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Influence of the application of *Tithonia diversifolia* and phosphate rocks on the performances of rainfed rice

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Abstract

Gradient concentrations of *Tithonia diversifolia* green leaves and phosphate rocks were used to investigate their contributions as a fertilizer to the yield and quality improvement of a rainfed rice cultivar. Six treatments were compared: (1) T0, no fertilization (control); (2) T1, 1.28 g of phosphate rocks; (3) T2, 250 g of organic matter; (4) T3, 500 g of organic matter; (5) T4, 250 g of organic matter + 1.28 g of phosphate rocks; (6) T5, 500 g of organic matter + 1.28 g of phosphate rocks. The results showed that the germination percentage recorded 15 days after sowing varied from 58 - 76% between T0 and T5. The number of panicles ranged between 2 (T0) to 6.3 (T5). Moreover, the recorded length of the panicles ranged between 7.5 (T1) to 15.8 cm (T2), and the number of grains per panicle ranged between 25.5 (T1) to 273.5 (T3). The plant height was significantly increased in the T5 (79.27 cm) group compared to the T1 (33.63 cm) and control treatment (T0) (40.08 cm) groups. Although the plant height in the T2, T3, and T4 groups was slightly lower than the T5 group, the difference was not statistically significant. The average of the grain number per plant was high in the T3 (273.6 grains) group compared to the T1 and T0 (25.5 and 32.8 grains) groups, respectively. These results suggest that the combination of *T. diversifolia* leaves and phosphate rocks as a natural fertilizer would be beneficial when integrated into soil fertility management strategies and would contribute to improving crop yield and quality.

Keywords: phosphate rocks of Kanzi, productivity, rice plant growth, *Tithonia diversifolia*

Introduction

Rice (*Oryza sativa* L.) production covers about 9% of the arable lands in the world (Tann et al., 2012). At global scale, rice is a staple food for more than 50% of the world's population (Kawakatsu et al., 2008; Sadou et al., 2008; Saythong et al., 2012) and it is serving as a source of calories for millions people (Taleshi et al., 2013; Nuemsi et al., 2018). In addition, rice is among the world top three cereal crops including wheat and maize (N'guetta et al., 2005) and the average annual rice consumption in sub-Saharan Africa is increasing at a faster rate (4%) than rice production (3.3%).

However, rice cultivation is subjected to drastic biotic and abiotic constraints in tropical regions (Bangata et al., 2013). Particularly, rainfed rice is of paramount importance in the Democratic Republic of Congo (DRC) but rice production fails to meet the ever-increasing demand (Kasongo et al., 2003). Despite the natural resource potentiality that the DRC has, 75% of its population suffers from malnutrition (Bangata et al., 2013). In this regard, the National Institute for Agronomic Research (INERA) through the National Rice Research Program (NRRP) has promoted rice research activities aiming to improve both productivity and quality of rice cultivars since 1987 (Kasongo et al., 2003). Therefore, various efforts to increase crop production to ensure food security and contribute to increasing farmers' income are of great importance (Massawe and Mrema, 2017).

Generally, low soil fertility (Rashid and Khan, 2008; Tully et al., 2015) and imbalanced plant nutrition are important constraints pining agricultural productivity (Kalala et al., 2017). Therefore, effective management of nutrients in soils is important to provide plants with enough resources for their growth, development, and productivity (Abbott and Murphy, 2003, 2007). In rice, soil fertility would largely contribute to improving the productivity of paddy (Ratnayake et al., 2018). Thus, available soil nutrients supplying can be maintained by an external supply of fertilizers (Sahrawat, 2005). The resort to mineral balance through the use of organic matter and mineral fertilizers to maintain soil fertility (Doran et al., 1999; Stockdale et al., 2002; Lal, 2016) and to increase biological productivity (Ouda and Mahadeen, 2008) is a plausible alternative (Masiala and Ngoyi, 2017).

The green biomass of *Tithonia diversifolia* (Hemsley) A. Gray, commonly known as a Mexican sunflower and belonging to the family of Asteraceae, is used as an organic fertilizer to improve soil fertility and is recognized to be great in nutrients and effective as nutrient sources (Ademiluyi and Omotoso, 2007; Kaho et al., 2011). Roy et al. (2018) reported that the application of their organic matters improves the physical, chemical and biological properties of soil. Despite their advantages, organic fertilizers alone are insufficient to compensate for the low level of nutrients in tropical soils (Bilong et al., 2017; Moe et al., 2019).

Phosphate rock is used worldwide for manufacturing phosphoric acid and various brands of chemical fertilizers (Saueia et al., 2005). From the igneous, metamorphic or sedimentary origin, phosphate rock is source of phosphorous (Kotch et al., 2010) and is one of the basic raw materials needed in the manufacture of phosphate fertilizers (Kumari and Phogat, 2014). Phosphorus (as phosphate) application is highly recommended especially for rice cultivation (Kone et al., 2010; Bruulsema et al., 2011). Because phosphorus allows better root growth and promotes more active tillering with fertile tillers and acts on the good development of grains by raising their nutritional value in rice (Ministère du Développement Rural et de l'Environnement, 2001). Thus, influence of the application of the *T. diversifolia* leaves as an organic matter and phosphate rock of Kanzi as a mineral fertilizer was investigated to improve the yield and quality of rainfed rice.

Materials and Methods

Plant material

Seeds of rainfed rice (*Oryza sativa* L.) var. IRAT112 were used as genetic materials to conduct the study. This variety is characterized by a high tillering power with medium resistance of thatch (Anonymous, 2009). Prior to performing the experiments, seeds were germinated, and healthy and vigorous seedlings were grown in black polyethylene bags placed in the experimental field of the Department of Biology, University of Kinshasa, Democratic Republic of Congo (DRC) (4°21′57″ S, 15°17′17″ E, and 440 m Altitude). This region is characterized by a humid tropical climate, type AW_4 as classified by KOPPEN (Rusaati et al., 2019). In essence, pots were filled with 5 Kg of soil taken from about 30 cm depth. The physicochemical compositions of the soil are as follows: pH H_2O 4.68, pH KCl 4.11, organic carbon 0.92%, total nitrogen 0.039%, C/N ratio 23.59, K^+ 0.027 $mEq·L^{-1}$, Ca^{++} 0.447 $mEq·L^{-1}$, Mg^{++} 0.227 $mEq·L^{-1}$, Phosphorous available 0.179 $mg·100\ g^{-1}$; cation exchange capacity (CEC) 1.47 $mmol·kg^{-1}$.

Experimental design

The experiments were performed following the Randomized Complete Block Design (RCBD), during the cultivation season of 2012 - 2013. Green leaves of *Tithonia diversifolia*, an Asteraceae commonly recognized to have the potential to raising the fertility of soils depleted in nutrients, were use as organic fertilizer (Table 1) applied in different levels, and phosphate rock of Kanzi (PR) as inorganic fertilizer (Table 2). Treatments were: T0, no fertilization (control); T1, 1. 28 g phosphate rock; T2, 250 g of organic matter; T3, 500 g of organic matter; T4, 250 g of organic matter + 1.28 g phosphate rock; T5, 500 g of organic matter + 1.28 g phosphate rock. Each treatment was 6 times replicated in a completely randomized block design. The number of pots per treatment was 30. Both organic fertilizer and the inorganic fertilizer were incorporated in soil two weeks before planting the rice.

Table 1. Chemical composition of *Tithonia diversifolia* (Lele et al., 2016).

Characteristics	TOC	Nt	C/N	P	K	Ca	Mg
Concentration (%)	34.8	3.2	10.5	0.3	3.1	2.8	0.6

TOC, total organic carbon; Nt, total Nitrogen; C/N, carbon-Nitrogen ratio.

Table 2. Chemical properties of Kanzi rock phosphate (Kasongo et al., 2010).

Characteristics	P_2O_5	S_iO_2	Fe_2O_3	Al_2O_3	CaO	K_2O	Na_2O	MgO	F
Values (%)	21.99	37.80	4.69	9.22	13.44	0.52	0.29	0.13	1.2

SiO_2, silicon dioxide; Fe_2O_3, iron (III) oxide; Al_2O_3, aluminium oxide; CaO, calcium oxide; K_2O, potassium oxide; Na_2O, sodium oxide; MgO, magnesium oxide; F, fluorine.

The germination percentage was recorded for each treatment 15 days after sowing, and calculated as reported earlier (Mohammadi et al., 2013) using the following formula: $Gr\ (\%) = G1/N \times 100$. G1 is the number of germinated seeds 15 days after planting, and N is the total number of seeds sown. Ninety days after sowing, growth parameters such as number of panicles per plant, panicle length per treatment, number of grains per plant were counted and the quality of rice seeds determined. Fifteen pots were harvested per treatment and fresh and dry weight of plants were measured. The fresh weight of plants was measured immediately after they were harvested, and the dry weight was recorded by dehydrating plants in an oven at 65°C for 48 h (Chan and Fowled, 1992). The dry weight was determined immediately upon removal from the oven.

Statistical analysis

Data were subjected to statistical comparisons with one-way ANOVA (Analysis of variance), and where necessary, the least significant difference (LSD) test was done at $p \leq 0.05$ using R software. The correlation analysis was done to investigate the relationship between growth and productivity parameters. Graphs were generated using Microsoft Excel.

Results

Tithonia diversifolia combined with phosphate rock improved germination of rice seeds

Seed germination is an important parameter, which determines crop establishment, regardless of the agronomic values of a given crop (Rajjou et al., 2012). Our data indicate that the percentage of germinated IRAT112 seeds showed an increasing pattern in all treatments (T1 to T5) (Fig. 1) higher than the control (T0). The highest germination percentage was obtained with T5, which is the application of 500 g of organic matter (Tithonia leaves) combined with 1.28 g phosphate rock, 15 days after sowing. Rice seeds sown under 250 g phosphate rock only (T2) and 250 g *Tithonia diversifolia* combined with 1.28 g of phosphate rock (T4) had similar germination patterns. Seeds sown in soil supplemented with phosphate rock only showed a similar germination pattern with the control (T0).

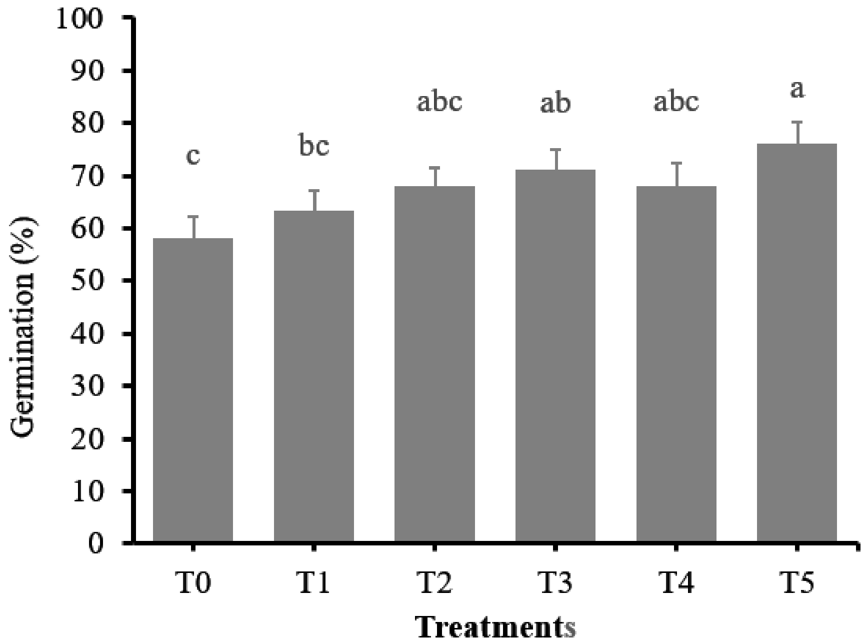

Fig. 1. Germination of rice seeds grown on different soil fertility levels. T0, no fertilization (control); T1, 1.28 g phosphate rock; T2, 250 g of organic matter; T3, 500 g of organic matter; T4, 250 g of organic matter + 1.28 g phosphate rock; T5, 500 g of organic matter + 1.28 g 1.28 g phosphate rock. Bars are means ±SD. a - c: The values followed by the same letter are not significantly different ($p \leq 0.05$) by the least significant difference (LSD) test.

Organic matter and phosphate rock application promoted plant growth and increased dry matter content in rice

Organic matter application to plant crops serves as an important source of essential nutrients such as nitrogen, phosphate, and potassium that are beneficial for plant growth and productivity (Kochakinezhad et al., 2012; Hameedi et al., 2015; Pangaribuan et al., 2018; Hammed et al., 2019). Here, the results show that green leaves of *Tithonia diversifolia* applied as organic matter to rice alone or in combination with phosphate rock promote plant growth and dry matter of rice (Fig. 2). Application of 500 g of Tithonia + 1.28 g phosphate rock (T5) promoted the growth of rice plants by the increase in plant height (Fig. 2A). Similarly, a reduced amount of Tithonia (250 g) combined with phosphate rock (T4), or Tithonia applied alone (500 g) (T3), and (250 g) (T2) showed a similar increased plant height pattern. However, the results further show an opposite pattern of Phosphate rock alone (T1).

Fig. 2B is given the dry matter percentage. The dry matter percent in all treatments was statistically significant ($p < 0.05$). The 250 g of organic matter (T2) treatment shown a high significance difference. In treatments T3, T5, the dry matter content was statistically similar to T2 but higher than T1 and the control (T0). To further investigate the improvement of grain physical characteristics, we measured the diameter of grains under different fertilizer conditions. It was found that 500 g of organic matter + 1.28 g phosphate rock (T5) and 250 g of organic matter + 1.28 g phosphate rock (T4) treatments increase in rice grain diameter compared to the control (T0), followed by T3 and T2 (Fig. 2C). In contrast, phosphate rock applied alone (T1) exhibited a significant reduction in grain diameter compared to the control (T0).

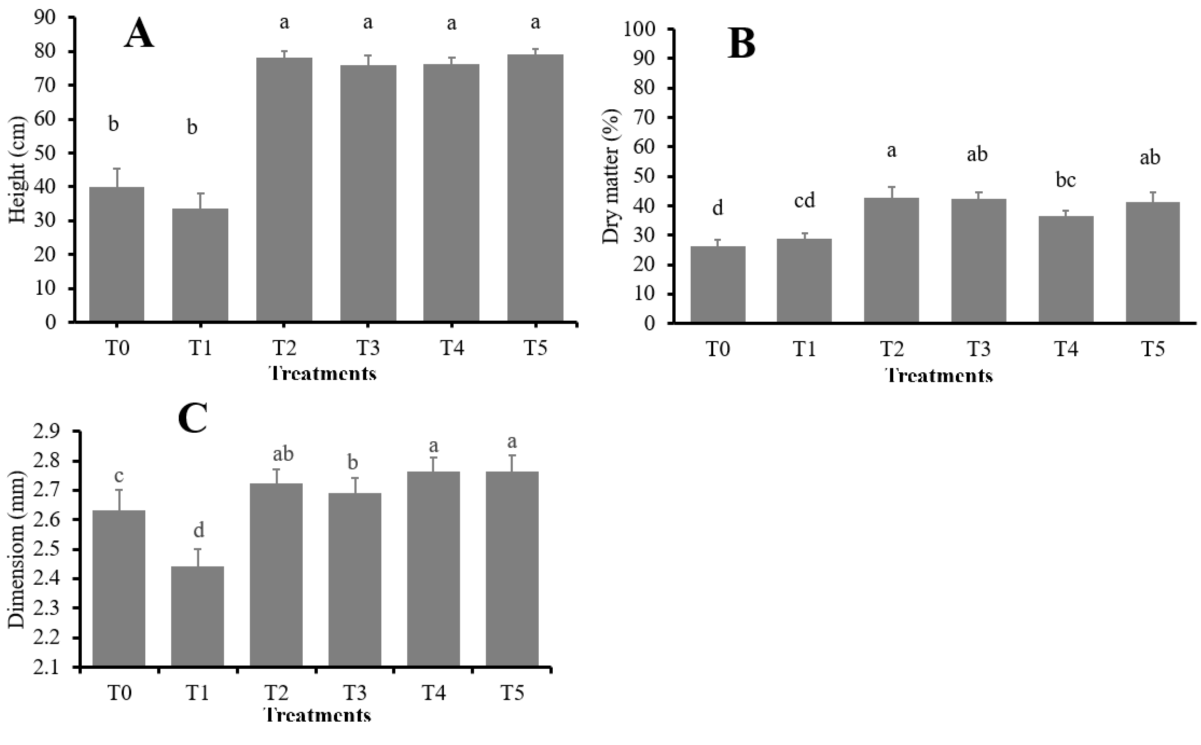

Fig. 2. Growth related parameters of rice Irat112 under different fertilizer concentrations. (A) Height of plants, (B) the dry matter percentage, (C) diameter of grains. T0, no fertilization (control); T1, 1.28 g phosphate rock; T2, 250 g of organic matter; T3, 500 g of organic matter; T4, 250 g of organic matter + 1.28 g phosphate rock; T5, 500 g of organic matter + 1.28 g 1.28 g phosphate rock Bars are means ±SD a - d: The values followed by the same letter are not significantly different ($p \leq 0.05$) by the least significant.

Increased panicle number, length and grain number per plant in response to organic matter and phosphate rock

The number of panicles and grains in rice production are important traits, for assessing the productivity, quality and yield (Efisue et al., 2014; Iqbal et al., 2018; Li et al., 2019). In addition, long panicles are expected to have more grains than short panicles (Thakur et al., 2009). In the present study, we observed a significant increase in panicle number in T5 compared to the control (T0) (Fig. 3A). A similar pattern was recorded in T4. Moreover, a much lower effect on panicle number was observed in T1 treatment. In addition, the panicle length (Fig. 3B) and the number of grains per plant (Fig. 3C) showed a positive and similar effect under Tithonia combined with phosphate rock or Tithonia applied alone. However, phosphate rock applied alone had shorter panicles and less number of grains per plant compared to control (T0). In essence, the contribution of each treatment to the increase in number of grains ranged between 637.2, 661.6, 693, and 734.1% for T5, T4, T2, and T3 respectively.

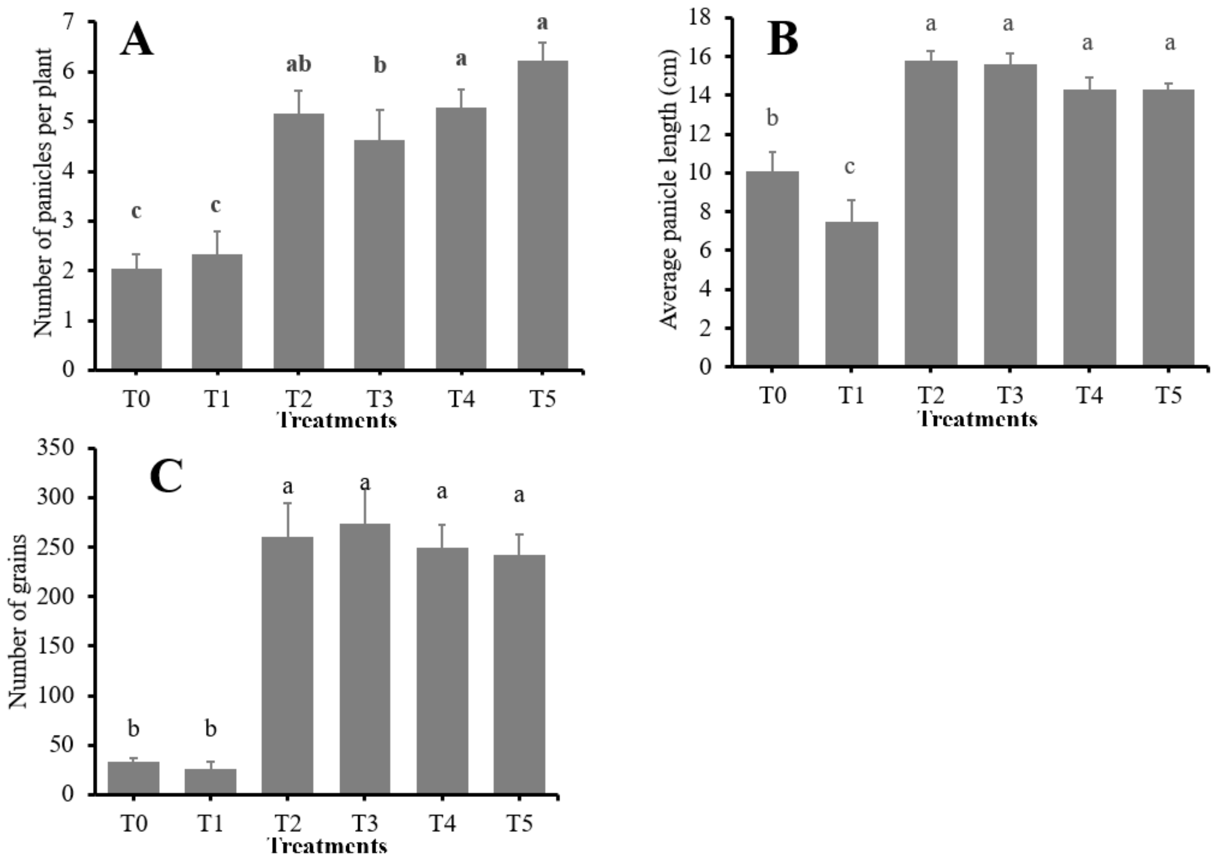

Fig. 3. Enhanced rice productivity under different sources of fertilizers. (A) Number of panicles per plant, (B) average panicles length, (C) number of grains. T0, no fertilization (control); T1, 1.28 g phosphate rock; T2, 250 g of organic matter; T3, 500 g of organic matter; T4, 250 g of organic matter + 1.28 g phosphate rock; T5, 500 g of organic matter + 1.28 g 1.28 g phosphate rock. Bars are means ±SD a - c: The values followed by the same letter are not significantly different ($p \leq 0.05$) by the least significant difference (LSD) test.

Correlation analysis between growth and productivity parameters

Our data showed that there was a strong correlation between growth-related parameters and productivity, which were significantly affected by the dosage of organic matters (Tithonia) applied in combination with phosphate rock or Tithonia alone (Table 3). The number of panicles significantly correlated with the number of grains (R^2 = 0.76) and with dry weight (R^2 = 0.73). Fresh weight was very significantly correlated with a dry weight (R^2 = 0.93) but the number of panicles was less correlated with length of panicles (R^2 = 0.41).

Table 3. Correlation coefficients among the parameters studied.

Items	Length of panicles	Number of grains	Plant height	Fresh weight	Dry weight
Number panicles	**0.41**	**0.76**	**0.63**	**0.65**	**0.73**
	p = 0.00016	p = 0.000	p = 0.000	p = 0.000	p = 0.000
Length of panicles		**0.73**	**0.86**	**0.7**	**0.7**
		p = 0.000	p < 0.0001	p = 0.000	p = 0.000
Number of grains			**0.76**	**0.77**	**0.78**
			p < 0.0001	p < 0.0001	p < 0.0001
Plants height				**0.8**	**0.8**
				p < 0.0001	p < 0.0001
Fresh weight					**0.93**
					p < 0.0001

The statistically significant correlations are shown in bold. All the shown correlations are positive.

Discussion

Seed germination is considered as an important factor for plant establishment (Al-Ansari and Ksiksi, 2016) and of species fitness (Navarro and Guitián, 2003). Generally, seed germination and emergence of plants are affected by soil type and moisture. Organic matters are usually considered as necessary for improving soil texture and composition in terms of nutrients. The ability of soil to maintain a level of moisture required for germination and emergence, depend it's the physical properties such as texture and structure (Blanco-Canqui and Lal, 2008; Lal, 2013). The recorded results showed that seed germination was affected by a different source of fertilizers at various dosages. The treatment with Tithonia combined with phosphate rock helped to improve seed germination up to 15 days after sowing. The availability of essential macronutrients in the soil is of great importance for plant crops to complete their cycle (Martínez-Alcántara et al., 2016). In contrast, low soil fertility is a limiting factor that impairs plant growth and development and reduces plant crop productivity (Chianu et al., 2012). In a converse approach, a previous study investigating the effect of calcium and humic acid on seed germination, growth, and nutrient content of tomato seedlings exposed to salt stress revealed that germination was significantly affected by humus (Türkmen et al., 2004). The application of organic fertilizers has been suggested to be useful for sustaining plant performances and increase soil fertility while playing a fundamental role in the integrated soil fertility management for sustainable agriculture (Moyin-Jesus, 2015; Kuzucu, 2019). Furthermore, as per some evidence, to increase plant productivity, one should consider both enhancing nitrogen utilization efficiency and the improvement of agricultural practices (Yousaf et al., 2016). In our study, the green leaves of *Tithonia diversifolia* supplemented to soil combined with phosphate rock induced a significant increase in growth-related traits such as plant height, dry matter percentage, and the yield. This effect is shown to be dose-dependent. In addition, the productivity of rice was shown to increase when plants were fertilized with the organic matter (Tithonia) combined with phosphate rock rather than Tithonia alone and much less when phosphate rock was applied alone. A similar finding demonstrated that the decomposition rate of organic matter in the soil, plant nutrients uptake and the increase in yield significantly correlated (Cobo et al., 2002; Kaho et al., 2011; Goss et al., 2013). In addition, Muna-Mucheru et al. (2007) found improved maize yield in plants fertilized with green leaves of Tithonia, alone or in combination with mineral fertilizer. In a converse approach, Kasongo et al. (2013) reported in their study that the Soybean plants grown under Tithonia, applied as organic fertilizer, recorded the highest yield compared to other treatments. Moreover, Bilong et al., (2017) reported that Tithonia combined with inorganic matter produced the highest number of cassava roots (tubers), contrasting with our results when the phosphate rock (T1) was applied alone. Similar findings were reported in studies conducted earlier in other crops (Nziguheba et al., 2000; Nziguheba et al., 2002; Ademiluyi and Omosoto, 2007).

From another perspective, rice yield and grain quality are perceived as key parameters that significantly contribute to enhancing rice productivity. Furthermore, rice dry matter has been previously suggested to be a key characteristic that significantly contribute to the yield of rice. Therefore, the recorded exponential increase in dry matter shown in Fig. 3c would indicate that Tithonia diversifolia biomass applied in combination with inorganic fertilizer help substantially enhance the quality and the yield of rice for food and industry.

Conclusion

Rice is the solely cereal crop cultivated for human consumption. Major characteristics of rice productivity such the ability of seeds to germinate, the yield and the quality of the seeds or grains are of great value. To achieve that, fertilization, associated to good cultivation practices, has been shown to contribute significantly. In the present study, we investigated the contribution of gradient concentrations of *Tithonia diversifolia* and phosphate rock as a natural fertilizer to the growth and productivity of rainfed rice cultivar IRAT 112. Our findings revealed that the growth and yield of rice plants grown on soil supplemented with green leaves of Tithonia in combination with phosphate rock significantly enhanced. Therefore, Tithonia green leaves could serve as an alternative source of organic matter and phosphate rock of Kanzi as a mineral fertilizer in tropics to restore or improve soil fertility and contribute the crop productivity.

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Conflict of Interest

Authors declare that there is no conflict of interest.

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