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Research Article
Effects of Pretilachlor and 2,4-Dichlorophenoxyacetic Acid on the Proximate and Mineral Compositions of *Oryza sativa* L.

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Abstract

Background and Objective: Rice (*Oryza sativa* L.) is the most important staple food in the world and information on the effects of chemical weed control on rice grain quality is insufficient. Hence this study examined the effects of 2 herbicides pretilachlor and 2,4-dichlorophenoxyacetic acid on the proximate and mineral compositions of *Oryza sativa* L. **Materials and Methods:** Field experiment was conducted in evaluating the effect of herbicides on the proximate and mineral compositions of *Oryza sativa*. The experimental setup was a completely randomized block design with 7 treatments and 4 replicates. The treatments include; T_1: Weedy check, T_2: 1.5 L ha^{-1} pretilachlor, T_3: 2.0 L ha^{-1} pretilachlor, T_4: 2.5 L ha^{-1} pretilachlor, T_5: 6.0 L ha^{-1} 2,4-dichlorophenoxyacetic acid, T_6: 8.0 L ha^{-1} 2,4-dichlorophenoxyacetic acid and T_7: 10.0 L ha^{-1} 2,4-dichlorophenoxyacetic acid. **Results:** Using one-way analysis of variance, the result showed that pretilachlor and 2,4-dichlorophenoxyacetic acid at all application rates considered in this study significantly increased ($p<0.05$) the proximate parameters of harvested rice grains except for moisture content which was found to increase significantly only in 2,4-dichlorophenoxyacetic acid treated plots. Regardless of the application rates, the 2 herbicides considered significantly enhanced all the mineral contents investigated in this study except for iron content which showed a significant decrease in all the application rates. **Conclusion:** The results concluded that applications of pretilachlor and 2,4-dichlorophenoxyacetic acid in rice cultivation did a lot more than weed management as they significantly enhanced proximate and mineral compositions of harvested rice grains except for moisture and iron content.

Key words: Pretilachlor, 2,4-dichlorophenoxyacetic acid, proximate composition, mineral composition, *Oryza sativa*, staple food

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Rice (*Oryza sativa* L.) is ranked the most important staple food crop for over 50% of the world population[1]. It is extensively cultivated in both the sub-tropical as well as the tropical regions of the world. On a world scale, its cultivation reaches 154 M ha with an annual production of around 426 Mt, meaning an average productivity[2] of 3.9 t ha^{-1}. The continuously growing world population and the consequent increment in the demand for rice have necessitated the need for the realization of the crop's full production potentials[3]. Several biotic and abiotic factors have been identified to restrict the crop's potential performance. Some of these factors include drought, flood, erratic rainfall, extreme temperature, soil erosion, soil nutrient imbalance, high phosphorus fixation, weed competition, pest and diseases infestation[4]. The most severe of all the aforementioned factors is weed competition, which accounts for the greatest yield loss[2]. Uncontrolled weed growth in lowland and upland rice for yield loss was reported in the range[5,6] of 12-81%. Several weed control methods have been reported ranging from cultural control method[4,7], manual weeding[8,9], mechanical weeding[10,11] and chemical control method[12,13]. However, the chemical control method has been reported to be the most effective, less time consuming[2], less tedious[14] and offers an advantage of a better labor efficiency[15]. The influence of herbicides on the yield of rice have been well documented by several studies[14,16,17] but the knowledge on how these herbicides affect proximate and mineral compositions of the harvested rice seeds is still fragmentary. The present study was evaluating the effect of two different herbicides (pretilachlor and 2,4-dichlorophenoxyacetic acid) on the proximate and mineral compositions of *Oryza sativa* (L.).

MATERIALS AND METHODS

Study site: The experiment was conducted at the University of Ilorin Botanical Garden, Southern Guinea savanna zone at the 4°38.920'E-4°39.971'E and 8°27.810'N-8°28.230'N.

Experimental layout and treatment details: The experimental field dimension was 17 by 7 m containing 24 unit plots each measuring 2 by 2 m with a net-plot spacing of 0.5 m. The arrangement was a completely randomized block design with 7 treatments and 4 replicates. The treatments include; T_1: Weedy check, T_2: 1.5 L ha^{-1} pretilachlor, T_3: 2.0 L ha^{-1} pretilachlor, T_4: 2.5 L ha^{-1} pretilachlor, T_5: 6.0 L ha^{-1} 2,4-dichlorophenoxyacetic acid, T_6: 8.0 L ha^{-1} 2,4-dichlorophenoxyacetic acid and T_7: 10.0 L ha^{-1} 2,4-dichlorophenoxyacetic acid.

Soil analysis: Mechanical analysis by the hydrometer method was employed to determine particle size distribution of the soil. The soil pH was determined by the use of a pH meter. Electrical conductivity was resolved using a conductivity meter. Organic matter, ash content and organic carbon concentration were determined using Walkley-Black method[18]. Using an ammonium ion-selective electrode, cation exchange capacity (CEC) was evaluated through ammonium saturation of exchange sites and estimation of saturated ammonium. Base saturation was calculated as[19]:

$$\text{Base saturation (\%)} = \frac{\text{Total bases}}{\text{CEC}} \times 100$$

Soil calcium, magnesium, potassium and sodium were determined by flame photometry.

Planting operation and cultural management: Manual weeding was done on the experimental plots. This was followed by ploughing to loosen the soil in preparation for planting. Viable rice seeds obtained from the African rice center were pre-treated with 2.5 g of dress force per kg rice grain before planting to prevent soil borne diseases. The pretreatment chemical contained 20% w/w thiamethoxam, 2% w/w difenoconazole and 20% w/w metalaxyl-M. The seeds were planted and raised on a nursery bed for 21 days. Thereafter, they were transplanted at the rate of two seedlings per hole and a spacing of 20 by 20 cm. Rice spikelets were harvested from matured plant by manual cutting the panicle from the parent plant. Thereafter, the husk was removed from the harvested spikelets and the rice grains were kept in an air-tight container for mineral and proximate analysis.

Proximate analysis of harvested rice grains: Proximate composition of harvested rice grain was analyzed according to the methods of the Association of Official Analytical Chemists[20]. Moisture content of the harvested rice grains was determined by drying 2 g of sample in an oven at 105°C for 5 h. Ash content was determined by incinerating 2 g of sample in a muffle furnace at 600°C for 3 h, till a greyish ash was formed. Crude fibre was accounted for by extracting 2 g of milled rice sample with hexane in a thimble for 6 h to exclude the fat sample. Subsequently, the sample was hydrolysed using 1.25% tetraoxosulphate (VI) acid to liberate digestible nutrient in the fat. Filtration was then carried out and the resulting filtrate was combusted in a muffle furnace at 600°C for 30 min. It was then cooled in a desiccator and weighed. Crude protein was calculated by multiplying factor (N%×6.25) following a nitrogen (%) determination by the Kjeldahl method using 2 g of milled seed samples. Crude fat was determined by manually extracting 2 g of milled seed samples with 150 mL petroleum ether in a soxhlet extractor at a boiling point of 60-80°C. Total carbohydrate was determined by deducting the sum of ash, crude protein, crude fibre, crude fat and moisture from one hundred.

Mineral analysis of harvested rice grains: Total nitrogen was assayed using the micro-Kjeldahl procedure[21]. Total phosphorus was determined by the ammonium molybdate/vanadate yellow colour method following ternary acid perchloric-nitric-sulphuric acid wet digestion[22], total boron was determined by azomethane-hydrogen method following ternary acid digestion[23]. Atomic spectrophotometer was used in determining total cations: calcium (Ca), magnesium (Mg), copper (Cu), iron (Fe), manganese (Mn) and zinc (Zn). Elements such as sodium (Na) and potassium (K) were analysed using flame photometry following a wet digestion with perchloric-sulphuric ternary acid[23].

Statistical analysis: Data were analysed using one-way analysis of variance (F-test) with Statistical Package for Social Science (SPSS) software version 23.0. Significant test results followed the Duncan multiple range test (DMRT) at 5% level of probability for identification of important contrasts.

RESULTS

Soil physico-chemical properties: The results in Table 1 showed the physico-chemical properties of the experimental plots. The soil textural class was found to be loamy with a pH of 7.3 which is higher than the standard soil pH requirement for rice cultivation. The soil had moderate levels of organic matter, moderately high in total nitrogen. It was high in available phosphorus and potassium (Table 1). The exchangeable calcium was low when compared with standard land quality requirements for rice cultivation in Southern Guinea Savanna Ecological Zone of Nigeria.

Effect of herbicides on the proximate composition of rice: The proximate composition of the harvested grain as influenced by the herbicides is presented in Table 2. Significantly higher moisture content was recorded in T_5 and T_6 treatments while significant least moisture content was recorded in T_2, T_3 and T_4 treatments. Ash content, crude fibre and crude protein of harvested grains were significantly higher in T_3 plants. The T_1 plants had generally the lowest values for all the proximate parameters assessed.

Effect of herbicides on the nutrient composition of harvested rice grains: Regardless of the treatment rates, overall grains harvested from herbicide treated plants recorded a significantly higher ($p<0.05$) nitrogen (except T_3), phosphorus (except T_4), potassium, calcium and magnesium content when compared to the T_1 plants (Table 3). The

Table 1: Soil physico-chemical properties of the experimental soils in comparison to land quality (ranges) for rice cultivation

Soil properties	Experimental soil	Land quality (ranges) for rice cultivation*
Physical		
Sand (%)	55.50	-
Silt (%)	22.00	-
Clay (%)	24.48	-
Textural class	Loamy	-
Gravel	9.23	-
Soil pH	7.30	3.1-5.3
Chemical		
Organic carbon (%)	1.00	0.20-21.0
Organic matter (%)	1.72	0.34-24.6
Nitrogen (%)	0.28	0.02-0.10
Cation exchange capacity (cmol kg^{-1})	2.28	2.12-11.39
Ca^{2+} (cmol kg^{-1})	0.83	0.85-.2.70
Mg^{2+} (cmol kg^{-1})	0.57	0.10-0.84
Na^{2+} (cmol kg^{-1})	1.28	-
K^+ (cmol kg^{-1})	2.51	0.04-0.23
Base saturation (%)	92.85	
Bulk density (g cm^{-3})	8.90	
Available phosphorus (%)	5.24	0.00086-0.0083
Total acidity (cmol kg^{-1})	0.20	

*Source: Aondoakaa and Agbakwuru[24]

Table 2: Proximate composition of rice seed as affected by pretilachlor and 2,4-dichlorophenoxyacetic acid

Treatments	Moisture	Ash content	Crude fibre	Protein	Crude fat	Carbohydrate
	(%)					
T_1	12.28±0.09[c]	1.33±0.01[d]	1.16±0.04[e]	9.15±0.03[e]	1.72±0.10[b]	71.80±0.08[b]
T_2	11.57±0.16[d]	1.47±0.00[c]	1.27±0.01[d]	9.72±0.03[c]	1.88±0.38[a]	73.77±0.07[a]
T_3	11.48±0.04[d]	1.59±0.17[a]	1.54±0.02[a]	10.50±0.08[a]	1.87±0.21[a]	73.02±0.14[a]
T_4	11.88±0.11[d]	1.53±0.12[b]	1.46±0.01[b]	10.13±0.09[b]	1.92±0.02[a]	73.04±0.12[a]
T_5	13.10±0.60[a]	1.52±0.20[b]	1.33±0.01[c]	9.24±0.06[d]	1.77±0.15[a]	73.74±0.11[a]
T_6	13.64±0.07[a]	1.51±0.01[b]	1.23±0.02[d]	9.57±0.07[c]	1.73±0.21[a]	73.25±0.14[a]
T_7	12.91±0.25[b]	1.56±0.35[ab]	1.48±0.01[b]	10.34±0.12[b]	1.84±0.13[a]	73.05±0.14[a]
p-value	<0.001	0.03	<0.001	0.02	0.03	0.03

Values represent Means±SEM, means with the same superscript along the same column are significantly the same at $p \leq 0.05$, n = 4, T_1: Weedy check, T_2: 1.5 L ha^{-1} pretilachlor, T_3: 2.0 L ha^{-1} pretilachlor, T_4: 2.5 L ha^{-1} pretilachlor, T_5: 6.0 L ha^{-1} 2,4-dichlorophenoxyacetic acid, T_6: 8.0 L ha^{-1} 2,4-dichlorophenoxyacetic acid, T_7: 10.0 L ha^{-1} 2,4-dichlorophenoxyacetic acid

Table 3: Mineral analysis of rice seed as affected by pretilachlor and 2,4-dichlorophenoxyacetic acid

Treatments	Nitrogen	Phosphorus	Potassium	Calcium	Magnesium	Iron
	(mg kg^{-1})					
T_1	1185.40±56.05[d]	39.87±4.20[f]	1.86±0.00[e]	7.21±2.54[e]	2.23±0.35[d]	8.80±0.32[a]
T_2	1232.73±14.26[c]	50.42±1.02[e]	2.50±0.27[d]	16.80±0.05[b]	4.74±0.01[b]	6.70±0.55[b]
T_3	912.99±30.16[f]	55.86±3.08[d]	8.29±0.02[a]	17.30±1.53[a]	5.07±0.02[a]	6.23±0.41[b]
T_4	1092.65±22.44[e]	32.42±0.02[g]	7.76±0.02[b]	19.35±0.03[a]	4.88±0.12[b]	7.00±0.21[b]
T_5	1211.08±51.37[b]	59.36±2.14[c]	4.83±0.22[c]	19.28±0.06[a]	4.73±0.02[b]	6.50±0.53[b]
T_6	1563.06±23.08[a]	74.83±0.03[a]	4.29±0.51[c]	12.75±0.05[d]	3.68±0.11[c]	6.53±0.61[b]
T_7	1326.76±63.05[b]	71.36±0.07[b]	2.75±0.00[d]	15.36±0.12[c]	4.55±0.21[b]	7.15±0.56[b]
p-value	<0.001	0.02	0.04	0.03	0.04	0.03

Values represent Means±SEM, means with the same superscript along the same column are significantly the same at $p \leq 0.05$, n = 4, T_1: Weedy check, T_2: 1.5 L ha^{-1} pretilachlor, T_3: 2.0 L ha^{-1} pretilachlor, T_4: 2.5 L ha^{-1} pretilachlor, T_5: 6.0 L ha^{-1} 2,4-dichlorophenoxyacetic acid, T_6: 8.0 L ha^{-1} 2,4-dichlorophenoxyacetic acid, T_7: 10.0 L ha^{-1} 2,4-dichlorophenoxyacetic acid

herbicides tend to significantly limit iron content of the harvested grain when compared to the T_1 plants (Table 3).

DISCUSSION

The result of the soil analysis is an indication that the soil is capable of supporting the growth of rice given the reference standard land quality requirement for rice cultivation. The values reported for most of the physico-chemical properties were within ranges reported previously while assessing land suitable for rice cultivation[24].

It is indicated from the results that plants treated with 2,4-dichlorophenoxyacetic acid (T_5, T_6 and T_7) retained more moisture when compared to pretilachlor (T_2, T_3 and T_4). Moisture content is of importance in storage because the lower the moisture contents of food material, the higher the keeping quality[25], therefore seeds harvested from pretilachlor treated plants have a better shelf life when compared to 2,4-dichlorophenoxyacetic acid. The result is in consonance with the moisture content previously reported[26]. Ash content, crude fibre and crude protein of harvested grains were significantly higher ($p<0.05$) in T_3 plants. This was followed by T_7, T_4 and T_5 plants with significant least ash, crude fibre and protein recorded in the T_1 plants. Higher ash content, protein content and crude fibre in all herbicide treated plants as compared to weedy check could be attributed to reduced weed competition for available resources necessary for proper plant growth and yield as suggested by an earlier report[27]. The values obtained for ash, fibre and protein content in this study are slightly higher than those from an earlier report[26]. Crude fat and carbohydrate content of harvested grains from the T_1 plots were found to be significantly lower compared to all other considered treatments. Significantly lower fat and carbohydrate content recorded in T_1 plots could be as a result of serious competition for moisture, light, nutrient and space between the weeds and the rice crop. The values were in conformity with those recorded from a study on mineral content, proximate composition and fatty acids analysis of aromatic and non-aromatic Indian rice[26,28].

Significantly lower iron content was recorded in all application rates for both herbicides considered when compared to the weedy check. However, no significant differences were recorded in plants receiving herbicide treatments. The general increase in nitrogen, phosphorus, potassium, calcium and magnesium in all herbicide treated plants could be due to a better crop performance resulting from reduced weed competition for space, water and available nutrient. Workers have attributed increase in rice yield and nutrient composition to a better plant performance owing to reduced competition between the crop and the weed; promoting increased availability of water, light and nutrients[29]. A researcher has adduced the greater nutrient uptake in spring barley under chemically suppressed weed growth condition to reduced weed competition[30]. Significant lowest nitrogen, phosphorus, potassium, calcium and magnesium in the weedy check plots could be traced to enormous competition for moisture, space, light and nutrient between the weeds and the rice crops[28]. Significantly lower iron content obtained in all herbicide treated plots when compared to the weedy check could be due to decreased soil iron availability caused by reduced soil microbial activates. In rice plant, increased soil pH and low soil microbial activity have been described as being vital to soil iron availability[31]. The importance of microbial biomass in the availability of trace elements in the soil has also highlighted[32]. The values obtained for mineral content of rice in this study aligns with those reported in a previous experiment[26]. Further studies need to be carried out to determine that; is the harvested grains containing the herbicides residue in ensuring crop safety for consumers?

CONCLUSION

In this study weed management in rice cultivation using pretilachlor and 2,4-dichlorophenoxyacetic acid within the application rates were significantly enhanced all the proximate parameters except for moisture content which was only enhanced in 2,4-dichlorophenoxyacetic acid. The 2 herbicides at all the concentration were significantly improved all the mineral content investigated in this study except for iron content which showed a significant decrease in all the application rate considered for both herbicides. The 2 herbicides can therefore be regarded as quite indispensable in maintaining the quality of rice while simultaneously combating the menace of weeds in rice cultivation.

SIGNIFICANCE STATEMENT

This study established the suitability of 2 herbicides; pretilachlor and 2,4-dichlorophenoxyacetic acid in serving the dual purpose of weed management and enhancement of the quality of *Oryza sativa*. This area of study is thus of significance to not only plant biologists but also to agriculturists in the field of weed management.

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