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Optimizing Application of Biochar Amendment for Nitrogen use Efficiency in Upland Rice under *Melaleuca cajuputi* Stands

E. Faridah[1], P. Suryanto[1], H.H. Nurjanto[1],
E.T.S. Putra[2], M.D. Falah[3], M.H. Widyawan[2], T. Alam[2]

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ABSTRACT

Background: The main problem in nitrogen fertilization for crop cultivated is the very low efficiency due to the leaching process. The purpose of this study was to the determination of the optimum levels of biochar amendment made from *Melaleuca cajuputi* biochar (MCB) and urea fertilizer (UF) for nitrogen use efficiency in upland rice under *M. cajuputi* stands.

Methods: The study was conducted during dry season within March to June 2019 in Menggoran Forest Resort, Playen Forest Section, Yogyakarta Forest Management District, Indonesia. The experimental design was laid out in a randomized complete block design factorial with three replications as the response surface methodology (RSM). The treatments consisted of MCB levels (0, 5, 10, 15 tons ha^{-1}) and UF levels (0, 100, 200, 300 kg ha^{-1}) as independent variables. The observation parameters were nitrate reductase activity (NRA), total chlorophyll (TC), leaf photosynthesis rate (LPR), nitrogen loss (NL), nitrogen use efficiency (NUE) and seed yield (SY). The data was analyzed using RSM approach and ridge regression.

Result: The optimizing applications of 11.14 tons ha^{-1} of MCB and 281.13 kg ha^{-1} of UF resulted in NUE and SY by 2.14 kg grain kg $N_{fertilizer}^{-1}$ and 5.83 tons ha^{-1} or increased by 19.07% and 13.02%, compared to a single application of UF by 300 kg ha^{-1}.

Key words: Amendment, *M. cajuputi* biochar, Nitrogen use efficiency, Upland rice, Urea fertilizer.

INTRODUCTION

Rice is the staple food for most people in Indonesia. In just one year alone from 2018 to 2019, the harvested area of rice agriculture in Indonesia shrunk by 700,000 hectares (6.15%), with rice production reduced by 4.60 million tons (7.76%) (Statistics Indonesia, 2020). One strategy to expand the areas of upland rice farming is by planting rice between *M. cajuputi* stands. Intensification of the areas among *M. cajuputi* stands for upland rice had various problems, namely low levels of N content (NH_4^+ and NO_3^-) in the soil and low NUE value. In general, the NH_4^+ and NO_3^- contents in the soil on *M. cajuputi* forests were 39.39 and 86.18 ppm, while the NH_4^+ and NO_3^- losses through the leaching process by 28.10% and 187.50% (Alam *et al.* 2019; Suryanto *et al*. 2020b; Suryanto *et al.* 2020c; Zhao *et al*. 2019).

Biochar is a product of the pyrolysis of organic materials and has several functions, such as absorbing CO_2 in the atmosphere, improving soil physical and chemical fertility and increasing fertilizer efficiency and yields (Coumaravel *et al.* 2011). Biochar can absorb nutrients directly to its surface by surface binding of both cation and anion due to its greater porosity and surface area (Atkinson *et al.* 2010). *M. cajuputi* waste can be used for soil amendment in the form of biochar. The pH H_2O, C, H, O and N contents in the MCB were 8.05, 72.48%, 2.32%, 22.44% and 0.17%, respectively (Alam *et al.* 2020b). The research study by Alam *et al*. (2020b) informed that the applications of *M. cajuputi* waste (biochar and compost) and ammonium sulfate fertilizer by 2.89 and 2.27 tons ha^{-1} and 67.85 kg ha^{-1}, respectively, can increased NUE and soybean yield by 7.23% and 17.29%.

[1]Department of Silviculture, Faculty of Forestry, Universitas Gadjah Mada, Bulaksumur-55281, Yogyakarta, Indonesia.
[2]Department of Agronomy, Faculty of Agriculture, Universitas Gadjah Mada, Bulaksumur-55281, Yogyakarta, Indonesia.
[3]Stiper Institute of Agriculture, Papringan-55281, Yogyakarta, Indonesia.

Corresponding Author: P. Suryanto, Department of Silviculture, Faculty of Forestry, Universitas Gadjah Mada, Bulaksumur-55281, Yogyakarta, Indonesia. Email: psuryanto@ugm.ac.id

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The purpose of this study was to the determination of the optimum levels of biochar amendment made from MCB and UF in upland rice under with *M. cajuputi* stands. The research results will provides the information related to the effectiveness of MCB for the NUE and increased of upland rice yield and gave the problem solution of *M. cajuputi* waste that had not been utilized.

MATERIALS AND METHODS

The study was conducted during dry season within March to June 2019 in Menggoran Forest Resort, Playen Forest Section, Yogyakarta Forest Management District, Indonesia. The areas in the *M. cajuputi* forest belongs to the Department of Forestry and Plantation, Yogyakarta, Indonesia. Total

rainfall during rice planting and in a year were 407 and 2,005 mm, respectively. The average air temperature and relative humidity were 25.54°C and 83.90%. The soil type was Lithic Haplusterts (Alam *et al.* 2019; Alam *et al.* 2020a; Suryanto *et al.* 2017; Suryanto *et al.* 2020a). The soil texture was dominated by clay texture with very slow drainage (0.001 cm $hour^{-1}$). The CEC included in a high category (57.78 $cmol^{(+)}$ kg^{-1}) and the pH H_2O was alkaline (8.18). SOC (1.62%), total N (0.13%), available of P (7 ppm) and available of K (0.41 $cmol^{(+)}$ kg^{-1}) were classified in the low category. Biochar was made from the waste of distilled *M. cajuputi* leaves. Biochar was made by using the Kiln Traditional Method (Emrich, 1985). The laboratory analysis showed that the content of pH H_2O, C, H, N and O in the MCB was used in this experiment by 8.21, 72.48%, 2.32% and 0.17% and 22.44%, respectively.

The experimental design was laid out in a randomized complete block design factorial with three replications as the response surface methodology (RSM). The treatments consisted of MCB levels (0, 5, 10, 15 tons ha^{-1}) and UF levels (0, 100, 200, 300 kg ha^{-1}) as independent variables. Biochar was applied during rice planting, while urea applied in 2, 4 and 8 week after planting (wap). The observation parameters were nitrate reductase activity (NRA) (Krywult and Bielec, 2013), total chlorophyll (TC) (Gross, 1991), leaf photosynthesis rate (LPR) (Li-Cor, 1999), nitrogen loss (NL) (Fageria, 2014), nitrogen use efficiency (NUE) (Rathke *et al.,* 2016) and seed yield (SY) (Suryanto *et al.* 2017; Suryanto *et al.* 2020a). The observations of NRA, TC and LPR were carried out during the maximum vegetative phase, while NL, NUE and SY in the harvest time.The RSM equation used in this experiment applied the uncoded independent variables (Koocheki *et al.* 2014, Myers *et al*. 2009). The fitted model were an evaluation by the R^2, RMSE and lack-of-fit. The lack-of-fit criterion used in this study was that the significance of lack-of-fit tested with a F-test should be less than 5% (Myers *et al.* 2009). The optimum MCB and UF levels were calculated under the economy scenario using the SY parameter and estimation with ridge regression (Koocheki *et al.* 2014, Marquardt and Snee, 1975). All analysis was performed using PROC RSREG in SAS 9.4 software (SAS Institute, 2013).

RESULTS AND DISCUSSION

Evaluation of the fitted models for upland rice parameters

The R^2, RMSE and the lack-of-fit test was used to evaluate the quality of the fitted model. Based on the regression equations showed that R^2 dan RMSE indicated that all models showed fitted (Table 1). The lack-of-fit tested was not significant in all soybean parameters (Table 1).

Estimated response for upland rice parameters of experimental factors

The MCB and UF applications very significantly influenced NRA (Table 1). The highest NRA by 4.46 µmol NO_2^- g^{-1} $hour^{-1}$ obtained in the treatments of 10 tons ha^{-1} of MCB and 300 kg ha^{-1} of UF (Table 2). There was no interaction between MCB with UF in the NRA. The MCB and UF showed linear and quadratic patterns (Table 1). The increase of N levels has a significant effect on NH_4^+ and NO_3^- concentrations in the soil and NRA in the rice (Nascente and Lanna, 2016). The applications of 13.29 tons ha^{-1} of MCB and 245.35 tons ha^{-1} of UF increased the NRA content by 35.28%, compared to a single UF application by 300 kg ha^{-1} (Nurmalasari *et al.* 2020).

The treatments of MCB and UF in the soil gave significantly and very significantly influenced TC (Table 1). The applications of 10 tons ha^{-1} of MCB and 300 kg ha^{-1} of UF showed the highest TC by 0.94 g g $leaf^{-1}$ (Table 2). There was no interaction between MCB with UF in TC. The MCB and UF showed a linear patterns (Table 1). The N fertilization of 120 kg ha^{-1} combined with biochar of 9 ton ha^{-1} significantly increased TC in rice (Lai *et al.* 2017).

The applications of MCB and UF significantly and very significantly influenced LPR (Table 1). The LPR showed the highest value by 415.71 µmol CO_2 m^{-2} s^{-1} in the applications of 10 tons ha^{-1} of MCB and 300 kg ha^{-1} of UF (Table 2). There was no interaction between MCB with UF in LPR. The UF showed a quadratic pattern, while MCB showed a linear pattern (Table 1). In general, the amendments using biochar on crops significantly increased the photosynthesis rate, stomatal conductance, transpiration rate, water use efficiency and chlorophyll content by 27.1%, 19.6%, 26.9%, 26.8% and 16.1%, respectively (He *et al.,* 2020). The effect of N supply in rice can increase flag leaf photosynthesis, slow down the aging of flag leaves and prolong photosynthesis times (Sun *et al.* 2014).

The MCB and UF treatments very significantly influenced NL (Table 1). The treatments of 15 tons ha^{-1} of MCB and 0 kg ha^{-1} of UF showed the lowest NL by 3.25 kg ha^{-1}, while the highest NL by 54.00 kg ha^{-1} in the applications of 0 tons ha^{-1} of MCB and 300 kg ha^{-1} of UF (Table 2). There was an interaction between MCB and UF in NL. The quadratic patterns showed in MCB and UF treatments (Table 1). The addition of biochar to the soil can increase water-holding capacity, thus reducing N loss risk through the leaching process (Zheng *et al.* 2013).

The additions of MCB not significantly increased NUE, while UF showed very significantly increased NUE (Table 1). The applications of 15 tons ha^{-1} of MCB and 100 kg ha^{-1} of UF gave the highest NUE by 2.21 kg grain kg $N_{fertilizer}^{-1}$ (Table 2). There was no interaction between MCB and UF in NUE. The MCB showed a linear pattern, whereas UF showed a quadratic pattern (Table 1). Based on the eco-environmental scenario, it showed that the applications of *M. cajuputi* waste in the form of biochar and compost by 2.89 and 2.27 tons ha^{-1} and ammonium sulfate by 67.85 kg ha^{-1} resulted in NUE maize by 6.87 kg kg^{-1} grain by $N_{fertilizer}^{-1}$ or increased by 7.23%, compared to the single application of ammonium sulfate fertilizer (Alam *et al.* 2020b).

Table 1: Regression coefficients of the fitted model.

Run	Response Variables					
	NRA (μmol NO_2^- g^{-1} h^{-1})	TC (g g $leaf^{-1}$)	LPR (μmol CO_2 m^{-2} s^{-1})	NL (kg ha^{-1})	NUE (kg grain kg $N_{fertilizer}^{-1}$)	SY (tons ha^{-1})
b_0	2.12**	0.32**	202.44**	6.77**	-0.05^{ns}	1.65
$b_1 x_1$	0.05**	0.01*	3.9*	-1.08**	0.02^{ns}	0.06
$b_2 x_2$	0.01**	0.002**	0.75**	0.12**	0.02**	0.01
$b_{11} x_1^2$	-0.0005^{ns}	-0.0003^{ns}	-0.03^{ns}	0.06**	0.0001^{ns}	-0.0004
$b_{12} x_1 x_2$	0.00002^{ns}	0.00002^{ns}	0.002^{ns}	-0.005**	0.00009^{ns}	0.0002
$b_{22} x_2^2$	-0.00002**	-0.0000009^{ns}	-0.0006*	-0.0001**	-0.00005**	-0.00002
R^2	0.99**	0.96**	0.96**	0.99**	0.90**	0.97**
RMSE	0.09	0.05	14.91	1.48	0.27	0.28
Lack-of-Fit	0.083^{ns}	0.128^{ns}	0.135^{ns}	0.268^{ns}	0.339^{ns}	0.207^{ns}

* and ^{ns} significantly and no significantly at (p<0.05). ** significantly at (p<0.01). x_1 and x_2 indicates *M. cajuputi* biochar (tons ha^{-1}) and urea fertilizer (kg ha^{-1}). NRA- Nitrate reductase activity; TC- Total chlorophyll; LPR- Leaf photosynthesis rate; NL- Nitrogen loss; NUE- Nitrogen use efficiency; SY- Seed yield.

Table 2: Actual values of experimental factors and estimated response for upland rice variables.

Run	Factors		Estimated Response					
	MCB	UF	NRA	TC	LPR	NL	NUE	SY
1	0	0	2.16	0.33	213.88	6.25	0.00	1.79
2	0	100	3.05	0.48	264.69	18.00	1.48	2.88
3	0	200	3.70	0.62	326.50	36.00	1.25	3.95
4	0	300	3.94	0.74	367.68	54.00	1.09	4.67
5	5	0	2.36	0.39	226.54	4.38	0.00	2.04
6	5	100	3.24	0.51	270.32	12.60	1.65	3.16
7	5	200	3.84	0.68	348.10	25.20	1.44	4.29
8	5	300	4.12	0.83	398.77	37.80	1.31	5.25
9	10	0	2.52	0.42	233.35	3.75	0.00	2.16
10	10	100	3.42	0.55	295.73	10.80	1.88	3.36
11	10	200	4.02	0.78	383.88	21.60	1.74	4.90
12	10	300	4.45	0.94	415.71	32.40	1.56	5.98
13	15	0	2.68	0.45	257.87	3.25	0.00	2.48
14	15	100	3.61	0.58	313.38	9.36	2.21	3.78
15	15	200	4.37	0.91	412.39	18.72	2.13	5.84
16	15	300	4.25	0.88	403.06	28.08	1.46	5.59

MCB- *M. cajuputi* biochar (tons ha^{-1}); UF: Urea fertilizer (kg ha^{-1}). NRA- Nitrate reductase activity (μmol NO_2^- g^{-1} h^{-1}); TC- Total chlorophyll (g g $leaf^{-1}$); LPR- Leaf photosynthesis rate (μmol CO_2 m^{-2} s^{-1}); NL- Nitrogen loss (kg ha^{-1}); NUE- Nitrogen use efficiency (kg grain kg $N_{fertilizer}^{-1}$); SY- Seed yield (tons ha^{-1}).

The MCB and UF applications significantly and very significantly influenced SY (Table 1). The SY showed the highest value by 5.98 tons ha^{-1} in the applications of 10 tons ha^{-1} of MCB and 300 kg ha^{-1} of UF (Table 2). There was no interaction between MCB and UF in SY. The MCB showed a linear pattern, while UF showed a quadratic pattern (Table 1). A biochar amendment of <30 ton ha^{-1} can increase plant productivity by 11% (Liu *et al.* 2013). Nitrogen fertilization of 240 kg ha^{-1} with a schedule of 30% at basal, 20% at 10 days after transplanting (DAT) and 50% at 36 DAT resulted in average rice productivity of 10.20 tons ha^{-1} or an increase of 46.87%, compared to without N fertilizer (Pan *et al.* 2012).

Based on economic scenario showed that the optimum values of 11.14 tons ha^{-1} of MCB and 281.13 kg ha^{-1} of UF produced a maximum NRA, TC, LPR, NL, NUE and SY by 3.91 μmol NO_2^- g^{-1} h^{-1}, 0.95 g g $leaf^{-1}$, 411.85 μmol CO_2 m^{-2} s^{-1}, 12.36 kg ha^{-1}, 2.14 kg grain kg $N_{fertilizer}^{-1}$ and 14.13 tons ha^{-1}, respectively (Fig 1a, 1b, 1c, 1d, 1e, 1f). This recommendation reduced use of UF by 15.75%, while to an increased NRA, TC, LPR, NL, NUE and SY by 17.72%, 12.98%, 10.29%, -63.41%, 47.45% and 44.76%, respectively, in comparison to the single application of UF by 300 kg ha^{-1}.

The research was conducted by Dong *et al.* (2015) in 2009 and 2010 provides information that the addition of biochar to soil can increased rice yields by 11.30% and

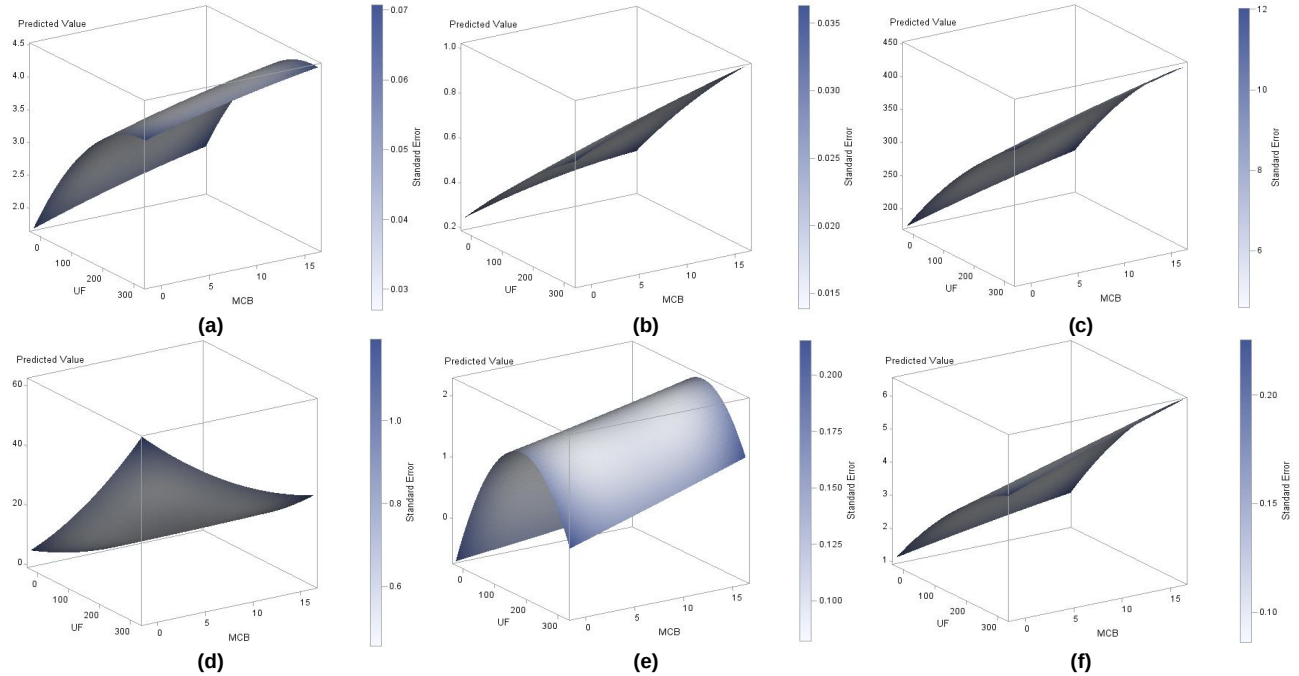


Fig 1: The variables response to the *M. cajuputi* biochar (MCB) (tons ha^{-1}) and urea fertilizer (UF) (kg ha^{-1}). a). NRA- Nitrate reductase activity (µmol NO_2^- g^{-1} h^{-1}); b). TC- Total chlorophyll (g g leaf^{-1}); c). LPR- Leaf photosynthesis rate (µmol CO_2 m^{-2} s^{-1}); d). NL- Nitrogen loss (kg ha^{-1}); e). NUE- Nitrogen use efficiency (kg grain kg $N_{fertilizer}^{-1}$), f); SY- Seed yield (tons ha^{-1}).

14.40%. Coumaravel *et al.* (2015) informed that the application of biochar combined with NPK fertilizer can increase the sustainability of soil fertility and maize productivity.

CONCLUSION

The optimum values of 11.14 tons ha^{-1} of MCB and 281.13 kg ha^{-1} of UF produced a maximum NRA, TC, LPR, NL, NUE and SY by 3.91 µmol NO_2^- g^{-1} h^{-1}, 0.95 g g leaf^{-1}, 411.85 µmol CO_2 m^{-2} s^{-1}, 12.36 kg ha^{-1}, 2.14 kg grain kg $N_{fertilizer}^{-1}$ and 14.13 tons ha^{-1}, respectively. This recommendation reduced use of UF by 15.75%, while to an increased NRA, TC, NP, NL, NUE and SY by 17.72%, 12.98%, 10.29%, -63.41%, 47.45% and 44.76%, respectively, in comparison to the single application of UF by 300 kg ha^{-1}.

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REFERENCES

Alam, T., Kurniasih, B., Suryanto, P., Basunanda, P., Supriyanta., Ambarwati, E., Widyawan, M.H., Handayani, S., Taryono. (2019). Stability analysis for soybean in agroforestry system with *kayu putih*. SABRAO Journal of Breeding and Genetics. 51: 405-418.

Alam, T., Muhartini, S., Suryanto, P., Ambarwati, E., Kastono, D., Nurmalasari, A.I., Kurniasih, B. (2020a). Soybean varieties suitability in agroforestry system with *kayu putih* under influence of soil quality parameters. Revista Ceres. 67(5): 410-418.

Alam, T., Suryanto, P., Handayani, S., Kastono, D., Kurniasih, B. (2020b). Optimizing application of biochar, compost and nitrogen fertilizer in soybean intercropping with *kayu putih* (*Melaleuca cajuputi*). Revista Brasileira Ciencia do Solo. 44: e0200003.

Atkinson, C.J., Fitzgerald, J.D., Hipps, N.A. (2010). Potential mechanisms for achieving agricultural benefits from biochar application to temperate soils- A review. Plant Soil. 337: 1-18.

Coumaravel, K., Santhi, R., Kumar, V.S., Mansour, M.M. (2011). Biochar- A promising soil additive- A review. Agricultural Reviews. 32: 134-139.

Coumaravel, K., Santhi, R., Maragatham, S. (2015). Effect of biochar on yield and nutrient uptake by hybrid maize and on soil fertility. Indian Journal of Agricultural Research. 49(2): 185-188. DOI: 10.5958/0976-058X.2015.00028.1.

Dong, D., Feng, Q., McGrouther, K., Yang, M., Wang, H., Weixiang, W. (2015). Effects of biochar amendment on rice growth and nitrogen retention in a waterlogged paddy field. Journal of Soils and Sediments. 15: 153-162.

Emrich, W. (1985). Handbook of charcoal making- The traditional and industrial methods. Commission of the European Communities Directorate, Luxembourg.

Fageria, N.K. (2014). Nitrogen Management in Crop Production. CRC Press, New York.

Gross, J. (1991). Pigmentin vegetable, chlorophyll and caretinoids. Van Nonstrand Reinhold, New York.

He, Y., Yao, Y., Ji, Y., Deng, J., Zhou, G., Liu, R., Shao, J., Zhou, L., Li, N., Zhou, X., Bai, S.H. (2020). Biochar amendment

boosts photosynthesis and biomass in C_3 but not C_4 plants- A global synthesis. GCB-Bioenergy. 12(8): 605-617.

Koocheki, A., Mahallati, M.N., Moradi, R., Mansoori, H. (2014). Optimizing water, nitrogen and crop density in canola cultivation using response surface methodology and central composite design. Soil Science and Plant Nutrition. 60: 286-298.

Krywult, M., Bielec, D. (2013). Method of measurement of nitrate reductase activity in field conditions. Journal Ecological Engineering. 14:7-11.

Lai, L., Ismail, M.R., Muharam, F.M., Yusof, M.M., Ismail, R., Jaafar, N.M. (2017). Effects of rice straw biochar and nitrogen fertilizer on rice growth and yield. Asian Journal of Crop Science. 9: 159-166.

Li-Cor. (1999). Using the Li-6400- Portable photosynthesis system. LI-Cor Inc., Lincoln, Nebraska.

Liu, X., Zhang, A., Ji, C., Joseph, S., Bian, R., Li, L., Pan, G., Paz-Ferreiro, J. (2013) Biochar's effect on crop productivity and the dependence on experimental conditions- A meta-analysis of literature data. Plant Soil. 373: 583-594.

Marquardt, D.W., Snee, R.D. (1975). Ridge Regression in Practice. The American Statistician. 29: 3-20.

Myers, R.H., Montgomery, D.C., Cook, C.M.A. (2009). Response surface methodology- Process and product optimization using designed experiments. John Wiley and Sons, New Jersy.

Nascente, A.S., Lanna, A.C. (2016). Straw and early nitrogen fertilization affect soil properties and upland rice yield. Pesquisa Agropecuária Tropical. 46(3): 284-291.

Nurmalasari, A.I., Supriyono, Suryanto, P., Alam, T. (2020). Effectiveness of *M. cajuputi* biochar as a leaching loss for nitrogen fertilizer and intercropping in maize. Indian Journal of Agricultural Research. 54(4): 506-510. DOI: 10.18805/IJARe.A-579.

Pan, S., Huang, S., Zhai, J., Wang, J., Cao, C., Cai, M., Zhan, M., Tang, X. (2012). Effects of N management on yield and N uptake of rice in Central China. Journal of Integrative Agriculture. 11(12): 1993-2000.

Rathke, G.W., Behrens, T., Diepenbrock, W. (2006). Integrated nitrogen management strategies to improve seed yield, oil content and nitrogen efficiency of winter oilseed rape (*Brassica napus* L.)- A review. Agriculture, Ecosystems and Environment. 117: 80-108.

SAS Institute. (2013). SAS system for windows 9.4. SAS Institute Inc., North Carolina.

Statistics Indonesia. (2020). The harvested area and rice production in Indonesia 2019. Statistics Indonesia, Jakarta, Indonesia. https://www.bps.go.id/pressrelease/2020/02/04/1752/luas-panen-dan-produksi-padi-pada-tahun-2019-mengalami-penurunan-dibandingkan-tahun-2018-masing-masing-sebesar-6-15-dan-7-76-persen.html.

Sun, Y.J., Ma, J., Sun, Y.Y., Xu, H., Yan, F.J., Dai, Z. (2014). Effects of water and nitrogen management patterns on population quality and yield of hybrid rice Gangyou 527. Scientia Agricultura Sinica. 47(10): 2047-2061.

Suryanto, P., Taryono, Supriyanta, Kastono, D., Putra, E.T.S., Widyawan, M.H., Alam, T. (2020a). Assessment of soil quality parameters and yield of rice cultivars in *Melaleuca cajuputi* agroforestry system. Biodiversitas. 21(8): 3463-3470.

Suryanto, P., Faridah, E., Nurjanto, H.H., Supriyanta, Kastono, D., Putra, E.T.S., Handayani, S., Dewi, A.K., Alam, T. (2020b). Influence of siam weed compost on soybean varieties in an agroforestry system with *kayu putih* (*Melaleuca cajuputi*). Biodiversitas. 21(77): 3062-3069.

Suryanto, P., Kurniasih, B., Faridah, E, Nurjanto, H.H., Rogomulyo, R., Handayani, S., Kastono, D., Muttaqien, A.S, Alam T. (2020c). Influence of furrow with organic material and *Chromolaena odorata* compost on upland rice productivity in an agroforestry system with *Melaleuca cajuputi*. Biodiversitas. 21(2): 780-791.

Suryanto, P., Tohari, Putra, E.T.S, Alam, T. (2017). Minimum soil quality determinant for rice and 'kayu putih' yield under hilly areas. Journal of Agronomy. 16(3): 115-123.

Zhang, X., Huang, G., Bian, X., Zhao, Q. (2013). Effects of root interaction and nitrogen fertilization on the chlorophyll content root activity, photosynthetic characteristics of intercropped soybean and microbial quantity in the rhizosphere. Plant Soil and Environment. 59: 80-88.

Zhao, H., Li, X., Jiang, Y. (2019). Response of nitrogen losses to excessive nitrogen fertilizer application in intensive greenhouse vegetable production. Sustainability. 11: 1-15.

Zheng, H., Wang, Z.Y., Deng, X., Zhao, J., Luo, Y., Novak, J., Herbert, H., Xing, B.S. (2013). Characteristics and nutrient values of biochars produced from giant reed at different temperatures. Bioresource Technology. 130(2): 463-471.