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Pistia *Stratiotes* Utilization to Improve the Straw Compost Quality

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ABSTRACT
Pistia has no economic value. However, when mixed into straw compost, it tends to enhance its quality. Therefore, this study aims to determine how the Pistia mixture can improve the straw compost quality, thereby increasing rice production. The treatments consisted of soil (control) in values of P100, P75 + J25, P50 + J50, P25 + J75, J100, and NPK. The quality of compost observed was: N, P, K, C/N, lignin, polyphenols, cellulose, and organic matter content. N cumulative and N mineralization rate observed in the second stage was carried out at the incubation 1, 2, 4, and 8 weeks, N mineralization, N uptake, N absorption efficiency, growth, and yield as variables observed in the third stage. This research was conducted to determine the effect of adding a compost mixture with Pistia and straw towards the efficiency, growth, and production of upland rice plants. The results showed that the more Pistia mixed in the straw, the better the compost quality, growth, and yield above J100. N uptake was associated very strongly with the number of panicles and total dry weight of the plant.

Keywords: N uptake, N cumulative, N uptake efficiency, N mineralization rate, compost mixture.

INTRODUCTION

Rice *(Oryza sativa)* is an important food commodity for developing the agricultural sector in Indonesia. Therefore, the country produces abundant straw production with no economic value, usually left in the fields or burned/processed as compost (Klotzbücher et al., 2015). According to (Afify et al., 2002), straw has caused a lot of problems in some countries because of its abundant production. According to the Agency for Agricultural Research and Development, straw contains lignin, cellulose, crude fiber, less protein, and hemicellulose (Jin and Chen, 2007), as well as Zn and Si (Zhu et al., 2004; Doberman and Fairhurst, 2002). The high lignin and cellulose content lead to its increased C/N ratio, which means that it is an organic material with low quality and prolonged decomposition process (Ekawati, 2003). Therefore, it is highly recommended to combine the straw compost with other high-quality organic materials to achieve the required amount of nutrients for the target yield.

Pistia is an aquatic weed that grows rapidly in rice cultivation at paddy fields during summer, causing severe damage to the environment (Gusain and Suthar., 2017). According to Calahan et al., (2015) and Suthar et al., (2016), the rapid growth of Pistia leads to the formation of thick layers in water bodies, thereby blocking light penetration and the exchange of gasses in the aquatic environment. The removal of these weeds produces large amounts of fresh biomass, causing other problems in its disposal and management (Gusain & Suthar, 2017). Meanwhile, Kanwal et al., (2011) stated that Pistia has a nutrient content of 49.3% C, 2.95% N, 0.57% P, 4% K, 103.6 ppm Zn, 19.03 ppm B in leaf, and 17.08 ppm B in the root. This weed is called a high-quality organic material, due to its high N content and low C / N ratio, with a faster decomposition process.

Furthermore, the different quality of N content between straw and Pistia will determine the amount of N released into the soil (Whitmore et al., 2000; Zentner et al., 2003). Therefore, to optimize rice straw as compost, the quality needs to be improved by mixing it with Pistia. Subsequently, this study aims to determine how the Pistia mixture can improve the straw compost quality, thereby increasing rice production.

MATERIALS AND METHODS

This study was conducted from February – July 2019, at the Green House, located at 7.5° South Latitude and 137.35° North Latitude, ± 500 masl, with day/night temperatures of 24–28 °C and 16–21 °C, respectively. During the day, relative humidity is approximately 79% and 95% at night, while the average rainfall is 167.6 mm/day. Furthermore, the composition process was carried out in the vermicompost laboratory of the Agriculture Faculty, Islamic University of Malang.

Stage 1 – compost making

Pistia and straw were dried to reduce moisture content in this stage to hasten the fermentation process. After preparing the compost, it is mixed with the composition in the following processes: Pistia 100% (P100), Pistia 75% + straw 25% (P75 + J 25), Pistia 50% + straw 50% (P50 + J 50), Pistia 25% + straw 75% ((P25 + J 75), and straw 100% (J100). Furthermore, 15 ml of Effective Microorganism-4 (EM-4) is added until the water content of the compost mixture is around 40%. The compost is then put in a plastic bag for three weeks, with the temperature-controlled daily. When the temperature is above 40 °C, the compost is stirred and aerated to ensure even maturity. After the compost is finished, quality analysis is carried out using elements of N, P, K, C/N, lignin, polyphenols, cellulose, and organic matter content.

Stage 2 – unwashed incubation experiment

This research was conducted to determine soil N mineralization dynamics with a mixture of Pistia and straw compost. In this stage, polybags are filled with media containing a mixture of 400 g soil, which is added with 4 g of compost mixture from stage 1 (equivalent to a dose of 20 tonnes·ha^{-1}). The tested treatments were: pure soil without compost and NPK, P100, P75 + J25, P50 + J50, P25 + J75, J100, and NPK. Furthermore, Media and NPK were used to determine the ability of the mixture to replace the need for NPK fertilizer. The experimental media was then added with water until the capacity condition was filled using Random Block Design research. Each treatment was repeated three times using three samples, with observations made on ammonium and nitrate (cumulative N mineral) at the incubation ages of 1, 2, 4, and 8 weeks. The rate of N mineralization was calculated using Mary et al., (1999) method with the following equations :

$$Vm(j) = Vpf(Tj) \sum_{i=1}^{Nm} \mathrm{g}(\theta \mathrm{ij}) \quad (1)$$

where: $V_m(j)$ is the actual mineralization rate (kg N ha^{-1}·day^{-1});
V_p is the potential mineralization rate (kg N ha^{-1}·day^{-1}) at a given reference temperature; T_j is the mean daily temperature measured in the soil or the air;
T_{ij} and θ_{ij} are the mean daily temperature and water content of layer *i* on day *j*,
Nm is the number of layers contributing to N mineralization. The cumulative N mineralized (kg N·ha^{-1}) over each measurement interval Δt (days).

Stage 3 – applications in rice plants

This research was conducted to determine the effect of adding a compost mixture with Pistia and straw towards the efficiency, growth, and production of upland rice plants. The seeds are sown in a medium that consists of a mixture of sand: soil: manure in the ratio of 1: 3: 1 and maintained for 21 days. The media, which consists of Inceptisol rice paddy soil plus compost, was prepared in a plastic pot with a capacity of 20 kg soil and treated with a dose of 20 tonnes·ha^{-1}. In contrast, the administered NPK fertilizer dose was according to the recommendation for fertilizing rice plants namely Urea (Nitrogen) 300 kg·ha^{-1}, SP-36 (Phosphor) 100 kg·ha^{-1}, and KCl (Potassium) 100 kg·ha^{-1}. The first fertilization was done when the rice plants are 10 days after planting (DAP). The fertilizers used are Urea 75 kg, SP-36 100 kg, and KCL 50 kg. The second fertilization was given when the rice plants are 21 DAP using Urea as much as 150 kg. The third fertilization at the age of 42 DAP using 75 kg of urea and 50 kg of KCl. Before planting, the media were analyzed to determine the initial soil conditions, pH, C-organic, organic matter, N total, total P_2O_5, total K_2O, C/N ratio, ammonium, and nitrate content (Tandon et al., 2005).

Soil pH is measured using a pH meter. The tip of the pH meter was plugged at several points on the compost. Contents of total organic carbon (TOC) was determined according to the method of Yeomans and Bremner (1988), total N content by Kjeldhal's method and total P and K contents were determined directly by the nitric-perchloric digestion of the materials. Total and available P contents (extracted with 0.5 mol·L^{-1} $NaHCO_3$, pH 8.5) were determined by Murphy and Riley's method (Murphy and Riley, 1962) and total and available K contents by flame photometry. The available nitrogen compost samples were determined using an automated distillation system in conjunction with the following procedure: 0.5 g of the prepared samples (dried and milled) were applied to the Kejeldahl tablet as a catalyst and 7cc of concentrated sulfuric acid in a 10 ml vial and left at room temperature for stabilization for 24 hours. The vial was later put into the distillation method, and the temperature was steadily increased from 120 °C to 390 °C. The samples were then titrated with 0.25 percent hydrochloric acid until their color was converted from light green to black, and the volume of acid was registered. Finally, according to the following equation, the volume of nitrogen was determined:

$$N = \frac{(a - b) \times n}{m} \times 1.4 \quad (2)$$

where: a and b reflect the sum of acid used for the sample and blank titration, respectively, n is the acid normality and m is the dry weight of the sample. The C/N ratio of the compost samples was calculated between composting processes using these data.

Organic matter was distilled in a bath at 37 °C with 0.1 mol·L^{-1} $Na_4P_2O_7$ (solid-liquid ratio 1:10) and shaken for 24 hours; the extract was centrifuged for 25 min at 15,000 x g and filtered through a membrane of 0.45 um. The extracts were then passed through the Amicon PM-10 diaflo-membrane, which had been cut off under a nitrogen atmosphere. Eliminate unstable fractions of low molecular weight carbon. It had been before, It has been shown (Garcia et al., 1992) by gel chromatography (G-50) that the organic matter obtained by this process is distinguished by medium and high molecular weight. And, thus, it is more stable.

Furthermore, the media is watered in the field capacity, with each pot consisting of 5 plants. Subsequently, the treatment was repeated three times, with each containing 5 samples. The analysis used the Random Block Design to determine the following variables growth and rice production, N uptake using the Kjeldhal method (Ryan et al., 2001), and N absorption efficiency.

N absorption = (% *N* leaves and roots) x total dry weight of the plant (mg pot^{-1})

$$N\ absorption\ efficiency = \\ = \frac{N\ absorption}{the\ cumulative\ N\ release} \times 100\ \% \quad (3)$$

Statistical analysis

Data were analyzed using SPSS. The data were expressed as means ± standard error, which was statistically compared by Duncan's multiple range test (DMRT) at the p below 0.05% significant level.

RESULTS AND DISCUSSION

Compost analysis results

The analysis results of various compost compositions showed varying qualities (Table 1). The highest N content and organic matter were found at P100, while the lowest was at J100. Furthermore, an increase in the number of Pistia added to the straw leads to a rise in the N content and the organic matter following P100> P75 + J25> P50 + J50> P25 + J75> J100. The lowest C / N ratio is at P100, while the highest is J100 with a pattern of P100 <P75 + J25 <P50 + J50 <P25 + J75 <J100.

The C/N ratio is the most widely used parameter to control the N mineralization and immobilization process (Zinn et al., 2018), polyphenols (Chaves et al., 2005), and lignin contents (Hofmann et al., 2009). An increase in the C/N ratio leads to a rise in the C content and a prolonged timeframe needed for the decomposition process; therefore, N availability is slow for plants. Furthermore, it also affects the N immobilization and mineralization by soil microorganisms. The critical value needed for the N content is 1.75%, and C/N is 20. Therefore, the mineralization of organic material can occur. When the C/N ratio value is above 25, it can increase the N immobilization in the soil (Hadas et al., 2004; Sainju et al., 2005; Reichel et al., 2018; Walecka-Hutchison and Walworth, 2007). All the compost straw compositions have a C/N ratio value above the critical limit except P100.

Table 1. The analysis results of various compost compositions

Sample	N total (%)	Ratio C/N	P_2O_5	K_2O	C-Organic	Organic material	Lignin	Cellulose	Polyphenols
Control (soil)	0.29	10.18	0.02	0.04	2.99	3.88			
P100	2.14	24.42	0.35	0.35	51.29	66.61	6.86	14.92	0.82
P75+J25	1.98	25.20	0.39	1.05	50.45	65.52	8.54	18.54	0.76
P50+J50	1.90	26.07	0.43	1.11	49.31	64.04	9.16	21.23	1.98
P25+J75	1.78	26.70	0.51	1.18	48.12	62.50	22.36	26.54	2.42
J100	1.73	27.13	0.62	0.62	44.56	57.86	32.65	35.87	2.65

However, the addition of Pistia in straw decreases the C/N ratio, and such organic material has undergone a decomposition process. Therefore a shorter application time is needed. Based on the compost analysis results, it was found that the Pistia compost has a lower C/N value when mixed with straw, and this indicates that the organic material is ready to be applied due to the occurrence of the decomposition process. This is following the research carried out by (Kastono, 2005), which stated that the lignin, cellulose, and polyphenols contents increase, along with the decreasing number of Pistia mixed in the straw. Polyphenols in plant residues have a detrimental effect on N availability in the early stages of decomposition (Trinsoutrot et al., 2000).

N mineralization and the speed

The N mineral cumulative amount released by the organic mixture increases along with a rise in incubation time. From week 1 to 4, the highest cumulative N mineral was in NPK treatment, and after the 4th week, it was in P75 + J25, as shown in Figure 1. It is suspected from weeks 1 to 4, and there is a process of material transformation by microorganisms. Therefore the N released is still small. This is in line with the studies carried out by Corbeels et al., (2000) and Roy et al., (2011), which stated that wheat straw induces the net N immobilization during the early stages, with the amount of N released at the later stage dependent on the biotic and abiotic factors. It was reported that the application of plant residues reduces N losses due to slower decomposition cycles, thereby causing greater N retention in the soil compared to inorganic fertilizers (Delgado et al., 2010). The variability in the amount of N released during the mineralization process is due to the variability in the composition and the material type (Bolan et al., 2010).

The highest rate of N mineralization was found in the P100 treatment at 0.043 mg·week^{-1} and decreased along with the decreasing composition of Pistia, as shown in Figure 2. The biochemical composition of plant residue complexes with high

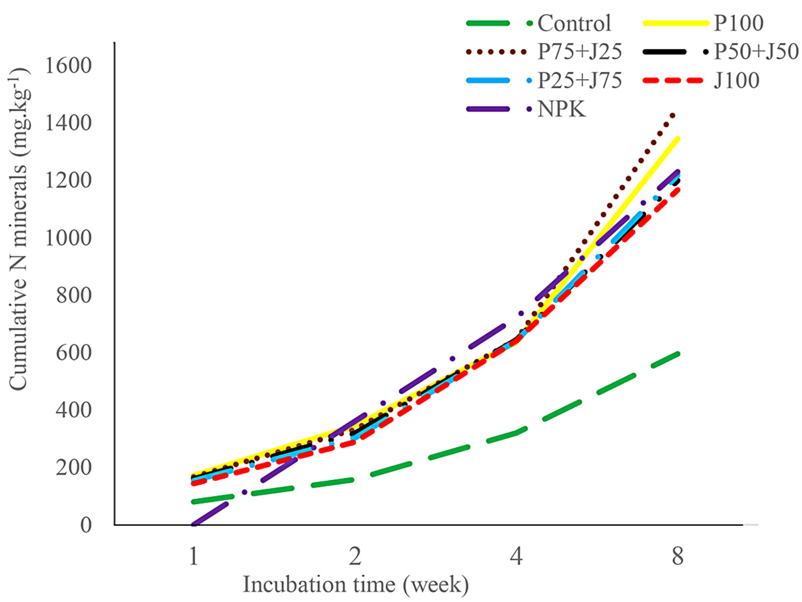

Figure 1. N cumulative minerals amount at various incubation times

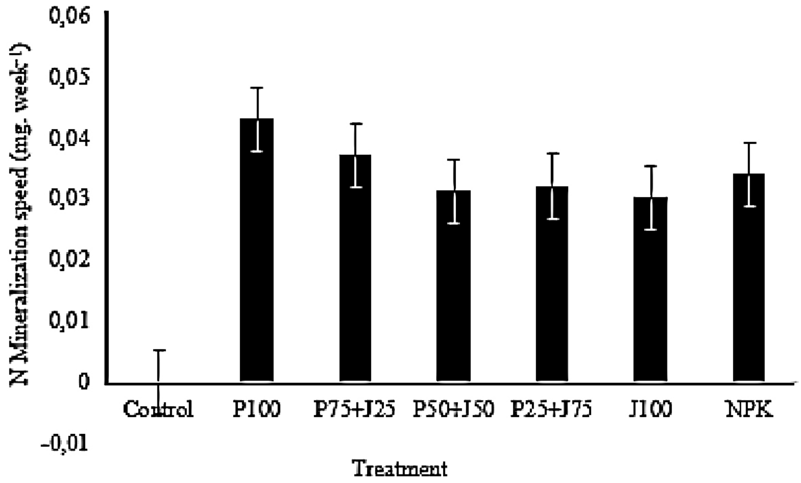

Figure 2. Speed of N mineralization

C/N ratios, such as in straw, is responsible for the initial net immobilization (Mubarak et al., 2001). According to Achakzai and Bangulzai, (2006), plant residues with high C/N ratio, lignin, and polyphenols, tend to release N slowly. The higher the composition of the pistia added to the straw, the lower the mineralization rate.

Plant growth

Plant growth consists of its height, number of leaves, tillers, and total root length. It insignificantly decreases along with a reduction in Pistia and straw composition in all treatments except for controls, which shows the lowest growth. The downward trend in growth due to a reduction in the Pistia mix is P100> P75 + J25> P50 + J50> P25 + J75> J100, as shown in Figure 3.

Plant growth is an indicator of the response parameter from the fertilizer application. This study shows that Pistia had a higher N content than other compost mixtures. Therefore, the rice given compost P100 showed better growth in line with the research carried out by Hossain et al., (2018) on

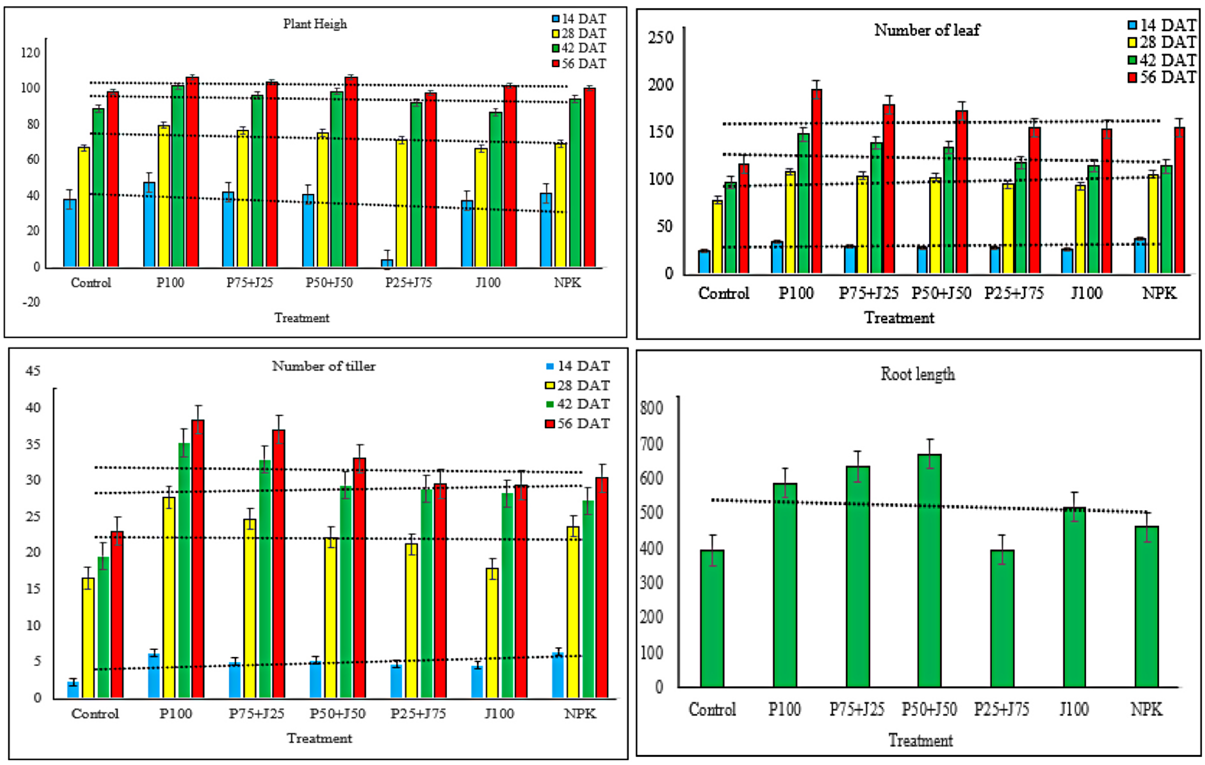

Figure 3. Rice growth in various compost mix treatments

mixing pistia compost with rice husks. Nitrogen is a source of energy for microorganisms in the soil, which plays an important role in the weathering process of organic matter and is needed in the photosynthesis process (Hajama and Nursyakia, 2014). Sriharti and Salim, (2010) stated that the greater the nitrogen content, the faster breaking organic matter because microorganisms for compost development need it. The varying quality of organic matter, in specific the N content, determines the amount of N released into the soil, which is the most important nutrients for plant growth and fertilization in the plant cultivation system (Whitmore et al., 2000; Zentner et al., 2003).

N absorption and N efficiency

P100 treatment provided the highest N uptake, which was insignificantly reduced by the addition of Pistia. Treatment without compost (control) had the lowest N absorption value with the best N absorption efficiency obtained at various Pistia and straw mixture. Furthermore, the lowest N absorption efficiency was obtained using NPK fertilizer, as shown in Figure 4.

Plant nutrient uptake is an important indicator used to achieve the expected harvest quality. The amount of nutrients that plants can absorb affects the production in achieving the desired plant quality. The higher the nutrients absorbed by plants, the greater their ability to grow and develop optimally. Absorption efficiency is the ratio between the nutrients absorbed from the fertilizer and the amount provided, as expressed in percent. The absorption efficiency figure is useful as a correction factor in fertilizer recommendations (Tambunan et al., 2014).

The low N availability of straw is largely due to its immobilization by microbial activity (Ghoneim et al., 2006; Ghoneim, 2008). According to Asagi et al., (2007) and Ebid et al., (2007), available N is involved in processes such as soil nitrification and denitrification. The low N availability of the straw leads to its low uptake and absorption efficiency.

Yield

The production variables of the total panicles, dry weight of grain, and harvest index per pot showed insignificant differences between all treatments. Figure 5 showed that the Pistia compost at 100% had a total dry weight, grain weight per pot, and hectare better than the other treatments.

In this study, Pistia had high N content, low lignin and cellulose, and low C: N ratio, thereby leading to a high mineralization level. Conversely, straw has a lower level of N mineralization, hence affects nitrogen immobilization (Chaves et al., 2006); Gentile et al., 2009; Manzoni et al., 2008; Ghoneim et al., 2008).

The relationship of correlation coefficient between growth, N uptake, N efficiency, and rice production variables

The relationship between growth, N uptake, N efficiency, and production variables is determined based on the correlation coefficient (r) value. Furthermore, the r-value shows the relationship between growth, N uptake, N efficiency, and rice production variables, as illustrated in Table 2.

Table 2 shows the highest or strong correlation coefficient (r) between the observation variable for the number of tillers and panicles, N uptake with the number of panicles, total dry weight of plants, total plant dry weight, grain weight per pot, and grain weight per Ha, with correlation coefficient (r) values of 0.86; 0.82; 0.99; 0.83; 0.89 and 0.89. The r-value close to 1 means that the two observed variables are correlated with one another.

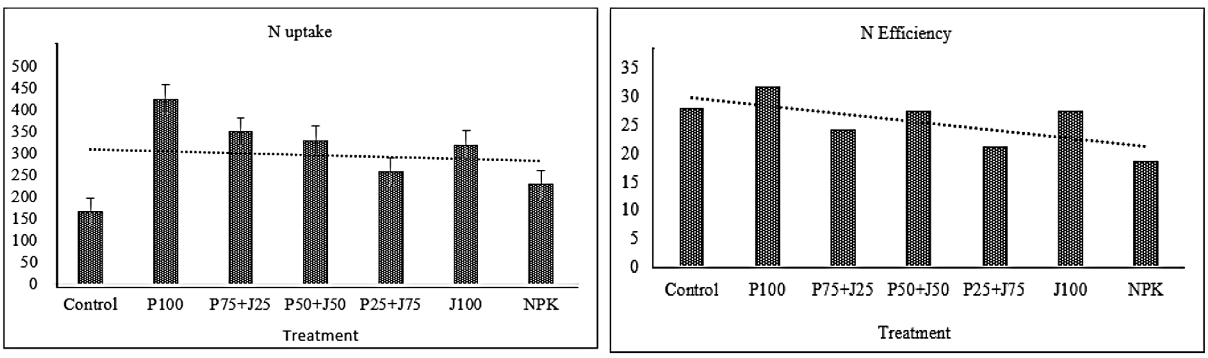

Figure 4. N uptake and its efficiency in various types of compost compositions

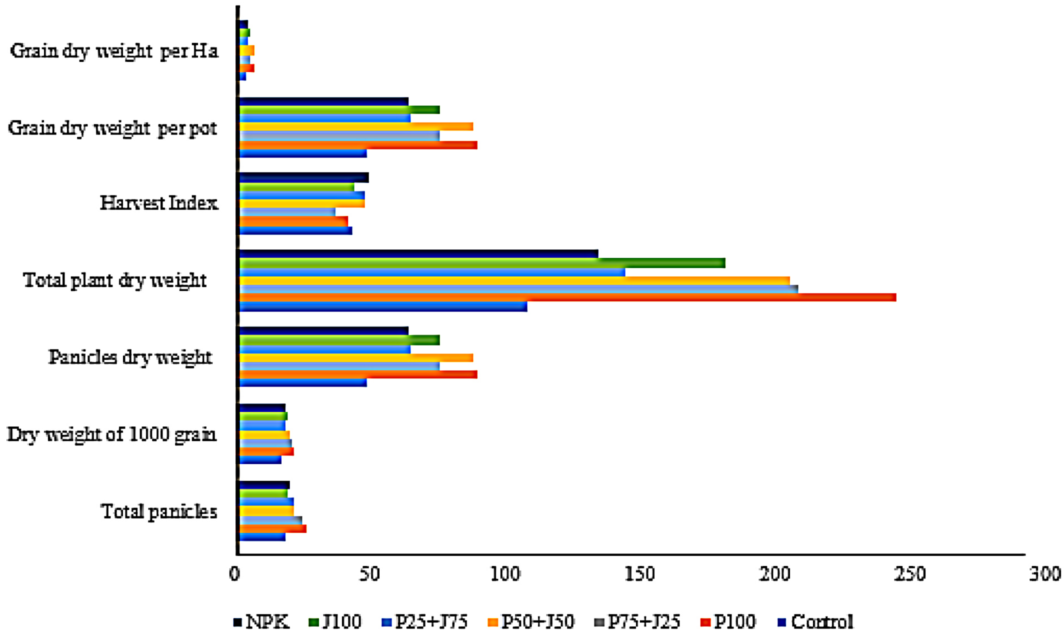

Figure 5. Rice production in various compost mix treatments

The results showed that N uptake had a very strong correlation with the number of panicles and the total plant dry weight. Therefore, the higher the N absorbed by the plant, the more panicles formed with an increase in the total dry weight of the plant. This is because rice grains are found in panicles, which increases production following a rise in number. Several studies have shown that agronomic properties, such as panicle, are strongly associated with grain yield (Zhang et al., 2009; Huang et al., 2011; (Ao et al., 2008).

CONCLUSIONS

Overall, the results showed that the mixture of straw compost and Pistia compost had a significant and positive effect on soil fertility. The higher the proportion of Pistia compost, the higher the quality of the compost including C-organic, total N, and speed of N mineralization. Pistia compost has low lignin content so it is easy to decompose. It is the opposite of straw compost. A mixture of low quality organic matter (straw compost) and

Table 2. Correlation coefficient of growth, N uptake, N efficiency and production variables

Observation variable	PH	NL	NT	TRL	NU	NE	TP	DWG	PDW	TPDW	HI	GWP	GWH
PH	1.00 a	0.14 e	0.05 e	0.67 b	0.34 d	0.13 e	0.25 d	0.09 e	0.37 d	0.35 d	-0.03	0.37 d	0.37 d
NL		1.00 a	0.77 b	0.42 c	0.67 b	0.31 d	0.70 b	0.64 b	0.52 c	0.66 b	-0.26	0.60 b	0.52 c
NT			1.00 a	0.40 c	0.68 b	0.35 d	**0.86 a**	0.53 c	0.66 b	0.68 b	-0.17	0.63 b	0.66 b
TRL				1.00 a	0.48 c	0.11 e	0.49 c	0.35 d	0.63 b	0.51 c	-0.02	0.63 b	0.63 b
NU					1.00 a	0.73 b	**0.82 a**	0.36 d	0.66 b	**0.99 a**	-0.56	0.67 b	0.66 b
NE						1.00 a	0.50 c	0.13 e	0.31 d	0.76 b	-0.65	0.09 e	0.31 d
TP							1.00 a	0.45 c	0.71 b	**0.83 a**	-0.32	0.65 b	0.71 b
DWG								1.00 a	0.39 d	0.35 d	-0.03	0.42 c	0.39 d
PDW									1.00 a	0.68 b	0.20 d	**0.89a**	1.00 a
TPDW										1.00 a	-0.56	0.64 b	0.68 b
HI											1.00 a	0.15 e	0.20 d
GWP												1.00 a	**0.89 a**
GWH													1.00 a

Note: a = 0.80–1.00 (very strong); b = 0.60–0.79 (strong); c = 0.40–0.59 (moderate); d = 0.20–0.39 (weak); e = 0.00–0.19 (very weak). PH – plant height, NL – the number of leaves, NT – number of tillers, TRL – total root length, NU – N uptake, NE – N efficiency, TP – total panicles, DWG – dry weight of 1000 grains, PDW – panicle dry weight, TPDW – total plant dry weight, HI – harvest index, GWP – grain weight per pot, GWH – grain weight per Ha high quality (Pistia compost) is expected to increase nutrient synchronization which in turn can increase crop production. This is seen as seen from the production of better quality, growth, and rice yield after its addition.

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