

Effect of Soil Tillage and Adaptability of Argomulyo and Burangrang Varieties in Madagascar Dry Season with Cold Temperature

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ABSTRACT

This research aimed to study soybean response to different soil tillage and soybean adaptability to dry season with cold temperature. Two Indonesian varieties ('Argomulyo' and 'Burang-rang') and three Madagascar varieties ('FT10', 'OC11' and 'Malady') were grown under soil tillage and no soil tillage in Antananarivo Avarandrano, Madagascar. The planting date was from June to November 2014 in which the season was dry season with average temperature ranging 14-19 °C. Results showed that there was no variety × tillage interaction on the observed characters. Tillage system was significantly different on plant height, number of pods plant⁻¹, grain size, and grain yield. The differences among varieties were found on vegetative and generative phases, plant height, number of branches and pods plant⁻¹, grain size, and grain yield. Cold temperature suppressed growth and development of vegetative and generative phases causing agronomical characters decreased. However, soybean plants were still able to grow and develop indicating that soybean can be grown under no tillage system with cold temperature. Indonesian varieties ('Argomulyo' and 'Burangrang') showed equal grain yield to Madagascar Varieties ('FT10' and 'OC11'), suggesting that 'Argomulyo' and 'Burangrang' were adaptable in Madagascar dry season with cold temperature.

Keywords: cold temperature; dry season; no soil tillage; soil tillage; soybean

INTRODUCTION

In Madagascar, there is no crop cultivation in dry season. Usually, crop cultivation is carried out only once a year during the rainy season. Entering dry season, agricultural land is left without any crop growing. It leads to low efficiency of land usage, or even the land usage is inefficient. The main problem in Madagascar dry season is the low temperature and low water availability that inhibit farmers to grow crop, because farmers are afraid if the crop cannot grow and develop well or even the crop will be die. Therefore, cultivation in dry season in Madagascar does not develop. Even, information of land preparation also is very low, as well as the information of crops species and its varieties that can be grown in this condition. To develop crop cultivation in Madagascar dry season, those main problems should be resolved by the pioneering research in soil tillage and variety adaptability. In this article, land preparation was studied with two soil tillage systems, and crop species was studied by using five soybean varieties. We used soybean as plant material because soybean is one of the crops that usually grown in Madagascar. In addition, soybean requires relatively low water availability than other crops such as rice.

Soil tillage is able to change physical soil properties, such as soil porosity, hydraulic conductivity, mean weight diameter (Celik, Turgut, & Acir, 2012), bulk density, water holding capacity, air capacity (Husnjak, Filipovic, & Kosutic, 2002), penetration resistance, pH, electrical conductivity,

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and water content (Fan, Yang, Drury, Reynolds, & Zhang, 2014). Soil tillage can also change biological soil properties, such as soil microbial communities (Mathew, Feng, Githinji, Ankumah, & Balkcom, 2012). Omondi, Mungai, Ouma, & Bajjukya (2014) stated that biological nitrogen fixation can be encouraged by practicing no tillage. Optimum soil condition can be achieved by application of suitable soil tillage for certain crop species on specific soil type. Therefore, tillage system can increase soybean yield by using suitable soil tillage. In other crop, reduced tillage combining with corn-soybean crop rotation could increase corn yield (Reddy, Zablutowicz, & Krutz, 2013).

Temperature is very important in crops growth and development. Higher temperature can accelerate metabolic processes in the plant that can enhance its growth and development, and vice versa. Low temperature is a major environmental factor that greatly influences plant growth, development, and crop yield (Kim *et al.*, 2004). Some plants species are capable to tolerate extreme temperature, but many plants only adapt on certain temperature. Soybean is more cold temperature susceptible, than other crops such as bean, and has less potential; thus breeding for improving cold tolerance and appropriate phenology is needed (Clements, 2014). To improve cold tolerance plant, some genes have been studied. Many genes respond to low temperature at transcriptional level and the gene products play role in tolerance and response of the stress. In physiological point of view, some low temperature tolerance mechanisms have been identified.

Environmental factors do not influence separately to a plant, but they interact each other

and perform growth and development of plants simultaneously. Similarly, cold temperature influences soil environmental condition and finally affects plant growth and development. Therefore, cold temperature can affect plant indirectly by modifying soil physical and biological properties, such as soil structure, soil moisture, microbial communities (Henry, 2013) and soil respiration (Jiang *et al.*, 2015). Cold temperature also affects altitudinal variations in soil physico-chemical properties at cold desert high altitude such as sand, clay, and silt percentages, and pH, total dissolved solid, CaCO₃, and soil organic matter (Charan *et al.*, 2013). In biological properties, cold temperature not only affects microbial biomasses but their enzymatic activity as well (Shi, Lalande, Hamel, & Ziadi, 2015).

MATERIALS AND METHODS

Research Site

Experiment was conducted in Ambohimangakely, Antananarivo Avarandrano, on cold dry season from June to November 2014 (Table 1). This site is located on coordinate of 18°54' South, 47°36' East and altitude of 1276 m above sea level. The soil type was Oxisols with soil pH about 7. The normal soil pH of Oxisols is due to the intensive soil management for paddy field.

Plant materials: Materials were consisted of two Indonesian varieties ('Argomulyo' and 'Burangrang') and three Madagascar varieties ('FT10', 'OC11' and 'Malady'). 'Argomulyo' and 'Burangrang' are the early maturing varieties in Indonesia, whereas 'FT10' and 'OC11' are medium maturing varieties and 'Malady' is early variety in Madagascar.

Table 1. Temperature data in Antananarivo, Madagascar. Dry season 2014

Month	Minimum temperature (°C)	Maximum temperature (°C)	Average temperature (°C)
May	11	26	16
June	10	25	14
July	8	21	14
August	10	26	14
September	10	27	16
October	13	32	19
November	15	31	19

Source: www.climatevo.com/2014,antananarivo,mg

Soil Preparation

Two soil tillage systems, i.e. soil tillage and no tillage, were applied in this study as environment treatments. Soil tillage system was conducted by ploughing down to 20 cm depth. After ploughing, soil was flatted by using hue to get flat plot. For no soil tillage system, the soil was prepared by clearing the grass manually. Drainage canals were made every 5 m apart with 20 cm depth. The design was a randomized complete block design with four replications in each environment.

Planting

Every genotype was grown on 5 m × 2 m with planting space 0.4 m × 0.15 m. Weeding was carried out at 30, and 60 days after planting (DAP). Organic fertilizer was applied 5 % of soil weight based on 5 cm depth, while inorganic fertilizer was applied by using 400 kg NPK (16:16:16). The material of organic fertilizer was the waste of cattle that available in the surrounding field. Fertilizers were applied at the sowing time. Weeding was conducted mechanically by removing the weed using hue at 1, 30, 60 and 90 DAP, where at 30 and 60. Watering was conducted at 1, 30, 60 and 90 DAP, where at 30 and 60 watering were applied after weeding.

Observation

Observations were recorded for vegetative and generative phases, plant height, number of branches plant⁻¹, number of filled pods plant⁻¹, 100 grains weight, and grain yield. Vegetative phase was calculated from planting date to 50 % flowering age, while generative phase was calculated from 50 % flowering age to 95 % maturing age.

Statistical Analysis

The data were analysed by using analysis of variance. The significant variable from analysis of variance were further analysed by using least significant different at 5% significant level (LSD α 0.05). The software for analysing the data was Statistical Tool for Agricultural Research (STAR).

RESULTS AND DISCUSSION

The result showed that there was no interaction between variety and tillage system on all observed characters, even though most of the observed characters were significantly different in tillage system and variety separately (Table 2). The differences among varieties were found on characters of vegetative and generative phases, plant height, number of branches plant⁻¹, number of pods plant⁻¹, 100 grains weight, and grain yield. It indicates that each variety had different genetic structures. The response of each variety with different genetic structure to the environment lead different plant performance (Table 2 and 3).

Vegetative and generative growths are the components of plant duration. Those phases in no tillage system were not significantly different to the tillage system. However, there were differences among varieties. The longest vegetative phase was shown by 'Argomulyo', while the shortest was shown by 'Malady'. Similarly, 'Argomulyo' and 'Malady' were also shown the longest and shortest generative phase respectively. 'Burangrang' showed shorter vegetative and generative phases than 'Argomulyo' (Figure 1). In Indonesia, 'Argomulyo' and 'Burangrang' are early varieties with the same days to maturity and flowering days, i.e. about 80-82 days and about 35 days. The prolonged of flowering and maturing days in Madagascar is caused by the lower temperature.

Table 2. Combined analysis of some agronomical characters of three Indonesian soybean varieties and two Madagascar soybean varieties in tillage and no tillage systems, Madagascar dry season 2014

Source	df	Vegetative	Generative	Height	Branch	Pod	100GW	Yield
E	1	0.225	0.0000	346.5088*	1.156	232.8062*	36.6531*	0.7156**
R within E	6	0.625	0.3167	45.9991	0.6547	25.8902	3.2247	0.0336
G	4	958.2875**	147.7125**	1058.3689**	7.3465**	108.5027**	16.3166**	0.5277**
ExG	4	0.0375	0.0625	17.7626	0.3385	32.2762	3.6483	0.027
Pooled Error	24	0.3125	0.6708	34.6622	0.3938	14.0948	2.6045	0.034
Total	39							

Remarks: Vegetative = vegetative phase (days), Generative = generative phase (days), Height = plant height (cm), Branch = number of branches plant⁻¹, Pod = number of pods plant⁻¹, 100 GW = 100 grains weight (g 100⁻¹), Yield = grain yield (t ha⁻¹)

Table 3. Means of some agronomical characters of two Indonesian soybean varieties and three Madagascar soybean varieties in tillage and no tillage systems, Madagascar dry season 2014

Agronomical characters	Tilled soil	No tilled soil
Vegetative phase (days)	81.93 ^a	81.85 ^a
Generative phase (days)	71.65 ^a	71.65 ^a
Plant height (cm)	30.3 ^b	36.2 ^a
Number of branches plant ⁻¹	1.5 ^a	1.8 ^a
Number of pods plant ⁻¹	13.0 ^b	17.9 ^a
100GW (g 100 ⁻¹)	17.27 ^a	15.36 ^b
Yield (t ha ⁻¹)	0.83 ^b	1.10 ^a

In this study, average temperature was about 14-19 °C. Even though there were maximum temperatures up to 31 and 32 °C, but these temperatures were only occurred occasionally on October and November 2014. This temperature is extremely different compared to tropical Indonesian temperature that can reach of average temperature up to 27 °C with the highest

temperature up to 35 °C. The low temperature in Madagascar increased vegetative and generative phases. In contrast, Kuswanto *et al.* (2014) reported decreasing vegetative and generative phases of Korean soybean varieties grown in Indonesia. The increasing of vegetative phase can increase days to maturing, because days to maturing is the resultant of vegetative phase and generative phase. Generative phase is more important than vegetative phase, because longer generative phase can lead higher number of pods and seed plant⁻¹ (Kuswanto *et al.*, 2014) and grain yield (Fatichin, Zheng, Narasaki, & Arima, 2013). However, the temperature in this study was not an optimal condition for soybean growth causing different responses of yield and yield components compared to their growth under optimal condition. In genotype originates from tropical areas, grain yield is not improved by increasing the growth period with a longer juvenile growth stage (Fatichin, Zheng, Narasaki, & Arima, 2013).

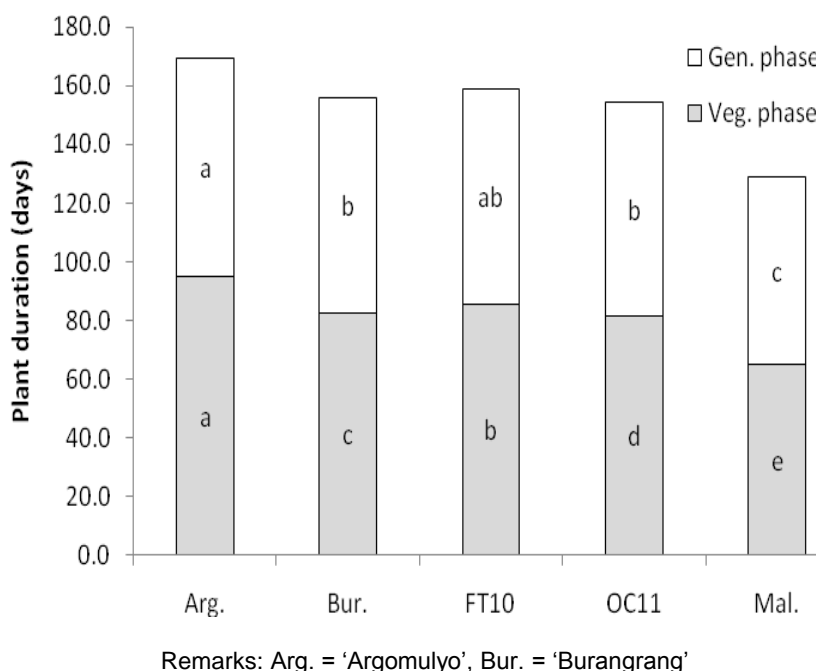


Figure 1. Duration of vegetative and generative growth phases of two Indonesian soybean varieties and three Madagascar soybean varieties in tillage and no tillage systems, Madagascar dry season 2014

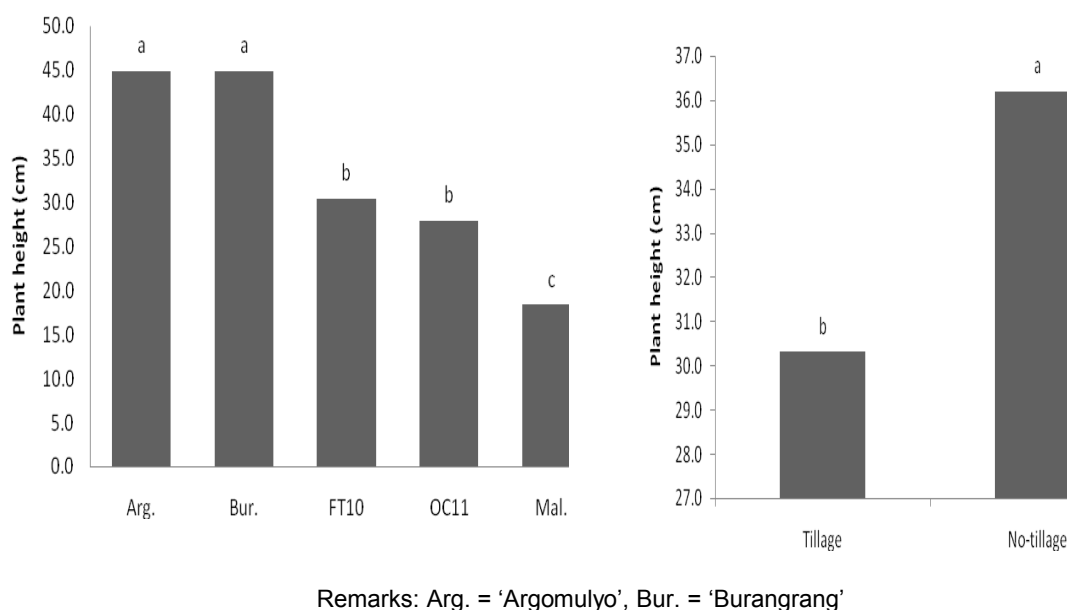


Figure 2. Plant height of two Indonesian soybean varieties and three Madagascar soybean varieties in tillage and no tillage systems, Madagascar dry season 2014

Plant height in no tillage system was higher than in tillage system. Presumably, it was due to the nature of the soil, where the soil was crumbly allowing better environment condition for soybean growth. Beside, the tillage system lead the soil becoming too porous for soybean growth. The higher porosity in tillage system than no tillage system causes direct effect on soil temperature. Genotypic factor has equal role as much as the environment, in this case tillage system. Comparing among the varieties, 'Argomulyo' had similar plant height with 'Burangrang', while 'FT10' was similar to 'OC11' (Figure 2). Plant height of 'Argomulyo' and 'Burangrang' were higher than 'FT10' and 'OC11'. 'Malady' was the lowest varieties in plant height compared to all the other varieties. This result is different to Gawęda, Cierpiało, Bujak, & Wesółowski (2014) that reported reducing plant height of soybean without soil tillage. The difference result was due to the temperature in that experiment was optimal for soybean growth. Hence, there is no metabolic inhibition lead by the low temperature.

Plant height is a character that influenced by vegetative phase. Longer vegetative phase causes higher plant height (Kuswanto et al., 2014). Plant height of 'Argomulyo' and 'Burangrang' in this study were lower than when they

grown in Indonesia. It is because the temperature was extremely low causing low metabolic processes. The low metabolic processes lead to the low plant growth including plant height. However, contribution of thermal parameters in determining rate of different developmental stages is inconsistent (Shahsavari, Yasari, & Rezaeei, 2014). Kuswanto et al. (2014) reported decreasing plant height of Korean soybean varieties grown in Indonesia with warmer temperature than the origin site. Similarly, Moosavi, Mirhadi, Imani, Khaneghah, & Moghanlou (2011) reported that higher temperature decreased plant height due to the reduction of plant duration. Therefore, there is a different response of the plants on extreme temperature and optimal temperature.

Significant differences among genotypes were found on number of branches plant⁻¹, but genetic × environment interaction and between tillage systems did not significantly different (Table 2 and Table 3). It indicated that the role of genotype is more important than the environment, where in this case is soil condition. Three genotypes ('Burangrang', 'FT10' and 'OC11') showed same number of branches plant⁻¹. The highest number of branches plant⁻¹ was achieved by 'Argomulyo' while the lowest was achieved by 'Malady' (Figure 3).

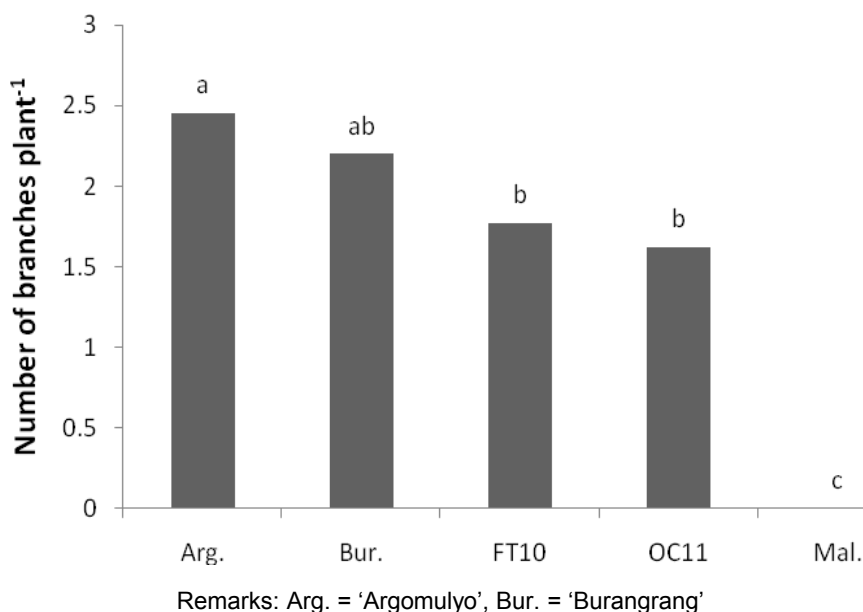


Figure 3. Number of branches plant⁻¹ of two Indonesian soybean varieties and three Madagascar soybean varieties in tillage and no tillage systems, Madagascar dry season 2014

In Indonesia, 'Argomulyo' can reach about 3-4 number of branches plant⁻¹ (Kuswanto et al., 2014). It indicates that in this study soybean branches did not grow well, especially for 'Argomulyo'. The similar pattern between plant height (Figure 2) and number of branches plant⁻¹ (Figure 2) indicates the relationship between the two characters. The relationship between number of branches plant⁻¹ and plant height (Kuswanto et al., 2014) is assumed to be a cause of low number of branches plant⁻¹, or the higher plant height causes the high number of branches plant⁻¹.

In soil tillage system, number of pods plant⁻¹ was lower than in no soil tillage system (Figure 4). Even though significant differences among varieties and between tillage systems were found, but geneticxenvironment interaction was not found on this character. 'Argomulyo', and 'Burangrang' performed equally to 'OC11'. 'Malady' showed the lowest number of pods plant⁻¹ compared to all the other varieties (Figure 4). The cold season may be affect nutrients uptake from the soil, because roots are faced directly by low temperature in tillage than in no soil tillage. Increasing of soil porosity and air capacity lead to decrease temperature and soil moisture in tillage system. Then, the low temperature caused decreasing nutrients uptake. Gawęda, Cierpiąła, Bujak, & Wesółowski (2014) showed that soil tillage

system was not significantly increases in number of pods plant⁻¹.

Numbers of pods plant⁻¹ were different among the tested soybean varieties. The highest numbers of pods plant⁻¹ was achieved by 'Argomulyo'. However, it was not statistically different to 'Burangrang' and 'OC11'. The lowest number of pods plant⁻¹ was achieved by 'Malady'. This variety was statistically different to other varieties with less than 10 pods per plant. Number of pods plant⁻¹ of 'Argomulyo' and 'Burangrang' varieties (Figure 4) grown in Madagascar dry season were very low compared to grown in normal tropical temperature condition in Indonesia. The low temperature in this study (Table 1), lead to decrease number of pods plant⁻¹. Cold temperatures during early reproductive development may result in reduced pod and seed formation in soybean (Cober, Molnar, Rai, Soper, & Voldeng, 2013). Higher daily radiation or longer duration of generative phase suggested that long photoperiods increase the number of pods (Kantolic, Peralta, & Slafer, 2013) due to pod filling depending on photosynthetic process.

Grain size that described in 100 grains weight was larger in soil tillage system than without soil tillage system (Figure 5). Reproductive growth stages of R6-R7 for seed development had higher seed growth rate and seed filling period due to seed growth rate and seed filling period positively

correlate with final grain size (El-Zeadani *et al.*, 2014). 'Malady' showed the lowest grain size in soil tillage system, while the other four varieties were not significant difference (Figure 5). It indicated that grains size was influenced by the environment. Grain size was controlled by multiple genes lead to easily changed by the environment

alteration. Grain size is also sensitive to different temperature (Tacarinduaa, Shiraiwaa, Homma, Kumagaib, & Sameshima, 2012) that causes grain size alteration in different temperature condition. It is suggested that there may be several mechanisms responsible for the variation in soybean grain size (Egli, 2012).

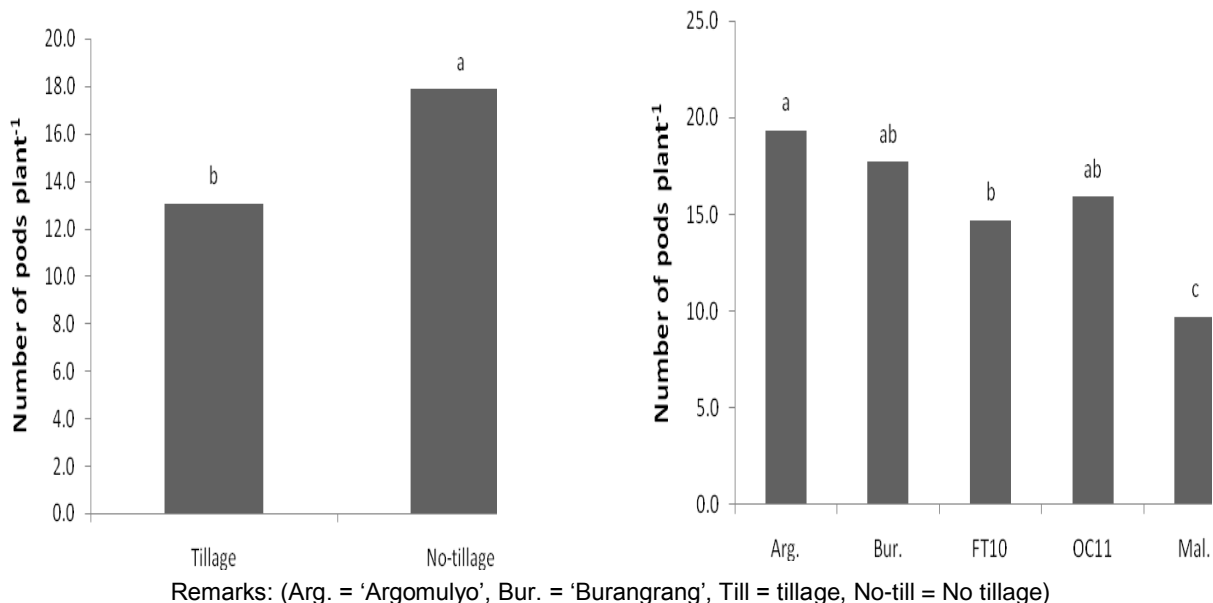


Figure 4. Number of pods plant⁻¹ of two Indonesian soybean varieties and three Madagascar soybean varieties in tillage and no tillage systems, Madagascar dry season 2014

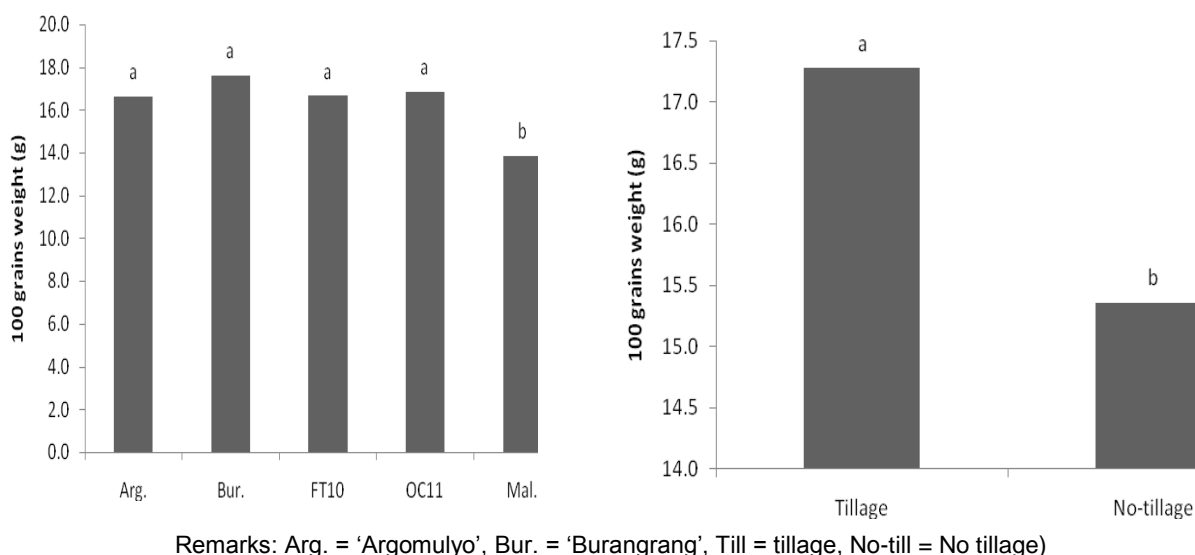
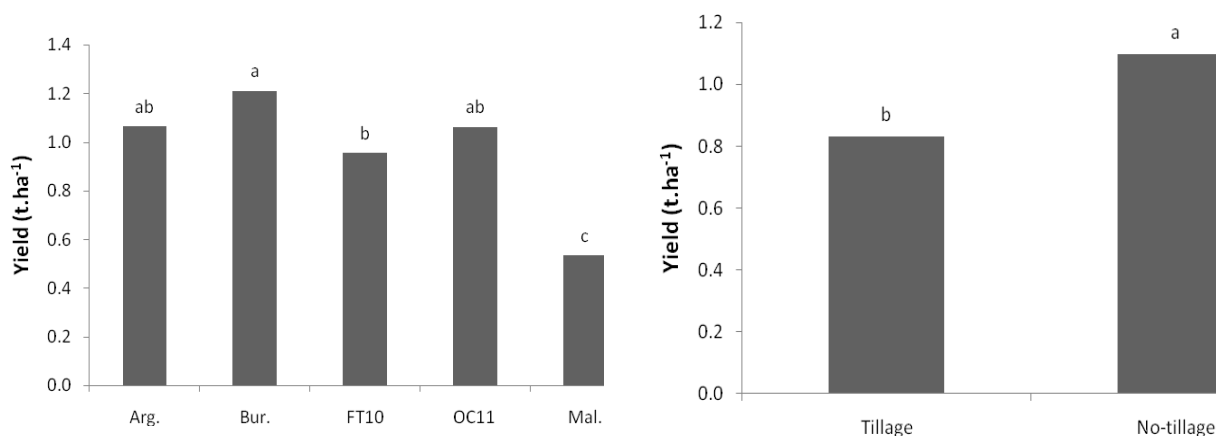


Figure 5. 100 grains weight of two Indonesian soybean varieties and three Madagascar soybean varieties in tillage and no tillage systems, Madagascar dry season 2014



Remarks: (Arg. = 'Argomulyo', Bur. = 'Burangrang', Till = tillage, No-till = No tillage)

Figure 6. Grain yield of two Indonesian soybean varieties and three Madagascar soybean varieties in tillage and no tillage systems, Madagascar dry season 2014

Grain yield in no tillage system was higher than in tillage system (Figure 6). Obalumi, Igwel, Obil, & Wakatsuki (2011) also reported similar result that grain yield in no tillage was higher than tillage. 'Burangrang' performed the highest grain yield, while 'Malady' showed the lowest grain yield. As a result of agronomical characters, grain yield is affected by other agronomical characters such as number of pods plant⁻¹ and grain size. The similar pattern of grain yield to number of pods plant⁻¹ (Figure 4 and Figure 6) is reflected this relationship of these two characters. Different result was found by Karuma et al. (2014) in which no significant difference among the tested tillage systems on soil porosity. Higher porosity means higher air capacity but lower soil moisture. Franchini et al. (2012) reported higher soybean yields in no tillage from the 7th year of the experiments, especially in planting seasons with lower water availability. No tillage is capable to increase some soil nutrients that can improve these nutrients availability in the soil. These two nutrients, especially nitrogen, cause high plant growth and finally lead high plant development that indicate in grain yield.

Temperature is more important than tillage systems because metabolic processes in plant are highly affected by the temperature. The main effect of cold temperature is to slow plant metabolic processes. This condition causes reduction of yield components and finally decrease yield. Soybean needs to increase its growth and development rates to increase grain yield. Grain number was associated with rapid growth rate, increased partitioning and greater grain set efficiency

(Rotundo, Borrás, de Bruin, & Pedersen, 2012). Higher grain yield is also affected by higher grain size (Gawęda, Cierpiąta, Bujak, & Wesółowski, 2014). This research showed higher grain yield than a research in Western Australia (Clements, 2014) and in Canada (Cober, Molnar, Rai, Soper, & Voldeng, 2013). Grain yield in tillage is higher than in no tillage in normal season without cold (Gawęda, Cierpiąta, Bujak, & Wesółowski, 2014), may caused by the lower temperature in soil with tillage than in soil without tillage due to higher soil porosity.

CONCLUSION AND SUGGESTION

Even though most of the observed characters were significantly different in tillage system and variety separately, but varietyx tillage interaction was not found on plant height, number of pods plant⁻¹, 100 grains weight and grain yield. Varieties had higher role than tillage system on vegetative and generative phases, and number of branches plant⁻¹, because there were no significant different on those characters. Plant height, number of pods plant⁻¹, and grain yield were higher in no tillage than in tillage system. Cold temperature elongates vegetative and generative phases, led decreasing agronomical characters. 'Malady' showed the lowest vegetative and generative phases and other agronomical characters among the five varieties. Grain yield of Indonesian varieties ('Argomulyo' and 'Burangrang') were not different to two Madagascar varieties ('FT10' and 'OC11'). It suggests that soybean can be grown in Madagascar's dry season with cold

temperature and better grain yield will be achieved by no tillage system. Indonesian varieties ('Argomulyo' and 'Burangrang') were adaptable in Madagascar, even though the temperature was cold.

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