BIODIVERSITAS
Volume 21, Number 7, July 2020
Pages: 3062-3069

ISSN: 1412-033X
E-ISSN: 2085-4722
DOI: 10.13057/biodiv/d210725

Influence of siam weed compost on soybean varieties in an agroforestry system with *kayu putih* (*Melaleuca cajuputi*)

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Manuscript received: 24 May 2020. Revision accepted: 14 June 2020.

Abstract. *Suryanto P, Faridah E, Nurjanto HH, Supriyanta, Kastono D, Putra ETS, Handayani S, Dewi AK, Alam T. 2020. Influence of siam weed compost on soybean varieties in an agroforestry system with kayu putih (*Melaleuca cajuputi*). Biodiversitas 21: 3062-3069.* Siam weed (*Chromolaena odorata* (L.) R.M.King & H.Rob.) has grown wild in many *kayu putih* (*Melaleuca cajuputi* Powell) forest can be utilized as compost for complementary of inorganic fertilizers in annual crops. The experiment was conducted during November-February 2020 in Menggoran Forest Resort, Playen Forest Section, Yogyakarta Forest Management District, Indonesia. The experiment was arranged in a randomized complete block design (RCBD) with three replications. The first factor was soybean varieties consisted of Anjasmoro, Dering I, and Grobogan. The second factor was siam weed compost (SWC) application consisted of 0, 5, 10, and 15 tons ha^{-1}. The data were analyzed using Two-way ANOVA, ANCOVA, and stepwise regression. The SWC application of 10 tons ha^{-1} showed the highest yield of Anjasmoro, Dering I, and Grobogan were 1.42, 1.56, and 1.51 tons ha^{-1}, respectively, or increased by118.46%, 102.60%, and 112.68%, respectively, compared to the without SWC application. The optimum dosage of SWC application for Anjasmoro, Dering I, and Grobogan were 13.05, 14.35, and 14.93 tons ha^{-1}, respectively, with a maximum yield of 1.45, 1.59, and 1.52 tons ha^{-1}, respectively. Soil quality and physiological parameters that had a significant influenced on the production of soybean varieties in agroforestry systems with *M. cajuputi* were SOM, K, LPR, TC, and PRO.

Keywords: Agroforestry, *kayu putih*, *Melaleuca cajuputi,* siam weed compost, soybean varieties

Abbreviations: SWC: siam weed compost, SOM: soil organic matters, N: total nitrogen, P: available of phosphorus, K: potassium exchange, SMC: soil moisture content, ST: soil temperature, NC: nitrogen content in the leaf tissue, NC: phosphorus content in the leaf tissue, KC: potassium content in the leaf tissue, TC: total chlorophyll, PRO: proline content, LPR: leaf photosynthesis rates, SY: soybean seed yield per hectare

INTRODUCTION

Soybean which is one of the oilseed crops in the world provides 58% of the total global oilseed production (Board 2013). It is also one of the primary commodities in Indonesia after rice and maize (Ministry of Agriculture 2015). The consumption of soybean per year was projected to continuously rise from 812 thousand tons in 2005 to 946 thousand tons in 2020, indicating an average increase of 1.02% per year within 2005-2020. Besides, the average population growth within the same period also is projected at 1.40% per year. Thus, the total soybean production was expected to increase from 1.84 million tons in 2005 to 2.64 million tons in 2020, or an average rise of 2.44% per year (Sudaryanto and Swastika 2016).

To anticipate the soybean deficit, it required to have a strategy to increase soybean production. One way is by the use area between *kayu putih* (*Melaleuca cajuputi* Powell) stands as well as improving the soil quality by fertilization. *M. cajuputi* forests in Yogyakarta Forest Management District, Indonesia have a strategic role, especially in support of intercropping to produce food for farmers. Intercropping in *M. cajuputi* can last for 30 years because leaf harvesting is done routinely every year. Intercropping in *M. cajuputi* forests can be done for several crop rotations with rice, maize, soybean, peanut, and other locally developed species (Suryanto et al. 2017a). Pigali (2012) showed that food crop production increased during the green revolution through genetic improvements and inorganic fertilization applications. The application of inorganic fertilizers has been carried out since the green revolution in the 1960s and proven to increase crop productivity (Haygarth et al. 2013).

However, in the 1990s productivity of food crops, especially soybean experienced stagnation due to leveling off (Brisson et al. 2010; Grassini et al. 2013; Ray et al. 2012). Leveling off is a condition where the addition of inputs is no longer able to increase crop production of annual crops (rice, maize, soybean, etc.) due to the use of inorganic fertilizers. Closely related to a nutrient imbalance in the soil, especially micronutrients (Wang et al. 2016). One affecting factor was the reduction of the organic matter in the soil due to prolonged and intensive use of agrochemicals (Baishya 2015; Lipper et al. 2014). In addition to the management of biogeochemical cycles in a sustainable manner, improvement of fertilizer efficiency is essential in agricultural systems (Rumpel et al. 2015). The crop residues or agricultural waste should be considered as a source of organic fertilizer useful for improving soil quality and productivity. One of the efforts is by converting crop residues or waste into raw materials for organic fertilizer (Medina et al. 2017).

Siam weed (*Chromolaena odorata* (L.) R.M.King & H.Rob.) is an alternative source of organic material. Siam weed biomass has a reasonably high nutrient content (2.56% N, 0.38% P, 2.41% K). Siam weed has grown wild among many *M. cajuputi* forests and had the potential to be used as a source of organic material for the production of high biomass (Ojeniyi et al. 2012). Siam weed can produce biomass by 80 tons ha^{-1} $year^{-1}$ (Nugroho et al. 2019). Siam weeds are very difficult to control and cause many problems in various agriculture and plantations (Karim et al. 2017). Siam weed is the fastest-spreading species after aquatic invaders (Chakraborty et al. 2011). Siam weed compost application of 20 tons ha^{-1} can substitute urea of 200 kg ha^{-1}, while increasing the yield of chilli paper (Setyowati et al. 2014). The application of siam weed compost of 10 tons ha^{-1} showed the highest yield in upland rice by 2.97 tons ha^{-1} and increased yield by 91.75% compared to without the application of siam weed compost (Suryanto et al. 2020).

The experiment aimed to evaluate the influence of siam weed compost on soybean varieties in an agroforestry system with *M. cajuputi*. The results of this experiment will provide information related to increased production of soybean varieties and to overcome the problem of siam weeds that grow wild among many *M. cajuputi* forests.

MATERIALS AND METHODS

Experimental area

The experiment was conducted during November-February 2020 in Menggoran Forest Resort, Playen Forest Section, Yogyakarta Forest Management District, Indonesia. This area was located ±43 km to the south-east from downtown Yogyakarta City (Figure 1). The altitude of the study site was ±100 meters above sea level. The total rainfall during the experiment was ±1,182mm. The mean air temperature (Tair) and the relative humidity (RH) were 29.38°C and 81.90%, respectively. The study site had ustic soil moisture regime (Alam et al. 2019a; Alam et al. 2019b; Suryanto et al. 2017a). Ustic is a soil regime containing limited moisture but is suitable for plant growth when the environmental conditions favorable when the water requirements for plants fulfilled (Boettinger et al. 2015).

Soil in the study site was classified as Lithic Haplusterts (Alam et al. 2019a; Alam et al. 2019b; Suryanto et al. 2017a). Lithic Haplusterts is a Vertisol soil type that has shallow solum and a lithic contact within 50 cm of the soil surface (Soil Survey Staff 2014). The seasonal cracking pattern pertains to non-irrigated soils. Cracks are >5 mm wide and extend through >25 cm within 50 cm of the soil surface (Boettinger et al. 2015). Soil texture in the location was clay with very poorly drained category with availability of water at 9.15%. Cation exchange capacity (CEC) and pH H_2O were included in the very high and alkaline category. Soil organic matters (SOM) had very low values, while total nitrogen (N), available of phosphorus (P), and potassium exchange (K) had low values (Table 1) (Soil Survey Staff 2014).

Experimental design

The experiment was arranged in a randomized complete block design (RCBD) with three replications. The first factor was soybean varieties consisted of Anjasmoro, Dering I, and Grobogan. The second factor was siam weed compost (SWC) application consisted of 0, 5, 10, and 15 tons ha^{-1}. The soybean varieties were provided from the Indonesian Legumes and Tuber Crops Research Institute in Malang Regency, Province of East Java, Indonesia. The experimental plots covered a 24 m^2 (6 x 4 m) of the area between *M. cajuputi* stands and the harvest area of 20 m^2, excluding the border rows. Soybean planting was carried out by direct seed planting method. The number of seeds per planting hole was two seeds with a spacing of 40 x 20 cm. Siam weed composted was using the Traditional Method (Misra et al. 2003). Siam weed compost was applied together with soybean planting following the treatment dosage. The recommended dosage of Urea, SP-36, and KCl for soybean in agroforestry with *M. cajuputi*

Table 1. Environment variables in experimental area

Environment variables	Unit	Value	Notes*
Soil physical characteristics			
Soil texture:			
Clay	%	60.34	Clay
Sand	%	7.08	Texture
Silt	%	32.58	Class
Soil moisture (pF):			
pF 0	%	55.83	-
pF 2.54	%	48.54	-
pF 4.2	%	39.39	-
Bulk Density	gcm^{-1}	1.15	
Permeability	cm $hour^{-1}$	0.001	Very poorly drainage
Soil chemical characteristics			
pH H_2O	-	8.6	Alkaline
Soil Organic Matters	%	1.9	Low
CEC	$cmol^{(+)}kg^{-1}$	58.87	Very high
Total nitrogen	%	0.09	Very low
P_2O_5 (Olsen)	ppm	5	Low
Potassium	$cmol^{(+)}$ kg^{-1}	0.19	Low
Sodium	$cmol^{(+)}$ kg^{-1}	0.81	High
Magnesium	$cmol^{(+)}$ kg^{-1}	8.32	High
Calcium	$cmol^{(+)}$ kg^{-1}	22.72	High
Climate characteristics			
Total rainfall	mm	1,182	-
Air temperature	°C	29.38	-
Relative humidity	%	81.90	-

Note: * Soil Survey Staff (2014)

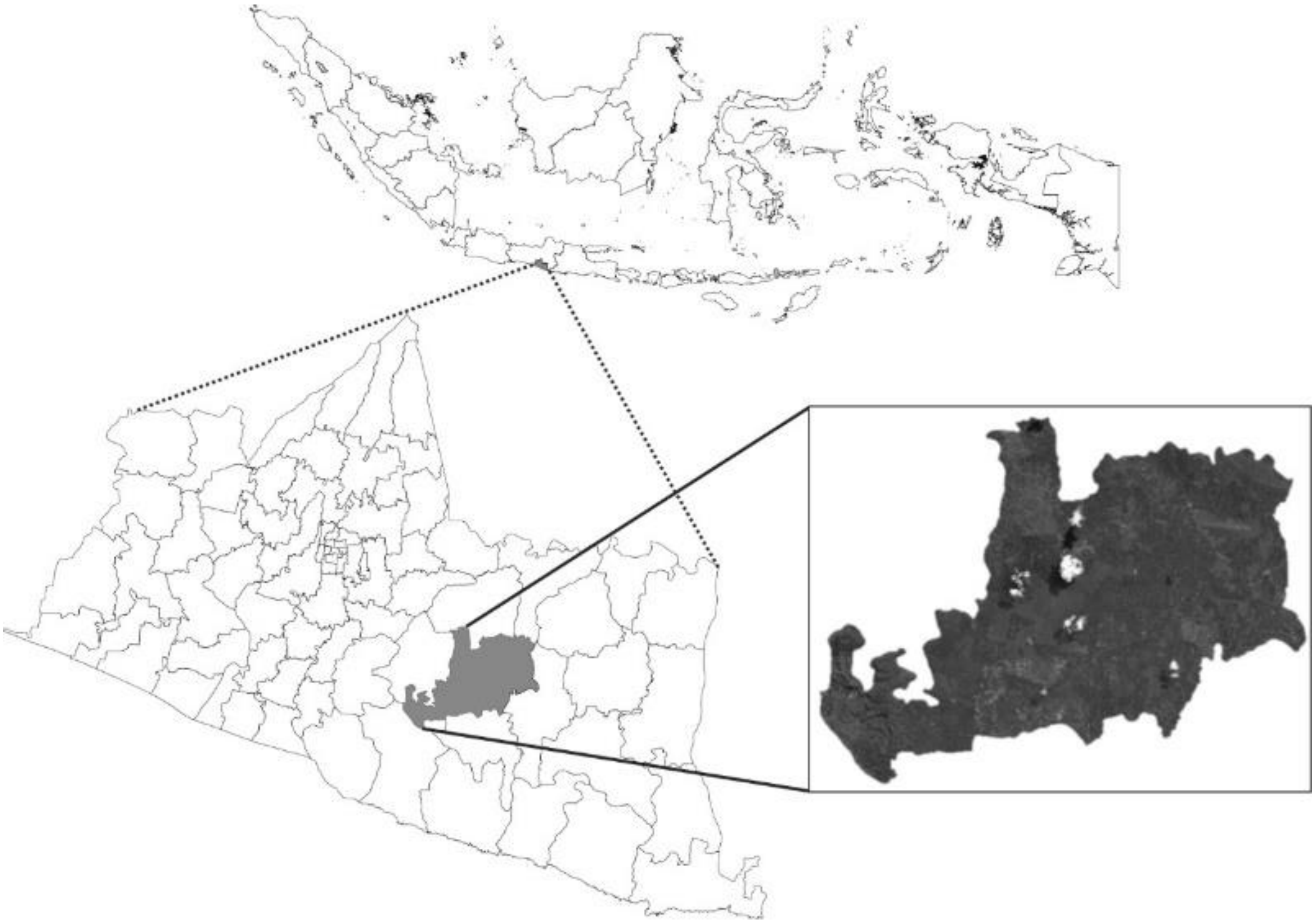

Figure 1. Geographical locations of the study area in Menggoran Forest Resort, Playen Forest Section, Yogyakarta, Indonesia (latitude 7º 52` 59.5992`` S to 7º 59` 41.1288`` S and longitude 110º 26` 21.462``E to 110º 35` 7.4868`` E).

were 50, 300, and 150 kg ha^{-1}, respectively (Jati et al. 2017). The inorganic fertilizer was applied a week after planting (wap). No pesticide was applied in this study; neither did the irrigation because the field was in the rainfed areas. Based on the laboratory analysis showed that the pH H_2O, C, N, P, and K in the siam weed compost were 7.4, 24.8%, 2.72%, 1.37%, and 2.46%, respectively.

Soil sampling and analysis

The observed parameters were soil organic matters (SOM) (Black 1965), total nitrogen (N) (Stenhom et al. 2009), available of phosphorus (P) (Olsen et al. 1954), potassium exchange (K) (Burt 2004; Jones 1984), soil moisture content (SMC) (Edy 2012; Alam 2014), and soil temperature (ST) (Edy 2012; Alam 2014). The SOM, N, P, and K were observed at the end of the experiment, while SMC and ST were observed once a week. Soil samples were taken at 30 of the soil surface. Soil sampling was carried out at each treatment in each repetition. Soil analysis was carried out at the General Soil Laboratory, Faculty of Agriculture, Universitas Gadjah Mada, Yogyakarta, Indonesia.

Soybean variables

The observed of soybean parameters were nitrogen, phosphorus, potassium content in the leaf tissue (NC, PC, KC) (ACIAR 1990; Association Official Agriculture Chemists 2000; Jones 1984), total chlorophyll (TC) (Gross 1991), proline content (PRO) (Bates et al. 1973), leaf photosynthesis rates (LPR) (Li-Cor 1999), and soybean seed yield per hectare (SY). Soybean seeds were dried under the sunlight to reach 11% of moisture level (Suryanto et al. 2017b).

Statistical approach

To ensure the efficiency of the model's principal assumptions checked. The test of normality performed using Kolmogorov test and Q-Q plot (Mocanda et al. 2014). Two-way analysis of variance (ANOVA) used to test the environment variables for soybean varieties indifference of siam weed compost (SWC) application and the separation of means subjected to Scott-Knott test ($p<0.05$). Analysis of covariance (ANCOVA) to test the effect of soybean varieties and siam weed compost (SWC) application on environment variables (Hinkelman and

Kempthorne 2008). Stepwise regression used to see in detail the parameters of each variable that affected the soybean yield (Suryanto et al. 2017a). All analyses performed by using the PROC GLM, MIXED, and PROC REG in SAS 9.4 (SAS Institute 2013).

RESULTS AND DISCUSSION

Influence of soybean varieties and siam weed compost application for the environment variables

The results of Two-way ANOVA provides information that there was no interaction between soybean varieties with siam weed compost (SWC) application in environment variables (Table 2). Soybean varieties showed that there is no significant increase in soil organic matters (SOM), total nitrogen (N), available of phosphorus (P), potassium exchange (K), soil moisture content (SMC), and soil temperature (ST). The increase of SWC application significantly increased in the SOM and N of the soil. The application of 15 tons of ha^{-1} SWC provided the highest SOM and N values of 3.444% and 0.789% compared to without the SWC application of 1.647% and 0.120%. SOM and N increased by 109.11% and 557.50% compared to without SWC application (Table 2).

The application of SWC 15 tons ha^{-1} showed the highest P and K values were 16.12 ppm and 0.606 $cmol^{(+)}$ kg^{-1}, whereas without the SWC application showed the lowest values of 6.780 ppm and 0.216 $cmol^{(+)}$ kg^{-1}. The percentage of increase in P and K values was 137.64% and 180.56%, respectively (Table 2). The SWC application of 15 tons ha^{-1} showed the highest value in soil moisture content (SMC) by 45.696% compared without SWC application by 39.484% or increased by 15.73% (Table 2). The application of SWC 15 tons ha^{-1} significantly reduced soil temperature (ST) compared without the application of SWC with a value of 26,003ºC or decreased by 10.02% (Table 2). The results of stepwise regression indicate that the environmental parameters that influenced of soybean yield were SOM and K. The regression equation was Y = -0.19^{ns} + 0.71 SOM** - 1.35 K** (R^2 = 0.86**).

The response of soybean varieties towards siam weed compost application in physiological characters and soybean yield per hectare

The results of ANCOVA showed that there was an interaction between soybean varieties with siam weed compost (SWC) application in the nitrogen, phosphorus, and potassium content in the leaf tissue (NC, PC, KC), total chlorophyll content (TC), and leaf photosynthesis rates (LPR) (Figures 2.a, 2.b, 2.c, 2.e, 2.f). At the same time, there was no interaction in the proline content (PRO) (Figure 2.d). The NC, PC, and KC indicated a linear pattern. The SWC application of 15 tons ha^{-1} showed the highest of NC, PC, and KC in Anjasmoro, Dering I, and Grobogan varieties (Figures 2.a, 2.b, 2.c). The increase of SWC application decreased by the PRO in all soybean varieties (Figure 2.d). TC and LPR showed there were two different patterns between soybean varieties for SWC application. Anjasmoro varieties showed a positive linear pattern, while Dering I and Grobogan showed a quadratic pattern. Dering I varieties showed the highest of TC and LPR values followed by Grobogan and Anjasmoro (Figures 2.E-F).

Dering I varieties with SWC application of 10 ton ha^{-1} showed the highest yield per hectare was 1.56 ton ha^{-1}, while the lowest yield was Anjasmoro varieties without SWC application (Figure 3). The SWC application of 13.05 tons ha^{-1} showed the maximum yield for Anjasmoro varieties was 1.45 tons ha^{-1}. Dering I varieties showed that SWC application of 14.35 tons ha^{-1} giving maximum yield was 1.59 tons ha^{-1}, while for Grobogan varieties with SWC application of 14.93 tons ha^{-1} giving maximum yield was 1.52 tons ha^{-1} (Figure 3). Based on stepwise regression showed that the physiological parameters that affect soybean yield are LPR, TC, and PRO. The regression equation is Y = -1.52** + 0.02 LPR** + 1.49 TC** - 0.005 PRO** (R^2 = 0.99**).

Table 2. Influence of soybean varieties and siam weed compost application for the environment variables

Treatments	Environment variables					
	SOM (%)	**N (%)**	**P (ppm)**	**K ($cmol^{(+)}$ kg^{-1})**	**SMC (%)**	**ST (°C)**
Soybean Varieties:						
Anjasmoro	2.616±0.211^a	0.442±0.076^a	12.347±1.085^a	0.394±0.044^a	42.511±0.692^a	27.257±0.274^a
Dering-I	2.609±0.214^a	0.439±0.074^a	12.345±1.087^a	0.393±0.045^a	42.506±0.691^a	27.255±0.284^a
Grobogan	2.601±0.207^a	0.438±0.076^a	12.332±1.085^a	0.396±0.044^a	42.392±0.704^a	27.125±0.307^a
Siam Weed Compost:						
0 tons ha^{-1}	1.647±0.013^d	0.120±0.003^d	6.780±0.047^d	0.216±0.004^d	39.484±0.066^d	28.609±0.037^a
5 tons ha^{-1}	2.271±0.015^c	0.316±0.006^c	11.639±0.025^c	0.314±0.005^c	41.406±0.105^c	27.360±0.048^b
10 tons ha^{-1}	3.072±0.015^b	0.534±0.006^b	14.834±0.024^b	0.442±0.007^b	43.293±0.056^b	26.877±0.028^c
15 tons ha^{-1}	3.444±0.012^a	0.789±0.007^a	16.112±0.014^a	0.606±0.002^a	45.696±0.051^a	26.003±0.113^d
CV (%)	1.574	4.451	0.655	3.756	0.437	0.673

Notes: Values followed by the same rows are not significantly different according to Scott-Knott test ($p<0.05$). No interaction between soybean varieties with siam weed compost application.

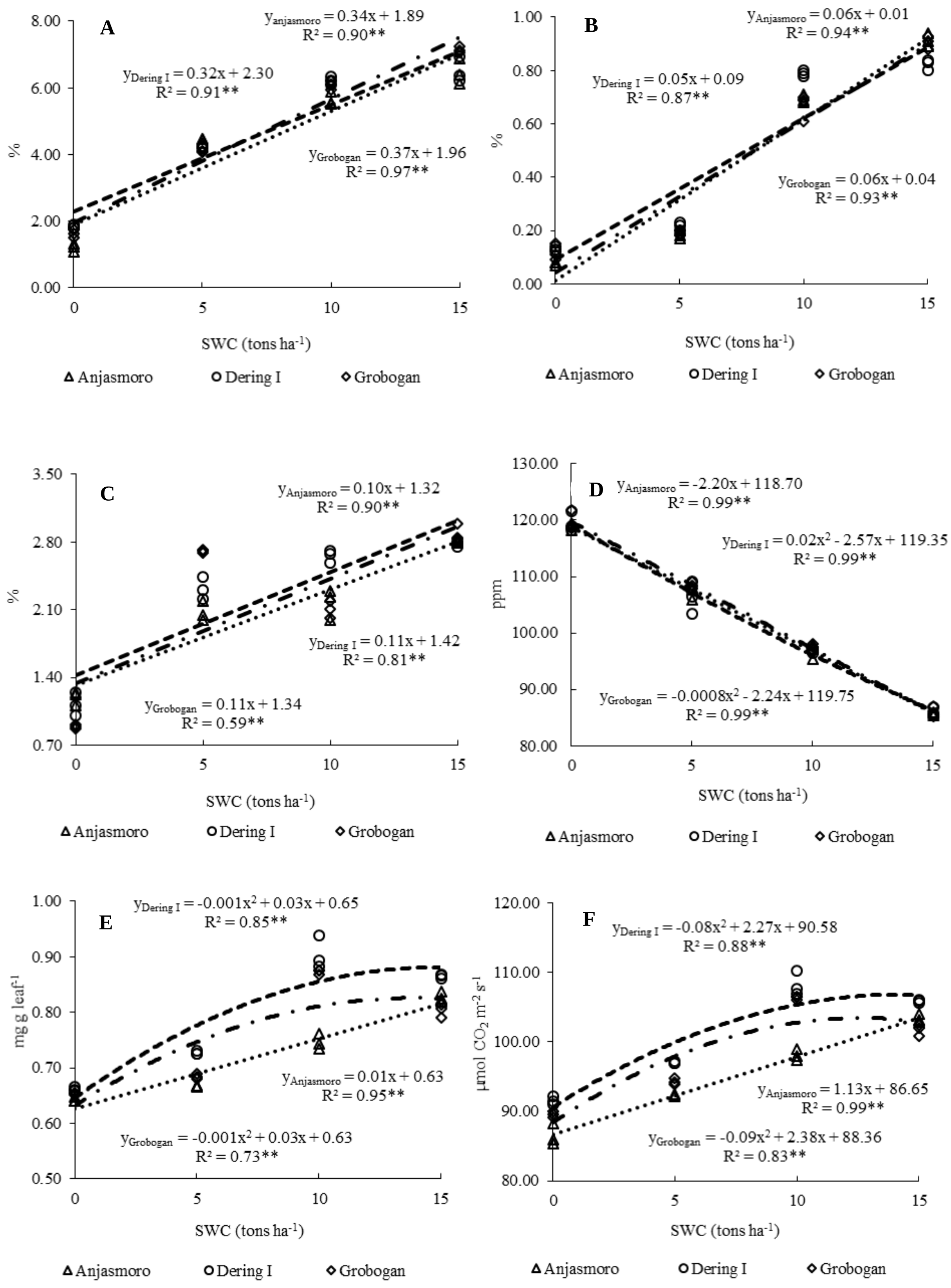

Figure 2. Analysis of covariance (ANCOVA) to the physiological characters. A. N content in the leaf tissue, B. P content in the leaf tissue, C. K content in the leaf tissue, D. Proline content, E. Total chlorophyll content, F. Leaf photosynthesis rates

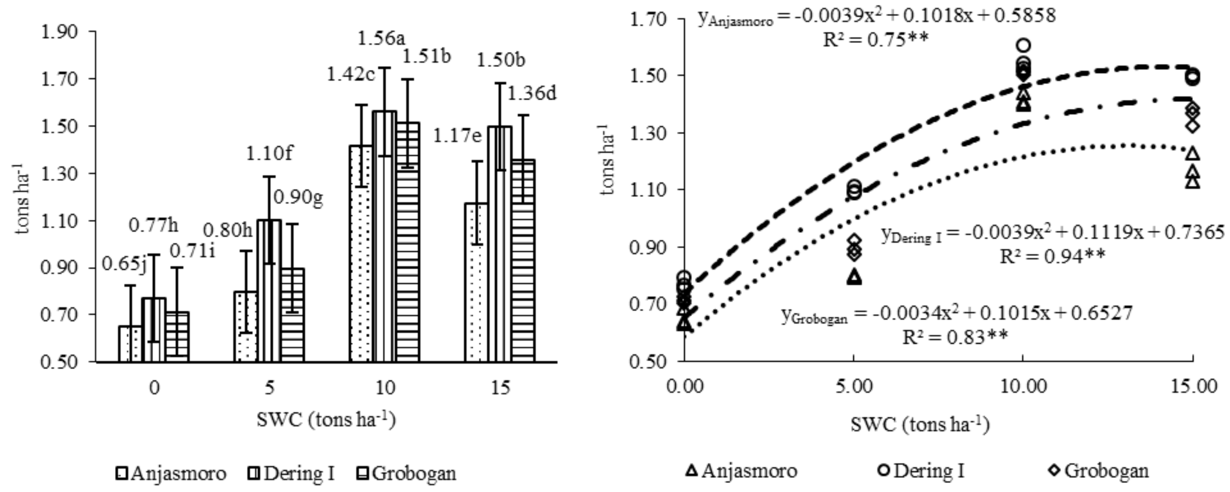

Figure 3. Soybean yield per hectare. Values followed by the same lowercase letter are not significantly different according to Scott-Knott test ($p<0.05$). The bars were indicated standard error of mean (SEM)

Discussion

The main problems with annual crop cultivation, especially soybean between *M. cajuputi* stands were low soil fertility and leveling off (Suryanto et al. 2017; Wang et al. 2016). The soil in the experimental area is included in the Verisol order. These soils are often less productive and observed to be mainly in areas where the population is suffering from low nutrition and high poverty (Moussadek et al. 2017). It can be seen from the soil fertility analysis in the experimental sites that included in the very low to low category. Low soil fertility reflected in the low level of soybean productivity at the experimental site. The mean of soybean productivity of Anjasmoro, Dering I, and Grobogan varieties were 1.02, 1.38, and 0.94 tons ha^{-1}, respectively, while the potential yields for the three varieties were 2.03-2.25, 2.80, and 2.77 tons ha^{-1}, respectively (Alam et al. 2019a; Mejaya et al. 2015). Giller et al. (2011) suggested that each plant has a different response in absorbing nutrients, fertilizers, and lime applications in a site.

One solution to increase soybean productivity is by applying organic matter into the soil. Soil fertility can be increased by applying an organic substance. It provides beneficial compounds that play an essential role in improving the physical, chemical, and biological characteristics by increasing the water holding capacity, N content in the soil, and soil microbial population (Zhong et al. 2010). Siam weed (*Chromolaena odorata*) is an alternative source of organic material. The increased in SWC application was significantly increased SOM, N, P, K, and SMC in the soil, while an increased in SWC application was significantly decreased in ST. The SWC was used in this study contained a high C of 24.8%. Element C plays an important role in improving the physical, chemical, and biological properties of soils (Al-Bataina et al. 2016).

Sukartono et al. (2011) informed that siam weed when incorporated into the soil, can increase amounts of nitrogen, phosphorus, potassium, calcium, magnesium, and C/N ratio but not the soil pH. According to Tanhan et al. (2007), low C/N ratio means poor soil fertility, which leads to the reduction of microbial activities hence low nutrient mineralization due to the shortage of energy sources. The increase or decrease of some nutrients in the soil depends on soil pH, organic matter, and flooding (Flis 2008; Hesse 1971; Shuman 1991; Sillanpaa 1982; Welch et al. 1991). In this study, the application of SWC increased the value of SOM in the soil. This can improve nutrition for plants and increased soil biodiversity. The SOM content was positively correlated with N, P, S, K, and CEC values in the soil. Compost application significantly increased SOM content in soils (Duong et al. 2012). Suryanto et al. (2020) informed that the application of SWC could decrease of ST by 4.88% compared to without SWC application. ST in without SWC was 28.61ºC, and it will inhibit the growth of soybean roots and will further reduce soybean yield. Arai-Sanoh et al. (2010) provide information that the optimum temperature in the rice root zone was ±25ºC.

Based on stepwise regression analysis showed that environmental parameters that affect soybean yield were SOM and K. The SWC application increased the SOM content in the soil (Table 2). The increased of SOM significantly increased of soybean yield per hectare. SOM plays a critical role in the maintainability of soil fertility and productivity. The SOM value in the study site was 1.9%. It was still a very low category (Soil Survey Staff 2014). The influence of the organic matter may be either direct or indirect. Organic matter acts directly as a source of plant nutrients and indirectly influences the physical and chemical properties. Organic fertilizer application can restore damaged natural fertility of the soil and improve plant productivity. Organic fertilizer improves the natural soil process, thereby giving a long term effect on soil fertility (Singh 2012). SOM was a crucial feature in health and crop productivity (Fageria 2012).

Potassium was a critical macronutrient and the most abundant cation in plants. It accomplished essential functions in plants including photosynthesis, osmoregulation, enzyme activities, maintaining the plasma membrane potential, and protein synthesis. K deficiency was abiotic stress (Hafsi et al. 2014). The SWC application generally increased the K content very high in the soil at the end of the experiment (Table 2). This was allegedly causing toxic for soybeans. K can also be toxic. In this research, the increased K significantly reduced soybean yield. The K values in the soil after the SWC application varies from 0.314-0.606 $cmol^{(+)}$ kg^{-1}. This classified in the moderate up to high category (Soil Survey Staff 2014).

During charge compensation, K was the dominant cation for counterbalancing immobile anions in the cytoplasm, chloroplasts, vacuoles, xylem, and phloem. When plants take up excess K, organic acid anions will then accumulate to counterbalance the excess K transported into the cytoplasm. Notably, with the K counterbalance anion of NO_3^+ at the time of nitrate metabolism and the reduction of excess NO_3^+ in the leaves, the K concentration was increased. As a result, organic acids such as malate was synthesized in the leaf tissue to support the charge balance. Part of this K-malate transported to the root cells for NO_3^+ uptake (Farooq et al. 2008).

The physiological parameters that affected soybean yield were TC, LPR, and PRO. The increment of TC and LPR followed by the increment of soybean yield, while PRO showed the opposite pattern. Photosynthesis is a process used by plants and other organisms to convert light energy into chemical energy that can later be released to fuel the organism activities (Lambers et al. 2008). Efthimiadou et al. (2010) reported that the use of organic ingredients in maize plants increased the photosynthesis rate by 49.65% compared to without organic matters application.

Chlorophyll pigmented with green color found in diverse plants, algae and cyanobacteria functioning to converse the solar energy to become chemical energy for building important carbohydrate molecules useful as the food source for the whole plant (Hynninen and Leppakases 2002). A study by Shaheen et al. (2017) indicated that organic fertilizer significantly increases TC in soybean in comparison to the control (without fertilizer). The content of TC with organic fertilizing and control was 2.913 g dm^{-2} and 1.852 g dm^{-2}, respectively. Similar findings were also reported by Alam et al. (2009) that lower chlorophyll content would limit the rate of photosynthesis that significantly decreased the soybean yield.

Proline is a typical physiological response in many plants in response to a wide range of biotic and abiotic stresses. It is responsible for osmotic adjustment in plant cells. Osmotic adjustments maintain turgor pressure, control cell expansion and growth and stomatal aperture, photosynthesis, and water flow during periods of water shortage (Königshofer and Löppert 2015). The application of SWC significantly increases soil moisture availability in the soil, thereby reducing the synthesis of proline in soybean leaves. Suryanto et al. (2020) informed that the SWC application could increase soil moisture by 6.77% compared to without SMC application on upland rice cultivation in agroforestry with *M. cajuputi*.

In general, the SWC application increases the yield of soybean per hectare in all varieties. However, this increase has not yet reached the yield potential of each of these varieties. Nutrient losses due to leaching, volatilization, fixation, and the activated risk of nitrate leaching after fertilizer added to the soil. The release rate of a nutrient from the fertilizer must be slower than that of a fertilizer in which the nutrient is readily available for plant uptake (Torne et al. 2017). We suggested the effective alternative might be the use of nutrient briquettes technology for efficient use of soil nutrients in soybean cultivation.

ACKNOWLEDGEMENTS

The research for this article was fully funded by Universitas Gadjah Mada, Yogyakarta, Indonesia through the university grant-in-aid scheme under PTUPT (2018-2019) and RTA (2020).

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BIODIVERSITAS
Volume 21, Number 7, July 2020
Pages: 3062-3069

ISSN: 1412-033X
E-ISSN: 2085-4722
DOI: 10.13057/biodiv/d210725