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INFLUENCE OF SELECTED SOIL PHYSICAL PROPERTIES AND INVERTASE ENZYME ACTIVITY ON YAM GROWTH IN JOS NORTH AREA OF PLATEAU STATE

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ABSTRACT

Soil properties and soil enzymes are distinct characteristics of the soil that can either stimulate or hinder the growth and performance of crops, bringing about a good yield or low yield in different locations. This experiment was conducted on the influence of selected soil physical parameters and invertase enzyme activity on yam performance in selected locations in Jos North area of Plateau State. Four experimental sites were selected based on simple random sampling method and they include two non-yam producing areas (Federal College of Forestry, Jos and Maza) and two yam producing areas (Babele and Bida bidi) which formed the treatments. Soil samples were freshly collected from 0-15 cm and 15-30 cm depth.Some selected soil physical properties such assoil pH, water holding capacity and bulk density were analyzed using completely Randomized Design (CRD). The samples were incubated for seven days after the addition of enzyme substrates and other reagents. Samples were filtered daily and their optical density (O.D) taken using spectrophotometer for the invertase activity. The equivalence of the optical density was extrapolated on a glucose:fructose standard curve. The result showed that Babele sample gave the lowest Bulk density value of 0.60±0.02 at 0-15 cm and 1.00±0.02 at 15-30 cm while Bida bidi gave the highest bulk density value of 1.75±0.04 at 0-15 cm and Maza (1.30±0.03) at 15-30 cm. FCF sample gave the lowest mean pH value of 7.09±0.17 and 8.37±0.91 at 0-15 and 15-30 cm respectively while Bida Bidi and Babele gave the highest pH value of 8.61±0.54 and 9.38±0.53 at 0-15cm and 15-30cm respectively. Maza sample produced the highest water holding capacity of 6.50±0.2 and 6.00±0.26 at 0-15 cm and 15-30 cm respectively, while Babele gave the lowest values of 5.50±0.50 and 5.00±0.20 at 0-15 and 15-30 cm respectively. The invertase enzyme activity result showed that FCF had the lowest mean value of 4.09±0.33 and 3.76±0.63 at 0-15 and 15-30 cm respectively, while Babele gave the highest enzyme activity of 11.08±1.33 and 10.18±0.23 at the 0-15 and 15-30 cm depth respectively. The soil physical properties showed that high water holding capacity, high bulk density and pH towards the acidity value at FCF and Maza locations might have hindered yam growth while low water holding capacity, neutral pH and low bulk density could have favoured yam growth in Babele and Bida bidi. The high invertase enzyme activity in Babele and Bida bidi might have induced the good yam growth in the areas.

Keywords: Invertase activity, soil, enzyme, bulk-density, pH, yam.

Introduction

Soil is the top-most part of the earth that is regarded as a complex matter comprising of mineral matter, organic matter, water, and air. These fractions greatly influence soil texture, structure, and porosity which all contribute to the growth and development of crops (Easton and Bock, 2016). Among all its uses, soil plays a key role in agriculture, serving as a medium on which plants grow to provide food for man (Nortcliff *et al*., 2012). The organic material in the soil is crucial to agriculture as it provides nutrients for plant growth and also harbour micro-organisms and enzyme that accelerate plant growth.

Enzymes are complex protein molecules, often called biocatalysts, which are produced by living cells. They are found in every substrate that exist and they are specific both in the reactions they catalyze and in their choice of reactants (substrates). They are found in the soils, water, air, living tissues and cells in the body of microbes, plants as well as animals (Sang-Hwan *et al*., 2020).Enzymes are of various types and they are known to speed up the rate of biological reactions by lowering reaction activation energy, thereby reducing the time it takes reactions to occur in multiple folds (Robinson, 2015). This means without the existence of enzymes in biological systems, such reactions will take months or years to complete.

Enzymes found in the soil are regarded as 'soil enzymes' and they partake in many processes such as seed rotting, germination, leaf formation, stem expansion, flowering, seed formation and all other agronomical processes (Benjamin, 2013).In general, enzyme activity decreases with an increase in soil depth and they provide early detection of changes in soil health. Understanding the possible roles of different soil enzymes can help in soil health and fertility management, particularly in agriculture (Mukhopadhyay *et al*., 2014)and also in soil productivity, microbial activity, inhibiting effects of pollutants and the types of crops that should be grown in a given area (Nare *et al*., 2014).In view of the many contributions impacted by the activities of enzymes in the soil, this study therefore aims at estimating some soil physical properties and invertase enzyme activity on yam performance as a case study, in Jos North local government area of Plateau State.

Materials and Methods

Study Area

The experiment was conducted at Federal College of Forestry, Jos in Biology and Chemistry laboratory. Jos is the State Capital of Plateau State and it lies at latitude 7^{o}N and 11^{o}N and longitude of 7^{o}N and 25^{o}E with elevation of about 1200 m above the sea level. It is located in the middle belt zone within the Southern Guinea Savannah of Nigeria (Olowolafe and Dong, 2013). The climate is generally humid with mixed temperate and tropical weather, cool climatic condition, relative humidity of 60 %, annual rainfall of 1460 mm – 1480 mm and mean annual temperature of 25^{o}C.

Sample Collection

The soil samples were freshly collected from various farm lands where yam is produced and some farm locations where yam is reported not to do well. The samples were collected from 0-15 cm and 15-30 cm depth from four locations in Jos North local governments area of Plateau State. The locations include Federal College of forestry, Jos (FCF Jos) Babele, Bida bidi and Maza. They were packaged in clean polythene bags and taken to the lab where they were immediately used.

Experimental Treatment and Layout

Four (4) locations were used for this experimental work which were picked using simple random sampling method and they include Federal College of Forestry, Jos (FCF), Babele, Bida bidi and Maza. The four locations are situated within the Jos North Metropolis. Each of the sample from these locations was taken as a treatment and each sample was replicated three times. The control experiment consisted of the samples in which sucrose was only added after the incubation of the sample. The locations have similar average climatic conditions with differences in soil type.

T_0	Control
T_1	FCF sample
T_2	Babale sample
T_3	Bida bidi sample
T_4	Maza sample

Experimental Methods

Determination of Soil pH

The method described by (ASTM, 1995) was adopted in the determination of soil pH. Briefly, 10 g of the sieved soil sample was placed in a beaker and covered up with solution of calcium chloride (0.01M, 1.11g/dm^3), to about 5 cm^3 above the soil sample. The solution was then thoroughly mixed and allowed to stand for 1 hour. A pH meter was calibrated with pH buffer 7.0 and 10.0 before the commencement of the readings. The pH meter probe was immersed in the solution, above the soil and readings were taken and then recorded.

Measurement of Water Holding Capacity

The soil samples were thoroughly air-dried and then poured into measuring cylinder until it reaches the 100 mL mark. The sample was then poured into a big funnel that was initially padded with filter paper and a rubber tubing connected to the mouth of the funnel. The mouth of the tubing was then clamped and the funnel covered with a polythene material and suspended with a retort stand. The soil sample (100 mL) was poured into the funnel after which 100 mL of water was carefully added until the soil becomes saturated. The clip holding the rubber tubing was then released and the excess water in the funnel was allowed to run down into a measuring cylinder. The amount of water that drained out after 30 minutes was recorded.

Determination of Bulk Density

The bulk density of the various soil samples was determined by weighing the mass of soil sample with weighing balance (Model: BC ORMA Bilance) and taking the volume of water occupied by the same quantity of soil using measuring cylinder. The particle density (Pb) was calculated using the method described by AOAC (1990), through the formula;

$\mathrm{Pb} = \mathrm{m/v}$............ (1).

Where: pb = particle density, m = mass of soil in air; v = volume of the container.

Preparation of Reagents

Preparation of Universal Modified Buffer

The buffer stock solution was prepared by weighing 3.025 g of tris-(hydroxymethyl)-aminomethane, 2.9 g maleic acid, 3.5 g of citric acid, 1.57 g of boric acid, 1 M NaOH (40 g/mol) (122 mL) and 250 mL of distilled water. 1 M (122 mL) sodium hydroxide was prepared by weighing 4.88 mL of the base and dissolving it in 122 mL of distilled water. The content was thoroughly mixed after which 3.025 g of tris was weighed and added to the solution, then 2.9 g maleic acid, 3.5 g citric acid and 1.57 g of boric acid were all added to the solution. The volume was then increased to 250 mL and the pH adjusted as required. The solution was stirred using glass rod and allowed to stabilize and kept until when needed.

Preparation of 10% Sucrose Solution

Sucrose solution was prepared by weighing 10 g of sucrose (342.29 g/mol) and dissolving in little quantity of distilled water. The volume was raised to 100 mL by the addition of MUB to make up the volume.

Preparation of 2 M NaOH

Sodium hydroxide (2M) was prepared by weighing 8 g of sodium hydroxide and dissolving it in little quantity of water. The content was properly mixed and the volume raised to 100 mL with distilled water.

Preparation of Colour Reagents

This reagent was prepared by weighing 0.2 g 3,5-dinitrosalicylic acid monohydrate (Sigma Aldrich), 0.025 g of sodium carbonate (St. Louis, MO) and 0.005 g of ethylene dinitro tetra-acetic acid disodium salt (EDTA) into a 50 ml beaker. The content was mixed and the volume increased to 50 mL.

Determination of Soil Invertase Activities

The activity of the invertase enzyme activity was determined by the method described by (Frankenberger and Johanson (1983). 3 g of soil sample was sieved using 2 mm mesh net and placed in a volumetric flask after which 0.2 mL of toluene and 5 mL of modified universal buffer (MUB) was added. The content was mixed and 5 mL of 10% sucrose solution added and it was mixed again after which it was placed in an oven at 37^{o}C for seven days. Samples were withdrawn daily for optical density (O.D) readings after sample filtration using Whatman number 42 filter paper.

Determination of reducing sugar in the sample was done by pipetting 1 mL of sample into test tube and 5 mL of deionized water, 2 mL of 2 M NaOH and then 2 mL of colour reagent. Addition of the colour reagent terminates the enzyme activity and the content was exposed to a stream of nitrogen gas. It was then placed in a boiling water-bath for 5 minutes, cooled and the colour intensity (O.D) measured using spectrophotometer at 540 nm wavelength. A standard glucose:fructose solution was prepared and the optical density read and aglucose:fructose graph plotted to measure the amount of the released glucose:fructose concentration from the soil through extrapolation using excel function (O.D =Trend(Cell range).

Statistical Analysis

Data obtained from the experiment were subjected to one way analysis of variance (One Way ANOVA) at 95% confidence interval in a Completely Randomize Design (CRD) arrangement with the use of SPSS Version 23. Least Significant Difference (LSD) was used evaluate the statistical difference between the means and where differences occurred, Duncan Multiple Range Test (DMRT) was used to separate the means.

Results

Bulk Density

The result of the bulk density is as displayed (Table 1). The result shows that significant difference occurred in the sample at 0-15 cm and 15-30 cm depth. In the 0-15 cm, Bida bidi, Napa sample was observed to be statistically similar to Maza and significantly different from Babele and FCF samples at p = 0.05. Bida bidi produced the highest mean value (1.75) while the lowest mean value was observed in Babele (0.60). In the 15-30 cm depth, Bida bidi and Maza samples are not significantly different from each other at p = 0.05, and are significantly different from FCF and Babele. The highest mean value occurred in Maza (1.30), while FCF and Babele gave the lowest mean value of 1.0.

Soil pH

The result of the soil pH (Table 1) shows that the pH differs for the four locations at 0-15 cm and at 15-30 cm depth. The pH is however not significantly different from each of the locations at p = 0.05. Bidabidid produced the highest mean value of 8.61, followed by Babele with a mean value of 8.47, Maza with a mean value of 7.93 while FCF gave the lowest mean value of 7.09 at 0-15 cm sample respectively. At the 15-30 cm depth, the highest mean value occurred in Babele (9.38), followed by Napa (9.28), Maza (8.73) and FCF gave the lowest value.

Water Holding Capacity

The water holding capacity of the different locations is as presented in Table 1. The result show that at the surface soil, Maza and FCF have the highest water retention capacity followed by Bida bidi and Babele. The result shows that significant differences occurred among the locations. In the 0-15 cm sample, Maza is significantly different from Babele sample but statistically similar to FCF and Bida bidi at $p = 0.05$. Maza produced the highest water holding capacity among all the locations (6.50) while Babele gave the lowest mean value of 5.50. In the 15-30 cm depth, the water holding capacity of Maza gave the highest value of 6.00, followed by Bida bidi (5.90), FCF (5.30) and Babele (5.00).

Invertase Enzyme Activity of the Soil

Table 2 shows the result of soil invertase activity for 0-15 cm for seven days in four locations in Jos North. The result shows that no significant difference occurred in day 1, 3 and 6 among all the locations at p=0.05 level of significance. In these three days, the sample from Babele, a yam producing area gave the highest mean value, while FCF produced the lowest mean value on day 3 and 6 (Table 2). On the other hand, the result also showed that Babele gave the highest mean value on day 2, 4, 5 and 7 with mean values of 11.00±0.52, 10.58±0.63, 10.25±0.03 and 10.18±0.02 respectively at p=0.05 (Table 2).

Table 1: Bulk Density, pH and Water Holding Capacity of Soil Samples from Four Locations in Jos North, Plateau State

Sample Location	Bulk Density (g/mL)		pH		Water Holding Capacity (mL/L)	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
FCF	1.20±0.35^{b}	1.00±0.09^{b}	7.09±0.17	8.37±0.91	6.00±0.50^{ab}	5.30±0.20^{bc}
Babele	0.60±0.02^{c}	1.00±0.02^{b}	8.47±0.18	9.38±0.53	5.50±0.50^{b}	5.00±0.20^{c}
Bida Bidi	1.75±0.04^{a}	1.25±0.03^{a}	8.61±0.54	9.28±0.46	5.90±0.20^{ab}	5.90±0.26^{ab}
Maza	1.30±0.04^{ab}	1.30±0.03^{a}	7.93±1.42	8.73±0.19	6.50±0.20^{a}	6.00±0.26^{a}
L.S	*	*	N.S	N.S	*	*

Values are presented as mean of three readings±S.D, * = significant difference, N.S = Not significant. Mean values within the same column having different superscript letters are significantly different.

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Table 2: Soil Invertase Activity of 0-15 cm soil sample at four Locations in Jos North, Plateau

	Amount of Glucose:Fructose Released (mg/mL)						
Location	**Day 1**	**Day 2**	**Day 3**	**Day 4**	**Day 5**	**Day 6**	**Day 7**
FCF	10.17±0.37	9.24±0.25[c]	9.47±0.56	8.95±1.01[b]	8.90±0.83[b]	5.43±1.50	4.09±0.33[c]
Babale	10.75±0.39	11.00±0.52[a]	11.08±1.33	10.58±0.63[a]	10.25±0.03[a]	9.40±3.77	10.18±0.02[a]
Bida bidi	10.14±0.28	9.87±0.8[bc]	10.28±0.05	10.35±0.03[ab]	9.52±0.17[ab]	10.03±0.28	9.16±0.54[ab]
Maza	10.16±0.27	10.06±0.04[b]	9.78±0.01	9.64±0.17[ab]	8.72±0.77[ab]	9.41±0.10	8.46±0.75[b]
L.S	N.S	*	N.S	*	*	N.S	*

Values are presented as mean of three readings±S.D, * = significant difference, N.S = Not significant. Means within the same column having different superscript letters are significantly different.

Enzyme Activity at 15-30 cm Depth

The result of the soil invertase activity for 15-30 cm in the four locations is as shown in Table 3.The result showed that no significant difference occurred on day 3 and 4 at *p*= 0.05. The result of day 1, 2, 5,6 and 7 showed significant difference with Babele producing the highest mean value on day 1 and 7 respectively (Table 3).Bidabidi location gave the highest mean value on day 2, 5 and 6, with mean values of 10.22±0.00, 8.91±0.15 and 8.71±0.09 respectively. FCF gave the lowest mean value on day 2, 5, 6 and 7 with values of 6.59±0.81, 6.10±0.92, 4.29±0.40 and 3.76±0.63 respectively, while Maza gave the lowest mean values on day 1, 3 and 4 with values of 7.00±0.39, 7.29±0.50 and 7.79±0.65 respectively at *p*= 0.05.

Table 3: Soil Invertase Activity of 15-30 cm soil sample at four Locations in Jos North, Plateau

	Amount of Glucose:Frucose Released (mg/mL)						
Location	**Day 1**	**Day 2**	**Day 3**	**Day 4**	**Day 5**	**Day 6**	**Day 7**
FCF	8.53±0.24[a]	6.59±0.81[b]	7.61±1.41	8.00±0.13	6.10±0.92[b]	4.29±0.40[c]	3.76±0.63[b]
Babale	9.54±0.34[a]	10.18±0.23[a]	9.13±0.28	8.79±0.87	7.54±0.34[ab]	7.68±0.55[b]	9.13±0.47[a]
Bidabidid	9.10±0.26[a]	10.22±0.00[a]	8.68±0.14	8.77±0.65	8.91±0.15[a]	8.71±0.09[a]	7.42±0.94[a]
Maza	7.00±0.39[b]	10.00±0.09[a]	7.29±0.50	7.79±0.65	8.40±0.59[a]	8.68±0.03[a]	8.33±0.62[a]
L.S	*	*	N.S	N.S	*	*	*

Values are presented as mean of three readings±S.D, * = significant difference, N.S = Not significant

Discussion

Soil invertase is an enzyme that catalyzes the rate of degradation of sucrose substrate to yield glucose and fructose. The activity of this enzyme in the soil is measured by the amount of glucose:fructose released after sample incubation. The product released by this enzyme activity serves as nutrient for plant germination, growth and development (Zhang *et al*., 2021).

The result of the bulk density showed variations across the four locations. In the yam producing areas which are Bida bidi and Babale, low bulk density was observedin the twoareas (Bidabidi and Babele), while that of FCF and Maza showed high bulk density. Bulk density depicts the level of compaction of the soil in that area and this could bring about increase or decrease in the crop root penetration. This is similar to what was reported by Agbede and Adekiya (2013) stating that different tillage systems brought about changes in the soil density and hence, variation in the growth parameter of yam.

The water holding capacity of an area shows the ability of the soil to retain water. In as much as water is required for yam growth, high amount of water would penetrate the tender tubers and influence bacterial attack, causing spoilage (Osunde and Orhevba, 2009). The water holding capacity of the yam producing area are observed to be significantly low compared to the other two locations (FCF and Maza). This could be a great influence on the performance of yam in these four locations cited.

The action of the enzyme degradation of sucrose in the four locations shows that higher enzyme activity occurred in Bida bidi and Babele compared to the other two locations. This result could be due to the amount of hydrogen ion concentration and hydroxyl ion concentration present in the soil. It could be observed that Babele and Bida bidi have pH values that tend towards the neutral pH, while FCF and Maza have pH value towards acidic values. This could be one of the factors that contributed to the enhanced invertase activity as observed in Babele and Bida bidi compared to those observed in FCF and Maza. The differences observed in this result could also be associated to the amount of organic matter and microbial contents present. This can be explained according to the work of Shah *et al*. (2013) stating that an increase in the soil invertase activity could be due to the activity of micro-organisms present in that soil. The difference observed in the invertase enzyme activity can also be likened to the different activities taking place in these locations. Wang *et al*. (2020) stated that environmental disturbances can affect soils enzyme activity in a location and this in turn can affect the soil and plant growth.

In the soil invertase enzyme activity result, it was observed that the soil enzyme activity was higher at the 0-15 cm sample compared to the 15-30 cm depth. This could be due to the reduced substrate activity at the 15-30 cm depth compared to the surface sample. Microbial content, which releases enzymes are also expected to be higher at the soil surface. This result is in line with the work of Wang *et al*. (2011) which states that urease enzyme activity decreases with depth which can be attributed to lack of substrate, microbial biomass and soil organic carbon at the lower soil depth.

Conclusion

Conclusively, the findings of this work showed that soil invertase enzyme plays a significant role in yam performance. The presence of this enzyme in the soil stimulates yam growth and development through the breakdown of sucrose to release glucose and fructose. The activities of the enzyme decrease with increase in soil depth and it is also a function of the soil compaction and this helps yam tuber penetration into the soil. Based on the findings in this study, commercial production of this enzyme could improve yam performance in area where its availability is minimal.

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