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Displacement of Nitrogen, phosphorus and potassium by rice harvest product planted in newly opened wetland rice

Adel Belhassen

Agronomy Department, Manouba University

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Highly weathered soils and potential acid sulphate soils in Indonesia are mainly granted for developing newly opened wetland rice field to meet rice growing demand. Nutrient removal by rice harvest product of Inpari 10 variety planted in newly opened wetland rice was studied in Bulungan District, in 2011. The aims were to study the nutrient taken out by rice harvest product and to manage its fertility status to sustain rice farming. The results indicated that the highest concentrations of N, P, and K in rice grain and rice straw were observed at NPK recommended rate, in which P was split two times (T6). The T6 also showed the highest nutrient removal by harvest product. Depending on the treatments, total nutrients removal through rice grains and rice straw varied from 37.25 and 93.75 kg N, 2.99 and 8.49 kg P, 53.03 and 149.03 kg K ha^{-1} season^{-1}, meaning that at least about 83 to 208 kg urea, 19 to 53 kg SP-36 and 103 to 289 kg KCl ha^{-1} season^{-1} should be given to replace nutrient removed by harvest product and to avoid any nutrients depletion. As recently the spirit of Indonesian rice farming is applying more organic fertiliser, to sustain better rice yield, the fertiliser application rate of 200 kg urea, 75 kg SP-36 and 200 kg KCl ha^{-1} season^{-1} plus 3000 kg compost made of rice straw and 2000 kg dolomite ha^{-1} season^{-1} can also be recommended.

Keywords: Nitrogen, phosphorus, potassium, removal, rice harvest product, newly opened wetland rice.

INTRODUCTION

Indonesia is one of the biggest producer and consumer of rice. Over two third of total population depend on agricultural sector and wetland rice plays an important role in sustaining food security and providing job and income. Rice is not only taking effect in social and economic aspects, but also political life in Indonesia. Recently, the Indonesian agricultural faces many problems including producing more rice with limited soil and water to meet rice growing demand. In addition, applications of fertilizers rate and crop residue management differ among farmers within sub district, resulting variability in production and soil fertility properties. The shrinking of agricultural land in Indonesia due to a) increasing agricultural land conversion to non-agricultural purposes, b) increasing water competition among agricultural sector and industrial as well as domestic purposes, c) water pollution reducing total harvest areas are also agriculture challenge ahead to sustain rice security (Anonymous. 2002; Baghat *et al.,* 1996; Bouman and Tuong, 2001; Sukristiyonubowo. 2007; Sukristiyonubowo *et al.,* 2011a).

In Indonesia, highly weathered soils and potential acid sulphate soils in outside Java and Bali Islands are mainly granted for developing newly opened wetland rice field to meet rice growing demand in Indonesia. These soils are acidic with low natural level of major plant nutrients, but having toxic levels of Al, Mn and Fe (Sudjadi. 1984; Sukristiyonubowo *et al.,* 2011). The soils fertility status can effectively be enhanced by addition of mineral fertilisers and the balance fertilization of N, P and K promote microbial biomass growth as well as improve community composition (Dobbermann *et. al*., 1996; Zhang and Wang 2005). However, for the smallholder farmers living in transmigration areas, the costs to purchase fertilisers are problem. The chemical fertiliser is beyond their financial reach. Consequently, to sustain crop production, proper management practices using more organic matter plus liming, and inorganic fertiliser is recommended (Fageria and Baligar. 2001; *Fenning et. al*. 2005; Yan *et al.* 2007; Sukristiyonubowo *et al.* 2011; Sukristiyonubowo and Du Laing 2011; Sukristiyonubowo and Tuherkih. 2009; Whitbread *et al.* 2003). The effects of fertilisers on crop production in terms of quantity and quality of yields have been studied and well documented. Many researchers reported that application of mineral fertilisers increases rice yield and the responses to fertilisers vary depending on varieties, soil-climate, and cultural practices. (Min *et al.,* 2007; Sukristiyonubowo. 2007; Cho *et al.,* 2002 and 2000; Fageria and Baligar. 2001; Soepartini, 1995; Uexkull, 1970).

Many studies reported that nutrients uptake depends on variety, cultural practices, nutrients supply, and climate (Sukristiyonubowo and Tuherkih. 2009; Sukristiyonubowo.2007; Yang *et al.,* 2004; Singh *et al.,* 2001; Kemmler, 1971; Sanchez and Calderon, 1971; Uexkull, 1970). In accordance with variety and climate, Sukristiyonubowo (2007) and Uexkull (1970) observed that the total nutrients removals through rice grains and rice straw in the wet season range from 77 to 163 kg N, 14 to 16 kg P, and 150 to 198 kg K ha^{-1} $season^{-1}$ and these are lower than in the dry season. According to Uexkull (1970), high yielding rice variety needs about 2.5 times more N and P and 4.5 times more K than the traditional varieties. Furthermore, Sukristiyonubowo (2007) and Uexkull (1970) reported that nutrient concentrations in high yielding varieties from 1.50 to 1.59 % N, 0.19 to 0.32 % P and 0.30 to 0.37 % K are found in rice grains and from 1.05 to 1.28 % N, 0.09 to 0.14 % P and 1.78 to 2.47 % K are observed in rice straw. Hence, nutrients taken away by harvest products of high yielding varieties are higher than local varieties. Depending on nutrient inputs and climate, the total nutrients removed through harvest products of high yielding varieties range between 192 and 248 kg N, 24 and 34 kg P, 125 and 198 kg K ha^{-1} $year^{-1}$. While, depending on the treatments, total nutrients removal through rice grains and rice straw of Ciliwung variety varied from 61.81 to 101.71 kg N, 4.31 to 13.69 kg P and from 95.77 to 171.16 kg K ha^{-1} $season^{-1}$. (Sukristiyonubowo *et al*. 211b; Sukristiyonubowo and Du Liang. 2010; Uexkull, 1970). Yang *et al.* (2004) observed that incorporation of organic manure in alternating wet and dry water regimes significantly increases N, P, and K uptakes by the rice plants and facilitates translocation of P to rice panicles and grains. Significant improvements in nutrient uptake, rice grains and rice straw yields were also observed in trials combining 12.5 t ha^{-1} of *Gliricidia* leaves manure with inorganic phosphate fertiliser (Kaleeswari and Subramanian, 2004). Another study reported that applications of different sources of organic matter in the rice-wheat cropping system statistically increased total uptake of N, P, and K and rice yield (Singh *et al.,* 2001). Therefore, it is interesting to study nutrient removal by harvest product and to properly manage its fertility status to sustain rice farming in newly opened wetland rice.

MATERIAL AND METHOD

Study on N, P and K removal by harvest product was carried out in Tanjung Buka SP-2 Village, Bulungan District, East Kalimantan Timur Province in 2011. Seven treatments were tested including T0: farmer practices (as control), T1: farmer practices + straw compost + dolomite, T2: NPK with recommendation rate, in which P was split two times, T3: NPK with recommendation rate + compost, T4: NPK with recommendation rate, T5: NPK with recommendation rate + straw compost + dolomite, and T6: NPK with recommendation rate in which P was split two times. They were arranged into Randomized Complete Block Design and replicated three times. The plot sizes were 5m x 5m with the distance among plot was 50 cm and between replication was 100 cm. NPK fertiliser used originated from single fertiliser namely urea, super phosphate-36 (SP-36) and potassium chloride (KCl). Based on the direct measurement with Soil Test Kits, the recommendation rate was determined about 250 kg urea, 100 kg SP-36 and 100 kg KCl ha^{-1}, while the farmer practices rate was 100 kg urea and 50 kg SP-36 ha^{-1}. For the treatment T2 and T6, P was split two times. Urea and KCl were applied three times namely 50 % at planting time, 25 % at 21 DAT (day after planting) and the last 25 % was given at 35 DAT. For the T0 and T1, urea was split two times, 50 % at planting time and 50 % at 21 DAT, while P was given one times at planting time. Dolomite as much as two tons ha^{-1} and rice straw compost of about two tons ha^{-1} were broadcasted a week before planting. The detail treatment is presented in Table 1.

Inpari 10 rice variety was planted as plant indicator. Transplanting was carried out in the end of June 2011 and harvest in the mid of October 2011. Twenty-one-day old seedlings were transplanted at about 25 cm x 25 cm plant and row spacing with about three seedlings per hill. Rice biomass productions including grains, straw, and residues were observed. On a hectare basis, biomass productions were extrapolated from sampling areas of 1m x 1m. These sampling units were randomly selected at every plot. Rice plants were cut about 15 cm above the ground surface. The samples were manually separated into rice grains, rice straw, and rice residues. Rice residues included the roots and the part of the stem (stubble) left after cutting. Fresh weights of rice grain, rice straw, and rice residue were immediately weighed at each sampling unit.

Plants were sampled at harvest and were collected from every plot, one hill per plot. After pulling out, the

Table 1. The detail treatment of the effect of NPK fertilization, dolomite and compost made of straw in newly opened wetland rice.

Code	Treatment	Urea (kg ha^{-1})	SP-36 (kg ha^{-1})	KCl (kg ha^{-1})	Dolomite (kg ha^{-1})	Compost (kg ha^{-1})
T0	Farmer Practices (as control)	100	50	-	-	-
T1	Farmer Practices + Compost + Dolomite	100	50	-	2000	2000
T2	NPK with recommendation rate, in which P was split two times	250	100	100	-	-
T3	NPK with recommendation rate + compost	250	100	100	-	2000
T4	NPK with recommendation rate	250	100	100	-	-
T5	NPK with recommendation rate + Compost + Dolomite	250	100	100	2000	2000
T6	NPK with recommendation rate + compost + dolomite, in which P was split two times	250	100	100	2000	2000

plant roots were washed with canal water. For the laboratory analyses, the samples were treated according to procedures of the Analytical Laboratory of the Soil Research Institute, Bogor. Samples were washed with deionised water to avoid any contamination, and dried at 70^{0} C. The dried samples were ground and stored in plastic bottles. N was determined by wet ashing using concentrated H_2SO_4 (97%) and selenium, while P and K were measured after wet ashing using $HClO_4$ and HNO_3 (Soil Research Institute, 2009).

Nitrogen, phosphorous and potassium removal by harvest product was calculated according to sum of nutrient taken away by rice grain and by rice straw. Nutrient removed by rice grain was estimated based on rice grain yield multiplied with nutrient concentration in the grains. Meanwhile, nutrient taken out by rice straw was calculated according to the total rice straw production multiplied by nutrient concentration in the straw. According to Sukristiyonubowo (2007) as the rice residue is remained in the field, therefore it is not considered as nutrient taken out by rice harvest products.

All data were statistically examined by analysis of variance (ANOVA) and computed using software SPSS program. Means were compared to Duncan Multiple Range Test with a 5 % degree of confidence.

RESULTS AND DISCUSSION

Rice Production

Rice biomass production is presented in Table 2. Compared to farmer parctices (T0), the treatments significantly increased the rice biomass production, namely rice residues, rice straw and rice grain. In addition, at the treatment T6 showed the highest rice residues, rice straw, and rice productions, and significantly different with others treatments. The yields reached were about 3.83 ± 0.13; 4.32 ± 0.28 and 4.18 ± 0.10 t ha^{-1} for rice residues, rice straw, and rice grain, respectively. Compared to T0, the improvement was about 2.13 t ha^{-1} or 104 %, 1.99 t ha^{-1} or 85 % 1.99 t ha^{-1} or 99 % for rice grain, rice straw and rice residues, respectively (Table 2). T6 reached the highest rice yield because the better condition of the soil. This soil can support more nutrient needed by rice plant. Therefore, it can be said that these findings mean that application of NPK with recommendation rate plus two tons dolomite ha^{-1} and two tons compost of rice straw ha^{-1} are necessary to enhance and sustain rice yield of newly opened wetland rice originated from wetland. These improvements create better of soil fertility resulting in more nutrients available for rice growth (Sukristiyonubowo *et al.* 2011a).

Nutrient Concentrations and Removed in Rice Harvest Products

The N, P and K concentrations in rice grain and rice straw are given in Table 3. Compared to farmer practices (T0), the concentrations of N, P, and K in rice grain and rice straw in all treatments were significantly increased. The highest concentrations of N, P, and K in rice grain and rice straw were observed at T6 (NPK recommendation rate + dolomite + compost, in which P was split two times), indicating more nutrient quantity is taken up by rice grain and rice straw. In addition, these also mean more nutrients are taken away by rice grain and rice straw. The concentrations of N, P, and K in rice grain were 1.28 % N, 0.15% P, and 0.32 % K and in rice

Table 2. Rice biomass production of Inpari 10 variety at different treatments and their increase compared to farmer practices cultivated at newly opened wetland rice in Tanjung Buka SP-2 Village, Bulungan District.

	Biomass Production (t ha^{-1})			Increasing rice grain yield	
Treatments	Rice Residue	Rice Straw	Rice Grain	t ha^{-1}	%
T0	1.92 ± 0.19 a	2.33 ± 0.29 a	2.05 ± 0.20 a	-	
T1	2.48 ± 0.10 b	2.96 ± 0.30 b	3.15 ± 0.30 b	1.10	54
T2	3.58 ± 0.10 c	4.20 ± 0.05 c	3.93 ± 0.14 c	1.88	92
T3	3.55 ± 0.38 c	4,17 ± 0.50 c	4.02 ± 0.14 c	1.97	96
T4	3.30 ± 0.35 c	3.97 ± 0.41 c	3.88 ± 0.02 c	1.83	89
T5	3.62 ± 0.19 c	4.21 ± 0.30 c	4.11 ± 0.16 c	2.06	100
T6	3.83 ± 0.13 c	4.32 ± 0.28 c	4.18 ± 0.10 c	2.13	104

Note: The mean values in the same column followed by the same letter are not statistically different
T0: Farmer Practices (as control);
T1: Farmer Practices + Compost + Dolomite
T2: NPK with recommendation rate, in which P was split two times
T3: NPK with recommendation rate + Compost
T4: NPK with recommendation rate
T5: NPK with recommendation rate + Compost + Dolomite
T6: NPK with recommendation rate + Compot + Dolomite, in which P was split two times

Table 3. Nutrient concentrations of rice grain and rice straw of Inpari 10 variety planted in newly opened wetland rice in Tanjung Buka SP-2 site, Bulungan District

	N concentration (%)		P concentration (%)		K concentration (%)	
Treatments	Rice Grain	Rice Straw	Rice Grain	Rice Straw	Rice Grain	Rice Straw
T0	1.10	0.63	0.08	0.06	0.20	2.10
T1	1.14	0.83	0.09	0.07	0.22	2.68
T2	1.18	0.87	0.12	0.09	0.26	2.98
T3	1.15	0.86	0.10	0.09	0.25	2.95
T4	1.14	0.76	0.09	0.07	0.25	2..97
T5	1.22	0.88	0.12	0.09	0.31	3.11
T6	1.28	0.89	0.15	0.09	0.32	3.14

straw 0.89 % N, 0.09 % P, and 3.14% K.

The data also suggested that the concentrations of N and P in rice grain were higher than in the rice straw. This presumably because of higher protein contents in rice grain than in rice straw.

In line with the nutrients concentrations, the N, P, and K uptake were also different among the treatments (Table 4). This is due to a significant increase of rice plant weights during rice growth and their concentrations. These results confirm to the findings reported by Sukristiyonubowo (2007) that N, P and K uptakes increase in relation to the rice growth. The highest N, P and K uptakes are taken place at harvest stage. Compared to farmer practices (T0), the T1 to T6 treatments showed higher N, P and K uptakes, indicating more nutrients are needed during rice growth and development. The results also confirmed that the highest N, P and K uptakes were observed in T6. The highest nutrient uptakes were about 55.30 kg N, 4.60 kg P, and 13.38 kg K ha^{-1} season^{-1} and 38.45 kg N, 3.89 kg P, and 135.65 kg K ha^{-1} season^{-1} for rice grains and rice straw.

As in fact only rice residues were left in the field, the nutrient amounts taken up by rice straw and rice grains reflect the nutrients removal from the field through harvest product. The total removal ranged between 37.25 and 93.75 kg N, 2.99 and 8.49 kg P, 53.03 and 149.03 kg K ha^{-1} season^{-1} depending on the treatments and indeed the T6 treatment showed the highest nutrient removal by harvest product. Similar ranges have been reported in other studies. Uexkull (1970) found that about 77 kg N, 14 kg P, and 151 kg K ha^{-1} season^{-1} are removed through rice straw and rice grains during wet season by a high yielding variety. These amounts are higher than those removed by an improved local variety. Sanchez and Calderon (1971) also noticed that the N uptake at harvest ranges from 34 to 107 kg N ha^{-1} season^{-1}, depending on

Table 4. Nutrient taken up by rice grain and rice straw of Inpari 10 variety planted in newly opened wetland rice in Tanjung Buka-SP2 site, Bulungan District

Treatments	N uptake (kg ha^{-1} season^{-1})		P uptake (kg ha^{-1} season^{-1})		K uptake (kg ha^{-1} season^{-1})	
	Rice Grain	Rice Straw	Rice Grain	Rice Straw	Rice Grain	Rice Straw
T0	22.55	14.68	1.60	1,39	4.10	48.93
T1	35.91	24.95	2.79	2.10	5.53	77.57
T2	46.37	36.54	4.72	2.94	10.21	125.16
T3	46.23	35.86	4.02	3.75	10.05	118.59
T4	44.23	30.17	3.49	3.57	9.70	111.91
T5	50.14	37.14	4.11	3.38	11.74	131.24
T6	55.30	38.45	4.60	3.89	13.38	135.65

rice variety. Kemmler (1971) observed that with a yield of 5 t ha^{-1} season^{-1}, between 90 and 100 kg N, 20 and 30 kg P, 60 and 80 kg K are removed from the field by high yielding varieties. Sukristiyonubowo (2007) concluded that total nutrient removal through rice grains and rice straw of IR 64 variety vary from 88 to 164 kg N, 8 to 16 kg P, and 104 to 198 kg K ha^{-1} season^{-1} in the WS 2003-04 and from 94 to 165 kg N, 10 to 18 kg P, and 107 to 179 kg K ha^{-1} season^{-1} in the DS 2004.

The nutrients removed through harvest product also meant that about 83 to 208 kg urea, 19 to 53 kg SP-36 and 103 to 289 kg KCl ha^{-1} season^{-1} were taken out from the field through rice grain and rice straw. As recently the spirit of Indonesian agriculture practices is applying more organic fertiliser, therefore, to avoid nutrient mining and to maintain its inherent soil fertility about 200 kg urea, 75 kg SP-36 and 200 kg KCl ha^{-1} season^{-1} plus 3000 kg compost made of rice straw and 2000 kg dolomite ha^{-1} season^{-1} can also be recommended. Like in T6, the urea and KCl should be split three time 50 % at planting time, 25 % at 21 days after planting (DAP) and the last at 35 days after planting (DAP).

CONCLUSION

Depending on the inputs, total nutrients removed by rice grains and rice straw varied from 37.25 to 93.75 kg N, 2.99 to 8.49 kg P, 53.03 t0 149.03 kg K ha^{-1} season^{-1} depending on the treatments. These equal to 83 to 208 kg urea, 19 to 53 kg SP-36 and 103 to 289 kg ha^{-1} season^{-1}. To substitute the nutrients taking away by harvest product and to manage its soil fertility, the fertiliser application rate of 200 kg urea, 75 kg SP-36 and 200 kg KCl ha^{-1} season^{-1} plus 3000 kg compost made of rice straw and 2000 kg dolomite ha^{-1} season^{-1} can also be recommended.

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