed *et al.*, 2009). Under water deficit level, grain yield of soybean per unit area in Inceptisols is higher than in Ultisol and Andisol (Ahmed *et al.*, 2009). In Entisols, soybean is still capable to produce high yield at the range of water stress 60-80% of field capacity (Nurhayati, 2009).

Yield is a complex character which is supported by other characters. This phenomenon can be described through the relationships of grain yield with those characters. Many researchers have reported these relationships. There are relationship between grain yield to indirect relationship characters, such as flowering day (Arshad *et al.*, 2014; Koladiya *et al.*, 2012), maturity days (Koladiya *et al.*, 2012) and plant height (Koladiya *et al.*, 2012; Malik *et al.*, 2011). Further, relationship between grain yield with direct relationship characters, such as number of pods per plant (Arshad *et al.*, 2014; Koladiya *et al.*, 2012; Machikowa and Laosuwan, 2011; Malik *et al.*, 2011), number of grains per plant (Salimi and Moradi, 2012) and grain size or 100 grains weight (Athoni and Basavaraja, 2012; El-Badawy and Mehasen, 2012; Malik *et al.*, 2011; Salimi and Moradi, 2012) are also often found.

CONCLUSION

Genotype×environment interaction led different response of the tested genotypes to the environments. Response of acid-adaptive soybean genotypes in associated Entisols-Inceptisols was different than in Vertisols. The G10 (Tanggamus) as acid-adaptive soybean variety showed the high grain yield in both soil types indicating that it is potential to be grown in associated Entisols-Inceptisols and Vertisols soil types. There were three genotypes with higher grain yield in Vertisols than in associated Entisols-Inceptisols, i.e., G2 (Tgm/Anj-833), G5 (Tgm/Anj-846) and G6 (Tgm/Anj-847). Shrink-swell in vertisols might lead detrimental effect on soybean roots and caused growth and developing restriction.

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