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SIMPLE PREDICTION MODEL FOR POTATO YIELD BASED ON WATER AND NUTRIENTS AVAILABILITY IN SOIL WITH DIFFERENT FERTILIZERS AND BIOCHARS APPLICATION

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ABSTRACT

The yield of potato crop strongly depends on water and nutrients availability in soil, which in turn are affected by type/rate of fertilizer and soil-amendment applied. This research was aimed to develop simple prediction model for potato crop (Atlantik variety) yield based on water and nutrients availability in its growing soil (pot) with different types/rates of fertilizers and biochars. The totally 60 pots of inorganic (P1; N: 100 kg/ha, P: 300 kg/ha, K: 150 kg/ha) and organic fertilizer (P2; NPK-dosage was equalized to inorganic-NPK) in combination with zero-(A0), wood-(A1), rice-husk-(A2), and activated-charcoal (A3) having dosage of 5 ton/ha (D1), 10 ton/ha (D2), and 15 ton/ha (D3) each were prepared in a screen-house located at Serang village, Purbalingga regency, and sowed by Atlantik potato seed. For the entire treatments, the water requirement (evapotranspiration) was determined from daily weather data (temperature, relative humidity, wind-speed, and solar-radiation), while soil-nutrients contents were monthly sampled and analyzed in laboratory. The yield was then measured in each cropping-pot at harvesting time. The results showed that the yield of Atlantic potato with different types/rate of fertilizers and biochars was well predicted by a simple model, in which the errors were ranged from 0.33 – 0.77%. The organic fertilizer with wood-charcoal of 10 ton/ha gave the highest yield of Atlantic potato crop.

***Kata kunci** : Simple prediction model, Atlantik potato yield, inorganic and organic fertilizer, biochars, water and nutrients availability*

INTRODUCTION

In Indonesia, the domestic demand of potato is nowadays increasing year by year (BPS, 2009). However, the production covers only about 20% of the demand, and is allocated mainly for potato processing industry (Warnita, 2007). This has encouraged an intensive cultivation of potato crop in the tropical highland areas involving conventional cultivation (vertical- or slopping-ridge) system, which in turn has caused severe land and environmental degradation (Soleh et al., 2002, Gangcai et al., 2005, Auerswald e al., 2006).

The conservation-based cultivation (horizontal- or contour-ridge) system has been introduced by Wijaya et al. (2010) and Umedi et al. (2010) to overcome severe erosion problem in Serang village, Purbalingga regency, Central Java, Indonesia since 2007. Accordingly, they reported that the horizontal-ridge system could significantly be effective to reduce surface runoff and soil loss in potato fields with from 17 – 34% and 67 – 73%, respectively, depended upon the degree (percentage) of field slope. However, the system has still supported the productivity of crop insufficiently, due to waterlogged or oversaturated condition in the ridge. In fact, the waterlogged condition in soil might then activates the anaerobic soil pathogen to grow (Soesanto at al., 2011). Therefore, there is a need to modify the physical and chemical properties of potato-growing soil to improve aeration as well as water and nutrients storage for better crop production.

Biochars potent to be used as soil-amendment for improving soil quality (Oguntunde et al., 2004, Gundale et al., 2007, Yao et al., 2011), and may serve as botanical controller for crop pests and diseases (Gao et al., 2012). The biochars has capability as a carrier to grasp as well as to slowly release water and nutrients in soil to crop (Steiner et al., 2009, Makoto et al., 2011). Furthermore, the combination of rice-husk-charcoal and compost could improve the physical properties (water content, dry bulk density, and hydraulic conductivity) and biochemical properties (pH and

electrical conductivity) of soil (Tini and Wijaya, 2010). However, the applicability of combined biochars and nutrients inputted into soil in relation to the productivity of crop especially potato has not been fully understood.

This research was aimed to develop simple prediction model for Atlantik-potato crop yield based on water and nutrients availability in growing soil (pot) with different types/rates of fertilizers and biochars. By this model, it is expected that the appropriate type/rate of fertilizer and biochar could be also identified, which in further might be useful as basic information for developing sustainable farming system of potato crop.

MATERIALS AND METHODS

Time Period and Location

The research was carried out in a screen-house located at Serang village, Purbalingga regency, Central Java, Indonesia. The analysis of samples was conducted at Laboratory of Agricultural Engineering and Laboratory of Soil Science and Land Resource, Jenderal Soedirman University, Purwokerto city, Central Java, Indonesia.

Experimental Design

The potato-growing pots with inorganic (P1; N: 100 kg/ha, P: 300 kg/ha, K: 150 kg/ha) and organic fertilizer (P2; NPK-dosage was equalized to inorganic-NPK) in combination with zero-(A0), and wood-(A1), rice-husk-(A2), and activated-charcoal (A3) having dosage of 5 ton/ha (D1), 10 ton/ha (D2), and 15 ton/ha (D3) each were prepared, and then sowed by Atlantic-potato crop. Each combination was then replicated 3 times, thus there were totally about 60 pots to be investigated (Figure 1).

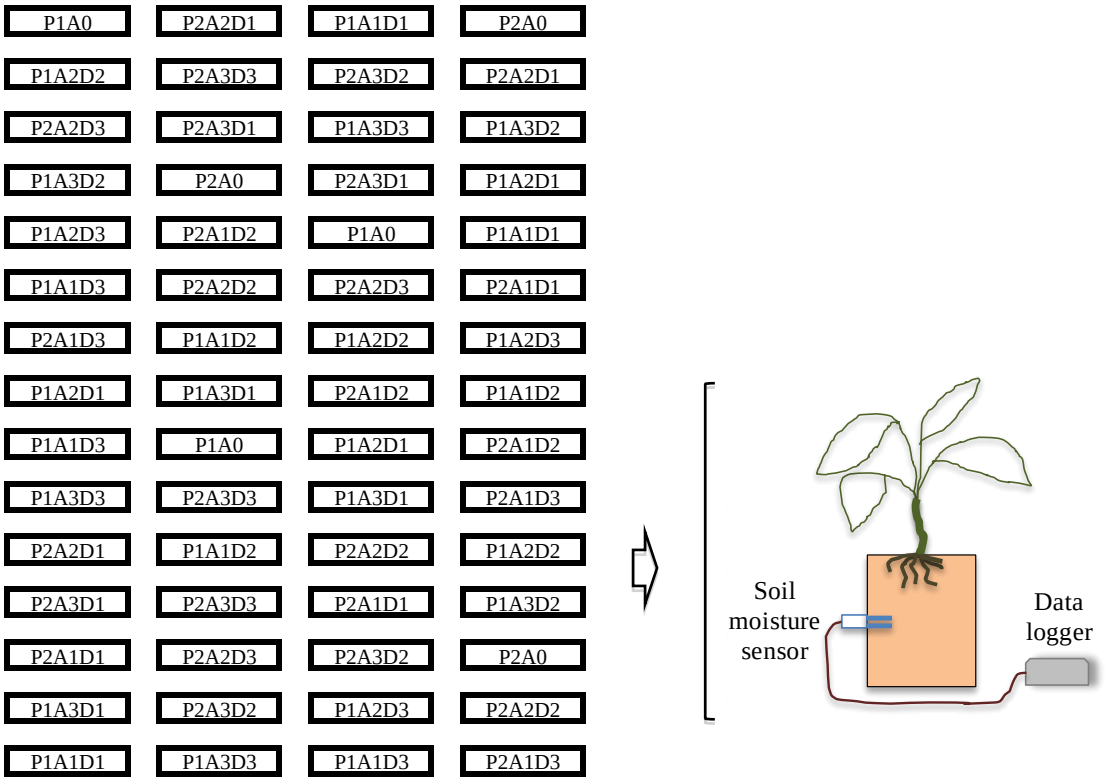

Figure 1. Schematic diagram of the screen-house experiment for identifying Atlantik-potato crop yield in relation to different types/rates of fertilizers and biochars applied (Wijaya et al., 2014, 2015)

For the whole combinations, the crop-water uptake or -requirement was determined from evapotranspiration (ET) value based on daily weather data (temperature, RH, wind-speed, and solar-radiation). The soil-nutrients contents were monthly sampled and analyzed in laboratory, while the yield of the crop in each pot was then measured at harvesting time.

Data Analysis

The parameters related to the growth and yield of Alantik-potato crop were determined by using several methods as follows:

(1) The evapotranspiration (ET) was calculated by using Penman-Monteith formula:

$$ET = K_c \,.\, ET_o \quad (1)$$

$$ETo = \frac{0.408\Delta(Rn - G) + \gamma \frac{37}{T + 273} U2(es - ea)}{\Delta + \gamma(1 + 0.34U2)} \quad (2)$$

where, K_c is the crop coefficient; ET_o is the potential evapotranspiration; T is the air temperature at 2 m height; (e_s-e_a) is the vapor pressure deficit; u_2 is the wind speed at the 2 m height; R_n is the net radiation at the crop surface; Δ is the slope vapor pressure curve; γ is the psychometric constant; and G is the soil heat flux density.

(2) The production of potato crop was modeled based on the Modified Cobb-Douglas formula:

$$Y = \mathrm{a}\, N^{\mathrm{b1}}\, P^{\mathrm{b2}}\, K^{\mathrm{b3}}\, \mathrm{e}^{(\mathrm{u} + \mathrm{b4Ar})}\, ET^{\mathrm{b5}} \quad (3)$$

where, Y is the Atlantik-potato-crop yield; N, P, and K is the nitrogen, phosphorus, potassium content in potato-growing soil, respectively; and Ar is the biochars dosage; a, b1, b2, b3, u, b4, and b4 are the fitted/optimized parameters.

(3) The accuracy of the predicted/modeled against the measured potato production was determined by using root mean square error (RMSE) formula as follow:

$$RMSE = \sqrt{((Y_{predicted} - Y_{measured})^2/n)} \quad (4)$$

where, $Y_{predicted}$ and $Y_{measured}$ are the predicted/modeled and measured yield of Atlantik-potato crop, respectively; and n is the number of data

RESULTS AND DISCUSSION

Crop Water Uptake

Figure 2 shows the crop-water uptake or -evapotranspiration rate in potato-growing pots under inorganic and organic fertilizer application with various types and rates of biochars. Among the treatments, the evapotranspiration rate as well as water uptake by potato crop in organic-growing pots was slightly higher than that in inorganic-growing pots throughout a cultivation period. In combination with biochars, the organic fertilizer could improve the structure of growing/pot soil better than the inorganic fertilizer, resulted in increasing water-holding capacity of the soil (Tini and Wijaya, 2010). Accordingly, the biochars added into the soil could contribute to not only maintaining its physico-chemical properties of growing/pots, but also to improving its capability to release its water and nutrients to the crop (Sommer et al., 2002, Steiner et al., 2009).

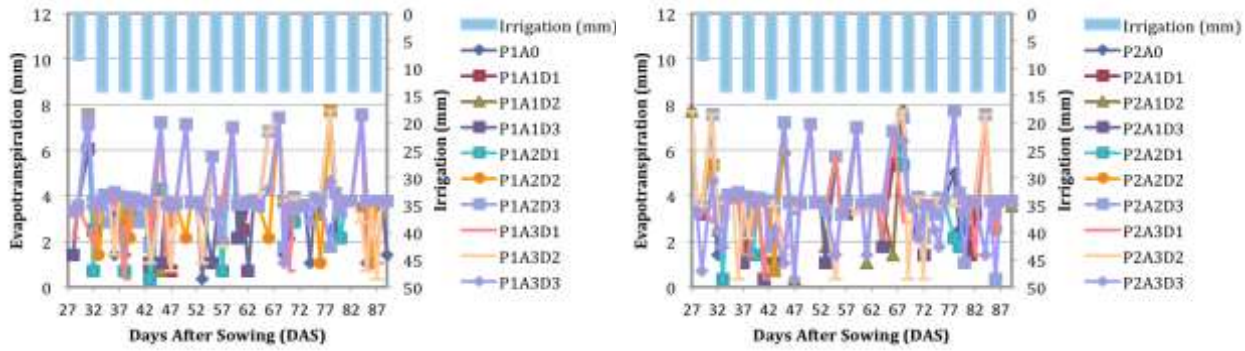

Figure 2. Crop water-uptake or evapotranspiration rate in potato-growing pots under inorganic and organic fertilizer application with various types and rates of bio-chars (Wijaya et al., 2014)

Potato Production

The yields of Atlantik-potato crop under inorganic and organic fertilizer application with various types and rates of bio-chars are illustrated in Figure 3. The yield under the organic fertilizer and biochars combination averaged about 4.95% higher than that under the inorganic fertilizer and biochars combination (Figure 3A). Among the former combination, the maximum yield of 405 g/crop was obtained in the treatment with wood-charcoal of 10 ton/ha, in which about 46% of the tubers was categorized as grade C (Figure 3B). This revealed that the combination of organic fertilizer and wood-charcoal tended to have positive impact on improving the yield of Atlantik-potato crop, which might be due to its high capability in maintaining as well as releasing water and nutrients in growing/pot-soil to the crop (Makoto et al. 2011).

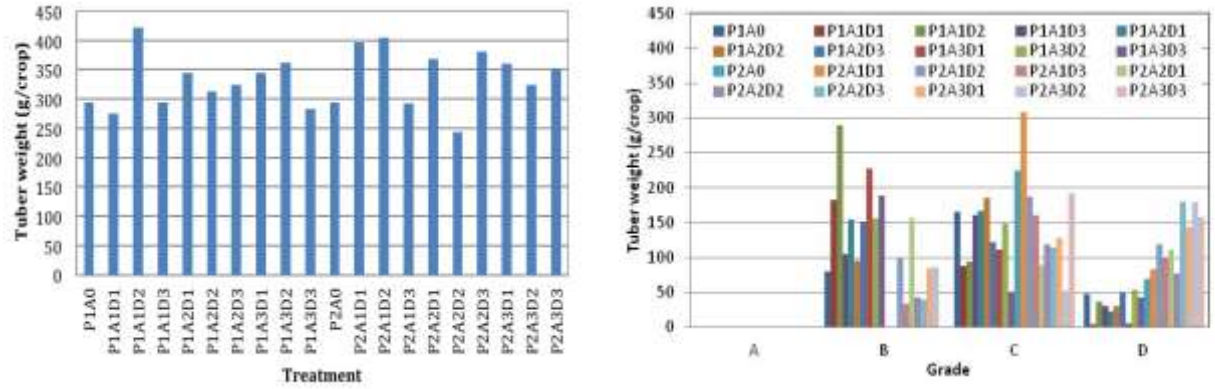

Figure 3. Yield of the potato crop under inorganic and organic fertilizers application combined with various types and rates of bio-chars: (A) Treatments-based tuber weight and (B) Grade-based tuber weight

Prediction Model of Potato Production

The yields of Atlantik-potato crop in response to the rates of different biochars types under inorganic and organic fertilizer application are described in Figure 4A and 4B, respectively. For both combinations, the predicted/modeled yields were agreed well with the measured yields of Atlantik-potato crop with significantly low RMSE value ranged from 0.0033 – 0.0077 ton/ha (or equivalent to 0.33 – 0.77%). The wood-charcoal of 10 ton/ha produced the highest yield of Atlantik-potato crop than others. More specifically, in the range of 0 – 10 ton/ha, the wood-charcoal combined with organic fertilizer could maintain the yield better than that combined with inorganic fertilizer. This might be because of the wood-charcoal could store and release nutrients in growing/pot-soil to the crop better than others (Steiner et al., 2009).

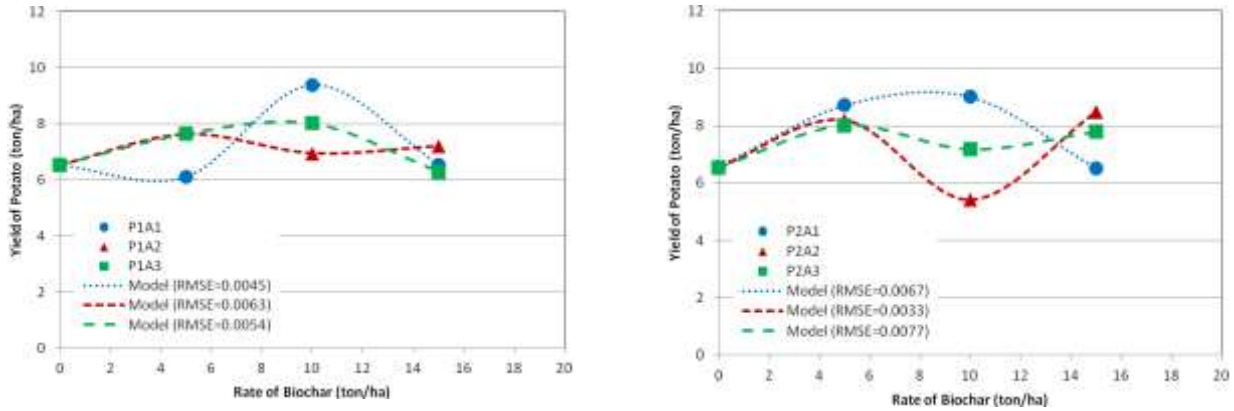

Figure 4. Predicted/modeled yields of the Atlantik-potato crop in response to the rate of different biochars types under: (A) Inorganic and (B) Organic fertilizers application

The capability of the different rates of wood-charcoal in maintaining water and nutrients availability in Atlantik-potato growing/pot soil could be specifically identified from the value of fitted/modeled parameters (Table 1). For instance, the wood-charcoal of 10 ton/ha under organic fertilizer could store and carry N, P, K, and ET consecutively about 6, 34, 967, and 65% higher than that under inorganic fertilizer application. Furthermore, the values of fitted/optimized parameters, especially b1, b2, b3, and b5, in the former combination overestimated those in the latter combination. Those results indicated that the wood-charcoal gave better yield when it was combined with organic fertilizer rather than with inorganic fertilizer.

Tabel 1. Fitted parameters of the modeled yields of Atlantik-potato crop with different rates of wood-charcoal under inorganic and organic fertilizer application

Fertilizer Type	Char. Rate	Modeled Formula	Fitted/Optimized Parameters							RMSE
	(t/ha)	$Y = aN^{b1}P^{b2}K^{b3}e^{(u+Arb4)}ET^{b5}$	a	b1	b2	b3	u	b4	b5	(t/ha)
Inorganic	0	$Y = a0.202^{b1}0.173^{b2}0.007^{b3}e^{u}244^{b5}$	6.545	-0.202	-0.221	-0.635	0.124	0.014	-0.733	0.0045
	5	$Y = a0.205^{b1}0.176^{b2}0.007^{b3}e^{(u+5b4)}279^{b5}$								
	10	$Y = a0.194^{b1}0.167^{b2}0.006^{b3}e^{(u+10b4)}205^{b5}$								
	15	$Y = a0.210^{b1}0.181^{b2}0.007^{b3}e^{(u+15b4)}284^{b5}$								
Organic	0	$Y = a0.190^{b1}0.208^{b2}0.056^{b3}e^{u}289^{b5}$	6.519	0.322	0.304	0.557	-0.191	0.012	0.496	0.0067
	5	$Y = a0.217^{b1}0.236^{b2}0.070^{b3}e^{(u+5b4)}301^{b5}$								
	10	$Y = a0.205^{b1}0.224^{b2}0.064^{b3}e^{(u+10b4)}338^{b5}$								
	15	$Y = a0.181^{b1}0.198^{b2}0.051^{b3}e^{(u+15b4)}235^{b5}$								

CONCLUSION

The yield of Atlantik-potato crop under different type/rates of fertilizers and biochars applied could be simply developed based on water and nutrients availability in growing/pot soil with RMSE values ranged from 0.33 – 0.77%. The combination of organic fertilizer and wood-charcoal of 10 ton/ha gave better results than others, thus it had a tendency to be applicable for developing sustainable farming system of Atlantik-potato crop.

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