AGRONOMIC STUDIES WITH AMARANTHUS

by

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A thesis submitted to the Faculty of Agriculture of the University of the West Indies in partial fulfilment of the requirement for the Degree of Master of Philosophy

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Trinidad

APRIL 1987

To Shardé

and

My Parents

ABSTRACT

Agronomic studies with Amaranthus

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A series of studies were undertaken to identify high yielding varieties of amaranths and to determine optimum cultural practices for the cultivation of the crop.

In a field study, 7 amaranth varieties, 6 from Trinidad (Trin 1, Trin 2, Trin 3, Trin 4, Trin 5, and Trin 6) and one from Jamaica (Jamaica Native), were evaluated. Jamaica Native was found to be most suitable for vegetable production because of its succulence, later flowering characteristics and high fresh and dry matter production. Yields of up to 18,670 kg/ha fresh weight and 3449 kg/ha dry weight were recorded. Trin 3 on the other hand, was less suitable because of its early and profuse flowering.

Jamaica Native was chosen for further agronomic studies involving yield response to different levels of nitrogen and potassium and the effect of nitrogen and harvesting frequency on yield. Additionally, the nitrogen, phosphorus, potassium, nitrate and oxalate content of the leaves and stems were measured.

Jamaica Native was found to be highly responsive to nitrogen but showed no response to potassium in the experiments conducted. Increasing nitrogen tended to increase fresh and dry matter yield.

Weekly harvesting proved to be more productive than 2-weekly and 3-weekly harvesting. At weekly harvesting there

was no significant increase in yield when nitrogen was increased from 300kg/ha to 600 kg/ha.

Increasing nitrogen also led to an increase in the nitrate ,oxalate and nitrogen content of the leaves and stems. Nitrogen and phosphorus content of the leaves and stems decreased with time.

Acknowledgements

I wish to express my sincere gratitude to my supervisor Dr T.U. Ferguson for his patient and kind guidance throughout the course of this study.

Thanks are also due to Mr Lauckner of CARDI for his help in the statistical analysis of the data, Messers Harryram and Shah, Crop Science technicians; Messers Ramdanie, Lochan and James, and other labourers at the University Field Station, for assistance in the field work; Keshwar John for helping in laboratory analysis; Mrs Commissiong, Mrs Rodriguez and Ms Sheila Daniel for their co-operation; Dr Wickham for reading the manuscript and Dr Harvey for printing it.

I also gratefully acknowledge my friends and family for their encouragement and support in many ways in particular my parents, my niece Sherma, sisters Esme and Jackie, my brother Irwin and my friend Joanne.

Thanks are also due to the government of the Republic of Trinidad and Tobago for providing the funds to carry out this work.

I finally thank God for granting me the health, strength and fortitude to complete this study.

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CHAPTER 1 GENERAL INTRODUCTION

1.0 INTRODUCTION

Research on vegetable amaranths was started by the Food and Agriculture Organization (FAO) in 1967. Field experiments began in 1968 in home garden projects in Nigeria and Benin and later germplasm collections were commissioned. As a result of an FAO published report, vegetable amaranth has started to attract the attention of researchers and development agencies (National Academy Press, 1984).

Several desirable characteristics justify increased interest in amaranth as a tropical food. Ferguson (1983) noted that, amaranth demonstrates the following qualities-:

1. Wide genetic diversity which suggests that genetic improvement may be rapid.
2. Wide range of climatic adaptability, the crop can tolerate very wet conditions in addition to showing some resistance to drought.
3. Rapid early growth and rapid accumulation of dry matter- the crop has a C4 photosynthetic pathway thus making it a more efficient convertor of solar energy than most other vegetables.
4. Yields are high, up to 300 kg/ha dry matter per day have been recorded.
5. It is possible to mechanise the whole production process.
6. Processing of the vegetable product into soups and other

convenience foods is possible.

1.1 Classification and Nomenclature

The genus Amaranthus belongs to the family Amaranthaceae in the order Caryophyllales which contains about 800 species and 60 genera (Feine et al, 1979). Grubben (1976) reported that the species are difficult to recognise because characteristics of minimal importance have been used to distinguish them and also because their cultivation has given rise to numerous species. He further stated that confusion in the taxonomy and nomenclature of the amaranth used as leafy vegetables has been noted by De Condolle in 1886, Bois in 1927, Sauer in 1950, and Bauer in 1975. Work on the taxonomic classification and description of amaranth is being done at Rodale Research Centre in Pennsylvania (Grubben and Van Sloten, 1981). It was however reported that the taxonomy of the amaranth is still confused, the basic problem being synonomy.

1.2 Origin and Distribution

Historically, people have cultivated amaranths in environments ranging from the tropical to semi-arid lands (National Academy Press,1984). The centre of origin of the crop is however debatable. Grubben (1976) observed that the centre of origin is difficult to trace because the wild ancestors are pantropical. He also pointed out that De Condolle 1886 formerly thought that because of the important cultivation of cereal amaranth in India, the

centre of origin was India. Grubben (1976) reporting on a later observation by Sauer (1967), noted that the presence of numerous species in tropical America gives rise to the hypothesis that this is the principal centre of origin. Grubben (1976) supported the view that all grain amaranths originated from Central and South America while the main vegetable type A.tricolor originated somewhere in Southern Asia. The National Academy Press (1984) in its report presented information which agreed with Grubben (1976) They reported that in Mexico, Central and South America are found the grain types A.hypochondracus A.cruentus and A.caudatus.The vegetable types are located in the hot, humid regions of Africa, Southern China, Southern India and the Caribbean. These include A.tricolor, A.dubius and A.cruentus. Among the Indians of the North American desert where summer is too hot for lettuce or cabbage,A.palmeri is the major green; and in Greece the leaves ofA.blitum form the favourite salad (National Academy Press, 1984).

The predominance of grain and vegetable amaranths in specific regions was noticed by Cole (1979). He suggested that the purpose for which amaranth was selected in Eurasia differed from those purposes in the Americas. In Eurasia the crop was domesticated as a leafy vegetable while the Americas developed it as a grain (Cole,1979). Basically, these two uses, vegetable and grain, predominate today.

1.3 Morphology

Amaranthus is an annual herbaceous plant whose growth habit is either prostrate or erect, branched or unbranched. The stems and simple leaves have colours ranging from red to green with a multitude of intermediates. The small chaffy flowers could be white, purple, orange, red, or gold. Seedheads are sometimes as long as 50 cm with seeds ranging from 0.9 to 1.7 mm in diameter. These seeds occur in large numbers sometimes more than 50,000 per plant and are cream, pink, gold, or black (Grubben,1976; Feine et al, 1979; Purseglove,1981; National Academy Press,1984).

1.4 Importance and Uses

Amaranth was once an important crop to the Aztec Empire before corn replaced it (Early,1971). As Berberich (1980) reported, the Mayan Indians of Mexico's distant past developed amaranth into a high yielding crop, then the Aztecs made it more than their main food staple. He noted that the Aztecs constructed idols of multiple deities from amaranth and great quantities were paid in tribute each year to the Aztec king Montezuma. The Spanish explorer, Cortez, in his determination to eradicate what he considered a pagan culture, ordered mass destruction of the crop (Cole,1979). Cortez reasoned that complete devastation of his enemy could only be achieved by eliminating amaranth which typified Aztec culture (Berberich,1980).

Today amaranth is important as a vegetable in parts

of tropical Africa and Asia. It often contributes as much as 25% of protein found in the daily diet (Grubben, 1976; Feine etal, 1979). It is also grown and consumed as a vegetable in many parts of the Caribbean region but particularly so in Jamaica, Guyana and Trinidad and Tobago.

As a grain the crop is produced in the highland areas of Latin America, Asia, India and parts of the United States of America (Grubben, 1976; Cole,1979). Amaranth seed can be used in breakfast cereals or as an ingredient in confection (Cole,1979; National Academy Press, 1984). The grain is ground into flour and mixed with wheat flour or corn giving an improved quality to the mixture (Berberich,1980; National Academy Press,1984).

Other minor uses include the extraction of oil from the seeds (Saunders and Baker,1982). This oil they indicated contains high amounts of linoleic, oleic and palmitic acids. Leaves and roots of amaranth have medicinal qualities (Grubben,1976). He also reported that amaranth is used as an ornamental eg fox's tail and cock's comb; as a forage eg pigweed; and in red dye preparation. In Africa, he noted, amaranth has been used in the preparation of potash, salt and soap.

1.5 Growth and Development of Vegetable Amaranths

Prior to 1976, there was little published data on the growth and development of vegetable amaranth. In 1976 however, Grubben conducted experiments in Western Dahomey on

the growth and development of the crop.To date, his work is the only published material on the growth and development of amaranths.

Grubben (1976) made the following conclusions from his study. He found that amaranth is chiefly propagated by seeds which germinate in 3-5 days.Seeds germinate rapidly at temperatures above 21 oC (70 oF) and grow to transplant size in approximately three weeks. Amaranth has a lower temperature of 20 oC (68 oF) below which it would not germinate or grow well.

Universally, two methods of cultivation are employed namely (1) sowing directly into the field or (2) transplanting 3-4 week old seedlings. He also reported two methods of harvesting (1) uprooting the entire plant at about 6 weeks or (2) repeated cuttings of the same plants. In Trinidad and Tobago, amaranth is grown from seedlings and harvested by repeated cuttings every week or every two weeks(Titus,unpublished data,1984).

Grubben (1976) concluded from his experiments that amaranth had a fast initial development and a high dry matter content. He further indicated that maximum leaf production was obtained when the leaf area reached about 7 times the surface of the soil (ie leaf area index=7). His experiments compared this C4 plant amaranth to the C3 plant celosia. He noted that the C4 cycle of photosynthesis resulted in rapid growth and high yields under conditions of high temperature (30-35 oC) and high light intensity. He

also observed differences between cultivars and that early flowering was caused by daylength among other factors.

Growth and development studies on amaranth are needed since as Grubben (1976) pointed out, bibliographical data on this aspect of the crop are practically absent. It is hoped that studies will yield information on differences between the various cultivars.

1.6 Human Nutrition

Although leafy vegetables are not normally considered an important source of protein, amaranth contains a significant amount of useable protein (Kauffman and Gilbert,1981). The good nutritional composition of amaranth leaves was reported by Grubben (1976),Feine et al (1979) and Kauffman and Gilbert (1981),(see Table 1). The protein content of the dry matter of the leaves is greater than 27%. When compared to tomato and cucumber, amaranth is high in protein, calcium, and ascorbic acid. Amaranth leaves also have significant levels of thiamine (0.7 mg/100g dry matter) and riboflavin (2.0mg/100g dry matter).

The above mentioned nutritional qualities contribute to amaranth being considered as an important food source. These nutritional qualities are important to its development as a food source for low income people of Third World countries as well as its use as an alternative crop in the industrialised world(Feine et al, 1979).The leaves of probably all amaranth species are already utilised in the

TABLE 1.1 Nutrient Content per 100 grammes of edible product. (Source Grubben and Van Sloten, 1981)

	Amaranth	Tomato	Cucumber
Dry Matter	160g	6.5g	4.9g
Carotene	5.7mg	0.5mg	trace
Iron	8.9mg	0.6mg	0.5mg
Calcium	410mg	10mg	13mg
Vitamin C	64mg	26mg	16mg
Protein	4.6g	1.0g	0.8g

diets of many tropical areas.

Amaranth however, has qualities which are a source of concern since they can affect human and animal health. High levels of nitrate and oxalate have been considered negative quality factors in leafy vegetables. Amaranth is known to contain quantities of oxalate and nitrate which could be toxic if injested in large amounts. (Kingsbury,1964).

Oxalic acid injested as a chemical is corrosive to the animal tissue it reaches (Kingsbury,1964). He further states that oxalic acid is known to be toxic to livestock under natural conditions and occurs in plants in the form of soluble oxalates. Associated with oxalate poisoning are nervous symptoms, reduced coagulability of the blood, acute nephritis and unavailability of calcium.

Plants containing more than 1.5% nitrate as KNO_3 dry weight have been known to be toxic to livestock (Kingsbury,19 64),producing such effects as abortion, depression of lactation, discoloured urine, digestive disturbances and vitamin A deficiency symptoms. Schmidt et al(1971), reported that intake of leafy vegetables highin nitrate content have been considered the possible cause of methaemoglobinmia after reduction of nitrate to nitrite.

Genetic factors are probably the primary determinant in oxalate accumulation in leafy vegetables (Kingsbury,1964; Maynard et al,1976).They also noted that many,if not most of the plant species with high oxalate containing leaves which are used as vegetables belong to the taxonomic

subclass Caryophillidae of which the family Amaranthaceae is a member.

In an experiment conducted to determine oxalate and nitrate contents of four tropical leafy vegetables grown at two soil fertility levels, Schmidt et al(1971) found that differences among species were greater than differences due to soil fertility. It was however reported by Lorenz, (1978) that environmental factors of fertilizer treatments, which increased the cation content of leaves may effect an increase in the oxalate content of the species in which the compound is normally high.

Increased nitrate accumulation often follows high rate applications of nitrogen fertilizers (Brown and Smith, 1966; Lorenz,1978; Feine et al 1979)
Brown and Smith (1966) however reported that nitrogen fertilization and weather conditions were of about equal importance as factors influencing nitrate accumulation in spinach, another green leafy vegetable. Fasset (1966), suggested that vegetable nitrate content in relation to fertilization needs to be studied.

It would be difficult to develop feasible fertilization practices which enhance growth, yield, succulence and general consumer appeal without somewhat increasing oxalic acid and nitrates in amaranth (Fasset,1966). Nevertheless, Kauffman and Gilbert (1981) indicated that the antinutritive factors of nitrates and oxalates are found in levels in amaranth similar to those

found in other green leafy vegetables such as spinach and chard. Adverse nutritional effects are not to be feared with a consumption of 100-200 grammes per day (Grubben and Van Sloten,1981).

The concern about nitrates centres around its possible linkage to cancer. Nitrates can be converted to nitrites which can combine with amines in the stomach to form nitrosamines and these in turn can cause cancer (Whitney and Hamilton,1981; Fretz,1983). It has however been reported by Fretz (1983) that the vegetables containing nitrites also have high levels of vitamins A,C, and E and the mineral selenium, which are thought to block nitrosamine formation. Eating fruits high in vitamins A and C is therefore recommended.

1.7 Mineral Nutrition

Amaranth is an exacting crop with regard to soil fertility and reacts favourably to high fertilizing on poorer soils (Grubben,1976). In Nigeria,where the crop is grown as a vegetable, Oke (1981) reported that one of the major setbacks in the commercial production of amaranth is the fact that in spite of increasing availability of manures, not much work has been done on the optimum level for maximum yield of the leaves.

Grubben (1976) reviewed the work of Lexander et al (1970) which showed the results of a pot experiment done using three levels of nitrogen on A. caudatus. These results revealed that there were favourable responses of A. caudatus

to nitrogen fertilization regarding total production and protein content.

In his own studies, Grubben (1976) obtained an increase in the production of amaranth (fresh leaves and stems) with 0.22 kg/kg of refuse and of 12.48 kg/kg of N.P.K. fertilizer. He recommended using the complete fertilizer 10-10-20 at the rate of 600 kg/ha if the crop is harvested by cuttings.

Oke (1981) reviewed work done with respect to mineral nutrition of amaranth. Reporting on work done by Kogbe (1978), he noted thay after poultry manure was applied at 0, 10,000, 20,000, 30,000 and 40, 000 kg/ha there was an increase in yield with increased fertilizer application. The highest fresh weight yields that Kogbe (1978) recorded 50,000 kg/ha (50 tons/ha) and 26,000 kg/ha (26 tons/ha) respectively.Oke (1981) noted that Wilson (1971) obtained a superior response at higher levels of fertilization. When 200 kg/ha of 15-15-15 were applied, yield was 22,190 kg/ha fresh weight as opposed to 8,570 and 5520 kg/ha for 100 and 0 kg/ha 15-15-15 respectively.

Although the above results indicate a general increase in production with increased fertilizer application, there is clearly need for research in this area. It is important to determine an optimum level of fertilizer application beyond which it would not be economical to operate. From these results, it is not possible to ascertain maximum or minimum levels.

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1.8 Objectives of this Study

The general objectives of this study were to identify high yielding cultivars of amaranth, to study growth and development and to determine optimum cultural practices for the cultivation of the crop. The study was carried out in three experiments which examined the following -:

1. growth, development and yield of 7 cultivars of vegetable amaranth, six local and one imported from Jamaica.
2 the response of amaranth to varying amounts of nitrogen and potassium;
3 yield and composition as affected by nitrogen and harvesting frequency.

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2.0 CHAPTER 2: GROWTH, DEVELOPMENT AND YIELD OF SEVEN VARIETIES OF VEGETABLE AMARANTH

2.1 INTRODUCTION

Grubben (1976) conducted several experiments in Western Dahomey on growth and development of vegetable amaranths. He noted the absence of much bibliographical data pertaining to the vegetative growth of vegetables belonging to the family Amaranthaceae and pointed out that although there is a possibility of finding analogies in related plant species, these may not yield enough data to fully explain amaranth's behaviour in the field.

Grubben (1976) in a comparative study of amaranth and celosia, a leafy vegetable closely related to amaranth, noted that amaranth, with its C4 photosynthetic cycle, initially grows more rapidly in height and develops more rapidly than celosia, a C3 plant. He found that amaranth develops leaves quickly until the age of about 6 weeks after which the plant flowers and this has a negative effect on the total weight and quality of the leaves. He surmised from his studies,that amaranth is suitable for harvesting by repeated cutting since the plant branches and develops well after the 1st and 2nd biweekly cuttings. It was however observed that amaranth produces seeds and ages rapidly after the 3rd cutting. He further observed that from 5-6 weeks onwards, the main sink consists of " stalks"(stems) and inflorescenses. From this period on lengthening of the"

stalk"(stem) is as a consequence of development of the inflorescence. The advanced stage of flowering made a 4th cutting for vegetable material impractical in Grubben's (1976) studies.

From a survey conducted by Titus (1982,unpublished data), in the Aranguez/Mt Lambert area of Trinidad, it was observed that farmers generally harvest by repeated cuttings. Three week old seedlings are transplanted into the field and the 1st harvest begins about the 3rd week after transplanting. Subsequently, weekly harvests are done and continues even after flowering begins. When the plants start to flower, the farmers simply pick off the flowers and harvest the vegetative top growth. Several harvests are obtained from the same plants.

Yield experiments done in India by Mohideen (1982), have shown vegetable amaranth to produce (2.5-3.0 kg/m^2 /plot)25,000-30,000 kg/ha of green vegetable material. In these experiments, harvesting was done weekly for 70 days giving a total of 10 clippings (or cuttings) Oke (1981) in Nigeria reported a yield of up to 50,700 kg/ha (50.7 tons/ha) using 40 tons poultry manure. He however noted that Wilson (1971) achieved a yield of(100 tons/ ha) 100,000 kg/ha fresh weight using mineral fertilizer. Oke (1981) also reported that a yield of (30 tons/ha) 30,000 kg/ha of fresh vegetable material had been achieved in Taiwan after 30 days of growth.

The experiment reported here examines the growth, development and yield of seven varieties of vegetable

amaranth. The objective of this study was to determine whether different varieties of amaranth had similar patterns of growth, development and yield when grown under the same conditions and to identify high yielding cultivars.

2.2 Materials and Methods

An experiment was conducted at the University Field Station on the soil type described as River Estate Loam (see appendix) The area used was under bamboo grass (Paspalum fasiculatum) for the previous two years. The experimental design was a randomised block with four replications. Plants were spaced 30cm x 30cm apart, in plots that were 3.6cm x 1.8cm. Between the plots was a space of 1.5 metres.

Seven varieties of amaranth were used in this experiment, six were local and one was from Jamaica. The six local varieties were Trin 1 (Field Station Red), Trin 2 (Very Red Aranguez), Trin 3 (Pink Aranguez), Trin 4 (Pale Red Aranguez), Trin 5 (Big Leaf White), and Trin 6 (Pink Matura). The imported variety was Jamaica Native.

Seeds were sown in seed boxes on 84-01-24. The germinating medium consisted of soil, manure and rice husks in equal proportions. Seedlings were transplanted into the field, which had previously been ploughed and rotavated on 84-02-22.

The experimental plots were designed so that both growth analysis and yield analysis by repeated cuttings

could be done. Each plot was divided into two sections with fifty five plants for growth analysis and fifteen plants for repeated cuttings. All the sample plants were fully guarded by other plants.

Five harvests were done for growth analysis studies, the first one being on 84-03-19 and the others at weekly harvests thereafter.At each harvest three plants were uprooted and data taken on leaf area, leaf number and dry matter of leaves, stems, inflorescences and roots. Leaf area was measured on an automatic leaf area meter type AAM-5 manufactured by Tokyo Hayashi Denko Company Limited. To determine dry weight, samples were oven dried at a temperature of 80 0C for at least 48 hours.

For yield estimation, three plants were ratooned or repeatedly cut at each of the five harvests. Young, succulent leaves and stems (marketable material) were harvested. Both fresh and dry weights were recorded.

2.3 Results

2.3.1 Yield Analysis

2.3.1.1 Yield Fresh Weight

When harvesting was done by repeated cuttings, there were similar trends in fresh and dry matter production for the 6 local varieties (Table 2.1). For all these varieties, highest yield was at the 4th week (2nd harvest) and they were not significantly higher than all the other varieties.At the other cuttings, Jamaica Native recorded comparable yields to the 6 local varieties. Approximately

TABLE 2.1 Total fresh weight yield and fresh weight yield at weekly harvests for seven amaranth varieties (Kg/ha).

(Numbers in parentheses are weekly values expressed as a percentage of total yield).

Varieties	Weeks after transplanting 3	4	5	6	7	TOTAL
		SE 801.1				
TRIN 1	3607(22.1)	4175(25.6)	3542(21.7)	2488(15.3)	2486(15.3)	16,298
TRIN 2	3684(19.8)	5479(29.5)	3941(21.2)	3063(16.5)	2426(13.1)	18,593
TRIN 3	3742(20.4)	5034(27.4)	4236(23.1)	3105(16.9)	2261(12.3)	18,378
TRIN 4	3883(20.8)	5517(29.6)	3512(18.8)	3214(17.2)	2545(13.6)	18,671
TRIN 5	2366(16.0)	4021(27.1)	3165(21.3)	2697(18.2)	2578(17.4)	14,827
TRIN 6	3294(21.7)	3605(23.7)	2987(19.7)	2688(17.7)	2613(17.2)	15,187
JAMAICA NATIVE	6302(33.8)	3931(21.1)	3874(20.8)	2682(14.4)	1881(10.1)	18,670
		SE 302.2				
MEAN	3840	4537	3608	2848	2399	
		CV 46.48				

TABLE:2.2 Weekly and total dry matter yield of seven amaranth varieties (kg/ha)

Varieties	Weeks after planting 3	4	5	6	7	Total
		SE 86.3				SE 192.9
Trin 1	634	830	621	551	531	3167
Trin 2	668	994	671	628	542	3503
Trin 3	699	954	712	637	558	3560
Trin 4	639	926	600	633	527	3325
Trin 5	514	818	628	604	577	3141
Trin 6	614	751	591	573	553	3082
Jamaica Native	908	748	690	609	494	3449
		SE 32.6				
Mean	668	860	645	605	540	

CV 26.00 %

TABLE: 2. 3 Weekly and total yield dry matter percentage of seven amaranth varieties

Varieties	Weeks after planting 3	4	5	6	7	Mean
			SE 3.01			S.E. 1.35
Trin 1	18.80	23.61	20.91	26.34	29.99	23.93
Trin 2	18.56	18.74	18.50	23.59	23.86	20.65
Trin 3	19.33	19.45	17.86	22.63	27.17	21.17
Trin 4	18.06	18.75	19.08	23.8	23.52	20.69
Trin 5	22.78	22.20	21.39	24.94	25.60	23.38
Trin 6	18.74	21.03	19.94	21.88	21.41	20.60
Jamaica Native	15.23	21.01	18.98	23.33	23.65	20.44
			SE 1.14			
Mean	18.79	20.68	19.52	23.79	25.03	

CV 27.16 %

TABLE:2.4 Total dry matter of seven amaranth varieties
(yield in kg/ha)

	Weeks after planting					
Varieties	3	4	5	6	7	Mean
		SE	704.5		SE	315.1
Trin 1	2283	4982	7015	10,261	10,095	6927
Trin 2	2217	3997	7651	10,599	7392	6372
Trin 3	2832	5421	6312	7272	8341	6035
Trin 4	2002	5043	5667	9171	8904	6157
Trin 5	2308	5402	6736	8306	8766	6304
Trin 6	2506	5224	6758	8521	6976	5996
Jamaica Native	2444	4617	7382	9253	8435	6426
		SE	266.3			
Mean	2373	4955	6788	9055	8414	

CV 22.30 %

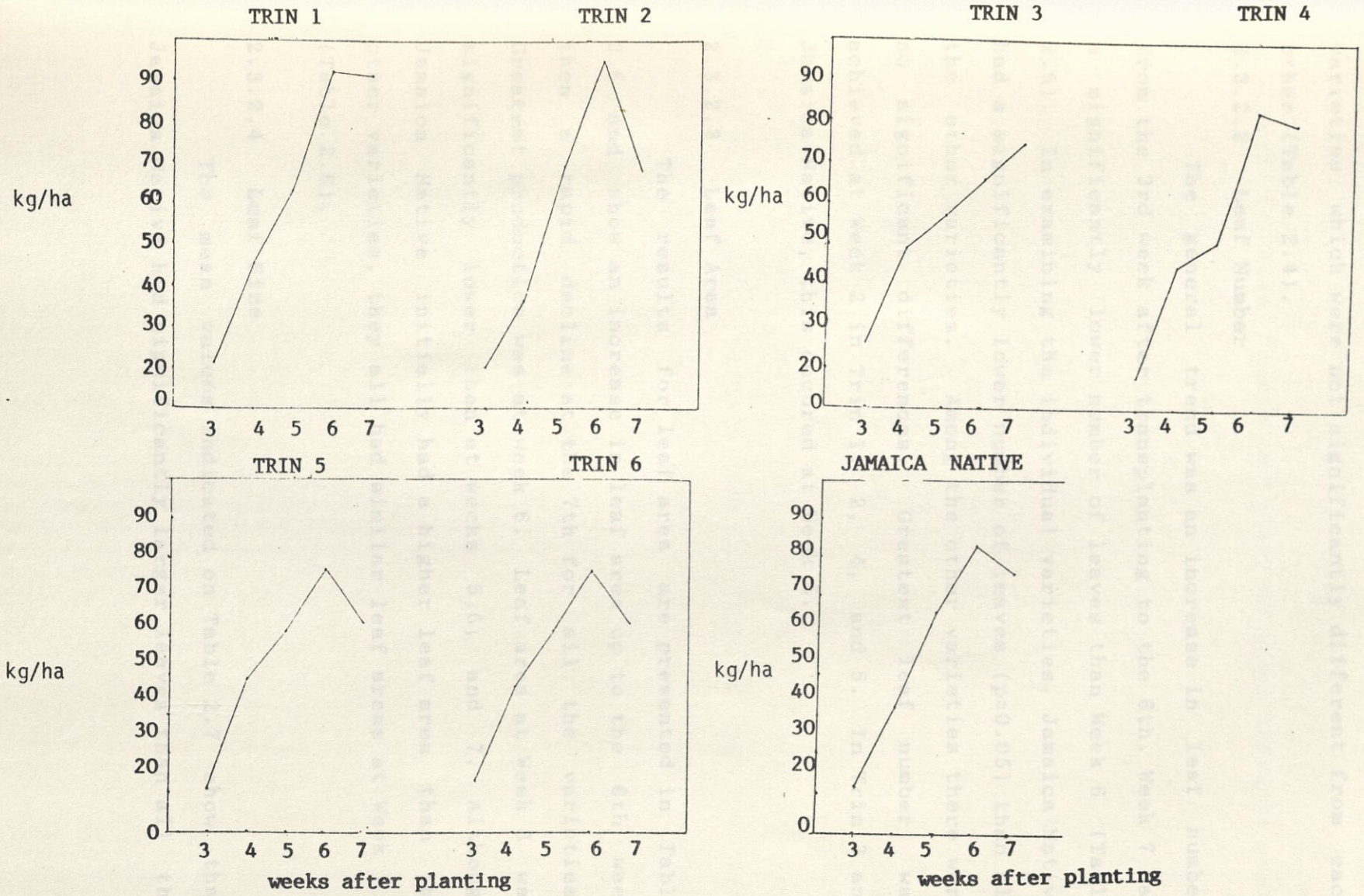

FIGURE 1: Total dry matter yield of seven amaranth varieties at 5 different harvest

gradual as Trin 1, Trin 4 and Jamaica Native. Trin 1 had significantly higher total dry matter values than the other varieties which were not significantly different from each other (Table 2.4).

2.3.2.2 Leaf Number

The general trend was an increase in leaf number from the 3rd week after transplanting to the 6th. Week 7 had a significantly lower number of leaves than Week 6 (Table 2.5). In examining the individual varieties, Jamaica Native had a significantly lower number of leaves ($p=0.05$) than all the other varieties. Among the other varieties there were no significant differences. Greatest leaf number was achieved at Week 2 in Trin 1, 2, 4, and 5. In Trin 3 and Jamaica Native, this occured at Week 5.

2.3.2.3 Leaf Area

The results for leaf area are presented in Table 2.6 and show an increase in leaf area up to the 6th week then a rapid decline at the 7th for all the varieties. Greatest production was at week 6. Leaf area at Week 3 was significantly lower than at weeks 5,6, and 7. Although Jamaica Native initially had a higher leaf area than the other varieties, they all had similar leaf areas at Week 7 (Table 2.6).

2.3.2.4 Leaf Size

The mean values indicated on Table 2.7 show that Jamaica Native had significantly larger leaves than all the

TABLE:2. 5 Leaf number per plant of seven amaranth varieties

Weeks after planting

Varieties	3	4	5	6	7	Mean
			SE 15.28			S.E. 6.83
Trin 1	102	126	152	191	149	144
Trin 2	88	101	189	190	114	136
Trin 3	110	154	206	135	189	159
Trin 4	84	147	148	164	161	141
Trin 5	93	125	164	179	167	145
Trin 6	105	125	174	173	161	148
Jamaica Native	66	93	135	121	95	102
			SE 5.77			
Mean	93	125	167	165	148	
			CV 21.67 %			

TABLE:2.6 Leaf area per plant of seven amaranth varieties (cm^2)

Varieties	Weeks after planting 3	4	5	6	7	Mean
			S.E. 305.2			S.E.136.5
Trin 1	1061	1545	2214	2913	2559	2058
Trin 2	1093	1436	2608	2736	1640	1903
Trin 3	1260	1533	1810	1568	1977	1630
Trin 4	1022	1977	1803	2353	2252	1881
Trin 5	974	1612	1902	2229	2203	1784
Trin 6	1046	1670	2127	2527	1762	1825
Jamaica Native	1305	1761	2630	2685	1573	1991
			SE 115.4			
Mean	1109	1648	2156	2430	1995	
				CV 32.67 %		

other varieties and that Trin 3 had significantly smaller leaves than Trin 1,2,4, and Jamaica Native. Among the other varieties there were no significant differences. Trin 1, 2, and Trin 5 had their largest leaves at Week 7 the other varieties had theirs at Week 6.

2.3.2.5 Leaf Dry Matter

Trin 1, Trin 2 and Jamaica Native produced the highest total leaf dry matter, though not significantly different from the other varieties (Table 2.8). Mean values show that the highest leaf dry matter production occured at the 5th week. After the 5th week, there was a general decrease in production. Leaf dry matter production was significantly lower at the 3rd week than at the others.

2.3.2.6 Leaf Weight Ratio

Although Jamaica Native had the largest proportion of leaves to total dry matter, this difference was not significant from the other varieties (Table 2.9). The mean weekly values indicate that leaf weight ratio decreased with time. There were no significant differences between the 3rd and 4th weeks but Weeks 5,6, and 7 were significantly lower than Weeks 3 and 4.

2.3.2.7 Stem Dry Matter

Stem dry matter showed no significant differences among the varieties (Table 2.10). Stem dry matter

TABLE:2.7 Leaf size of seven amaranth varieties (cm^2/leaf)

Varieties	Weeks after planting					Mean
	3	4	5	6	7	
			SE 1.65			SE 0.74
Trin 1	10.74	12.69	14.38	14.93	17.28	14.00
Trin 2	12.45	14.26	13.63	14.33	15.14	13.96
Trin 3	11.65	10.43	8.43	12.10	10.70	10.66
Trin 4	12.21	14.28	12.11	14.17	13.59	13.27
Trin 5	10.42	12.93	11.65	12.39	13.53	12.18
Trin 6	9.93	13.35	12.30	14.50	11.19	12.25
Jamaica Native	19.35	19.20	19.99	22.12	15.81	19.29
			SE 0.62			
Mean	12.39	13.88	13.21	14.93	13.89	
			CV 23.53 %			

TABLE:2.8 Weekly and total leaf dry matter of seven amaranth varieties (kg/ha)

Varieties	Weeks after planting 3	4	5	6	7	Total
		SE 196.6				S.E. 615.5
Trin 1	878	1371	2522	2306	2198	9275
Trin 2	894	1257	2692	2531	1688	9061
Trin 3	988	1319	1970	1584	1844	7704
Trin 4	794	1565	1889	2104	2048	8401
Trin 5	877	1381	2485	2028	2042	8812
Trin 6	895	1346	2422	2055	1626	8347
Jamaica Native	1008	1611	2624	2194	1794	9229
		SE 74.3				
Mean	905	1407	2372	2115	1891	

CV 22.63%

TABLE:2.9 Leaf weight ratio of seven amaranth varieties

Varieties	Weeks after planting 3	4	5	6	7	Mean
			SE 2.03			SE 0.91
Trin 1	29.55	30.78	34.24	45.38	47.36	37.46
Trin 2	31.58	33.70	34.19	43.01	44.64	37.43
Trin 3	30.54	30.24	32.08	40.59	43.74	35.44
Trin 4	29.15	30.79	35.99	42.87	44.33	36.63
Trin 5	31.53	30.25	32.68	43.50	43.13	36.22
Trin 6	27.15	31.57	33.85	42.00	43.65	35.65
Jamaica Native	29.68	30.88	37.03	42.64	44.50	36.94
			SE 0.77			
Mean	29.88	31.17	34.30	42.86	44.48	

CV 11.09 %

production however, increased significantly from the 3rd up to the 6th week.

2.3.2.8 Stem Weight Ratio

In Table 2.11 is seen the mean stem weight ratio for the 7 varieties at each week. According to the means, there was an increase in stem weight ratio each week and each was significantly higher than the other. There were no significant differences among the varieties.

2.3.2.9 Inflorescence Dry Matter

Inflorescence dry matter increased each week (Table 2.12). At the 3rd week, all the varieties had poorly developed inflorescences. Both Weeks 3 and 4 were significantly lower than the other weeks. The mean values show no significant differences among the varieties although Trin 3 had the highest inflorescence dry matter of all the varieties. The earliest flowering variety was Trin 3 and the latest Jamaica Native, as seen from Table 2.9.

2.3.2.10 Inflorescence Weight Ratio

Trin 3 had a significantly higher inflorescence weight ratio than all the other varieties (Table 2.13) which were not significantly different from each other. The general trend was a significant increase in inflorescence weight ratio as the plant aged.

2.3.2.11 Root Dry Matter

Root dry matter was highest at Week 6 (Table 2.14).

TABLE:2.10 Weekly and total stem dry matter of seven amaranth varieties (kg/ha).

	Weeks after planting					
Varieties	3	4	5	6	7	Total
			SE 392.2			SE 1227.7
Trin 1	672	1528	2389	4684	4909	14,181
Trin 2	702	1354	2638	4561	3317	12,573
Trin 3	868	1633	2030	2957	3656	11,144
Trin 4	585	1560	2087	3941	4027	12,200
Trin 5	719	1627	2209	3616	3797	11,967
Trin 6	681	1655	2315	3598	3053	11,302
Jamaica Native	727	1443	2809	3952	3804	12,735
			SE 148.2			
Mean	708	1543	2354	3901	3795	
			CV 31.89 %			

Table: 2.11 Weekly stem fresh weight ratios of seven amaranth varieties

Varieties	Weeks after planting 3	4	5	6	7	Mean
			SE 2.28			
Trin 1	38.47	35.46	27.71	22.42	22.03	29.22
Trin 2	40.18	35.88	31.41	23.85	23.04	30.87
Trin 3	35.00	31.47	24.34	21.75	22.07	26.93
Trin 4	39.70	34.13	30.98	22.99	22.99	30.16
Trin 5	38.55	36.78	25.78	24.35	23.50	29.79
Trin 6	35.82	36.18	25.61	24.20	23.39	29.04
Jamaica Native	41.19	35.92	34.58	23.67	21.26	31.35
			SE 0.86			
Mean	38.42	35.12	28.63	23.32	22.61	
			CV 15.42 %			

TABLE:2.12 Weekly and total inflorescense dry matter of seven amaranth varieties (kg/ha)

Varieties	Weeks after planting					
	3	4	5	6	7	Mean
			SE 105.6			SE 0.43
Trin 1	16.7	345.6	524.4	1089.9	1249.9	645.6
Trin 2	5.6	326.6	596.7	1384.4	968.8	656.7
Trin 3	58.8	605.6	914.4	1183.3	1454.4	843.3
Trin 4	13.3	334.4	597.8	1235.5	1326.7	701.1
Trin 5	11.1	359.9	601.1	951.1	1267.8	637.8
Trin 6	25.6	474.4	662.2	1033.3	971.1	633.3
Jamaica Native	4.4	317.8	549.9	1146.7	1221.1	647.7
			SE 39.9			
Mean	19.9	394.4	635.6	1146.6	1208.9	
			CV 31.03 %			

TABLE:2.13 Inflorescence weight ratios of seven amaranth varieties

Varieties	Weeks after planting 3	4	5	6	7	Mean
			SE 0.90			SE 0.40
Trin 1	0.74	7.13	7.49	10.54	12.87	7.76
Trin 2	0.24	8.23	7.96	13.00	13.17	8.52
Trin 3	2.11	11.57	14.52	16.31	17.57	12.41
Trin 4	0.65	6.84	10.26	13.39	15.02	9.23
Trin 5	0.57	6.88	9.23	11.46	14.38	8.50
Trin 6	1.06	9.23	9.83	11.73	13.94	9.16
Jamaica Native	0.15	7.00	7.25	12.34	14.34	8.22
			SE 0.34			
Mean	0.79	8.13	9.51	12.68	14.47	
				CV 19.68 %		

The 3rd week had a significantly lower leaf dry matter production than all the other weeks. Week 5 was also significantly lower than week 6. Trin 1 had the highest root dry matter which did not differ significantly from the total produced by the other varieties.

2.3.2.12 Root Weight Ratio

The mean root weight ratio for the 7 varieties as represented in Table 2.15 indicates that the varieties were not significantly different from each other. At the harvests however, a significant difference was observed. There was a decrease with time. Week 7 yielded the lowest root weight ratio which was significantly lower than all the other weeks.

2.4 Discussion

The results show that total dry matter, leaf number and leaf area of all the varieties follow the same trend of, a general increase up to week 6 and then a decline in production. The plant spacing which Grubben (1976) used was 15 cm x 15 cm while in this experiment the spacing was 30 cm x 30 cm. Leopold and Kriedemann (1980) pointed out that higher densities usually afford greater leaf area per unit land area and therefore a greater potential for yield. It is possible therefore that in this

TABLE:2.14 **Weekly and total root dry matter of seven amaranth varieties (kg/ha)**

Varieties	Weeks after planting 3	4	5	6	7	Mean
		SE 189.6				SE 593.6
Trin 1	716	1581	1739	2182	1740	7958
Trin 2	617	1726	1060	2124	1418	6945
Trin 3	918	1399	1864	1549	1388	7118
Trin 4	610	1094	1583	1891	1503	6681
Trin 5	701	1442	2033	1712	1660	7548
Trin 6	904	1359	1749	1836	1322	7170
Jamaica Native	707	1400	1247	1961	1617	6932
		SE 71.7				
Mean	739	1429	1611	1894	1521	

CV 26.36 %

TABLE 2. 15 Root weight ratio of seven amaranth varieties

Varieties	Weeks after planting					Mean
	3	4	5	6	7	
			S.E. 2.03			S.E. 0.91
Trin 1	34.38	31.24	22.81	21.67	17.74	25.57
Trin 2	26.65	28.01	21.97	20.13	19.15	23.18
Trin 3	33.85	32.35	21.93	21.36	16.63	25.22
Trin 4	31.39	30.51	19.62	20.75	17.66	23.99
Trin 5	37.09	29.36	21.30	20.69	18.99	25.49
Trin 6	33.60	35.97	20.15	22.06	19.02	26.16
Jamaica Native	27.54	28.97	19.80	21.35	19.90	23.51
			S.E. 0.77			
Means	32.07	30.91	21.08	21.15	18.44	

experiment with its wider spacing, the full yield potential was not achieved. Total dry matter, (1976) increased with age up to week 6 then declined.The declining leaf area from Week 6-7 could account for the reduction in dry matter at the similar time period. Grubben (1976) made a similar observation in his experiments and attributed this decline to leaf fall from the base of the plant.

Although the highest leaf dry matter was achieved at the 5th week highest total dry matter occured at the 6th week. As the results show, inflorescence and stem dry matter continued to increase in all cases right up to the final harvest. Grubben (1976) pointed out that leaf production is adversely affected by inflorescence growth. This was clearly shown in the results, with an increase in inflorescence dry matter, there was a decrease in leaf dry matter. Leaf weight ratio decreased from the 3rd to the 4th week, but an increase in leaf area occured over the same time period. This was probably due to the partitioning of dry matter to stems since stem dry matter increased dramatically over the same time period. All the varieties had comparable stem dry matter and stem weight ratios. Results in this experiment confirmed previous reports by Grubben (1976) who noted stem dry weight to increase with age. This was generally the case with all varieties.

It was observed that a higher leaf number did not necessarily indicate a higher total dry matter yield. This

was exemplified by the variety Jamaica Native. As the results show, this variety had the lowest leaf number of all the varieties but nevertheless, produced the 2nd highest leaf dry matter. The results also indicated that Trin 3 had the highest leaf number but the lowest leaf dry matter production. Further, the results show that Jamaica Native had the largest leaves and Trin 3 the smallest among the varieties. The large leaf size enabled Jamaica Native to achieve a comparable leaf area with all the other varieties. at the 6th week when leaf area was highest, the plants also produced their largest leaves.

The varieties exhibited a difference in flowering times and intensity. Trin 3 and Jamaica Native were the extremes. Trin 3 could be described as early flowering while Jamaica Native flowered late. The profuse flowering of Trin 3 and subsequently high inflorescence weight ratio, makes this variety among the least attractive for vegetable production, Jamaica Native on the other hand is more desirable because later and lesser flowering means more vegetative material will be available.

The amount of leaves and stems harvested was due to the availability of vegetative material.It could therefore be concluded that Jamaica Native with its early and high dry matter production, can be described as an early variety (producing 908 kg/ha dry matter at the first harvest)

At subsequent harvests however, dry matter production for Jamaica Native was similar to that of the other varieties. This could probably to due to the fact that the large amount

of photosynthetic material (leaves and stems) removed retarded regrowth. Looking at the final cumulative fresh marketable material produced, Jamaica Native still produced significantly more than many of the varieties.

3.0 CHAPTER 3: RESPONSE OF AMARANTH TO VARYING AMOUNTS OF NITROGEN AND POTASSIUM.

3.1 INTRODUCTION

In general the fertilizer rates for leafy vegetables have been adopted by vegetable amaranth growers. High nitrogen is usually suggested since nitrogen is important for good vegetative growth. Leafy vegetables are considered to be typical nitrogen responsive plants (Purshothaman,1982). The effect of nitrogen as noted by Russel (1978), is to increase leaf growth, produce more succulent leaves and darken the green colour. Low nitrogen supply produces hard fibrous leaves (Russel,1978). If well supplied with nitrogen, leafy vegetables can be harvested earlier. Insufficient nitrogen would give rise not only to reduced yields but also to pale green leaves of low market value (Purshotaman,1982).

The lack of information on nutrient response in amaranth has been noted by several authors including Grubben(1976), Oke (1981), who both studied the response of the crop to applied nutrients and concluded that increasing the level of nitrogen is responsible for higher yields.

Weeds belonging to the genus Amaranthus are particularly efficient in the uptake of potassium (Hoveland 1976). Grubben (1976) noted that amaranth also has a great need for potassium in photosyhnthesis.

Grubben (1976) explained that data on nutrient removal constitutes important information on the manuring of amaranth. He noted that the mineral elements in the soil are not enough to support productive growth of a crop of amaranth since amaranth can exhaust a rather rich soil. It is therefore necessary for each crop to be fertilized.

3.2 Objectives

The objective of this study was to examine the response of the amaranth variety Jamaica Native , to varying amounts of nitrogen and potassium fertilizer. The study also looked at nutrient uptake in the plant tissue.

3.3 Materials and Methods

An experiment was conducted at The University Field Station on land that had previously been fallow and with no fertilizer applied to it for a number of years. The experimental design was a completely randomized block with 3 replications using the variety Jamaica Native. Four levels of nitrogen were applied, 0 kg/ha (N_0), 75 kg/ha (N_1), 100 kg/ha (N_2), and 300 kg/ha (N_3). For potassium the levels were 0 kg/ha (K_0), 100 kg/ha (K_1), 200 kg/ha (K_2), and 400 kg/ha (K_3). Phosphorus was applied to all the plots at the rate of 75 kg/ha. The fertilizers used were sulphate of ammonia, triplesuperphosphate and muriate of potash. All the fertilizer was incorporated into the field the day before planting.

Transplanting of 3 week old seeedlings 25 cm apart

was done on 14/8/84. Each plot measured 75cm x 125cm. The first harvest was done three weeks after transplanting and at two week intervals thereafter for 4 harvests. Yield data were recorded by measuring the fresh and dry weight of the harvested leaves and stems. The method of harvest was by ratooning (repeatedly cutting the same plants). Dry matter was obtained by drying the harvested material in an oven set at 80 0C for at least 48 hours. Eight plants per plot were sampled at each of the four harvests. Chemical analysis of the leaves and stems were conducted to determine nitrogen, phosphorus and potassium uptake. The dried leaves and stems were ground using a 20 mesh wire and analyses done on the harvested material. The samples were digested using hydrochloric acid. On aliquots of the digested material, phosphorus was determined using a spectrophotometre (Olsen and Dean,1965) and potassium by flame photometer (Pratt,1965). Nitrogen was analysed for by the Kjeldahl method (Bremner,1965).

3.4 Results

3.4.1 Total Fresh Weight (leaves and stems)

Amaranth showed a highly significant response to nitrogen with very high yields at high nitrogen levels (Tables 3.1 and 3.2). The response to potassium was significant only at the 1st harvest when K_0 produced significantly lower fresh weight of both leaves and stems (Table 3.2) than K_3. The percentage distribution of the fresh weight yields between harvests (Table 3.3), shows that

TABLE:3.1 The effect of nitrogen and potassium on the total fresh weight yield of Jamaica Native (kg/ha).

	Nitrogen Levels				
vels	N_0	N_1	N_2	N_3	Potassium Means
K_0	2345	6419	8580	16,865	8552
K_1	3255	7109	9295	17,083	9186
K_2	2512	6895	10,370	13,457	8309
K_3	2616	5365	6524	20,841	8837
rogen eans	2682	6447	8692	17,062	

P = 0.05(nitrogen) 1469.2

P = 0.05(potassium) 1469.2

P = 0.05(nitrogen x potassium) 2938.4

(%) 42.20

K_0 = 0 kg/ha

K_1 = 100 kg/ha

K_2 = 200 kg/ha

N_0 = 0 kg/ha

N_1 = 75 kg/ha

N_2 = 100 kg/ha

TABLE:3. 2 The effect of nitrogen and potassium on the total fresh weight yield of Jamaica Native at 4 different harvests (kg/ha).

	Harvests				
Nitrogen Levels	H_1	H_2	H_3	H_4	Total
N_0	703	718	639	622	2682
N_1	2750	1806	1082	807	6445
N_2	3830	2531	1479	851	8691
N_3	4660	8059	3386	957	17,062
Harvest Means	2986	3279	1646	809	
Potassium Level					
K_0	2560	3327	1877	787	8551
K_1	2995	3591	1751	849	9186
K_2	3067	2994	1446	801	8308
K_3	3320	3204	1512	801	8837
Harvest Means	2988	3281	1648	810	

LSD P = 0.05 (harvest) 367.3

LSD P = 0.05 (nitrogen)367.3

LSD P = 0.05 (potassium) 367.3

LSD P = 0.05 (nitrogen x potassium) 734.6

CV (%) 42.20

N_0 = 0 kg/ha

N_1 = 75 kg/ha

N_2 = 100 kg/ha

N_3 = 300 kg/ha

K_0 = 0 kg/ha

K_1 = 100 kg/ha

K_2 = 200 kg/ha

K_3 = 400 kg/ha

TABLE:3. 3 The effect of nitrogen and potassium on the distribution of yields among harvests of Jamaica Native.

Nitrogen Levels	Harvests			
	H_1	H_2	H_3	H_4
N_0	26.9	26.5	23.6	22.9
N_1	42.7	28.0	16.8	12.5
N_2	44.1	29.1	17.0	9.8
N_3	27.3	47.2	19.8	5.6
Mean	35.3	32.7	19.3	12.7

N_0 =0 kg/ha

N_1 = 75 kg/ha

N_2 = 100 kg/ha

N_3 = 300 kg/ha

without nitrogen (N_0), the yield was evenly distributed from Harvest 1 to Harvest 4. With nitrogen however, (N_1, N_2, and N_3), the first two harvests yielded 70-75% of the total yield.

3.4.2 Fresh Weight of Leaves

Leaves showed a marked response to nitrogen (Tables 3.4 and 3.5), fresh weight increased with increasing levels of nitrogen. The response to potassium was not significant except at harvest 1 with K_0 producing significantly less fresh weight than K_3 (Table 3.5).

3.4.3 Fresh Weight of Stems

Stem fresh weight responded moderately to added nitrogen (Tables 3.6 and 3.7). The response to potassium was not significant.

3.4.4 Leaves as Percent of Total Fresh Weight

At the first two harvests, leaves made up more than 70 % of the total fresh weight (Table 3.9). There was a decrease in the amount of leaves, as a portion of fresh weight with time. When no nitrogen was applied, leaves constituted a lower proportion of the total fresh weight.

3.4.5 Total Dry Weight

There was a significant increase in total dry weight as nitrogen was increased from 0 kg/ha to 300 kg/ha (Tables 3.10 and 3.11). There was no significant response to

Table:3.4 The effect of nitrogen and potassium on leaf fresh weight yield of Jamaica Native (kg/ha)

Potassium Levels	Nitrogen Levels N_0	N_1	N_2	N_3	Potassium Means
K_0	1522	4622	6380	12,053	6144
K_1	2273	5359	6651	11,675	6489
K_2	1656	5113	7767	9597	6033
K_3	1747	4017	4913	14,399	6270
Nitrogen Means	1799	4778	6428	11,931	

LSD P= 0.05 (nitrogen) 972.8

LSD P= 0.05 (potassium) 972.8

LSD P= 0.05 (nitrogen x potassium) 1946.0

CV % 39.09

N_0 = 0 kg/ha

N_1 = 75 kg/ha

N_2 = 100 kg/ha

N_3 = 300 kg/ha

K_0 = 0 kg/ha

K_1 = 100 kg/ha

K_2 = 200 kg/ha

K_3 = 400 kg/ha

TABLE:3.5 The effect of nitrogen and potassium on leaf fresh weight yield of Jamaica Native at 4 different harvests (kg/ha).

	Harvests				
	H_1	H_2	H_3	H_4	Total
N_0	479	518	403	400	1799
N_1	2138	1379	731	529	4777
N_2	2990	1931	954	554	6429
N_3	3614	5430	2253	634	11,931
MEAN	2309	2315	1085	529	
Potassium Levels					
K_0	1985	2379	1266	515	6145
K_1	2307	2522	1098	563	6490
K_2	2398	2160	955	520	6033
K_3	2532	2197	1022	519	6270
Mean	2309	2315	1085	529	

LSD P = 0.05 (harvest) 243.2

LSD P = 0.05 (potassium) 243.2

LSD P = 0.05 (harvest x potassium) 486.5

CV % 39.09

TABLE:3.6 The effect of nitrogen and potassium on stem fresh weight yield of Jamaica Native (kg/ha)

	Nitrogen Levels				
Potassium Levels	N_0	N_1	N_2	N_3	Potassium Means
K_0	824	1796	2200	4808	2408
K_1	984	1748	2644	5408	2696
K_2	856	1780	2604	3860	2275
K_3	868	1348	1608	6444	2568
Nitrogen Means	884	1668	2264	5132	

LSD P= 0.05 (nitrogen) 554.8

LSD P = 0.05 (potassium) 554.8

LSD P = 0.05 (nitrogen x potassium)1109.6

CV % 55.93

N_0 = o kg/ha
N_1 = 75 kg/ha
N_2 = 100 kg/ha
N_3 = 300 kg/ha

K_0 = 0 kg/ha
K_1 = 100 kg/ha
K_2 = 200 kg/ha
K_3 = 400 kg/ha

TABLE:3.7 The effect of nitrogen and potassium on stem fresh weight yield of Jamaica Native at 4 different harvests (kg/ha)

	Harvests				
	H_1	H_2	H_3	H_4	Total
N_0	224	201	236	222	883
N_1	612	427	351	279	1668
N_2	840	601	525	297	2263
N_3	1046	2629	1133	323	5131
Mean	681	964	561	280	

LSD P = 0.05 (nitrogen) 138.7

LSD P = 0.05 (harvest) 138.7

LSD P = 0.05 (harvest x nitrogen) 277.3

CV % 55.93

K_0	576	948	612	272	2408
K_1	688	1068	653	286	2695
K_2	669	834	491	280	2274
K_3	789	1007	489	282	2567
Mean	681	964	561	280	

LSD P = 0.05 (potassium) 138.7

LSD P = 0.05 (harvest) 138.7

LSD P = 0.05 (harvest x potassium) 277.4

CV % 55.93

TABLE:3.9 The effect of nitrogen and potassium on the percent of leaves in the total fresh weight of Jamaica Native at 4 different harvests (%)

	Harvests				
Nitrogen Levels	H_1	H_2	H_3	H_4	Nitrogen Means
N_0	65.6	72.1	64.0	64.4	67.1
N_1	77.7	76.4	67.6	65.5	74.1
N_2	78.2	76.3	64.4	65.1	74.1
N_3	77.6	67.4	66.5	66.3	69.9
Harvest Means	77.2	70.6	64.3	65.4	
Potassium Levels					Potassium Means
K_0	77.5	71.5	67.4	65.4	71.9
K_1	77.1	70.3	62.7	66.3	70.7
K_2	78.2	72.2	66.1	65.0	72.6
K_3	76.3	68.6	67.7	64.8	70.9
Harvest Means	77.2	70.6	65.9	65.4	

K_0 = 0 kg/ha N_0 = 0 kg/ha

K_1 = 100 kg/ha N_1 = 75 kg/ha

K_2 = 200 kg/ha N_2 = 100 kg/ha

K_3 = 400 kg/ha N_3 = 300 kg/ha

TABLE:3.10 The effect of nitrogen and potassium on the total dry weight of Jamaica Native (kg/ha).

Potassium Levels	Nitrogen Levels N_0	N_1	N_2	N_3	Potassium Means
K_0	632	1640	2172	3316	1940
K_1	864	1780	2256	3228	2032
K_2	656	1784	2436	2772	1912
K_3	684	1308	1732	3660	1848
Nitrogen Means	708	1628	2149	3224	

LSD P = 0.05 (Nitrogen) 210.0

LSD P = 0.05 (potassium) 210.0

LSD P = 0.05 (nitrogen x potassium) 419.6

CV % 27.24

N_0 = 0 kg/ha

N_1 = 75 kg/ha

N_2 = 100 kg/ha

N_3 = 200 kg/ha

K_0 = 0 kg/ha

K_1 = 100 kg/ha

K_2 = 200 kg/ha

K_3 = 400 kg/ha

Table 3.11 The effect of nitrogen and potassium on total dry weight of Jamaica Native at 4 different harvests (kg/ha).

	Harvests				
Nitrogen Levels	H_1	H_2	H_3	H_4	Total
N_0	179	172	188	168	708
N_1	635	438	326	228	1628
N_2	786	636	462	265	2149
N_3	805	1306	835	297	3243
Harvest Means	601	638	453	240	

Potassium Levels					Total
K_0	551	670	480	237	1938
K_1	619	687	470	257	2032
K_2	615	613	453	230	1912
K_3	620	583	409	234	1846
Harvest Means	601	638	453	240	

LSD P = 0.05 (nitrogen) 52.5

LSD P = 0.05 (potassium) 52.5

LSD P = 0.05 (potassium x nitrogen) 104.9

CV (%) 27.24

N_0 = 0 kg/ha
N_1 = 75 kg/ha
N_2 = 100 kg/ha
N_3 = 300 kg/ha

K_0 = 0 kg/ha
K_1 = 100 kg/ha
K_2 = 200 kg/ha
K_3 = 400 kg/ha

potassium except at the 1st harvest when K_1 was significantly higher than the other potassium levels (Table 3.10).

3.4.6 Dry Weight Leaves

Leaf dry weight (Tables 3.12 and 3.13) showed a significant increase with increasing amounts of nitrogen. Potassium response was only significant at the 1st harvest where K_0 was significantly lower than the other potassium levels (Table 3.12).

3.4.7 Stem Dry Weight

Stem dry weight increased moderately with nitrogen (Tables 3.14). Although there was a general increase with added nitrogen, the difference was only significant between N_0 and N_3. The response to potassium was however not significant.

3.4.8 Dry Matter Percent

The dry matter response to nitrogen applicaton was significantly lower at the highest nitrogen level (300 kg/ha) than at the other levels (Table 3.16) There was no significant difference among the potassium levels. Leaf and stem dry matter percent on Tables 3.17 and 3.18 show that N_3 had significantly lower dry matter percent than the other nitrogen levels. An increase in potassium had no significant effect on the dry matter percent of the leaves and stems.

TABLE:3. 12 The effect of nitrogen and potassium on leaf dry weight yield of Jamaica Native (kg/ha).

Potassium Levels	Nitrogen Levels N_0	N_1	N_2	N_3	Potassium Means
K_0	328	1156	1580	2504	1392
K_1	608	1368	1600	2256	1460
K_2	416	1344	1740	1956	1364
K_3	444	964	1268	2596	1316
Nitrogen Means	464	1208	1548	2312	

LSD P = 0.05 (nitrogen) 157.6

LSD P = 0.05 (potassium) 57.6

LSD P = 0.05 (nitrogen x potassium) 315.2

CV (%) 28.56

N_0 = 0 kg/ha

N_1 = 75 kg/ha

N_2 = 100 kg/ha

N_3 = 300 kg/ha

K_0 = 0 kg/ha

K_1 = 100 kg/ha

K_2 = 200 kg/ha

K_3 = 400 kg/ha

TABLE 3.13 The effect of nitrogen and potassium on leaf dry weight yield of Jamaica Native (kg/ha).

	Harvests				
Nitrogen Levels	H_1	H_2	H_3	H_4	Total
N_0	118	121	116	109	464
N_1	462	344	239	162	1208
N_2	564	478	308	197	1547
N_3	595	943	557	216	2311
Harvest Means	435	472	305	171	
Potassium Levels					Total
K_0	400	480	339	171	1390
K_1	445	513	311	190	1458
K_2	443	460	298	164	1364
K_3	452	434	273	159	1318
Harvest Means	435	472	305	171	

LSD P = 0.05 (nitrogen) 39.4

LSD P = 0.05 (potassium)39.4

LSD P = 0.05 (nitrogen x potassium) 78.8

CV (%) 28.56

N_0 = 0 kg/ha

N_1 = 75 kg/ha

N_2 = 100 kg/ha

N_3 = 300 kg/ha

K_0 = 0 kg/ha

K_1 = 100 kg/ha

K_2 = 200 kg/ha

K_3 = 400 kg/ha

Table:3.14 The effect of nitrogen and potassium on stem dry matter yield of Jamaica Native (kg/ha)

Nitrogen Levels	Harvest H_1	H_2	H_3	H_4	Total
N_0	61	52	72	59	244
N_1	173	94	88	66	418
N_2	222	158	154	68	602
N_3	210	363	278	81	933
Harvest Means	167	167	145	69	
Potassium Levels					
K_0	151	190	141	65	548
K_1	174	174	159	68	574
K_2	172	154	155	66	548
K_3	169	149	136	75	529
Harvest Means	167	167	145	69	

LSD P = 0.05 (nitrogen) 16.6

LSD P = 0.05 (potassium) 16.6

LSD P = 0.05 (nitrogen x potassium) 33.2

CV (%) 30.29

N_0 = 0 kg/ha

N_1 = 75 kg/ha

N_2 = 100 kg/ha

N_3 = 300 kg/ha

K_0 = 0 kg/ha

K_1 = 100 kg/ha

K_2 = 200 kg/ha

K_3 = 400 kg/ha

TABLE: 3.15 The effect of nitrogen and potassium on stem dry weight of Jamaica Native (kg/ha)

Potassium Levels	Nitrogen Levels N_0	N_1	N_2	N_3	Potassium Means
K_0	236	485	592	878	548
K_1	255	412	655	974	574
K_2	240	440	696	814	548
K_3	243	344	463	1064	529
Nitrogen Means	244	420	602	933	

LSD P = 0.05 (nitrogen) 16.6

LSD P = 0.05 (potassium) 16.6

LSD P = 0.05 (nitrogen x potassium) 33.2

CV (%) 30.29

K_0 = 0 kg/ha

K_1 = 100 kg/ha

K_2 = 200 kg/ha

K_3 = 400 kg/ha

N_0 = 0 kg/ha

N_1 = 75 kg/ha

N_2 = 100 kg/ha

N_3 = 300 kg/ha

Table:3.16 The effect of nitrogen and potassium on total dry matter percent of Jamaica Native (%)

Potassium Levels	Nitrogen Levels N_0	N_1	N_2	N_3	Potassium Means
K_0	26.8	27.0	27.8	22.9	26.1
K_1	26.4	26.6	26.5	22.7	25.5
K_2	26.5	27.1	26.7	24.0	26.1
K_3	26.4	25.6	28.0	22.5	25.6
Nitrogen Means	26.5	25.6	27.2	23.0	

LSD P = 0.05 (nitrogen) 1.4

LSD P = 0.05 (potassium) 1.4

LSD P = 0.05 (nitrogen x potassium) 2.7

CV % 13.23

N_0 = 0 kg/ha

N_1 = 75 kg/ha

N_2 = 100 kg/ha

N_3 = 300 kg/ha

K_0 = 0 kg/ha

K_1 = 100 kg/ha

K_2 = 200 kg/ha

K_3 = 400 kg/ha

Table:3.17 The effect of nitrogen and potassium on leaf dry matter percent of Jamaica Native (%)

Potassium Levels	Nitrogen Levels N_0	N_1	N_2	N_3	Potassium Means
K_0	25.8	27.4	29.2	23.9	26.5
K_1	26.4	27.7	28.1	23.1	26.3
K_2	25.7	28.9	26.7	24.1	26.4
K_3	25.7	25.4	28.3	23.4	25.7
Nitrogen Means	25.9	27.3	28.1	23.6	

LSD P = 0.05 (nitrogen) 1.89

LSD P = 0.05 (potassium) 1.89

LSD P = 0.05 (nitrogen x potassium) 3.8

CV % 17.99

N_0 = 0 kg/ha

N_1 = 75 kg/ha

N_2 = 100 kg/ha

N_3 = 200 kg/ha

K_0 = 0 kg/ha

K_1 = 100 kg/ha

K_2 = 200 kg/ha

K_3 = 400 kg/ha

TABLE:3.18 The effect of nitrogen and potasium on stem dry matter percent of Jamaica Native (%)

	Nitrogen Levels				
Potassium Levels	N_0	N_1	N_2	N_3	Potassium Means
K_0	28.7	26.9	26.3	21.1	25.8
K_1	26.2	23.5	25.1	22.4	24.3
K_2	28.0	23.9	27.4	24.2	25.9
K_3	28.0	25.8	28.1	21.2	25.8
Nitrogen Means	27.8	25.0	26.7	22.2	

LSD P = 0.05 (nitrogen) 1.8

LSD P = 0.05 (potassium) 1.8

LSD P = 0.05 (nitrogen x potassium) 3.6

CV % 17.54

N_0 = 0 kg/ha

N_1 = 75 kg/ha

N_2 = 100 kg/ha

N_3 = 300 kg/ha

K_0 = 0 kg/ha

K_1 = 100 kg/ha

K_2 = 200 kg/ha

K_3 = 400 kg/ha

3.4.9 Total Plant Nitrogen Removed

Mean amounts of nitrogen removed by the plant showed an increase when the amount of nitrogen added to the soil was increased (Table 3.20) The amounts removed at the N_0 and N_1 levels were significantly lower than that removed at the N_2 level. At the N_2 level also, significantly lower amounts were removed than at the N_3 level (Table 3.20). Increasing potassium had no significant effect on nitrogen removal.

3.4.10 Percent Nitrogen in Leaves and Stems

The concentration of nitrogen in the leaves and stems increased as nitrogen added to the soil was increased and decreased with time (Table 3.19, 3.21-3.24). The increase in percent total plant nitrogen in the leaf and stem,(Tables 3.22 and 3.24) at the N_1 level was significantly higher than the N_0 level. Potassium had no significant effect on nitrogen concentration in the leaves and stems.

3.4.11 Total Plant Phosphorus Removed

The phosphorus content of the leaves and stems as reflected by the amount removed (Table 3.25) was not significant neither when nitrogen nor potassium were increased.

3.4.12 Percent Phosphorus Leaves and Stems

TABLE:3. 19 The efffect of nitrogen and potassium on the total concentration of nitrogen in Jamaica Native (%).

	Harvests				
Nitrogen Levels	H1	H2	H3	H4	Nitrogen Means
N_0	3.53	4.34	3.71	3.29	3.72
N_1	4.76	3.72	3.42	4.05	3.99
N_2	6.46	3.64	3.68	4.27	4.51
N_3	8.94	5.22	4.72	4.34	5.81
Harvest Means	5.92	4.23	3.88	3.99	
Potassium Levels					Potassium Means
K_0	5.99	4.22	3.99	4.10	4.55
K_1	5.89	4.84	3.93	4.02	4.67
K2	5.71	4.31	3.72	3.74	4.37
K_3	6.19	3.55	3.90	4.09	4.43
Harvest Means	5.62	4.23	3.88	3.99	

LSD P = 0.05 (nitrogen) 0.49

LSD P = 0.05 (potassium) 0.49

LSD P = 0.05 (harvests) 0.49

LSD P = 0.05 (nitrogen x potassium) 0.98

CV (%) 27.29

N0 = 0 kg/ha	K0 = 0 kg/ha
N1 = 75 kg/ha	K1 = 100 kg/ha
N2 = 100 kg/ha	K2 = 200 kg/ha
N_3 = 300 kg/ha	K_3 = 400 kg/ha

TABLE 3.20 The effect of nitrogen and potassium on the total amount of nitrogen removed by Jamaica Native (kg/ha)

Potassium Levels	Nitrogen Levels N_0	N_1	N_2	N_3	Potassium Means
K_0	20.3	66.9	106.9	198.9	98.3
K_1	34.8	75.7	95.7	198.5	101.2
K_2	25.3	70.1	114.9	137.8	87.0
K_3	25.8	48.3	72.2	223.3	92.4
Means	26.6	65.3	97.4	189.6	

N_0 = 0 kg/ha
N_1 = 75 kg/ha
N_2 = 100 kg/ha
N_3 = 300 kg/ha

K_0 = 0 kg/ha
K_1 = 100 kg/ha
K_2 = 200 kg/ha
K_3 = 400 kg/ha

TABLE:3.21 The effect of nitrogen and potassium on the nitrogen content of the leaf of Jamaica Native (%)

Potassium Levels	Nitrogen Levels N_0	N_1	N_2	N_3	Potassium Means
K_0	1.95	2.48	2.83	3.17	2.61
K_1	2.18	2.63	2.58	3.58	2.59
K_2	2.27	2.29	2.85	2.94	2.59
K_3	2.21	2.19	2.34	3.43	2.55
Nitrogen Means	2.15	2.40	2.65	3.28	

LSD P = 0.05 (nitrogen) 0.27

LSD P = 0.05 (potassium) 0.27

LSD P = 0.05 (nitrogen x potassium)0.54

CV 36.63

N_0 = 0 kg/ha

N_1 = 75 kg/ha

N_2 = 100 kg/ha

N_3 = 300 kg/ha

K_0 = 0 kg/ha

K_1 = 100 kg/ha

K_2 = 200 kg/ha

K_3 = 400 kg/ha

TABLE:3. 22 The effect of nitrogen and potassium on nitrogen content of the leaf at 4 different harvests (%)

	Harvests				
Nitrogen Levels	H1	H2	H3	H4	Nitrogen Means
N_0	1.98	2.45	2.13	2.06	2.15
N_1	2.51	2.28	2.25	2.55	2.40
N_2	3.36	2.14	2.36	2.75	2.65
N_3	4.52	3.19	2.84	2.58	3.28
Harvest Means	3.09	2.51	2.39	2.48	
Potassium Levels					Potassium Means
K_0	2.88	2.33	2.58	2.63	2.61
K_1	3.09	2.89	2.37	2.61	2.74
K_2	3.12	2.68	2.24	2.31	2.59
K_3	3.27	2.16	2.38	2.37	2.55
Harvest Means	3.09	2.51	2.39	2.48	

LSD P = 0.05 (nitrogen) 0.27

LSD P = 0.05 (potassium) 0.27

LSD P = 0.05 (harvests) 0.27

LSD P = 0.05 (nitrogen x potassium) 0.54

CV (%) 36.63

N_0 = 0 kg/ha

N_1 = 75 kg/ha

N_2 = 100 kg/ha

N_3 = 300 kg/ha

K_0 = 0 kg/ha

K_1 = 100 kg/ha

K_2 = 200 kg/ha

K_3 = 400 kg/ha

Table:3.23 The effect of nitrogen and potassium on the nitrogen content of the stem of Jamaica Native (%).

Potassium Levels	Nitrogen Levels N_0	N_1	N_2	N_3	Potassium Means
K_0	1.26	1.60	2.09	2.83	1.95
K_1	1.85	1.63	1.66	2.57	1.93
K_2	1.59	1.64	1.86	2.03	1.78
K_3	1.56	1.49	1.83	2.67	1.89
Nitrogen Means	1.56	1.59	1.86	2.53	

LSD P = 0.05 (nitrogen) 0.29

LSD P = 0.05 (potassium) 0.29

LSD P = 0.05 (harvest x nitrogen)0.59

CV % 38.98

N_0 = 0 kg/ha

N_1 = 75 kg/ha

N_2 = 100 kg/ha

N_3 = 300 kg/ha

K_0 = 0 kg/ha

K_1 = 100 kg/ha

K_2 = 200 kg/ha

K_3 = 400 kg/ha

TABLE:3.24 The effect of nitrogen and potassium on the nitrogen content of the stem at 4 different harvests (%)

	Harvests				
Nitrogen Levels	H_1	H_2	H_3	H_4	Nitrogen Means
N_0	1.55	1.89	1.58	1.24	1.57
N_1	2.25	1.44	1.17	1.50	1.59
N_2	3.10	1.51	1.32	1.53	1.86
N_3	4.43	2.03	1.88	1.76	2.53
Harvest Means	2.83	1.72	1.41	1.51	
Potassium Levels					Potassium Means
K_0	3.02	1.90	1.41	1.46	1.95
K_1	2.80	1.95	1.55	1.41	1.93
K_2	2.59	1.63	1.48	1.43	1.78
K_3	2.92	1.39	1.52	1.72	1.89
Harvest Means	2.83	1.72	1.49	1.51	

LSD P = 0.05(nitrogen) 0.29

LSD P = 0.05(potassium) 0.29

LSD P = 0.05(harvests) 0.29

LSD P = 0.05(nitrogen x potassium) 0.59

CV (%) 38.98

N_0 = 0 kg/ha

N_1 = 75 kg/ha

N_2 = 100 kg/ha

N_3 = 300 kg/ha

K_0 = 0 kg/ha

K_1 = 100 kg/ha

K_2 = 200 kg/ha

K_3 = 400 kg/ha

TABLE:3. 25 The effect of nitrogen and potassium on the total amount of phosphorus removed by Jamaica Native (kg/ha)

Potassium Levels	Nitrogen Levels N_1	N_2	N_3	N_4	Potassium Means
K_0	53.6	147.1	206.1	277.2	171.0
K_1	72.4	172.8	196.3	237.6	169.8
K_2	55.7	177.2	223.9	235.9	173.2
K_3	61.0	105.7	151.0	302.7	155.1
Means	60.7	150.7	194.3	263.4	

N_0 = 0 kg/ha
N_1 = 75 kg/ha
N_2 = 100 kg/ha
N_3 = 300 kg/ha

K_0 = 0 kg/ha
K_1 = 100 kg/ha
K_2 = 200 kg/ha
K_3 = 400 kg/ha

Tables 3.26 to 3.29 show the phosphorus concentration in the leaves and stems at different harvests and nitrogen levels. The phosphorus concentration in leaves showed no significant difference among the nitrogen or potassium levels (Table 3.26) . With the stems however, at N1, a significantly higher concentration of phosphorus was found than at the N_3 level.

3.4.13 Total Plant Potassium

As Table 3.30 shows, total potassium removed by the plant tended to increase with increasing levels of both nitrogen and potassium. When neither potassium nor nitrogen were added, lower amounts of potassium were removed than at the other levels.

3.4.14 Percent Potassium in Leaves and Stems

The percent potassium in the leaves and stems tended to increase with increasing amounts of potassium and nitrogen added to the soil (Tables 3.31 to 3.34). When no potassium was added, the potassium concentration was significantly lower in both leaves and stems than when potassium was added to the soil. There tended to be a decrease in potassium concentration with time.

3.4.15 Leaf Protein Content

Table 3.35 shows the protein content for the four harvests at the various nitrogen levels.Leaf protein content was noticed to increase with increasing nitrogen from N_0 to N_3 (Table 3.36). At the N_3 level protein content was

TABLE:3.26 The effect of nitrogen and potassium on the concentration of phosphorus in the leaves of Jamaica Native (%).

Potassium Levels	Nitrogen Levels N0	N1	N2	N3	Potassium Means
K_0	0.37	0.39	0.46	0.38	0.41
K_1	0.35	0.40	0.41	0.38	0.39
K_2	0.42	0.35	0.45	0.48	0.43
K_3	0.39	0.37	0.35	0.40	0.38
Nitrogen Means	0.38	0.38	0.42	0.41	

LSD P = 0.05 (nitrogen) 0.07

LSD P = 0.05 (potassium) 0.07

LSD P = 0.05 (nitrogen x potassium) 0.14

CV % 44.51

K_0 = 0 kg/ha

K_1 = 100 kg/ha

K_2 =200 kg/ha

K_3 = 400 kg/ha

N_0 = 0 kg/ha

N_1 = 75 kg/ha

N_2 = 100 kg/ha

N_3 = 300 kg/ha

TABLE 3.27 The effect of nitrogen and potassium on the total concentration of phosphorus in the leaves of Jamaica Native(%)

Nitrogen Levels	Harvests H1	H2	H3	H4	Nitrogen Means
N_0	0.49	0.40	0.22	0.45	0.39
N_1	0.63	0.32	0.21	0.37	0.38
N_2	0.78	0.29	0.25	0.36	0.42
N_3	0.86	0.31	0.19	0.30	0.42
Harvest Means	069	0.33	0.22	0.37	
Potassium Levels					
K_0	0.66	0.29	0.28	0.39	0.41
K_1	0.65	0.32	0.19	0.39	0.39
K_2	0.74	0.41	0.19	0.37	0.43
K_3	0.69	0.31	0.19	0.33	0.38
Harvest Means	0.69	0.33	0.22	0.37	

LSD P = 0.05 (harvest) 0.07

LSD P = 0.05 (nitrogen) 0.07

LSD P = 0.05 (potassium) 0.07

LSD P = 0.05 (harvest x potassium)0.14

CV (%) 44.51

K_0 = 0 kg/ha
K_1 = 100 kg/ha
K_2 = 200 kg/ha
K_3 = 400 kg/ha

N_0 = 0 kg/ha
N_1 = 75 kg/ha
N_2 = 100 kg/ha
N_3 = 300 kg/ha

TABLE:3.28 **The effect of nitrogen and potassium on the concentration of phosphorus in the stems of Jamaica Native (%).**

Potassium Levels	Nitrogen Levels N0	N1	N2	N3	Potassium Means
K_0	0.47	0.49	0.48	0.45	0.47
K_1	0.48	0.57	0.45	0.35	0.46
K_2	0.42	0.64	0.46	0.36	0.47
K_3	0.49	0.43	0.51	0.42	0.46
Nitrogen Means	0.46	0.53	0.58	0.39	

LSD P = 0.05 (nitrogen) 0.09

LSD P = 0.05 (potassium) 0.09

LSD P = 0.05 (nitrogen x potassium) 0.19

CV % 51.16

K_0 = O kg/ha

K_1 = 100 kg/ha

K_2 = 200 kg/ha

K_3 = 400 kg/ha

N_0 = 0 kg/ha

N_1 = 75 kg/ha

N_2 = 100 kg/ha

N_3 = 300 kg/ha

TABLE: 3.29 The effect of nitrogen and potassium on the concentration of phosphorus in the stems of Jamaica Native at four different harvests.(%)

Nitrogen Levels	Harvests H 1	H 2	H 3	H 4	Nitrogen Means
N_0	0.84	0.41	0.22	0.41	0.47
N_1	0.94	0.49	0.27	0.43	0.54
N_2	0.87	0.46	0.21	0.38	0.48
N_3	0.61	0.35	0.26	0.38	0.39
Harvest Means	0.82	0.43	0.24	0.40	
Potassium Levels					Potassium Means
K_0	0.69	0.51	0.28	0.43	0.48
K_1	0.84	0.39	0.20	0.42	0.46
K_2	0.86	0.37	0.26	0.41	0.48
K_3	0.86	0.43	0.22	0.35	0.47
Harvest Means	0.82	0.43	0.24	0.40	

LSD P = 0.05 (nitrogen) 0.09

LSD P = 0.05 (potassium) 0.09

LSD P = 0.05 (harvest) 0.09

LSD P = 0.05 (nitrogen x potassium) 0.19

CV (%) 51.16

N_0 = 0 kg/ha
N_1 = 75 kg/ha
N_2 = 100 kg/ha
N_3 = 300 kg/ha

K_0 = 0 kg/ha
K_1 = 100 kg/ha
K_2 = 200 kg/ha
K_3 = 400 kg/ha

TABLE:3. 30 The effect of nitrogen and potassium on the total amount of potassium removed by Jamaica Native (kg/ha)

Potassium Levels	Nitrogen Levels N_0	N_1	N_2	N_3	Potassium Means
K_0	77.2	198.4	268.7	325.6	217.5
K_1	113.6	279.1	332.3	464.8	297.5
K_2	85.8	266.7	348.3	419.4	280.1
K_3	88.4	199.9	275.0	685.5	312.2
Means	91.3	236.0	306.1	473.8	

N_0 = 0 kg/ha
N_1 = 75 kg/ha
N_2 = 100 kg/ha
N_3 = 300 kg/ha

K_0 = 0 kg/ha
K_1 = 100 kg/ha
K_2 = 200 kg/ha
K_3 = 400 kg/ha

TABLE:3.31 The effect of nitrogen and potassium on the concentration of potassium in the leaves of Jamaica Native (%).

Potassium Levels	Nitrogen Levels N0	N1	N2	N3	Potassium Means
K_0	4.65	5.10	4.70	4.10	4.64
K_1	4.98	5.10	5.52	6.30	5.48
K_2	4.98	5.76	4.85	5.77	5.34
K_3	4.38	5.95	6.22	6.88	5.86
Nitrogen Means	4.75	5.48	5.32	5.76	

LSD P = 0.05 (nitrogen) 0.58

LSD P = 0.05 (potassium) 0.58

LSD P = 0.05 (nitrogen x potassium) 1.16

CV % 27.20

K_0 = 0 kg/ha

K_1 = 100 kg/ha

K_2 = 200 kg/ha

K_3 = 400 kg/ha

N_0 = 0 kg/ha

N_1 = 75 kg/ha

N_2 = 100 kg/ha

N_3 = 300 kg/ha

TABLE:3.32 The effect of nitrogen and potassium on the concentration of potassium in the leaves of Jamaica Native at 4 different harvests (%)

	Harvests				
Nitrogen Levels	H1	H2	H3	H4	Nitrogen Means
N_0	3.87	4.85	6.48	3.80	4.75
N_1	5.47	5.45	5.85	5.15	5.48
N_2	5.98	4.73	6.12	4.43	5.32
N_3	6.17	6.22	6.20	4.47	5.76
Harvest Means	5.37	5.31	6.16	4.46	
Potassium Levels					Potassium Means
K_0	4.27	4.80	5.48	4.00	4.64
K_1	5.50	5.28	6.72	4.38	5.47
K_2	5.48	5.58	5.63	4.67	5.34
K_3	6.28	5.58	6.82	4.80	5.86
Harvest Means	5.37	5.31	6.16	4.46	

LSD P = 0.05 (nitrogen) 0.41

LSD P = 0.05 (potassium) 0.41

LSD P = 0.05 (harvest) 0.41

LSD P = 0.05(nitrogen x potassium) 0.82

CV (%) 27.20

N_0 = 0 kg/ha

N_1 = 75 kg/ha

N_2 = 100 kg/ha

N_3 = 300 kg/ha

K_0 = 0 kg/ha

K_1 = 100 kg/ha

K_2 = 200 kg/ha

K_3 = 400 kg/ha

TABLE:3.33 **The effect of nitrogen and potassium on concentration of potassium in the stems of Jamaica Native (%)**

Nitrogen Levels

Potassium Levels	N0	N1	N2	N3	Potassium Means
K_0	7.56	7.00	7.67	5.72	6.99
K_1	8.17	10.58	9.22	8.10	9.02
K_2	8.10	9.18	9.45	9.37	9.03
K_3	8.53	9.33	9.67	11.85	9.85
Nitrogen Means	8.09	9.03	9.00	8.76	

LSD P = 0.05 (nitrogen) 1.01

LSD P = 0.05 (potassium) 1.01

LSD P = 0.05 (nitrogen x potassium) 2.02

CV (%) 28.97

N0 = 0 kg/ha

N1 = 75 kg/ha

N2 = 100 kg/ha

N_3 = 300 kg/ha

K0 = 0 kg/ha

K1 = 100 kg/ha

K2 = 200 kg/ha

K_3 = 400 kg/ha

TABLE:3. 34 The effect of nitrogen and potassium on the concentration of potassium in the stems of Jamaica Native at 4 different harvests (%)

	Harvests				
Nitrogen Levels	H1	H2	H3	H4	Nitrogen Means
N_0	7.78	9.28	7.25	8.05	8.09
N_1	9.37	9.97	8.85	7.92	9.03
N_2	10.30	10.43	8.15	7.12	9.00
N_3	9.05	9.75	8.45	7.78	8.76
Harvest Means	9.12	9.86	8.18	7.72	
Potassium Levels					Potassium Mevels
K_0	6.61	7.48	7.02	6.83	6.99
K_1	9.92	11.32	6.77	8.07	9.02
K_2	8.77	10.47	9.38	7.48	9.03
K_3	11.20	10.17	9.53	8.48	9.85
Harvest Means	9.12	9.86	8.18	7.72	

LSD P= 0.05 (nitrogen) 0.41

LSD P = 0.05 (potassium) 0.41

LSD P = 0.05 (harrvest) 0.41

LSD P = 0.05 (nitrogen x potassium) 0.82

CV (%) 28.97

N_0 = 0 kg/ha

N_1 = 75 kg/ha

N_2 = 100 kg/ha

N_3 = 300 kg/ha

K_0 = 0 kg/ha

K_1 = 100 kg/ha

K_2 = 200 kg/ha

K_3 = 400 kg/ha

TABLE:3.35 Effect of nitrogen and potassium on leaf protein content of Jamaica Native (%).

	Nitrogen Levels				
Harvests	N0	N1	N2	N3	Harvests Means
H1	12.35	15.69	21.03	28.22	19.32
H2	15.31	14.23	13.34	19.96	15.71
H3	13.31	14.04	14.76	17.76	14.97
H4	12.84	15.94	17.16	16.09	15.51
Nitrogen Means	13.45	14.97	16.57	20.51	

LSD P = 0.05 (nitrogen) 2.4

LSD P = 0.05 (harvest) 2.4

LSD P = 0.05 (harvest x nitrogen 4.8

CV % 36.63

N_0 = 0 kg/ha

N_1 = 75 kg/ha

N_2 = 100 kg/ha

N_3 = 300 kg/ha

significantly higher than at all the other levels. There was a general decrease in protein from harvest 1 to 4. Protein content at the 1st harvest was significantly higher than at the other harvests.

3.5 Discussion

The effect of nitrogen is reflected in the increase in dry matter with nitrogen application. As the results indicated, leaf and stem dry matter production increased as nitrogen increased. A similar effect was noted earlier by Grubben (1976) and Oke (1981). The increase of dry matter with increasing nitrogen suggests that it is possible that higher levels of nitrogen than the highest used in this experiment (300 kg/ha) could lead to higher dry matter production. The lower dry matter percent at the N_3 level, but higher fresh weight is probably related to the succulence of the plant. As Russel (1978) indicated, nitrogen promotes more succulent growth. Leaves at the N_3 level would therefore have a higher moisture content relative to the other levels.

When nitrogen was added, the first two harvests as the results show, yielded 70-75 % of the total recorded yields. This suggests that after the first two harvests the effect of nitrogen was no longer significant. It is possible that adding nitrogen after the 2nd harvest may lead to a significant increase in yield or it might be more profitable to replant a new crop. Further work is necessary to justify

these assumptions. The best time for applying nitrogen should also be investigated.

The yield response to nitrogen as shown in the results, were not significantly affected by potassium. Higher levels of potassium did not affect the nitrogen trend to increased leaf and stem dry matter with increased nitrogen. This suggests that potassium is not essential for nitrogen uptake in amaranth.

It was also observed that nitrogen and phosphorus are usually present in progressively diminishing amounts as the leaves and stems age. This could probably be due to the plant's decreased ability to absorb these nutrients with age or as Grubben (1976) pointed out, there were large demands relative to the supply of these elements. Phosphorus content in this experiment ranged from .35% to .9% while Grubben (1976) reported an average of 6%.

The decreasing nitrogen with age was explained by Grubben (1976), as the possible result of amaranth remobilising an important part of the nitrogen to the inflorescences and other parts of the plant when the plant is finished its life cycle. Nitrogen content of the leaves and stems in this experiment ranged from 2% to 6%. Grubben (1976) reported 10% in young leaves of amaranth. These lower levels could probably be attributed to the lower levels of nitrogen used, cultivar differences,or stage of harvest.

The potassium content of the plant tissues in this

experiment ranged from 4-12%. Grubben (1976) however reported a potassium content of 12- 14%. He also noticed that the potassium content of the stems was higher than that of the leaves. This was also found to be so in this experiment.

High protein content is positively linked to high nitrogen application (from the results). The decrease in nitrogen as the plant aged resulted in a decrease in protein. Similar results were obtained by Oke (1966). He reported 30% protein in amaranth leaves which is higher than those obtained in this experiment (12-28%).

The results with regard to nutrient uptake are definitely not conclusive. Sampling of the entire plant, flowers and roots, is necessary to determine the amount of nutrient partitioned to these parts. It would seem that adding nitrogen seems to increase both dry matter and protein content. It is however necessary to determine an optimum level after which it would not be profitable to apply more nitrogen. The response to nitrogen differs under environmental conditions, more studies should therefore be undertaken to confirm these findings.

4.0 CHAPTER 4: AMARANTH YIELD AND COMPOSITION AS AFFECTED BY NITROGEN AND HARVESTING FREQUENCY

4.1 INTRODUCTION

Vegetable amaranth is harvested either by uprooting the entire plant or repeatedly cutting the same plant. The time interval between harvesting by the latter method varies. Grubben (1976), in Dahomey, noted that the yield from three cuttings at two week intervals was less than cutting at three week intervals in two harvests. On the other hand, Mohideen (1982) reported that in India, clipping is done at weekly intervals. The farmers in Trinidad also harvest the crop every week (Titus,unpublished data,1984).

Grubben (1976) concluded from his studies that amaranth is suitable for harvesting by repeated cuttings since taking away an important portion of the assimilating parts while leaving the root system intact stimulates the plant to repair the lost assimilating organs. He also noted that after a cutting, new leaves originate from the axillary buds until a sufficient leaf surface has been gained for reaching the reproductive stage.

Nitrate accumulation in plants is a natural phenomenon resulting from uptake of the nitrate ion in excess of its reduction and subsequent assimilation (Maynard et al,1976; Lorenz,1978). Schmidt (1971) suggested oxalic acid is the possible compulsory end product of incomplete respiration of organic substrates.

He also suggested that oxalic acid may be synthesised in response to cation excess created by metabolic incorporation of some inorganic ions. The nitrate and oxalate contents of some vegetable crops have caused concern since, if eaten in large quantities both nitrate and oxalate may be toxic to humans and animals. As already indicated (Chapter 1) the intake of vegetables high in nitrates have been linked to methemoglobin and eventually cyanosis (Schmidt, 1971; Maynard et al, 1976).

When large quantities of oxalic acid are injested by humans, calcium uptake is inhibited (Oke,1967). He indicated that calcium becomes bound in the digestive tract as calciun oxalate and is excreted in the faeces. Reporting on work done by Hazard et al(1938), Oke (1967) noted that oxalate can decrease serum calcium which leads to a reduction in the coagulability of the blood resulting in a decrease in the function of the heart.

Environmental factors were also recognised as affecting nitrate levels in plants (Schmidt et al, 1971; Maynard et al, 1976). Influential environmental factors include shading and water availability. Vegetables grown under deficient light conditions have been reported to accumulate more nitrates (Lorenz,1978). He also pointed out that moisture stress which causes a reduction or cessation in growth can lead to nitrate accumulation since nitrate assimilation continues despite the lessened growth.

High levels of soil nitrogen have been linked to

high oxalate and nitrate levels in plant tissues (Barker et al, 1971; Schmidt et al1971; Brown et al,1966) It was observed that with a plentiful supply of nitrogen, nitrate absorption may then exceed its reduction and assimilation within the plant. In experiments conducted on spinach by Barker et al (1971), increased rates of nitrogen application were reported to cause a substantial increase in the nitrate concentration of the tissues.The highest concentration (3.65%) was found at the highest rate of application(450 kg/ha). The lowest concentration occured where no nitrogen was applied (0.13%). A study on amaranth by Schmidt et al(1971) revealed that both nitrate and oxalate content of amaranth increased with increasing fertility levels. It was however suggested that application of nitrogen fertilizers are probably too often blamed in instances of high nitrate accumulation (Barker et al, 1971). These authors cited as evidence the fact that spinach harvested from several fields over a period of years varied in nitrate concentration by a factor of 5 or more with the same amount of fertilizer.

Hill and Rawate (1982) noted that although they found a high level of oxalate in amaranth, the values reported were comparable to those reported for other leafy vegetables eg spinach and chard. Schmidt et al(1971) also noted the similarity in oxalate and nitrate content of amaranth to those vegetables belonging to Caryophillidae.

The lethal dose of oxalic acid for man has been reported as 2-5 grams (Oke,1967). Nitrate toxicity is said to be low and widely varied, being in the order of 15-70 mg

nitrate N(NO_3 N) per kilogram of body weight (Maynard *et al*, 1971). Amaranthus is generally cooked before it is eaten and cooking removes most of the nitrates and oxalates (Grubben, 1976). The danger of oxalates and nitrates in amaranth is therefore perhaps exaggerated.

The objectives of this experiment were to determine under Trinidad conditions (1) the effect of nitrogen on yield and nitrate and oxalate content of amaranth and (2) the effect of harvesting frequency on yield and nitrate and oxalate levels in amaranth.

4.2 Materials and Methods

An experiment was conducted at the University Field Station from December 3rd 1984 to January 6th 1985 using the variety Jamaica Native. The area used had been planted with cassava to which no fertilizer had been applied for a number of years. Land preparation included ploughing and rotavating. The experimental design was,a randomised block with three replications. Phosphorous (75 kg/ha) and potassium (100kg/ha) were applied to all the plots as triplesuperphophate and muriate of potash respectively. The levels of nitrogen were 0 kg/ha, 300 kg/ha and 600 kg/ha. Nitrogen was applied as sulphate of ammonia, and was applied in split equal dosages the day before transplanting and immediately after the 2nd harvest at week 4.

Repeated cuttings were taken every week (6 harvests), every two weeks (3 harvests) and every three

weeks (2 harvests). Harvesting started on the 3rd week after transplanting. Marketable material, young succulent material, was harvested from 10 plants per plot and fresh and dry weight recorded. Dry weight was obtained by drying the plant material in an oven at 80 0C for at least 48 hours. On the harvested material, leaf number was counted, stem thickness was measured using a vernier caliphers and leaf area determined on a leaf area metre type AAM-5 manufactured by the Tokyo Hayashi Denko Company Limited. Immediately before each cutting plant height was measured from the soil level to the top most part of the plant.

Other cultural operations included pest control by spraying every week with Decis, Tamaron, or Ambush at the rate of 50 cc/l. Hand weeding operations were also carried out in the early growth stages of the plants.

Levels of nitrate and oxalate were determined on the dried material. For each sample, stems and leaves were ground together using a 20 mesh wire. Nitrate was determined by a nitrate Ion Specific Electrode Orion Model 93-07 (Orion Booklet). A 400 mg sample of ground material was placed in a 125 ml Erlenmeyer flask with an aqueous extracting solution which contained 0.025 M $N_2(SO_4)_3 18 H_2O$, 0.02 M H_3BO_3, 0.015 M Ag_2SO_4 and 0.025 M NH_2SO_3H. Extraction was done on a shaker for 30 minutes. The sample was filtered and the nitrate content of the filtrate determined (Marderosian et al,1980).

Oxalate analysis was done using the colorimetric method according to Burrows (1950). One gram of dried plant

material was added to 10 ml distilled water and 10 ml citric acid reagent in a 125 ml Erlenmeyer flask. The sample was extracted on a shaker for 30 minutes at room temperature. After filtering, the extract was dissolved in 50 ml of 0.4N HCl and shaken in a 125 ml Erlenmeyer flask for a further 30 minutes. The sample was filtered and 2 ml of filtrate added to 2 ml iron ferrous reagent. The absorbance was read at 540 nm using a Bausch and Lomb spectrophotometer.

4.3 Results

4.31 General Observations

At transplanting, all the seedlings were similar in appearance. After one week in the field, definite differences in the growth of the plants could be observed. The plants which were not supplied with nitrogen appeared stunted with small pale green leaves and reddish stems. Those supplied with 300 kg/ha and 600 kg/ha nitrogen, were taller with large dark green leaves and stems.There was a marked increase in plant height with nitrogen and also with lengthening of time between cuttings(Table 1a) .Those cut every week remained short averaging 27 cm compared to 42 cm for every two weeks and 63 cm for every 3 weeks. Floral initiation began earliest in the no nitrogen plants (N_0) while N_1 (300 kg/ha) and N_2 (600 kg/ha) started flowering around the same time. Rainfall, totalling 84.5 mm for the entire growing period, was heaviest during the first three weeks.

Table:4.1 **The effect of nitrogen and frequency of harvest on plant height in Amaranth variety Jamaica Native** (cm^2)

Nitrogen Levels	Harvesting Intervals: Every Week	Every 2 Weeks	Every 3 Weeks	Nitrogen Means
N_0	18.65	23.59	26.09	22.77
N_1	31.42	50.20	80.49	54.04
N_2	29.66	50.75	83.75	54.72
Harvest Means	26.58	41.51	63.44	

LSD P=0.05 (nitrogen) 5.78

LSD P=0.05 (harvest) 5.78

LSD P=0.05 (harvest x nitrogen) 10.02

CV (%) 15.73

4.3.1.1 **Fresh Weight / Dry Weight**

The general trend observed was towards an increase in total fresh and dry weight with increasing nitrogen (Tables 4.1,4.2) The yield obtained without nitrogen was significantly lower than at the other nitrogen levels (300 kg/ha and 600 kg/ha).At the 2 weekly and 3 weekly harvesting intervals, yield increased with increasing nitrogen up to 600 kg/ha. Highest total fresh weight was recorded when harvesting was done every week. There was a decrease in yield with an increase in the time interval (Table 4.2), with the 3 weekly interval having a significantly lower yield than harvesting every week. There was however, no significant difference in total dry matter between the three different intervals (Table 4.1a). This resulted from an increase in the dry matter content of the plant tissues as the interval between harvests increased (Table 4.5).

On Tables 4.3 and 4.4, fresh and dry weight yields of nitrogen treated plants tended to increase with each harvest both when the plants were harvested every week and when they were harvested every 2 weeks. The final harvest in each case (at the 9th week after transplanting) had significantly higher fresh and dry matter yields than all the other harvests. Harvesting every 3 weeks however, showed a decrease in yield from the 1st to the 2nd harvest.

The means for leaf fresh weight (Table 4.6) showed that fresh weight yield decreased with increasing time between harvests. The decrease was however only significant up to

TABLE:4.2 Effect of nitrogen and harvesting frequency on total dry weight yield of Jamaica Native (kg/ha).

Nitrogen Levels	Harvesting Frequency: Every week	Every 2 weeks	Every 3 weeks	Mean
N_0	1410	1351	1085	1282
N_1	6409	5869	5603	5960
N_2	5754	8222	7709	7228
Mean	4524	5147	4799	

LSD P = 0.05 (nitrogen) 986

LSD P = 0.05 (harvests) 986

LSD P = 0.05 (harvests x nitrogen) 1707

CV % 24.2

N_0 = 0 kg/ha

N_1 = 300 kg/ha

N_2 = 600 kg/ha

TABLE: 4.3 The effect of nitrogen and frequency of harvest on total fresh weight yield of Jamaica Native (kg/ha).

Nitrogen Levels	Harvesting frequency: Every Week	Every 2 weeks	Every 3 Weeks	Mean
N_0	5784	4703	3441	4643
N_1	25,830	19,580	17,700	21,030
N_2	22,970	24,208	23,720	23,630
Mean	18,190	16,160	14,950	

LSD P = 0.05 (nitrogen) 2793

LSD P = 0.05 (harvests) 2793

LSD P = 0.05 (harvests x nitrogen) 4837

CV % 20.3

N_0 = 0 kg/ha

N_1 = 300 kg/ha

N_2 = 600 kg/ha

THE EFFECT OF NITROGEN AND FREQUENCY OF HARVEST

ON TOTAL FRESH WEIGHT OF JAMAICA NATIVE (Kg/ha)

Table : 44

	Every week							Every 2 weeks				Every 3 weeks		
	1	2	3	4	5	6	TOTAL	2	4	6	TOTAL	3	6	TOTAL
N_0	623	476	863	I022	I233	I569	5786	I046	I443	22I4	4703	I324	2II8	344I
N_1	2505	4095	5077	4062	4964	5I24	25827	6I53	5886	7539	I9578	9445	8254	I7698
N_2	2I99	33I9	4269	3776	4250	5I52		65I6	7885	9807	24208	I3I68	I0547	237I5
Mean	I776	2630	3403	2954	3483	3948	22965	4572	507I	6520		7979	6973	

LSD P = 0.05 (harvest) = 763.4

LSD P = 0.05 (nitrogen) = 539.8

LSD P = 0.05 (harvest x nitrogen) = I322.3

CV% = 30.93

LSD P = 0.05 (harvest) = I444.8

LSD P = 0.05 (nitrogen) = I444.8

LSD P = 0.05 (harvest x nitrogen = 2502.5

CV% = 3I.98

LSD P = 0.05 (harvest) = I526.2

LSD P = 0.05 (nitrogen) = I906.I

LSD P = 0.05 (harvest x nitrogen = 2695.5

CV% = 24.0I

Table : 4.5

THE EFFECT OF NITROGEN AND FREQUENCY OF HARVEST ON TOTAL DRY WEIGHT OF JAMAICA NATIVE (Kg/ha)

	Every week							Every 2 weeks				Every 3 weeks		
	1	2	3	4	5	6	TOTAL	2	4	6	TOTAL	3	6	TOTAL
N_0	I39	I26	I5I	266	288	44I	I4II	294	4I5	642	I35I	459	626	I085
N_1	4I8	9I7	I024	II72	II37	I74I	6409	I600	I886	2382	5868	3I62	2442	5604
N_2	438	793	I942	II38	909	I533	5753	I945	232I	3956	8220	4522	3I87	7709
Mean	332	6I2	706	858	778	I238		I280	I540	2327		27I4	2085	

LSD P = 0.05 (harvest) = 223.4

LSD P = 0.05 (nitrogen) = I58.0

LSD P = 0.05 (harvest x nitrogen) = 387.2

CV% = 36.40

LSD P = 0.05 (harvest) = 886.9

LSD P = 0.05 (nitrogen) = 886.9

LSD P = 0.05 (harvest x nitrogen = I536.2

CV% = 61.65

LSD P = 0.05 (harvest) = 639

LSD P = 0.05 (nitrogen) = 783

LSD P = 0.05 (harvest x nitrogen = II07

CV% = 30.72

TABLE:4.6 Effect of nitrogen and frequency of harvest on total dry matter percent of Jamaica Native (%)

	Harvesting Frequency			
	Every Week	Every 2 Weeks	Every 3 Weeks	Mean
Nitrogen Levels				
N_0	24.6	28.7	31.5	28.2
N_1	24.8	30.0	33.0	29.3
N_2	24.9	33.9	33.6	30.8
Mean	24.8	30.8	32.7	

LSD P = 0.05 (nitrogen) 2.6

LSD P = 0.05 (harvests) 2.6

LSD P = 0.05 (harvests x nitrogen) 4.4

CV % 10.35

N_0 = 0 kg/ha

N_1 = 300 kg/ha

N_2 = 600 kg/ha

the 10% level. Leaf dry matter yield was lowest at weekly harvesting, Weekly harvesting show a significant increase in fresh and dry matter of the leaves from N_0 to N_1 (Tables 4.7 and 4.8). A decrease from N_1 to N_2 which was significant in the case of fresh weight. Both leaf fresh and dry matter continued to increase when plants were harvested every 2 and 3 weeks (Table 4.7, Table 4.8). Stem fresh weight decreased with increasing harvesting interval (Table 4.13) while stem dry matter showed an increasing trend (Table 4.14). Harvesting every week showed a significant increase in fresh and dry weight of stems from N_0 to N_1, then a decrease at N_2. When harvesting was done every 2 and 3 weeks stem fresh and dry weight increased significantly from N_1 to N_2 (Tables 4.11, and 4.12).

Total dry matter percent as shown on Tables 4.5 and 4.10 indicates an increase with increasing nitrogen. N_0 nitrogen was significantly lower than N_1 (300 kh/ha) and N_2 (600 kg/ha). The difference between N_1 and N_2 however was not significant. The means for dry matter percent at weekly harvesting (Table 4.10),showed no significant difference among nitrogen levels. At the two weekly harvesting interval, dry matter percent increased at every harvest while it decreased from the 1st to the 2nd harvest when the plants were cut every 3 weeks. Leaf dry matter percent (Table 4.15), show an increase with nitrogen and with harvesting interval. The difference at the weekly harvest and at zero nitrogen was significantly lower than at the other harvests and at the

TABLE:4.7 The effect of nitrogen and frequency of harvesting on leaf fresh weight yield of Jamaica Native (kg/ha)

Nitrogen Levels	Harvesting Frequency			
	Every Week	Every 2 Weeks	Every 3 Weeks	Mean
N_0	3995	3429	2622	3349
N_1	21,248	16,112	14,622	17,327
N_2	18,656	20,208	19,872	19,568
Mean	14,632	13,250	12,373	

LSD P = 0.05 (nitrogen) 2453

LSD P = 0.05 (harvests) 2453

LSD P = 0.05 (harvest x nitrogen) 4249

CV % 21.8

N_0 = 0 kg/ha

N_1 = 300 kg/ha

N_2 = 600 kg/ha

Table : 4.8

THE EFFECT OF NITROGEN AND FREQUENCY OF HARVEST ON LEAF FRESH WEIGHT OF JAMAICA NATIVE (Kg/ha)

	Every week							Every 2 weeks				Every 3 weeks		
	1	2	3	4	5	6	TOTAL	2	4	6	TOTAL	3	6	TOTAL
N_0	452	331	669	618	822	1104	3995	817	936	1675	3428	1051	1571	2622
N_1	2139	3397	4237	3230	4053	4195	21251	5120	4783	6213	16115	7917	6706	14623
N_2	1850	2755	3410	2981	3428	4222	18646	5473	6532	8198	20203	11160	8719	19873
Mean	1480	2161	2772	2276	2768	3174		3803	4084	5362		6708	5665	

LSD P = 0.05 (harvest) = 671.3

LSD P = 0.05 (nitrogen) = 474.7

LSD P = 0.05 (harvest x nitrogen) = 1162.8

CV% = 33.82

LSD P = 0.05 (harvest) = 1273.9

LSD P = 0.05 (nitrogen) = 1273.9

LSD P = 0.05 (harvest x nitrogen = 2206.5

CV% = 34.40

LSD P = 0.05 (harvest) = 1353.9

LSD P = 0.05 (nitrogen) = 1658.3

LSD P = 0.05 (harvest x nitrogen = 2345.1

CV% = 25.24

TABLE:4.9 **The effect of nitrogen and frequency of harvests on leaf dry weight yield of Jamaica Native** (kg/ha)

Nitrogen Levels	Harvesting Intervals			
	Every Week	Every 2Weeks	Every 3 Weeks	Mean
N_0	948	1013	854	938
N_1	5265	4950	4737	4984
N_2	4669	7146	6575	6116
Mean	3614	4370	4056	

LSD P = 0.05 (nitrogen) 898

LSD P = 0.05 (harvests) 898

LSD P = (harvests x nitrogen) 1555

CV % 26.7

N_0 = 0 kg/ha

N_1 = 300 kg/ha

N_2 = 600 kg/ha

Table : 4.10

THE EFFECT OF NITROGEN AND FREQUENCY OF HARVEST ON LEAF DRY WEIGHT OF JAMAICA NATIVE (Kg/ha)

	Every week							Every 2 weeks				Every 3 weeks		
	1	2	3	4	5	6	TOTAL	2	4	6	TOTAL	3	6	TOTAL
N_0	II0	93	II8	I44	I74	309	948	243	27I	499	I0I3	363	490	853
N_1	296	757	799	980	945	I489	5266	I327	I597	2026	4950	2705	2032	4736
N_2	3II	604	729	935	737	I3I4	4670	I686	I978	348I	7I46	3832	2743	6574
Mean	239	498	549	686	6I8	I037		I086	I282	2002		2300	I755	

LSD P = 0.05 (harvest) = 204.8

LSD P = 0.05 (nitrogen) = I44.8

LSD P = 0.05 (harvest x nitrogen) = 354.8

CV% = 4I.62

LSD P = 0.05 (harvest) = 829.3

LSD P = 0.05 (nitrogen) = 829.2

LSD P = 0.05 (harvest x nitrogen = I436.3

CV% = 67.90

LSD P = 0.05 (harvest) = 594.9

LSD P = 0.05 (nitrogen) = 728.7

LSD P = 0.05 (harvest x nitrogen = I030.5

CV% = 33.84

TABLE:4.11 The effect of nitrogen and frequency of harvests on the stem fresh weight yield of Jamaica Native (kg/ha)

Nitrogen Levels	Harvesting Frequency: Every Week	Every 2 Weeks	Every 3 Weeks	Mean
N_0	1789	1274	819	1294
N_1	4576	3462	3075	3704
N_2	4318	4005	3842	4054
Mean	3562	2914	2579	

LSD P = 0.05 (nitrogen) 358

LSD P = 0.05 (harvest) 358

LSD P = 0.05 (harvest x nitrogen) 620

CV % 14.2

N_0 = 0 kg/ha

N_1 = 300 kg/ha

N_2 = 600 kg/ha

TABLE:4.12 The effect of nitrogen and frequency of harvests on stem dry weight yield of Jamaica Native (kg/ha).

	Harvesting Interval			
	Every Week	Every 2 Weeks	Every 3 Weeks	Mean
Nitrogen Levels				
N_0	462	338	231	344
N_1	1144	918	865	976
N_2	1085	1076	1134	1098
Mean	897	777	744	

LSD P = 0.05 (nitrogen) 144

LSD P = 0.05 (harvests) 144

LSD P = 0.05 (harvests x nitrogen) 248

CV % 20.1

N_0 = 0 kg/ha

N_1 = 300 kg/ha

N_2 = 600 kg/ha

Table : 4.13

THE EFFECT OF NITROGEN AND FREQUENCY OF HARVEST ON STEAM FRESH WEIGHT OF JAMAICA NATIVE (Kg/ha)

	Every week							Every 2 weeks				Every 3 weeks		
	1	2	3	4	5	6	TOTAL	2	4	6	TOTAL	3	6	TOTAL
N_0	I7I	I45	I94	404	4I0	465	I789	229	506	539	I274	273	547	820
N_1	367	697	840	832	9II	929	4576	I033	II03	I326	3462	I527	I548	3075
N_2	349	563	859	795	822	930	43I8	I043	I353	I608	4005	20I3	I829	3842
Mean	296	468	63I	677	7I5	774		768	988	II58		I27I	I308	

LSD P = 0.05 (harvest) = I07.7

LSD P = 0.05 (nitrogen) = 76.2

LSD P = 0.05 (harvest x nitrogen) = I86.6

CV% = 22.30

LSD P = 0.05 (harvest) = I74.8

LSD P = 0.05 (nitrogen) = I74.8

LSD P = 0.05 (harvest x nitrogen = 302.8

CV% = 2I.47

LSD P = 0.05 (harvest) = 209.

LSD P = 0.05 (nitrogen) = 256.

LSD P = 0.05 (harvest x nitrogen = 362.4

CV% = I8.72

Table : 4.13

THE EFFECT OF NITROGEN AND FREQUENCY OF HARVEST ON STEM DRY WEIGHT OF JAMAICA (kg/ha)

	Every week							Every 2 weeks				Every 3 weeks		
	1	2	3	4	5	6	Mean	2	4	6	Mean	3	6	Mean
N_0	29	33	33	I22	II3	I32	462	5I	I44	I44	339	96	I36	232
N_1	I23	I60	225	I92	I92	252	II44	273	289	356	9I8	457	408	865
N_2	I27	I49	2I4	203	I72	220	I085	259	342	475	I076	690	444	II34
Mean	93	II4	I57	I72	I59	20I		I94	258	325		4I4	330	

LSD P = 0.05 (harvest) = 3I.4

LSD P = 0.05 (nitrogen) = 22.2

LSD P = 0.05 (harvest x nitrogen) = 54.4

CV% =

LSD P = 0.05 (harvest) = 67.I

LSD P = 0.05 (nitrogen) = 67.I

LSD P = 0.05 (harvest x nitrogen = II6.I

CV% = 30.86

LSD P = 0.05 (harvest) = 58

LSD P = 0.05 (nitrogen) = 7I

LSD P = 0.05 (harvest x nitrogen = I00

CV% = I7.84

Table : 4.15

THE EFFECT OF NITROGEN AND FREQUENCY OF HARVEST ON THE DRY MATTER PERCENT OF JAMAICA NATIVE AT 4 DIFFERENT HARVESTS (%)

	Every week							Every 2 weeks				Every 3 weeks		
	1	2	3	4	5	6	Mean	2	4	6	Mean	3	6	Mean
N_0	21.9	26.6	17.7	27.1	23.7	28.1	24.2	27.4	29.2	28.9	28.5	34.8	29.8	32.3
N_1	16.9	23.7	20.4	29.6	23.1	33.8	24.6	25.3	31.9	31.1	29.4	33.7	29.2	31.4
N_2	20.7	23.7	22.4	29.0	21.6	29.5	24.5	29.0	29.4	38.1	32.2	34.3	29.7	32.0
Mean	19.8	24.7	20.1	28.6	22.8	30.4		27.2	30.2	32.7		34.2	29.5	

LSD P = 0.05 (harvest) = 3.9

LSD P = 0.05 (nitrogen) = 2.7

LSD P = 0.05 (harvest x nitrogen) = 6.7

CV% = 19.50

LSD P = 0.05 (harvest) = 5.8

LSD P = 0.05 (nitrogen) = 5.8

LSD P = 0.05 (harvest x nitrogen = 10.0

CV% = 22.93

LSD P = 0.05 (harvest) = 1.1

LSD P = 0.05 (nitrogen) = 1.1

LSD P = 0.05 (harvest x nitrogen

CV% = 11.22

other nitrogen levels. Stem dry matter percent (Table 4.16) also showed an increasing trend with increasing nitrogen and harvest interval.

4.3.1.2 Leaf to Total Weight Ratio

The proportion of leaves in the total fresh weight increased with nitrogen application (Table 4.17). Similarly, leaf weight ratio also increased significantly with the lengthening of the harvesting interval. Zero nitrogen produced a significantly lower proportion of leaves to total weight than N_1 and N_2 which were not significantly different from each other. The dry weight ratio was similar for N_1 and N_2 levels, but zero nitrogen was significantly lower than both N_1 and N_2 (Table 4.19).

4.3.1.3 Leaf Number

The results for leaf number harvested are presented in Table 4.21 The means indicate a significant increase in leaf number as nitrogen increased from 0 kg/ha to 300 kg/ha. No significant differences were observed when nitrogen was increased from 300 to 600 kg/ha. Leaf number at the weekly harvesting was significantly higher than those at 2 and 3 weekly and 2 weekly cuttings showed a significant reduction in leaf number as harvesting interval lengthened.

4.3.1.4 Leaf Area

An increase in leaf area of the harvested material was observed with an increase in applied nitrogen (Table

TABLE:4.16 **The effect of nitrogen and frequency of harvests on leaf dry matter percent of Jamaica Native** (%)

Nitrogen Levels	Harvesting Interval: Every Week	Every 2 Weeks	Every 3 Weeks	Mean
N_0	24.1	29.3	32.5	28.6
N_1	24.8	30.7	32.6	29.3
N_2	24.9	35.3	33.0	31.0
Mean	24.6	31.8	32.7	

LSD P = 0.05 (nitrogen) 2.9

LSD P = 0.05 (harvest) 2.9

LSD P = 0.05 (harvest x nitrogen)

CV % 11.7

N_0 = 0 kg/ha

N_1 = 300 kg/ha

N_2 = 600 kg/ha

TABLE:4.17 The effect of nitrogen and frequency of harvests on stem dry matter percent of Jamaica Native.

	Harvesting Interval			
Nitrogen Levels	Every Week	Every 2 Weeks	Every 3 Weeks	Mean
N_0	25.8	26.7	28.2	26.9
N_1	24.9	26.7	28.1	26.6
N_2	25.4	26.8	29.5	27.2
Mean	25.4	26.7	28.6	

LSD P = 0.05 (nitrogen) 3.5

LSD P = 0.05 (harvest) 3.5

LSD P = 0.05 (harvest x nitrogen) 5.6

CV % 8.85

N_0 = 0 kg/ha

N_1 = 300 kg/ha

N_2 = 600 kg/ha

TABLE:4.18 **The effect of nitrogen and frequency of harvest on leaf weight ratio(fresh weight) of Jamaica Native.**

Nitrogen Levels	Harvesting Interval: Every Week	Every 2 Weeks	Every 3 Weeks	Mean
N_0	0.69	0.72	0.76	0.73
N_1	0.82	0.82	0.83	0.82
N_2	0.81	0.83	0.84	0.83
Mean	0.77	0.79	0.81	

LSD P =0.05 (nitrogen) 0.014

LSD P = 0.05 (harvest) 0.014

LSD P = 0.05 (nitrogen x harvest) 0.025

CV % 2.16

N_0 = 0 kg/ha

N_1 = 300 kg/ha

N_2 = 600 kg/ha

TABLE:4. 19 The effect of nitrogen and frequency of harvests on leaf weight ratio (dry weight) of Jamaica Native.

	Harvesting Interval			
Nitrogen Levels	Every Week	Every 2 Weeks	Every 3 Weeks	Means
N_0	0.67	0.74	0.86	0.76
N_1	0.82	0.84	0.82	0.83
N_2	0.81	0.86	0.82	0.83
Mean	0.77	0.81	0.83	

LSD P = 0.05 (nitrogen) 0.026

LSD P = 0.05 (harvest) 0.026

LSD P = 0.05 (nitrogen x harvest) 0.045

CV % 3.89

N_0 = 0 kg/ha

N_1 = 300 kg/ha

N_2 = 600 kg/ha

TABLE:4.20 The effect of nitrogen and frequency of harvests on leaf number per plant of Jamaica Native.

Nitrogen Levels	Harvesting Interval: Every Week	Every 2 Weeks	Every 3 Weeks	Mean
N_0	56	48	36	47
N_1	152	108	96	119
N_2	155	119	107	127
Mean	121	92	80	

LSD P = 0.05 (nitrogen) 12

LSD P = 0.05 (harvest) 12

LSD P = 0.05 (nitrogen x harvest) 21

CV % 14.7

N_0 = 0 kg/ha

N_1 = 300 kg/ha

N_2 = 600 kg/ha

4.22). The increase was significant from the zero nitrogen to the N_1 level but the difference was not significant when nitrogen was increased to 600 kg/ha. Highest leaf area occured at the weekly harvests and was lowest when the plants were cut every 3 weeks.

4.3.1.5 **Leaf Size**

Results for leaf size on Table 4.23 show that there was no significant difference in leaf size when harvesting intervals differed. The general trend nevertheless, was towards a small increase in leaf size as the harvesting interval lengthened. A significant increase in leaf size to increasing levels of nitrogen was observed. The largest leaves were produced at the highest level of nitrogen (600 kg/ha). Zero nitrogen had significantly smaller leaves than the other levels.

4.3.1.6 **Stem Thickness**

The means for stem thickness (Table 4.24) indicate that increasing nitrogen from zero to 300 kg/ha caused stem thickness to increase significantly. A further increase to 600 kg/ha did not however have any significant effect. The stems also became thicker as the time between harvests lengthened.

4.3.1.7 **Oxalate and Nitrate Content**

Oxlate and nitrate content in the plant tissue are

TABLE:4.21 The effect of nitrogen and frequency of harvests on leaf area per plant of Jamaica Native (cm^2)

Nitrogen Levels	Harvesting Interval: Every Week	Every 2 Weeks	Every 3 Weeks	Mean
N_0	516	465	341	441
N_1	3442	2471	2077	2663
N_2	3334	2836	3042	3071
Mean	2431	1924	1820	

LSD P = 0.05 (nitrogen) 420

LSD P = 0.05 (harvest) 420

LSD P = 0.05 (nitrogen x harvest) 727

CV % 24.33

N_0 = 0 kg/ha

N_1 = 300 kg/ha

N_2 = 600 kg/ha

TABLE:4.22 **The effect of nitrogen and frequency of harvests on leaf size of Jamaica Native (cm^2)**

Nitrogen Levels	Harvesting Interval: Every Week	Every 2 Weeks	Every 3 Weeks	Mean
N_0	9.14	9.83	9.65	9.54
N_1	22.58	22.91	21.58	22.36
N_2	21.39	23.74	28.34	24.49
Mean	17.70	18.83	19.86	

LSD P = 0.05 (nitrogen) 1.61

LSD P = 0.05 (harvest) 1.61

LSD P = 0.05 (harvest x nitrogen)

CV % 14.4

N_0 = 0 kg/ha

N_1 = 300 kg/ha

N_2 = 600 kg/ha

Table:4.23 The effect of nitrogen and frequency of harvests on stem thickness of Jamaica Native (mm).

Nitrogen Levels	Harvesting Interval: Every Week	Every 2 Weeks	Every 3 Weeks	Mean
N_0	0.27	0.35	0.41	0.35
N_1	0.54	0.66	0.93	0.71
N_2	0.54	0.68	1.02	0.75
Mean	0.45	0.56	0.79	

LSD P = 0.05 (nitrogen) 0.047

LSD P = 0.05 (harvest) 0.047

LSD P = 0.05 (harvest x nitrogen) 0.082

CV % 9.42

N_0 = 0 kg/ha

N_1 = 300 kg/ha

N_2 = 600 kg/ha

given on Tables 4.25 and 4.26. The means indicate a general increase in both oxalate and nitrate with increasing nitrogen. Oxalate content, like nitrate content tended to decrease from the 1st harvest to the last. On the other hand, nitrate increased with time. The difference in mean nitrate and oxalate content as a result of different harvesting frequencies was not significant. There was a marked increase in nitrate content of plant tissue at 600 kg/ha nitrogen, with increasing frequency of harvesting.

4.4 Discussion

Fresh and dry matter production increased in general with higher nitrogen application. Harvesting every 2 and 3 weeks showed an increase in both fresh and dry weight with increasing nitrogen. Harvesting every week on the other hand, gave no significant differences in fresh and dry weight yields between 300 and 600 kg/ha. This suggests that at 2 and 3 week intervals, the plants probably had a longer time to respond to the applied nitrogen and so gave a positive response to the higher levels of nitrogen. Harvesting every week probably did not enable the plants to effectively convert the absorbed nitrogen to dry matter. It is implicit that for weekly harvesting, applications of up to 600 kg/ha may be excessive. The agronomic optimum under the conditions tested is probably somewhere between 300 kg/ha and 600 kg/ha.

The results also show that although there was no significant difference in the dry weight values for the 3

TABLE:4.24 **The effect of nitrogen and frequency of harvests on oxalate content of Jamaica Native** (%)

Nitrogen Levels	Harvesting Interval: Every Week	Every 2 Weeks	Every 3 Weeks	Mean
N_0	0.45	0.24	0.30	0.33
N_1	0.89	0.68	0.48	0.68
N_2	1.47	1.61	1.93	1.67
Mean	0.93	0.84	0.91	

LSD P = 0.05 (nitrogen) 0.28

LSD P = 0.05 (harvests) 0.28

LSD P = 0.05 (nitrogen x harvest) 0.49

CV % 37.90

N_0 = 0 kg/ha

N_1 = 300 kg/ha

N_2 = 600 kg/ha

TABLE:4.25 **The effect of nitrogen and frequency of harvests on nitrate content of Jamaica Native (%).**

Nitrogen Levels	Harvesting Interval			
	Every Week	Every 2 Weeks	Every 3 Weeks	Mean
N_0	1.26	1.33	1.25	1.28
N_1	1.30	1.45	1.34	1.36
N_2	1.68	1.48	1.38	1.51
Mean	1.41	1.42	1.33	

LSD P = 0.05 (nitrogen) 0.14

LSD P = 0.05 (harvests) 0.14

LSD P = 0.05 (harvests x nitrogen) 0.24

CV % 12.0

N_0 = 0 kg/ha

N_1 = 300 kg/ha

N_2 = 600 kg/ha

harvesting frequencies, 3 weekly harvests (2 harvests) yielded somewhat less than weekly harvests (3 harvests). From the results, it could be surmised that plants harvested weekly were more succulent than those which remained in the field for a longer period of time as shown by their high fresh weight but comparable low dry weight because of lower dry matter content. This is probably due to fresh young regrowth being harvested at each weekly cutting whereas, after two and three weeks the harvested material was somewhat older and less succulent. As indicated, the three week interval was the least productive; it yielded the lowest leaf dry matter, leaf number and leaf area. Grubben (1976) from his experiments in Dahomey recommended harvesting every three weeks. Here in Trinidad this period is probably too long as seen from the results. As already pointed out, amaranth is a rapidly growing C4 plant which grows best under high temperatures. The average temperature during the growth period was 30.6 oC which can be considered high and capable of promoting rapid growth.

The results show that harvesting every three weeks and the highest level of nitrogen combined to produce the highest leaf weight ratio. The increasing leaf weight ratio with increasing nitrogen is to be expected since nitrogen stimulates leaf growth in preference to stem growth. The larger plants at 2 and 3 weeks intervals also had a higher leaf weight ratio than those cut every week. The similarity in dry weight ratios at 300 kg/ha and 600 kg/ha, but difference in fresh weight is probably because at the

higher nitrogen level, the leaves are more succulent. This succulence is reflected in the higher fresh weight and low dry matter. The optimum for dry matter production is probably reached at the N_1 level (300 kg/ha) or somewhere below the N_2 level (600 kg/ha)

Nitrogen promoted the development of leaf number, larger leaves and thicker stems which combine to give a higher fresh weight. Palatability was decreased when no nitrogen was added since the leaves and stems were less succulent.

Corresponding to results of Barker et al (1971), and Schmidt et al(1971), oxalate and nitrate content generally increased with added nitrogen. The results of this experiment also indicated an increase in the nitrogen content of the leaves and stems as the amount of nitrogen added to the soil increased. This suggests a positive relationship between increasing nitrogen in the soil, increasing amounts of nitrogen in the plant tissue and increasing amounts of nitrates and oxalates in the plant. Barker et al (1971), reported that when nitrogen was sidedressed onto plots previously fertilized, there was an increase in the nitrate concentration in the plant tissue.Similar results were obtained in this experiment. Nitrogen was sidedresed onto the experimental plots at week 5 and the nitrate and oxalate content showed an increase when analysed at week 6.

It should be noted that only at high nitrogen levels

(600 kg/ha) was there a marked difference in the nitrate content of the leaves, This difference was evident at the weekly harvesting treatment. Oxlate content of the plant tissue on the other hand, showed significant increases from the N_1 level. This shows that oxalate content of plant tissue is more rapidly affected by nitrogen application than nitrate content.

Increased nitrogen which promotes higher dry matter content and greater succulence, also leads to increased nitrate and oxalate content. As suggested by Fasset et al (1966), it would be difficult to develop feasible fertilization practices which enhance growth, yield, succulence and general consumer appeal without somewhat increasing oxalic acid and nitrate content.

From the results obtained, it can be concluded that weekly harvesting is the most productive. It is necessary to do further fertilizer experiments to determine the optimun level for maximum production, since no definite conclusion can be drawn from these results. Under the conditions of this experiment, it is possible that the optimum lies etween 300 kg/ha and 600 kg/ha for weekly harvesting.

5.0 Chapter 5: GENERAL DISCUSSION

From the experiments conducted, it could be concluded that amaranth exhibited a potential for high yields. Fresh weight yields of up to 23,827 kg/ha and dry weight yields of 6,409 kg/ha were recorded. These yields were lower than those obtained by Grubben (1976) and Oke (1981).

In comparing the seven varieties it was discovered that all seven had similar growth and development patterns since total dry matter, leaf number and leaf area all followed the same trend. They all also showed a significant increase in inflorescence and stem dry matter from week 3 to week 6.

In selecting an outstanding cultivar, the parameters of high dry matter yield and early time to flowering were the most important. Jamaica Native was selected for further work on the basis of its high dry matter yield (908 kg/ha at the 1st harvest, 3 weeks after field establishment). It was also taken into account that more than 50% of the total marketable material of this variety was obtained at the 1st two harvests. This variety also flowered latest and produced the least amount of inflorescence material among the other varieties, which gave it an advantage over the other varieties as a good selection for vegetable production.

A number of factors emerged during these studies which could be recommended for the more efficient cultivation of amaranth. When establishing amaranth from seedlings, three week old seedlings should be planted into the field at a recommended spacing of 25cm x 25cm. Weed control is necessary during the early growth stages of amaranth. The rapid growth of amaranth however should enable sufficient ground cover to preclude further weed control from about the 5th week after the plant has been transplanted into the field.

Harvesting should be done weekly starting at the 3rd week after transplanting. Weekly spraying with a broad spectrum insectcide eg. Decis or Tamaron will provide adequate control under Trinidad conditions.

Applying nitrogen at 300 kg/ha and harvesting weekly provided the best yields. Applications of up to 600 kg/ha at this harvesting interval did not give a further increase in yield. High nitrogen application not only increased quantity (dry matter accumulation), but quality (succulence). Plants to which nitrogen was added had a lower dry matter content than those to which no nitrogen was added. High crude protein accumulation also paralled high nitrogen application.

Adding nitrogen led to an increase in the levels of nitrate and oxalate found in the leaves and stems. This negative quality factor, as already pointed out, should not cause concern since both nitrate and oxalate may not have accumulated in sufficient quantities to be detrimental.

Potassium application did not affect the yield response to nitrogen in amaranth. Both nitrogen and phosphorus content of the leaves and stems decreased as the plant parts aged.

It could therefore be concluded that for higher yields and more succulent vegetable material, it is necessary to add nitrogen under Trinidad conditions. Amaranth could also be considered to have a high nitrogen requirement.

It is suggested that the effect of direct seeding as opposed to transplanting be evaluated in order to determine the better method of establishing the crop. A greater density than those used in these experiments could probably lead to higher yields as suggested in Chapter 2. This should be examined.

In addition, since there are no concrete recommendations as to the best level of nitrogen required for the most economical production of amaranth, further experiments should be conducted to determine the best level.

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APPENDIX TABLE 1. Physical and chemical properties of soils of the River Estate Series (Source Brown & Bally (1970))

Depth (cm)	pH	Mechanical Analysis (% oven dry soil)				CEC	Ca	Mg	K	Na	% Base Sat.	C	N	P (ppm)
		Coarse Sand	Fine Sand	Silt	Clay	m.e. per 100 gm. oven dry soil)						(% oven dry soil)		
0 - 7.5	6.6	12	54	16	18	9.3	10.3	1.1	0.05	0.05	100	2.0	0.26	94
7.5 - 22.5	6.6	20	56	9	16	5.2	3.8	0.4	0.02	0.01	100	0.7	0.08	28
22.5 - 52.5	6.6	19	58	8	15	3.4	1.8	0.3	0.01	0.01	92	0.7	0.07	12
52.5 - 82.5	6.3	2	49	18	34	5.8	4.7	0.3	0.03	0.01	87	1.1	0.13	1
82.5 - 125.0	6.3	1	48	18	34	4.6	4.0	0.3	0.02	0.09	85	-	-	5