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EFFECT OF IRRIGATION INTERVAL AND SOIL AMENDMENTS ON SOIL ORGANIC C, NITROGEN AND POTASSIUM OF SANDY SOIL AND GROWTH OF *Jatropha curcas* L.

Djajadi[*)] and Sulis Nur Hidayati

Indonesian for Sweetener and Fiber Crops Research Institute
Jl. Raya Karangploso Km 4 P.O. Box. 199 Malang East Java Indonesia
[*)] Corresponding author Phone: +62-341 - 491447 E-mail: jaydjajadi61@gmail.com

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ABSTRACT

Inherently, sandy soil is low in all aspects of soil fertility and has a low capacity to retain water and applied nutrients. To improve the fertility of sandy soil as media growth for *Jatropha curcas*, clay and organic matter may have important role when they are incorporated to the sandy soil. This study investigated the effect of irrigation interval and incorporation of clay together with organic matter to sandy soil on soil organic C, N, and K and growth of *J. curcas*. The rates of clay and organic matter incorporated to top sandy soil were 5% clay + 0.8% organic matter and 10% clay + 1.6% organic matter. Two irrigation intervals tested were 10 day and 20 day. The results found that incorporation of 10% clay + 1.6% organic matter to sandy soil increased soil organic C, total N and exchangeable K which in turn increased the number of leaves and number of lateral branches of *J curcas*, while irrigation intervals had no effect on all parameters observed.

Keywords: *Jatropha curcas,* C organic*,* Nitrogen, Potassium, clay, organic matter, irrigation interval, plant growth

INTRODUCTION

Jatropha curcas L. (physic nut) has many uses including as biofuel (Jingura *et al*., 2010). The main source of energy from *Jatropha* is the seed oil, which can be used in the raw form or as biodiesel oil. Consequently, the plant is currently has a lot of attention as an energy plant (Kumar dan Sharma, 2008), even though *Jatropha* oil had been used as a mineral diesel substitute during the Second World War (Agarwal, 2007).

J. curcas grows in tropical and subtropical climates across the developing world (Openshaw, 2000). *Jatropha* seems likely to be well adapted to conditions of low to very low soil fertility (Makkar and Becker, 2009), such as soil with low content of total N, P and K. The plant should have an enormous capacity to absorb and utilize nutrients under low-fertility conditions as it grows even on the poorest, mostly P deficient and acid soils such as sandy soil in Situbondo, East java, Indonesia. However, *J curcas* plantations require frequent irrigation and nutrients supply for optimizing development and yield (Behera *et al*., 2010).

Sandy soil in Situbondo which is used as a central area for *J. curcas* seed production has poor soil physical properties as indicated by low capacity to retain water, so that irrigation of the soil has been done with interval of 10 days to support *J. curcas* growth. Such sandy soil is inherently low in all aspects of soil fertility and has a low capacity to retain water and applied nutrients (Farrington and Campbell, 1970). Further-more, sandy soils contain low proportions of clay and silt particles which hinders aggregation and they are associated with low levels of organic bonding formed during the decomposition of organic matter (Oades, 1993).

For plant growth of physic nut, the sandy soil properties need to be improved. Previous study found that incorporation of clay together with organic matter to the sandy soil increased aggregate stability, total soil porosity, available water content and plant growth of *J. curcas* (Djajadi *et al.,* 2011). However, the previous study did not focus on changing of soil chemical properties. The recent study was designed to identify the effect of irrigation intervals and incorporation of clay together with organic matter on sandy soil chemical properties and growth of *J.*

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curcas L. By irrigating the sandy soil with an appropriate interval and adding the soil with clay and organic matter, it was expected that organic C, total N and exchangeable K of the soil would be increased which in turn the growth of *J. curcas* might be improved.

MATERIALS AND METHODS

Land Preparation

A field trial was conducted at an Experimental Site of Indonesian for Sweetener and Fiber Crops Research Institute which is located at Situbondo, East Java, Indonesia from April to November 2009. The soil contains 77% sand, 17% silt and 6% clay. The soil charac-teristics are presented in Table 1. The site was chosen because it has been designed as a seeding production area for *J. curcas* (physic nut).

Table 1. Characteristics of soil at the experimental site

Soil Characteristics	Value	Category *)
N total (%)	0.03	Very low
Available P (mg/kg)	8.86	Low
C organic (%)	0.32	Low
Exchangeable K (me/100 g)	0.16	Low
CEC (me/100 g)	10.62	Low
pH H_2O (1:1)	6.65	neutral
Texture:		
-. Sand (%)	77.00	
-. Silt (%)	17.00	Sandy loam
-. Clay (%)	6.00	

*) Remarks: Hardjowigeno, 2003

Experimental Design

The treatments included of two factors: (1) Three kinds of plant growth media (a. Sandy soil as a control, b. Sandy soil + 5 % clay soil + 0.8% organic matter, c. Sandy soil + 10% clay soil + 1.6% organic matter) and (2) Two irrigation intervals (a. 10 days interval, and b. 20 days interval). The arrangement of treatments was a Split Plot with four replicates and each plot size was 36 m^2. As main plot was frequency of irrigation and as sub plot was growth media.

Addition of Clay Soil and Organic Matter

Firstly, clay soil (67% clay) was collected from sub soil at a site located at about 2 km from experimental site. The clay soil was added with the rates as treatments, i.e 5% (equivalent to 538.6 kg/plot or 96 tones/ha) and 10% (equivalent to 1077.3 kg or 192 tones/ha). *Crotalaria juncea* (Sun hemp*)* was used as a source of organic matter which was planted on another plot 45 days before it was added to the sandy soil. Before being added, *Crotalaria* sp. was cut and sliced into pieces of 5-10 cm size, and incorporated to the soil. The organic matter was added at rates of 0.8% (equivalent to 123.4 kg/plot or 22 tones/ha) and 1.6% (equivalent to 246.8 kg/plot or 44 tones/ha). Incorporation of clay and organic matter to the sandy soil was done at three weeks prior to planting of *Jatropha*.

Interval of Irrigation

Irrigation of the soil was done by flood irrigation method. The ground water from the reservoir was transferred into the plots through irrigation channels. At about 3362 dm^3 of water was flooded into each of 36 m2 plot with the depth of 20 cm. Irrigation was done at intervals on 10 day and 20 day.

Planting of *Jatropha*

After incorporating sandy soil with clay and organic matter, the soil was irrigated and equilibrated for 24 hours before *Jatrophas* were planted. Initially, stem cuttings of *Jatropha* with 30 cm long had been forming seedlings in polybags for one month before they were transplanted with plant spacing of 2 m x 2 m into plots of 36 m^2 of each treatment.

Determination of Soil Chemical Properties and Plant Growth

Changes in soil chemical properties due the treatments were analyzed from the composite samples which were collected at 1, 2 and 3 months after treatment. The sampels then were stored until ready to analyze. The soil chemical properties observed were soil organic C, total N, P_2O_5, K_2O, and soil pH. Soil organic C was determined using Walkey and Black Method. Soil total N was analyzed employing Kjeldahl method, soil exchangeable K was extracted with 1 N ammonium acetate at pH 7 and measured with Flame photometry. Soil pH was analyzed using Glass Electrode method. Plant growth indicators observed include number of leaves and number of lateral branches.

Table 2. Effect of irrigation interval, clay soil and organic matter on C-organic content of sandy soil

Treatments	C-organic (%)		
	1 month	**2 month**	**3 month**
Irrigation interval (days)			
10	1.14	0.37	0.29
20	0.93	0.31	0.27
LSD 5%	ns	ns	ns
Plant media			
Sandy soils (Control)	0.69 a*	0.08 a	0.06 a
Sandy soils + 5% clay soils + 0.8% organic matter	1.00 b	0.35 b	0.28 b
Sandy soils + 10% clay soils + 1.6% organic matter	1.42 c	0.59 c	0.49 c
LSD 5%	0.25	0.03	0.03

Remarks: ^ Numbers followed by different letter at each column are significantly different at P<0.05 ns= not significant

RESULTS AND DISCUSSIONS

In this study, interaction between irrigation interval and soil amendments (clay and organic matter) did not significantly effect on soil organic C content, total N and exchangeable K, and the growth of *J curcas*. However, all parameters in this study were significantly affected by addition of clay and organic matter. In contrast, there was no significant effect of irrigation interval on any parameters observed. Different irrigation interval (between 10 and 20 days) had no effect on mostly parameters observed which might because the average of maximum temperature in the location was height enough to cause high transpiration. In this area, the maximum temperature rises to 34^{o}C with total precipitation 909 mm per year. However, there is still limited information about water requirement of *J curcas*; the plants will not suffer due to water stress if they are planted in an area with an average precipitation between 31.4 up to 260 mm per month (da Schio, 2010).

Soil Organic C Content

The process of soil organic C accumu-lation and its decomposition was affected by clay particles and organic matter in soil. The increase in sandy soil C organic content which occurred with addition of clay soil was probably due to the accumulation of *Crotalaria* addition and clay protection of soil organic matter (Table 2). In this present study, for all three times of observation (1, 2, and 3 months after treatment), C organic matter content of sandy soil was significantly influenced (p<0.05) by addition of clay and organic matter. C organic content was most pronounced when 10% clay and 1.6% organic matter were added to the sandy soil at 1 month after treatment. Compared to the control, incorporation of 10% clay soil and 1.6% organic matter to sandy soil increased soil C organic content by 1, 6 and 7 folds at observation of 1, 2 and 3 months after treatment respectively. Increasing of soil C organic content occurred because *C juncea* produced biomass which content high organic C (da Schio, 2010). It seems likely that the organic C from *C. juncea* was stabilized and protected against decomposition in sandy soil when the soil was added with clay.

Soil C organic percentage decreased in all treatments related to the time of observations (Table 2). This might be indicated that soil C organic matter was decomposed rapidly in the sandy soil in short period of time. This could occur because of processes of organic matter decomposition in tropical soil is fast. For example, Cleveland *et al.* (2006) found that decreasing of soil C-organic due to decom-position of organic matter in tropical forest of Costa Rica reached 80% in 300 days. In the current study, the most pronounced decreasing C-organic content occurred in sandy soil (control) which reached 88% during two months and 93% during three months. In sandy soil which was amended with 10% clay and 1,6% organic matter, decreased in soil C-organic matter to a level lower than in control (i.e. as much 56 % and 65% at two and three months respectively). A possible reason for this lower decomposition rate is that addition of clay protects the organic matter added to the soil, so that the highest decomposition rate occurred in the sandy soil without added with clay. Some researchers reported that the amount of soil C organic protected from decomposition was increased with an increased clay fraction of the soil (Chantigny *et al*., 1997; Guggenberger *et al*., 1999).

Total Nitrogen Content

Addition of clay soil and organic matter to sandy soils significantly increased ($p<0.05$) soil N total content at 1, 2 and 3 month after planting, yet the interval of irrigation did not effect on N total content of sandy soil (Table 3). The most pronounced increase in N total content occurred when sandy soil was amended with 10% clay and 1.6% organic matter. Compared to the control, sandy soil with added 10% clay and 1.6% organic matter contained N total 50%, 67% and respectively higher at 1, 2 nd 3 months after planting, respectively. This is in agreement with Hamarashid *et al*. (2010) who investigated field soil with different texture and found that soil organic matter and N content was more accumulated in soil with more clay content than in soil with coarse particle content. Soil with more clay content also shows more stable aggregates, which in turn has greater amount of organic C and total nitrogen contents (Raiesi, 2006). Previously, Djajadi *et al*. (2011) reported that sandy soil added with clay and organic matter had more stable aggregate than sandy soil without added with clay and organic matter.

C. juncea as a source of organic matter contributed to accumulation of N in soil. Biomass of 5 tones/ha *C juncea* provided about 250 kg N (Smith, 2004). Incorporation of *C juncea* into the soil also increased cation exchange capacity (Sumarni, 2008).

Potassium Content

Exchangeable potassium (K) is commonly used for determining the soil K status and prediction of crop K requirements (Samadi, 2006). At three times of observation, increasing of potassium content of sandy soil significantly occurred when the soil added with clay and organic matter (Table 4). Compared to the control, the highest increase in exchangeable K was found in the sandy soil amended with 10% clay and 1.6% organic matter, as much as 2.5, 0.3 and 7.2 folds higher than the exchangeable K of the control soil at 1, 2 and 3 months observation respectively. It seems likely that addition of clay and organic matter was able to retain K_2O either added as fertilizer or from mineralized organic matter. These results appear be in agreement with Ajiboye and Ogunwole (2008) who identified 25 samples of field soil of Southern Nigeria and found that exchangeable potassium was more abundant in soil with higher clay content than in soil dominated by sand.

Table 3. Effect of irrigation interval, clay soil and organic matter on total N content of sandy soil

Treatments	N total content (%)		
	1 month	2 month	3 month
Interval of irrigation (day)			
10	0.07	0.09	0.11
20	0.07	0.08	0.11
LSD 5%	ns	ns	ns
Plant media			
Sandy soils (Control)	0.06 a	0.06 a	0.08 a
Sandy soils + 5% clay soils + 0.8% organic matter	0.07 a	0.09 b	0.11 b
Sandy soils + 10% clay soils + 1.6% organic matter	0.09 b	0.10 b	0.12 b
LSD 5%	0.01	0.01	0.01

Soil pH

Soil pH of the sandy soil was not affected either by irrigation interval or soil amendments (Table 4). It seems likely that irrigation and soil amendments were not able to change soil pH in a short period of time. For example addition of 10% clay and 1.6% organic matter did not affect on changing of the soil pH.Naturally, decaying organic matter produces H^+ which is responsible for decreasing of soil pH. The same result was also reported by Abu-Zahra and Tahboub (2008) that addition of 40 tones/ha organic matter did not effect on soil pH which was attributed to decayed organic matter was absorbed by high content of $CaCO_3$. In contrast, Tang and Yu (1999) reported for a pot study that addition of legume residues at a rate of 1% soil weight increased pH of all soils examined by up 2 units after incubation for 35 and 100 days under non-sterile conditions. They concluded that incorporation of crop residues with high concentration of cations (such as Ca^{2+} and K^+) could minimize change of soil pH. In this field study, the source of organic matter was *C. juncea* which contain up to 2.08% Calcium.

Plant Growth

Addition of clay and organic matter significantly increased plant growth indicated by increasing number of leaves and lateral branches at 1, 2 and 3 months after treatment. The highest increment of number of leaves and number of lateral branches was shown in *J. curcas* grown in sandy soil amended with 10% clay and 1.6% organic matter, even though these increments were not significantly different with plants grown in sandy soil added with 5% clay and 0.8% organic matter (Tables 5 and 6). The possible reason for those increments was the ability of soil amendments (clay and organic matter) to increase soil C organic, N total and exchangeable K which are important for plant growth. Akbarian *et al*. (2010) reported that addition of NPK fertilizer increased dry matter of *J curcas.*

Table 4. Effect of irrigation interval, clay soil and organic matter on exche able K_2O content of sandy soil

Treatment	Exchangeable K_2O (me/100 g)		
	1 month	**2 month**	**3 mo4nth**
Irrigation interval (days)			
10	6.60	1.99	0.29
20	11.30	2.03	0.27
LSD 5%	n.s	n.s	n.s
Plant media			
Sandy soils (Control)	3.70 a	1.70 a	0.06 a
Sandy soils + 5% clay soils + 0.8% organic matter	9.30 ab	2.00 b	0.28 b
Sandy soils + 10% clay soils + 1.6% organic matter	13.80 b	2.33 c	0.49 c
LSD 5%	6.40	0.15	0.03

Table 5. Effect of irrigation interval, clay soil and organic matter on pH of sandy soil

Treatment	Soil pH		
	1 month	**2 month**	**3 month**
Irrigation interval (days)			
10	6.75	6.55	6.59
20	6.70	6.53	6.61
LSD 5%	n.s	n.s	n.s
Plant media	6.76	6.52	6.62
Sandy soils (Control)	6.73	6.63	6.61
Sandy soils + 5% clay soils + 0.8% organic matter	6.68	6.47	6.56
Sandy soils + 10% clay soils + 1.6% organic matter			
LSD 5%	n.s	n.s	n.s

Table 6. Effect of irrigation interval, clay soil and organic matter on number of leaves of J. curcas

Treatment	Number of leaves		
	1 month	2 month	3 month
Irrigation interval (days)			
10	35.66	106.52	159.03
20	36.86	102.46	190.19
LSD 5%	n.s	n.s	n.s
Plant media			
Sandy soils (Control)	28.79 a	78.26 a	131.29 a
Sandy soils + 5% clay soils+ 0.8% organic matter	40.92 b	112.21 b	193.25 b
Sandy soils + 10% clay soils + 1.6% organic matter	39.40 b	123.00 b	199.28 b
LSD 5%	3.90	21.81	22.10

Table 7. Effect of irrigation interval, clay soil and organic matter on number of generative shoot of J. curcas

Treatment	Number of lateral branches		
	1 month	2 month	3 month
Irrigation interval (days)			
10	1.79	2.18	4.53
20	1.59	2.44	4.03
LSD 5%	n.s	n.s	n.s
Plant media			
Sandy soils (Control)	1.26 a	1.65 a	2.47 a
Sandy soils + 5% clay soils + 0.8% organic matter	1.90 b	2.57 b	4.69 b
Sandy soils + 10% clay soils + 1.6% organic matter	1.90 b	2.69 b	5.67 b
LSD 5%	0.50	0.66	1.25

Irrigation at different time intervals (at 10 day and 20 day) did not significant difference on number of plant growth. (Table 7). Similar results were reported by Behera *et al*. (2010) where irrigation intervals (7 day, 15 day and 30 day) did not affect significantly on *J curcas* growth indicated by no significant different of plant height, stem diameter, number of lateral branches. They found that rain-fed *J curcas* had poorest growth among the treatment supporting that irrigation as one of limiting factor in *J curcas* cultivation for high biomass production.

CONCLUSIONS

The present study provides evidence that soil amendments (clay and organic matter) could improve soil chemical properties of sandy soil and plant growth of *J curcas*. Incorporation of 10% and 1.6% organic matter to sandy soil increased soil organic C, total N and exchangeable K which in turn supported *J curcas* to have more number of leaves and number of lateral branches, but irrigation intervals had no effect on all parameters observed.

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