Assessment of Soil Physico-Chemical Properties in Selected Natural Habitats of The Wild Rice (*Oryza Longistaminata)* and their Effects on the Species Morphological Characters

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Abstract: *The aim of this study was to assess variation in some soil physical and chemical properties among four selected natural habitats of the wild rice species (Oryza longistaminata) in Tanzania, and their effects on the species morphological characters. Oryza longistaminata is a perennial wild rice species with agronomically important genes, including genes for tolerance to biotic and abiotic stresses that can be used in rice breeding. In Tanzania O. longistaminata grows sympatrically with the cultivated rice (Oryza sativa) in most rice cultivating areas. The selected natural habitats assessed were located in four districts, namely Bagamoyo, Kibaha, Kilombero and Mbarali. Soil samples were collected at the depth of 0 - 20 cm from the four districts and analysed in the laboratory for soil physico-chemical properties using standard protocols. The species morphological characters were assessed based on the morphological descriptors for wild and cultivated rice species developed by Bioversity International and International Rice Research Institute. One way ANOVA was used to determine the extent of variation in soil physico-chemical properties (parameters) among the four natural habitats of O. longistaminata. Canonical Correspondence Analysis (CCA) was used to determine the effects of assessed soil parameters on the morphological characters of O. longistaminata in the study areas. The study revealed variation in soil physico-chemical properties among the districts. Statistically there were significant differences among the habitats (districts) for most of soil physico-chemical properties investigated. In addition, the assessed soil physico-chemical properties were found to influence variation in morphological characters among O. longistaminata populations from different habitats.*

Keywords: Natural habitat, *Oryza longistaminata*, Soil physico-chemical properties, Morphological characters, Wild rice.

Introduction

Soil is the unconsolidated mineral on the surface of the earth that serves as a natural medium for plant growth (Imran *et al*., 2010). It is the main reservoir

of plant nutrients and water. The physical and chemical (physico-chemical) properties of the soilvary drastically in time and space, depending on the texture, climate, organic matter content, soil biological activity and tillage practices (Alletto *et al*., 2010). Tillage is one of the main causes of spatial and temporal variability in soil physical properties, but its effects have not always been consistent depending on the location and soil type (Green *et al*., 2003). Soil plays an important role in the formation and heterogeneity of habitats that may result into changes in vegetation structure and plant diversity (Rodrigues *et al*., 2018). Therefore, the structure and diversity of vegetation are determined by the discontinuous distribution of biotic and abiotic factors in the habitat. Spatial variation in soil physico-chemical properties occurs as the result of soil forming factors, including time, nature of parent material, topography, climate and organisms (Sağlam *et al*., 2011). Soil physico-chemical properties have effects on plant growth and consequently plant morphology. Evaluation of soil spatial variation is important in agricultural and environmental researches, since the information on soil properties has agronomic applications (Sauer *et al*., 2006). Soil, as the main reservoir of plant nutrients and water is one of the key environmental factors that may affect plant morphological characters.

Morphological variation among plant populations may be caused by either genetic factors or environmental factors (Crispo, 2008). Among the environmental factors, soil properties are the key factor that may influence plant morphological characters, hence morphological variation among populations or sites. There are several soil physical and chemical properties which play various roles in the soil, hence influencing the morphological characters of various plant species, including *O. longistaminata*. For example, soil pH determines the acidity or alkalinity of the soil, which affects the chemical reactions between water and soil minerals (Imran *et al*., 2010). There is a strong relationship between soil pH and nutrient availability because the uptake of various plant nutrients is pH dependent (Marschner, 1986). Moreover, most of the primary nutrients, such as nitrogen, phosphorus and potassium, as well as secondary nutrients, such as calcium, magnesium and sulphur are best utilized by plants at pH ranging from 5.5 to 7.9 (Imran *et al*., 2010). Likewise, several other soil physico-chemical properties of the soil play roles in the soil that may influence plant morphological characters at different levels.

The present study was conducted to assess soil physico-chemical properties in four natural habitats of the wild rice species, *O. longistaminata* and the influence of such properties on morphological characters of the species, which is the only perennial wild rice species in Tanzania. The species is

potential source of genetic resources for rice breeding as ithas genes for tolerance to biotic and abiotic stresses (Kiambi *et al*., 2005). These genes can be introgressed into the cultivated rice in order to improve rice quality and yield or productivity. Knowledge on the soil physico-chemical properties and their effects on the morphological characters of *O. longistaminata* is essential not only for understanding spatial variability in soil characteristics among the natural habitats of the species, but also for determination of a suitable or optimum soil characteristics and conditions for better growth performance of this plant species that may result into higher yield or productivity. However, prior to this study no comprehensive study had been conducted in the study area to assess soil physico-chemical properties in natural habitats of *O. longistaminata* and their effects on the species morphological characters, therefore the information on variation in soil properties and their effects on the morphological characters of wild rice, *O. longistaminata* was inadequate. This study was therefore conducted in order to bridge this knowledge gap.

Materials and Methods

Location of the Study Areas

This study was carried out in four selected natural habitats of the wild rice species (*O. longistaminata*). The natural habitats of O. *longistaminata* were located four districts of Tanzania, namely Bagamoyo, Kibaha, Kilombero and Mbarali (Figure 1). The selection of these study areas was based on availability of the species in high abundance.

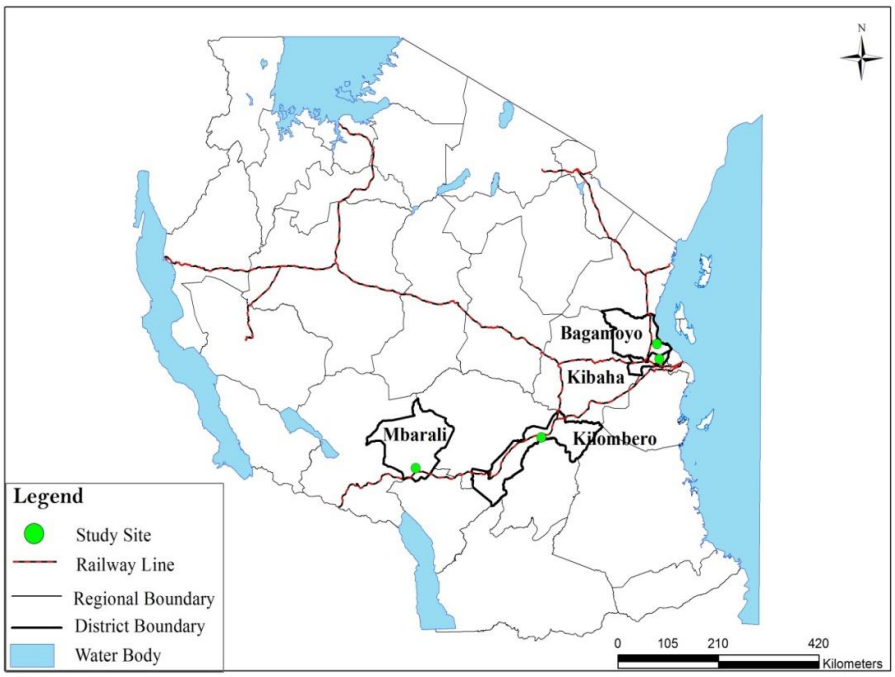

Figure 1: **The map of Tanzania showing the location of study areas (sites)**

Sampling Methods
The study methods involved collection and characterization of both soil samples and *O. longistamata* plants from the four populations. Soil characterization was based on their physico-chemical parameters while characterization of *O. longistminata* was based on their morphological characters.

Soil Sampling Methods
A total of 25 soil samples (consisting of two composite samples each) were collected from the points of collection of *O. longistaminata* data (samples) in each study site for laboratory determination of soil physico-chemical properties. At each sampling point soil samples were collected at the depth of 0 - 20 cm by using soil auger (Sagˇlam *et al*., 2011). This depth was considered because the *O. longistaminata* roots are mostly localized within 0 to 20 cm depth. The two soil samples from each sampling point were thoroughly mixed up before laboratory analysis. In the laboratory the soil physico-chemical properties were determined were soil texture, soil pH, soil organic matter, soil total nitrogen, percentage base saturation, available phosphorus content and cation exchange capacity. These were determined as follows:

Soil texture was determined by using the pipette method as described by Gee and Bauder (1986). The method involved a pre-treatment stage where 80 g of dried, ground soil sample was weighed into a 250 ml flask. 100 ml of water was added followed by 10 ml of 1 M NaOAC and centrifuged for 10 minutes at 1500 revolutions per minute (rpm). The supernatant, which was a clear solution, was poured off and the remaining soil suspension was washed with 50 ml of distilled water, centrifuged and decanted again. This pre-treatment was done to remove carbonates and soluble salts. In order to remove organic matter 4 ml of H_2O_2 was added and the samples were heated until frothing ceased. The purpose of this pre-treatment was to remove soluble salts and organic matter.

Separation of the sand sized particles was done by pouring the treated soil through a 270 mesh (53 μm) sieve followed by washing the sand. All the washings were collected in a 1 litre cylinder. The soil suspension collected in a cylinder was stored for analysis of silt and clay. The sand on the 270 mesh (53 μm) sieve was collected in a weighing dish, dried at 105^0 C and weighed. Determination of silt (2 - 20 μm) and clay (< 2 μm) was done by using the pipette method as described by Gee and Bauder (1986). To the filtrate in a 1 litre cylinder obtained above, 10 ml of hexametaphosphate solution was added and then made to 1 litre with distilled water. The cylinder was covered with a stopper and shaken end-over-end for one minute.

After settling for 4 to 6 minutes at 22^{0} C, a 25 ml volume sub-sample was taken from a depth of 10 cm using a pipette. The solution was placed in a pre-weighed evaporating dish and dried at 105^{0} C. The residue represented the silt fraction. Another 25 ml was taken at a depth of 10 after 6 to 7 hours, and dried at 195^{0} C. The residue represented the clay fraction.

All fractions dried in the oven were cooled in a desiccator before weighing. Determination of the weight of the remaining treated soil was done by adding 10 ml of $CaCl_2$ and 1ml of 1 M HCl to the remaining suspension in the cylinder to prevent the formation of calcium carbonate, and to cause flocculation. After flocculation the clear solution was removed using a siphon and discarded. The soil flocculant was poured into an evaporating dish, dried at 105^{0} C and weighed. The purpose of weighing the treated sample was to compensate for the difference between the original soil weight and the remaining weight after the loss of soil during pre-treatment, solution loss, sieving loss, and the samples removed for pipette analysis. The total oven dry weight of the treated sample was used as a base for calculating the size of the soil fractions. The total weight was obtained using the following formula:

$$Ws + Wp + Wr = Wt$$

Where, Ws = Weight of the sand fraction, Wp = Weight of the fractions taken by pipette (silt and clay), Wr = Weight of the remaining fraction, and Wt = Total oven dry weight.

Data were presented as percentage of sand, silt and clay and texture was determined based on the International Soil Science Society System (ISSSS) textural classification system (Gee and Bauder, 1986).

Soil pH was measured electrometrically using a metrohm E510 pH meter. This was done using 1:1 soil: water mixture, which was allowed to equilibrate for 30 minutes (McLean, 1982). The pH of a stirred suspension was read from the pH meter and recorded as pH in water. To determine electrical conductivity a saturated paste of 2 mm sieved soil was prepared by adding 150 g of soil sample in 500 mL capacity beaker using deionized water. Then the paste of soil samples was introduced to Cyber scan 500 conductometer.

Determination of soil organic matter involved determination of soil organic carbon, which was determined by Walkley-Black potassium dichromate method as described by Nelson and Sommers (1982). For each sample, a 200 mg air-dry soil sub-sample was accurately weighed into 500 ml wide mouth

Ertemmeyer flask to which 20 ml of 1 M $K_2Cr_2\ 0_7$ was added and swirled to disperse the soil and the solution. Then 20 ml of concentrated H_2SO_4 was rapidly added. After shaking the soil-dichromate mixture was left to stand for 30 minutes after which 200 ml of distilled water was added. The resulting solution was then titrated against 0.5 M FeSO4 using O-phenanthroline.

The percentage organic carbon was calculated as follows:

$$\% \text{ Organic C} = \frac{(\text{meg K2 } Cr_2O_2 - \text{meg FeSO4})\ (0.3) \times f}{\text{Weight in g of dry soil}}$$

Where, f = 1.3, a correction factor used to account for carbon that does not oxidize in the procedure.

The organic matter content was then obtained by multiplying the organic carbon concentration by 1.72 (Nelson and Sommers, 1982).

Total soil nitrogen was determined by using semi-micro Kjeldahl digestion (Bremmer and Mulvaney, 1982) and colorimetric determination of the resultant ammonium by color reaction (Indo-phenol blue method). In this method, 0.2 g of air-dry soil was weighed into a Kjeldahl flask. To the sample 0.2 g of copper metal, 0.1 g Selenium (Kjeldahl tablets) and 15 ml of sulphuric acid-salicylate mixture were added. The sulphuric acid-salicylate ($H_2SO_4\ Na_3S_2O$) mixture was used in order to include the nitrate and nitrite forms of nitrogen present in the soil. In order to oxidize the organic matter, 2 ml of hydrogen peroxide was added and then heated to boiling point for 5 minutes. In the mixture, 4 g of K_2S0_4 was added and the mixture digested at 430^0 C using a thermal Kjeldahl apparatus. The nitrogen present in the sample was thus converted to ammonium form and the ammonium was determined calorimetrically using a spectrophotometer. The amount of total nitrogen in the sample was obtained from the calibrated curve of standard NH_4^+.

Available soil phosphorus was extracted using Olsen and Kurtz method, as described by Emteryd (1989). Ortho-phosphate was determined calorimetrically using a spectrophotometer from Ascorbic Acid Method (Allen, 1989). The amount of phosphorus in the sample was obtained from a calibration curve of standard phosphate ion.

Exchangeable bases (Sodium, Magnesium, Potasium and Calcium) concentration was determined by flame emission spectrophotometer, according to Allen (1989). Fivegrams of oven-dry soil samples were put into 250 ml conical flasks. Exchangeable bases were then extracted from the soil samples by introducing 100 ml of 0.4 M Lithium chloride acetate in each flask. The extractions involved shaking for 2 hours and filtering using a suction pump. The filtrates collected were then analyzed for exchangeable cations $Ca2^{+}$, Mg^{2+}, Na^{+} and K^{+} using an Atomic Absorbency Spectrophotometer (Perking Elmer 3100).

To determine Cation Exchange Capacity (CEC) of the soil, five grams of oven-dry soil was weighed into a conical flask and 100 ml of the saturated potassium chloride solution was added. Samples were shaken for 2 hours and filtered using suction pump. The filtrates were analyzed for exchangeable bases. The soil suspensions were rinsed onto the filter paper with 200 ml alcohol until the electrical conductivity of alcohol reached 5 mS per centimeter. This was done to remove excess un-adsorbed Lithium. Then Lithium was exchanged with 100 ml of 1 M potassium chloride solution. This was shaken and filtered and the filtrates collected were then analyzed for CEC using an Atomic Absorbency Spectrophotometer (Perking Elmer 3100).

Assessment of Morphological Characters of *Oryza longistaminata*

Morphological data were collected based on descriptors for wild and cultivated rice species developed by Bioversity International and International Rice Research Institute (IRRI). In each sampling site *O. longistaminata* individuals were randomly sampled at 25 different points (sampling points) within an area of 10000 m^2. A total of 25 samples were collected from each habitat (study site). At each sampling point a total of 5 randomly selected individuals were sampled and their average was calculated and recorded as a single sample. i.e. each of the 25 samples collected from each habitat is the average of 5 individuals, hence a total of 125 individuals were sampled from each habitat. Twelve selected quantitative morphological characters were assessed from each individual sample. The characters assessed were culm length, flag leaf length, flag leaf width, penultimate leaf length, penultimate leaf width, panicle length, number of primary branches per panicle, number of primary branches per node, number of nodes with more than two primary branches, number of grains per panicle, grain length and grain width.The average from four randomly selected *O. longistaminata* individuals were randomly were and sampled from each sampling point In each study site, *O. longistaminata* individuals were randomly sampled.

The culm length was measured (using a tape measure) from the ground level (base of the plant) to the base of the panicle and panicle length was measured from base of the panicle to its tip. Flag leaf was measured from the ligule to the tip of the blade. Penultimate leaf which is the highest leaf below the flag leaf was also measured from the ligule to the tip of blade. The leaf width was measured at the widest portion of the leaf. Awn length was measured from the base to its tip using a ruler. Grain length was measured as the distance from the base of the lower most glume to the tip of the lemma or palea. The grain width was measured as the distance across the lemma and palea at the widest point. All measurements were done using either a tape measure or a ruler. Grain number per panicle and number of primary branches per panicle and number of nodes with more than two branches were determined by counting the respective parts. Measurement, assessment and counting were done soon after heading of *O. longistaminata* individuals.

Data Analysis

Both soil and morphological data were analysed using SPSS version 16 software package. Summary statistics such as mean, standard deviation and standard error of the mean were determined for each of the soil physico-chemical properties and morphological characters assessed. One-way ANOVA was used to determine the significance of differences between sites (habitats) for all assessed soil parameters. Where the comparison showed significant differences, multiple comparison tests were performed. Canonical Correspondent Analysis (CCA) was used to determine the effects of soil physico-chemical parameters on the morphological characters of *O. longistaminata* in the four habitats (districts) in which soil data was used as environmental data and the data on *O. longstaminata* quantitative morphological characters was used as species morphological data. The CCA was based on the mean values of the soildata and the species morphological data.

Results

Variation in Soil Physico-chemical Parameters Among the Four Habitats

The statistical analysis using one-way ANOVA showed significant differences among the study sites (habitats) at $p \leq 0.05$ for all assessed soil physico-chemical properties except the percentage silt content and phosphate ion concentration. The variation in soil physico-chemical properties was as follows:

The percentage Silt Content

The results showed that the percentage silt content of the soils was highest in soil sample from Kilombero with the mean of 17.77±1.536 % followed by that from Bagamoyo (with the mean of 16.035 ± 2.792 %) and the lowest was in soil sample from Kibaha (with mean of 11.705 ± 2.938%).

Phosphate Ion Concentration

The mean phosphate ion concentration in the soil was highest in soil sample from Mbarali, which ranged from 0.11 to 11 mg/kg with a mean of 0.703 ± 0.491 mg/kg followed by that from Bagamoyo which ranged from 0.11 to 3.14 mg/kg with the mean of 0.611 ± 0.169 mg/kg and lowest in soil samples from Kibaha that ranged from 0.05 to 0.18 with a mean of 0.118 ± 0.009 mg/kg.

Soil pH

The pH of the soil samples from the four habitats or districts ranged from slightly acidic to slightly basic. The pH values were highest in soil samples from Bagamoyo, which ranged from 5.03 to 8.86, while that of the soil samples from Kibaha ranged from 5.0 to 7.73. The soil samples from Kilombero had pH value that ranged from 5.56 to 7.06 and soil samples from Mbarali had pH which ranged from 7.01 to 7.86.

The percentage clay content

The percentage clay content was highest in soil samples from Mbarali and ranged from 64% to 95% with the mean of 82 ± 1.92%, followed by soil from Kibaha that ranged from 35% to 98% with the mean of 78 ± 4.44 %. The soil samples from Kilombero had the lowest clay content that ranged from 2% to 84% with the mean of 31.41±0.079%.

The percentage sand content

The percentage sand content of the soil samples from Bagamoyo ranged from 0.2% to 65%, the mean was 22.84%, while that of Kibaha ranged from 0.5% to 30%, the mean was 7.75 ± 2.37. The soil samples from Kilombero had percentage sand content that ranged from 1% to 80% with the mean of 48.55 ± 5.89% and the soil samples from Mbarali had percentage sand content ranging from 0.2% to 30% with the mean of 3.00 ± 1.44%.

Percentage Water Content

The percentage water content of the soil samples was highest in soil samples from Mbarali which ranged from 85% to 90% with mean of 88.05 ± 0.499%, followed by soil samples from Kibaha that ranged from 30% to 90% with the mean of 70.14 ± 4.227%. The percentage water content was lowest in soil samples from Kilombero which ranged from 5% to 75% with the mean of 36.36 ± 4.50%.

Electrical conductivity (electro-conductivity)
Electro-conductivity of the soil ranged from 166.5 to 687 mS/m with a mean of 406 ± 125 mS/m for Bagamoyo soil, from 133 to 856 mS/m for Kibaha soil with a mean of 385.773 ± 49.549 mS/m. Mbarali soil samples had electro-conductivity that ranged from 66 to 157 mS/m with a mean of 105.705 ± 5.695 mS/m and that of Kilombero had 36.1 to 180 mS/m with a mean of 66.777 ± 7.426 mS/m.

The soil Organic Matter Content
The organic matter content was highest in soil samples from Kilombero, which ranged from 1.8 to 3.95% (mean of 2.50 ± 0.130 %) followed by soil samples from Mbarali, which had organic matter content ranging from 1.01 to 2.93% (mean 2.27 ± 0.093 %) whereas soil samples from Kibaha had the lowest organic matter content that ranged from 0.11% to 2.99% with a mean of 1.26 ± 0.200 %.

Total Nitrogen concentration
The total nitrogen concentration was highest in soil samples from Kilombero that ranged from 0.203 mg/Kg to 0.41 mg/Kg with a mean of 0.288 ± 0.012 mg/Kg and lowest in soil samples from Kibaha which had nitrogen concentration that ranged from 0.01 to 0.31 mg/Kg with a mean of 0.120 ± 0.012 mg/Kg. Nitrogen concentration for Bagamoyo soil samples ranged from 0.03 mg/Kg to 1.2 mg/Kg with a mean of 0.208 ± 0.054 mg/Kg and that of Mbarali ranged from 0.1 to 0.26 mg/Kg with a mean of 0.202 ± 0.008 mg/Kg.

The percentage water-filled air space

The mean percentage of water-filled air spaces was highest in soil samples from Kibaha (71.73%) followed by the Mbarali's soil samples (70.27%) and lowest in soil samples from Kilombero (43.21%).

The Cation Exchange Capacity (CEC)

The mean values for CEC of the four study sites, Bagamoyo, Kibaha, Kilombero and Mbarali were 66.65 ± 3.72%, 72.79 ± 2.97, 30.25 ± 1.19% and 55.24 ± 0.56% respectively. Statistically there was significant difference in CEC of the soil samples among the four study sites.

Exchangeable bases

Statistical analysis showed significant difference in exchangeable bases concentration between soil samples from the four study sites ($p < 0.01$). Generally, soil samples from Bagamoyo and Kibaha had higher

concentrations of exchangeable bases (Ca, K, Mg and Na) than soil samples from Kilombero and Mbarali. The soil samples from Kilombero had the lowest concentration of all the four bases as shown in the Table 1.

Table 1: The Mean Concentrations of the Exchangeable Bases in the Four Habitats

	Mean Concentrations of Exchangeable Bases (mg/kg)			
Study Site	**Na**	**K**	**Ca**	**Mg**
Bagamoyo	1.584 ± 0.241	5.444 ± 0.171	10.693 ± 0.365	6.391 ± 0.310
Kibaha	1.982 ± 0.147	4.858 ± 0.132	9.701 ± 0.313	6.485 ± 0.352
Kilombero	0.129 ± 0.004	1.785 ± 0.146	4.625 ± 0.142	2.677 ± 0.116
Mbarali	0.215 ± 0.016	3.074 ± 0.081	6.223 ± 0.152	3.251 ± 0.173

Variation in morphological characters among the study sites (habitats)

The statistical analysis of the species morphological data using one-way ANOVA showed significant differences among the study sites (habitats) for all assessed morphological characters, except grain length. The results further indicated that *O. longistaminata* individuals from Mbarali had highest values for most of the morphological characters assessed followed by those from Kilombero while individuals from Kibaha had the lowest values for most of the morphological characters assessed. Individuals from Mbarali had highest values of flag leaf width, penultimate leaf width, panicle length, number of primary branches per panicle, number of primary branches per node, number of nodes with two or more primary branches and number of grains per panicle. Individuals from Kilombero had highest values of culm length and penultimate leaf length. Individuals from Kibaha had lowest values for all assessed morphological parameters except the awn length and grain length.

The Effects Soil Physico-chemical Properties on Morphological Characters of *Oryza longistaminata* Populations

The analysis of species-environment relationship was done using Canonical Correspondence Analysis (CCA) in which species morphological data was used as vegetation data and soil physico-chemical properties (parameters) as environmental data. Species-environment correlation matrix based on CCA showed strong relationship between the species quantitative characters and the assessed soil physico-chemical parameters. That is, variation in morphological characters among *O. longistaminata* individuals from the study area was highly related to variation in soil physico-chemical

parameters. The results further showed that the CCA ordination in the first three axes was constrained by assessed soil physico-chemical parameters. The first three axes accounted for all (100%) of variations among the *O. longistaminata* samples. That is, the first three eigenvalues were canonical, but the fourth was not, since only three independent constraints could be formed from the soil variables.
Results of the present study also showed that in Bagamoyo among the soil parameters that hadsignificant effects on the morphological characters of *O. longistaminata* were soil electro-conductivity and concentration of exchangeable bases namely, Ca, Mg, K and Na. These soil physico-chemical parameters were found to have moreinfluence on: flag leaf length and width, penultimate leaf length and width and grain length. In Kibaha and Kilombero the soil physico-chemical properties that significantly affected or influenced the morphological characters of *O. longistaminata* were of silt and sand contents as well as total nitrogen concentration. These soil physico-chemical variables influenced awn length, culm length and grain width. In Mbarali soil properties which influenced morphological characters of *O. longistaminata* were cation exchange capacity, soil pH, phosphate concentration, percentage clay content, percentage water content and percentage water-filled pore spaces of the soils. These soil factors had effects on several morphological characteristics, including number of grains per panicle, number of primary branches per node, branching patterns of the panicles and number of nodes with more than one primary branch per node. Soil organic matter content had influence on the panicle length (Figure 2).

The results further showed variation in the extent to which different soil parameters influenced morphological characters of *O. longistaminata* in the four study sites. Therefore, the degree of influence of soil parameters on the morphological characters of *O. longistaminata* varied not only between one soil parameter and another, but also between one site or habitat and another. This is denoted by variation in length of arrows in simple ordination plot (Figure 2). Soil parameters indicated by longer arrows had relatively greater influence on the morphological characters than those indicated by shorter arrows. The results indicated that the percentage water content, phosphate ion concentration, percentage clay content, exchangeable base concentration, pH, percentage sand content and cation exchange capacity had much more influence on the morphological characters of *O. longistaminata* individuals in the study areas. On the other hand, organic matter content, nitrogen concentration and percentage silt content had relatively low effects on the morphological characters of *O. longistaminata* individuals as denoted by shorter arrows in the simple ordination plot (Figure 2).

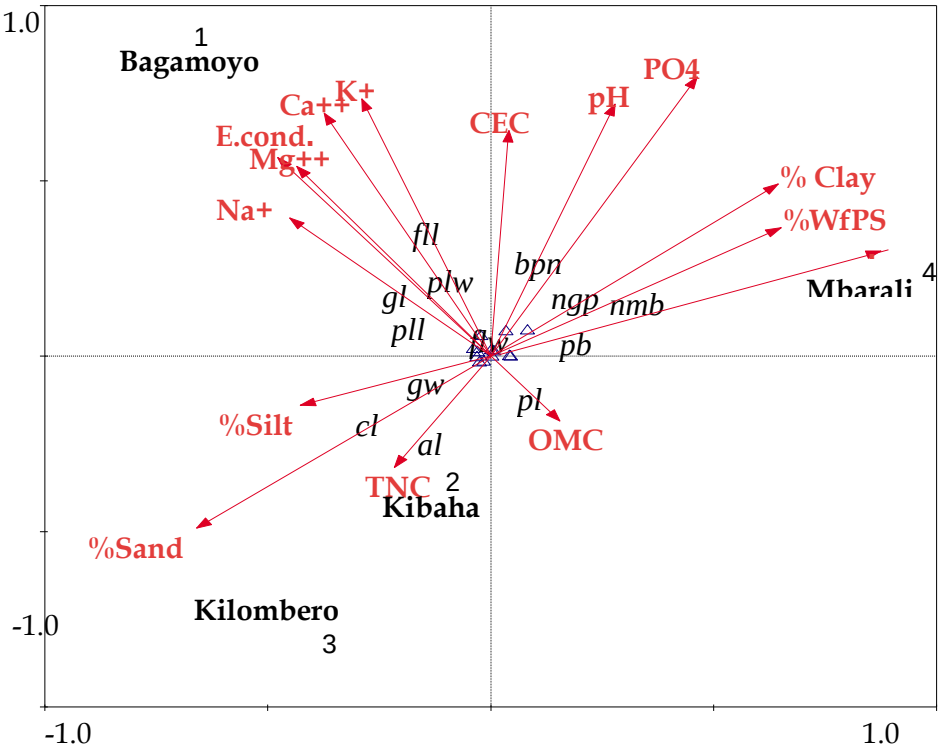

Figure 2: **Simple ordination showing the soil physico-chemical properties affecting the morphological characters of *O. longstaminata* in the four selected habitats**

Legend: al = awn length, gl = grain length, ngp = number of grains per panicle, gw = grain width, pl = panicle length, bp = branching pattern of a panicle, pll = penultimate leaf length, plw = penultimate leaf width, bpn = number of primary branches per node, fll = flag leaf length, flw = flag leaf width, nmb = number of nodes with more than two branches per panicle.

Ca++ = calcium ion concentration, K+ = potassium ion concentration, Mg++ = magnesium ion concentration, Na+ = sodium ion concentration, E.cond. = electro-conductivity, OMC = organic matter content, TNC= total nitrogen concentration, PO_4^-= phosphate ion concentration, CEC = cation exchange capacity, WfPS = percentage water filled pore space, %Sand = percentage sand content, %Clay = percentage clay content, %Silt = percentage silt content.

Discussion

Variation in Soil Physico-chemical Parameters in the Four Natural Habitats of *Oryza longistaminata*

Results of the present study showed spatial variation in soil physico-chemical properties among the four study areas (habitats). Comparison results of soil samples from the four study sites (habitats) based on the soil physico-chemical parameters using One Way Analysis of Variance (ANOVA) showed significant differences among habitats for all parameters studied, except phosphate ions concentration and percentage silt content.

This finding seems to be consistent with what was reported by several other studies that soils tend to vary with time and space (Onweremadu and Akamigbo, 2007; Alletto *et al*., 2010). Studies show that spatial and temporal variation or variability in soil properties between or among localities or sites is something common, and may be caused by various factors (Asadu and Enete, 1997; Green *et al*., 2003; Onweremadu, 2007; Onweremadu, 2008; Sagˇlam, *et al*., 2011). According to studies, there are several factors that can contribute to spatial or temporal variation in soil physico-chemical properties including: changes in lithological origin (Onweremadu, 2008), land use (Asadu and Enete, 1997; Onweremadu, 2007), landscape position (Onweremadu, 2008), tillage practices (Green *et al*., 2003) and soil forming factors (Sagˇlam, *et al*., 2011). The observed variations and similarities in soil physico-chemical properties among the four study areas or habitats are likely to have been caused by some of the factors stated above. Each of the factors may have influence on a particular soil physico-chemical property, or particular soil physico-chemical properties in a particular area. For example, land use and/or tillage practices may significantly influence the levels or concentrations of Ca, K, P, Mg, total nitrogen and organic matter (Akamigbo, 1999). Therefore, the spatial variation in these soil parameters among the study areas (habitats) is probably the result of variation in land use or tillage practices among the study areas, especially in the major rice cultivating areas, such as Mbarali and Kilombero. In general, the variation or variability in soil physico-chemical properties in the areas investigated is likely be caused by variation in climatic conditions, topographical factors, tillage practices, nature of the rocks and soil forming factors.

Further analysis of the results of this study showed or revealed some similarities (lack of significant differences) between Bagamoyo and Kibaha soil samples for most of the soil parameters assessed. Likewise, there were slight similarities (no significant differences) between Kilombero and Mbarali soil samples for most of the soil parameters assessed. In Bagamoyo and Kibaha soil samples the similarities were found in the following soil

properties: percentages of clay, sand and silt contents, phosphate ion concentration, electro-conductivity, nitrogen concentration, and cation exchange capacity. In Kilombero and Mbarali soil samples the similarities were found in the following soil physico-chemical properties: soil characteristics, silt content, electro-conductivity, organic matter content, total nitrogen content, phosphate ion concentration, sodium ion concentration and magnesium ion concentration. Generally, soil samples from Kilombero and Mbarali had higher values for most of the soil parameters investigated than soil samples from Bagamoyo and Kibaha. This is may be due to various reasons. For example, low clay and silt contents in the soil may result from strong weathering and leaching of clay particles (Ihem *et al*., 2014).

Among the soil physico-chemical parameters investigated in the present study, soil pH isone of the most important parameters because of its great influence on other soil parameters. The soil pH influences not only on chemical reactions between water and soil minerals, but also on the availability of several other soil parameters, including nutrient availability in the soil (Imran *et al*., 2010). Nutrient availability, which also influences soil fertility, affects growth performance of the plants, including *O. longistaminata*. According to literature, most of the primary nutrients (such as nitrogen, phosphorous andpotassium) and secondary nutrients (such as calcium, magnesium and sulphur) are best utilized by the plants when the pH range of the soil is 5.5 - 7.9 (Imran *et al*., 2010).In the present study, the pH of the soils in the study sites was within this range, implying that there was optimum soil condition for nutrients utilization by *O. longistaminata* within the study areas. Meanwhile, the uptake of most of the micronutrients takes place at low pH.

The Effects of Soil Physico-chemical Properties on Morphological Characters of *Oryza longistaminata* in the Four Habitats

Both soil characterization results and species morphological characterization results showed significant differences among the study sites (districts) for most of the parameters assessed. The correspondence between the two sets of results may imply causal relationship. Although variation in morphological characters among *O. longistaminata* individuals from the four habitats could be caused bycompetition for resources among plant individuals or species growing in a particular habitat (Sauer *et al*., 2006), species-environment correlation matrix based on Canonical Correspondence Analysis (CCA) showed strong relationship between the species quantitative characters and assessed soil physico-chemical parameters. In general, the results of this study indicated that soil physico-chemical properties influenced variations in morphological characters among *O. longistaminata* populations from the four districts.

The role of ecological factors, including soil characteristics in influencing the extent and distribution of genetic diversity in wild relatives of crop has also been emphasized by several other studies (Nevo *et al*., 1981; Nevo *et al*., 1983). Studies conducted using different genetic markers have quite clearly established the way in which genetic diversity of the plant species varies with variation in soil type (Owuor *et al*., 1997). Generally, the plants (individuals or populations) growing in areas with similar soil characteristics are more likely to be morphologically similar than those growing in areas with different soil characteristics. Literature shows that there is strong relationship between plants' morphological characters and the environmental conditions of the habitat in which the character evolved (Nevo *et al*., 1981). However, plasticity can allow rather genetically similar populations to occur in widely differing environments (McNeill, 1997). Variation among plant individuals growing in habitats with different ecological or soil characteristics may be due to their adaptation to the habitats. According to the study by Rao and Hodgkin (2002) adaptive genetic variation, which is usually quantitative is responsive even to small habitat differences.

Conclusion

The study revealed spatial variation in soil physico-chemical properties in the four natural habitats of *O. longistaminata* investigated, implying that there was significant difference in soil physico-chemical properties among the four *O. longistaminata* habitats (districts) studied. The variations in soil properties observed in this study are likely to be caused by variation in soil forming factors, such as climate, topography and landscapes position among the four habitats. Moreover, the study revealed that soil physico-chemical properties have influence on the morphological characters of *O. longistaminata*. Generally, the species (*O. longistaminata*) was found to prefer soils with pH that ranges from slightly acidic to slightly basic.

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