THE EFFECTS OF NITROGEN AND PLANT POPULATION ON THE GROWTH AND YIELD OF VEGETABLE AMARANTH (*Amaranthus cruentus*. L.)

BY

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DECLARATION

I hereby declare that this thesis has been written by me and that it is a record of my own research work. It has not been presented before in any previous application for a higher degree.

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CERTIFICATION

This thesis titled "THE EFFECTS OF NITROGEN AND PLANT POPULATION ON THE GROWTH AND YIELD OF VEGETABLE AMARANT (Amaranthus cruentus, L.) by Auwalu, Bindawa Mansur, meets the regulations governing the degree of Master of Science of Ahmadu Bello University, Zaria, and is approved for its contribution to scientific knowledge and literary presentation.

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DEDICATION

This work is dedicated to my Father (ALHAJI AUWALU BINDAWA) and Mother (BABA SALAMATU A. BINDAWA) who are the coldness of my eyes.

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- B.M. AUWALU (1988)

ABSTRACT

A field experiment was conducted during the wet and dry seasons of 1987 at Samaru, Zaria in northern Guinea Savanna of Nigeria to study the effects of nitrogen and plant population en the growth and yield of vegetable amaranth (Amaranthus cruentus, L.). The treatments consisted of four N levels (0.0, 45.0, 90.0 and 180.0 kg N/ha) and five plant populations (9, 16, 25, 49 and 100 plants/m) laid out in a randomized complete block design with four replications.

Nitrogen application increased plant height, leaf area, shoot dry weight and length of harvested branches significantly over the control. Application of 180 kg N/ha increased marketable, edible and total dry matter yield by 19.5, 20.0 and 17.8 percent, respectively over the control. Percent protein content of the edible yield was significantly increased by N application.

Number of leaves, leaf area, shoot dry weight, number and length of harvested branches per plant as well as percent stand court at harvest were significantly decreased by increase in plant population. Plant height however, increased significantly with increase in plant population.

Marketable, edible and total dry matter yields of vegetable amaranth increased significantly with increase in plant population.

In terms of marketable, edible and total dry matter yields, the dry season crop out-yielded the wet season crop by 59.0, 58.8 and 58.1, respectively.

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Chapter 1

INTRODUCTION

1.1 Origin and Spread

Vegetable amaranth, Amaranthus cruentus L. (Allayafu: Hausa; Tete: Yoruba; Inine: Ibo), a member of the family Amaranthaceae, is widely cultivated in Nigeria (Omidiji, 1978). It was introduced to Africa from Central America by European explorers. In Africa, it passed quickly from tribe to tribe, probably as a weed in millet and sorghum seed. Today, it is being planted and gathered all year round in the humid regions of a large part of African (National Research Council (NRC), 1984).

Amaranthus cruentus is also cultivated for its grains. As grain crop, it is an ancient food, and in the famous Tehaucan caves in central Mexico, archaeologists have dug up remains - both the pale grain and bundles of plants brought in for thresing - at a dozen levels dating 5,500 years back. The species is still grown there and in a few Indian villages of southern Mexico and Guatemala as a grain crop. It has also survived as a crop used to extract a red dye for colouring corn-based foods in the Indian pueblos of the arid south western United States, where it probably became established in prehistoric times (NRC, 1984).

1.2 Botanical Characters

Vegetable amaranth is an erect annual herb which grows to a height of 2m and often with branching habit (Grubben and van Sloten, 1981). The leaves are alternate and simple with long petioles. The blades are variable in shape, from almost lanceolate to broadly trinagular, and slightly decurrent; the tips are often obtuse. The inflorescences are spikes of racemes, axillary or terminal. The flowers are very small and unisexual, occuring in small clusters that sometimes completely cover the spikes. The seeds are tiny, glossy, black and bicovex (Van Epenhuijsen, 1974). The plant develops a tap root system.

1.3 Ecological Requirement

According to NRC (1984), Amaranthus cruentus, L. is probably the must adaptable of all amaranth species. It is useful both as a grain and a leafy vegetable. The vegetable type requires loose humus rich soil (Van Epenhuijsen, 1974) with high contents of potassium and nitrogen (NRC, 1984). For seeds to germinate and establish roots, amaranths require well-moistened soil and for optimum yield vegetable amaranth requires high level of soil moisture throughout the growing season. It is routinely grown in areas receiving 3000 mm of annual

rainfall, and in West Africa production continues even during the torrrential rainy season (NRC, 1984). It also grows well during the dry season under irrigation. Amaranths are C_4 photosynthesizing plants. In common with other C_4 plants such as millet, maize and sorghum, they prefer hot and bright sunlight and are twice as efficient as the C_3 plants in converting to carbohydrate the incident solar radiation (Teutonico and Knorr, 1986).

1.4 Uses, Economic and Nutritional Importance

Vegetable amaranth is grown primarily for its tender stems and succulent leaves which are used in soups and stews. Young shoots are sometimes dried and stored for future use. It is also useful as a forage crop for feeding livestock. Leaf protein concentrates can be extracted from the versatile amaranth and used for feeding young children and other persons with particularly high protein, vitamin A and iron needs (NRC, 1984).

Vegetable amaranth is a fast growing crop with an extremely high yield potential. According to Grubben and Van Slotten (1981) yield of leaves may amount to 30 tons of fresh matter or 4.5 tons of dry matter per hectare in four weeks. It is less susceptible to diseases than most other vegetables and respond well to fertilization. In addition, because of the low production cost involved, it is among the cheapest vegetables in the market

(Grubben and Van Sloten, 1981). Leaf amaranth is grown mainly for local consumption and the crop is sold in the local markets throughout the year.

The nutritional quality of vegetable amaranth is similar to that of other leafy vegetables. Moreover, because its dry matter content (about 13.1%) is often high, an equivalent amount of fresh amaranth often provides two to three times the amount of nutrients in other vegetables (NRC, 1984). Because of its high contents of minerals (Ca and Fe), vitamins such as carotene, riboflavin, niacin, ascorbic acid and folic acid (Oyenuga and Fetuga, 1975) the nutritional value of its products is excellent. According to Oke (1980), amaranth leaves average on a dry weight basis, 30% crude protein, 420 ppm vitamin C, 287 ppm iron, 250 ppm b-carotene and 2.1% calcium. Vegetable amaranth is therefore a good source of protein and of valuable contribution to the diet when protein intake is marginal. In fact, in some African societies protein from amaranth leaves provides as much as 25% of the daily protein intake during the harvest season (NRC, 1984). Amaranth species have also been found to contain high levels of the nutritionally critical amino acids, lysine and methionine (Koch et al., 1965). Thus when judiciously utilized, vegetable amaranth will contribute immensely to the diets,

1.5 Justification for the Study

Although vegetable amaranth is an important crop for the people of the developing world in general, and Nigeria in particular, not much research has been done on the agronomy of the crop. For example, there is very little data on its nitrogen requirements and optimum plant population levels for maximum yields. The few experiments conducted on the crop in Nigeria have been carried out outside the savanna ecological zone (IITA , 1971; Schmidt, 1971; Kogbe, 1977; NIHORT, 1981; Ayodele and Olufolaji, 1982; Ketiku, et al., 1985; Okhiria et al., 1987). Therefore the need to collect more detailed information on the effects of these factors, especially in the savanna ecological zone, justifies this study.

The objective of this study, therefore is to investigate the effects of nitrogen, plant population and their interaction on the growth and yield of vegetable amaranth with a view of optimising the yields and production of the crop.

Chapter 2

LITERATURE REVIEW

Little research work has been carried out in the savanna ecological zone of Nigeria on the effect of agronomic practices on the growth and yield of vegetable amaranth. However, some work has been done and published in the forest zone and other countries where amaranth is a popular leaf vegetable. A review of these findings, is necessary to provide an adequate knowledge of the crop and to serve as a guide on the best way of growing the crop.

2.1 The Effects of Nitrogen on the Growth and Yield of Vegetable Amaranth

Nitrogen is one of the most important elements for plant life. It is essential for the growth of plants as it is a constituent of proteins and nucleic acids. According to NRC (1984) vegetable amaranth requires high level of soil fertility, particularly potassium and nitrogen. Some researchers have observed and reported considerable increase in leaf production due to nitrogen fertilization (Schmidt, 1971; IITA, 1971; Grubben, 1975; Makus, 1983; Abidin and Suwahyo, 1985). Both IITA (1971) and Abidin and Suwahyo (1985) found 30 kg N/ha to be optimum for maximum production of vegetable amaranth. According to these workers

higher level of nitrogen application does not result in better yields. On the other hand Makus (1983) observed a quadratic response to nitrogen treatment with 132 kg N/ha split application giving the greatest response of 19 tonnes/ha averaged over the first three harvests. Since soils vary widely with regard to their physical and chemical fertility, differences in nitrogen requirements are to be expected.

Nitrogen fertilization has also been reported to significantly increased fresh weight by 123%, dry weight of leaves by 121% and to decrease the percent dry matter content by 0.3% in vegetable amaranth (Vuurmans and Grubben, 1977). Decrease in percent dry matter content has also been reported by Abidin and Hilman (1986).

2.2 The Effect of Nitrogen Application on the Quality of Vegetable Amaranth

Nitrogen has been reported to affect the quality of vegetable amaranth products. Schmidt (1971) and Vuurmans and Grubben (1977) observed that nitrogen fertilized vegetables were more succulent than the unfertilized ones. Because consumers prefer fresh and succulent vegetables, this is a qualitative advantage in marketing. Nitrogen has also been reported to increase protein production per plant (Lexander, et al., 1970)

and the percent protein contents of leaf dry matter (Vuurmans and Grubben,1977; Anonymous, 1985). Similarly the carotene, total nitrogen as well as nitrate contents of leaf vegetables were found to increase with increased nitrogen application (Vuurmans and Grubben, 1977).

Ketiku, et al. (1985) reported that application of poultry manure (1.67% N) at the rate of 20 tons/ha increased the crude protein, P, Ca and Mg contents of amaranth leaves. The K, Na and Fe contents were however not much affected by the manure treatment. These workers observed that the levels of nutrients in the crop particularly P and crude protein were sufficiently high that the vegetable could be recommended as a rich source of these nutrients.

In a field experiment to test the hypothesis that plant composition is affected by environmental factors, Vityakon (1986) found that nitrogen plays an important role in controlling the synthesis of oxalate and the accumulation of nitrate in amaranth shoot. He further stated that the highly variable oxalate and nitrate contents in plants grown in environmentally different sites were, to a large extent, due to different soil nitrogen contents. Increase in oxalic acid and decrease in iron contents on high fertility plots have earlier

been reported (Schmidt, 1971; Vuurmans and Grubben, 1977). Since nitrogen affects the nutritional factors of vegetable amaranth, there is need to know the sum total effects and probably arrive at the optimum rate.

2.3 The Effects of Plant Population on the Growth and Yield of Vegetable Amaranth

Plant population plays an important role in the growth and yields of crops. In general, the biological yield or total dry matter production increases with an increase in population, reaches maximum and remains constant even with further increase in population, folllowing asymptotic curve (Willey and Heath, 1969). Thereafter, further increase in plant population could decrease dry matter production through excessive intraspecific competition.

Misra et al. (1985) observed increase in plant height with high density planting. In a field experiment, Olufolaji and Ayodele (1982) working with Celosia argentea,L., (another leafy vegetable in the same family with amaranth and with similar growth characteristics) observed that spacing seedlings at 15 x 15 cm produced the maximum leaf number and leaf area and resulted in the highest marketable and edible yields.

In his work Mathai (1978) found a spacing of 20 x 20 cm to be optimum for amaranth leaf production. Grubben and Van Sloten (1981) suggested that plants be spaced in the range of 10 x 10 cm and 20 x 20 cm depending on the method of harvest anticipated. The narrow spacing (10 x 10 cm) for single harvest while the wide spacing (20 x 20 cm) for repeated cuttings (topping). At the National Horticultural Research Institute (NIHORT), Ibadan, optimum spacing obtained for the crop when harvested by topping was 15 x 15 cm (NIHORT, 1981). Earlier, Deutsch (1977) observed that total dry matter production by vegetable amaranth increased with increase in plant population up to 200 plants/m^2. Similarly, Abidin and Suwahyo (1985) found a population of 190 plants/m^2 to be superior to all other treatments tested (40, 90 and 140 plants/m^2). It can be concluded, therefore, that high plant population gives better yields of vegetable amaranth.

2.4 Interaction between Nitrogen and Plant Population on Vegetable Amaranth

In a field experiment to determine the best combination of plant population and nitrogen levels, Abidin and Suwahyo (1985) found that yields of vegetable amaranth were significantly improved by high density planting andnitrogen fertilisation. Treatments of plant

density placement levels without nitrogen showed that the 190 plants/m^2 gave the highest yield among the four plant population levels of 40, 90, 140 and 190 plants/m^2 studied. However, when nitrogen was added at three levels of 20, 30 and 40 kg N/ha, the highest production of 12.9 tons/ha was obtained with a plant population of 140 plants/m^2 combined with nitrogen at 30 kg N/ha. Their findings demonstrated that nitrogen not only increases leaf production but also decreases the optimum population for maximum yield. Similar effect of soil fertility on plant density have been reported by Misra et al. (1985).

Chapter 3

MATERIALS AND METHODS

3.1 Experimental Sites

The experiment was conducted at the Horticultural Field Unit of the Institute for Agricultural Research, and the Ahmadu Bello University Farm, Samaru, during the 1987 wet (21 June - 5 September) and dry (24 September - 10 December) seasons, respectively. The two sites are located at approximately $11^{o}10'N$, $7^{o}35'E$ and 686m above sea level in the Northern Guinea Savanna ecological zone of Nigeria.

3.2 Treatments and Experimental Deisgn

Four levels of nitrogen 0.0, 45.0, 90.0 and 180.0 kg N/ha and five plant population levels, 9, 16, 25, 49 and 100 plants/m^2 were tested. The total number of treatment combinations was 20 (4x5) each of which was replicated four times. The experiment was laid out in a randomized complete block design with factorial arrangement.

3.3 Cultural Practices

3.3.1 Nursery practices

Seeds of vegetable amaranth (Variety: local green) mixed with sand were sown in trays filled with a mixture of sandy loam soil and properly decomposed farm yard manure (FYM) in the

ratio 3:1. Soon after, the trays were mulched and watered regularly to ensure good germination. The resultant seedlings were nursed for three weeks and then transplanted on the field.

3.3.2 Land preparation

The land was ploughed once and harrowed twice to produce a fine seed-bed. Plots were demarcated with a measuring tape, pegged and made into raised beds during the wet season and sunken ones during the dry season. The plot size was $4m^2$ (2x2m)

3.3.3 Transplanting

Three weeks old amaranth seedlings were transplanted to individual plots in the late afternoon. Plant spacings utilized to achieve the required plant population treatments were 33.3 x 33.3 cm; 25 x 25 cm; 20 x 20 cm; 14.3 x 14.3; and 10 x 10 cm for 9, 16, 25, 49 and 100 plants/m^2, respectively.

3.3.4 Moisture supply

The wet season crop depended on rainfall received during the period (Table 1) which was adequate for crop growth and development. The dry season crop was watered thoroughly, once a week.

3.3.5 Fertilizer application

Fertilizers were applied a week after transplanting in a groove, about 5 cm away from the plants. In addition to the nitrogen treatments, each plot received a blanket application of phosphorus (P_2O_5) and potassium (K_2O) each at the rate of 60 kg/ha. The sources used were: calcium ammonium nitrate (26% N) for nitrogen; single superphosphate (18% P_2O_5) for phosphorus; and muriate of potash (60% K_2O) for potassium.

3.3.6 Weed and pest control

Weekly hand pullings were employed to remove weeds growing on the plots while hand hoe was used to remove weeds between the plots and along foot-paths.

The crop was sprayed weekly with Cymbush 10% EC at the rate of 200ml in 100 litres of water per hectare using the CP-3 knapsack sprayer for the control of insects and their larvae. Spraying was terminated a week before harvest.

3.3.7 Harvesting

Harvesting was done three times. The first harvest was done four weeks after transplanting by cutting the main stem 20 cm above the ground level. Subsequent harvests were done at fortnightly intervals. The second

harvest involved cutting the branches in excess of 10cm, while at the third harvest the plants were cut at the ground level. Yield per hectare for individual plots was assessed from the weight of the middle 20 plants and the area occupied by them. The total 'marketable' and 'edible' yields were determined from the three harvests. The marketable yield includes the fresh weight of both the stems and the leaves while the edible yield refers to the weights of the leaf blades and the petioles. At the last harvest the stand count of individual plots was taken.

3.4 Data Collection

3.4.1 Meteorological data

Data on rainfall distribution, temperature figures, sunshine hours and relative humidity for Samaru during the experimentation period were compiled and presented in table 1.

3.4.2 Soil and plant analysis

For each season's experiment, soil samples were taken randomly after ploughing at the 0-15 and 15-30 cm soil depths using a tubular auger. The samples were analysed to determine their physico-chemical properties using standard procedures as described by Black (1965).

Table 1 Total rainfall, mean temperature, relative humidity and sunshine hours at ten day intervals during the period of the experiment experiment at Samaru in 1987.

Month	Days	Total rainfall (mm)	Mean Diurnal Temperature (°C)	Humidity (%) a.m.	p.m.	Sun-shine (hours)
May	1-10	Nil	30.0	36.0	10.7	9.9
	11-20	Nil	31.0	47.7	16.8	8.1
	21-31	135.7	27.7	66.6	45.6	8.5
June	1-10	85.4	25.2	31.5	63.5	6.4
	11-20	8.2	27.0	71.2	53.3	8.9
	21-30	45.1	25.6	76.7	68.2	7.5
July	1-10	52.3	25.6	77.6	61.7	8.4
	11-20	102.4	25.5	78.9	64.3	7.9
	21-31	118.0	24.5	82.6	68.6	6.8
August	1-10	105.4	24.9	83.0	67.7	7.0
	11-20	75.2	23.9	86.6	76.6	5.1
	21-31	35.4	24.8	86.5	72.8	6.1
Sept	1-20	33.0	25.2	78.7	64.8	8.0
	11-20	57.1	25.4	75.9	65.6	7.1
	21-30	12.0	25.7	73.2	59.1	8.9
October	1-10	42.6	25.4	73.4	57.1	8.0
	11-20	Nil	25.1	62.6	47.3	9.4
	21-31	Nil	22.5	28.4	28.8	8.3
Nov.	1-10	Nil	21.3	22.0	19.0	9.4
	11-20	Nil	22.1	23.7	19.7	9.2
	21-30	Nil	23.0	22.3	18.1	10.0
December	1-10	Nil	22.6	24.5	18.9	8.5
	11-20	Nil	20.6	29.9	16.7	8.9
	21-31	Nil	21.5	27.3	21.6	7.4

Source: Meteorological Unit, Institute for Agricultural Research, Samaru, Zaria, Nigeria.

Results of the analysis are presented in table 2.

The total nitrogen content of the edible yield was determined using the A.O.A.C. (1970) methods. The figures were converted into percent crude protein.

3.4.3 Assessment of growth characters

Assessment of growth characters was done at the second, third and fourth week after transplanting except for number and length of harvested branches which was done at the second harvest. Samples were taken randomly and at each sampling two plants per plot were cut at ground level using a sharp knife. Samples from each plot were then put into polythene bags to minimize moisture loss and taken to the laboratory for detail observations. Each sample was first of all weighed and separated into stem and leaves and the following observations recorded:

- Shoot fresh weight
- Number of leaves
- Plant height from ground level to the growing point
- Number of primary branches
- Leaf area: Here, the leaves of three randmoly selected plants were detached, traced on square graph sheets to determine their areas.

Table 2 Physico-chemical properties of the soil at the experimental sites before the trials at 0-15 cm and 15-30 cm soil depths.

Soil property	Horticultural Field Unit[1]		University Farm[2]	
	0-15cm	15-30cm	0-15cm	15-30cm
Particle size distribution				
% sand	49	49	37	39
% silt	34	34	44	42
% clay	15	17	19	19
Textural class	sandy loam	sandy loam	loam	loam
pH 1:2.5				
- Water	5.0	4.9	5.9	5,9
- 0.01 $CaCl_2$	4.0	4.0	5.5	5.5
Organic carbon (%)	0.26	0.24	0.68	0.52
C.E.C. (meq/100g soil)	4.80	5.00	6.00	6.20
Available phosphorus (ppm)	16.80	16,10	20,30	18.20
Total Nitrogen (%)	0.028	0.028	0.056	0.056
Exchangeable bases (meq/100g soil)				
Ca	1.28	1.45	2.80	2.89
Mg	0.32	0.40	1.43	1.43
K	0.14	0.17	0.54	0.56
Na	0,11	0.14	0.12	0.12

[1]Horticultural Field Unit of IAR, Samaru - site for wet season trial.

[2]A.B.U. University Farm - site for the dry season trial.

The leaves were then oven dried and weighed. Using this leaf area - dry weight relationship, the leaf area of the other plant samples were determined by proportion.

- Shoot dry weight (dry weights of leaves and stem).

Samples were then air-dried for a day and then placed in paper envelopes and transfered to an electric oven maintained at 70°C to a constant weight.

3.5 Analysis of Data

An analysis of variance was done to test the treatment effects for significance using the 'F' test as described by Snedecor and Cochran (1967). The effects of nitrogen, plant population, season and their interactions in all parameters measured were considered. Where the 'F' test showed significance, the means were compared using the Duncan's multiple range test (Duncan, 1955). Analysis of correlation between growth characters and amaranth yields was done to determine their relationship.

Chapter 4

RESULTS

4.1 Growth Characters

4.1.1 Number of leaves

Data on the effect of nitrogen, plant population and season on number of leaves per plant of vegetable amaranth at weekly intervals are presented in Table 3a. The effect of nitrogen was significant only at 3 WAT. Number of leaves increased with increase in nitrogen application. However, there was no difference in the number of leaves between fertilizer rates of 0.0 and 45.0 kg N/ha and 90.0 and 180.0 kg N/ha.

The effect of plant population on number of leaves per plant was significant at 2 and 4 WAT. At 2 WAT, populations of 16, 25, 49 and 100 plants/m^2 had statistically the same but higher number of leaves per plant than the treatment of 9 plants/m^2. However, the difference between the number of leaves produced at the populations of 9 and 16 plants/m^2 was not statistically significant. At 4 WAT, number of leaves decreased with increase in population, and the 100 plants/m^2 produced significantly lower number of leaves than the other treatments, which were statistically at par.

Table 3a Number of leaves per plant of vegetable amaranth recorded at weekly intervals as influenced by nitrogen, plant population and season at Samaru in 1987.

Treatment	Weeks after transplanting		
	2	3	4
Nitrogen (kg N/ha)			
0.0	18.25	38.10b[1]	70.41
45.0	17.68	39.48b	84.25
90.0	20.65	47.65a	83.55
180.0	20.18	50.68a	84.54
S.E. ±	1.051	2.591	6.387
Plant population (plants/m^2)			
9	16.34b	38.02	85.25a
16	18.88ab	43.31	94.08a
25	18.48ab	44.84	91.94a
49	21.55a	46.55	78.31a
100	20.69a	47.16	53.86b
S.E. ±	1.175	2.896	7.141
Season			
Wet	10.45b	32.30b	45.75b
Dry	27.93a	55.65a	115.63a
S.E. ±	0.743	1.832	4.516

[1]Means followed by the same letter(s) within a treatment are not significantly different at 5% level of significance using DMRT.

The effect of season on the number of leaves was significant throughout the period of sampling; the dry season crop produced significantly higher number of leaves per plant.

Table 3b shows the interaction between nitrogen and plant population on number of leaves per plant at 4 WAT. The two factor interaction showed that application of 45.0 kg N/ha combined with the 16 plants/m^2 population produced the highest number of leaves. On the other hand the lowest number of leaves was produced by 100 plants/m^2 population combined with 0.0 kg N/ha. Irrespective of nitrogen level, leaf production dropped drastically at the highest population tested.

4.1.2 Leaf area

Table 4a shows the effects of nitrogen, plant population and season on leaf area per plant. Leaf area increased with increase in nitrogen application throughout the stages of the experiment. The nitrogen fertilized plants produced statistically the same, but significantly higher leaf area than the unfertilized control.

Table 3b Interaction between nitrogen and plant population on the number of leaves per plant of vegetable amaranth at 4 weeks after transplanting at Samaru in 1987.

Treatment	Nitrogen (kg N/ha) 0.0	45.0	90.0	180.0
Plant population (plants/m^2)				
9	81.19b-e	71.69c-e	80.19b-e	107.94a-c
16	81.81b-e	138.13a[1]	88.44b-d	67.94c-e
25	87.13b-d	76.88b-e	122.44ab	81.31b-e
49	67.44c-e	81.44b-e	64.63c-e	99.75a-d
100	34.5e	53.13de	62.06c-e	65.75c-e
SE ±		14.282		

1 Means followed by the same letter(s) within a treatment are not significantly different at 5% level of significance using DMRT.

Table 4a Leaf area (cm^2) per plant of vegetable amaranth recorded at weekly intervals as influenced by nitrogen, plant population and season at Samaru in 1987.

Treatment	Weeks after transplanting		
	2	3	4
Nitrogen (kg N/ha)			
0.0	88.12c[1]	215.66c	829.54b
45.0	99.84bc	261.11c	1039.93a
90.0	114.01b	341.47b	1167.76a
180.0	149.38a	422.41a	1092.98a
SE ±	8.275	21.285	68.326
Plant population (plants/m^2)			
9	95.33	285.98	1179.91a
16	109.88	295.28	1100.09a
25	114.41	304.37	1265.99a
49	117.90	335.63	1082.75a
100	126.67	329.55	705.03b
S.E. ±	9.252	23.997	76.390
Season			
Wet	111.35	381.97	548.38b
Dry	114.33	238.35	1585.13a
S.E. ±	5.851	15.050	48.313

[1]Means followed by the same letter(s) within a treatment are not significantly different at 5% level of significance using DMRT.

The effect of plant population was significant at 4 WAT only. Planting at a population of 100 plants/m^2 produced plants with significantly lower leaf area than the other treatments which were at par.

Table 4a also shows that seasonal differences were significant at 4 WAT; the dry season crop gave a larger leaf area per plant than the wet season crop.

Nitrogen x plant population interaction was significant at 4 WAT (Table 4b). Irrespective of nitrogen applied there was a decrease in leaf area with increase in plant population. On the other hand there was a general increase in leaf area with increased nitrogen application, at all plant population levels.

4.1.3 Plant height

Application of nitrogen significantly increased plant height throughout the sampling period (Table 5a). At 4 WAT there was no difference in plant height among the nitrogen fertilized plants, but these were significantly higher than the unfertilized plants.

Plant height increased significantly with increase in plant population. At 4 WAT, there was no difference in plant height between the treatments of 9, 16 and 25 plants/m^2 and also between the treatments

Table 4b Interaction between nitrogen and plant population on the leaf area (cm^2) per plant of vegetable amaranth at 4 weeks after transplanting at Samaru in 1987.

Treatments	Nitrogen (kg N/ha) 0.0	45.0	90.0	180.0
Plant population (plants/m^2)				
9	1078.91b-f[1]	1009.26b-f	1240.95a-d	1390.53ab
16	992.99b-f	1306.60a-c	1283.03a-d	817.75c-f
25	946.53b-e	1077.84b-f	1710.00a	1329.60a-c
49	1110.78b-e	1166.97b-e	890.79c-f	1162.45b-e
100	702.55f	638.96f	714.03f	764.59d-f
		152.781		

1 Means followed by the same letter(s) within a treatment are not significantly different at 5% level of significance using DMRT.

Table 5a Plant height (cm) of vegetable amaranth recorded at weekly intervals as influenced by nitrogen, plant population and season at Samaru in 1987.

Treatment	Weeks after transplanting		
	2	3	4
Nitrogen (kg N/ha)			
0.0	4.73d[1]	8.98d	19.86b
45.0	6.20c	11.47c	25.42a
90.0	7.63b	14.44b	24.03a
180.0	8.94a	16.42a	25.04a
S.E. (±)	0.418	0.700	0.989
Plant population (plants/m^2)			
9	6.15bc	11.33b	21.48b
16	5.96c	11.94b	20.88b
25	7.08abc	11.86b	23.30ab
49	7.41ab	14.30a	25.90a
100	7.77a	14.70a	26.37a
S.E. ±	0.467	0.779	1.106
Season			
Wet	9.28a	16.86a	22.48b
Dry	4.47b	8.79b	24.70a
S.E. ±	0.295	0.493	0.699

[1]Means followed by the same letter(s) within a treatment are not significantly different at 5% level of significance using DMRT.

of 25, 49 and 100 plants/m^2, however the latter group were significantly higher.

Seasonal effects on plant height were significant at 2, 3 and 4 WAT. At 2 and 3 WAT the wet season crop produced significantly higher plants. However, at 4 WAT the highest plants were produced during the dry season.

There was a significant nitrogen x season interaction throughout the period of sampling (Table 5b). At 2 and 3 WAT highest plant was produced during the wet season due to the application of 180.0 kg N/ha. At 4 WAT, the highest plant was produced during the dry season due to the application of 45.0 kg N/ha. However, this was statistically at par with the plants due to application of zero and 90.0 kg N/ha during the dry season, and also 90.0 and 180.0 kg N/ha during the wet season.

4.1.4 Shoot dry weight

The effect of nitrogen, plant population and season on shoot dry weight per plant of vegetable amaranth is presented in Table 6a. Nitrogen affected dry matter accumulation throughout the period of sampling. A trend was established; increase in nitrogen application resulted in increased shoot dry

Table 5b Interaction between nitrogen and season on plant height (cm) of vegetable amaranth recorded at weekly intervals at Samaru in 1987.

	2 WAT[1]		3 WAT		4 WAT	
	Season		Season		Season	
Nitrogen (kg N/ha)	Wet	Dry	Wet	Dry	Wet	Dry
0.0	5.26d[2]	4.20d	9.64d	8.32d	15.18c	24.53a
45.0	8.31c	4.09d	14.98d	7.96d	23.14d	27.7a
90.0	10.47b	4.79d	19.49b	9.39d	24.38ab	23.68ab
180.0	13.07a	4.81d	23.34a	9.50d	27.22ab	22.87b
SE. ±	0.591		0.935		1.399	

[1] WAT = weeks after transplanting

[2] Means followed by the same letter(s) are not significantly different at 5% level of significance using DMRT.

Table 6a Shoot dry weight (g) per plant of vegetable amaranth recorded at weekly intervals as influenced by nitrogen, plant population and season at Samaru in 1987

Treatment	Weeks after transplanting		
	2	3	4
Nitrogen (kg N/ha)			
0.0	0.71c[1]	1.74c	7.15b
45.0	0.85bc	2.28c	8.32ab
90.0	1.04b	3.11b	9.44a
180.0	1.40a	4.33a	9.25a
S.E. (±)	0.076	0.264	0.507
Plant population (plants/m^2)			
9	0.85	2.66	9.24a
16	0.90	2.66	8.68a
25	1.04	2.87	9.77a
49	1.04	2.93	9.05a
100	1.17	3.21	5.97b
S.E. (±)	0.085	0.295	0.567
Season			
Wet	1.24a	4.25a	6.51b
Dry	0.76b	1.48b	10.57a
S.E. ±	0.054	0.186	0.507

[1]Means followed by the same letter(s) within a treatment are not significantly different at 5% level of significance using DMRT.

weight per plant. However, at 4 WAT, there was no difference between the control and 45.0 kg N/ha on one hand and 45.0, 90.0 and 180.0 kg N/ha on the other, but the latter group produced heavier shoot than the former.

The effect of plant population was significant only at 4 WAT when treatments of 9, 16 and 25, and 49 plants/m^2 had statistically the same but significantly heavier shoots than the 100 plants/m^2 population level. Seasonal effects on shoot dry weight per plant were significant at 2, 3 and 4 WAT. At 2 and 3 WAT the wet season crop produced significantly heavier shoots. The reverse was the case at 4 WAT when the dry season crop produced the heavier shoots.

Interaction between nitrogen and season was significant throughout the sampling period (Table 6c). At the initial stages of growth (2 and 3 WAT) the wet season trial produced heavier shoots at all nitrogen levels. At 4 WAT, however, the reverse was the case and the dry season crop gave heavier shoots.

The significant interaction between nitrogen and plant population on shoot dry weight per plant

Table 6b Interaction between nitrogen and season on shoot dry weight weight (g) per plant of vegetable amaranth recorded at weekly interval at Samaru in 1987

Nitrogen (kg N/ha)	2 WAT[1]		3 WAT		4 WAT	
	Season		Season		Season	
	Wet	Dry	Wet	Dry	Wet	Dry
0.0	0.64d[2]	0.78cd	2.14d	1.34d	4.46e	9.84ab
45.0	1.04bc	0.67d	3.36c	1.20d	6.24de	10.41ab
90.0	1.29b	0.79cd	4.52b	1.70d	6.99cd	11.88a
180.0	1.98a	0.81cd	7.00a	1.66d	8.37bc	10.14ab
SE ±	0.108		0.373		0.717	

[1]WAT = weeks after transplanting

[2]Means followed by the same letter(s) are not significantly different at 5% level of significance using DMRT.

at 4 WAT is presented in Table 6c. In general, dry weight increased with increase in nitrogen application, at all populations tested. Conversely, shoot dry weight per plant decreased with increase in plant population. The heaviest shoot was due to combination of 25 plants/m^2 and 90.0 kg N/ha, and lightest due to 100 plants/m^2 with no nitrogen. Irrespective of nitrogen level, shoot dry weight per plant was drastically reduced at the highest population tested.

4.1.5 Number and length of harvested branches

Number of harvested branches per plant of vegetable amaranth increased with increased nitrogen application, but the difference between levels was not significant (Table 7a). However, length of harvested branches was significantly affected by nitrogen levels. The longest branch was due to the application of 90.0 kg N/ha which was statistically at par with branches due to application of 180.0 kg N/ha.

Increase in plant population resulted in a significant reduction of both the number and length of harvested branches. Planting at 100 plants/m^2 produced the lowest number and shortest kind of harvested branches.

Table 6c Interaction between nitrogen and plant population on shoot dry weight (g) per plant of vegetable amaranth at 4 weeks after transplanting at Samaru in 1987.

Treatment	Nitrogen levels (kg N/ha) 0.0	45.0	90.0	180.0
Plant population (plants/m^2)				
9	8.18b-e[1]	7.86b-f	9.48b-e	11.47ab
16	7.36c-f	9.97a-d	10.71a-c	6.66d-f
25	8.96c-f	8.33b-e	13.28a	10.49a-c
49	8.56b-d	9.49b-d	7.44c-f	10.69a-c
100	4.69f	5.97ef	6.27d-f	6.96c-f
SE ±		1.134		

[1] Means followed by the same letter(s) within a treatment are not significantly different at 5% level of significance using DMRT.

Table 7a Effect of nitrogen, plant population and season on number and length of harvested branches per plant and percent stand count at harvest of vegetable amaranth at Samaru in 1987.

Treatment	Number of harvested branches/ plant	Length of harvested branches/ plant (m)	Percent stand count
Nitrogen (kg N/ha)			
0.0	7.83	1.77b[1]	92.05
45.0	8.13	1.81b	89.45
90.0	8.30	2.02a	90.08
180.0	8.08	1.96ab	90.88
SE ±	0.247	0.070	0.903
Plant population (plants/m^2)			
9	8.75a	2.48a	95.19a
16	8.75a	2.34ab	90.88b
25	8.84a	2.25b	88.53b
49	7.25b	1.39c	88.53b
100	6.81b	1.01d	89.94b
SE ±	0.276	0.078	1.010
Season			
Wet	5.79b	1.26b	90.19
Dry	10.38a	2.53a	91.04
SE ±	0.175	0.049	0.639

[1]Means followed by the same letter(s) within a treatment and a column are not significantly different at 5% level of significance using DMRT.

Season affected both the number and length of branches, and the dry season crop produced significantly more and longer branches.

Table 7b shows that the interaction between plant population and season was significant for both the number and length of branches. It is evident that at all populations tested more and longer branches were produced during the dry season.

4.1.6 Percent stand count

Table 7a also shows the data on percent stand count recorded at 8 WAT as influenced by nitrogen plant population and season. Both nitrogen levels and season did not affect percent stand count at harvest significantly. Percent stand count decreased with increase in plant population. Planting at 9 plants/m^2 resulted in significantly higher stand count than the other populations which were at par.

4.2 Effect of Nitrogen, Plant population and Seasons on the Yields of Vegetable Amaranth

Table 8a shows the main effects of nitrogen, plant population and season on marketable , edible and total dry matter yields (tons/ha) of vegetable amaranth.

Table 7b Interaction between plant population and season on the number and length of harvested branches per plant of vegetable amaranth at Samaru in 1987.

Treatment	Number of harvested branches		Length of harvested branches	
Plant population (plants/m^2)	Season Wet	Dry	Season Wet	Dry
9	6.44d[1]	11.06a	1.52b	3.44a
16	5.88de	11.63a	1.37bc	3.30a
25	5.94de	11.75a	1.35bc	3.15a
49	5.13e	9.38b	1.18cd	1.61b
100	5.56de	8.06c	0.80d	1.14d
S.E. ±	0.390		0.110	

[1] Means followed by the same letter(s) within a treatment are not significantly different at 5% level of significance using DMRT.

Table 8a Effects of nitrogen, plant population and season on marketable, edible and total dry matter yields (t/ha) and percent crude protein content of vegetable amaranth at Samaru in 1987.

	Marketable yield	Edible yield	Total dry matter yield	Percent crude protein
Nitrogen (kg N/ha)				
0.0	82.65b[1]	39.40b	11.14b	27.29c
45.0	94.66a	45.38a	12.69a	29.11b
90.0	95.14a	45.28a	12.64a	30.38b
180.0	102.71a	49.23a	13.55a	32.45a
SE ±	3.182	1.548	0.417	0.548
Plant population (plants/m^2)				
9	50.34e	24.02e	6.68e	29.36
16	67.42d	32.31d	8.97d	29.54
25	89.95c	42.59c	11.97c	30.39
49	105.48b	50.59b	14.06b	30.92
100	155.77a	74.63a	20.80a	28.83
S.E. ±	3.558	1.730	0.467	0.613
Season				
Wet	54.55b	26.17b	7.38b	29.07
Dry	133.03a	63.49a	17.63a	30.54
S.E. ±	10.281	4.808	1.342	0.388

1 Means followed by the same letter(s) within a treatment and a column are not significantly different at 5% level of significance using DMRT.

Application of nitrogen increased yields significantly, however the differences in yields due to the application of 45.0, 90.0 and 180 kg N/ha were not significant.

Marketable, edible and total dry matter yields of vegetable amaranth increased significantly with successive increase in plant population. At 100 plants/m^2, these were 155.77; 74.63 and 20.80 t/ha, respectively. Similarly seasonal effects on yields were highly significant. The dry season crop produced significantly higher yields than the wet season crop.

Plant population x season interaction was significant for marketable, edible and total dry matter yields. At all plant population tested, the dry season crop yielded more than the wet season crop (Table 8b).

4.3 Percent Crude Protein Content

Percent crude protein content of vegetable amaranth increased significantly with increase in nitrogen application (Table 81). Application of 180.0 kg N/ha gave the highest percent crude protein content. Plant population and season did not affect percent crude protein content of the edible yield significantly.

Table 8b Interaction between plant population and season on marketable, edible and total dry matter yields (t/ha) of vegetable amaranth at Samaru in 1987.

Treatments	Marketable Yield		Edible Yield		Total dry matter yield	
	Season		Season		Season	
Plant population (plants/m^2)	Wet	Dry	Wet	Dry	Wet	Dry
9	13.54h[1]	87.14e	6.49h	41.56e	1.82h	11.55e
16	30.01g	104.83d	14.41g	50.21d	4.06g	13.88d
25	37.05g	142.84bc	17.77g	67.41bc	5.02g	18.93bc
49	57.82f	153.15b	27.74f	73.45b	7.83f	20.29b
100	134.33c	177.21a	64.46c	84.82a	18.18c	23.48a
SE ±	5.031		2.447		0.660	

1 Means followed by the same letter(s) within a treatment are not significantly different at 5% level of significance using DMRT.

4.4 Correlation

Results of correlation analysis revealed a significant positive correlation between amaranth yields and growth characters (Table 9). However, a highly significant negative correlation was observed between stand count at harvest and length of harvested branches. Similarly, there was a significant negative correlation between stand count at harvest and shoot dry weight per plant at 4 WAT.

Table 9 Correlation between marketable yield (MY), edible yield (EY), total dry matter yield (TDY), shoot dry weight (SDW), plant height (PH), number of leaves (NL), leaf area (LA), number of harvested branches (NHB), length of harvested branches (LHB), and stand count (SC) at harvest.

	MY	EY	TDMY	SDW	PH	NL	LA	NHB	LHB	SC
MY	1									
EY	.967**	1								
TDMY	.879**	.895**	1							
SDW	.294**	.226**	.201*	1						
PH	.359**	.392**	.387**	.502**	1					
NL	.359**	.269**	.140	.652**	.228*	1				
LA	.439**	.345**	.209*	.896**	.320**	.735**	1			
NHB	.473**	.358**	.221*	.490**	.069	.572**	.675**	1		
LHB	.205*	.091	.001	.526**	.009	.558**	.641**	.828**	1	
SC	.613**	.690**	.621**	-.218*	286**	-.146	-.144	-.145	-.452**	1

Values above .195(*) are significant at 5% level of significance
Values above .254(**) are significant at 1% level of significance

Chapter 5

DISCUSSION

5.1 The Effect of Nitrogen

The result of this investigation indicates the beneficial effect of N in increasing the growth, yield and quality of amaranth. These results are expected since nitrogen is known to encourage vegetative growth of plants. Tsuno (1973) reported that high nitrogen concentration in plants is a favourable condition for protein synthesis which is essential to the building of new organs.

Although the number of leaves and harvested branches per plant increased with nitrogen application, the difference over the control was not significant. It is possible that enough nitrogen was present in the soil for leaf and branch formation but not for their expansion. This is further confirmed by the significant increase in leaf area and length of branches recorded at harvest with application of nitrogen in this investigation. The fact that leaf number did not significantly differ between the control and the other nitrogen levels while at the same time leaf area increased significantly with nitrogen application indicates that nitrogen fertilized leaves were larger and probably thicker as well. In

vegetable amaranth leaf and branch numbers could also be genetic characters while their expansion being a function of the environment.

Marketable, edible and total dry matter yields of vegetable amaranth were significantly increased by nitrogen application. These were increased by 19.5, 20.0 and 17.8 percent, respectively when the rates of nitrogen was raised from 0 to 180 kg N/ha. However, application of nitrogen beyond 45 kg N/ha did not bring about a significant increase in yields. The lack of yield response beyond 45 kg N/ha may be due to the soil N status during the dry season (0.056 percent) which was higher than the average value (0.038 percent) reported for the savanna cultivated soils (Balasubramania, et al., 1984). The high soil N content had therefore satisfied a large proportion of the crops N requirements.

The increase in yield recorded in response to nitrogen application is in conformity with the findings of earlier workers (Schmidt, 1971; IITA, 1971; Grubben, 1975; Makus, 1983; Abidin and Suwahyo, 1985). However, the non-significant response beyond 45 kg N/ha contradicts earlier finding by Makus (1983) who observed the greatest response at 132 kg N/ha rate and not below. The observed differences in these two findings can be explained from differences in soil fertility status. Since soils vary widely with regards to their physical

and chemical fertility status, differences in nitrogen requirements are to be expected.

Differences in yield levels and yield response to nitrogen application can also be traced to variation in environmental resources especially rainfall and solar radiation over the globe. Varietal differences may be very important in vegetable amaranth as in other crops. According to Terman (1971) and Anonymous (1977) the fertilizer efficiency on crop yields is also dependent on the crop varieties among other factors.

The crude protein content of the edible yield was significantly increased from 27.29 percent in the control to 29.11, 30.36 and 32.45 percent by the application of 45, 90 and 180 kg N/ha, respectively. Nitrogen is a constituent of proteins and with increase in its application more is taken for protein synthesis. This result is in conformity with those reported by Vuurmans and Grubben 1977 and Anonymous, 1985. Similarly, application of poultry manure (1.67% N) at the rate of 20 tons/ha has been reported to increase amaranth yields (Kogbe, 1977) as well as the crude protein, P, Ca and Mg contents of amaranth leaves (Ketiku et al., 1985). The beneficial effects of the poultry manure in these reports must primarily be linked with the nitrogen content of the manure inaddition to P, Mg and trace elements.

5.2 The Effect of Plant Population

The effect of plant population on growth characters and yields of vegetable amaranth was highly significant. The plant growth characters such as number of leaves, leaf area, shoot dry weight, number and length of harvested branches per plant all showed a decreasing trend with increase in plant population. The decrease in these parameters with increase in plant populcation can be attributed to increased interplant competition. Indidivual plants had competed with one another for space, water, nutrients and light. Although the number of leaves, leaf area and shoot dry weight per plant decreased with increase in plant population, the decrease was not significant up to 49 plants/m^2. However, these were drastically reduced at 100 plants/m^2, indicating a probable point of maximum stress of competition.

Plant height increased significantly with increase in plant population. The highest plants were recorded at the highest population. Increase in plant height is in accordance with the phenomenon of competition for light between individual plants which became acute at high populations. Similar observation was made by Misra *et al.* (1985), working with grain amaranth. According to these workers a plausible explanation for the height increase of plants observed with increasing density could

be the channelling of energies from branch formation into the main stalk at higher densities. This is further confirmed in this experiment by the lowest number and shortestkind of harvested branches recorded at the highest population.

Although yield per plant, as expressed by growth characters, and dry matter accumulation decreased with increase in plant population, the yield per unit area showed an increasing trend due to greater number of plants. This is also expected. With increase in plant population more light is intercepted and subsequently convered into dry matter yield. In a field experiment Deutsch (1977) noted that total dry matter production by vegetable amaranth increased with increasing density up to 200 plants/m^2. Also Abidin and Suwahyo (1985) found a density of 190 plants/m^2 to be superior to lower populations.

The yield increase up to 100 plants/m^2 obtained in this study however, contradicts earlier finding in the forest zone of Nigeria where highest yields were obtained at 15 x 15 cm spacing which approximately correspond with 49 plants/m^2 population (Ayodele and Olufolaji, 1982). At comparable plant population (49 plants/m^2) the marketable (105.48 t/ha) and edible (50.59 t/ha) yields obtained in the present study more

doubled those obtained by these workers (47.97 t/ha and 24.16 t/ha, respectively). These differences can be explained from the amount of solar radiation and the resultant dry matter accumulation which has been shown to be twice as high in the savanna as in the forest zone (Kassam and Kowal, 1973).

Percent stand count at harvest decreased with increased plant population in accordance with the survival of the fittest and the phenomenon of self thinning which has been observed with most field crops (Harper and White, 1970).

5.3 The Effect of Season

The dry season crop excelled the wet season crop in growth characters and yields at harvest. The significant seasonal effects on the growth and yield of vegetable amaranth in this study can be explained from the combined effect of two factors.

The first and by far the most important is the effect of conducive environmental conditions. Of this kind is the longer sunshine hours received during the dry season (Table 1). Then comes the effects of soil moisture condition. During the wet season excessive rainfall received during the months of July and August (Table 1) must have leached the fertilizer nitrogen

added to the sandy soil of the experimental site. Excess rainfall had also resulted in water logging and consequently reduced crop vigour and poor yields. The incidence of pests and diseases is also noteworthy. While no pest or disease attack was of economic importance during the dry season, the wet season crop was heavily attacked by anthracnose disease induced by Colletotricum sp a week to the first harvest. This in addition to leaf damage by insects and their larvae reduced the yield of the wet season trial considerably.

The second factor which could explain the yield difference between the two seasons was the issue of soil fertility. The soil at the University Farm was both physically and chemically better compared with the soil at the Horticultural Unit. While the former was a loam the latter was a sandy loam (Table 2). Soil pH determination in both water and $CaCl_2$ indicated that the wet season soil was more acidic and poorly buffered than the dry season soil. Chemically the soil at the University Farm excelled the one at the Horticultural Unit in organic carbon, cation exchange capacity, total nitrogen, available P, as well as exchangeable bases such as Ca, Mg, and K (Table 2).

The high soil fertility of the soil at the University farm was historic. The field had served as an animal pen before it was brought under cultivation. For the past three years the field had been green manured to winged bean (Psophocarpus tetragonolobus), a legume capable of symbiotic nitrogen fixation. Sinnadurai (1977) showed that winged bean crop increased the levels of soil N and the beneficial effect of this N was evident in a succeeding tomato crop. Also, according to Lombin and Abdullahi (1981), a field previously cropped with legumes may fix up to 100-150 kg N/ha. Thus, it is no wonder that there was the high nitrogen content and the lack of significant response to nitrogen application on this soil.

In terms of marketable, edible and total dry matter yields, the dry season crop excelled the wet season crop by 59.0, 58.8 and 58.1 percent, respectively. The better growth and yield obtained during the dry season is in conformity with earlier findings with vegetable crops in the savanna ecological zone. According to Kumar and Owonubi (1987) vegetable yields in the wet season are less than half of that obtained during the dry season.

The slight but non-significant increase in the crude protein content of the dry season crop over the wet season is a reflection of high fertility of the soil at the University farm.

5.4 Interactions

5.4.1 Nitrogen x plant population

This interaction was significant (P=0.05) for number of leaves, leaf area and shoot dry weight per plant at 4 WAT. These parameters showed a decreasing trend with increase in plant population - in accordance with competition for environmental resources - irrespective of nitrogen level. Nitrogen application increased these parameters, however for each plant population level, values obtained were comparable with those of the control . The high percent soil nitrogen content of the soil at the University Farm and hence the non-significant response to nitrogen during the dry season explains this comparability.

5.4.2 Nitrogen x season

Plant height and shoot dry weight per plant at 2, 3 and 4 WAT were significantly (P=0.05) affected by nitrogen x season interaction. At all nitrogen levels tested the wet season crop was superior to the dry season crop in these parameters at the initial stages of growth (2 and 3 WAT). The reverse was the case later at 4 WAT. The wet season crop showed a more or less uniform growth pattern. This can be attributed to the uniform temperature condition throughout the period of the experiment. The

slow start of the dry season can be adduced to the low temperature prevalent at that time (Table 1). The rate of germination of seeds, of seedling growth and of root growth depends on the soil temperature, being negligible below a certain temperature, rising to a maximum and then falling off as the temperature rises (Russel, 1973). Also temperature affects crop growth indirectly because of its overriding influence on the rates of water and nutrient uptake. The rate at which roots can take up water and nutrients from the soil increases with soil temperature, and for some crops at least, this rate may continue to increase until the temperature gets sufficiently high to start harming the roots (Russel, 1973).

5.4.3 Plant population x season

Plant population x season interaction significantly ($P=0.05$) increased the number and length of harvested branches as well as marketable, edible and total dry matter yields of vegetable amaranth. The dry season crop at all population levels adopted was superior to the wet season crop. This superiority can be attributed to a more conducive environmental condition and more fertile soil.

5.5 Correlation

The significant positive correlation between yields and the various growth characters indicates that these are critical determinants of amaranth yields. Also, the highly significant positive correlation between amaranth yields and stand count at harvest suggests that for high yields the number of plants per unit area must be sufficiently high. The significant negative correlation between shoot dry weight and length of harvested branches per plant and stand count at harvest is the result of interspecific competition between individual plants for space, light, water and nutrients.

SUMMARY AND CONCLUSION

A field experiment was carried out to determine the effects of nitrogen and plant population on the growth and yield of vegetable amaranth (Amaranthus cruentus, L.). The experiment was conducted during the wet and dry seasons of 1987 at the Horticultural Field Unit of the Institute for Agricultural Research and the Ahmadu Bello University Farm, Samaru, Zaria, respectively. Treatments consisted of four nitrogen levels (0.0; 45.0; 90.0 and 180.0 kg N/ha) and five plant populations (9; 16; 25; 49 and 100 plants/m^2). A randomized complete block design with factorial arrangement was used.

Application of nitrogen increased the vegetative growth characters of vegetable amaranth. Plant height, leaf area, shoot dry weight and length of harvested branches at harvest were significantly increased by N application.

Marketable, edible and total dry matter yields (t/ha) of vegetable amaranth were significantly increased by N application. The N fertilized plants produced statistically the same but significantly higher yields than the unfertilized control. Application of N at 180 kg N/ha increased the marketable, edible and total dry matter yields by 19.5, 20.0 and 17.8 percent, respectively

over the control. Percent protein content of the edible yield increased significantly with increase in N application. Application of 180 kg N/ha gave the highest percent crude protein content (32.45%).

Number of leaves, leaf area, shoot dry weight, number and length of harvested branches per plant as well as percent stand count at harvest were significantly decreased by increase in plant population. However, plant height increased significantly with increase in plant population.

Marketable, edible and total dry matter yields of vegetable amaranth increased significantly with successive increase in plant population. At the highest population (100 plants/m^2) these were 155.77; 74,63 and 20.80 tonnes/ha, respectively.

Seasonal effects on growth and yield of vegetable amaranth were highly significant. In terms of marketable, edible and total dry matter yields, the dry season crop outyielded the wet season crop by 59.0, 58.8 and 58.1% respectively.

The investigation has, therefore, shown that nitrogen is beneficial for improvement of both the yield and quality of vegetable amaranth and an application of 45.0 kg N/ha is adequate for optimum yield. For high yields plant population should not be less

than 100 plants/m^2. Furthermore, appropriate crop protection measures are necessary, especially for the wet season crop if optimum yields of vegetable amaranths are to be obtained.

In view of the lack of significant response beyond 45 kg N/ha further work with lower rates of N application is needed so as to arrive at the optimum rate. Although increase in plant population above 100 plants/m^2 may bring about increase in yield, however, very high plant population is not convinient for cultural practices such as weeding, mulching and fertilizer application.

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