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Effect of soil-applied and foliar fertilizer on rice (*Oryza sativa*)

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Utilization of foliar fertilizer is not a common practice in field crop production in Ghana, upon this background this research was carried out to assess the combined effect of soil-applied and foliar fertilizer on growth and yield parameters of rice. Four treatments comprising of a control, soil-applied fertilizer and three others comprising of a combination of soil-applied and foliar fertilizer were used. The analyzed results showed some significant differences in growth and yield parameters measured. Treatments that received the combination of soil-applied and foliar fertilizer performed better than the treatment that received the soil-applied fertilizer alone. Amongst the three treatment that received the combination of soil-applied and foliar fertilizer, T3 (soil-applied fertilizer + 150ml Boost-Extra/15l H_2O) performed better than its counterparts. The results suggest that the combination of soil-applied fertilizer as basal and 150 ml Boost-Extra/15l H_2O at panicle initiation stage is an option that can be adopted in the cultivation of rice.

Key words: Foliar fertilizer, boost-extra, Amankwatia rice, soil-applied fertilizer.

INTRODUCTION

Foliar fertilizers are fertilizers that are applied to foliage to boost nutrient concentration in crops and to correct nutrient deficiencies, as well as to enhance the plant growth.

Foliar spraying has long been used in agricultural production (Eichert et al., 1999). The main benefit of foliar spraying is that it can have up to a 90% efficiency rate of uptake as opposed to 10% efficiency from soil applications. This makes them perfect for correcting nutrient deficiencies. Soil amendments may take several days to take effect and the nutrients may be tied up with other elements and made unavailable to the plant.

Foliar application can also reduce the lag time between application and uptake of the plant (Ahmad and Jabeen, 2005).

Furthermore, it is an economical way of supplementing the plant's nutrients when they are in short supply or unavailable from the soils and it has been shown that the efficiency of foliar application is three-five folds greater than soil-applied fertilizers, and can thus significantly reduce the amount of fertilizer usage. According to (Kerin and Berova, 2003; Fageria et al., 2009; Kannan, 2010),

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most foliar fertilizers do not contain impurities that can damage plants and also cause accumulation of toxic residues because they are hundred percent water soluble. Sharply et al. (1994) had reported the reduction of phosphorus contamination of lakes and streams compared with soil application of phosphorus.

This indicates the great potential of foliar fertilization as a means of reducing soil and ground water pollution. In addition, it can be mixed with pesticide and sprayed to reduce cost (Witek, 2000).

Rice (*Oryza sativa* L.) is a staple food for more than half of the world's population (Vibhuti et al., 2015). Globally, rice is grown on 161 million hectares, with an average annual production of 678.7 million tonnes (Bargali et al., 2009).

Currently in Sub Saharan Africa (SSA), rice is the second largest source of caloric intake after maize, and it is anticipated that demand will increase continuously given the high rate of population growth and rapid urbanization in the region (Balasubramanian et al., 2007).

In recent times, rice has become one of the main staples in Ghana, but most of the consumption is met by imports (MOFA, 2010). According to Duffuor (2009), the country imported over 350,000 tons of milled rice worth 600 million US dollars. The high dependence of Ghana and the West African sub-region on imported rice has attracted the attention of governments, donors, civil society organizations, the media and scientists (MOFA, 2000; Nwanze et al., 2006; JICA, 2008; Mohapatra, 2011).

Utilization of foliar fertilizers is not common in field crop production in Ghana despite its advantages. Many field crops farmers in Ghana especially those who are into rice production are adapted to soil-applied fertilizers than foliar fertilizers.

This practice as known creates numerous problems to the soil, the plants, the environment. To reduce these problems, there is the need for foliar fertilizers to be introduced into the cropping system. To achieve this, it is imperative to study the effect of foliar and soil-applied fertilizers. Haytova (2013) reported that, initial soil application of nutrient, and foliar application of subsequent nutrients would help reduce the problems associated with depending solely on soil-applied fertilizers.

Based on these issues, this research was carried out to evaluate, the effect of foliar fertilizer and soil-applied fertilizer on the growth and yield parameters of rice.

MATERIALS AND METHODS

Plant culture

A pot research was done from October 2019 to February 2020 at the Plantation crops and Experimentation section of the Department of Crop and Soil Sciences, Faculty of Agriculture, Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, Ghana (latitude 06° 43'N and longitude 01° 33'W). The chemical characteristics of the soil and nutrient concentration of the foliar fertilizer used are shown in Tables 1 and 2 respectively. Four treatments comprising of a control (Recommended fertilizer application rate for farmers) and three others which are the combinations of soil-applied and foliar fertilizer were used. Details of the treatments are shown in Table 3. A local rice variety Amankwatia which was obtained from CSRI-Crop Research Institute, Fumesua, Kumasi was used as a test crop. 12 litre size plastic pots were filled with 13.1 kg sieved top soil and watered to field capacity. Two, twenty-one (21) days old rice seedlings, were transplanted into each pot. One week after transplanting, the required quantity of NPK 15: 15: 15 fertilizer was applied to each of the treatments as basal and seven weeks after transplanting (WAT), the required quantity of nitrogen (Urea) was applied to T1 as top dressing during the panicle initiation stage. For T2, T3 and T4, the required volume of the foliar fertilizer (Boost Extra) was mixed in a knapsack sprayer and sprayed onto the leaves during the panicle initiation stage. Based on calculation,100ml Boost Extra/15L H_2O was applied to the 5 pots under treatment two (T2), 150ml Boost Extra/15L H_2O was applied to the 5 pot under treatment three (3) and 200ml Boost Extra/15L H_2O was applied to the five pots under treatment four (T4). During the foliar fertilizer application, treatments were shield to prevent droplets from getting onto the other treatments. The crops were irrigated as required throughout the cultivation. All other agronomic requirements were done as and when necessary. The treatments were arranged in a completely randomized design (CRD) and replicated five times.

Measurements

A sample of the soil was taken for chemical analysis. Total Nitrogen and available Phosphorus were determined by the Kjeldahl and Bray-1 method respectively. Exchangeable cations; potassium was determined by the flame photometer method, and $Ca^{2+}$and Mg^{2+} were determined by the EDTA titration method (Moss, 1961). Data collection started four weeks after transplanting through to harvest. A chlorophyll meter model (CCM-200 PLUS) was used to measure the chlorophyll content on ten fully expanded leaves at the peak growth stage. Plant height was measured using a wooden rule (100 cm) from the soil level to the longest tip of the leaf. Plants were harvested at the physiological maturity stage. Plant shoots were cut at soil level at harvest and air dried for seven days and weighed. Five crops per treatment were harvested for yield components and yield analysis. Climatic information during the cultivation period was obtained from KNUST meteorological station.

Statistical analysis

All data collected were analyzed with ANOVA using GENSTAT 12th Edition and differences among treatment means was determined by the Least Significant Difference (LSD) test at 5% probability.

RESULTS

The climatic conditions during the period of the experiment are presented in Table 4. On the whole the temperature regime was favorable for the crops. The plant height, number of tillers and straw weight are presented in Table (5). For all these parameters measured, no significant difference was observed between T2, T3 and T4. They were all at par and significantly different from T1. For the chlorophyll content (Table 5), no significant difference was observed

Table 1. Chemical characteristics of the soil used.

Property	Soil
pH	6.28
Total Nitrogen N (%)	0.383
Available phosphorus P (mg/kg)	2.926
Exchangeable potassium K (cmol+/kg)	0.095
Exchangeable calcium Ca (cmol+/kg)	3.400
Exchangeable magnesium Mg (cmol+/kg)	0.300

Source: Authors

Table 2. Chemical properties of the foliar fertilizer (Boost Xtra) (wt/vol) according to the label.

Parameter	Values (%)
pH (H_2O) (10% Solution)	4.0-4.5
Nitrogen (N)	20
Phosphate (P)	20
Potassium (K)	20
Magnesium (Mg)	1.5
Iron EDTA (Fe)	0.15
Manganese EDTA (Mn)	0.075
Copper EDTA (Cu)	0.075
Zinc EDTA(Zn)	0.075
Boron (B)	0.0315
Cobalt EDTA (Co)	0.0012
Molybdenum (Mo)	0.0012

Source: Authors

Table 3. Treatment details and abbreviations.

Treatment	Abbreviation
Control 100kg/ac NPK basal + 50kg/ac Urea at panicle initiation	T1
100kg/ac NPK basal + 100ml/15L H_2O Boost Extra at panicle initiation	T2
100kg/ac NPK basal + 150ml/15L H_2O Boost Extra at panicle initiation	T3
100kg/ac NPK basal + 200ml/15L H_2O Boost Extra at panicle initiation	T4

T1 Recommended rate for farmers, T2: 100ml/15L H_2O Boost Extra = (2L/ha Boost Extra), T3:150ml/15L H_2O Boost Extra = (3L/ha Boost Extra), T4: 200ml/15L H_2O Boost Extra = (4L/ha Boost Extra).
Source: Authors

between all the treatments. For number of tillers, T3 had the highest number of tillers followed by T2 and T4 which were all statistically the same but significantly different from T1 which had the lowest number of tillers. The same trend was observed for the number of panicles per plant (Table 6). For the number of grains per panicle (Table 6), T3 had the highest value followed by T2 which were both significantly the same. T3 was significantly different from T1 and T4 which had lower number of grains per panicle. The percentage ripened grains results as presented in Table (6), also shows T3 having the highest number of ripened grains followed by T2 and T4, but being significantly the same. T1 had the lowest percentage ripened grains and was significantly different from T3. 1000-grain weight results (Table 6) showed no significant difference among all the treatments, though T3 had the greatest weight. For the grain yield, T3 still recorded the highest grain yield followed by its counterparts T2 and T4

Table 4. Climatic observation during the experimental period.

Year	Month	Maximum temp (°C)	Minimum temp (°C)	Mean temp (°C)	Total rainfall (mm)	Relative humidity (%)
2019	August	29.1	21.5	25.1	24.8	86
	September	30.2	22.2	26.2	158.1	88
	October	30.9	22.3	26.6	316.6	86
	November	33.3	22.9	28.1	8.8	82
	December	33.5	22.9	28.2	41.8	82
2020	January	34.6	21.3	28.0	00.0	71
	February	36.1	22.3	29.2	00.0	74
	March	34.8	23.3	29.1	124.1	80
	April	33.5	23.0	28.3	96.6	80
	May	33.1	22.9	28.0	165.3	82

Source: Meteo station, KNUST.

Table 5. Effect of treatment on growth components and chlorophyll content.

Treatment	Height (cm)	Number of tillers per plant	Straw weight (g)	Chlorophyll content
T1	63.1[b]	10.40[b]	31[b]	22[a]
T2	73.48[ab]	23.60[a]	52[a]	24[a]
T3	77.80[a]	29.00[a]	56[a]	22[a]
T4	75.74[a]	21.80[a]	45[a]	20[a]

The same letter (s) means no significant difference among treatment means at 5% LSD.
Source: Authors

Table 6. Effect of treatment yield parameters and grain yield.

Treatment	No. of panicles per plant	No. of grains per panicle	% Ripened grains	1000 grains weight (g)	Grain yield (g/m^2)
T1	12.0[b]	90.5[b]	63.5[b]	24[a]	538[b]
T2	21.6[a]	101.5[ab]	72.9[ab]	26[a]	1440[a]
T3	23.0[a]	113.4[a]	79.4[a]	27[a]	1837[a]
T4	22.4[a]	87.3[b]	70.7[ab]	25[a]	1218[ab]

The same letter (s) indicates no significant difference among treatment means at 5% LSD.
Source: Authors

and, were significantly different from T1. T4 was an intermediary being at par with T1. Cost estimates for each fertilizer treatment is presented in Figure 1. The cost estimates show that, application of soil-applied fertilizer is expensive compared to applying the foliar fertilizer combined with the soil-applied fertilizer.

DISCUSSION

At the end of the experiment, treatments that received the combination of soil-applied and foliar fertilizer performed better than the treatment that received the soil-applied fertilizer alone. Though other factors could have contributed to the low performance of T1 and not specifically the soil applied fertilizer alone. Plant height was significantly higher for the treatments that received the combination of soil-applied fertilizer and foliar fertilizer (T2, T3, T4). The same trend was observed for the straw weight. This could be attributed to the micronutrients in the foliar fertilizer applied.

The tillering capacity of the treatments that received soil-applied fertilizer as basal and later foliar fertilizer at the panicle initiation stage (T2, T3 and T4) all performed better than T1 which received the soil-applied fertilizer as basal and at the panicle initiation stage. This result is in

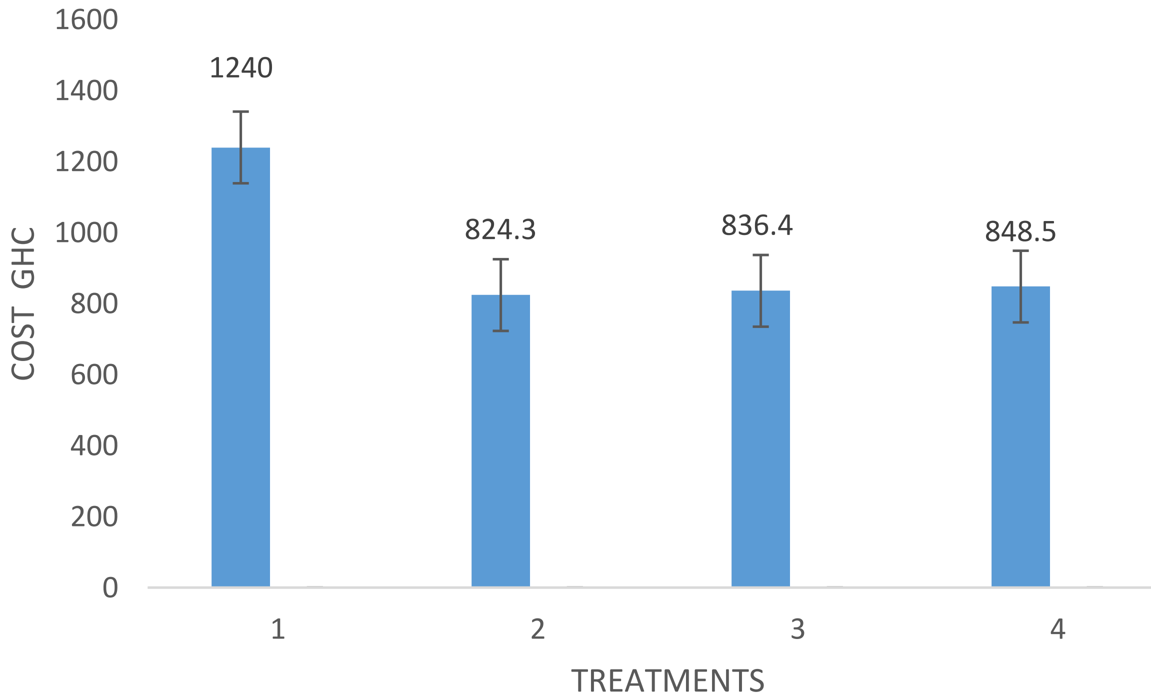

Figure 1. Total cost of fertilizer for each treatment.
Source: Authors

conformity with the findings of Budhar and Palaniappan (1996) who did a work on rice and reported that, foliar application of fertilizers especially nitrogen and micronutrients increased number of tillers per plant and the number of productive tillers of rice. Also, Amand et al. (2017) reported a significant higher number of tillers per plant of rice as were affected by foliar application of micronutrients. Other research though not rice, but cereal crops like wheat also have reported increase in tiller numbers as affected by application of foliar fertilizers. Seth and Mosluh (1981) who researched on wheat reported that, soil application of nutrients at the vegetative stage and foliar application of nutrients at the reproductive stage resulted in an increase in the number of tillers per plant of wheat. Similar finding was also reported by Amal et al. (2011) they reported that foliar applied fertilizers especially nitrogen at the reproductive stage increased the number of tillers per plant of wheat. And this, as they reported might be attributed to the more uptake and utilization of foliar fertilizers by the wheat plant.

The same trend of tiller numbers was observed for the number of panicles as well, with T3, T4 and T2 producing more panicles than T1. This trend is not quite surprising as panicles are produced from tillers therefore the output of tillers usually reflect on the number of panicles. This may be as a result of the ease and rapid utilization of the foliar fertilizer by the rice plant. And it agrees with the findings of Bhuvan et al. (2012), who reported that foliar fertilizers increased the number of panicles per plant of rice. The result is also in agreement with the finding of Soylu et al. (2005) and Kenbaev and Sade (2002). They reported that number of panicles per plant is significantly increased by foliar application of different micronutrients on wheat and barley respectively.

Number of grains per panicle for T2 and T3 were statistically the same although T3 had the highest in terms of numerical values, and significantly different from T1 and T4. T4 was statistically at par with T1. The foliar fertilizer affected the number of grains per panicle significantly. This may be due to an increased in dry matter accumulation as a result of high nutrients absorption by the leaves. This result is in line with the findings of Borrell et al. (1998) who did a research on Aman rice and reported that, foliar application of nutrients resulted in a higher increase in the number of grains per panicle of Aman rice. The result is also in support of the findings of Akhtar et al. (2003). They reported that, the number of grains per panicle of rice increased following the foliar application of fertilizer. Bhuyan et al. (2012) reported a higher number of grains per panicle of rice as was affected by foliar spray.

Treatments that received the combination of soil-applied and foliar fertilizers (T2, T3 and T4) had higher percentage ripened grains compared to that which received the soil-applied fertilizer alone (T1). This could be attributed to the micronutrients in the foliar fertilizer which might have cause better assimilates production and availability during the reproductive phase of the rice crops resulting in better grain filling. As suggested by (Gifford and Evans, 1981; Kush and Peng, 1996; Xu et al., 1997), adequate supply of assimilate and proper accumulation of assimilate during early grain filling rapidly increase grain ripening, as assimilate supply is a key factor in determining ripening in rice.

Grain yield was also higher for the combination of soil-applied and foliar fertilized crops as compared to the soil-applied fertilizer alone. Amongst the three, T3 had the highest yield followed by T2 and T4 although all were at par statistically. This suggests that basal application of soil-applied fertilizer and topdressing with 150ml /15l foliar fertilizer (T3) is better than the others. The overall performance of the combined soil-applied and foliar fertilizer applied treatments can be attributed to the micronutrients in the foliar fertilizer applied, resulting in good grains per panicle production and grain filling, all culminating into good grain yield. Similar reports of increase in grain yield have been reported by Bhuyan et al. (2012) who stated that, foliar application of N fertilizer increased grain yield of Aman rice as compared to the conventional method (soil fertilization). The result is also in support with that of Hobbs and Gupta (2003) who reported that, foliar application of fertilizer elements increased grain yield of Aman rice and wheat. Bybordi (2014), who conducted an experiment on rice, reported that, foliar application of micronutrients depicted more promising results. Other researches have reported on a similar cereal crop like wheat. For instance, Barut (2019), who did a research on wheat, indicated that foliar fertilizer treatments had positive effects on grain yield and quality of wheat.

Hamouda et al. (2015) also reported a similar finding. Mesdah (2009) had also reported higher grain yield of wheat as was affected by the application of foliar fertilizer nutrients.

The lower value recorded by treatment one (T1) could be attributed to the fact that the soil-applied fertilizer lack micronutrients such as zinc, copper, sulfur, etc. and as reported by Sohota (2006), insufficient levels of micronutrients like sulfur prevent grain cereals from reaching their yield potential.

It could be concluded based on the present findings that, foliar fertilizer treatments as topdressing, during the panicle initiation stage generally had positive effects on the rice crop. In this experiment, foliar fertilizer rates at 100ml Boost-Extra/15l H_2O (T2), 150ml Boost-Extra/15l H_2O (T3) and 200ml Boost-Extra/15l H_2O (T4) significantly affected the growth and yield parameters of Amankwatia rice variety. Foliar fertilizer at a rate of 150ml/15l H_2O (T3) was the best. The soil-applied fertilizer had no significant effect on the growth and yield of parameters of the rice variety.

Also cost estimates for each treatment shows that, it cost less to apply the combination of the soil-applied and foliar fertilizer compared to applying the soil-applied fertilizer alone.

Conclusion

On the whole, the results suggest that the combination of soil-applied fertilizer as basal and 150ml Boost-Extra/15l H_2O at panicle initiation stage is an option that can be adopted in the cultivation of rice.

CONFLICT OF INTERESTS

The authors have not declared any conflicts of interests.

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