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Assessment of Indigenous N, P and K Supply for Rice Site Specific Nutrient Management in Buru Regency

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ABSTRACT

Rate of fertilizer that should be applied to rice soil based on Site Specific Nutrient Management (SSNM) depends on indigenous nutrient supply, its recovery efficiency, and the amount of nutrients requirement to achieve the yield target. Research on nutrient omission plot was conducted in farmers irrigated land on Waeapo plain, Buru Island. In this area, N, P, and K were the main limiting factors of rice growth and yield. To overcome the constraint, this assessment was conducted to determine the indigenous supply of N, P and K and optimal target of rice productivity. Results of this assessment showed that the average of rice optimum productivity (Mg grain water content/w.c. 14% ha^{-1}) in Waeapo plain was 6.55 Mg DGM (Dry Grain Milled) ha^{-1}, with range from 5.6 to 7.3 Mg DGM ha^{-1} depended on the indigenous supply of N, P and K. The average value of the indigenous N, P and K supplies in Waeapo plain Buru was 65.59 kg N ha^{-1}, 13.70 kg P ha^{-1} and 78.65 kg K ha^{-1}, respectively while average productivity of rice on that indigenous N, P and K supplies was 5.05, 5.96 and 6.05Mg DGM ha^{-1}, respectively. The value of indigenous nutrient supply of this nutrient can be used as a basis of fertilizer recommendation with the SSNM concept.

Keywords: Indigenous nutrient supply, nitrogen, phosphorus, potassium, Site Specific Nutrient Management

INTRODUCTION

Nutrient management is needed to overcome the surfeited tendency in increasing grain productivity in the center of rice production in Asia caused by rice cultivation that is carried out continuously two or three times a year (Adhikari *et al.*1999; Dobermann and Cassman 2002; Dobermann *et al.* 2003). Setyorini *et al.* (2004) reported that the wetland productivity in Java for the last 20 years showed 'leveling off' symptoms of fertilizer inputs to get the same level of yield. Many studies over the last ten years showed that plants response to fertilization was varied and depended on the soil fertility and season.

Current recommendations of applied fertilizer are generally applicable for a wide area and not based on the specific soil fertility status, cropping systems or other specifications. Site specific nutrient management become very important because the cost of fertilizer becomes higher and the expectation of high fertilization efficiency by farmers also becomes higher due to achieve a higher profits (Dobermann and Cassman 2002). The cost of N fertilizer can be saved around 12% on the same level of yield if N fertilizer recommendation was based on soil fertility status and the value of N indigenous supply (Wang *et al.* 2012).

Site specific nutrient management is an approach in providing nutrients to the plants according to its needed (IRRI 2004). Application and nutrient management are dynamically adapted to the needs of plants by location and season. This method proved to increase the productivity and fertilization efficiency of lowland rice (Wang *et al.* 2001; Dobermann *et al.* 2003; Khurana *et al.* 2007; Wang *et al.* 2007). Recommended fertilizer of N, P and K in this approach is based on how much needs of N, P, K fertilizer to obtain an outcome targets and how much the indigenous N, P and K supplies in the soil as well as how efficient absorption by plants (Dobermann *et al.* 2003). Haefele and Konboon (2009) reported that site specific nutrient management recommendations should be based on the distribution of soil fertility status and its nutrient value of the indigenous supply that was studied through direct research on farmers land (on farm experiments).

Native nutrient supply is all nutrients that are added to derive soil fertilization in the planting cycle. Paddy soil nutrient supply can be derived in native from (i) the transformation of chemical and biological soil solid phase, (ii) biological N_2 fixation in soil systems, water and plants, (iii) additional nutrients from the atmosphere, and (iv) solut sedimentation by irrigation or flood (Cassman *et al.* 1998; Dobermann *et al.* 1998). Determination of the indigenous supply of nutrients can be carried out with omission plot trials to compare the productivity of rice in optimum fertilizer condition without giving one nutrient such as N, P and K (Abduracman *et al.* 2002; 2003; Center for Food Crops Research and Development 2003).

The objective of this study was to determine the optimum level of rice productivity and indigenous supply value of N, P and K on irrigated low land rice with its distribution in the Waeapo Plain, Buru Regency.

MATERIALS AND METHODS

Site Description

The experiment was conducted from May to August in 2009 and 2010 Plant Season (PS) II at irrigated land of Waeapo Plain, Buru at coordinates 126°48'03''to 127°06'42'' EL (East Longitude) and 3°15'45'' to 3°32'04'' SL (South Longitude). Omission plot trials were conducted at 12 sites spread over five villages as follows: Debowae Sub Regency (SR) (2 units), Waegeren SR (2 units), Waenetat SR (2 units), Waitina SR (2 units), and Waelo SR (4 units) as seen at Table 1.

Research Implementation

Omission plot trials was carried out by the technical guidance from Abdulrachman *et al.* (2002; 2003), module-specific fertilization paddy rice (Abdulrahman *et al.* 2008) and the national research and assessment guidelines crops (Center for Food Crops Research and Development 2003) with a new superior variety of Inpari 6 Jete that has a potential production about 12 Mg ha^{-1} and a national production average 6.82 mg ha^{-1} (Suprihatno *et al.* 2010). There were four main treatments as follows: (1) NPK plot: plot that was given N, P and K fertilizer based on soil nutrient status at a dose of 138 kg N, 16 kg P, and 50 kg K ha^{-1} for optimal growth of lowland rice, the results of this plot was used as rice production target at optimal condition; (2) –N plot: plot that was not applied with N fertilizer, but was applied with P and K fertilizer in sufficient dose, the results was used as the indicator of indigenous N supply (INS); (3) –P plot: plot that was not applied with P fertilizer, but was applied with N and K in sufficient dose, the results were used as the indicator of indigenous P supply (IPS), and (4) –K plot: plot that did not received K fertilizer, but received P and N with sufficient dose, the results were used as an indicator of indigenous K supply (IKS) .

Each treatment plot was sized 5 m × 5 m, so the total land area of each unit experiment was 16 m^2 outside the dikes and channels. Each experimental plot was separated with other treatments by making the dike, with a height of about 20 cm and a width of 20-30 cm in order to avoid contamination of fertilizer between treatments. Rice planting distance was 20 cm × 20 cm, 2-3 stems per clump. Fertilizer application was applied in accordance to the treatment of each plots. Watering was done according to the needs of plants with regard inlet and exit. Rice harvest was done at harvest plots with a size of 2 m × 2.5 m. Yields were weighed and measured water content of the grain was measured. Grain yield per plot treatment was converted to Mg ha^{-1} with a water content of 14%. Sketch of omission plot is shown in Figure 1.

Observed Parameters

The observed parameters were grouped as: (1) Soil chemical and physical characteristics and (2) Growth and yield of rice. Soil parameters before planting included pH H_2O, total C (%), total N (%), P_2O_5 25% HCl extracts (mg 100 g^{-1}), available P (mg kg^{-1}), Cation Exchange Capacity/CEC (cmol$^+$ kg^{-1}), K-dd (cmol$^+$ kg^{-1}), Ca-dd (cmol$^+$ kg^{-1}), Ca/CEC (%), Na-dd (cmol$^+$ kg^{-1}), Mg-dd (cmol$^+$ kg^{-1}), Base Saturation/BS (%), K_2O extract HCl 25 % (mg 100 g^{-1}), Si-Morgan Wolf (mg kg^{-1}), clay (%), silt (%) and sand (%). Growth and yield of rice parameters measurement included maximum height of vegetative phase (cm), number of tillers/clump, number of filled grains/panicle, number of empty grains/panicle, number of filled and hollow grains/panicle, weight of 1,000 grains (g), weight of straw (Mg ha^{-1} oven dry), and grain production water content 14% (Mg ha^{-1}).

Data Analysis to Determine the Optimal Productivity of Lowland Rice, Indigenous N Suplay (INS), Indigenous P Suplay (IPS), and Indigenous K Suplay (IKS)

The optimal productivity of lowland rice grain based on the results achieved in plot + NPK while the value of INS, IPS and IKS were calculated based on the results of Dobermann and Fairhurst (2000) study as follows: (1) the optimum level of rice plot productivity was determined by the omission results with complete fertilizer (+ NPK plots); (2) INS calculation was done in two ways depending on the level of productivity (LProdv) +NPK plots with –N plot. If LProdv +NPK plots $\geq$ LProdv –N plot, then the INS (kg N ha^{-1}) = LProv –N plot × 15. If LProdv +NPK plots > LProdv –N plot, the amount of INS (kg N ha^{-1}) = LProdv –N plot × 13; (3) IPS calculation was done in two ways: if LProdv +NPK plots $\geq$ LProdv –P plot, then magnitude of IPS (kg P ha^{-1}) = LProdv –P plot × 2.6. If LProdv +NPK plots > LProdv –P plot , the magnitude of IPS (kg P ha^{-1}) = LProdv –P plot × 2.3, and (4) IKS was calculated in two ways, namely If LProdv +NPK plots (Mg ha^{-1}) $\geq$ LProdv –K plot, the amount of IKS (kg K ha^{-1}) = LProdv –K plot × 15. If LProdv + NPKplots > LProdv –K plot, the amount of IKS (kg K ha^{-1}) = LProdv –K plot × 13.

According to experience, the maximum grain yield for tropical regions such as in Indonesia is between 6-9 Mg ha^{-1} (Center for Food Crops Research and Development 2003).

RESULTS AND DISCUSSION

Location and Land Characteristics of Omission Plots

Omission plot trial was conducted at 12 sites spread in five villages in the plains of Waeapo, Buru, *i.e* Debowae, Waegeren, Waenetat, Waitina, and Waelo village (Table 1). The results of soil physical and chemical analysis from 12 sampling units are shown in Table 2. The content of soil total C, total N, available P, CEC, and K availability were low to very low according to Sulaiman *et al.* (2005). The value of land CEC was low and became a major limiting factor inherent soil fertility (Kyuma 2004) .

Fairhurst *et al.* (2007) stated that if the content of available P < 7 mg kg^{-1}, then the soil is in the status of P deficiency and almost certainly rice crops responsive to P fertilizer. Likewise, when the average content of available K is 0.03 cmol^{+} kg^{-1}, the soil is categorized as critical to the growth of rice. Soil chemical properties in this study were favorable for the rice growth because the content of P and K extract HCl 25%, Mg-dd, Na-dd, and Base Saturated (BS) were high, with the exception of soil pH that was categorized as slightly acid. Coefficient of variance of chemical and physical lowland rice on research location ranged from 20 to 77.91%.

Results of Omission Plot Test

There was differences results of yield, range of minimum and maximum values as well as the coefficient of variance of the observed parameters among four omission plots (Table 3). Main limiting factor of rice growth and yield in this study was N nutrient that was indicated by plant height, number of tillers/clump, weight of 1,000 grain, and yield which were compared to P and K nutrient applications.

Average productivity of rice with optimal management and fertilization of 138 kg N, 16 kg P and 50 kg K ha^{-1} (+NPK plots) was 6.55 Mg ha^{-1}

Table 1. Description of each omission plot site on irrigated land of Waeapo District, Buru.

Village	Soil Unit[1]	Code of Ommission Plot Test	Geographic Position	
Debowae	Association Typic Endoaquepts	DW-1	3° 24' 24.77"	127° 00' 46.66"
	and Typic Epiaquepts	DW-2	3° 23' 21.95"	127° 00' 55.24"
Waegeren	Association Typic Endoaquepts	WG-1	3° 24' 48.72"	126° 55' 50.54"
	and Fluvaquentic Endoaquepts	WG-2	3° 24' 20.22"	126° 55' 30.46"
Waelo	Association Typic Fluvaquents and Fluvaquentic Endoaquepts	WL-1	3° 25' 35.28"	126° 57' 00.54"
		WL-2	3° 25' 06.94"	126° 57' 31.44"
		WL-3	3° 26' 46.11"	126° 56' 15.35"
		WL-4	3° 26' 05.76"	126° 56' 23.79"
Waenetat	Association Typic Endoaquepts	WN-1	3° 21' 37.16"	126° 58' 68.27"
	and Fluvaquentic Endoaquepts	WN-2	3° 21' 12.26"	126° 57' 30.89"
Waetina	Complex Fluvaquentic	WT-1	3° 28' 06.48"	126° 55' 52.75"
	Endoaquepts, Typic Fluvaquents and Typic Eutrudept	WT-2	3° 28' 07.08"	126° 55' 54.70"

[1]Semi detail map of Waeapo plain soil, Buru, scale 1 : 50,000 (Sirappa *et al.* 2005).

Remarks: DW: Debowae; WG: Waegeren, WL: Waelo; WN: Waenetat; WT: Waetina

Table 2. Soil characteristics of paddy topsoil (0-20 cm) at twelve points in Waeapo Plain, Buru.

Soil Characteristics	Average	Range	Min.	Max.	Coefficient of Variance (%)	Average Value[1)]
pH H_2O	5.84	0.75	5.26	6.01	3.61	Slightly acid
Total C (%)	1.08	1.13	0.64	1.77	30.94	Low
Total N (%)	0.11	0.11	0.06	0.17	24.90	Low
P_2O_5-HCl 25% (mg $100g^{-1}$)	57.29	68.91	18.98	87.89	31.01	High
Available P (mg kg^{-1})	6.77	20.31	1.17	21.48	82.31	Low
CEC (cmol$^+$ kg^{-1})	9.08	8.16	4.43	12.59	24.07	Low
K-dd (cmol$^+$ kg^{-1})	0.03	0.07	0.01	0.08	59.31	Very Low
Ca-dd (cmol$^+$ kg^{-1})	3.57	4.32	1.24	5.56	33.61	Low
Na-dd (cmol$^+$ kg^{-1})	0.84	1.70	0.25	1.95	62.23	High
Mg-dd (cmol$^+$ kg^{-1})	1.19	1.22	0.73	1.95	29.12	Medium
BS(%)	63.32	48.07	41.04	89.11	21.28	High
K_2O-HCl 25% (mg $100g^{-1}$)	175.00	228.00	60.00	288.00	43.90	Very high
Clay (%)	24.85	38.16	11.09	49.25	40.70	
Silt (%)	55.55	34.46	34.93	69.39	20.78	Silty clay
Sand (%)	19.60	47.05	2.80	49.85	77.91	

[1]Criteria by Sulaeman *et al*. (2005)

Table 3. Growth and yield of rice at omission plot on Waeapo Plain, Buru.

Omission Plot	Statistical Description	Parameter						
		Plant Height (cm)	Number of Tillers/ Clumps	Number of Unhulled grain/ Panicle	Number of Empty grain/ Panicle	Weight of 1,000 grain (g)	Weight Of oven dried Straw (Mg ha^{-1})	Grain Yield w.c. 14% (Mg ha^{-1})
+NPK	Average	80.33	13.28	80.00	17.34	27.82	5.00	6.55
	Range	17.50	11.75	80.88	42.67	6.56	1.50	1.64
	Minimum	72.00	8.00	41.08	4.83	25.34	3.99	5.62
	Maximum	89.50	19.75	121.96	47.50	31.90	5.50	7.26
	Variance (%)	6.19	26.07	27.75	73.18	7.54	10.34	7.69
-N	Average	76.25	11.50	81.87	16.34	26.10	4.39	5.05
	Range	28.35	12.75	71.22	36.83	11.05	1.60	2.44
	Minimum	56.15	6.25	55.46	5.67	19.76	3.79	3.97
	Maximum	84.50	19.00	126.68	42.50	30.80	5.39	6.42
	Variance (%)	9.80	29.75	28.55	70.91	11.46	11.21	13.38
-P	Average	80.75	13.38	85.09	18.03	27.04	4.78	5.96
	Range	15.35	10.00	151.67	27.25	8.62	1.50	1.54
	Minimum	72.15	6.75	42.08	6.75	22.55	3.93	5.18
	Maximum	87.50	16.75	193.75	34.00	31.17	5.43	6.72
	Variance (%)	5.35	23.27	44.79	56.91	8.74	10.21	8.83
-K	Average	79.42	12.29	79.21	15.98	26.29	4.77	6.05
	Range	16.94	10.36	104.72	38.46	9.70	1.73	2.03
	Minimum	74.06	8.25	44.75	4.38	20.97	3.80	5.09
	Maximum	91.00	18.61	149.47	42.83	30.67	5.53	7.12
	Variance (%)	6.70	25.34	38.49	73.60	9.02	12.51	11.61

with a range between 5.62 to 7.26 Mg ha^{-1}. Without N fertilizer (–N plot), the productivity average was only 5.05 Mg ha-1 with a range of 3.97 to 6.42 Mg ha^{-1}. Without P fertilizer (–P plot), the productivity average achieved higher value than plot without N fertilizer as 5.96 Mg ha^{-1} with a range of 5.18 to 6.72 Mg ha^{-1}. Productivity average of rice without K fertilizer (–K plot) was higher than without N and P fertilizer as 6.05 Mg ha^{-1} with a range of 5.09 to 7.12 Mg ha^{-1}. These results indicated that the N

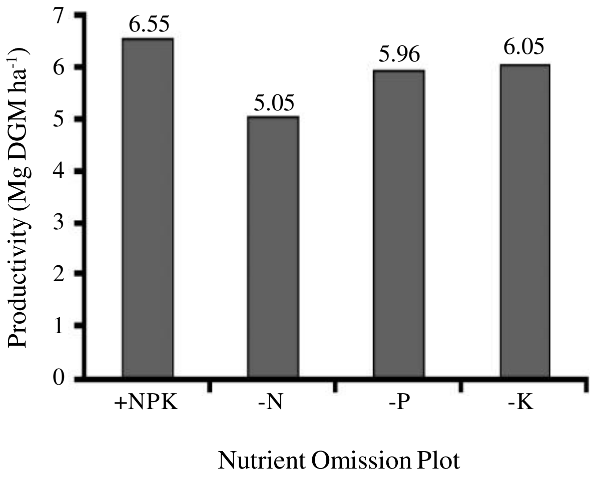

Figure 1. Productivity of lowland rice in nutrient omission plots.

nutrient was the major limiting factor in the productivity of lowland rice in Waeapo plains, followed by P and K nutrient (Figure 1). The variance of results obtained by the omission plot was fairly stable coefficient of variance, shown by the low value of +NPK plots, –N, –P and –K as 7.69, 13.38, 8.83, and 11.61% respectively.

According to Makarim (2005), the productivity ratio (percentage yield) of lowland rice on –N , –P, –K plot +NPK plot could be used as a clue of N, P, K nutrient status in a region. The yield percentage is the ratio between crop yield without certain nutrient with yield nutrient concerned which expressed in %. The status is categorized as low if nutrient value is < 70%, medium status if the value is 70-90%, and categorized as high if the value is > 90%. Referred to this study, N status of the study sites were categorized as medium (77.09%), while P and K were categorized as high which were 91.02% and 92.44%, respectively.

Maximum and Optimum Productivity of Rice

The maximum productivity of rice was determined by four main factors, such as plant genetic factors (varieties), climate, soil and crop management. Dobermann and Fairhurst (2000) reported that when the condition of the soil and crop management is not a limiting factor of growth, then the maximum productivity is determined by plant genetic and climate. Maximum production of lowland rice in Asia ranges from 7-10 Mg ha^{-1} depending on the season (Witt *et al.* 2007).

Average productivity of rice was 6.55 Mg ha^{-1} in Waeapo plain (Table 4). Susanto *et al.* (2011) reported that the soil fertility status of rice in Waeapo Plain is low to very low with few limiting factors such as CEC and the availability of K, Ca and Mg. Inpari 6 Jete variety that was planted on lowland rice in Cilacap with medium class of soil fertility status produced yield up to 8.33 Mg grain ha^{-1} with R/C ratio of 2.26 (Sularno 2012).

Indigenous N, P and K Supplies

The calculation of the indigenous supply value of N (INS), P (IPS) and K (IKS) was based on the productivity of rice in the - N, - P and - K omission plot. Value of INS, IPS and IKS represented the total amount of the nutrient that was able to be provided by the soil and water irrigation in addition to fertilization (Fairhurst *et al.* 2007). The average value of INS, IPS and IKS in this study were 65.59 kg N, 13.70 kg P, and 78.65 kg K ha^{-1}, respectively (Table 5).

Comparison between the average value of INS, IPS and IKS with an average productivity of rice in the –N plot, –P plot and –K plot in Waeapo plain shown in Figure 2. If the INS was 65.59 kg N ha^{-1}, the rice production was 5.05 Mg DGM ha^{-1}, as well as when the IPS was 13.70 kg P ha^{-1} and IKS of 78.65 kg K ha^{-1} then the production were 5.96 Mg and 6.05 Mg DGM ha^{-1}, respectively.

The highest INS value was obtained from rural areas Waetina (WT-1) as 83.40 kg N ha^{-1} and the lowest in the Waelo village (WL-1) as

Table 4. Optimum productivity and the expected maximum productivity of lowland rice at different locations in the nutrient omission plot, Waeapo Plain, Buru Regency.

Location	Optimum Productivity (Mg DGM ha^{-1})[1]	Expected Maximum Productivity (Mg DGM ha^{-1})[2]
DW-1	6.40	8.00
DW-2	6.30	7.88
WG-1	6.20	7.75
WG-2	6.00	7.50
WL-1	7.30	9.13
WL-2	7.10	8.88
WL-3	6.90	8.63
WL-4	6.20	7.75
WN-1	6.80	8.50
WN-2	7.00	8.75
WT-1	6.80	8.50
WT-2	5.60	7.00
Average	6.55	8.19

[1]Productivity of +NPK plots; [2](100/80) x optimum productivity. Remarks: DW: Debowae; WG: Waegeren, WL: Waelo; WN: Waenetat; WT: Waetina

Tabel 5. Grain productivity, reduction of yield in +NPK plot and the indigenous supply of N, P, K at all locations on Waeapo plain.

Location name	Value			Grain productivity on plot				Increasing yield to +NPK plot		
	INS	IPS	IKS	+NPK	-N	-P	-K	-N*	-P**	-K***
	....	kg ha^{-1}	....	....	Mg DGM ha^{-1}	....		....	%	....
DW-1	72.83	13.59	81.43	6.39	5.60	5.91	6.26	12.37	7.55	2.03
DW-2	72.74	13.49	78.40	6.31	5.60	5.86	6.03	11.32	7.06	4.42
WG-1	69.52	13.62	74.78	6.16	5.35	5.92	5.75	13.21	3.88	6.65
WG-2	67.54	12.70	67.27	5.99	5.20	5.52	5.17	13.19	7.72	13.55
WL-1	51.64	14.48	92.51	7.26	3.97	6.30	7.12	45.29	13.28	1.98
WL-2	60.95	14.21	90.55	7.07	4.69	6.18	6.97	33.73	12.69	1.54
WL-3	70.02	14.88	82.32	6.91	5.39	6.47	6.33	22.07	6.38	8.38
WL-4	56.69	12.07	69.66	6.21	4.36	5.25	5.36	29.79	15.52	13.72
WN-1	57.23	12.64	66.11	6.83	4.40	5.50	5.09	35.55	19.52	25.55
WN-2	62.15	15.45	88.20	7.00	4.78	6.72	6.78	31.75	4.09	3.15
WT-1	83.40	15.36	82.50	6.79	6.42	6.68	6.35	5.58	1.68	6.59
WT-2	62.33	11.92	70.09	5.62	4.79	5.18	5.39	14.68	7.79	4.05
Average	65.59	13.70	78.65	6.55	5.05	5.96	6.05	22.38	8.93	7.63

Remarks : * = (LProdv +NPK plot – LProdv –N plot)/ LProdv –N plot, ** = (LProdv +NPK plot –LProdv –P plot)/LProdv -P plot, *** = (LProdv +NPK plot –LProdv –K plot)/ LProdv –K plot, INS = Indigenous N Supply; IPS = Indigenous P Supply; IKS = Indigenous K Supply, DGM = Dry Grain Milled, DW: Debowae; WG: Waegeren, WL: Waelo; WN: Waenetat; WT: Waetina

51.64 kg N ha^{-1}. The highest IPS value was found in Waenetat village (WN-2) as 15.45 kg P ha^{-1} and the lowest was in Waetina village (WT-2) as 11.92 kg P ha^{-1}. The highest value of IKS was determined from Waelo village (WL-1) as 92.51 kg K ha^{-1} and the lowest in Waenetat (WN-1) as 66.11 kg ha^{-1} (Table 5).

INS value of 65.59 kg N ha^{-1} in Waeapo - Buru as the result of this study was categorized lower when compared to the INS in Jinhua-China as 74.69 kg N ha^{-1} (Wang *et al.* 2001). In contrast, it was higher than the INS in Thanjavur-India, Aduthurai-India, Maligaya-Philippines, Hanoi-Vietnam and Sukamandi-Indonesia as 44.73; 50.50; 55.24; 61.60 and 64.93 kg N ha^{-1}, respectively as reported by Dobermann *et al.* (2003b). IPS value= 13.70 kg P ha^{-1}as the result of this study was also slightly higher than the IPS of Sukamandi (13.61 kg P ha^{-1}), but lower than the PIS of Hanoi, Aduthurai, Maligaya, Thanjavur, and Jinhua as 15.81; 18.20; 18.36; 18.53 and 21.90 kg P ha^{-1}, respectively. Likewise IKS value as 78.65 kg K ha^{-1}, it was lower than KIS of Hanoi, Aduthurai, Maligaya, Jinhua, and Sukamandi as 75.98; 92.50; 105.67; 105.78 and 119.26 kg K ha^{-1}, respectively. However, it was higher than the IKS in Thanjavur as 62.94 kg K ha^{-1}.

The correlation between INS, IPS and IKS to the productivity of lowland rice at all test sites omission plot of N, P and K is shown in Figure 3.

The magnitude of the rice productivity (Mg DGM ha^{-1}) without N fertilizer (- N plot) was proportional to 0.077 × ISN (kg N ha^{-1}) - 0.015. It means that to produce 1 ton of rice in an area of 1 ha requires about 13.2 kg N. The magnitude of the rice productivity without P fertilizer (- P plot) was determined by 0.435 × IPS (kg P ha^{-1}) - 0,009. It means that every 1 ton of rice per hectare requires about 2.3 kg of P. While the productivity without K fertilizer (- K plot) follows the equation as 0.077 ×

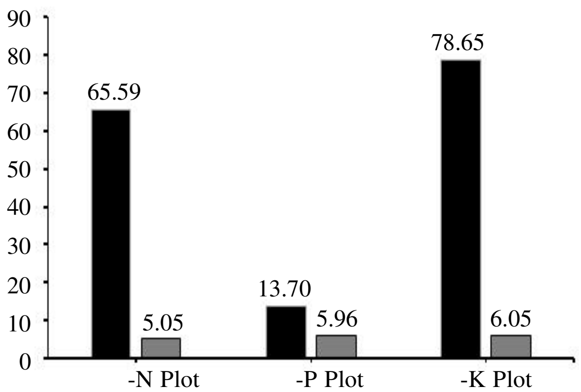

Figure 2. Comparison between the average indigenous supply of N, P and K with rice productivity of –N plots, –P plots and –K plots in Waeapo Plain. ■: Indigenous supply nutrient (kg ha^{-1}); ■: Productivity (Mg DGM ha^{-1}).

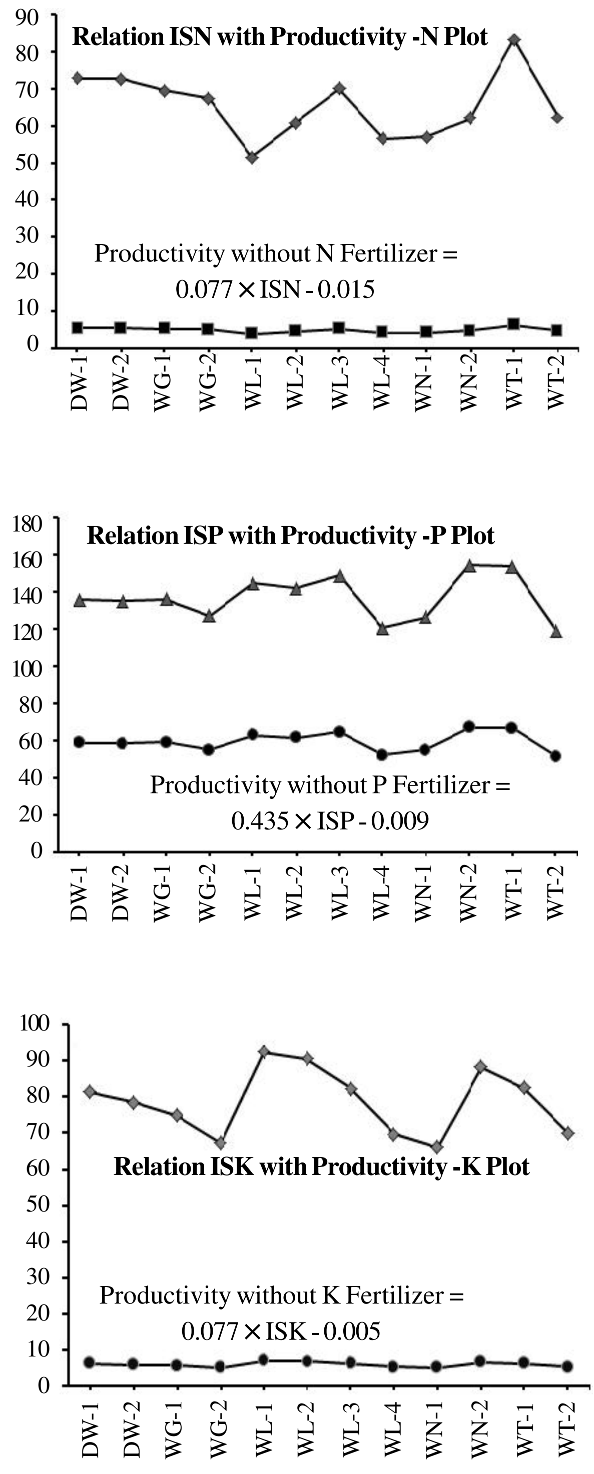

Figure 3. Corelation between N indigenous supply (INS); —◆—: ISN (Kg N ha^{-1}), —■—: Productivity -N Plot (Mg DGM. ha^{-1}). P indigenous supply (IPS); —▲—: ISP (Kg P ha^{-1}), —●—: Productivity -P Plot (Mg DGM ha^{-1}). K indigenous supply (IKS) with rice productivity of –N plot, – P plot, and –K plot in all omission plot locations in Waeapo Plain; —◆—: ISK (Kg K ha^{-1}), —●—: Productivity -K Plot (Mg DGM ha^{-1}).

IPK (kg K ha^{-1}) - 0.005. It means that every increasing of 1 ton of rice in the one hectare area requires about 13.0 kg K.

Fairhurst *et al.* (2007) reported that the ratio between the amount of nutrients absorbed to produce optimum crop productivity in a region in called the optimal nutrient balance. Optimal nutrient balance was achieved when the plant rice absorbed 14.7 kg N, 2.6 kg P and 14.5 kg K per ton of grain produced from an area of one hectare. This balance is equivalent to 68 kg grain kg^{-1} N, 385 kg grain kg^{-1} P and 69 kg grain kg^{-1} of K. Dobermann *et al.* (1996) stated that the optimal equilibrium of N, P and K in the range of lowland rice was 35-90 kg grain kg^{-1} N ; 220-900 kg grain kg^{-1} P, and 30-110 kg grain kg^{-1} K. Referred to research of Fairhurst *et al.* (2007), the average of the optimal balance of N was lower as 1.5 kg (14.7 to 13.2), P was lower as 0.3 kg (2.6 to 2.3) and K was lower as 1.5 kg (14.5 to 13.0). This deficiency is the amount of nutrients that must be managed with the efficiency of fertilizer use and the amount of nutrients required to achieve a certain outcome targets.

A comparison between the level of lowland rice productivity on +NPK plot with – N plot, – P plot, and – K plot can also be used as an optimal balance of nutrients instructions in Waeapo plain. The increase of productivity on – N plot , – P plot, and – K plot compared to + NPK plot is shown on Table 5. It is an indication that fertilizers are needed because there are no areas where the supply of N, P and K are sufficient to support the optimal growth of rice. The reduction of yield is also be used as guidance that nutrients are the dominant limiting factor in each location. The average of grain production on – N plot was 21.63% lower than + NPK plot with a range between 5.58 to 45.29%. It became a major limiting factor for lowland rice productivity in the research location. While the average production on – P plot and – K plot were 8.96 and 8.03%, respectively which were lower with a range from 1.68 to 19.52% for the – P plot and 1.54 to 25.55% for – K plot.

The same thing was reported by E Sheng *et al.* (2010) that in the long time experiment the crop yields (wheat and corn in rotation system) are significantly increased under the application of N fertilizer combined with P fertilizer, especially N and P fertilizers combined with the farmyard manure. For the application of K fertilizer, there were likely no obvious effects on the increasing of the grain yields during the initial 6 years, moderate effects in the next 5 years, and significant effects in the last 14 years. Indigenous soil P supply is always decreased, and at present time it is not reach to a stable level, while indigenous soil K supply is relatively steady.

Results of the study of Liu *et al*. (2005) also reported that N-fertilizer application on wheat significantly increased total N, ammonium-N and nitrate-N contents in paddy field, resulting in high indigenous N supply of soil (INS). Compared to low INS, the effect of N rate on the grain yield of rice was reduced significantly, and fertilizer N use efficiency was decreased under high INS. These results indicated that high INS was one of the main reasons for the low fertilizer N use efficiency in rice.

CONCLUSIONS

The average of optimum rice productivity in Waeapo plain, Buru was 6.55 Mg ha^{-1}, with a range from 5.6 to 7.3 Mg grain ha^{-1} depended on the indigenous supply of N, P and K. The main nutrient which became a limiting factor for rice growth and yield in Waeapo plain, Buru was N, followed by P and K. The average value of the indigenous supply of N, P and K in Waeapo plain, Buru was 65.59 kg N ha^{-1}, 13.70 kg P ha^{-1} and 78.65 kg K ha^{-1} respectively with an average productivity of rice was 5.05; 5.96 and 6.05 Mg grain ha^{-1}, respectively. Optimal balance of N : P : K to produce one ton of dry grain milled in Waeapo plain, Buru was 13.2 kg N : 2.3 kg P : 13.0 kg K, respectively, that was lower than the standard optimal balance as 14.7 kg N : 2.6 kg P : 14.5 kg K .

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