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Effects of Copper (Cu) on Yield Components and Associated Traits in Segregating Populations of Lowland Rice (O. sativa L.)

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Abstract: Trace elements are very critical for rice growth of which Cu is one of the essential trace elements for rice and excess of cupper becomes toxic to rice growth. The aim of this study was to determine the productivity increase in rice crop and genotype reactions to application of Copper under the tropical rainforest condition. Three experiments were established concurrently in randomized complete block design in three replications in pots. Treatment comprised of 6 breeding lines each from two rice populations of F2 and F3 generations and two popular checks. Experiment one is the control without $CuSO_4$ treatment, while experiment two and three is the F2 and F3 populations, respectively treated with $CuSO_4$ solution. Three concentration levels of $CuSO_4$ solution (15mg Cu /kg of soil, 30mg Cu /kg of soil and 60mg Cu /kg of soil) were applied into each pots a week before transplanting in the treated experiments. This study observed that at 30mg of Cu/kg of soil is the optimum level for rice performance based on these experiments beyond, reduction in rice performance. Reduction of 24.92% and 22.12% of total grain yield of F2 and F3 populations at 60mg of Cu/kg of soil as compared to the control were recorded, stable and high yielding genotypes across the copper concentration levels were identified for copper breeding programme.

Keywords: Genotypes, Populations, Micronutrients, GGE Biplot, Rice

1. Introduction

Rice is one of the cereal crops globally consumed and is now become a staple crop mostly in Asian countries and part of the developing counties in the world. The demand for rice is far outstrip its production globally and there is need to address some of the limiting factors of rice production at least closing the gap between demand and production of rice. The soil fertility level is depleting annually due to human activities as well, the scenario of global warming thus affecting rice production. Soil micronutrients as the name implied but very important elements in rice production, often, they are one of the most depleted by the aforementioned factors, thus, there is need to mitigate the effects on rice production.

Copper being a transition metal is considered as a trace element with a low concentration in biological tissues but essential for life [1]. Copper was first identified as a plant nutrient and its solubility in soil is greatly dependent on soil pH and dissolved organic matter content [2] and becomes readily available at a pH below 6 [3, 4]. The requirement of Cu for healthy plant growth and development varies with plant species and cultivars [5]. Excess Cu in plants can also be genotoxic, means is capable of generating genetic mutations. In rice roots, excess Cu specifically altered levels of genes involved in fatty acid metabolism and cellular component biogenesis. Toxic effects of Cu in plants can be observed by reduction of yield, poor seed germination, stunted leaf and root growth [6, 7]. In plants, Cu deficiency altered root and leaf construction, as well as significant reduction in chlorophyll pigments and photosynthesis [8].

The requirement of Cu for plant growth particularly rice varies with species and genotypes [5]. Phytotoxicity of Cu depends mostly on its solubility and availability in the soil. However, the deficiency and excess of Cu affect plant growth and this could alter important biochemical processes. There are reports on the threshold for Cu deficiency in plants, however, it depends on crop species and other environmental factors [5]

The plant height of rice was reduced as a result of Copper toxicity [10]. Plant height could be used for assessing crop performance [9]. A report showed that tillering ability is delayed with increasing levels of soil Copper and excess Cu concentration led to slow recovery from transplanting, delayed tillering and reduction of maximum tiller numbers [10]. Soil Cu treatments had a large impact on number of spikelets per panicle, which decreased with the increase levels of soil Cu [10]. The toxic effect of Copper on rice yield significantly increased with increasing level of Cu concentration. Micronutrient fertilization also referred to agronomic fortification improves crop yield for human consumption, and could also address crop nutritional quality and micronutrient dietary of humans' health [11]. The aim of this study was to determine the productivity increase in rice crop and genotype reactions to the application of Copper under the tropical rainforest condition.

2. Materials and Methods

The study was conducted in the screenhouse using soil collected from the experimental farm of the International Institute of Tropical Agriculture (IITA) Onne, (longitude 7°95′28″E and latitude 4°43′78″N) in the Humid forest ecological zone of Nigeria. Mean annual rainfall in the zone is 2310.9 mm and it falls mainly within the months of February to November with peak rainfall received in September. This is a pot experiment and Soil was collected from the research station field at 0 – 15 cm depth, sterilized and filled into 4kg pot to minimize uneven distribution of $CuSO_4$ in the pots [12]

Three experiments were established concurrently in randomized complete block design in three replications in pots. Treatment comprised of 6 breeding lines each from two rice populations of F2 and F3 generations and two popular checks (Table 1.). Experiment one is the control without $CuSO_4$ treatment, while experiment two and three are F2 and F3 populations, respectively treated with $CuSO_4$ solution. Three concentration levels of $CuSO_4$ solution (15mg Cu /kg of soil, 30mg Cu /kg of soil and 60mg Cu /kg of soil) were applied into each pots a week before transplanting in the treated experiments. The rice seeds were raised in the normal seedling nursery beds with untreated soil. The seedlings were transplanted at 21 days after sowing into treated pots with $CuSO_4$ [13] two seedlings per pot.

Table 1. *Genetic material used for the experiment.*

S/N	Genetic materials	Pedigree	Source
1	UPN 59	323845/FARO 44	Uniport Germplasm Uniport
2	UPN 82	323861/UPIA 3	Uniport Germplasm Uniport
3	UPN 86	323865/UPIA 2	Uniport Germplasm Uniport
4	UPN 95	323876/FARO 52	Uniport Germplasm Uniport
5	UPN 103	323879/FARO 44	Uniport Germplasm Uniport
6	UPN 107	323892/FARO 57	Uniport Germplasm Uniport
	Checks		Uniport Germplasm Uniport
7	FARO 44		Uniport Germplasm Uniport
8	UPIA 2		Uniport Germplasm Uniport

2.1. Data Collection

Data was collected at appropriate stage of the crop development. The agronomic characters were measured at weekly intervals. The 'Standard Evaluation System (SES) for Rice' reference manual [14] was used for all trait measurements except where stated otherwise.

2.2. Statistical Analysis

Analysis of variance (ANOVA) was performed separately on the individual experiments using the PROC GLM of SAS [15]. Simple linear correlation analysis was performed using the PROC CORR program of SAS. Biplot analysis was employed to investigate the cultivar-by-environment interaction (site regression model) [16]. Biplot construction was based on the first two principal components (PC1 and PC2). The PC1 and PC2 are referred to as primary and secondary effects, respectively, and were derived from singular-value decomposition (SVD) of the environment-centred data [16]. The environment-centred data were subjected to SVD for the construction of the biplots. This resulted in three component matrices: singular value (SV) matrix, the cultivar eigenvector matrix, and the environment eigenvector matrix. Thus, the biplot was constructed based on the following model,[17]:

$$Yij - G - Ej = \sum \lambda n \, \varepsilon in \, \eta in + \varepsilon ij,$$

where Yij = the measured mean trait of cultivar i in environment j; G = the grand mean; Ej = the mean effect of environment j; (G + Ej) being the mean trait in environment j; λn = the SVD of nth principal component (PC), the square of which is the sum of square explained by PCn; εin = the eigenvector of cultivar i for PCn; ηjn = the eigenvector of environment j for PCn; and εij = the residual variation associated with genotype i in environment j.

3. Results

3.1. Agronomic Performance of the Tested Genotypes

Plant height showed highly significant difference among the tested genotypes (Table 2). Plant height increased with increasing concentration of copper in the soil up to 30mg Cu /kg of soil concentration and declined when above this level. It was observed that genotypes from F2 populations were taller than those from F3 population. These genotypes (UPN 103 and UPN 107), performed better than the overall mean (98cm) at 30mg Cu /kg of soil and as well, at F2 and F3 generations. These genotypes performed better than the two checks in all concentration levels of $CuSO_4$ solution (Table 2).

There was a significant difference among all the tested genotypes for maximum number of tillers (Table 3). More genotypes including the two checks performed better than the overall mean in all concentration levels. The number of tillers increases with increasing copper concentration up till 30mg Cu /kg of soil and beyond, which the maximum tillering declined. Generally, the F3 population produced more tillers than the F2 population in all concentration levels. Genotype UPN 59 tiller more at 60mg Cu/kg of soil while UPN 86 and UPN 95 had more tillers at 30mg Cu /kg of soil level. (Table 3)

Table 2. *Effects of copper concentrations on plant height (cm) of genotypes within F2 and F3 populations.*

Genotype	Control		15mg of Cu		30mg of CSikirouau		60mg of Cu	
	F2	F3	F2	F3	F2	F3	F2	F3
UPN 59	72.50c	69.75de	77.75c	75.50c	88.50c	81.25e	68.25de	63.75d
UPN 82	70.25c	66.00f	82.75c	80.00c	95.25b	90.50c	65.75f	62.25d
UPN 86	73.75c	71.25d	81.75c	79.75c	87.50c	85.25d	74.00c	71.25c
UPN 95	72.25c	68.25ef	79.00c	75.25c	87.75c	82.00de	66.50ef	63.25d
UPN 103	87.25b	77.25c	106.50a	95.75a	123.25a	111.00a	80.25b	76.75b
UPN 107	96.25a	94.00a	101.00ab	90.75b	119.75a	107.50a	91.00a	87.50a
UPIA 2	82.50b	85.25b	89.75bc	89.75b	98.25b	97.25b	74.50c	73.25c
FARO 44	74.75c	76.50c	78.75c	80.00c	83.75c	84.50de	70.25d	71.75c
Mean	78.69	76.03	87.16	83.34	98	92.41	73.81	71.22
Coefficient of variation	3.58	1.49	5.72	2.27	1.94	1.67	1.33	1.33
Level of Significance	**	**	**	**	**	**	**	**

**=significant at the 1%.

Table 3. *Effect of copper concentration on Maximum number of tillers of genotypes within F2 and F3 population.*

Genotype	Control		15mg of Cu		30mg of Cu		60mg of Cu	
	F2	F3	F2	F3	F2	F3	F2	F3
UPN 59	9.00abc	9.75cde	11.25ab	12.50bc	14.00abcd	15.00cd	10.00a	9.25a
UPN 82	8.25bc	9.25e	10.00b	11.00de	12.75cd	15.50de	8.50b	8.75ab
UPN 86	9.5ab	10.00bcd	12.00a	13.00ab	16.25a	17.50a	7.75b	8.75ab
UPN 95	9.50ab	10.25abc	12.25a	14.00a	14.75abc	17.00ab	8.25b	9.00a
UPN 103	8.00c	9.50cde	10.25b	11.75cd	13.75bcd	14.00def	6.25c	8.00b
UPN 107	6.25d	7.75f	8.25c	10.00e	12.00d	13.00f	5.00d	5.75c
UPIA 2	10.25a	10.50ab	12.75a	13.00ab	15.25ab	16.00bc	8.00b	8.75ab
FARO 44	10.25a	10.75a	11.50ab	11.50cd	13.25bcd	13.50ef	8.50b	8.75ab
Mean	8.88	9.72	11.03	12.09	14	15.06	7.78	8.38
CV	6.39	3.04	5.67	3.96	6.47	3.32	5.66	4.51
LOS	**	**	**	**	*	**	**	**

*= significant at the 5%, **=significant at the 1%.

3.2. Performance of Post-harvest Traits of the Tested Genotypes

Effective tiller is the tiller that produce economic panicle at the time of harvest, which is very important in the determination of total grain yield of genotype. There was significant difference among all the genotypes both in F2 and F3 populations in all the Cu concentration levels except F3 population at 60mg Cu/kg of soil (Table 4). The 30mg Cu /kg of soil of copper concentration had the highest effective tillers for all the genotypes and UPN 95 and UPN 86 were highest in F3 population. At 60mg Cu/kg of soil, all genotype had reduction in effective tiller number, while FARO 44 had the highest number of effective tillers (Table 4).

Table 4. *Effect of Copper concentration on effective tillers of genotypes within F2 and F3 population.*

Genotypes	Control		15mg of Cu		30mg of Cu		60mg of Cu	
	F2	F3	F2	F3	F2	F3	F2	F3
UPN 59	6.25ab	7.50ab	8.00cd	10.25ab	11.75ab	12.50abc	4.00c	6.00ab
UPN 82	6.50ab	7.50ab	8.50c	8.75cd	10.75bc	12.00bc	4.75bc	5.75ab
UPN 86	6.25ab	7.75ab	9.25b	10.00ab	13.00a	13.75a	5.00bc	6.00ab
UPN 95	7.50a	7.50ab	9.25b	10.75a	12.50ab	13.75a	4.00c	5.50abc
UPN 103	5.50bc	6.75b	7.75d	8.50cd	11.75ab	11.75c	4.00c	5.25bc
UPN 107	4.00c	4.75c	7.00e	7.75d	9.00c	10.00d	3.75c	4.00c
UPIA 2	7.75a	7.75ab	10.75a	11.00a	12.75ab	13.25ab	5.50ab	5.50abc
FARO 44	8.00a	8.25a	9.50b	9.50bc	12.00ab	12.25bc	6.75a	7.00a
Mean	6.47	7.22	8.75	9.56	11.69	12.41	4.72	5.63
Coefficient of variation	11.29	6.89	2.86	4.74	7.05	4.29	11.97	12.11
Level of Significance	*	**	**	**	*	**	*	Ns

Ns= not significant, *= significant at the 5%, **=significant at the 1%.

1000 grain weight for the populations as influenced by copper concentrations. For all the genotype tested, significant difference was observed in F3 populations for the three levels of $CuSO_4$ solution and the control experiment (Table 5). Similar trend was observed as in Table 4 in-terms of increase in Cu concentration and the corresponding increase in traits value for the tested genotypes. The grand mean of F3 at 60mg of Cu was the lowest (Table 5).

Table 5. *Effect of Copper concentration on 1000 grain weight of genotypes within F2 and F3 population.*

Genotype	Control		15mg of Cu		30mg of Cu		60mg of Cu	
	F2	F3	F2	F3	F2	F3	F2	F3
UPN 59	22.50	22.00ab	23ab	22.25ab	22.75	21.75de	22.50	21.25c
UPN 82	22.25	21.50b	22.75ab	22.00b	22.50	21.50e	22.5	20.75c
UPN 86	22.25	21.50b	22.75ab	22.00b	23.00	22.00cde	22.25	20.75c
UPN 95	22.75	22.00ab	22.50b	22.25ab	22.75	22.25bcd	22.50	21.50abc
UPN 103	23.00	21.50b	23.25a	22.25ab	23.00	22.50bc	22.75	21.75ab
UPN 107	22.75	21.50b	22.50b	20.50c	23.00	22.00cde	22.25	21.50abc
UPIA 2	23.00	22.75a	22ab	23.00a	23.00	23.25a	22.25	22.25a
FARO 44	22.500	22.50a	22.75ab	22.75ab	22.75	22.75ab	22.25	22.25a
Mean	22.63	21.88	22.78	22.13	22.84	22.25	22.41	21.5
Coefficient of variation	1.87	1.49	1.15	1.71	0.99	1.12	2.06	1.46
Level of Significance	ns	*	ns	**	ns	**	ns	*

ns= not significant, *= significant at the 5%, **=significant at the 1%.

For panicle length, there was significant difference among all the genotypes both in F2 and F3 populations in all the Cu concentration levels except at F3 population at 30mg of Cu and 60mg Cu/kg of soil (Table 6). It was observed that the two checks (UPIA 2 and FARO 44) had longer panicles than the test genotypes and F3 populations had longer panicle length than F2 in all the experiments. (Table 6).

The grain yield (GY) per hectare increased with increasing copper concentration in the soil but decreased at 60mg Cu/kg of soil. There is no significant difference among the genotypes in both F2 and F3 populations at 60mg Cu/kg of soil (Table 7). The F3 populations perform better than the F2 population in all Cu concentration levels based on grain yield. The UPN 59, UPN 82 and UPN 86 were among the best yielded tested genotypes in all Cu concentration and population levels. (Table 7)

Table 6. *Effect of Copper concentration on Panicle length of genotypes within F2 and F3 population.*

Genotype	Control		15mg of Cu		30mg of Cu		60mg of Cu	
	F2	F3	F2	F3	F2	F3	F2	F3
UPN 59	22.25d	25.00ab	24.50ab	25.25c	25.25b	26.00ab	19.25e	24.00a
UPN 82	20.75e	24.00c	22.00c	25.00c	23.00c	25.25b	19.25e	21.75b
UPN 86	22.50cd	24.50bc	23.25bc	25.25c	23.75c	25.75ab	23.25bc	24.50a
UPN 95	21.75de	25.00ab	22.75c	25.00c	22.75c	25.75ab	21.75d	24.25a
UPN 103	24.25b	25.50a	24.50ab	25.25c	25.50ab	26.50ab	22.75dc	23.50ab
UPN 107	24.50ab	25.50a	25.50a	26.25a	26.00ab	27.00a	24.25ab	24.75a
UPIA 2	25.75a	25.75a	25.75a	26.00ab	26.50a	26.50ab	25.25a	25.25a
FARO 44	23.75bc	23.75c	25.50a	25.50bc	26.00ab	26.00ab	24.75a	24.50a
Mean	23.19	24.88	24.22	25.44	24.84	26.09	22.56	24.06

Genotype	Control		15mg of Cu		30mg of Cu		60mg of Cu	
	F2	F3	F2	F3	F2	F3	F2	F3
Coefficient of variation	2.41	1.26	2.13	1.05	1.77	1.98	2.33	3.33
Level of Significance	**	**	**	*	**	ns	**	ns

ns= not significant, *= significant at the 5%, **=significant at the 1%.

Table 7. *Effect of Copper concentration on yield of genotypes (t/ha) within F2 and F3 population.*

Genotypes	Control		15mg of Cu		30mg of Cu		60mg of Cu	
	F2	F3	F2	F3	F2	F3	F2	F3
UPN 59	4.19a	4.69a	5.37ab	5.96a	5.86bcd	6.45ab	3.13ab	4.19a
UPN 82	4.00ab	4.69a	5.18bc	5.27bc	5.76cd	5.62b	3.32a	3.71ab
UPN 86	4.00ab	4.49ab	5.57a	5.86ab	6.74a	6.93a	3.32a	3.71ab
UPN 95	4.29a	4.49ab	5.37ab	5.76ab	6.35abc	6.93a	2.93ab	3.42abc
UPN 103	3.14bc	3.81bc	4.39d	4.79c	5.76cd	6.05ab	2.73b	3.32abc
UPN 107	3.13c	3.52c	4.29d	4.78c	4.98e	5.57b	2.93ab	2.73c
UPIA 2	4.19a	4.29ab	5.18bc	5.27bc	6.45ab	6.74ab	3.22a	3.22bc
FARO 44	4.00ab	4.00abc	4..88c	4.88c	5.66d	5.76ab	3.42a	3.52abc
Mean	3.91	4.25	5.03	5.32	5.94	6.26	3.13	3.48
Coefficient of Variation	6.55	6.67	2.54	4.6	4.19	7.93	6.14	9.94
Level of Variation	*	*	**	**	**	ns	ns	ns

ns= not significant, * = significant at the 5%, ** =significant at the 1%.

3.3. Phenotypic Correlation Among Traits in the Populations

Grain yield (GY) showed positive and significant correlation with tiller number, effective tiller, number of panicles per plant, plant height and 1000 grain weight. The 1000 grain weight had positive correlation with all plant growth parameters except with plant height (Table 8). The panicle length significantly (P ≤ 0.01) and positively correlated with plant height, number of tiller and effective tiller number (Table 8).

3.4. GGEbiplot Analyses

The first two principal components (PC1 and PC2) obtained by SVD of the centred data explained 94.6% of the total variation for grain yield in F2 population (Figure 1), while the first two principal components (PC1 and PC2) accounted for 92% of the total variation for grain yield in F3 populations (Figure 2). Three mega environments were identified for the two populations, environment one comprised the control C0 and C1 (15mg Cu/kg of soil), while environment two and three were Cu2 (30mg of Cu/kg of soil), and C3 (60mg of Cu/kg of soil), respectively (Figure 1 and Figure 2). The environment two and three were opposite of both side of the perpendicular double-headed arrows indicated the mean grain yield of the experiments. Environment one for both populations is very closed to the appendicular line, which indicates to be close to an ideal environment for the experiment. The genotypes at the vertices of the pentagon had highest GY at that environment, UPN 86 and UPN 95 had the highest GY in environment one and two respectively, while FARO 44 yield highest in environment three for F2 and UPN 59 for F3 population (Figure 1 and Figure 2).

Performances of genotypes were ranked in the direction indicated by the single-headed arrow (average tester coordinate) in ascending order of the mean grain yield of the experiments. Therefore, Stability of genotypes was ranked on the basis of their projection from the average tester coordinate (axis) on the average environment main effect. The greater the length of the projection of a genotype, the more unstable that genotype was (Figure 3 and Figure 4). The most stable genotype for F2 were UPN 59 and UPIA 2, while UPN 82 and UPN 86 for F3 population. The highest yielding genotype were UPN 86 and UPN 59 for F2 and F3 populations, respectively (Figure 3 and Figure 4).

Table 8. *Linear correlation coefficient of growth and yield parameters for F2 and F3 population (Copper environment).*

TRAITS	PHT-C2	NTI_C2	ET_C2	PAL_C2	NPPP_C2	1000GWT_C2	YLD_C2
PHT-C3							
NTI_C3	0.39ns						
ET_C3	0.40*	0.95***					
PAL_C3	0.66**	0.50**	0.57**				
NPPP_C3	0.36*	0.90***	0.90***	0.34*			
1000GWT_C3	0.20ns	0.51*	0.56**	0.51*	0.56**		
YLD_C3	0.31**	0.64**	0.65**	0.11ns	0.65**	0.58**	

C2 and C3 at the end of variables represent F2 and F3 populations, respectively. ns= not significant, *= significant at 5%, **=significant at 1%, ***=significant at 01%, ns = not significant, PHT=Plant height, NTI=Number of tillers, ET=Effective tillers, PAL=Panicle Length, NPPP=Number of Panicle per Plant, 1000-GWT=1000 grain weight, YLD=Yield/ha.

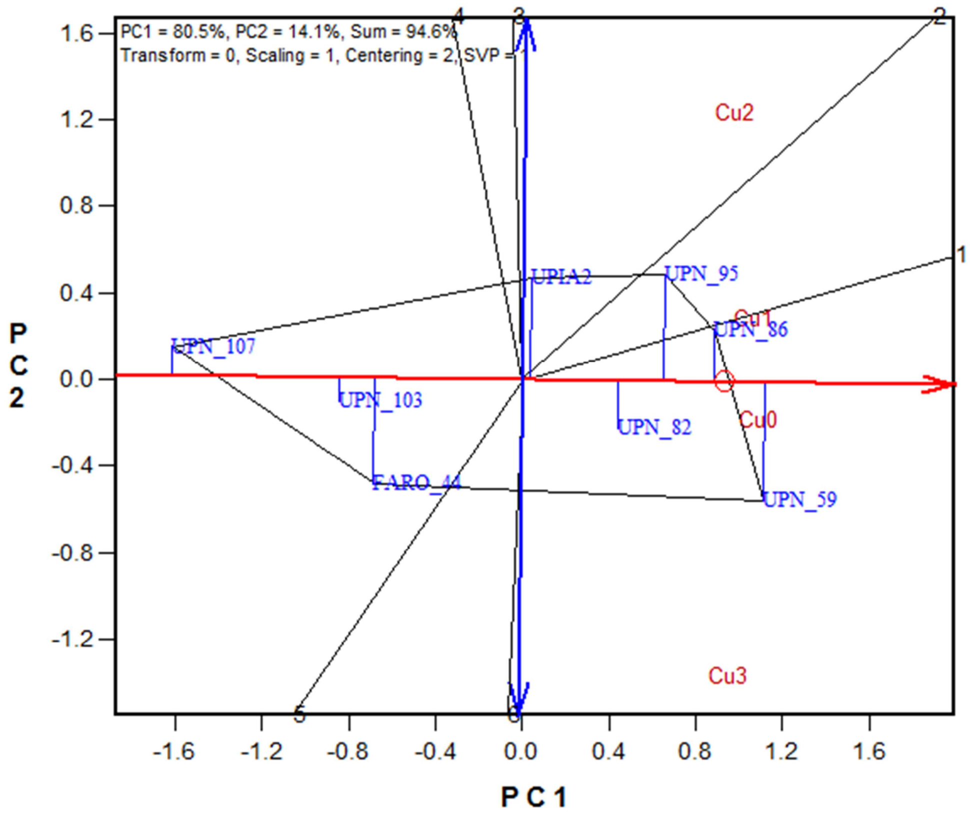

Figure 1. *F2 Cu which wins where.*

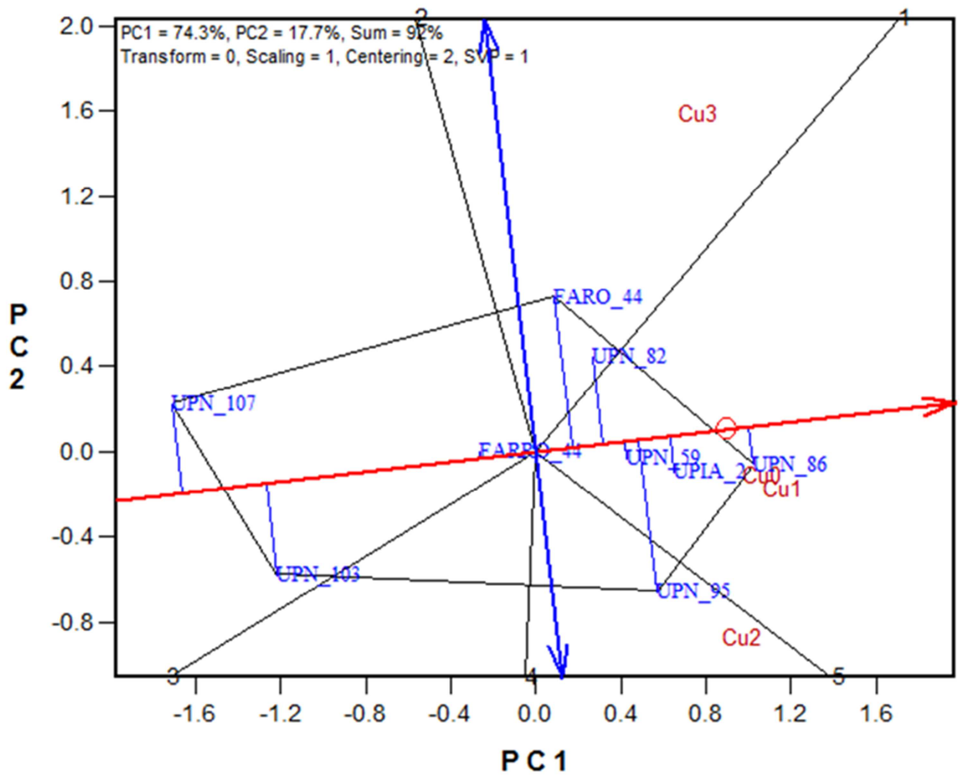

Figure 2. *F3 Cu which wins where.*

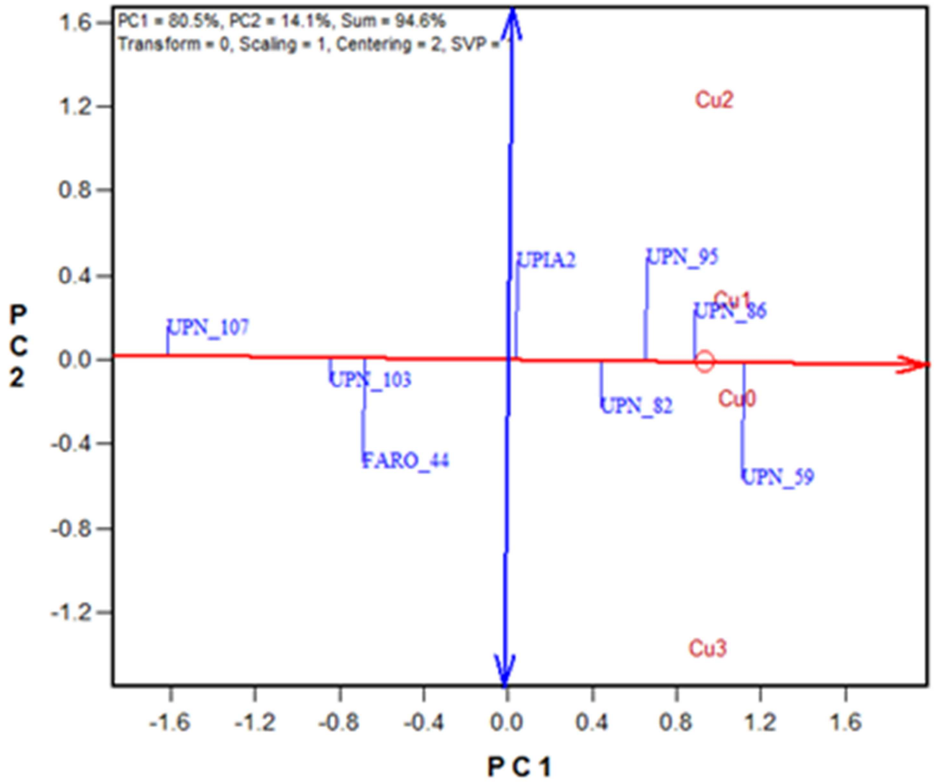

Figure 3. *F2 Cu GGE biplot analysis of Yield.*

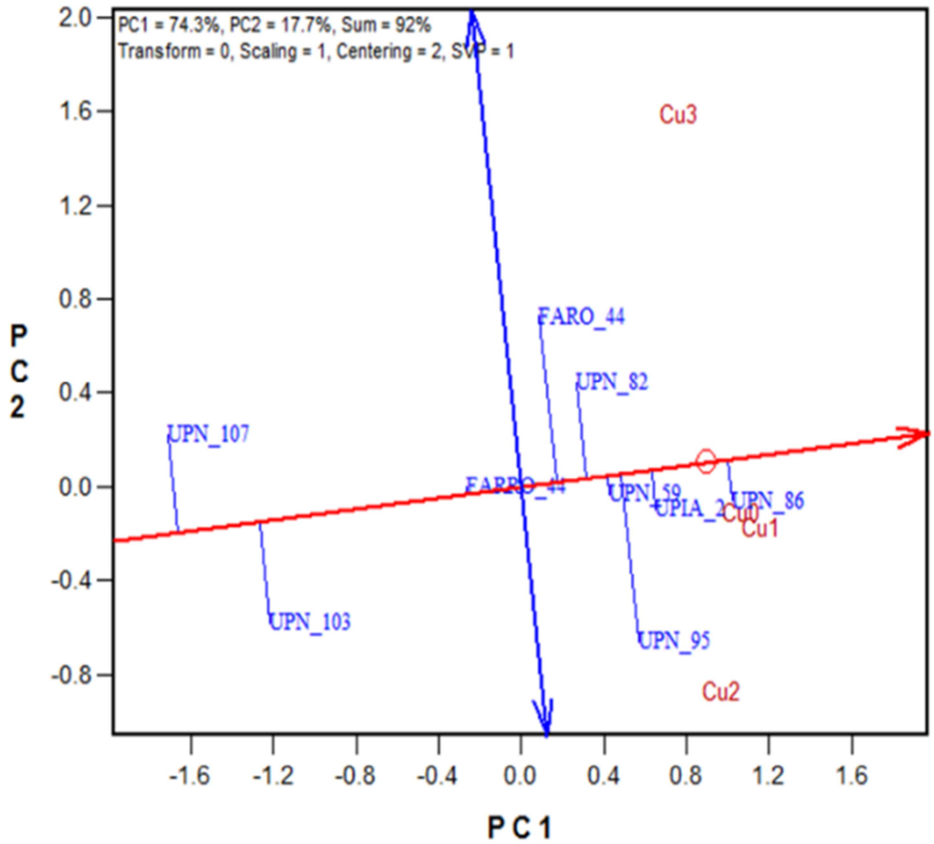

Figure 4. *F3 Cu GGE biplot analysis of yield.*

4. Discussion

4.1. Agronomic Performance of the Tested Genotypes

Micronutrient elements are very important for rice growth of which Cu is one of the essential trace elements for rice. As a trace element, copper is also an enzyme cofactor and played an important role in the inhibition of plant uptake of toxic trace elements. Plant height is a parameter for assessing crop performance [9]. This present finding revealed that Plant height increased with increasing in concentration $CuSO_4$ solution up to 30mg of Cu/kg of soil level and decreased when soil at 60mg of Cu/kg of soil. In rice, plant height was reduced as a result of Copper toxicity [10], although UPN 103 and UPN 107 were the tallest even at high copper concentration, however, smaller plants do not necessarily affect yield, especially in the absence of water stress [18].

In most abiotic stressed environments, rice crop performed very well to some concentration levels, beyond, which experienced decline in performance. In this study, tiller number increased up to (30mg of Cu/kg of soil) and decreased at (60mg of Cu/kg of soil), this corroborate the report on Cu in wheat [6]. Similar report on salinity and its effects on tillering ability on rice [19, 20]. The increase in tiller number even at high level 60mg of Cu/kg of soil may be attributed to the nitrogen fixation an attribute of copper as well as the role of Copper in biochemical processes like photosynthesis and respiration [21]. It was observed that F3 populations had more tiller numbers than the F2, this could be due to biased selections made at early stages of the crops.

4.2. Performance of Post-harvest Traits of the Tested Genotypes

The effective tillers which, is the number of tillers harvestable per plant, is very important in the determination of total grain yield of genotype. This study showed that the optimal level of copper concentration is at 30mg Cu /kg of soil, where all the genotypes hard the highest numbers of effective tiller both in F2 and F3 populations. Reports also showed that there was 10% reduction on the rice performance at 100 mgCu kg-1 and beyond, reduction by 50% in rice performance [22, 23]. The genotypes UPN 95 and UPN 86 had more effective tiller number even at 60mg of Cu/kg of soil, which could be used for population improvement in copper breeding programme.

The 1000 grain weight and panicle length are major yield components that determine the ultimate grain yield of rice. The panicle length determines the number of grains to be accommodated and higher grain yield for varieties with longer panicle length have been reported [24]. Most of the genotypes tested had high values of 1000 grain weight and long panicle length even at 60mg of Cu/kg of soil, which could be deployed to copper stressed environments.

The genotype UPN 59 performed better based on grain yield across in all copper concentration levels. Therefore, this genotype could a potential variety in copper stressed environment. Reduction of 24.92% and 22.12% of total grain yield of F2 and F3 populations at 60mg of Cu/kg of soil as compared to the control were recorded, the performance of F3 populations could be biased selection at the early generation of the crop. The decrease in grain yield as compared to the control could be a combination from the effects of yield components in Cu treated experiments as stated earlier.

4.3. Phenotypic Correlation Among Traits in the Populations

The grain yield had significant correlation at probability of 0.01 with plant height, effective tiller, 1000 grain weight. These results corroborate earlier reports [25, 19]. The existence of correlation may be attributed to the presence of linkage or pleiotropic effect of genes or environmental effect or combination of all [26]. The significant and positive correlation values observed could be used as secondary traits for yield selection especially, in early generation of the varietal development in rice.

4.4. GGEbiplot Analyses

The GGE refers to the genotype main effect (G) and the genotype x environment interaction (GE), which are the two most important sources of variation for cultivar evaluation in a multi environment trials [27]. GGE has been recognized as a useful tool to analyze and visualize the pattern of genotype x environment interaction of cultivar in multi environment and evaluation of different crops including cereals [27, 20]. Three mega environments were identified and could assist the breeders in prioritizing screening environments and genotypes for each environment as UPN 86 and UPN 95 had the highest GY in environment one and two, respectively. Screening for copper resistant genotypes at the early generation of the breeding cycle will assist breeders to reduce the number of genotypes to be carried into the next breeding cycles of the programme. The most stable genotype for F2 were UPN 59 and UPIA 2, while UPN 82 and UPN 86 for F3 population. The highest yielding genotype were UPN 86 and UPN 59 for F2 and F3 populations, respectively, these promising genotypes could accelerate breeding for copper resistance and immediate deployment to copper stressed environments.

5. Conclusion

Trace elements are very critical for rice growth of which Cu is one of the essential trace elements for rice. Selecting and breeding staple food crops which are more efficient in the uptake of micronutrients from the soil are beneficial for agricultural productivity. This study observed that 30mg of Cu/kg of soil is an optimum level for rice performance based on these experiments beyond, which reduction in rice performance. Reduction of 24.92% and 22.12% of total grain yield of F2 and F3 populations at 60mg of Cu/kg of soil as compared to the control were recorded, stable and high yielding genotypes across the copper concentration levels were identified for copper breeding programme.

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