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Effects of straw management on rice productivity in northern Uganda

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SUMMARY

Rice (Oryza sativa L.) is an important crop regarding food security worldwide. However, straw management is an important practice with a pronounced effect on the subsequent production cycle. The objective of the study was to determine the effects of straw management on rice genotype productivity in northern Uganda. Randomized complete block arranged as split plots experiments with three replications were conducted in 2021 and 2022 seasons, with two treatments including rice straw incorporation (RRI) and removal (RRR) Two rice varieties; PR107 and NamChe 5 were included in the study. The results showed that grain yield was significantly influenced by variety ($P<0.001$). Rice straw incorporation and removal within a period of two seasons did not significantly affect grain yield. However, incorporation of rice straw in the soil increased soil organic matter (SOM%), soil organic carbon (SOC%) and nitrogen (N%) content of the soil during dry and wet seasons, respectively. Therefore, the implication of this finding is that straw management is important in determining soil quality and its effects on rice productivity.

Keywords: *Oryza sativa; rice productivity; rice straw management*

INTRODUCTION

Rice (*Oryza sativa* L.) makes up half of the basic foods consumed worldwide, and it is crucial for ensuring food security (Singha et al., 2016). Accordingly, rice is the most important food crop in many developing and developed countries as evidenced by increased production and consumption over the years (Sack et al., 2012). According to Soullier et al. (2020), the per capita consumption of rice in sub-Saharan Africa (SSA) for the period 2013–2019 was estimated at 23 kg against 54 kg at the global level. However, 40% of the rice consumed in Africa is imported to bridge the gap of low level of production, yet the demand is expected to increase by 130% in 2035 (Saito et al., 2015). Bua and Ojirot (2014) noted that rice in Uganda accounts for 34% of food and 36% of revenue of rural dwellers, respectively.

The rice sector in Uganda is developing at a considerable pace, with domestic production of 350,000 metric ton (MT), annually (Hong et al., 2021). Rice is grown all over the country although the eastern region leads in lowland production followed by northern and western, respectively (Kijima et al., 2012). According to Kayuki et al. (2017), Apac, Pallisa, Lira, Tororo, Kamwenge, Bugiri, Jinja, and Iganga are among the principal rice growing districts. However, northern Uganda is known for growing both lowland and upland rice varieties, with upland rice cultivation being more common in Acholi sub-region, particularly in the districts of Amuru, Nwoya and Gulu respectively (Akongo et al., 2016). In fact, the rate of adoption of upland rice cultivation is higher in the north compared to the other regions. According to Masao (2013), the lowland and upland varieties take 60% and 40% of the total production in the country, respectively.

The constraints to local rice production include straw management, field maintenance, lack of farm machinery, lack of agricultural credit, increase in prices of inputs, poor water management, bird attack, pest attack, lack of rice cooperatives, poor seed quality, lack of irrigation systems, and drought among others (Loko et al., 2022). For rice straw management however, when properly managed, rice straw has the potential to improve the economic security of the people that depends on rice farming as well as the long-term viability of agricultural ecosystems. Retaining residues and managing rice straw carefully can alter the soil carbon cycle by reducing carbon emissions while increasing the amount of total soil organic carbon (Kumar et al., 2023). Despite its importance, other straw management options negatively affect rice production (Hussain et al., 2014). Managing rice straw has become a problem where intensive rice farming is practiced to fulfill the increased demand (Parihar et al., 2023). Indeed, disposal of rice crop residues shall become important aspects of rice production in the face of climate change (Samoy et al., 2019). Accordingly, the application of organic residues including rice straw has been demonstrated to increase rice yields as well as improve the total soil C and N contents, respectively (Tirol-Padre et al., 2005). However, the information on the effects of rice straw incorporation (RRI) and removal (RRR) on rice productivity in Uganda is scanty. Therefore, the objective of this study was to determine the effects of rice straw management on productivity of subsequently planted rice in northern Uganda.

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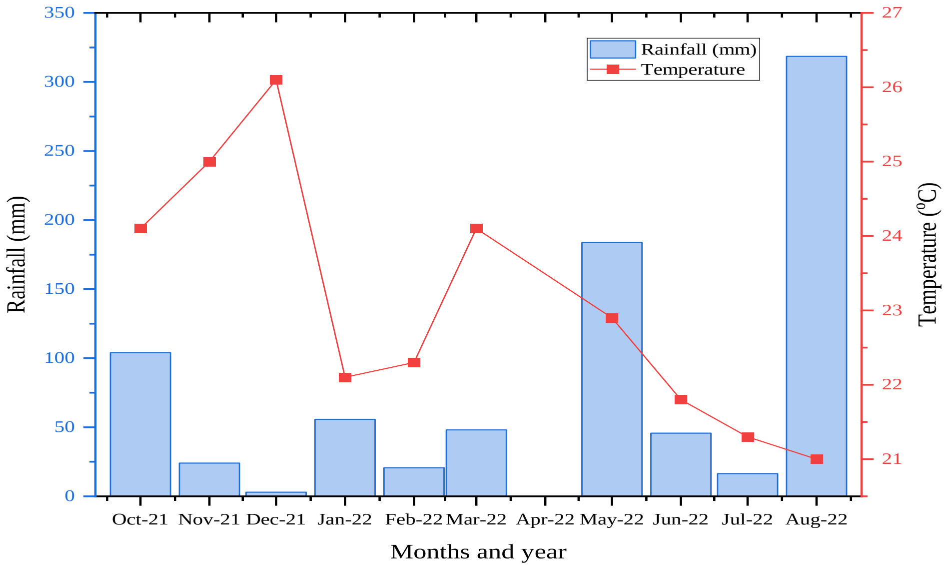
MATERIALS AND METHODS

Study area

The study was conducted in Itek sub county, Itek-Okile Olweny irrigation scheme, Lira district. The experiment was carried out on a farmer's field during the first and second rainy seasons of 2021 and 2022, respectively. Itek sub-county was chosen because it was the sub county leading in both lowland and upland rice production in Lira district. The coordinates of the site were 2011′55.4″N and 33005′21.3″E. The soil type of at the site was predominantly clay. Additionally, the area was characterized by tropical wet and dry/savanna climate. The area lies at an altitude of 1084.11 m ASL. The first experiment was conducted during the second rainy season of 2021 and the second experiment in the first rainy season of 2022. The temperature in the first season of the experiment was slightly elevated (dry season) compared to the second season (wet season) (*Figure 1*).

Figure 1. **Temperature and rainfall at the experimental area**



Source of the data: Uganda National Metrological Authority - Ngetta ZARDI, Lira

Experimental design, treatments, and experimental management

The experiment was set up in a randomized complete block design arranged as a split plot with different rice genotypes as main plots and rice straw treatments as sub plots, with three replications. Rice genotypes used during the two experiments were PR107 and NamChe 5 which represented lowland and upland varieties, respectively. The seeds for the two rice varieties were obtained from cereal programme at National Crop Resources Research Institute (NaCRRI). Before the experimental design, the field was tilled prior and then harrowed a week before planting. For the first and second season, harrowing took place on the 7th October, 2021 and 30th April, 2022 respectively. The field was fully established and an alley of one (1) meter was left between the plots to ease movement during data collection. Rice straws were chopped into smaller pieces of about two centimeters and then incorporated into the soil a week before planting after harrowing following the procedures of Goyal et al. (2009). Rice straw was added at a rate of 5 t ha^{-1}. For the other treatments where rice straws were removed, straws were cleared and removed prior to ploughing since the experiment was done where rice was previously planted. Planting was by direct seeding, two seeds per hill at the spacing of 30 cm x 15 cm on plots measuring 2 m x 2 m. For the first and second experiments, planting was done on the14th October, 2021 and 6th May, 2022 respectively. Weeding was done four times from the time of planting to harvest because of the presence of notorious weeds – couch grass. First weeding was done two weeks after planting, second weeding at the start of tillering, third weeding at maximum tillering, and the final weeding during panicle initiation stage. In both seasons, no fertilizers or other agrochemicals were used.

Data collection

Data collection commenced from 2nd November, 2021 and 20th May, 2022 for the first and second experiments, and ended on 4th February, 2022 and 25th August, 2022, respectively. Data collection was done at two weekly intervals. Data were collected on plant height, tiller number, number of panicles, straw weight, and grain yield. For plant height, data collection was continuous from planting to physiological maturity stage, tiller number during tillering stage, number of panicles during panicle stage, straw weight during the time of harvesting after drying, and grain yield after harvesting and drying the grains. Data on plant height was taken using a tape measure from five plants that were chosen at random from the middle of each treatment. Number of tillers and panicles from each of

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the five plants selected at random per treatment from the middle of each treatment plot. Straw and grain weight were determined by harvesting from 1 m^2 from the middle of each treatment plot. Harvested straw was air dried under a shade until there was no further loss in weight. The gathered grains were cleaned, threshed, and allowed to air dry in the shade until there was no more weight loss and grain yield calculated.

Soil samples to ascertain whether incorporation and removal of rice straws had effects on percentage soil organic matter (SOM), soil organic carbon (SOC), nitrogen (N), and Soil pH were collected from 0–15 cm. SOM and SOC were determined from a soil sample of two grams (2 g). Weight of the empty crucible was determined using electronic balance. Weight of both crucible and soil was also determined and the soil sample in a crucible inserted in to a burning furnace to burn for 2 hours. After burning, soil sample in a crucible was then removed and cooled. Weight of both crucible and soil after ignition and soil after ignition and cooling was then determined and the percentage of SOM and SOC calculated.

Data analyses

To determine the effects of different treatments, the t-test was performed on all of the agronomic data using the Genstat computer program, 14.1 edition. Principal component analysis and Pearson correlation was conducted to determine the relationship between the agronomic parameters.

RESULTS AND DISCUSSION

Plant height, number of tillers and number of panicles

Plant height did not significantly (P>0.05) differ between the two treatments, except in terms of season where higher plant height was registered in wet season than dry season (*Table 1*). Reduced plant heights during dry season could have been as a result of water stress. According to Sarvestani et al. (2008), water stress dramatically decreases plant heights during the vegetative stage but eventually has accumulative effects on the overall production. Therefore, the effects of stress at the vegetative stage during dry season on height of rice plants could have had a cumulative effect on the height of rice plant. Also, the immobilization of inorganic N may have contributed to lower plant height with RRI compared to treatment with RRR. The immobilization of inorganic N is cited by Mandal et al. (2004) as the primary drawback of incorporation. Additionally, Rao and Mikkelsen (1976) unmistakably showed that when soil and rice straw were not incubated prior to planting rice, applied N was immobilized, inhibiting plant growth and resulting in low N content in plants. However, the long-term effect could have resulted into RRI having higher plant heights than those with RRR. According to Dobermann & Fairhurst (2002), incorporation of the straw into the soil returns most of the nutrients and helps to conserve soil nutrients reserve in the long term but short-term effect is minimal. In a study by Bird et al. (2001), it was also discovered that there were no effects on the total soil C and N until six seasons had passed since the residues had been incorporated. However, throughout the fifth and sixth years of the study, RRI treatments had higher levels of microbial biomass C and N than RRR. NamChe 5 may have had a different genetic makeup because it consistently grew taller than PR107 across the seasons. According to Wei et al. (2010), the three most important agronomic traits of rice namely yield, plant height, and flowering time are controlled by many quantitative trait loci (QTLs). The number of tillers and panicles followed smaller results with RRR having higher tiller numbers. On average, PR107 had higher number of tillers than NamChe 5. PR107 genotype registered higher tiller numbers during dry season than NamChe 5. Reduced numbers of tillers in RRI could have been as a result of inhibition during early stages of rice growth. According to Gao et al. (2004), straw incorporation significantly reduced number of tillers.

Table 1. **Plant height, tiller number, and panicle number for the two rice genotypes under different straw management in northern Uganda**

			Dry season			
Variety	NamChe5			PR107		
Treatment	PH	NT	NP	PH	NT	NP
RRI	61.37	6.67	28.7	63.73	14.00	91.7
RRR	66.7	8.67	42.7	64.2	14.67	149.0
			Wet season			
RRI	79.73	9.33	93.7	74.2	10.0	114.7
RRR	85.00	10.67	117.7	74.7	7.67	131.0

RRR= rice straw removed, RRI = Rice straw incorporated, PH= Plant height (cm), NT= number of tillers, NP= number of panicles.

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Weight of straw and grain yield

Treatment with RRI registered slightly higher weight of straw than RRR in PR107 genotype than NamChe 5. Additionally, higher weight of straw was recorded during wet season than dry season for all the genotypes and treatments (*Table 2*). Lower weight of straw during dry season could have also been as a result of water stress. According to a field experiment carried out by Sarvestani et al. (2008) to assess the effects of water stress on biomass of the four rice cultivars, total biomass decreased under water stress in all cultivars under treatments involving the addition and removal of straw.

Variety had a substantial impact (P<0.001) on the grain yield. Grain yield was higher for PR107 than NamChe 5 across seasons. Generally, grain yield was higher during wet than dry season (*Table 2*). On the other hand, limited significant differences in rice grain yield under different straw treatments could have been as a result of limited time given to RRI to mineralise N which resulted in to the microbes immobilising available N to build their own tissues. According to Arai et al. (2021), effects of RRI and RRR treatments on rice yield were also insignificant within short term. The main reason for reduced grain yield during dry season possibly was as a result of water stress during the critical stages of growth. Grain yield of NamChe 5 which is an upland variety was severely affected then PR107 which is the lowland variety. Sarvestani et al. (2008) found out that water stress at flowering stage had a greater grain yield reduction than water stress at other stages.

Table 2. **Straw and grain weight for the two rice genotypes under different straw management in northern Uganda**

		Dry season		
Variety	NamChe5		PR107	
Treatment	WS	GW	WS	GW
RRI	1.59	0.78	4.04	3.33
RRR	1.58	0.62	3.53	3.1
		Wet season		
RRI	2.94	1.68	5.04	3.8
RRR	2.69	1.76	4.02	3.11

RRR - rice straw removed, RRI - rice straw incorporated. WS - Weight of straw (g) and GW - grain yield (t ha^{-1})

Percentage of SOM, SOC and N

Soil samples from treatments with RRI had higher percentages of SOM, SOC and N compared with soil samples from treatments with RRR for both seasons (*Table 3*). The SOM (%), SOC (%), and N (%) increase from the soil samples with RRI for both seasons could be attributed to the contribution of rice straw incorporated. The result of the research conducted by Jing et al. (2020) indicated that addition of rice straw increases SOC, however, it decreases with rice growth period. This therefore, implied that SOC contributed was being used by rice for its growth.

Table 3. **Percentage of SOM, SOC and N in the soil during dry season and wet season in northern Uganda**

Rice straw management practice	**SOM (%)**	**SOC (%)**	**N (%)**	**Rice filed ecosystem**
		Dry season		
RRR	7.85	4.56	0.03	Upland
RRI	11.38	6.61	0.05	Upland
RRR	10.38	6.03	0.06	Lowland
RRI	17.25	10.03	0.09	Lowland
		Wet season		
RRR	9.5	5.52	0.11	Upland
RRI	10.61	6.13	0.12	Upland
RRR	9.29	5.4	0.09	Lowland
RRI	10.85	6.31	0.11	Lowland

RRR - rice straw removed, RRI - rice straw incorporated, SMO - soil organic matter (%), SOC - soil organic carbon (%), N - Nitrogen (%). SOM, SOC and N before planting was 9.75%, 5.669% and 0.042%, respectively

Relationship between growth and yield parameters

The principal component analysis explained 85% of the variance (*Figure 2*). Conversely, there was a positive correlation between grain weight, weight of straw and number of tillers. However, a negative correlation was observed between plant height and number of tillers (*Figure 3*). These results guide on overall agronomic management of rice.

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Figure 2. **Clustering of different parameters of rice genotypes under straw application**

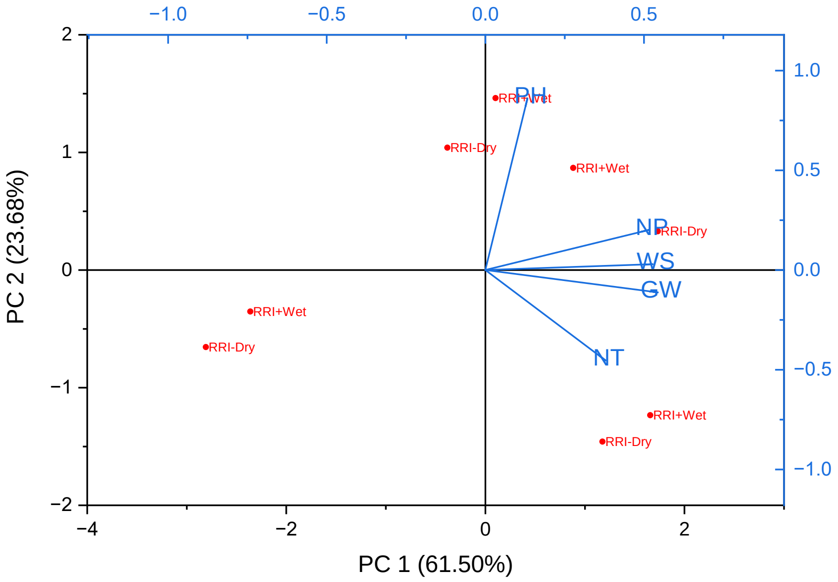
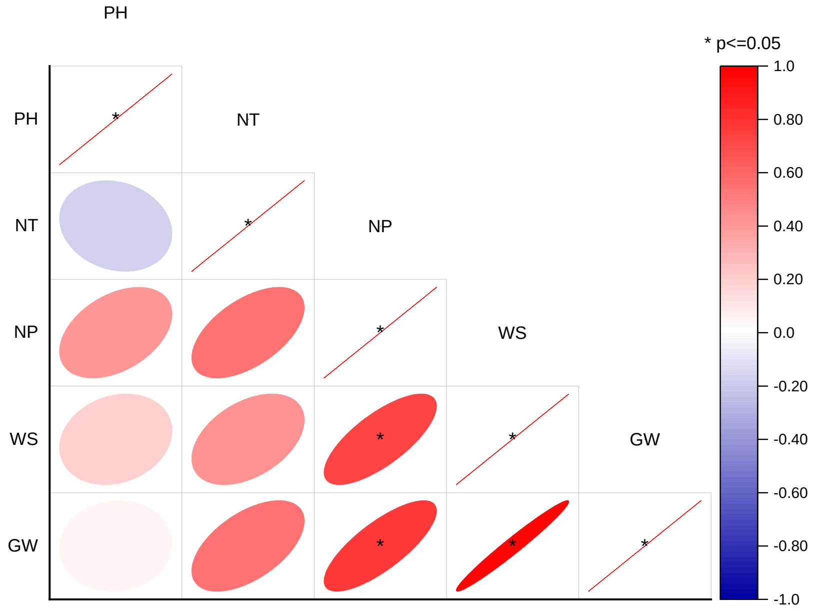


Figure 3. **The correlation between plant height (PH), number of tillers (NT), number of panicles (NP), straw weight (WS) and grain weight (GW) of rice genotypes**



CONCLUSIONS

The study assessed the effects of rice straw management on rice genotype productivity in northern Uganda. The incorporation and removal of rice straw, and genotypes elicited varying effects on rice agronomic traits and soil properties. Rice straw incorporation and removal within a period of two seasons did not contribute significantly to the grain yield. Whereas incorporation of rice straw in the soil increased soil organic matter, soil organic carbon and nitrogen content of the soil in both upland and lowland ecosystem across seasons. Therefore, the implication of this finding is that straw management is important in determining soil quality and its effects on rice productivity.

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