AGRIVITA VOLUME 38 No. 1 FEBRUARY - 2016 ISSN : 0126 - 0537

FERTILIZATION STRATEGY TO INCREASE RICE GROWTH AND PRODUCTION UNDER TWO FLOODING CONDITION ON TWO LOWLAND SWAMP TYPES

Gribaldi [1*], Rujito A. Suwignyo [2], Merry Hasmeda [2] and Renih Hayati [2]

[1] Faculty of Agriculture, Baturaja University
Jl. Ratu Penghulu No. 2301 Baturaja, Ogan Komering Ulu, South Sumatra
[2] Faculty of Agriculture, Sriwijaya University
Jl. Palembang-Prabumulih KM 32 Ogan Ilir, South Sumatra
*) Corresponding author E-mail: gribaldi64@yahoo.co.id

Received: December 11, 2014/ Accepted: October 5, 2015

ABSTRACT

Flood is general phenomenon found in most areas of Indonesia. This can obstruct rice crop cultivation on lowland swamp areas. Fertilization strategy is one of the efforts to increase rice crop growth and production on flooded condition. The objective of this research was to determine the best fertilization strategy on vegetative stage related to rice crop growth and production under flooded condition at two types of lowland swamp. The experimental design used in this research was split-plot design with three replications. The main plot was fertilization treatment consisting of P_1 = base fertilization, P_2 = fertilization before flooded, P_3 = fertilization after flooded and P_4 = fertilization before and after flooded. The subplot was rice variety which consisted of V_1 = Inpara 3, V_2 = Inpara 5, V_3 = IR 64 and V_4 = Ciherang. The results showed that fertilization strategy was capable of increasing rice crop growth and production under flooded condition at two types of lowland swamp. Rice variety Inpara 5 added with fertilizer before flooded on shallow-backswamp and fertilizer addition before and after flooded on middle-backswamp was the best treatment that had produced rice yield with magnitude of 4.48 and 3.43 t ha^{-1}, respectively.

Keywords: fertilization strategy; flooded stress; rice

INTRODUCTION

The coverage area for rice crop that experience flooded stress due to flood was estimated to increase due to the increase of rainfall and uplift of sea water surface as results of global warming (CGIAR, 2006). Flooding that cause stress on rice crop at South Asia and Southeast Asia regions was estimated of about 15 million ha year^{-1} (Septiningsih *et al*., 2009), whereas flooding prone area of paddy field at South Sumatra was about 124,465 ha (Indonesian Development Planning Agency, 2010). Moreover, potential area hindered by flooding stress to be developed into agricultural land was very extensive, especially at lowland swamp area. According to Pierik *et al*. (2005), potential area of lowland swamp in Indonesia that could be developed into agricultural land was about 13 million ha, whereas at South Sumatra was about 2.0 million ha (Waluyo *et al*., 2008).

The main problem found in agricultural cultivation management at lowland swamp was the occurrence of flooding that impede the crops growth and production. Moreover, there were low soil pH and high soluble Al as well as low nutrient (Triadiati *et al*., 2013). In addition, rice farmers at lowland swamp have difficulty in predicting the height of water flooding so that they encounter the risk of flooded rice crop at vegetative growth phase.

Flooding stress that occurred on crops might result in obstruction of photosynthesis and respiration processes. This is due to gas diffusion within water is 10^4 times slower than gas diffusion within air (Armstrong and Drew, 2002) and very low light penetration that is received by plants (Pierik *et al.*, 2005). Estimation of yield loss due to flooding was about 30-60% (Ikhwani*,* 2012). One of the solutions to overcome this problem is by using flooding tolerance variety and proper fertilization strategy in order to increase rice growth and production under flooding stress condition.

Grain yield for variety containing gene *Sub-1* was higher than variety yield without

Cite this as: Gribaldi, R.A. Suwignyo, M. Hasmeda and R. Hayati. 2016. Fertilization strategy to increase rice growth and production under two flooding condition on two lowland swamp types. AGRIVITA. 38(1):64-72. doi: 10.17503/agrivita.v38i1.498
Accredited: **SK No. 81/DIKTI/Kep/2011**
Permalink/DOI: **http://dx.doi.org/10.17503/agrivita.v38i1.498**

containing gene *Sub-1*. Grain yield for the variety of IR 64 *Sub-1* was 23% higher than the variety of IR 64 without containing gene *Sub-1* (ICFCRD, 2009). In addition to the use of flooding tolerance variety, proper fertilization strategy was also gives impact on the increase of rice growth and development under flooding stress condition.

Fertilization treatment before the plant was flooded might provide an opportunity for plant survival on flooded condition. Study results from Gribaldi *et al*. (2013) showed that fertiliza-tion with half dose of nitrogen fertilizer during planting as well as Si and Zn in which the remainder was applied at 42 days after planting had produced the highest grain yield for all tested varieties for flooding period of 7 to 14 days after planting.

Rice crop that had experienced flooding condition needs treatment in order to accelerate its recovery. Recovery treatment after flooding requires sufficient quantity of nutrients that might be quickly absorbed by crop. Fertilization through leaves is a supplement to fertilizer through soil or roots in a certain condition in which roots absorption capacity toward macro nutrients is decline. According to Suwignyo (2005), treatment application of *"*Plant Phytoregulator*"* and N was capable of supporting rice crop in increasing its recovery after flooded. Research results from Gribaldi *et al.* (2014b) showed that fertilizers application of N, P_2O_5 and K_2O added with PPC micro 2 cc L^{-1} water after 7 days of flooded condition for rice gave the highest yield of grain for all tested varieties.

The objective of this research was to determine the best fertilization strategy on vegetative phase for rice growth and develop-ment in flooded stress condition at two lowland swamp types.

MATERIALS AND METHODS

This study was conducted in two locations, i.e. shallow-backswamp and middle-backswamp areas at Sako Village, Rambutan Subdistrict, Banyuasin District, South Sumatra. It was conducted from April to September 2011. The experimental design used in this research was split-plot design with three replications. The main plot was fertilization treatment consisting of P_1 = base fertilization, P_2 = fertilization before flooded, P_3 = fertilization after flooded and P_4 = fertilization before and after flooded. The subplot was rice variety which consisted of V_1 = Inpara 3, V_2 = Inpara 5, V_3 = IR 64 and V_4 = Ciherang.

The shallow-backswamp and middle-backswamp were used as the study plot. This area was then cleared and divider ridge was improved. Installation of the plastic wall with 1 m height as the divider of study plot was conducted during land preparation.

Rice seeds of Inpara 3, Inpara 5, IR 64 and Ciherang varieties were germinated and seeded on floating seedbed that had prepared previously until one week period. Subsequently, seedling was moved and reared on seedbed with dimension 1.2 m x 8 m for 21 days period. Fertilizers used in this study were N, P_2O_5, K_2O, Si and Zn as well manure fertilizer with doses of 60 kg ha^{-1}, 40 kg ha^{-1}, 40 kg ha^{-1}, 30 kg ha^{-1}, 20 kg ha^{-1} and 10 ton ha^{-1} (Suwignyo *et al*., 2012). Seedling with 21 days old was moved into each subplot with dimension of 3 m x 4 m by pulling out from seedbed and was planted in upright position with planting distance of 20 cm x 20 cm which consisted of 2 seedlings per hole having 2 cm in depth.

Base fertilization was conducted during planting period with fertilizer doses as follows: N = 45 kg ha-1, P2O5 = 46 kg ha-1 and K2O = 60 kg ha-1. Fertilization treatment before flooding condition for 1 ha area was N = 45 kg, P2O5 = 46 kg, K2O = 60 kg + Si 40 kg and Zn = 20 kg. However, nitrogen fertilizer was applied two times, i.e. half dose was given during planting through spreading on plot surface followed by immersion and the remainder was applied during plant age was 42 days after planting (Gribaldi *et al*., 2013). Fertilization treatment after flooding condition for one hectare area was N = 50 kg, P_2O_5 = 30 kg, K_2O = 30 kg added with micro PPC of 2 mL L^{-1} water (Gribaldi *et al*., 2014b). Application of micro PPC fertilizer was conducted in one week interval until primordial phase, whereas organic fertilizer was given by immersion into the soil with a depth of 10 cm. Fertilization treatment before and after flooding was a combination of those two treatments.

Rice seedling of 7 days after planting was submerged by entering water into experimental plots either through high tide water or using water pump. Water source was taken from the closest river branch from the experimental plot. Submersion time was 7 days calculated when water height exceed crop crown.

Plant rearing was consisted of maintaining minimum water flooding height of 15 cm from plant crown during treatment through continue water input into plot by using pump. Agronomical characteristics were consisted of: 1) Percentage of survive plant (%), 2) Plant height (cm), 3) Number of productive tillers per plant, 4) Plant dry matter weight per clump (g), 5) Number of grains per panicle, 6) Grain weight per panicle, 7) Percentage of filled grains per panicle, 8) 1000 grains weight (g) and 9) Grain yield per plot converted into yield per hectare (ton).

RESULTS AND DISCUSSION

Analysis of variance results showed that most parameters amongst varieties had significant effect except parameters of number of productive tillers per plant and grain weight per panicle for shallow-backswamp as well as parameters of grain weight per panicle and 1000 grains weight for middle-backswamp (Table 1). Subsequently, each parameter amongst treatments had significant effect except parameters of number of grains per panicle and 1000 grains weight for shallow-backswamp as well as parameters of plant height at 42 days after planting, number of grains per panicle, percentage of filled grains per panicle and 1000 grains weight for middle-backswamp. Interaction between varieties and fertilization treatments had no significant effect, except parameter of plant height at 42 days after planting for shallow-backswamp as well as parameters of percentage of survive plant, plant height at 42 days after planting, number of grains per panicle and percentage of filled grains per panicle for middle-backswamp.

Table 1. Analysis of variance results in term of fertilization treatment effect on rice varieties on observed parameters

Observed parameters	**Shallow-backswamp**			**Middle-backswamp**		
	V	**P**	**VxP**	**V**	**P**	**VxP**
Percentage of survive plant	*	*	ns	*	*	*
Plant height at 42 day after planting	*	*	*	*	ns	*
Number of productive tillers per plant	ns	*	ns	*	*	ns
Plant dry matter weight	*	*	ns	*	*	ns
Number of grains per panicle	*	Ns	ns	*	ns	*
Grain weight per panicle	ns	*	ns	ns	*	ns
Percentage of filled grains per panicle	*	*	ns	*	ns	*
1000 grains weight	*	ns	ns	ns	ns	ns
Grain yield per plot converted into yield per hectare	*	*	ns	*	*	ns

Remarks: P = Fertilization; V = Variety; * = significantly different; ns = not significantly different

Table 2. Analysis results of soil characteristics before treatment

Analysis	**Results**			
	Shallow-backswamp	**Status**	**Middle- backswamp**	**Status**
pH H_2O	3.76	very acid	4.20	very acid
C-Organic (%)	3.09	high	3.63	high
N-Total (%)	0.28	moderate	0.31	moderate
P-Bray I (ppm)	6.00	very low	25.65	moderate
K-dd (me $100g^{-1}$)	0.26	low	0.38	moderate
Na (me $100g^{-1}$)	0.22	low	0.44	moderate
Ca (me $100g^{-1}$)	0.80	low	2.38	low
Mg (me $100g^{-1}$)	0.13	very low	0.75	low
CEC (me $100g^{-1}$)	17.40	moderate	17.40	moderate
Al-dd (me $100g^{-1}$)	4.88	very low	0.64	very low
Zn (ppm)	0.06	very low	0.04	very low
Si (%)	9.33		5.28	

Source: Soil Science Laboratory, Faculty of Agriculture, Sriwijaya University, South Sumatra (2011)

Soil Chemical Characteristics Before Treatment

Analysis results of soil chemical characteristics before treatment for two lowland swamp types showed that availability of N, P, K, Si and Zn nutrients was in the range of low to moderate (Table 2) so that fertilizer application can overcome these nutrients availability and was able to increase rice crop yield.

Percentage of Survive Plant

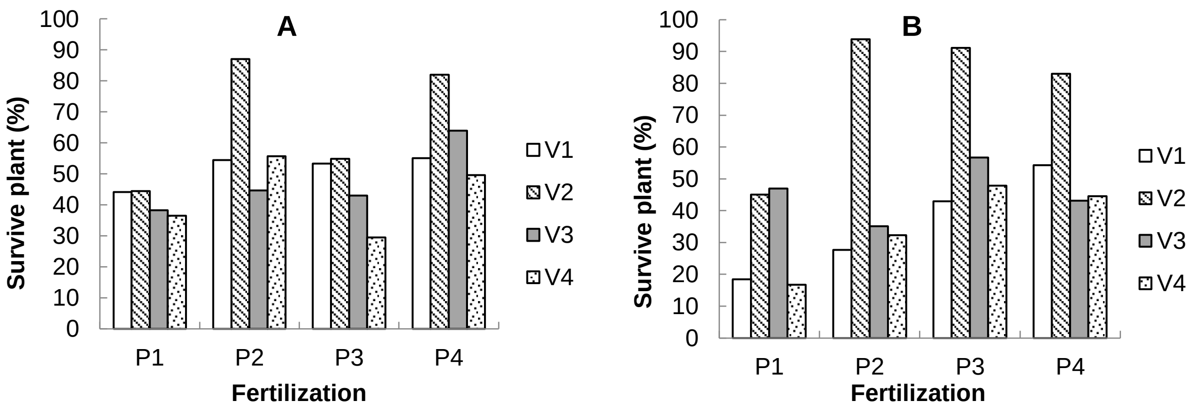
In relation of flooding stress condition and the effect of fertilization strategy on the percentage of surviving plant showed different responses from all tested rice varieties at two lowland swamp types (Figure 1). Inpara 5 variety produced high percentage of surviving plants (67 to 78%) for all fertilization treatments (Figure 2A). It showed that recovery capacity of Inpara 5 (V_2) was higher than that of other varieties. Recovery capacity is highly depends on plant capability to adapt quickly to certain condition after they experience flooding stress. According to Makarim *et al*. (2009), survival or life capability of a plant is also affected by *aerobic shock* when it is not in flooding condition. The change in concentration of antioxydant and enzymes such as superoxides dismutase (SOD) found in flooding tolerance rice cultivars and they produce protection system toward air after they were exposed into hypoxide or anoxide environments.

Low percentage of survive plants for Inpara 3 variety (V_1) was estimated that this variety was more appropriate to be developed on lowland swamp having high concentration of Al and Fe. This was shown by the change of plant height and dry matter weight that was higher than that of other varieties on shallow-backswamp that had high Al concentration (Table 2). Based on variety description, Inpara 3 is relatively tolerance toward Fe and Al toxicities (Indonesian Wetlands Research Institute, 2009).

In addition, fertilization treatment before and after flooding condition were able to increase survive plant percentage (Figure 2B). It was estimated that fertilizer application management before and after flooding condition were able to increase plant tugor which in turn was able to increase survive plant percentage. According to Suwignyo *et al.* (2012), fertilizer application especially nitrogen before and after flooding condition has highly significant effect on seedlings vigor.

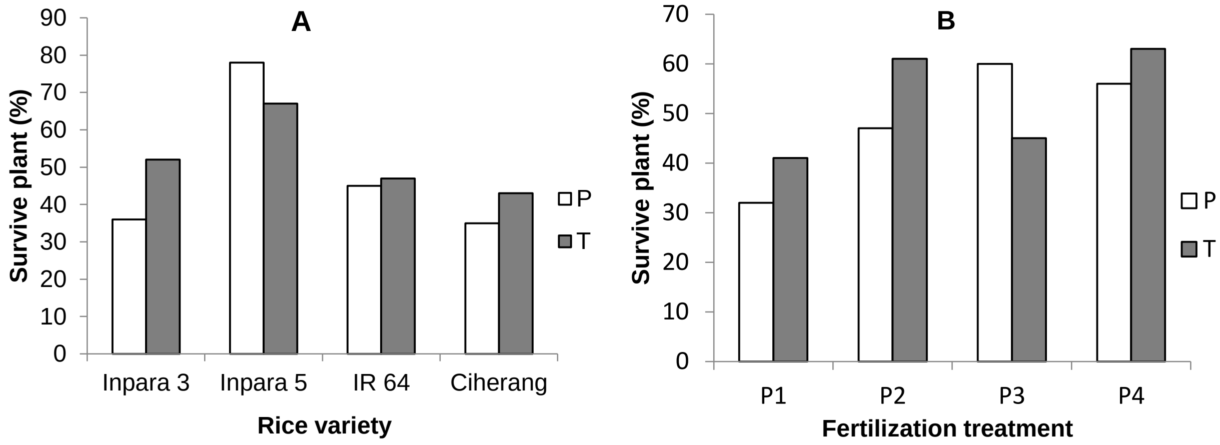
Plant Height

Inpara 3 (V_1) variety with fertilization treatment after flooding (P_3) at shallow-backswamp had the highest plant height of 88 cm, whereas Inpara 3 (V_1) variety with fertilization treatment before flooding (P_2) at middle-backswamp had the highest plant height of 89 cm (Table 3). This was due to the fact that fertilization treatment before or after flooding on these lowland swamp areas was able to provide nutritions for plants for further recovery and growth, for instance plant height.



Remarks: P_1 = base fertilization; P_2 = fertilization before flooded; P_3 = fertilization after flooded; P_4 = fertilization before and after flooded; V_1 = Inpara 3, V_2 = Inpara 5, V_3 = IR 64 and V_4 = Ciherang

Figure 1. Effect of fertilization treatment on percent of survive plant at shallow-backswamp (A) and middle-backswamp (B) for respective rice varieties



Remarks: P_1 = base fertilization; P_2 = fertilization before flooded; P_3 = fertilization after flooded; P_4 = fertilization before and after flooded; P = shallow-backswamp; T = middle-backswamp

Figure 2. Percentage of survive plant after recovery period for respective rice varieties (A) and fertilization treatment (B)

Table 3. Plant height (cm) at 42 day after planting for rice varieties and fertilization treatment at flooding stress condition in lowland swamp types

Varieties	Shallow-backswamp				Middle-backswamp			
	P_1	P_2	P_3	P_4	P_1	P_2	P_3	P_4
Inpara 3	85 g-1	86 hi	88 i	86 hi	85 g-h	89 h	86 g-h	82 e-h
Inpara 5	81 f-i	80 e-h	77 ef	62 b	80 c-g	76 b-f	86 g-h	73 a-e
IR 64	69 cd	66 bc	69 cd	50 a	83 f-h	71 ab	71 a-c	75 b-f
Ciherang	78 ef	74 de	77 ef	52 a	82 d-h	72 a-d	66 a	70 ab

Remarks: Numbers followed by the same characters are not significantly different at Least Significantly Different or $LSD_{0.05}$ = 7.02 (shallow-backswamp) and 8.76 (middle-backswamp)

According to Suwignyo *et al*. (2008), treatment of fertilizer application regulation especially nitrogen would produce effect on plant height and plant height increment rate of rice. In addition, Gribaldi *et al*. (2014a) stated that plant height after flooding stress period was more affected by rice variety than by fertilization treatment.

Number of productive tillers

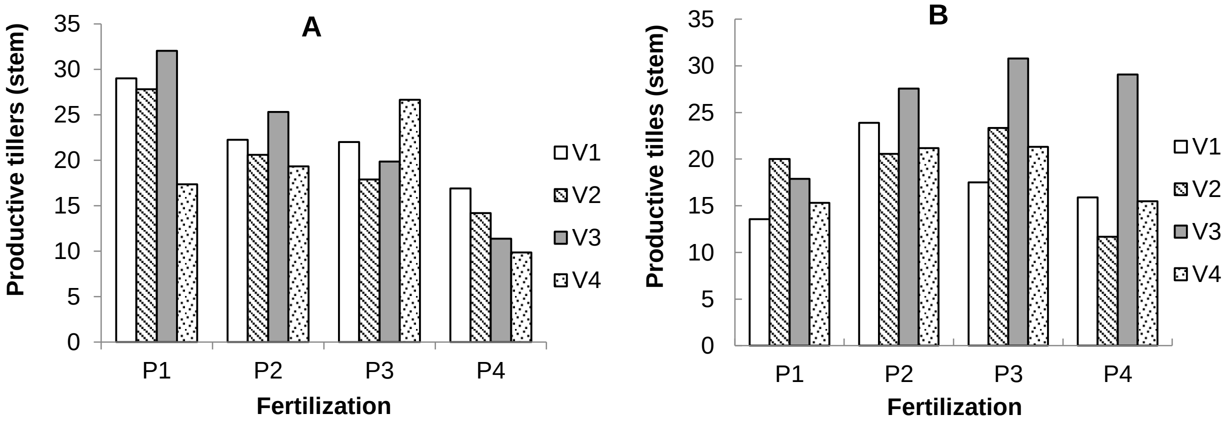
Results of study related to number of productive tillers showed different responses from several rice varieties treated with fertilization treatment for two lowland swamp types (Figure 3).

IR 64 (V_3) variety with base fertilization or without addition of Si and Zn (P_1) had the highest productive tiller numbers with magnitude of 32 clumps on shallow-backswamp, whereas IR 64 variety with fertilization treatment after flooding (P_3) had highest productive tiller numbers with magnitude of 31 clumps on middle-backswamp. High value of productive tiller numbers for IR 64 variety (not containing gene *Sub-1*) was due to low percentage of survive plant or some plants were death which results in very good growth of surviving clumps and development of many tillers due to availability of sufficient space to absorb light, nutrients and water which in turn were able to increase productive tiller numbers per clump. Study results from Makarim *et al*. (2009) showed that IR 64 variety which experience flooding stress had produced more death clumps, but had very good plant growth on survive clumps with many tiller numbers that was higher than that of un-flooding crops.

Plant Dry Matter Weight

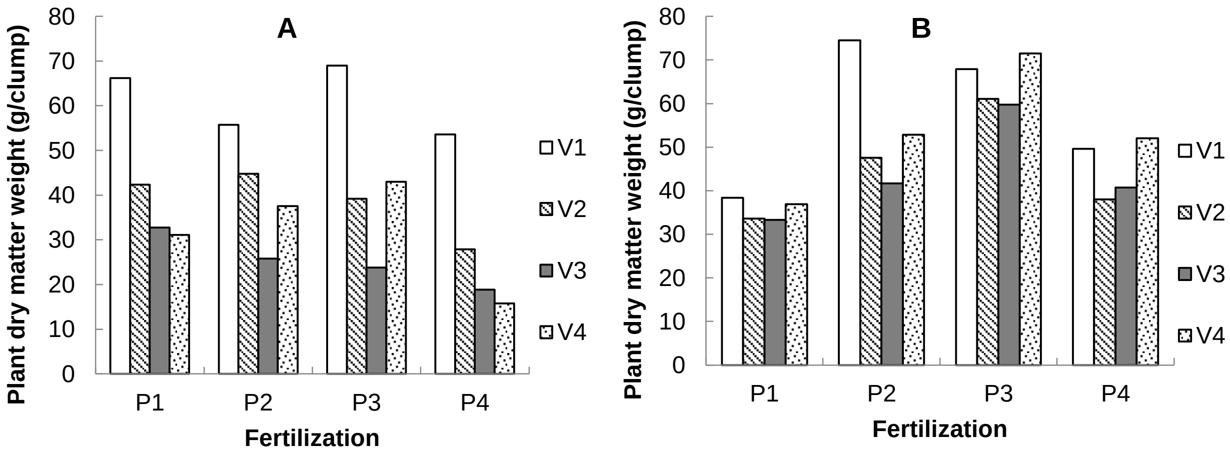
The response of several rice varieties in term of plant dry matter weight due to fertilization treatment before and/or after flooding at shallow-backswamp or middle-backswamp were varied such as shown in Figure 4.

Inpara 3 (V_1) variety in average had the highest dry matter weight with magnitude of 60 g clump^{-1} in response to several fertilization strategies either at shallow-backswamp or middle-backswamp, whereas fertilization application before or after flooding could increase dry matter weight of plant per clump on several rice varieties (Figure 4). This was due to the fact that Inpara 3 (V_1) variety had the highest plant height than other rice varieties so that it also produced high dry matter weight. Fertilization strategy could provide plant nutrients in coping with flooding stress condition or accelerating plant recovery. According to Suwignyo *et al.* (2008), regulation of fertilizer application especially nitrogen would have effect on plant height and rice height increment rate which in turn had effect on plant dry matter weight.



Remarks: P_1 = base fertilization; P_2 = fertilization before flooded; P_3 = fertilization after flooded; P_4 = fertilization before and after flooded; V_1 = Inpara 3, V_2 = Inpara 5, V_3 = IR 64 and V_4 = Ciherang

Figure 3. The effect of fertilization treatment on number of productive tillers at shallow-backswamp (A) and middle-backswamp (B) for respective rice varieties



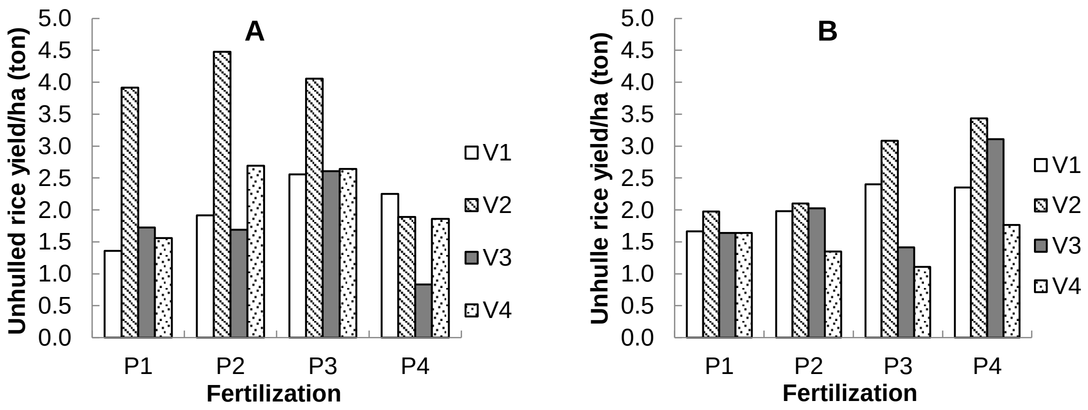
Remarks: P_1 = base fertilization; P_2 = fertilization before flooded; P_3 = fertilization after flooded; P_4 = fertilization before and after flooded; V_1 = Inpara 3, V_2 = Inpara 5, V_3 = IR 64 and V_4 = Ciherang

Figure 4. The effect of fertilization treatment on plant dry matter weight at shallow-backswamp (A) and middle-backswamp (B) for respective rice varieties

Yield and Yield Components

The results of study related to grain yield and yield components showed different responses from rice varieties by using fertilization strategies either at shallow-backswamp or middle-backswamp (Figure 5 and Table 4).

Inpara 5 (V_2) variety with fertilization application before flooding (P_2) had the highest grain yield with magnitude of 4.48 t ha^{-1} at shallow-backswamp, whereas Inpara 5 (V_2) variety with fertilization application before and after flooding (P_4) had the highest grain yield with magnitude of 3.43 t ha^{-1} (Figure 5). In addition, some yield components from rice varieties tend to increase with fertilization treatment strategy on flooding stress condition either at shallow-backswamp or middle-back-swamp. However, grain yield obtained from each variety per hectare was highly affected by percentage of survive crop. This was shown from high yield of grain of Inpara 5 variety at shallow-backswamp and middle-backswamp due to high percentage of survive plants with respective magnitude of 78% and 67% at shallow-backswamp and middle-backswamp resulting in higher plant population per hectare.



Remarks: P_1 = base fertilization; P_2 = fertilization before flooded; P_3 = fertilization after flooded; P_4 = fertilization before and after flooded; V_1 = Inpara 3, V_2 = Inpara 5, V_3 = IR 64 and V_4 = Ciherang

Figure 5. The effect of fertilization treatment on grain yield ha^{-1} at shallow-backswamp (A) and middle-backswamp (B) for respective rice varieties

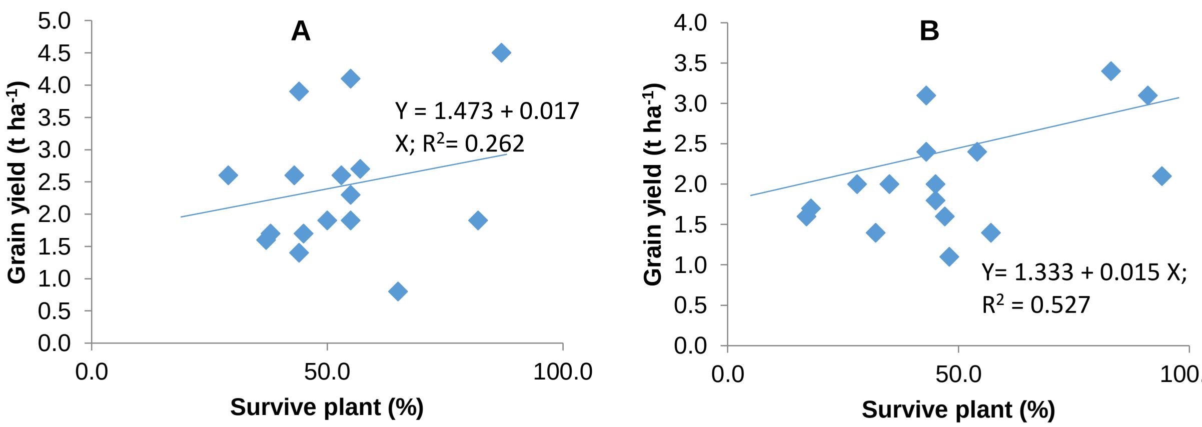


Figure 6. Relationship between survived plant percentage and grain yield of rice at shallow-backswamp (A) and middle-backswamp (B)

Table 4. The effect of fertilization treatment on several yield components at lowland swamp types

Treatment	Shallow-backswamp				Middle-backswamp			
	a	b	c	d	a	b	c	d
V_1P_1	89.50	1.03	45.65	22.81	112.63	2.11	57.33	23.26
V_1P_2	92.53	1.22	53.37	23.06	131.19	2.07	58.67	23.31
V_1P_3	97.91	1.22	58.59	22.69	146.01	2.52	62.00	23.53
V_1P_4	81.90	0.84	37.59	21.32	124.33	1.90	63.00	25.16
V_2P_1	76.59	1.64	83.11	24.02	64.23	1.56	72.00	23.40
V_2P_2	78.92	1.59	82.61	25.16	92.74	1.61	70.33	22.42
V_2P_3	69.78	1.36	77.20	23.65	105.99	2.65	57.00	23.54
V_2P_4	52.70	1.00	68.04	22.62	114.50	2.32	44.67	24.52
V_3P_1	80.88	1.68	79.50	25.98	125.41	1.38	69.33	24.89
V_3P_2	49.67	1.09	74.26	25.57	103.10	1.59	76.33	22.18
V_3P_3	67.49	1.52	75.57	24.45	88.70	2.23	74.33	24.20
V_3P_4	37.82	0.59	59.77	23.12	79.65	2.10	78.00	21.94
V_4P_1	84.52	1.66	48.42	26.40	95.30	1.51	65.67	25.44
V_4P_2	84.77	1.85	62.54	25.13	87.37	1.55	70.67	21.13
V_4P_3	98.93	1.90	69.60	25.29	125.53	2.26	61.00	22.57
V_4P_4	64.45	0.89	38.66	24.60	162.20	2.49	53.67	25.32

Remarks: P_1 = base fertilization, P_2 = fertilization before flooded, P_3 = fertilization after flooded, P_4 = fertilization before and after flooded; V_1 = Inpara 3, V_2 = Inpara 5, V_3 = IR 64 and V_4 = Ciherang; a = number of grains per panicle, b = grain weight per panicle, c = percentage of filled grains, d = 1,000 grains weight

Survive plant percentage had close relationship with determining grain yield. Relationship pattern between survive plant percentage and grain yield based on polynomial charateristics was linearly positive at shallow-backswamp (Y = 1.784 + 0.020X; R^2 = 0.256) and at middle-backswamp (Y = 1.589 + 0.018X; R^2 = 0.529*) (Figure 6). The higher the survive plant percentage, the higher was grain yield.

CONCLUSION

Fertilization strategy on the cultivation of flooding tolerance rice can increase rice growth and production in flooding stress condition at shallow-backswamp and middle-backswamp. Fertilization treatment for rice variety of Inpara 5 before flooding at shallow-backswamp and fertilization application for rice variety of Inpara 5 before and after flooding at middle-backswamp were the best treatments which produced the highest yield of grains with magnitude of 4.48 and 3.43 t ha^{-1}, respectively.

REFERENCES

Armstrong, W. and M.C. Drew. 2002. Root growth and metabolism under oxygen deficiency. In: Waisel, Y., A. Eshel and U. Kafkafi (Eds.), *Plant roots: The hidden half* (3rd edition). New York: Marcel Dekker. p. 1136.

CGIAR. 2006. Heat-tolerant wheat, flood-proof rice, satellites for carbon trading among new technologies. Consultative Group on International Agriculture Research. http://www.cgiar.org/web-archives/www-cgiar-org-newsroom-releases-news-asp-idnews-501/. Accessed on September 24, 2012.

Gribaldi, R.A. Suwignyo, M. Hasmeda and R. Hayati. 2013. The arrangement of nitrogen fertilizer application to increase the rice plant tolerance and recovery to the submerged stress (in Indonesian). Jurnal Lahan Suboptimal. 2*(2)*: 151-158.

Gribaldi, R.A. Suwignyo, M. Hasmeda and R. Hayati. 2014a. The effect of fertilization on morphophysiological changes of two rice varieties under submergence stress (in Indonesian). Jurnal Agronomi Indonesia. 42(1): 17-23.

Gribaldi, R.A. Suwignyo, M. Hasmeda and R. Hayati. 2014b. Effort in improving recovery rice plants into stress sub-merged through fertilization after sub-merged (in Indonesian). Jurnal Lahan Suboptimal. 3(2): 97-104.

ICFCRD. 2009. Flooding tolerance rice (in Indonesian). Indonesian Center for Food Crops Research and Development. Indonesian Agency for Agriculture Research and Development. Bogor. p. 105.

Ikhwani. 2012. The effect of submergence and N fertilizer application on plant growth and production of submerged tolerant rice variety (in Indonesian). Jurnal Lahan Suboptimal. 1(1): 12-21.

Indonesian Development Planning Agency. 2010. Indonesia climate change sectoral road-map (ICCSR), (1st Edition). Synthesis Report: adaptation in the agriculture sec-tor. p. 173.

Indonesian Wetlands Research Institute. 2009. Rice of tidal swamp/lowland swamp (in Indonesian). Indonesian Agency for Agriculture Research and Development. Banjarbaru. Accessed on September 24, 2012.

Makarim, A.K., E. Suhartatik, G.R. Pratiwi and Ikhwani. 2009. Assembly of rice production technology on swamp land and flooding prone swamp (>15 days) for minimum productivity of 7 t ha^{-1} (in Indonesian). A Final Report of ROPP DIPA 2009. Indonesian Rice Research Institute. Indonesian Agricultural Research and Development.

Pierik, R., F.F. Millenaar, A.J. Peeters and L.A. Voesenek. 2005. New perspectives in flooding research: The use of shade avoidance and *Arabidopsis thaliana*. Ann. Bot. 96(4): 533-540. doi: 10.1093/aob/mci208

Septiningsih, E.M., A.M. Pamplona, D.L. Sanches, C.N. Neeraja, G.V. Vergara, S. Heuer, A.M. Ismail and D.J. Mackill. 2009. Development of submergence-tolerant rice cultivars: The *Sub1* locus and beyond. Ann. Bot. 103(2): 151-160. doi: 10.1093/aob/mcn206

Suwignyo, R.A. 2005. Regrowth acceleration for rice seeds in post flooded after “plant phytoregulator” and nitrogen treatments (in Indonesian). Jurnal Tanaman Tropika. 8(2): 45-52.

Suwignyo, R.A., F. Zulvica and Hendryansyah. 2008. Technological adaptation for rice production at lowland swamp area: The effort to prevent the negative effect of rice crop flooding through regulation of nitrogen fertilizer application (in Indonesian). The 3rd National Seminar on Rice Day. Indonesian Rice Research Institute. Sukamandi. July 22-24, 2008.

Suwignyo, R.A., A. Wijaya, H. Sihombing and Gribaldi. 2012. Modification of nutrient application for the improvement of rice seedling vigor under submerged stress (in Indonesian). Jurnal Lahan Suboptimal. 1(1): 1-11.

Triadiati, N.R. Mubarik and Y. Ramasita. 2013. Growth response of soybean to acid tolerant *Bradyrhizobium japonicum* and fertilizers application in acid soil (in Indonesian). Jurnal Agronomi Indonesia. 41(1): 24-31.

Waluyo, Suparwoto and Sudaryanto. 2008. The fluctuation of lowland swamp puddles and its benefit for agriculture in Ogan Komering Ilir (in Indonesian). Jurnal Hidrosfir Indonesia. 3(2): 57-66.