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Evaluation of the Adaptability of Cabbage (*Brassica oleracae* L. Var. Capitata) to the Agro-Ecology of Ebonyi State, Southeastern Nigeria

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Abstract: Studies were conducted in 2007 and 2008 raining seasons, to evaluate the suitability of some locations for the production of Cabbage in Southeastern Nigeria. The locations were Abakaliki, Ezzamgbo, Ikwo and Okposi agricultural areas. Minor variations in weather conditions were observed among the four locations. The results of the soil environment showed that Ezzamgbo location had significantly ($p<0.05$) lower soil bulk density and higher hydraulic conductivity compared to the other locations. Significantly ($p<0.05$) higher levels of soil pH, organic matter, cation exchange capacity (CEC) and Mg were detected at Ezzamgbo and Abakaliki locations, whereas K and Ca were significantly ($p<0.05$) higher at Ezzamgbo location compared to the other locations. No consistent trend in the plant number of leaves, leaf area and plant height were observed among the plants in the different locations, while shoot dry matter was significantly ($p<0.05$) higher at Ezzamgbo than the other locations. The pooled yield results showed that Cabbage head yield at Ezzamgbo was 2.26, 2.18 and 2.09 t/ha significantly ($p<0.05$) higher than that of Ikwo, Okposi and Abakaliki locations. The average Cabbage head yield range of 5.5 - 7.7 t/ha obtained in the study was lower than the world average yield range of 10.0 - 40.0 t/ha.

Key words: Cabbage % Adaptability % Soil and climatic environment % Cabbage growth and cabbage yield and Ebonyi state % Nigeria

INTRODUCTION

Cabbage was regarded as exotic to the people of Southeastern Nigeria. The consumption for decades remains exclusively the priority of rich elites who reside in the cities. However, with the increasing urbanization now coupled with the rural urban migration of the population, the crop has been exposed to a greater number of people and this has made Cabbage consumption popular.

The bulk of Cabbage consumed in the Southern part of Nigeria is produced in the Northern section of the Country. This situation has led to prohibitive prices of Cabbage owing to the imputed cost of transportation from North to South of Nigeria. The demand of Cabbage also outstrips the supply; causing scarcity of the commodity. There is therefore the need to evaluate the possibility of growing the crop in the Southeastern Nigeria where the consumption is high. There is no recorded report of the production of the crop in the study area; because there is the age-long belief that Cabbage can only grow in the few montane climatic environments of Northern Nigeria.

The study is a pilot experiment; A four-runner research aimed at selecting suitable environment for possible break through in Cabbage production in Southeastern Nigeria.

MATERIALS AND METHODS

Description of the Study Area: The study area lies within latitude 7° 30'E and longitudes 5° 40'N and 6° 45'N, Southeast of the derived Savanna Zone of Nigeria. The soil of the area is characterized by shale parent materials and of shallow depth [1]. The mean monthly temperature ranges between 24°C to 28°C [2]. The rainfall pattern is

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Table 1: Weather Record for the Experimental location

	2007				2008			
Month	Rainfall (mm)	Max. Temp. (OC)	Min. Temp. (OC)	Relative Humidity (%)	Rainfall (mm)	Max. Temp. (OC)	Min. Temp. (OC)	Relative Humidity (%)
Abakaliki								
April	117.20	32.00	24.00	61.00	106.80	34.00	24.00	72.00
May	118.50	30.00	22.00	62.00	118.80	30.00	21.00	78.00
June	113.40	28.00	21.00	75.00	111.50	30.00	22.00	75.00
July	264.80	29.00	20.00	85.00	249.80	28.00	20.00	85.00
August	125.30	28.00	20.00	88.00	114.00	29.00	21.00	83.00
September	216.80	29.00	21.00	82.00	275.70	27.00	20.00	88.00
October	177.90	30.00	20.00	80.00	158.10	30.00	22.00	80.00
Total	1073.90	206.00	148.00	533.00	1134.70	208.00	150.00	561.00
Mean	153.41	29.49	21.14	76.14	162.10	29.71	21.43	80.14
Ezzamgbo								
April	96.60	28.22	17.05	76.40	262.10	32.10	24.50	68.00
May	101.20	27.90	15.71	73.80	321.90	31.00	23.30	71.00
June	224.40	28.84	18.54	79.70	104.25	30.50	22.60	67.00
July	283.25	24.86	13.90	84.10	202.70	33.00	24.60	51.00
August	117.24	23.50	15.26	94.28	215.00	28.70	22.70	85.00
September	240.65	24.45	16.58	94.75	215.70	31.50	25.00	80.00
October	190.90	24.92	15.61	93.88	97.75	25.90	18.05	90.93
Total	1254.25	182.69	112.65	596.91	1419.40	212.70	160.75	512.93
Mean	179.18	26.10	16.09	85.27	202.77	30.39	22.96	73.28
Ikwo								
April	110.04	27.65	16.62	81.15	231.40	32.10	23.80	87.00
May	89.70	28.86	14.56	70.37	286.30	31.10	24.00	87.00
June	216.13	27.17	14.54	86.04	193.40	30.00	21.80	65.00
July	281.21	24.57	19.49	83.50	234.20	34.90	26.00	73.00
August	186.93	23.69	15.37	93.36	224.60	28.40	23.00	82.00
September	291.30	24.10	16.13	94.17	234.10	33.40	29.40	83.00
October	132.08	24.79	15.48	93.93	101.20	31.40	26.30	50.00
Total	1306.59	180.83	112.19	602.52	1505.20	189.90	174.30	527.00
Mean	186.66	25.83	16.03	86.07	215.03	27.12	24.90	75.29
Okposi								
April	159.15	32.66	23.00	76.25	104.03	29.24	21.09	80.00
May	231.53	30.12	20.57	78.00	165.80	26.95	20.37	85.44
June	223.77	29.00	20.19	78.76	257.69	27.00	18.66	87.54
July	288.49	28.56	20.48	85.17	299.13	26.11	19.00	89.76
August	239.96	30.43	21.22	83.81	229.00	27.05	21.24	88.16
September	258.30	27.74	20.70	90.28	239.90	25.91	17.06	90.28
October	238.19	28.31	21.08	82.77	198.36	26.00	20.22	89.60
Total	1639.39	206.82	147.24	576.04	1493.91	188.26	137.64	610.78
Mean	234.20	29.55	21.03	82.29	213.42	26.89	19.66	87.25

Source: Ebonyi State Agricultural Development Programme (EBADEP) Abakaliki

Table 2: The Soil Texture and Chemical Properties of the Soils at the Locations

	Abakaliki Location	Ezzamgbo Location	Ikwo Location	Okposi Location
Texture				
Fine Sand (%)	50.00	46.00	60.00	40.00
Coarse Sand (%)	8.00	10.00	8.00	26.00
Silt (%)	25.00	19.00	19.00	21.00
Clay (%)	17.00	25.00	13.00	13.00
Textural Class	Silty Clay Loam	Silty Clay Loam	Silty Loam	Silty Loam
Chemical Properties				
pH (H_20)	5.00	4.10	5.10	5.00
Organic Matter (%)	2.02	1.06	1.45	1.89
Total N (%)	0.07	0.06	0.06	0.06
Available P (gm/kg)	42.79	25.87	24.88	25.87
Na [Cmol(+)/kg]	0.06	0.06	0.06	0.06
K [Cmol(+)/kg]	0.03	0.09	0.03	0.10
Ca [Cmol(+)/kg]	4.82	1.03	3.96	5.68
Mg [Cmol(+)/kg]	0.86	1.55	2.58	1.89
CEC[Cmol(+)/kg]	8.00	4.40	4.80	8.80

bimodal with peaks in the months of July and September. Annual amounts of rainfall range between 1500 mm to 2000 mm. Rainfall stabilizes around May and stops around October living a dried period between November and April. The meteorological data is shown in Table 1a - 1d.

The Test Crop: The test crop was Cabbage (*Brassica oleracae* L. var. Capitata). The vegetable seeds were sourced from the National Horticultural Research Institute of Nigeria (NIHORT) Okigwe, Imo State, Nigeria.

Field Work: The field experiments were carried out in four locations in the State. The locations are in the followings - community farm Ezzamgbo, Research and teaching farm College of Education Ikwo, Okposi and Resarch and teaching farm Ebonyi State University, Abakaliki. The soils of the study locations differed with respect to soil texture and chemical properties (Table 2).

Experimental Layout: The trials were done for two seasons (2007 and 2008), being the first and second cropping seasons. At each location the test crop was planted on raised beds arranged in a randomized complete block design (RCBD) replicated four times. The size of the experimental area in each location was 22 m x 17.5 m (385 m^2). The size of each replicate was 88 m^2. Each replicate contained five plots, each measuring 4 m x 4 m (16 m^2). The plots and replicates were separated from one another by 0.5 m space respectively. Plant spacing of 50 cm x 50 cm was adopted at all the locations, giving a plant population of 80,000 stands per hectare.

Cultural Practices

First Year Trial: The nurseries were established in May, each year. The clearing and tillage operations were done in the second week of June, while transplanting took place immediately after seedbed preparation. The seedlings were transplanted at 31 days after sowing (DAS). NPK fertilizer was applied at the rate of 150 kg N / ha as urea, 40 kg P / ha as single super phosphate and 40 kg K / ha as muriate of potash, in two split doses; half the dose was applied basally at 4 days before transplanting (DBT) and incorporated into the soil, while the rest was applied at 30 days after transplanting (DAT). Weeding was carried out as the need arose by manual method, using hoes. Cabbage pests were controlled using Malathion at 5 litres per hectare mixed in 80 litres of water, whereas Dithane M 45 was used as fungicide.

Second Year Trial: The second year trial was a repeat of the first year trial, employing the same materials and methods.

Observation and Data Collection: Data on rainfall, temperature and relative humidity were collected during the two growing seasons and analyzed. Six auger samples from 0 - 20 cm (for determination of soil chemical properties and texture) before planting were randomly collected from each location for laboratory analysis. Another six auger samples for the post harvest determination of chemical properties were collected from each plot after each season's cropping. Three undisturbed soil core samples from 0 -5 cm depth (for analysis of dry bulk density, soil total porosity and gravimetric moisture) were collected from each plot at 30 DAT each season. Three other soil core samples were collected from each plot at 50 DAP for the determination of soil hydraulic conductivity. The soil core samples collected using cores of 5 cm diameter and 5 cm height were analyzed separately and mean result obtained, whereas the auger samples were mixed and a composite sub sample taken for analysis. Five plants were randomly selected within the net plot, in each plot at 50 DAT for height, leaf area and number of leaves measurements. Plant height was measured as the vertical distance between the ground and the highest living part of the plant. Leaf area was determined by measuring the length and width of all the leaves on a plant with a simple ruler and the average leaf area of the five plants recorded as the leaf area. Number of leaves was measured by counting all the leaves on each plant and the mean of the five plants assumed as the number of leaves. Shoot dry matter was also taken at 50 DAP by cutting, oven drying and weighing the entire above ground vegetation of five plants randomly selected from the border rows of each plot and the mean weight of the five plants assumed as the shoot dry matter. Harvesting was carried out at 120 DAT, when the heads were mature, from a net plot of 2 m^2 in the centre of each plot and the yield converted to tons per hectare.

Laboratory Methods: The composite soil samples taken at the depth of 0 - 20 cm were analyzed in the laboratory for N, P, K, Ca, Mg, pH, organic carbon and CEC. Total nitrogen was determined by the macro Kjeldahl method [3], available phosphorus by the Bray II method as outlined in Page *et al*., [4] and Organic Carbon by the Walkely and Black method [5]. Soil pH in water

(2:1) was determined by the glass electrode pH meter [6]. The exchangeable bases were determined by the method of the Association of Official Analytical Chemists [7], while CEC was determined by the summation of the exchangeable cations. Particle size distribution was determined by the hydrometer method, [8]. Dry bulk density was determined by the cone method [9]. Total porosity was calculated from the dry bulk density as the fraction of total volume not occupied by soil assuming a particle density of 2.65 mg cmG^{3}. Soil gravimetric moisture was measured using the method outlined by Klute [10], while the hydraulic conductivity was determined by method outlined by Stolte [11].

Data Analysis: The data collected from the two experiments were subjected to statistical analyses using Analysis of Variance (ANOVA) and Correlation according to SAS [12].

RESULTS

The Weather Records: The weather records show that in the first year, the mean annual rainfall for the locations were in the order: Ezzamgbo > Ikwo > Okposi > Abakaliki, whereas in the second year mean rainfall values were in the order: Okposi > Ikwo > Ezzambgo > Abakaliki. During the first year also, the range of the rainfall values within the growing seasons (May - October) were 118.00 to 264.00 cm for Abakaliki, 240.65 to 517.24 cm for Ezzamgbo, 189.30 to 391.00 cm for Ikwo and 165.80 to 331.00 cm for Okposi, in the second year, the range of the rainfall values during the growing seasons were 114.00 to 275.70 cm for Abakaliki, 104.25 to 321.90 cm at Ezzambgo, 193.40 to 286.30 cm at Ikwo while that for Okposi was 223.77 to 288.49 cm. There was no consistent trend in rainfall during the growing seasons across the four locations. The temperature values in the first year of growing the crop were 28.00 - 30.00°C for Abakaliki, 23.50 - 28.84°C for Ezzamgbo, 23.69 to 28.86°C for Ikwo and 27.74 - 30.42°C for Okposi. In the second year, the temperature range values during the growing seasons were 27.00 - 30.00°C for Abakaliki, 25.90 - 33.00°C for Ezzamgbo, 28.40 - 34.90°C for Ikwo and 25.91 - 27.05°C for Okposi. There was also no consistent trend in the range of temperature values for the locations across the two seasons. The weather data also shows that the range of the relative humidity values during the first year growing seasons were 62.00 - 85.00 % for Abakaliki, 73.80 - 94.75 % for Ezzamgbo, 70.37- 94.17 % for Ikwo and 78.00 - 90.28 % for Okposi, whereas during the second year growing season, the range of relative humidity values were 73.00 - 88.00 % for Abakaliki, 51.00 - 90.93 % for Ezzamgbo, 50.00 - 87.00 % for Ikwo and 85.44 - 90.28 % for Okposi. This also shows no consistent trend in the pattern of relative humidity for the two seasons across the four locations.

The Soil Physical Properties: The result of the physical properties of the soils at the four locations is shown in Table 3. Bulk density was significantly ($p<0.05$) lower at Ezzamgbo whereas total porosity was reciprocatingly higher at Ezzamgbo than the other locations during the two-year study. There were no significant differences in soil moisture in the first year, but in the second year, the soil at Ezzamgbo location had 27% significantly higher ($p<0.05$) soil moisture than the soil at Ikwo location. The soil hydraulic conductivity values for Ezzamgbo location were 89, 81 and 64% in the first year and 81, 83 and 73 % in the second significantly higher ($p<0.05$) than at Abakaliki, Okposi and Ikwo locations. Soil temperature on the other hand was 11, 10 and 8°C significantly higher ($p<0.05$) at Okposi than at Ikwo, Abakaliki and Ezzambgo locations in the first year, whereas in the second year, the soil temperature at Abakaliki and Okposi locations were 9 and 8°C and 7 and 6°C, significantly higher ($p<0.05$) respectively than at Ikwo and Ezzamgbo locations.

The Soil Chemical Properties: The chemical properties of the soils used for the two years experiment, valued across the four locations are presented in Table 4. There was no consistent trend in the soil chemical properties among the four locations. Ezzamgbo and Abakaliki locations had 19 and 17% significantly higher ($p<0.05$) soil pH, respectively, when compared with the Okposi location. Soil pH between Abakaliki and Ezzamgbo on one hand and Okposi and Ikwo locations on the other hand, respectively were statistically comparable. The soil organic matter (SOM) levels at the Ezzamgbo location was 49 and 35% significantly higher ($p<0.05$) than at the Okposi and Ikwo locations, whereas Abakaliki location had 15 and 38% significantly higher ($p<0.05$) organic matter level than the Okposi and Ikwo locations. There were no significant differences in soil organic matter levels between Abakaliki and Ezzamgbo on one hand and between Okposi and Ikwo locations on the other respectively. There were also no significant differences in soil available P and exchangeable Na among the locations during the first and second years of the study. The soil K content at Ezzamgbo location was 65% significantly

Table 3: The physical properties of the soil used for production of Cabbage

	2007					2008				
Locations	Bulk Density (Mg/m^3)	Total Porosity (%)	Gravimetric Moisture (%)	Hydraulic Conductivity (Cm/hr)	Soil Temperature (^0C)	Bulk Density (Mg/m^3)	Total Porosity (%)	Gravimetric Moisture (%)	Hydraulic Conductivity (Cm/hr)	Soil Temperature (^0C)
Abakaliki	1.70	36.17	20.15	35.83	30.33	1.54	42.50	11.67	87.5	34.50
Ezzamgbo	1.57	40.50	14.16	62.25	40.00	1.49	44.00	10.65	76.0	36.00
Ikwo	1.72	35.50	13.20	120.00	29.00	1.56	42.00	9.98	125.3	27.00
Okposi	1.73	34.75	16.67	333.75	32.50	1.60	80.25	13.69	463.00	29.75
$LSD_{(0.05)}$	NS	NS	NS	186.63	7.32	NS	NS	3.18	277.34	3.99

Table 4: The Post harvest Mean Soil Chemical Properties

Locations	pH (H_20)	Organic Matter (%)	N (%/Kg)	Na	K	Ca	Mg	CEC	P Mg/Kg
				Cmol (+) Kg					
Abakaliki	5.85	1.56	0.077	0.67	0.045	5.81	0.63	19.80	
Ezzamgbo	6.00	1.49	0.079	0.72	0.135	7.04	1.84	21.20	22.38
Ikwo	5.55	0.97	0.057	0.72	0.045	3.58	1.89	14.60	22.89
Okposi	4.85	0.76	0.058	0.67	0.065	1.71	1.17	16.80	20.87
$LSD_{(0.05)}$	0.99	0.35	NS	NS	0.023	3.36	1.22	2.40	NS

Table 5: The effect of location on the growth and yield of Cabbage

	2007					2008				
Locations	No. Leaves	Height (cm)	Leaf Area (cm)	Dry Matter (gm)	Fresh Head (t/ha)	No. Leaves	Height (cm)	Leaf Area (cm)	Dry Matter (gm)	Fresh Head (t/ha)
Abakaliki	17.12	13.04	93.73	358.61	5.15	18.99	17.96	111.30	421.77	5.97
Ezzamgbo	17.92	13.63	94.95	355.69	5.02	19.33	13.65	148.23	797.82	10.28
Ikwo	20.56	20.10	122.76	495.00	5.54	19.59	21.71	118.93	336.32	5.40
Okposi	19.90	12.81	138.54	297.69	4.29	19.91	17.96	148.23	441.30	6.45
$LSD_{(0.05)}$	2.86	4.55	31.66	122.67	NS	NS	4.37	NS	121.58	2.29

($p<0.05$) higher than at Abakaliki and Ikwo locations respectively and 50% significantly ($p<0.05$) higher than the Okposi location. The soil exchangeable Mg content at Ikwo and Ezzamgbo were 67 and 66% significantly ($p<0.05$) higher than at Abakaliki location, while no significant differences in soil Mg content were observed between Abakaliki and Ezzamgbo on one hand and between Okposi and Ikwo locations on the other hand. The soil exchangeable Ca at Ezzamgbo location was 76 and 49% significantly ($p<0.05$) higher than at Okposi and Ikwo, while that of Abakaliki was 71% significantly higher than Okposi. The exchangeable Ca content of the soil at Okposi and Ikwo on the one hand and Ezzamgbo and Abakaliki on the other hand were, respectively, statistically comparable. 31 and 21% significantly ($p<0.05$) higher soil CEC levels were detected at Ezzamgbo location than at Ikwo and Okposi, while that of Abakaliki was also 28 and 15% significantly ($p<0.05$) higher than Ikwo and Okposi locations.

Cabbage Growth: The growth performances of the cabbage crops are presented in Table 5. The cabbage plants at Ikwo and Ezzamgbo locations produced significantly ($p<0.05$) more leaves than the cabbage plants at Abakaliki location in the first year, whereas the number of leaves of the plants at Ezzamgbo, Ikwo and Okposi and those planted at Abakaliki and Ezzamgbo were, respectively statistically comparable. During the second year, no significant differences in the plants number of leaves were observed among the plants in the four locations. The cabbage plants at Ikwo were 8.29, 6.96 and 6.47 cm significantly ($p<0.05$) taller than those at Okposi, Abakaliki and Ezzamgbo in the first year, whereas in the second year, the plants at Okposi and Ikwo were 8 cm significantly ($p<0.05$) taller than the Cabbage plants at Ezzamgbo location. The two years average values indicated that the plants at Ikwo location were significantly taller than those at Okposi, Ezzamgbo and Abakaliki. The Cabbage plants at Ezzamgbo location had

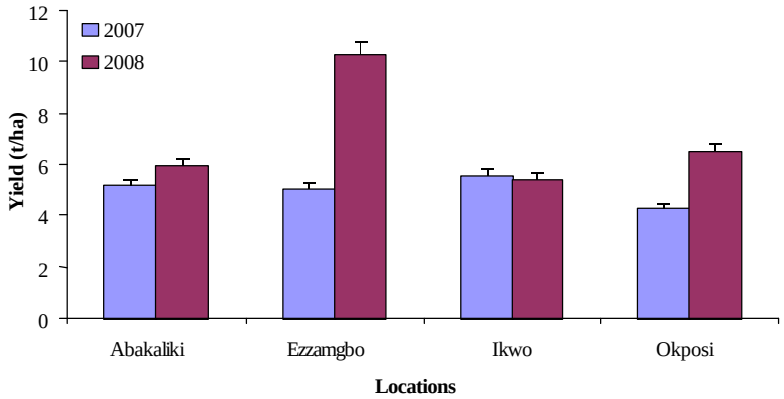

Fig. 1: Fresh Cabbage Head Yield (t/ha) at the Different Study Locations

39 and 40 cm^2 significantly ($p<0.05$) larger leaf area than those at Abakaliki and Okposi during the first year. However, there were no significant differences in leaf area among the plants in the four locations during the second year. The average of the two-year study showed that the Cabbage plants at Ezzamgbo had significantly ($p<0.05$) larger leaf area than those at Abakaliki, Ikwo and Okposi. The Cabbage shoot dry matter yield of the plant at Ezzamgbo were 197, 139 and 136 grams significantly ($p<0.05$) heavier than those at Okposi, Ikwo and Abakaliki locations, whereas the dry matter yield at Okposi, Ikwo and Abakaliki were statistically comparable. In the second year, the Cabbage plants at Ezzamgbo location also had 462, 376 and 357 grams significantly heavier shoot dry matter than the plants at Ikwo, Abakaliki and Okposi.

Cabbage Head Yield: The fresh Cabbage head yields at the different locations are presented in Figure 1. There were no significant differences in fresh Cabbage head yields among the locations in the first year of the study. In the second year, however Ezzamgbo location produced 4.88, 4.31 and 3.80 t/ha significantly ($p<0.05$) higher fresh Cabbage head yield when compared with the yields at Ikwo, Abakaliki and Okposi locations. The pooled yield for the two years showed that Ezzamgbo location produced 2.26, 2.18 and 2.09 t/ha significantly ($p<0.05$) higher Cabbage head yields compared to Ikwo, Okposi and Abakaliki locations.

DISCUSSION

The four study locations are within the same climatic location and had very little variations in the weather conditions during the study. The amount of rainfall and the distributions for the two cropping seasons across the four locations did not seem limiting for the production of the crop. The temperatures seem generally too high for the optimum production of the crop. The crop is of temperate origin and is usually produced at high altitude with a characteristic cool temperature [13]. The crop is reported to yield optimally at the temperature range of 15-20°C [13-16]. Generally, the rainfall and relative humility were quite adequate for the production of the crops. However, high atmospheric temperature was observed. This could have occurred due to high sunshine and solar radiation peculiar to tropical environments. The high temperature of the area could have contributed to the observed high soil temperature. On the other hand, the high temperature might have led to increased moisture evaporation from the soil and increased evapo-transpiration of the crops. This situation had adverse effects on the growth of the roots and shoots of the plants and crop productivity generally.

There were significant variations in the soil physical properties among the four locations which could account for variabilities in the productivity of the soils. Generally, however the soils physical properties were not quite conducive for the production of vegetable crops. The major soil physical constraints observed included high bulk density, low porosity and high soil temperature. The high soil bulk density particularly led to soil compaction, reduced pore space, aeration and water infiltration, increased runoff and loss of valuable soil nutrients. The high soil temperature created heat flux, leading to increased moisture evaporation from the soil. These soil physical problems constituted great constraints to the performance and yield of the crop in the study areas.

The result of the soil chemical properties shows that the fertility is rather low. The levels of the essential nutrients fall below the standard required for optimum crop production. The low pH, total N, other major nutrient elements, organic matter and Cation Exchange Capacity

Table 6: Relationship between Cabbage Yield and Yield Components (N = 5)

	No. of Leaves	Plant Height	Leaf Area	Dry Matter	Fresh Head Yield
No of Leaves	-	0.43	0.77**	0.30	0.32
Plant Height		-	0.084	-.014	0.016
Leaf Area			-	0.49	0.54*
Dry Matter				.-	0.89**
Fresh Head Yield					-

adversely affected the crop yields. The acidic nature of the soil affected the release of the essential nutrient elements in the soil, which reduced the fertility of the soil. Other studies which had reported low fertility status of the soils of the area of study include Asadu and Akamigbo [17] and Enwezor *et al*., [18]. Nnabude and Mbagwu [2] and Ogbodo and Nnabude [19] also reported poor physical and chemical properties of the soils of the area.

The average yield range of 5.5 to 7.7 tons per hectare obtained in the study is low compared to the world average yield range of 10.0 - 40.0 t/ha reported by Lannoy [20]. The restricted root growth owing to high bulk density might have impeded the capability of the plants to absorb nutrients for plant growth. Ashrad [21] showed that the minimum bulk density for root restrictions for soils like that of the area of study is 1.40 g cm^{3}. The high soil bulk density affected nutrient and water uptake, aeration and crop productivity. The high soil temperature also affected the crop yields; Cabbage is reported to produce best under soil temperature of between 16 and 24°C [22]. The high temperature caused stunted growth of most of the plants, a possible reflection of restricted root growth and the attendant reduced uptake of water and plant nutrients. The low soil pH of the soils on the other hand contributed to the low yield of the crops at the various locations. Under acidic soil conditions, plant nutrient deficiencies or elemental toxicities occur which have adverse effect on crop yields. The pH is lower than 6-7 recommended by Greg and Robert [23] and Jeff *et al*., [24] as generally most favourable for the plant growth. The low level of organic matter in the soil could, on its own, be a major factor that militated against high yield of cabbage in the study.

The significantly higher Cabbage yields obtained at Ezzamgbo location compared to the other locations was ascribed to the superior growth of the crops at Ezzamgbo location than the other locations. This was reflected in the higher leaf area and shoot dry matter of the crops at the location. The strong correlation (r = 0.54) between leaf area and Cabbage head yield on one hand and the very strong correlation (r = 0.89) between Cabbage head yield and shoot dry matter (Table 6) was an indication of the influence of these growth attributes on Cabbage yield. The interrelationships between these growth attributes equally influenced the plant size and ultimately the final head yield. Since Cabbage is made up entirely of vegetative portions, vigorous development of these variables indicated increased plant size, which determined the higher yield of the crop at Ezzamgbo locations. The superior growth of the crops at Ezzamgbo location was also ascribed to the lower soil bulk density, higher porosity and hydraulic conductivity; which provided for better root growth, nutrient and water uptake by the plants, nutrient and water mobility in the soil. The other possible reason for the superior yield of the crop at Ezzamgbo could be the significantly ($p<0.05$) higher soil pH, organic matter, exchangeable bases and CEC which improved the soil fertility and crop productivity.

CONCLUSION

The general characteristics of the soils and climate of the study locations indicated that it is possible to produce Cabbage at Ezzamgbo. However, adequate measures should be adopted to take care of the observed soil physical and chemical constraints of the study area. If the major soil constraints of acidity, low fertility, high soil bulk density and high soil temperature are ameliorated, the yield of the crops could be improved and the production of the crop adopted.

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