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Adapting Carrot (*Daucus carota* L.) Production to the Environment of Abakaliki Agro Ecological Zone, South East Nigeria

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Abstract: A Study was conducted between 2005 and 2006 rainy seasons at four different locations (Abakaliki, Ezzamgbo, Ikwo and Okposi) within Abakaliki agro-ecological zone of Southeastern Nigeria, to determine the suitability or otherwise of producing Carrot in the study area. The design of the experiment was a simple Randomized Complete Block Design (RCBD) replicated three times at each location. The measurement included weather parameters, soil physical and chemical characteristics and crop and yield attributes. The data collected were subjected to statistical analysis of variance (ANOVA) and correlation analysis. The result of the study showed that the yield range of 11.01 - 33.48 t/ha obtained in the study area compared favourably with the yield from other African countries that produce Carrot, but is below the world average potential yield, specifically Carrot root yield at Ezzamgbo was 5.91 and 5.58 t/ha significantly ($p<0.05$) higher than at Okposi and Ikwo, whereas the Carrot root yield at Abakaliki was also 5.75 and 5.42 t/ha significantly ($p<0.05$) higher than at Okposi and Ikwo. The significantly higher Carrot root yield at Ezzamgbo and Abakaliki was ascribed to superior growth performance of the crop at the two locations, and also the ability of the plants at the two locations to adapt to the inherent adverse soil physical and chemical properties of the study area. It was concluded that it is possible to produce Carrot in the Abakaliki agro-ecological zone, specifically best at Ezzamgbo and Abakaliki.

Key words: Carrot Adaptation, Soil Environment, Climatic Environment, Location, Carrot Growth and Carrot Yield.

INTRODUCTION

The inhabitants of Abakaliki agro-ecological zone of South Eastern Nigeria are essentially farmers. The majority of these farmers are engaged in subsistence agriculture, whereas the population engaged in commercial farming is comparably quite small. The farmers are major producers of grain cereals - specifically rice, and root crops, particularly yam and cassava. Since the farmers have a limited choice of crops to produce, their agricultural wealth base is rather weak.

It is therefore necessary to explore the possibility of adapting other ranges of cash crops that could assist in re-orientating the farmers from subsistence farming to commercial agriculture. If crops that command higher premium are adopted, this could lead to improved wealth base for the farmers and make farming attractive to the teeming youths who have now taken to other more lucrative professions. The production of carrot is a prospective proposal in this direction. However, there is an age long belief that carrot can only grow in the northern part of Nigeria, where the bulk of the carrot consumed in the southern Nigeria is currently produced. The study is an important area as it could lead to a breakthrough in producing carrot or confirm the notion held by those who have drawn the conclusion that the production of carrot in the South Eastern part of the country is impossible. A breakthrough will not only lead to economic and health improvement but will offer the farmers a wider range of crops cultivable in the area.

The study set out to assess the soil and climatic conditions for the production of carrot in the Abakaliki Agro – ecological Zone of Nigeria.

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MATERIALS AND METHODS

Description of the Study Location:

The study areas lie between latitude 7^0 30 E and longitude 5^0 40 N and 6^0 45 N, South East of the derived Savanna Zone of Nigeria. The soil of the area is characterized by shale parent materials and of shallow depth (FDALR, 1985). The mean monthly temperatures range between 24 ^{0}C and 28 ^{0}C (Nnabude, P.C. and J.S.C. Mbagwu, 1999). The rainfall pattern is bimodal with peaks in the months of July and September. Annual amounts of rainfall range between 1500 mm and 2000 mm. Rainfall stabilizes around May and stops around October, living a dry period between November and April. The weather data for the two cropping seasons are shown in Figure 1, while the soil texture and chemical properties of the soils at the Locations are shown in Table 1.

Table 1: 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 (H20)	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

Field Layout:

The field experiments were carried out in 2005 and 2006 rainy seasons at four different locations – Teaching and Research Farm Ebonyi State University Abakaliki, Community Farms Ezzamgbo, Teaching and Research Farm College of Education Ikwo, and Community Farms Okposi.

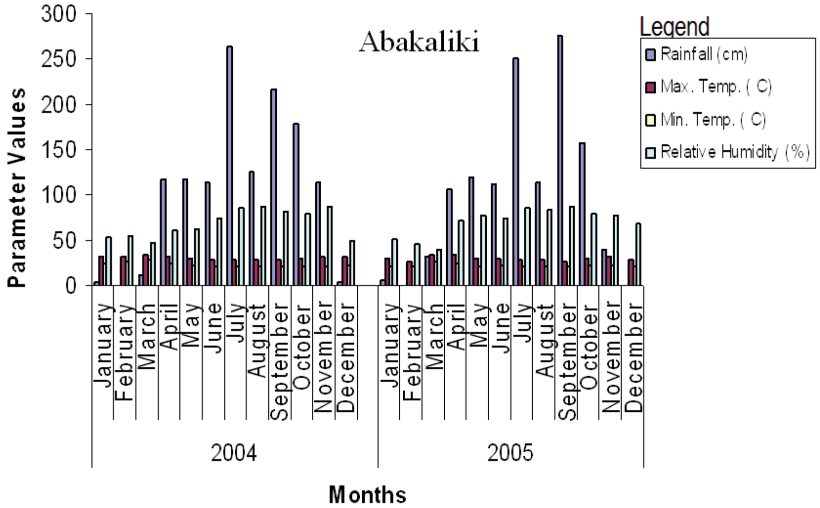
At each location the crop was planted on raised beds, replicated four times and arranged in a randomized complete block design (RCBD). The size of the experimental area in each location was 385 m^2 (22 m x 17.5 m). The size of each replicate was 88 m^2 (22 m x 4 m). Each replicate contained five plots, each measuring 16 m^2 (4 m x 4 m), giving a total of 20 plots in each location. The plots were separated from one another by 0.5 m spacing, while the replicates were also separated by 0.5 m spacing. A plant spacing of 40 cm between rows and 40 cm within rows was adopted for the experiment. The Carrot seeds used were sourced from National Horticultural Research Institute Okigwe, Imo State, Nigeria.

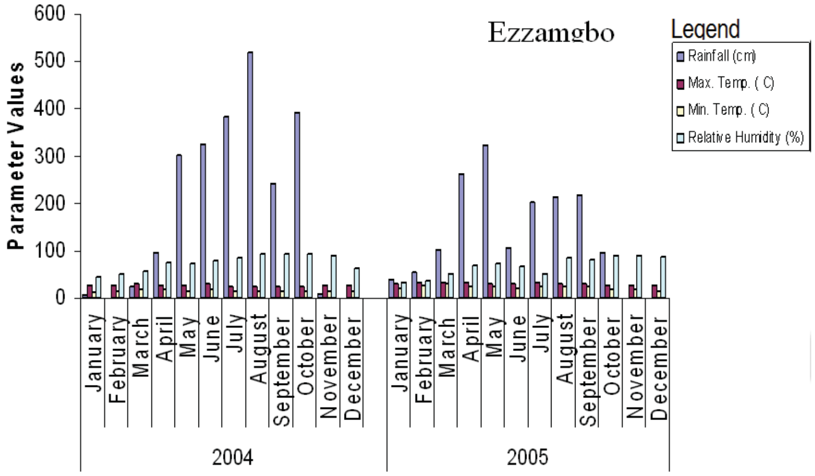
Cultural Practices:

Clearing and tillage operations were done manually in the third week of May, while planting took place one week after seedbed preparation each year. The seeds were drilled on the beds two weeks after seed bed preparation and later thinned down to a planting distance of 40 cm between plants and 40 cm between rows, 21 days after germination (DAG) giving a plant population of 80,000 stands per hectare. NPK fertilizer ratio 10: 20:10 (400 kg / ha) was applied in two split doses. Half the dose was applied basally immediately after seedbed preparation by incorporation with a hand hoe. The second dose was applied 50 DAG by side placement. Weeding was manually carried out as the need arise using hand held hoe.

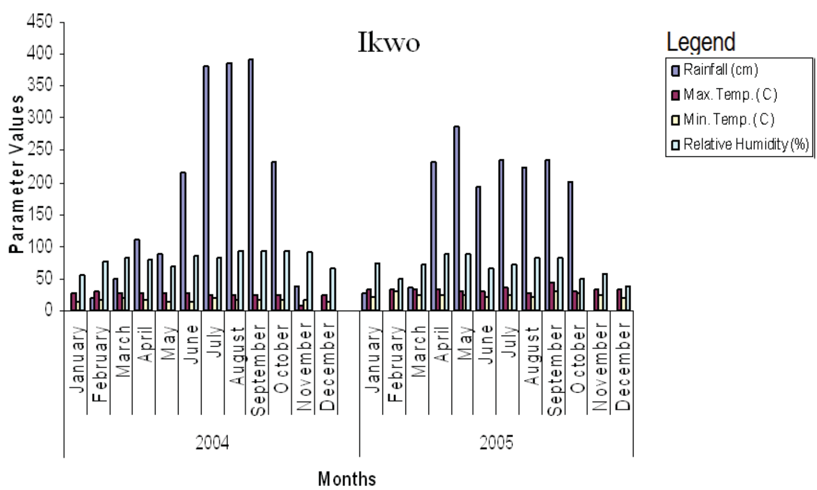
Field Observations:

Five plants were randomly selected within the net plot, in each plot at 60 DAG and observed for growth measurements. Plant height was measured with a metre rule, as the vertical distance between the ground and the highest living part of the plant. Leaf area was estimated by measuring the length and width of the leaves of the plant with a metre rule and the average leaf area of the five plants recorded as the leaf area. Number of leaves per plant was determined 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 60 DAG by cutting the entire above


Abakaliki
Legend
Rainfall (cm)
Max. Temp. (C)
Min. Temp. (C)
Relative Humidity (%)
Parameter Values
0
50
100
150
200
250
300
January
February
March
April
May
June
July
August
September
October
November
December
2004
2005
Months


Ezzamgbo
Legend
Rainfall (cm)
Max. Temp. (C)
Min. Temp. (C)
Relative Humidity (%)
Parameter Values
0
100
200
300
400
500
600
January
February
March
April
May
June
July
August
September
October
November
December
2004
2005
Months

Okposi


Ikwo
Legend
Rainfall (cm)
Max. Temp. (C)
Min. Temp. (C)
Relative Humidity (%)
Parameter Values
0
50
100
150
200
250
300
350
400
450
January
February
March
April
May
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July
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November
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2004
2005
Months

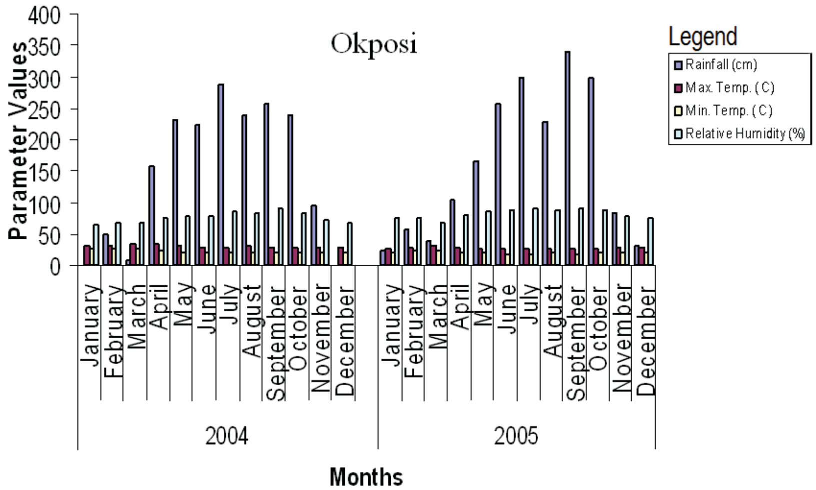

Fig. 1: The weather data for the two cropping seasons

ground vegetation of five plants randomly selected from the boarder rows of each plot and oven drying to a constant weight at 45 ^{0}C. The mean weight of the five plants was assumed as the shoot dry matter. The crops (roots) were harvested at 120 DAG, from a net plot of 4 m^2 (2 m x 2 m) in the centre of each plot. The roots were washed, weighed and converted to tones per hectare.

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 and physical properties) before planting and after planting were randomly collected from each location for laboratory analysis. Six undisturbed soil core sample from 0 -5 cm depth (for analysis of bulk density and total soil porosity) were collected from each plot at 30 DAG, while Six other soil core samples were collected for the determination of soil hydraulic conductivity. The soil core samples collected using cores of 5cm diameter and 5cm height were analyzed separately and mean result used, whereas the auger samples were mixed and a composite sub sample taken for laboratory analysis. Soil temperature was measured at 14, 28, 42 and 56 DAG were measured using a centrigate soil thermometer and the average assumed as the soil temperature

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 (Bremmer, J.M., 1965). Available phosphorus was determined using Bray II method as outlined in Page *et al.* (1982) and Organic Carbon by the Walkely and Black method (Nelson, D.W. and L.E. Sommers, 1982). Soil pH in water (2:1) was determined by the glass electrode pH meter (Maclean, E.O., 1982). The exchangeable bases were extracted using the ammonium acetate method (Chapman, H.D., 1965). Potassium was determined with a flame photometer, and Calcium and Magnesium were measured by atomic absorption spectroscopy. The CEC was determined according to the procedure described by Tel and Roa (1982). Particle size distribution was determined by the hydrometer method (Gee, G.W. and J.W. Bauder, 1986). Dry bulk density was determined by the cone method (Blake, G.R. and K.H. Hartge, 1986). Total porosity was calculated from the dry bulk density as the fraction of total volume not occupied by soil assuming a particle density of 2.65mg m^{-3}. Soil gravimetric moisture was measured using the method outlined by Klute (1986). The hydraulic conductivity was determined by the method outlined by Stolte (1979).

Data Analysis:

The data collected from the two experiments were subjected to statistical analyses using Analysis of Variance (ANOVA) and correlation analysis method according to SAS (2006).

Results:

Weather:

The weather records of the study locations are shown in Figure 1. There was no consistent trend in the weather pattern during the two cropping seasons.

Soils Physical Properties:

Table 2 shows the physical properties of the soil at the different locations of the experiment. Soil bulk density was significantly higher ($p<0.05$) at Okposi and Ikwo locations than at Abakaliki and Ezzamgbo locations in both years of the study. The soil total porosity was correspondingly significantly higher ($p<0.05$) at Abakaliki and Ezzamgbo than at Ikwo and Okposi locations in both years. In the first year, the soil moisture retention capacity was significantly ($p<0.05$) higher at Abakaliki than at Ikwo and Okposi, while the soil moisture capacity at Abakaliki and Ezzamgbo on one hand and Ikwo and Okposi on the other were respectively statistically comparable. In the second year, significantly higher ($p<0.05$) soil moisture values were detected at Abakaliki and Ezzamgbo locations than at Ikwo and Okposi locations, whereas the soil moisture at Ikwo and Okposi were statistically the same. The soil hydraulic conductivity values were also significantly higher ($p<0.05$) at Abakaliki and Ezzamgbo than at Ikwo and Okposi in both years, while there were no significant differences in soil temperature among the locations in the study.

Table 2: The Physical Properties of the Soil at the Locations

	2005					2006				
Locations	Bulk Den. (Mg/m^3)	Total Por. (%)	Soil Moist. (%)	Hyd. Cond. (Cm/hr)	Soil Temp. (^0C)	Bulk Den. (Mg/m^3)	Total Por. (%)	Soil Moist. (%)	Hyd. Cond. (Cm/hr)	Soil Temp. (^0C)
Abakaliki	1.47	44.00	20.43	225.0	35	1.46	45.00	15.68	259.75	35.75
Ezzamgbo	1.55	41.75	16.17	223.8	31.25	1.46	45.00	12.93	259.50	35.75
Ikwo	1.69	36.50	14.95	222.5	30.50	1.58	41.00	10.98	221.75	34.50
Okposi	1.74	34.25	11.91	202.5	32	1.68	37.00	9.99	239.75	36.50
$LSD_{(0.05)}$	0.14	2.56	4.34	20.21	NS	0.16	2.31	2.94	21.63	NS

Soil Chemical Properties:

The mean soil chemical properties after the experiment are shown in Table 3. Soil pH was significantly higher ($p<0.05$) at Okposi and Abakaliki locations than at Ezzamgbo location. Soil pH between Abakaliki and Okposi on one hand, and Ezzamgbo and Ikwo locations on the other hand, respectively were statistically comparable. Soil organic carbon (SOC) levels at Abakaliki were 15 and 38% significantly higher ($p<0.05$) than at Ezzamgbo and Ikwo. The soil at Okposi location had 49 and 35% significantly higher ($p<0.05$) organic carbon than at Ezzamgbo and Ikwo. No significant differences in organic carbon were found between Abakaliki and Okposi and between Ezzamgbo and Ikwo locations, respectively. There were no significant differences in soil available P, total N, soil Cation Exchange Capacity (CEC) and exchangeable Na among the locations. Okposi location had 65% significantly higher ($p<0.05$) soil K levels than Abakaliki, Ikwo and Ezzamgbo locations. The soil exchangeable Mg content at Ikwo and Okposi were 67 and 66% significantly ($p<0.05$) higher than at Abakaliki location. But no significant differences in soil Mg content were observed between Abakaliki and Okposi locations on the one hand, and between Ezzamgbo and Ikwo locations, on the other. The soil exchangeable Ca at Okposi location was 76 and 49% significantly higher ($p<0.05$) than at Ezzamgbo and Ikwo, while the soil Exchangeable Ca content at Abakaliki was 71% significantly ($p<0.05$) higher than at Ezzamgbo. The soil exchangeable Ca content at Ezzamgbo and Ikwo on the one hand, and Okposi and Abakaliki on the other hand were, respectively, statistically comparable.

Table 3: Mean Post Harvest Soil Chemical Properties of the Locations.

Locations	pH (H20)	Organic Matter (%)	N (%/Kg)	Na	K Cmol (+) / Kg	Ca	Mg	CEC	P Mg / Kg
1.	5.85	1.56	.077	0.67	0.045	5.81	0.63	21.20	25.34
2.	4.85	0.76	.058	0.67	0.065	1.71	1.17	16.80	20.87
3.	5.55	0.97	.057	0.72	0.045	3.58	1.89	14.60	22.89
4.	6.00	1.49	.079	0.72	0.135	7.04	1.84	19.80	22.38
LSD (0.05)	0.99	0.35	NS	NS	0.023	3.36	1.22	NS	NS

Carrot Growth:

The growth and yield of Carrot at the four locations are shown in Table 4. The Carrot plants at Abakaliki location produced significantly ($p<0.05$) more leaves than those at Ezzamgbo, Okposi and Ikwo locations in

Table 4: The growth and yield of Carrot at the Locations

Locations	2005 No. Leaves	Height (cm)	Leaf Area (cm^2)	Dry Matter (gm)	Fresh Root Yield (t/ha)	2006 No. Leaves	Height (cm)	Leaf Area (cm^2)	Dry Matter (gm)	Fresh Root Yield (t/ha)
Abakaliki	15.92	22.92	148.62	237.37	33.48	8.50	22.77	177.69	155.31	14.36
Ezzamgbo	11.44	22.48	134.09	225.93	28.23	9.52	26.40	170.88	136.13	19.92
Ikwo	12.18	20.59	129.93	212.51	25.98	7.46	19.94	167.85	127.88	14.49
Okposi	11.92	17.53	99.81	166.26	21.85	7.86	24.97	152.65	121.57	11.01
$LSD_{(0.05)}$	1.74	NS	23.86	47.31	9.48	NS	NS	20.61	20.71	5.54

the first year of cropping, but during the second year, no significant differences in the number of leaves were observed among the carrot plants in the four locations. The heights of the plants at the four locations were the same in the two years. The plants at Abakaliki and Ezzamgbo locations had significantly ($p<0.05$) higher leaf area than those at Okposi, while no significant differences in leaf area was observed among the plants in the two locations and Ikwo on the one hand, and between Ikwo and Okposi on the other in the first year. During the second year study, the plants at Abakaliki had significantly ($p<0.05$) higher leaf area than the ones at Okposi, whereas there were no significant differences in leaf area among the plants at Abakaliki, Ezzamgbo and Ikwo locations on the one hand and between those at Ezzamgbo, Ikwo and Okposi on the other. The shoot dry matter yield of the plants at Abakaliki location were consistently higher than the plants at Okposi in both years. The shoot dry matter yield of the plants at Ezzamgbo location was also significantly higher ($p<0.05$) than that of the plants at Okposi in the first year, however, there were no significant differences in plant dry matter yield of the plants at both locations in the second year. There were also no significant differences in the dry matter yield of the plant at both Ikwo and Okposi in the first year on the one hand, and among the plants at Ezzamgbo, Ikwo and Okosi locations on the other in the second year.

Carrot Root Yield:

The results of the carrot root yield at the four locations are presented in Figure 2 The fresh Carrot root yield at Abakaliki was 11.63 t ha $^{-1}$ significantly ($p<0.05$) higher than the yield of the Carrot plants at Okposi location in the first season, while there were no significant differences in fresh Carrot root yield at Abakaliki, Ezzamgbo and Ikwo locations in the first year. During the second year, the Carrot root yield at Ezzamgbo was 8.9 and 5.6 t ha $^{-1}$ significantly ($p<0.05$) higher than those planted at Ikwo and Okposi locations. The average root yield values for the two years across the four locations showed that the Carrot yield at Abakaliki and Ezzamgbo were significantly ($p<0.05$) higher than at Okposi and Ikwo locations.

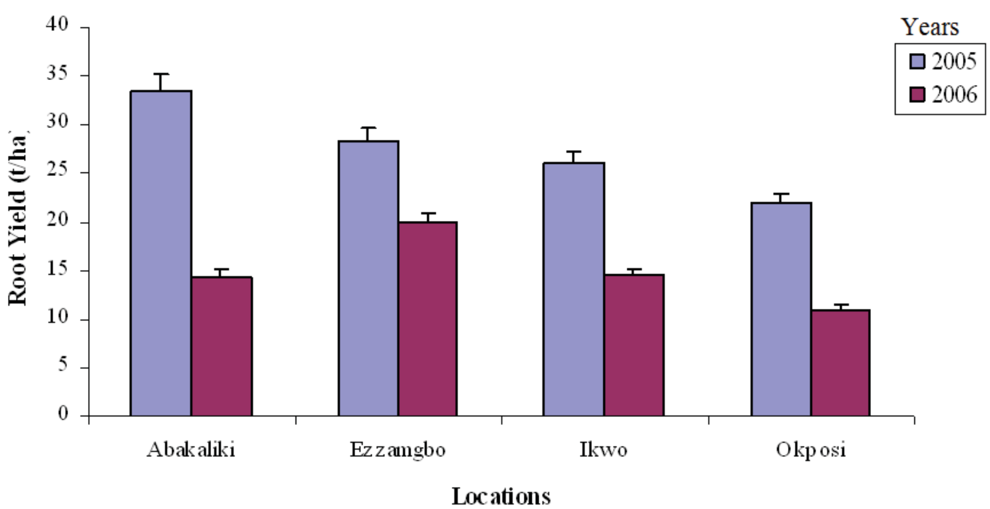

Fig. 2: The carrot root yield (t/ha) at the four locations

Discussion:

Weather Records:

The amount of rainfall and the distributions pattern in the study area did not seem limiting for optimum carrot production. Rainfall was therefore assumed not to have contributed much to the observed variation in the yield of the crop among the locations. Carrot is known to require adequate moisture for the production (David, M., 2003; United Nations, 2003; Agricultural Policy Framework, 2004). The temperatures seem generally too high for the optimum production of the crop. The crop is of temperate origin and usually produced at high altitude with a characteristic cool temperature (David, M., 2003; Agricultural Policy Framework, 2004). The high temperatures in part directly hindered the optimum performance of the crop on one hand and on the other indirectly through its influence on soil temperature and moisture regimes.

Soil Physical Properties:

Generally, the soil bulk density and temperature across the locations were too high for optimum carrot production. Nnabude and Mbagwu (1999) and Ogbodo and Nnabude (2004) had also reported high bulk density and high soil temperature of the soils of the study area. The recommended soil bulk density for optimum carrot production in soils representing the soil of the study area is 1.40 gcm^{-3} (Ashrad, M.A., 1996). Very high bulk density normally leads to soil compaction, poor drainage, reduced infiltration, loss of moisture and nutrients through surface run - off. The high bulk density of the soil most probably limited root penetration, elongation and expansive growth. Carrots have been reported to perform best in soils that are well drained ((Mills, H.A., 2001; SAS Institute Inc., 2006). Under high soil temperature conditions there is reduced root and shoot growth, thus restricting photosynthate partitioning to the tap root. The optimum soil temperature for carrot production is 18 – 22 ^{0}C (USDA, 2005). Soil moisture was generally not limiting throughout the growing period. The soil physical quality was specifically superior at Abakaliki and Ezzamgbo locations than at Ikwo and Okposi locations. The lower soil bulk density and higher total porosity of the soils of Abakaliki and Ezzamgbo areas will enhance root penetration, water infiltration, water conservation, gaseous exchange and nutrient mobility through the soil profile. The attendant higher soil water conductivity property of the soils at the two locations will also lead to better soil drainage conditions. These soil and water conservation properties will lead to improve crop productivity.

Soil Chemical Properties:

The result of the pre-planting soil chemical properties of the experimental area shows that the fertility status of the soil of the area is rather low. The levels of the essential nutrients fall below the standards required for optimum crop production. The low pH, total N, CEC, organic matter and other major nutrient elements, call for great concern. The low level of organic matter may have adversely affected the CEC, buffer capacity and nutrient availability and retention in the soil. Also, the acidic nature of the soil might have limited the release of the essential nutrient elements in the soil on the one hand, and encouraged the release of trace elements (Pb, Fe and Al), all of which impacted negatively on the fertility of the soil. Other researchers who had reported low fertility status of the soils of the area of study include Asadu and Akamigbo (1990), Nnabude and Mbagwu (1999), and Ogbodo and Nnabude (2004). Soils of this nature require adequate fertility management in order to improve the crop productivity.

Carrot Growth and Yield:

The average yield range of 11.01 – 33.48 t/ha observed in the study compared favourably with yield from some other African countries including: 5 – 7 t/ha in Gabon, 10 – 15 t/ha in Ivory Coast, 20 – 40 t/ha in Guinea and 25 – 42 t/ha in Mauritania and Chad (2001). However, the obtained yield range is below the world potential yield range of 40 to 50 t ha^{-1} (USDA, 2005). This was caused by the physical and chemical constraint of the soils of the study locations. The soils high bulk density must have reduced root penetration, plant growth and tuberization. It is a common knowledge that soils with high bulk density suffer compaction, reduced aeration due to low pore spaces, and loss of valuable plant nutrients to water run off. These conditions partly must have led to the level of the yield of the carrot obtained in the study.

The low level of organic matter and soil acidity also in part contributed to the observed low yield, by influencing the release of nutrient elements required for plant growth. The low organic matter levels also adversely affected moisture storage capability of the soil and moderation of soil temperature, which are essential for carrot production. The low pH of the soils at the various sites also led to the observed limited availability of plant nutrient elements very essential for plant growth and production, and therefore affected the availability of several plant nutrients, or could have led to the release of trace elements into the soil, which could be toxic to the plants. Normally carrot performs best at pH between 6.0 – 6.8 (Ontario Ministry of Agric. 1993).

The differences in soil chemical properties among the four locations had very little influence on carrot yields in the study. This was proved by the fact that there were hardly any positive relationships between the carrot root yield and soil chemical properties in the study (Table 5). However, the superior soil physical properties at Abakaliki and Ezzamgbo locations compared to Ikwo and Okposi locations, including lower bulk density, higher total porosity, hydraulic conductivity and water holding capacity lead to the significantly ($p<0.05$) higher carrot growth and yield at the two locations.

Table 5: Relationship between Carrot Root Yield and Soil Chemical Properties (N = 10).

	Root Weight Yield	pH	Organic Carbon	Total N	Na	K	Ca	Mg	CEC	P
Root Weight Yield	-	-.71**	0.56*	0.096	-.75*	-.40	-.32	0.16	-.70*	0.69*
PH		-	-.26	0.40	0.79*	0.42	0.74*	-.33	0.86**	0.67*
Organic Carbon			-	0.25	0.23	0.57*	0.80**	-.88**	0.39	0.67*
Total N				-	0.23	0.59*	0.80*	0.086	0.39	0.19
Na					-	0.38	0.31	-.48	0.96**	0.74**
K						-	0.58*	0.21	0.39	0.21
Ca							-	0.003	0.45	0.21
Mg								-	-.57*	0.25
CEC									-	0.78**
P										-

It was evident that the shoot performance and growth contributed immensely to the Carrot root yield. This influence of plant growth on root yield explained the higher yield at Ezzamgbo and Abakaliki locations. The significantly ($p<0.05$) higher number of leaves, leaf area and dry matter apparently made the plants at Ezzamgbo and Abakaliki to be able to accumulate enough photosynthate and effectively remobilized the stored photosynthate for active tuberisation. The correlation coefficients (Table 6) showed that the variables that motivated the differences in the yield among the locations were the number of leaves, which had very strong relationship ($r = 0.75$) with root yield, the plants leaf area, which showed a very strong correlation ($r = 0.86$) with carrot root yield. Shoot dry matter also showed very strong correlation ($r = 0.90$) with root yield. These growth attributes enabled the plants at Ezzamgbo and Abakaliki to better exploit the observed poor soil environment, available essential plants nutrient elements, and the ability for extraction of the less available ones for higher crop yields.

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

	No of Leaves	Height	Leaf Area	Dry Matter	Root Weight yield
No of Leaves	-	0.072	0.81**	0.72**	0.75**
Height		-	-.074	0.089	0.22
Leaf Area			-	0.93**	0.86**
Dry Matter				-	0.91*
Root Weight Yield					-

Conclusion:

The general characteristics of the soils and climate of the study locations indicated that it is possible to optimize the production of Carrot at Ezzamgbo and Abakaliki. 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 low organic matter, acidity, high soil bulk density and high soil temperature are taken care off, the yield of the crops could be improved.

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