Crop Sci

THE EFFECTS OF SPACING, FERTILIZER RATE AND METHOD OF FERTILIZER PLACEMENT ON THE YIELD AND YIELD COMPONENTS OF TWO POTATO (*SOLANUM TUBEROSUM L*) VARIETIES : ANNETT AND B53.

By

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DECLARATION

I, Irvine Kwaramba Mariga, hereby declare that this is my original work and has not been presented in any other University.

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CANDIDATE

This thesis has been submitted for examination with our approval as the Supervisors.

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ABSTRACT

This thesis reports on experimental work carried out on Irish Potato (*Solanum Tuberosum*) over two seasons: 1978 - 79 short rains (SEASON I) and 1979 long rains (SEASON II), at Kabete Faculty of Agriculture Field Station located 1^{o} 14' S and 36^{o} 44' E., with an altitude of 1850m above sea-level.

The average annual rainfall for Kabete is 925 mm. In the two seasons of the experiment, the rainfall recorded was 408 and 590 mm respectively. In the second season a continuous dry spell necessitated one sprinkler irrigation of 30.0 mm in the nin th week after 50% emergence.

The main objectives of the two experiments were:

1. To test feasibility of using different plant populations for ware and for seed tuber production.
2. To test the possibility of improving on fertilizer use by using hill placement.
3. To test the performance of three fertilizer rates.
4. To monitor some growth parameters and relate them to the final yield.

The importance of the potato in Kenya, the scope for improvement and the problems encountered in potato production have been given.

Both experiments were factorials laid out in Randomized Block Design. Experiment I (VarietyX Plant Population x Fertilizer rates) had two varieties: Annett and B53; three spacings: 75 x 20 cm, 75 x 25 cm, 75 x 30 cm and three fertilizer rates: 344, 430 and 517 kg DAP (diammoniumphosphate)/ha. Experiment II (Variety x Method of fertilizer placement x Fertilizer rates) had two varieties: Annett and B53, two methods of placement: hill placement and broadcasting in the furrow; and four fertilizer rates: 0, 344,430 and 517 Kg. DAP/ha.

Annett was found to yield more than B53. Annett gave more of its yield as ware than B53 which gave more yield in the seed grades. Annett developed peak leaf area very quickly but maintained it for shorter periods than B53 which had a longer leaf area duration *attained peak leaf area much later. *but

Hill placement of fertilizer attained higher total tuber yield than broadcasting in the furrow.

The three fertilizer levels tested significantly outyielded the control but they did not significantly differ. However, it was found that the recommended 517 Kg. DAP/ha was in excess of the most ideal fertilizer rate for Kabete conditions.

Raising plant population above 44444 to 66666 plants/ha did not significantly increase total tuber yields but the proportion of seed tubers increased as the plant(hill) density increased. Therefore, for seed production plant populations above 44444 plants/ha for Annett and B53 are better.

From the results of this work, the following suggestions for further experimentation are made :-

1. A broader fertilizer rates experiment to determine the most efficient rate for Kabete.
2. To test the economics of using plant populations higher than 44444 plants/ha for seed production, when the actual total tuber yields does not significantly increase.
3. To monitor fertilizer rates at which scorching begins when fertilizer is hill placed.

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CHAPTER ONE

INTRODUCTION

1.1. THE ORIGIN OF THE POTATO AND ITS INTRODUCTION TO EAST AFRICA

The Irish Potato (Solanum tuberosum L) is believed to have originated in the Andean highlands of South America (Burton, 1966; Smith, 1968; Litzenberger, 1974) such as those of Bolivia and Peru (Smith; 1968; Litzenberger, 1974) and in particular the Callao highlands of Bolivia where man first made use of the potato (Smith, 1968).

There are many theories as to how and when the potato was introduced to Europe. Potatoes were probably introduced into Spain from Peru in the early sixteenth century (Smith, 1968). Salaman (1937 a) and Dodds (1965) state that the potato was introduced into Spain around 1570 (Nyachae, 1979) whilst Dodds (1965) mentions that the plant came to Ireland directly from the New World around 1596 (Nyachae, 1979).

The potato was definitely introduced into Kenya during the late 19th century by the British East Africa Trading Company and early settlers, mainly of South African origin (Waithaka, 1976; Ballestrem and Holler, 1977).

1.2 POTATO PRODUCTION IN KENYA

Potatoes have become an important food and cash crop in Kenya since 1961 (Waithaka, 1976).

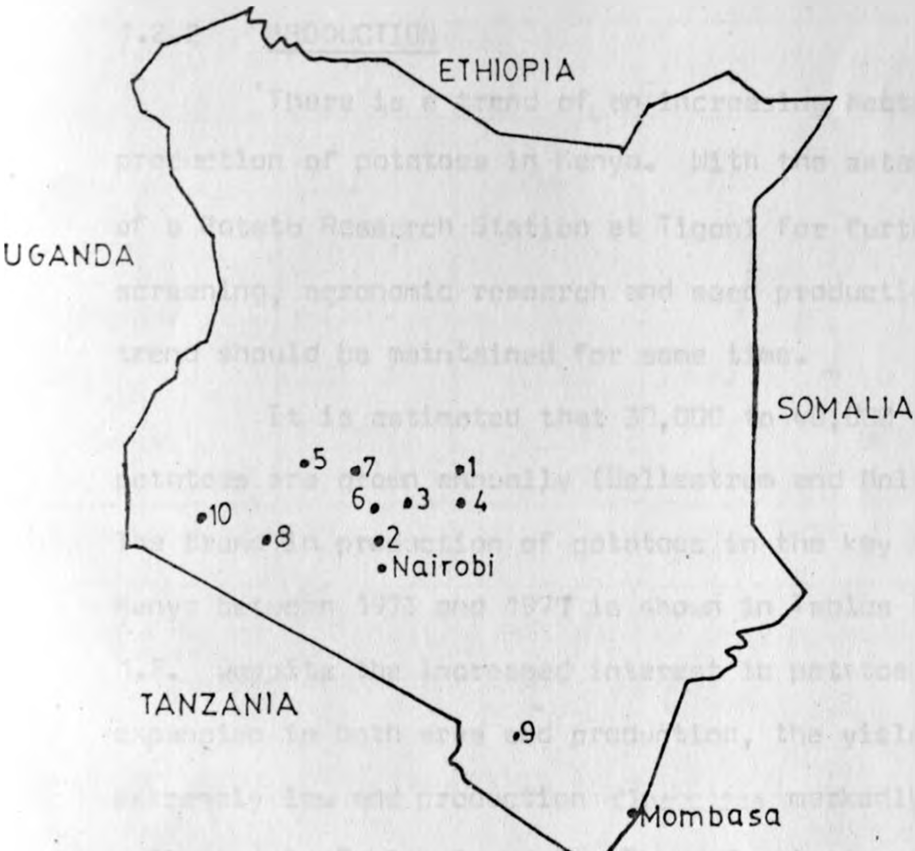
Most of the Kenyan potatoes are grown on the Highlands at altitudes ranging from 1600 - 2700 metres above sea-level. The potato growing areas of Kenya are Kibirichia, Molo, North and South Kinangop, Nyahururu, Nyeri, Embu, Limuru, Kiambu and Taita, whilst the only areas of concentrated potato growing are Kibirichia in Meru and Kinangop (Ballestrem and Holler, 1977). Most of these are shown in Figure 1.

The temperature conditions in Kenya in places of altitudes higher than 1500 metres (m) are almost optimal for potato growing though in some of the growing areas like Kinangop, temperatures of below -2^{0}C are possible and these damage the crop (Ballestrem and Holler, 1977). The high rainfall at the high altitudes does not adversely affect the potato crop as most of the soils are generally well drained. Soil and air temperatures at Mtwapa, on the coast, reach a critical stage of above 27^{0}C in April, May and June which hampers normal growth of potatoes (Ballestrem and Holler, 1977) although successful potato-growing at sea-level has been reported in Sri-Lanka. The optimal temperature range for potatoes is 15.6 to 23.9^{0}C (Winters and Miskimen,1967).

1.2.1 VARIETIES

The potato varieties grown in Kenya on commercial basis vary from early maturing: 3 to 3½ months, through medium to late maturing: 3½ to 4 months, to late maturing: 4 to 5 months, good resistance to susceptibility to late blight (*Phytophthora infestans*) but are generally

FIGURE: 1 POTATO GROWING AREAS IN KENYA



KEY

1 KIBIRICHIA / MERU

2 KIAMBU / LIMURU

3 NYERI / MURANGA

4 EMBU / KIRINYAGA

5 NAKURU / MOLO

6 NYANDARUA

7 OL JORO OROK / NYAHURURU

8 BOMET / KERICHO

9 WUNDANYI / TAITA

10 KEROKA / KISII

potentially high yielding. Most of them are of Scottish or German origin. The recommended ones are Annet, Kerr's Pink, Roslin Eburu, Roslin Gucha, Kenya Akiba, Kenya Baraka, Desiree, Pimpernell and Roslin Chania (Ballestrem and Holler, 1974).

1.2.2 PRODUCTION

There is a trend of an increasing hectarage and production of potatoes in Kenya. With the establishment of a Potato Research Station at Tigoni for further varietal screening, agronomic research and seed production, this trend should be maintained for some time.

It is estimated that 30,000 to 40,000 ha. of potatoes are grown annually (Ballestrem and Holler, 1977). The trend in production of potatoes in the key areas in Kenya between 1973 and 1977 is shown in Tables 1.1 and 1.2. Despite the increased interest in potatoes and expansion in both area and production, the yields remain extremely low and production fluctuates markedly as reflected in Tables 1 and 2. Thus, for instance the average yields in Meru in 1975, 1976 and 1977 were 19, 20 and 6 tonnes/ha. respectively. Research trials at Molo in 1972 to 1973 and at Limuru in the 1972-73 short rains (Holler, 1973) recorded much higher yields as shown in Tables 1.3 and 1.4.

1.3 FOOD VALUE AND COMPOSITION

The potato is perhaps the most balanced of the

Table 1.1: Area Under Potatoes in 1973 - 1977 (Central Province).

DISTRICT	HECTARES				
	1973	1974	1975	1976	1977
Kiambu	6193	6596	6700	692	473
Muranga	3328	4528	5330	6216	6217
Kirinyaga	252	908	466	483	472
Nyeri	2272	4472	5331	4828	7750
Nyandarua	5675	7228	-	6065	5059
TOTAL	17720	23732	17827	18284	19971

(Source: Central Province - Ministry of Agriculture Annual Reports, 1974 - 1977).

Table 1.2: Area and Production From 1975 - 1977 (Eastern Province).

DISTRICT	AREA (HECTARES)			PRODUCTION IN TONNES		
	1975	1976	1977	1975	1976	1977
Meru	6575	7250	7050	125600	145210	43500
Machakos	34	250	110	633	773	253
Embu	634	551	439	5072	1910	2531
Marsabit	-	8	-	5.4	-	-
TOTAL	7243	8059	7599	131310	147893	46284

(Source: Eastern Province - Ministry of Agriculture Annual Reports, 1976 - 1977).

Table 1.3: Molo - Yield Results of Variety Trials in 1972 - 1973.

Variety	Yield in Kg/Ha	
	1972 Long Rains	1972-73 Short Rains
Annett	43,851	38,889
853 (Roslin Eburu)	38,444	30,370
Kenya Akiba	40,740	26,630
Pimpernell	34,111	18,519
Atzimba	40,666	29,296
Fieldeslohn	42,370	-
Kenya Baraka	-	37,407

(Source: Holler, H.J. - Report on Potato Agronomy in Kenya (1973).

Table 1.4: Limuru - Yield Results of a Variety Trial - 1972/73 Short Rains.

Variety	Yield (Kg/Ha)
Annett	37,165
Kenya Baraka	34,259
853 (Roslin Eburu)	24,815
Atzimba	24,222
Kenya Akiba	21,148
Pimpernell	14,889

(Source: Holler, H.J. - Report on Potato Agronomy in Kenya (1973).

major food crops in that it provides calories and nitrogen in proportion to adult human requirements (Litzenberger, 1974). The protein supplied by the potato is deficient in some amino-acids notably methionine and cystine (Simmonds, 1965; Litzenberger, 1974) but these can be sufficiently supplied if a man feeds on 2 Kg of potatoes per day (Burton, 1966). Potatoes rank next to Soybeans and are superior to the cereals in total protein production per hectare (Litzenberger, 1974). This agrees with Beukema and Van der Zaag (1979) as shown in Table 1.5.

The potato produces more dry matter in tubers per unit area than cereals, in a much shorter time, and as shown in Table 1.6 in some aspects excels cereals in nutritive value and palatability (Nagaich, 1977).

The average composition of the potato tuber is 75 - 78% water, 1.8 - 2.0% protein, 17 - 20% carbohydrates (starch), 1.2% fibre, 1.0% ash, and less than 1% fat (Litzenberger, 1974). Schwimmer and Burr (1967) (cited by Smith, 1968) give the data shown in Table 1.7.

Smith (1968) notes that the chemical composition of potatoes varies with variety, soil type, location, cultural practices, maturity, method of vine kill, storage environment, methods of analysis used and other factors, hence the general nature of the data.

In terms of nutritive value, the potato is a valuable food crop (Table 1.8).

Table 1.5: Average Edible Protein Production per Ha. for Some Crops in the Netherlands.

Crop	Total Yield	Edible Yield	Protein
	Tonnes/Ha	Tonnes/Ha.	Kg/Ha
Potatoes	40	30	520
Wheat	5	5	500
Green Peas	3	3	610

(Source: Beukema and Van der Zaag, (1979) - Potato Improvement).

Table 1.6: Food Value of Potato in Relation to Cereals

Crop	Carbohydrate Kg/Ha	Protein Kg/Ha	Fats Kg/Ha	Ash Kg/Ha	Calories/ha
Wheat	519	81	10	7	2,422
Rice	710	64	11	7	3,163
Potato	1,335	139	7	69	5,664

(Source: Nagaich, BB (1977) - Potato in India).

Table 1.7: Proximate Analysis of Potatoes.

	Average %	Range %
Water	77.5	63.2 - 86.9
Total Solids	22.5	13.1 - 36.8
Protein	2.0	0.7 - 4.6
Fat	0.1	0.02 - 0.96
Carbohydrate Total	19.4	13.3 - 30.53
Crude Fibre	0.6	0.17 - 3.48
Ash	1.0	0.44 - 1.9

(Source: Smith, O. (1968) - Potatoes: Production, Storing, Processing).

Table 1.8: Percentage of the Daily Minimum Requirements for an Adult Provided by 100g Peeled Potatoes.

	%
Energy	3
Protein	8
Fe (Iron)	10
Vitamin BI	10
Vitamin C	20 - 50[2]

2) 50% in freshly lifted potatoes.

(Source: Beukema and Van der Zaag (1979) - Potato Improvement).

1.4 USES

The potato can be easily converted into sundried and processed articles of food and can be a good raw material for several industrial products such as starch and alcohol (Litzenberger, 1974; Nagaich, 1977) and as a by-product, high quality protein and fodder (Nagaich, 1977). For human consumption, potatoes can be cooked, or processed into dehydrated products like diced granules and flour; or can be fried into chips and french fries or be canned (Smith, 1968; Nagaich, 1977).

In Kenya, potatoes are mostly boiled and eaten with beef stew or on their own. They are at times cooked and mashed and mixed with beans, peas and vegetable leaves; "irio". In urban areas, potato chips and crisps are commonly eaten.

1.5 PROBLEMS

The problems often quoted for the low and fluctuating yields are many. There is a persistent lack of adequate clean certified seed (Anon, 1975a). There are low yields due to non-adherence to good husbandry practices like seed chitting, proper spacing, good storage and organised marketing (Anon, 1975b). Most of the potatoes are inter-planted with maize, beans and other crops (Anon, 1975c), a good example being Kiambu district where of the 6,700 hectares grown in 1975, only 2,000 hectares were purestand and the average yield was a mere 5,850 Kg/ha. (Anon, 1975d) as the potato is very sensitive to shading. Also a sizeable crop is allowed to come through as volunteer plants from the previous crop, and this encourages pests and diseases. Pests such as the potato tuber moth (Phthorimaea operculleIa), cutworms (Agrottis spp) and aphids are common, while diseases like late blight (Phytophthora infestans), bacterial wilt (Pseudomonas solanacearum) and virus diseases are also rampant.

Prolonged rains can damage the crop and favour the development of disease resulting in poor yields and little propagation material for the following season. Insufficient rains are common in some areas like along the Tigoni - Nairobi road (Holler, 1973).

To improve on the yield per unit area, there will undoubtedly be much need therefore to:

(a) Introduce or breed varieties resistant to late blight and other diseases.

(b) Carry out more agronomic experiments involving efficientfertilizer usage, spacing and crop mixtures aimed at attaining higher yields.

(c) Improve extension services so that farmers can appreciate and follow advice.

(d) Organise potato marketing to minimize rotting wastes and reduce price fluctuations, and thus increase available propagation material.

1.6 OBJECTIVES OF THE STUDY

1. To test the response to plant populations of Annett and 353 higher than the recommended 44,444 plants/ha. at three fertilizer rates in terms of tuber size distribution and total tuber yield with the view of monitoring: a) Possible different plant populations most ideal for ware and seed production, respectively.

b) Possible need for fertilizer rates to increase as plant population increases.

2. To test the response of Annett and 353 to two fertilizer rates reported to have given the highest tuber yields at Thika, in different seasons, (Holler, 1973) against the higher and recommended rate under Kabete conditions.

3. To test if hill replacement can improve on the efficiency of fertilizer use in potatoes.

CHAPTER TWO

2. LITERATURE REVIEW

2.1 GENERAL ECOLOGICAL EFFECTS ON POTATO GROWTH AND DEVELOPMENT.

Potato growth and development is sensitive to ecological effects. Important factors influencing the growth habit of a long cycle potato crop include long day, high temperature, low light intensity, physiologically young seed, low plant density, heavy nitrogen dressing, liberal moisture supply and gibberellic acid. The growth cycle of a potato crop is shortened by short day, low temperature, high light intensity, physiologically old seed, high plant density, low nitrogen dressing, restricted moisture supply and the hormones: chlormequat (ccc) and succinic acid - 2,2 - dimethyl hydrazide (B9) (Beukema and Zaag, 1979).

2.1.1 TEMPERATURE AND DAYLENGTH

Temperature is an important factor in potato development principal production areas being characterized by cool weather. Different workers found different ideal temperatures for potato growth. Tuberization is best at soil temperatures of 17.8°C (McGillivray, 1961) or 29°C (Chang, 1971). Winters and Miskiman (1967) give the temperature ranges of 15.6 to 23.9°C as ideal and that there is little or no tuberization above 26.7°C whilst Indian workers put a temperature of 20°C as ideal for tuber development (Nagaich, 1977). These differences in the ideal air temperatures for potato growth may be due to differences in varietal characteristics of the varieties used at the various places.

In many instances, soil temperature is more important to plant growth than air temperature (Chang, 1971). High soil temperatures (above 27°C), common in the tropics, are reported by many workers to cause degeneration of tubers in potatoes. Hay and Allen (1978) grew the variety B53 in Malawi in an area where average soil and air temperatures were 24 to 25°C and did not observe any tuber deformation. However, all plant development stages were much shorter than under temperate conditions, probably because of the high temperatures. Glover (1946) observed that the mountain areas of Tanzania with temperatures of 15-21°C gave high yields whereas yields on the hot plains were significantly low. Ballestrem and Holler (1977) reported that high soil and air temperatures during the April to May period at Mtwapa on the Kenyan coast, caused abnormal growth of the potato crop resulting in single stems, slow foliage growth, small leaves, formation of tubers close to the stem, no stolons, small misformed tubers and coloured tubers lost their colour. Emergence of sprouts above ground is delayed up to one month in Northern India where the maximum and minimum temperatures during planting are, respectively, 16 and 7°C, whilst in the hotter plains with temperatures of 35 and 25°C (maximum and minimum respectively), emergence takes 10 to 15 days (Mutri and Singh, 1975).

Each variety or species has its own critical day-length and tuber formation takes place only if the daylength is equal to or shorter than the critical daylength (Beukema and Zaag, 1979). Tuberization in the potato is initiated under shortday conditions. Yield response to daylength in potatoes is varietal : yield of Kerr's Pink, a day neutral variety, was not reduced appreciably at daylength of 11.75 - 11.90 hours (Glover, 1946), while the yield of Kufri Sindhuri, a short-day variety, decreased at daylength more than 10 hours (Mutri and Banerjee, 1976), and variety Katahdin, a long-day plant, had the highest yield at daylength of 15 hours (Beaumont and Weever, 1931).

An interaction between temperature and daylength exists and hence it is necessary to consider the thermophoto period. Gooding (1965) observed formation of far more tubers and higher tuber yields of variety King Edward VII in drier and sunny years than in wetter years with overcast skies. Short daylength and low temperatures stimulate tuber initiation (Mendoza and Haynes, 1977) and in this respect low night temperatures are more effective than low day temperatures (Beukema and Zaag, 1979). Under long day conditions, high temperatures greatly restrict tuber formation whilst a combination of high temperatures and short daylength result in earlier initiation and development of tubers by early maturing varieties than by late maturing varieties (Beukema and Zaag, 1979). High temperatures, long days and lots of nitrogen favours vegetative growth except tubers, whilst low temperatures, intermediate daylength and deficient nitrogen cause early tuberization (McGillivray, 1961; Beukema and Zaag, 1979).

High air temperatures of up to 35°C during the day have no negative effect on potato yield if night temperatures go down to 20°C (Ballestrem and Holler, 1977).

Mosaic-infested plants cannot be easily identified at 25°C or higher temperatures (McGillivray, 1961) and hence certified seed production is mostly restricted to cool areas.

2.1.2 SOIL

Potatoes grow well in loose, friable and well-drained and aerated soils which are neither saline nor alkaline. The potato plant can tolerate a wide range of soil reaction (Gruner, 1963) but soil pH 8.5 reduced yields (Nagaich, 1977) while Parent et al. (1967)concluded that good tuber growth and yield is obtained in slightly acid soils. Smith (1938) did extensive work using the variety Smooth Rural in the United States and concluded that alkaline soils ranging from pH 7.79 to 8.36 produced fewer tubers, lower weight of tubers per plant and lower total tuber yields than did plants in less alkaline or acid soils above pH 4.75. In his work, pH 5.34 - 5.99 gave the highest tuber growth rate.

Compact soils cause tuber deformations.

2.1.3 MOISTURE

The potato plant needs adequate moisture supply throughout its growth period. Concentrated rains usually result in high humidity which favours development of late blight (Phytophthora infestans). Plentiful moisture supply as found in peat soil favours abundant haulm growth and late tuber initiation than in soil conditions of less available water as in clay soils (Beukema and Zaag, 1979). Crosmer and Grison (1976) reported that abnormal dry weather caused secondary tuber formation.

2.2 GROWTH PATTERN

Three important phases can be distinguished in the growth cycle of the potato plant (Ngugi, 1972, Beukema and Zaag, 1979).

These are:

Phase I - pre-emergence/emergence

Phase II - haulm growth

Phase III - tuber growth

2.2.1 PRE-EMERGENCE/EMERGENCE

According to Headford (1961) cited by Ngugi (1972) during this phase, roots and leaves are formed at a rate which is determined by soil temperature and the size of sprouts before planting. If the seed tuber has already developed sprouts before being planted, root formation starts immediately and emergence is accelerated. Soil moisture is essential for early development of the plant and conditions of low soil moisture and low soil temperature delay emergence (Beukema and Zaag, 1979).

2.2.2 HAULM GROWTH

Haulm growth is most rapid under conditions of high radiation and temperature, plentiful nutrient and water supply (Milthorpe, 1963). The haulm and roots develop simultaneously and their growth is correlated (Beukema and Zaag, 1979). Early root formation and good growth results in healthy haulm development. Abundant early haulm development causes late tuber growth while moderate haulm development causes early tuber growth (Beukema and Zaag, 1979).

2.2.3 TUBER GROWTH

Tubers may be formed 2 - 4 weeks after emergence of the plants (McGillivray, 1961; Bremner and Taha, 1966; Beukema and Zaag, 1979). Most of the tubers which grow to harvestable size are formed within a period of two weeks and all the tubers formed after that are continually resorbed (Moorby and Milthorpe, 1973). Tuber growth curve is sigmoid but is dominated by a long period with constant bulking rate (Bremner and Taha, 1966). Bulking rate may be as high as 800 - 1,000 Kg/Ha per day under favourable conditions (Beukema and Zaag, 1979). The smaller the leaf area at the time of tuber initiation, the slower is the bulking rate and the lower the yield (Moorby and Milthorpe, 1973).

Tuber growth is affected by temperature, daylength; nutrient and moisture status of the soil. Temperatures above 27°C hamper tuberization and at times cause degeneration of tubers. Poor nutrient and moisture supply curtail healthy haulm development and thus lower both the bulking duration and the bulking rate. Tuber yield is a function of bulking rate and duration of bulking period.

2.3 AGRONOMIC FACTORS

Usage of certified seed of well adapted varieties alone will not result in high yields unless sound cultural practices are applied. Agronomic factors of importance for successful potato growing are spacing (plant density), adequate fertilization, timely planting, proper bed preparation, ridging, weeding and disease and pest control.

2.3.1 EFFECT OF SPACING (PLANT POPULATION)

The plant density of a potato crop is often given as the number of plants (hills) per unit area but several workers have demonstrated the need to indicate plant density as the number of stems per unit area (Bleasdale, 1965; Sharpe and Dent, 1968; Wurr and Allen, 1974). Mundy and Bowles (1972) calculated that variation in the stem population produced by their treatments accounted for 80 % of the yield variation.

Plant density affects total tuber yield and tuber size. Plant density can be increased by planting larger setts at a given population or by increasing the population of a given sett size (Jarvis and Shotton, 1971; Jarvis and Roger-Lewis, 1974; Wurr and Allen, 1974). Low plant density can be attained by planting smaller setts and/or use of wider spacing.

Bremner and Taha (1966) observed that total yield generally increased with decreasing spacing and Prytherch (1973) obtained the highest total yield at the highest seed rate for each tuber size used, and Smith (1977) in the United States reported increased total yield with closer spacing but this increased the percentage of small tubers so much that in most cases, the closer spacing did not result in the highest yield of marketable size tubers.

Relationships between plant density and yield components have been described by many workers. Increasing stem density by planting larger tubers will result in an increase of the number of tubers/hill despite the reduction in the number of tubers/stem, but where density is increased by planting more seed tubers, the number of tubers/hill will decrease as the number of tubers/stem decreases and the number of stem/seed tuber remains unaffected (Allen, 1978). Egorov and Fillipov (1975) found that decreasing the intra-row spacing of potatoes from 30 to 20 and 15 cm in rows 70 cm apart increased the total tuber yield and percentage of seed tubers under both irrigated and rainfed conditions. Mundy and Bowles (1972) got more seed and less ware (57 mm) with a closer spacing of 17½ cm in the row compared to planting at 30 cm. These findings agree with those of other workers like Bremner and Taha (1966), Jarvis and Shotton (1971), Wellings (1972), Holler (1973) and Mazur and Ciecko (1976). Working on yams, Gurnah (1974) also found that the highest plant population gave the highest yields but the highest average tuber weights were with the lowest plant population.

Working on six sweet potato (Ipomoea batatas) cultivars, Lowe and Wilson (1975) found significant negative correlation between tuber number and mean tuber weight, cultivars with lower tuber numbers usually produced a higher percentage of marketable yield.

tuber or root?

The findings of Jarvis and Roger-Lewis (1974), using plant populations of 19,769, 39,538, 59,306 and 79,075 plants/ha, with varieties Pentland Ivory and Record potatoes, differed in that yield of saleable ware increased both as sett population and sett size increased. Again Jarvis and Roger-Lewis (1976), using plant populations: 19,900, 33,100, 46,300, 59,800 and 79,500 plants/ha, found the yield of saleable ware from varieties Desiree and Stormont Enterprise increased with increasing sett population or increasing sett size at a given population. Ifenkwe and Allen (1978) also had the number of saleable ware tubers increasing with increased plant density. They used plant populations of 29,950, 37440, 49,920 and 74,880 seed tubers/ha.

variety?

Rao and Awasthi (1975) reported that increasing spacing from 45 x 20 cm to 60 x 30 cm and 70 x 40 cm increased the percent of cracked tubers from 10.6 to 16.2 and 21.3 respectively. Tuber cracking can be caused by excess nitrogen and moisture supply.

more cracking as spacing increases? variety? amount or volume?

The number of tubers/stem decreased with increasing stem density (Wurr and Allen, 1974; Ifenkwe and Allen, 1978;

Allen, 1978) but the overall number of tubers increased with increasing stem density (Ifenkwe and Allen, 1978). Bremner and Taha (1966) found that yield per stem increased more with decreased plant density than did tuber numbers, thus causing an increase in the mean tuber size.

High densities were reported to give tubers with high dry matter, at early lifting, than low densities and vice-versa later due to greater numbers of larger tubers from low densities (Wurr and Allen, 1974) but Ifenkwe and Allen (1978) observed a decrease in tuber fresh weight as planting density increased. Mazur and Ciecko (1976) reported increased dry matter and starch yields with increase in planting density.

High plant density increases interplant competition for light, nutrients and moisture. High leaf area indices which are characteristic of high plant densities result in shading and ultimately senescence at early stages in the growth cycle. This reduces the photosynthesizing surface, lowers the bulking rate and results in a low tuber yield. The many tubers initiated by the many stems will therefore tend to be smaller than those from low plant densities. Low plant density allows for healthy haulm development, full leaf development without shading : long duration; high bulking rates, prolonged bulking period and ultimately high tuber yield. Low plant densities result in fewer but bigger tubers/hill. At extremely low plant populations, the overall yield per unit area will be low because the higher tuber yield/plant cannot compensate for the fewness of plants (hills) per unit area.

The recommended spacing for potatoes in Kenya is 75 x 30 cm or 44,444 plants/ha (Anon 1). In a Nitrogen, Phosphorus and Spacing trial at Samuru during the 1971 long rains, Holler (1973) reported that the spacing of 75 x 20 cm (66,666 plants/ha) significantly outyielded the spacing of 75 x 30 cm (44,444 plants/ha) (P=0.05). The tuber yields obtained were 28.1 and 25.3 tonnes/ha respectively. At Samuru in 1973 (Holler, 1973) a Variety x Population x Phosphate trial was carried out using four plant population: 33,333, 44,444, 66,666 and 88,888 plants/ha and four varieties: 853, Annett, Kenya Akiba and Pimpernell. The 66,666 plants/ha (75 x 20 cm) spacing gave the highest yield but was not significantly higher than that of 44,444 plants/ha (75 x 30 cm). He noted that a population higher than 44,444 plants/ha increased the number of tubers but decreased their size. The plant population of 88,888 plants/ha (75 x 15 cm) greatly reduced tuber size while the low plant population of 33,333 plants/ha (75 x 40 cm) significantly dropped the yield (Table 2.1).

Fisher (1977) reported that most small holders in Meru district grow potatoes at a spacing of 60 x 30 cm (55,000 plants/ha).

Table 2.1 : Mean Effect of Plant Population on Tuber Yield.

TREATMENT	YIELD (KG/HA)
33,333 plants/ha	31,801
44,444 " "	33,009
66,666 " "	37,430
88,888 " "	37,702
L.S.D. 5 %	4,610

(Source: Holler, H.J. - Report on Potato Agronomy in Kenya, 1973)

2.3.2 FERTILIZATION

Nitrogen and Phosphorus are the most important nutrients in potato nutrition. Potatoes do not always respond to potash as most soils in Kenya have high enough levels.

Nitrogen has been reported to increase potato yields by increasing the number of tubers formed (Hanley, Jarvis and Ridgman, 1965; Dubetz and Bole, 1975) particularly that of the large tubers (Birch et al, 1967). Nitrogen affects potato quality in various ways. Work of Ionas (1975) found that applied nitrogen increased tuber dry matter and protein contents without decreasing the starch content obtained by applying phosphorus and potash. Painter et al (1978) reported that increased rates of applied nitrogen decreased tuber specific gravity and increased the number of tubers with light coloured skins, while Birch et al (1967) stated that excess nitrogen affected flavour and tuber texture.

The amount of nitrogen required is influenced by previous cropping and rainfall in the preceeding season (Birch et al, 1967). This may be because these two factors influence the amount of organic matter added into the soil and thus the nitrogen level in the soil. Dubetz and Bole (1975) reported that as nitrogen became available in large quantities, yield and grade went down, probably because of too lush haulm development at the expense of tuber development. Results from the work of Holmes, Peake and Stevens (1973) showed that seed potato crop needed 25 percent less nitrogen than a crop for ware production. Lack of adequate nitrogen results in a small leaf area at the time of tuber initiation and thus a slow bulking rate and ultimate low yield (Moorby and Milthorpe, 1973). Nitrogen is also essential later in the season to prolong the bulking period.

Need for nitrogen under tropical conditions may be more acute due to losses through leaching.

Phosphorus has been reported to increase yield in medium and small grades (Birch et al, 1967; Hanley et al, 1965) by generally increasing average tuber weight (Dubetz and Bole, 1975). Excess phosphorus may reduce yield by premature ripening of the crop (Anon 2). Birch et al (1967) observed that phosphorus had larger yield increases in potato yields on soils with low citric soluble phosphate.

Potash increased the yield of large tubers and depressed dry matter content (Birch et al, 1967) but potatoes do not always respond to potash in some soils as they already have high levels (Dubetz and Bole, 1975). Excess potash can give rise to magnesium deficiency (Anon. 2). It is thought that imbalance between nitrogen, phosphorus and potassium aggravates after-cooking blackening (Anon. 2) though it was reported by Kunkel and Holstad (1972) that no nutrient imbalance of nitrogen, phosphorus and potassium nor the total amount of fertilizer used greatly affected chip colour. This difference in findings may be due to differences of the varieties used. Increased rates of NPK fertilizer reduced specific gravity of tubers (Kunkel and Holstad, 1972) and increased the percentage of cracked tubers (Rao and Awasthi, 1975). Application of NPK fertilizer decreased dry matter and starch contents and slightly increased the tuber ascorbic acid contents (Chernilevskii and Yarmolenko, 1975). Archer et al (1976) reported that giving more nitrogen and potassium almost halved the amount of phosphorus needed for maximum yield by increasing the rate of phosphorus response.

The little work carried out in fertilizer trials at Thika from 1970 to 1973 as reported by Holler (1973) indicated that only nitrogen and phosphorus are important for good potato growth in Kenya. There was no response to potassium. The latosolic soils, common in Kenya, are characterised by a high phosphate fixation and a sufficient amount of potash (Ballestrem and Holler, 1977).

Fisher (1977) reported usage of farmyard manure to fertilize potatoes in Meru district but the Research Division of the Ministry of Agriculture does not recommend it for seed production since it is often a source of pests and diseases and adequate amounts are rare for most small holders.

After extensive experimentation on potato fertilization in Kenya, Ballestrem and Holler (1977) recommended 200 Kg P_2O_5 and 75 Kg N/ha and suggested lowering the phosphate level in cases of lower phosphate fixation. Their experimental results have excluded potash in the recommendations. An NxPxK trial at Thika during the 1970 long rains, using variety B53, found the optimum fertilizer rates to be 75 Kg N/ha and 200 Kg P_2O_5/ha (Holler, 1973). It was found from an NxPxSpacing trial during the 1971 long rains at Samuru that fertilizer rates higher than 75 Kg N/ha and 300 Kg P_2O_5/ha were not beneficial (Holler, 1973). In a Variety x Population x Phosphate trial in 1973 at Samuru, Holler (1973) found that phosphate levels of more than 150 Kg/ha to a standard plant population of 44,444 plants/ha did not give any significantly higher yield.

Method of fertilizer application is an important factor in efficient fertilizer use. Most work done suggests that fertilizer placement of phosphatic fertilizers is more efficient in potato cultivation than broadcasting. Nikitina (1976) reported higher potato yields by drilling than broadcasting and Batey and Boyd (1967), Harris (1978) found that potato yield response to fertilizer was greater when the fertilizer had been placed than when broadcast. Boyd et al (1968) compared three methods of fertilizer application: machine placement, application over the ridges and broadcasting on the flat and found the first two methods to be more efficient, requiring one third less fertilizer to achieve the same yield as broadcasting on the flat . Varis and Laneta (1975) used 650 and 1,300 Kg N.P.K. (7:11:13) fertilizer per hectare as drilled, placed and broadcast. At 650 Kg/ha yield increased by drilling and placement as compared to broadcasting increases were 7 % and 18% respectively, but at 1,300 Kg/ha, the yield increase was only 5% in both treatments. The higher rate of fertilizer increased the proportion of larger tubers and slightly increased scabiness and proportion of tubers infected with black scurf. At 1,300 Kg/ha growth was retarded by placing , but drilling increased stem number /hill and tuber number/hill increased by drilling and placing. The retarded growth by placing fertilizer at the higher 1,300 Kg/ha may have been due to scorching. Malstev and Kanyukhov (1976) also reported higher increase in tuber yields by drilling than broadcasting fertilizer.

Kabete soils, as well as those of most of the potatoes growing highlands of Kenya, mainly consist of Kaolinite clays (1 : 1 clays) (Nyandat and Michieka, 1970; Keya, 1978).

The 1 : 1 clays are known to fix large quantities of added phosphorus as they contain hydrous oxides of iron and aluminium which complex with phosphorus to form poorly available forms (Tisdale and Nelson, 1971).

Diammonium phosphate (DAP) is the recommended fertilizer for potatoes in Kenya (Anon 1.). DAP has high water and ammonium citrate solubility (Keya, 1978). Phosphorus forms of this nature react very quickly with the soil becoming readily available and readily getting transformed into unavailable forms (Keya, 1978). The more clay surface the phosphorus granules are intimately in contact with, the more the phosphorus fixation (Tisdale and Nelson, 1971).

From the fore-going, it would appear that the current recommendation of 500 Kg DAP/ha (90 Kg N and 232.5 Kg P_2O_5) is on the judicious side such that less fertilizer DAP may be found adequate or plant populations higher than 44,444 plants/ha are needed to efficiently utilize this amount of fertilizer.

In Kenya, both 'seed' and ware producers use the same spacing of 75 x 30 cm (44,444 plants/ha). Work by other workers quoted above strongly suggests that a closer spacing can be adopted for seed production to produce smaller but more tubers.

DAP in potato cultivation in Kenya is broadcast in the furrow and mixed with the soil. This method increases soil-fertilizer contact and promotes phosphorus fixation.

The nature of soils in potato growing areas and the vulnerability of phosphorus to soil fixation suggest that hill placement of DAP may be more appropriate than broadcasting in the furrow. Hill placement heaps the DAP and reduces the contact between the phosphate granules and clay particles and ensures that phosphorus is near the plant, since phosphorus is immobile in the soil.

CHAPTER THREE

3. MATERIALS AND METHODS

3.1 PLANTING MATERIAL

Two varieties: Annett and Roslin Eburu (B53) were used. They are among the most popularly grown varieties in Kenya both by commercial and small local farmers.

Ballestrem and Holler (1974) fully described the varietal and agricultural characteristics of most of the commercial potato varieties in Kenya.

Annett is a variety of German origin which is early maturing: 3 - 3½ months, and high yielding. Roslin Eburu (B53) is of Scottish origin and is medium high yielding and medium late maturing: 3½ - 4 months.

The 'seed' tubers planted were chitted with rindite (a growth stimulant made by mixing Ethylene Chlorohydrin, Ethylene Dichloride and Carbon Tetrachloride in the ratio of 7:3:1 respectively) at the rate of 0.5 cc to every 1 Kg of potatoes. Potato tubers of known weight were put in a polythene bag and a corresponding amount of rindite was soaked in cotton wool and put in the polythene bag. The bag was tied air-tight and left for at least thirty hours during which time the chemical diffused into the tubers.

In the first season (1978 short rains) the 'seed' tubers of both varieties were well sprouted at planting with some sprouts approaching 2 cm in length. In the second season (1979 long rains) the tubers were planted only 10 days after treatment with rindite when the chemical was just beginning to take effect : very small sprouts.

All the 'seed' tubers planted were of medium size (35 - 45 mm sieve grade) and only undamaged whole tubers were used. The potato seed was certified.

3.2 PLANTING

The 'seed' tubers were placed in the furrow above the fertilizer which had been covered with little soil and were then covered by about 2 - 3 cm of soil.

In the first season, experiments I and II were planted on 21st and 28th October respectively. In the second season, experiments I and II were planted on 12th and 19th April respectively.

3.3 FERTILIZER

A granular form of diammonium phosphate (DAP: 15% N, 45% P_2O_5) was either broadcast or hill-placed in the furrow and covered with a thin layer of soil.

3.4 FIELD DESCRIPTION

Both experiments were conducted on the Faculty of Agriculture farm at Kabete.

Gethin-Jones and Scott (1958) cited by Nyandat and Michieka (1970) placed the farm under Red to Strong Brown Friable Clay with laterite and Scott (1961) placed it under a Red Friable Clay.

According to the detailed soil-survey of the farm by Nyandat and Michieka (1970), the clay mineral is predominantly kaolin and the parent material is the Kabete Trachyte. The soil which is dominant on the farm has a topsoil pH ranging between 5.2 and 7.2 and a subsoil pH in the range of 5.2 to 7.7. The available nutrients, potassium, calcium, magnesium and phosphorus range from deficiencies to fairly high levels. The drainage is good and the water reception is fairly high lying in the region of 345 mm per hour.

The data from laboratory analysis of soil samples (0 - 30 cm) taken from the sites of both experiments in the first and second seasons is shown in Tables 3.1 and 3.2 respectively.

Table 3.1 : Analysis of Soil Samples (0 - 30 cm) from Site in First Season.

pH in Water	pH in $CaCl_2$	% N	% C	Mg me/100g	Ca me/100g	P ppm	K me/100	Na me/100g
6.40	5.90	0.32	2.71 2.09	5.8	11.8	6.10	14.6	7.5

Table 3.2 : Analysis of Soil Samples (0 - 30 cm) from Site in second season.

PH in water	PH in $CaCL_2$	% N	% C	Mg Me/ 100g	Ca Me/ 100g	P PPM	K Me/ 100g	Na Me/ 100g
6.3	5.8	0.34	3.5	0.5	12.4	7.11	2.5	1.2

The field used in the first season had been under grass (fallow) for three years, then a crop of beans was grown in the season preceeding the potato crop. The field used in the second season had been under beans, maize, beans, respectively, in the three seasons preceeding the potato crop.

3.5 DESIGN AND TREATMENT

Experiment I was a 2 x 3 x 3 factorial laid out in a Randomized Block Design with 3 replicates making a plot total of 54.

The treatments in experiment I were:

2 Varieties : Annett (A) and B53 (B)

3 Spacings : S_1 - 75 x 30 cm (44,444 plants/ha)

S_2 - 75 x 25 cm (53,333 " ")

S_3 - 75 x 20 cm (66,666 " ")

3 Fertilizer rates:

F_1 - 344 Kg DAP/ha (51.6 Kg N and 66.7 Kg P)

F_2 - 430 Kg DAP/ha (64.5 Kg N and 83.3 Kg P)

F_3 - 517 Kg DAP/ha (77.5 Kg N and 100 Kg P)

The treatment combinations for Experiment I were:

1. A S_3 F_3	10. B S_3 F_3
2. A S_2 F_1	11. B S_2 F_2
3. A S_1 F_1	12. B S_1 F_1
4. A S_3 F_2	13. B S_3 F_2
5. A S_2 F_2	14. B S_2 F_1
6. A S_1 F_3	15. B S_1 F_3
7. A S_3 F_1	16. B S_3 F_1
8. A S_2 F_3	17. B S_2 F_3
9. A S_1 F_2	18. B S_1 F_2

Experiment II was a 2 x 2 x 4 factorial laid out in a Randomized Block Design. It had 3 replicates and 48 plots. The treatments were as follows:

2 Varieties :Annett (A) and 853 (B).

4 Fertilizer rates :

F_0 - no fertilizer

F_1 - as in experiment I

F_2 - " " " "

F_3 - " " " "

2 Methods of fertilizer placement:

M_1 - Hill placement

M_2 - Broadcast in the furrow as in experiment I.

The treatment combinations (treatments) for experiment II were:

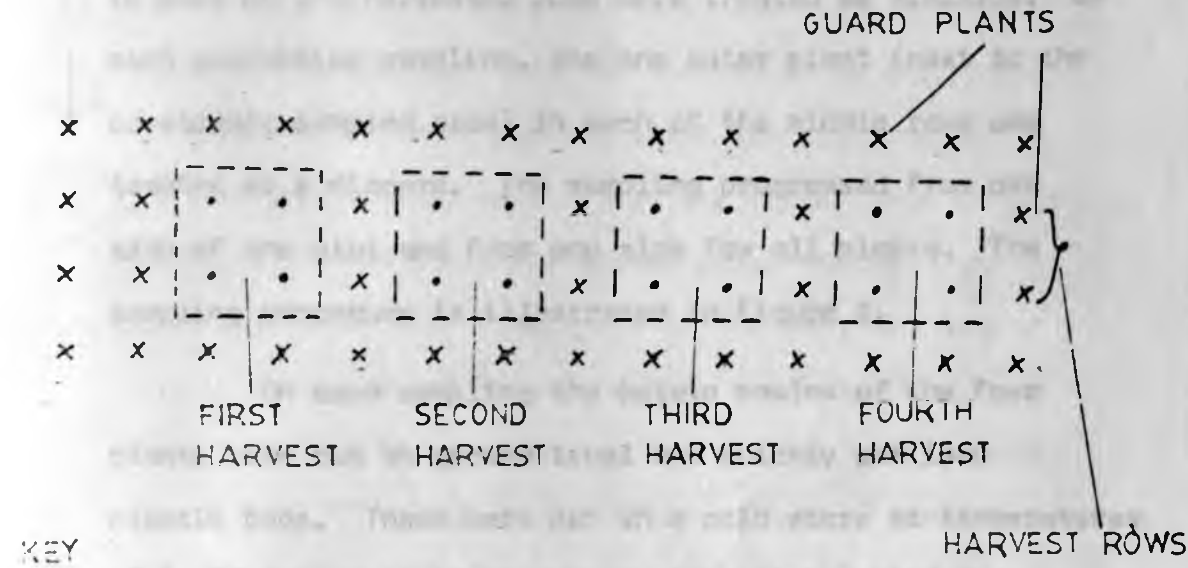
1. A M_1 F_0	9. B M_1 F_0
2. A M_2 F_3	10. B M_2 F_3
3. A M_1 F_2	11. B M_1 F_2
4. A M_2 F_1	12. B M_2 F_1
5. A M_1 F_1	13. B M_1 F_1
6. A M_2 F_0	14. B M_2 F_0
7. A M_1 F_3	15. B M_1 F_3
8. A M_2 F_2	16. B M_2 F_2

Treatments were randomized each block independently using randomization tables of Cochran and Cox (1957) and Fisher and Yates (1963).

3.6 SAMPLING PROCEDURE

Sampling in experiment I was done at 3, 5, 9, 11 and 12 weeks after emergence. Sampling in experiment II was done at 3, 6, 11 and 13 weeks after emergence. The first sampling for the two experiments in the first season was done 38 days after planting. In the second season, experiment I was sampled at 5, 7, 9, 11 and 13 weeks after emergence whilst parameters taken for experiment II were only at maturity (final harvest). A sampling interval of two weeks had been chosen but practical limitations, particularly labour and illnes, caused deviations. In the second season, the fortnightly interval was strictly adhered to.

FIGURE:2 SAMPLING PROCEDURE



KEY

• HARVEST PLANTS

x GUARD/DISCARDS

DISTANCE BETTWEEN SAMPLES?

During each sampling, four plants per plot from the two middle rows were harvested. The outermost plants in each of the harvested rows were treated as discards. On each successive sampling, the one outer plant (next to the previously sampled area) in each of the middle rows was treated as a discard. The sampling progressed from one side of the plot and from one side for all blocks. The sampling procedure is illustrated in Figure 2.

On each sampling the potato haulms of the four plants were cut at ground level and quickly put into plastic bags. These were put in a cold store at temperatures of 5-6°C for up to three days during which period dry matter and leaf area determination was done. During the last two samplings in both experiments I and II, no storage of the foliage was done. A single block was sampled a day and dry matter and leaf area determination was done immediately afterwards. Thus an experiment could be sampled over three days. In the second season, the same block a day procedure was used.

The stolons and roots were not included, only tubers were taken, because big errors are associated with root weight data.

3.7 DETERMINATIONS

3.7.1 DRY MATTER DETERMINATION

Dry weight determination of stems, leaves, petioles and tubers was done by oven drying at 90°C for periods between 48 and 72 hours. As soon as the sample plants were separated into component parts and fresh weights taken, the leaves were punched and the stems and petioles cut into small pieces and the plant material was put in the oven immediately to minimize dry matter loss through respiration. In the early stages whole samples were dried but later only subsamples of the weighed fresh materials were dried as per Bremmer and Taha (1966) and Ngugi (1972). The subsamples, for all plant components, ranged from 10 - 20 % of the fresh weight. These averaged 500g for tubers, 100g for leaves, 250g for stems and petioles were mostly dried as a whole sample. A ventilated oven was used.

3.7.2 LEAF AREA DETERMINATION

Simple area/weight relationship was used to estimate leaf area.

All the green leaves from the sample plants were heaped in a tray and punched at random by a cork borer 1.77 cm in diameter. For each plot 80 whole discs were dried and leaf area calculated as follows:

Leaf Area = Dry weight of all green leaves x area of 80 discs/Dry weight of the 80 discs.

Bremmer and Taha (1966) found the usage of only whole discs being more accurate than including discs which are more than half the size of the punch area. Yellowed leaves were weighed separately and dried.

3.7.3 TUBER GRADING

Tuber grading was done at final harvest only. The standardized potato seed sizes in Kenya are:

Diameter	Less than 25 mm	-	chats
"	25 - 35 mm	-	small seed
"	35 - 45 mm	-	medium seed
"	45 - 55 mm	-	large seed
"	more than 55 mm	-	ware potatoes

The largest sieve available was the 50 mm one and hence the large seed was 45 - 50 mm whilst the ware potatoes were any tubers that could not pass through the 50 mm sieve. The final tuber yield of each treatment from all replicates were grouped together, total weight taken and then grading was done. Thus the grade percentage in the first season, was on individual treatment basis and not on a plot basis. In the second season, grading was done on a plot basis to facilitate statistical analysis.

3.8 CROP MAINTENANCE

The potato crop in both seasons was kept weedfree by regular cultivation with pangas in early growth stages and by handpulling later.

The plants were well earthed up and sprayed with Dithane M45 to protect the crop against late blight at the rate of 1.4 Kg/ha. The spraying was done once every week when it did not rain continually and once every five days when it rained heavily and/or was cloudy for long periods. In the first season, both experiments were sprayed eight times. In the second season, the experiments were sprayed nine times. In all cases the spraying started two weeks after **emergence.** A mist blower was used in both seasons for effective penetration of the foliage particularly after the inter-row space had been covered.

Aldrin 40% W.P. was applied as a spray at the beginning of emergence to control cutworms (Agrotis spp).

In the second season, a continuous dry spell necessitated irrigation and as a result one sprinkler irrigation of 30.0 mm was applied in the ninth week after emergence.

3.9 RAINFALL

The average Annual Rainfall recorded at Kabete is 925 mm. In the two seasons of the experiments, the rainfall recorded was 408 and 590 mm respectively. The rainfall data for the two seasons is shown in Table 3.3.

TABLE 3.3 RAINFALL DATA

SEASON	1978/79 SHORT RAIN					1979 LONG RAINS					
MONTH	SEPT.	OCT.	NOV.	DEC.	JAN.	MAR.	APR.	MAY	JUN	JUL	AUG
RAINFALL(mm)	6.8	104.8	105.5	129.7	61.3	120.6	209.3	187.5	40.0	33.4	12.7

CHAPTER FOUR

4. RESULTS.

4.1 THE EFFECT OF PLANT POPULATION AND FERTILIZER RATE ON TOTAL TUBER YIELD AND YIELD COMPONENTS OF ANNETT AND B53.

GENERAL OBSERVATIONS

In the first season, Annett emerged after 16 days and B53 after 21 days. Annett developed more vigorously than B53 in the initial stages.

Mild late blight attacked Annett in both experiments I and II, six weeks after emergence. B53 was blight free throughout the season. This contradicts the varietal descriptions of the two varieties since Annett is supposed to be very resistant to late blight while B53 is just resistant.

Both varieties in both experiments were attacked by cutworms. This was later controlled. Towards maturity, birds and rats were exposing tubers, but this was mostly restricted to the outer edges of the blocks.

In the second season, Annett and B53 emerged after 19 days. There was no rat and bird problem in this season.

Again, only Annett had a mild infection of late blight around seven weeks after emergence.

In the first season, water stress symptoms were evident in B53 as the rains terminated early.

4.1.1 EFFECT OF PLANT POPULATION AND FERTILIZER RATE ON ON TOTAL TUBER YIELD.

Annett significantly ($P \leq 0.05$) outyielded B53 in both seasons (Table 4.1). The three plant populations and three fertilizer rates tested did not significantly affect total tuber yield in both seasons. There were no significant interaction effects. In the first season total tuber yield of Annett increased with increasing plant population but increased with decreasing plant population in the second season (Tables 4.2 and 4.3). In the first season, total tuber yield of B53 was highest, 29.4 t/ha, with the lowest plant population S_1 (44,444 plants/ha), followed by that at the highest S_3 (66,666 plants/ha), 27.5 t/ha and medium S_2 (53,333 plants/ha) 26.1 t/ha, respectively (Tables 4.2 and 4.3). The highest plant population gave the highest total tuber yield 33.1 t/ha in the second season followed by S_1 with 32.6 t/ha and S_2 with 31.8 t/ha, respectively (Fig. 4.A).

Total tuber yield of Annett increased with increasing fertilizer amounts in both seasons. This was also true for B53 in the second season. In the first season, B53 gave highest tuber yield at the lowest fertilizer rate F_1 followed by the yield at the highest fertilizer rate F_3 and lastly yield at fertilizer rate F_2 (Tables 4.4 and 4.5 and Fig. 4.B)

All the treatment means for both seasons are shown in Table 4.6 while the interaction effects are shown in Tables 4.7 and 4.8. These tables reflect the non-significance of fertilizer rate and plant population interaction effects on total tuber yield as the yield figures do not follow any trend. Statistical analysis for total tuber

TABLE 4.1 - MEAN EFFECT OF VARIETY ON TOTAL TUBER YIELD (T/HA) (EX I)

Variety	Yield*	
	First Season	Second Season
Annett	33.8 a	35.8 a.
B53	27.7 b	32.5 b.

* Similar letter after value in same column depicts non-significance (P = 0.05).

TABLE 4.2 - MEAN EFFECT OF SPACING ON TUBER YIELD (T/HA) (SEASON I)

Variety	Spacing			Variety Mean
	S_1	S_2	S_3	
Annett	33.2	33.8	34.5	33.8
B53	29.4	26.1	27.5	27.7
Spacing Mean	31.3	29.9	31.0	

TABLE 4.3 - MEAN EFFECT OF SPACING ON TOTAL TUBER YIELD (T/HA((SEASON II)

Variety	Spacing			Variety Mean
	S_1	S_2	S_3	
Annett	37.4	35.2	34.8	35.8
B53	32.6	31.8	33.1	32.5
Spacing Mean	35.0	33.5	34.0	

TABLE 4.4. - MEAN EFFECT OF FERTILIZER RATE ON TOTAL TUBER YIELD (T/HA) (SEASON I)

Variety	Fertilizer rate			Variety Mean
	F_1	F_2	F_3	
Annett	31.1	34.5	35.9	33.8
B53	29.7	25.5	27.9	27.7
Ferti-lizer Mean	30.4	30.0	31.9	

TABLE 4.5 - MEAN EFFECT OF FERTILIZER ON TOTAL YIELD (T/HA) (SEASON II)

Variety	Fertilizer rate			Variety Mean
	F_1	F_2	F_3	
Annett	34.5	36.4	36.4	35.8
B53	31.6	32.0	33.9	32.5
Fertilizer Mean	33.1	34.2	35.1	

TABLE 4.6 - MEAN EFFECTS OF FERTILIZER RATES AND PLANT POPULATION ON TOTAL TUBER YIELD (T/HA)

Variety	Fertilizer Rates	SPACING S_1 Season I	S_1 Season II	S_2 Season I	S_2 Season II	S_3 Season I	S_3 Season II	Fertilizer Means. Season I	Fertilizer Means. Season II
Annett	F_1	30.1	34.4	28.8	35.2	34.4	34.0	31.1	34.5
	F_2	33.4	39.8	37.9	36.6	32.2	32.9	34.5	36.4
	F_3	36.2	38.0	34.5	33.7	37.0	37.6	35.9	36.4
B53	F_1	35.6	32.1	28.7	33.8	24.9	29.0	29.7	31.6
	F_2	21.7	32.9	27.4	29.5	27.3	33.7	25.5	32.0
	F_3	31.0	32.9	22.2	32.0	30.4	36.7	27.9	33.9
SPACING MEANS		31.3	35.0	29.9	33.5	31.0	34.0		

TABLE 4.7 - MEAN EFFECT OF FERTILIZER RATE AND SPACING ON TOTAL TUBER YIELD (T/HA) (SEASON I)

Fertilizer Rate	Spacing		
	S_1	S_2	S_3
F_1	30.4	28.8	29.6
F_2	30.0	32.7	29.7
F_3	33.6	28.4	33.7

TABLE 4.8 - MEAN EFFECT OF FERTILIZER RATE AND SPACING ON TOTAL TUBER YIELD (T/HA) (SEASON II)

Fertilizer Rate	Spacing		
	S_1	S_2	S_3
F_1	33.2	34.5	31.5
F_2	36.3	33.1	33.3
F_3	35.4	32.8	37.2

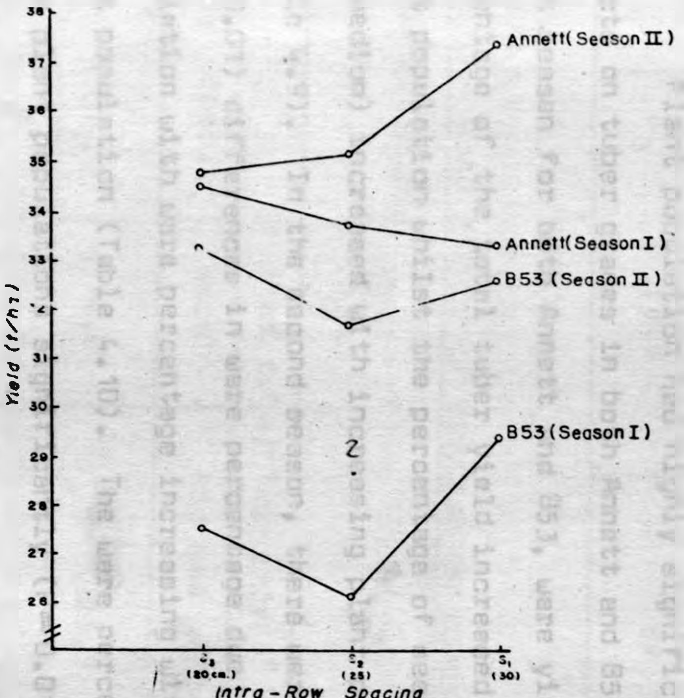


Fig. 4A. MEAN EFFECT OF PLANT POPULATION ON TOTAL TUBER YIELD OF ANNETT AND B53.

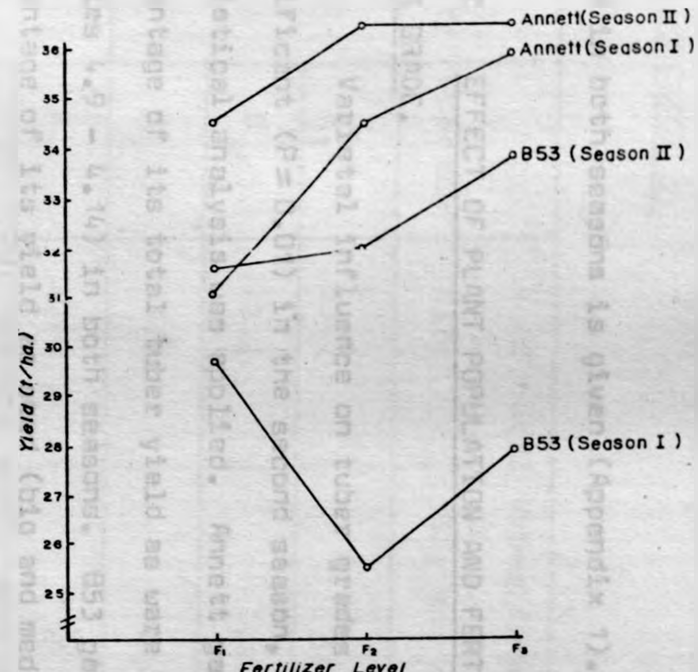


Fig 4B MEAN EFFECT OF FERTILIZER LEVEL ON TOTAL TUBER YIELD

yield in both seasons is given (Appendix 1).

4.1.2 EFFECT OF PLANT POPULATION AND FERTILIZER RATE ON TUBER GRADE.

Varietal influence on tuber grades was highly significant ($P = 0.01$) in the second season, the only time statistical analysis was applied. Annett gave a greater percentage of its total tuber yield as ware than did B53 (Tables 4.9 - 4.14) in both seasons. B53 gave a higher percentage of its yield as seed (big and medium) than did Annett in both seasons (Tables 4.9 - 4.14).

Plant population had highly significant ($P = 0.01$) effects on tuber grades in both Annett and B53. In the first season for both Annett and B53, ware yield as a percentage of the total tuber yield increased with decreasing plant population whilst the percentage of seed tubers (big and medium) increased with increasing plant population (Table 4.9). In the second season, there were significant ($P = 0.01$) differences in ware percentage due to plant population with ware percentage increasing with decreasing plant population (Table 4.10). The ware percentages of three plant populations significantly ($P = 0.01$) differed. In the second season, seed grade percentage was highest at the highest plant population S_3, then the medium population S_2 and lowest at the lowest plant population S_1 (Table 4.14). In Annett, seed grade percentage evenly increased with increasing plant population whilst for B53, the seed grade percentage at the highest plant population was much higher

TABLE 4.9 - MEAN EFFECT OF SPACING ON TUBER GRADES AT HARVEST (SEASON I)

Variety	Spacing	% of total tuber fresh weight	
		Ware	Big and medium seed
Annett	S_1	55.7	37.7
	S_2	42.2	48.7
	S_3	41.4	48.8
B53	S_1	30.0	59.3
	S_2	22.3	63.2
	S_3	18.6	64.3

TABLE 4.10 - MEAN EFFECT OF SPACING ON TUBER GRADES AT HARVEST (SEASON II)

Variety	Spacing	% of total tuber fresh weight	
		Ware	Big and medium seed
Annett	S_1	74.0	23.3
	S_2	58.2	36.6
	S_3	51.2	42.8
B53	S_1	35.7	57.6
	S_2	36.9	57.2
	S_3	25.2	65.0

TABLE 4.11 - MEAN EFFECT OF FERTILIZER RATE ON TUBER GRADE AT HARVEST (SEASON I)

Variety	Fertilizer Rate	% of total tuber fresh weight	
		Ware	Big and medium seed
Annett	F_1	48.5	41.9
	F_2	42.6	48.3
	F_3	48.1	45.1
B53	F_1	24.3	64.0
	F_2	26.9	58.6
	F_3	19.7	64.2

TABLE 4.12 - MEAN EFFECT OF FERTILIZER LEVEL ON TUBER GRADE AT HARVEST (SEASON II)

Relation with number of tubers?

Variety	Fertilizer rate	% of total tuber fresh weight	
		Ware	Big and medium seed
Annett	F_1	62.2	33.1
	F_2	62.1	33.2
	F_3	59.2	36.4
B53	F_1	34.6	58.0
	F_2	34.1	58.9
	F_3	29.1	62.9

TABLE 4.13 - MEAN EFFECTS OF PLANT POPULATION, FERTILIZER RATE AND VARIETY ON TUBER GRADE AT HARVEST (SEASON I)

Treatment	% of total tuber fresh weight.				
	Ware 50 mm	Big Seed 45-50 mm	Medium Seed 35 - 45 mm	Small Seed 25 - 35 mm	Chats 25 mm
F_1	36.4	20.0	33.0	8.8	1.9
F_2	34.7	20.4	33.0	10.0	1.8
F_3	33.9	22.4	32.2	9.4	2.0
S_1	42.8	18.1	30.4	7.3	1.5
S_2	32.2	22.6	33.3	9.8	2.0
S_3	30.0	22.1	34.5	11.2	2.3
Arnett	46.4	21.1	24.0	7.1	1.4
B53	23.6	20.8	41.4	11.7	2.4

TABLE 4.14 - MEAN EFFECTS OF PLANT POPULATION, FERTILIZER RATE AND VARIETY ON TUBER GRADE AT HARVEST (SEASON II)

Treatment	% of total tuber fresh weight				
	Ware 50 mm	Big Seed 45 - 50 mm	Medium Seed 35 - 45 mm	Small Seed 25 - 35 mm	Chats 25 mm
F_1	48.4	24.8	20.8	5.1	0.9
F_2	48.1	23.9	22.1	4.8	1.1
F_3	44.1	24.1	25.5	5.3	0.9
S_1	54.8	22.3	18.1	3.9	0.8
S_2	47.5	25.7	21.2	4.5	1.0
S_3	38.2	24.8	29.1	6.8	1.1
Annett	61.1	18.7	15.5	3.9	0.7
B53	32.6	29.9	30.0	6.2	1.2

than those at S_1 and S_2, which were almost equal (Table 4.10).

Fertilizer effects were not significant, nor were the interaction effects between variety and fertilizer rate as shown by the small differences in the percentage of each tuber grade (Tables 4.11 - 4.14).

Calculations for interaction effect?

The tables showing the mean effects of plant population, fertilizer rate and variety on tuber size distribution (Tables 4.13 and 4.14) in both seasons, clearly show that Annett gave more ware than B53 while B53 had higher seed percentage and that small seed and chats accounted for a very small proportion of the total tuber yield in both varieties, particularly in Annett.

Statistical analysis for tuber grades was done only in the second season and is given in Appendix 2.

4.1.3 EFFECT OF PLANT POPULATION AND FERTILIZER RATE ON LEAF AREA INDEX (LAI).

Annett reached peak L earlier (between 3 and 5 weeks after emergence in the first season and around 5 weeks after emergence in the second season) than B53 (which reached peak L at 5 weeks and 7 weeks after emergence in the first and second seasons, respectively) but the leaf area (L) was sustained for a short period before it dropped to LAI values between 1 and 2 within 4 weeks in both seasons (Figs. 4C - 4.F). All treatments within a variety attained peak leaf area at the same time.

In the first season, Annett had higher L at 3 weeks after emergence. There was no significant difference between the L of Annett and 853 five weeks after emergence but 853 had a significantly (P=0.01) higher L four weeks later. Even two weeks later, 853 still had maintained a markedly higher L than Annett. At twelve weeks after emergence (close to maturity), 853 still had little green leaf whilst Annett had none. In the second season, Annett had a significantly (P=0.01) higher L at 5 weeks after emergence and at seven weeks after emergence 853 had caught up with Annett, but at 9 weeks it had reversed with 853 having significantly (P=0.01) higher L. Two weeks later, at eleven weeks after emergence, the difference in L between the two varieties was very small as the leaves of 853 had also almost completely senesced.

Effects of fertilizer rates on L are shown in Figs. 4.C and 4.D. These were statistically non-significant at peak L and four weeks later when LAI was beginning to drop sharply. In the first season, in Annett, F_3 had highest L at three and five weeks after emergence, but thereafter, there were no differences in L at the different fertilizer rates. Fertilizer rate had no effect on L in the first season for 853. In the second season, F_3 had the highest L throughout the growth cycle in 853 but only at five and seven weeks after emergence in Annett. Fertilizer rates F_1 and F_2 did not have consistent trends.

Effects of plant population on leaf area are shown in Figs. 4.E and 4.F. The highest plant population in both varieties had the highest L between three and

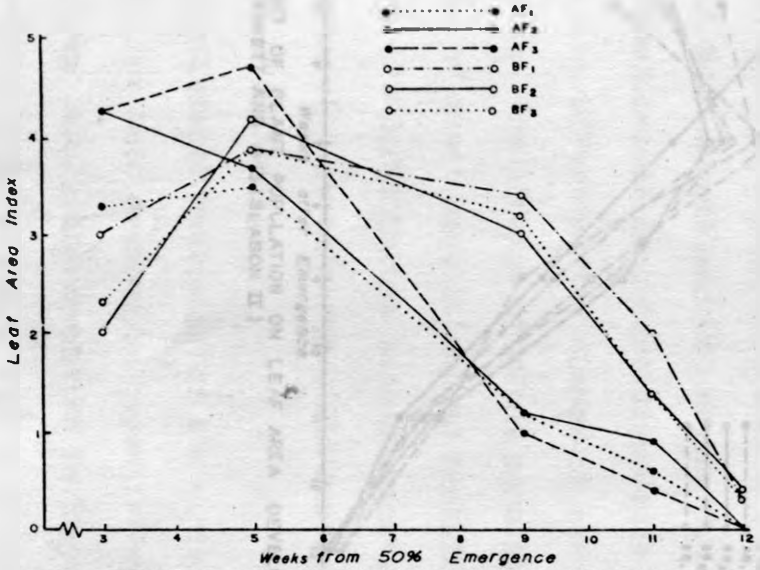


Fig. 4C. EFFECT OF FERTILIZER RATES ON LEAF AREA IN ANNETT AND B53 (SEASON I)

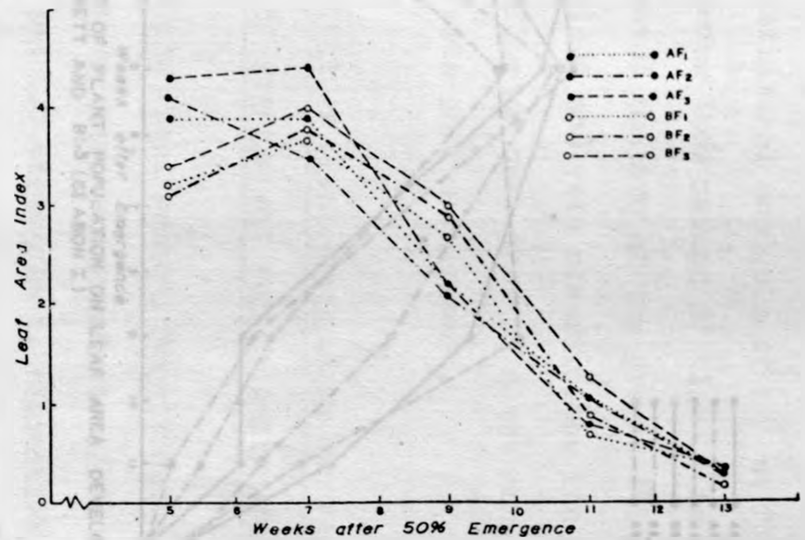


Fig. 4D EFFECT OF FERTILIZER LEVEL ON LEAF AREA DEVELOPMENT OF ANNETT AND B53 (SEASON II)

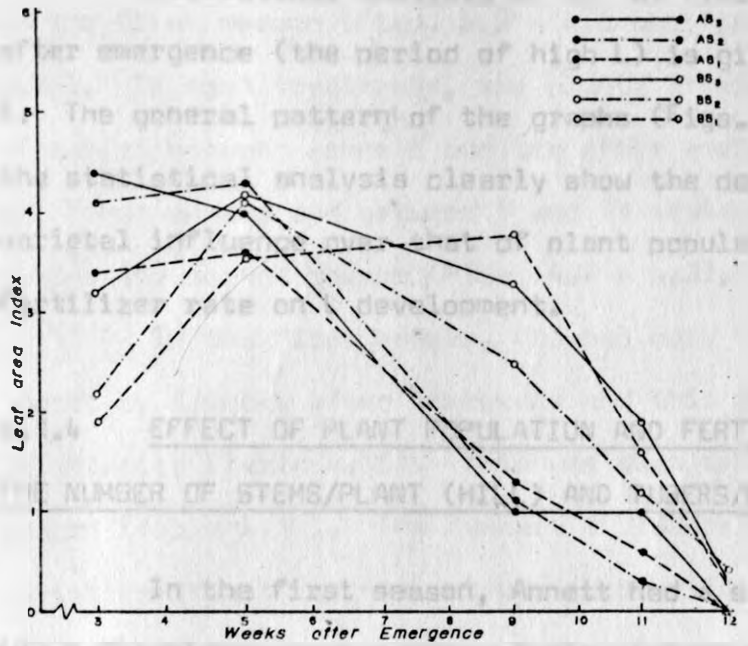


Fig. 4E EFFECT OF PLANT POPULATION ON LEAF AREA DEVELOPMENT OF ANNETT AND B53 (SEASON I)

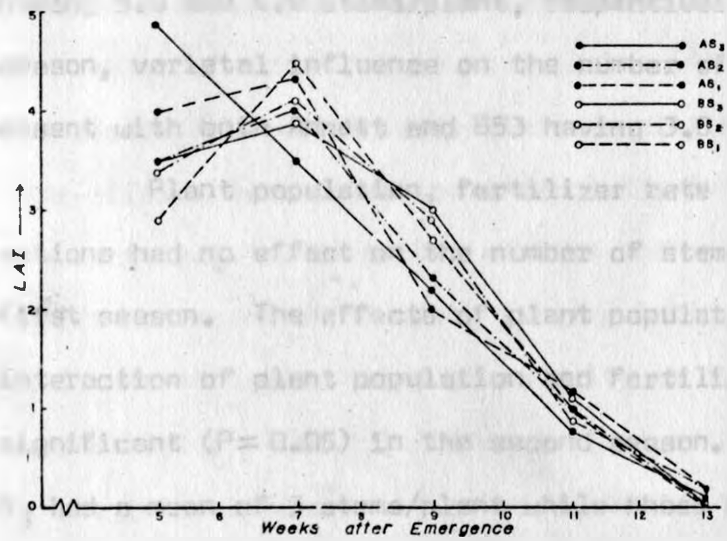


Fig. 4F EFFECT OF PLANT POPULATION ON LEAF AREA DEVELOPMENT OF ANNETT AND B53 (SEASON II) five weeks after emergence in both seasons but later in the season the effect of plant population was not apparent.

Statistical analysis of L at five and nine weeks after emergence (the period of high L) is given in Appendix 3. The general pattern of the graphs (Figs. 4.C - 4.F) and the statistical analysis clearly show the dominance of varietal influence over that of plant population and fertilizer rate on L development.

4.1.4 EFFECT OF PLANT POPULATION AND FERTILIZER RATE ON THE NUMBER OF STEMS/PLANT (HILL) AND TUBERS/PLANT (HILL).

In the first season, Annett had a significantly ($P = 0.05$) higher mean number of stems/plant than 853, each having 5.0 and 4.0 stems/plant, respectively. In the second season, varietal influence on the number of stems/plant was absent with both Annett and 853 having 3.0 stems/plant.

History of tubers?

Plant population, fertilizer rate and their interactions had no effect on the number of stems/plant in the first season. The effects of plant population and the interaction of plant population and fertilizer rate were significant ($P = 0.05$) in the second season. The plants at S_3 had a mean of 3 stems/plant while those at S_2 and S_1 had a mean of 2 stems/plant.

No. stems/m² could be better?

seed conditions for both varieties?

Statistical analysis for the number of stems/plant at maturity for both seasons is given in Appendix 4.

There was little variation in the mean number of tubers/plant in both varieties during the sampling period: 3 - 12 weeks after emergence in the first season and 5 - 13 weeks after emergence in the second season, except for 853 which had markedly low numbers at three weeks after emergence in the first season (Figs. 4.G - 4.J and Tables 4.15 and 4.16). In most treatments, the plants attained peak number of tubers between weeks 5 and ten after emergence period in the first season and between 7 and 11 weeks after emergence peri during the second season (Figs. 4.G - 4.J).

In the first season, 853 had more tubers/plant than Annett by 5 weeks after emergence and this trend was maintained to maturity (Table 4.15). This was also true for the second season (Table 4.16). The numbers of tubers/plant in both varieties dropped slightly towards maturity.

In the first season, variety, plant population and fertilizer rate and their interactions did not influence the number of tubers/plant at maturity (Appendix 4) but in the second season, variety, plant population and fertilizer rate effects were significant ($P \simeq 0.01$, $P = 0.01$, $P = 0.05$, respectively). Interaction effects were not significant. Annett had means of 12 and 9 tubers/plant while 853 had means of 13 and 10 tubers/plant at maturity in the two seasons, respectively. Thus 853 had on average more tubers/stem than Annett in both seasons. In both seasons F_3 gave a higher mean of tubers /plant at maturity than F_1 and F_2 (Tables 4.15 and 4.16). The lowest plant population had the highest number of tubers/plant at maturity whilst the highest plant population had the lowest number of tubers/plant in both seasons, although the difference was small : S_1 had 13 and 10 tubers/plant whilst S_3 had 11 and 9 tubers/plant in the

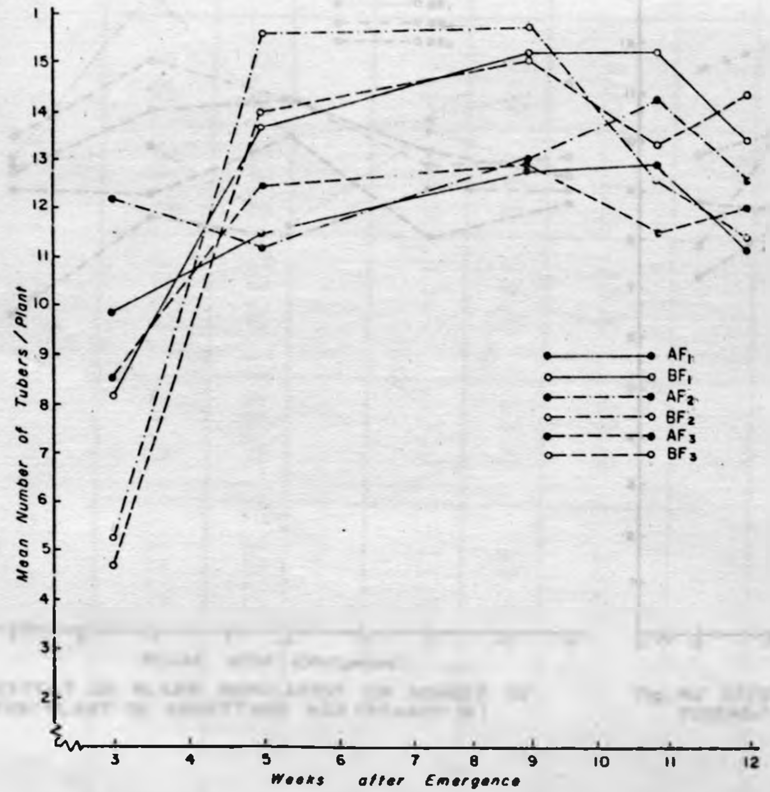


Fig. 4G EFFECT OF FERTILIZER LEVEL ON NUMBER OF TUBERS/ PLANT IN ANNETT AND B53 (SEASON I)

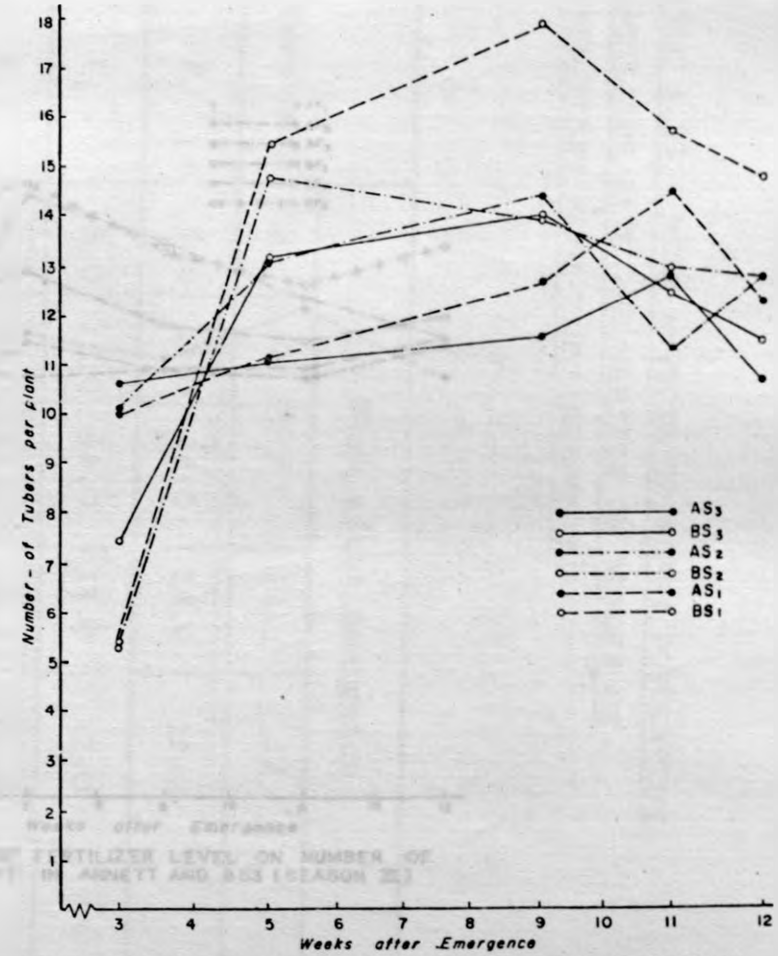


Fig. 4H EFFECT OF PLANT POPULATION ON NUMBER OF TUBERS/ PLANT IN ANNETT AND B53 (SEASON II)

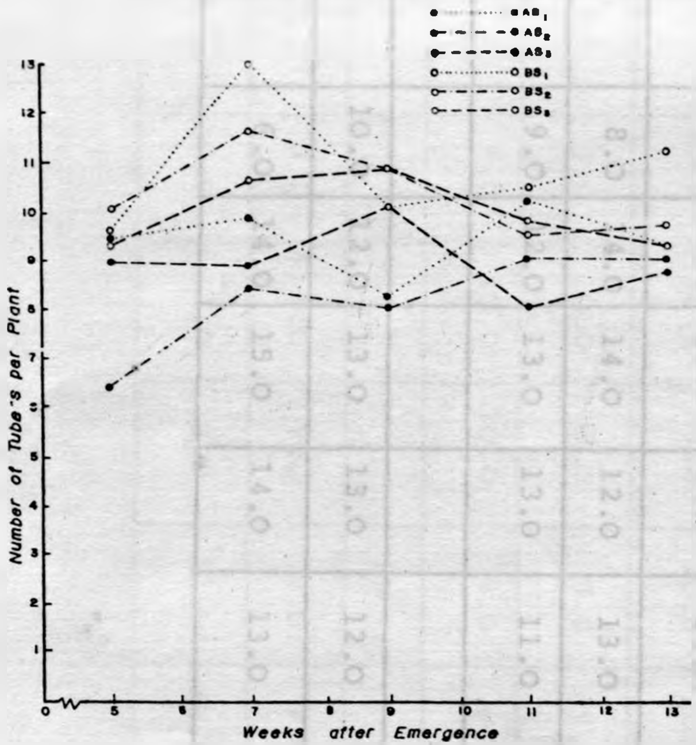


Fig.: 4I EFFECT OF PLANT POPULATION ON NUMBER OF TUBERS/PLANT IN ANNETT AND B53 (SEASON II)

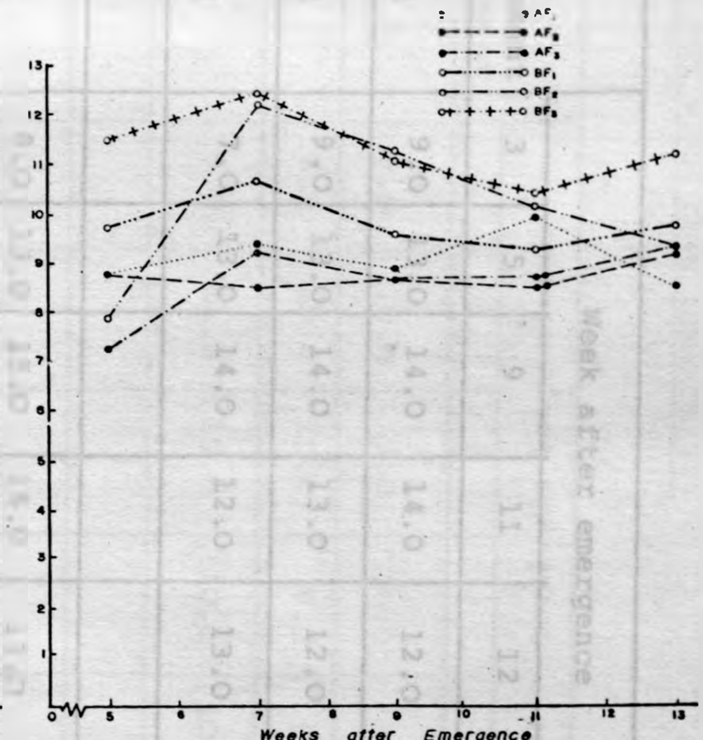


Fig. 4J EFFECT OF FERTILIZER LEVEL ON NUMBER OF TUBERS/PLANT IN ANNETT AND B53 (SEASON II)

TABLE 4.15 - MEAN EFFECTS OF PLANT POPULATION, FERTILIZER RATE AND VARIETY ON NUMBER OF TUBER/PLANT WITH TIME (SEASON I)

Treatment	Week after emergence				
	3	5	9	11	12
F_1	9.0	13.0	14.0	14.0	12.0
F_2	9.0	13.0	14.0	13.0	12.0
F_3	7.0	13.0	14.0	12.0	13.0
S_1	8.0	13.0	15.0	15.0	13.0
S_2	8.0	14.0	14.0	12.0	13.0
S_3	9.0	12.0	13.0	13.0	11.0
A	10.0	12.0	13.0	13.0	12.0
B	6.0	14.0	15.0	14.0	13.0

TABLE 4.16 - MEAN EFFECTS OF PLANT POPULATION, FERTILIZER RATE AND VARIETY ON NUMBER OF TUBER/PLANT WITH TIME (SEASON II)

Treatment	weeks after emergence				
	5	7	9	11	13
F_1	9.0	10.0	9.0	10.0	9.0
F_2	8.0	10.0	10.0	9.0	9.0
F_3	9.0	11.0	10.0	10.0	10.0
S_1	10.0	11.0	9.0	10.0	10.0
S_2	8.0	10.0	9.0	9.0	9.0
S_3	9.0	10.0	10.0	9.0	9.0
A	8.0	9.0	9.0	9.0	9.0
B	10.0	12.0	11.0	10.0	10.0

two seasons, respectively.

4.1.5 EFFECT OF PLANT POPULATION AND FERTILIZER RATE ON DRY MATTER ACCUMULATION AND PARTITIONING.

4.1.5.1 DRY MATTER PARTITIONING IN THE POTATO PLANT

Fig. 4.K shows dry matter partitioning in Annett and B53 in the second season (chosen because of consistent sampling interval). At 5 weeks after emergence in Annett, tubers accounted for 41.3% of total plant dry weight but this rose sharply to 71.7% within two weeks and steadied later to 85.3% by 11 weeks after emergence. In Annett, at 5 weeks leaves accounted for 38.2% of the total plant dry weight and this dropped sharply within two weeks to 16.3, 14.6 and 8.5% at 7, 9 and 11 weeks after emergence, respectively. Stems accounted for 12.2, 8.0, 6.0 and 5.2% of the total plant dry weight at 5,7,9 and 11 weeks after emergence, respectively. Petioles accounted for 8.0, 4.0, 2.0 and 1.1 % of the total plant dry weight at 5,7,9 and 11 weeks after emergence, respectively.

In B53 tubers accounted for 46.0, 56.8, 70.4 and 77.0 % of the total plant dry weight at 5,7,9 and 11 weeks after emergence. Leaves contributed 30.4, 21.8, 14.9 and 11.5 % of total plant dry weight at 5,7,9 and 11 weeks; stems 14.2, 14.4, 10.9 and 8.7 % at 5,7,9 and 11 weeks; and petioles 9.3, 6.9, 3.8 and 2.8 at 5,7,9 and 11 weeks after emergence, respectively (Table 4.17).

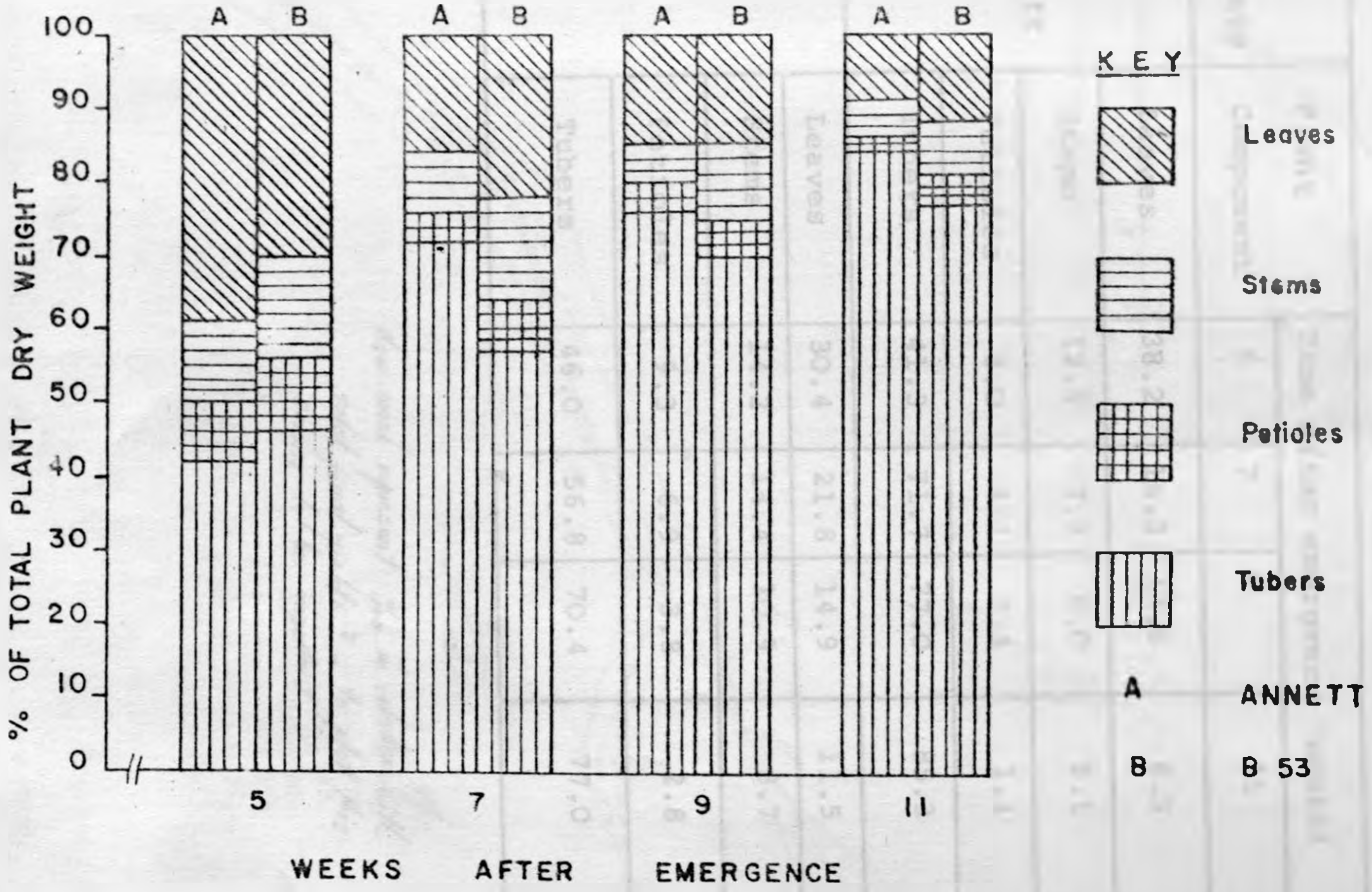


FIG. 4K : DRY MATTER PARTITIONING IN TWO POTATO CULTIVARS

(ANNETT and B53 SEASON II).

TABLE 4.17 - DRY MATTER PARTITIONING IN ANNETT AND B53 (% OF WHOLE PLANT DRY WEIGHT)

Variety	Plant Component	Time after emergence (weeks)			
		5	7	9	11
Annett	Leaves	38.2	16.3	14.6	8.5
	Stems	12.5	7.9	6.0	5.1
	Petioles	8.0	4.1	2.3	1.1
	Tubers	41.3	71.7	77.0	85.3
B53	Leaves	30.4	21.8	14.9	11.5
	Stems	14.2	14.4	10.9	8.7
	Petioles	9.3	6.9	3.8	2.8
	Tubers	46.0	56.8	70.4	77.0

14.7

23.0

How much represent %s in relation with total final yields? - to plot this seems to be important!

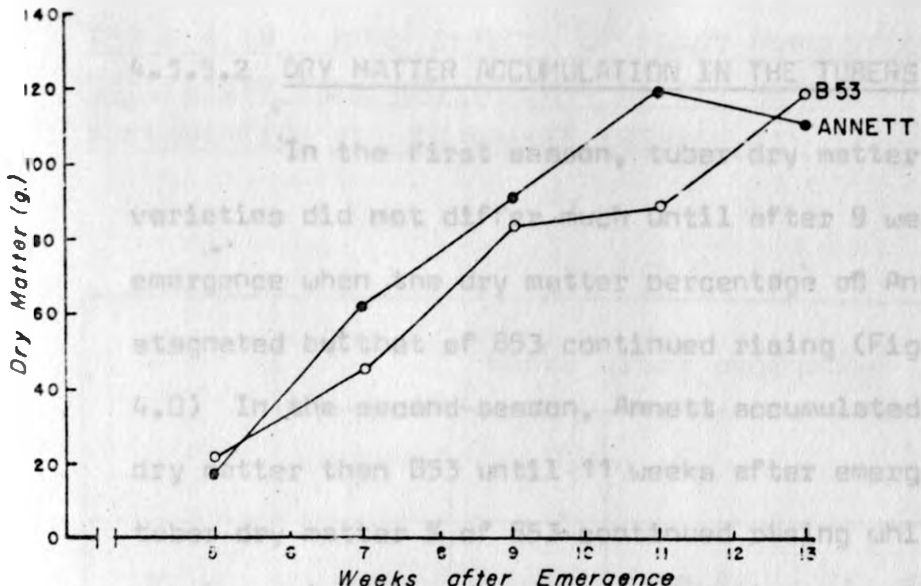


Fig 4M MEAN TOTAL TUBER DRY MATTER/PLANT (SEASON II)

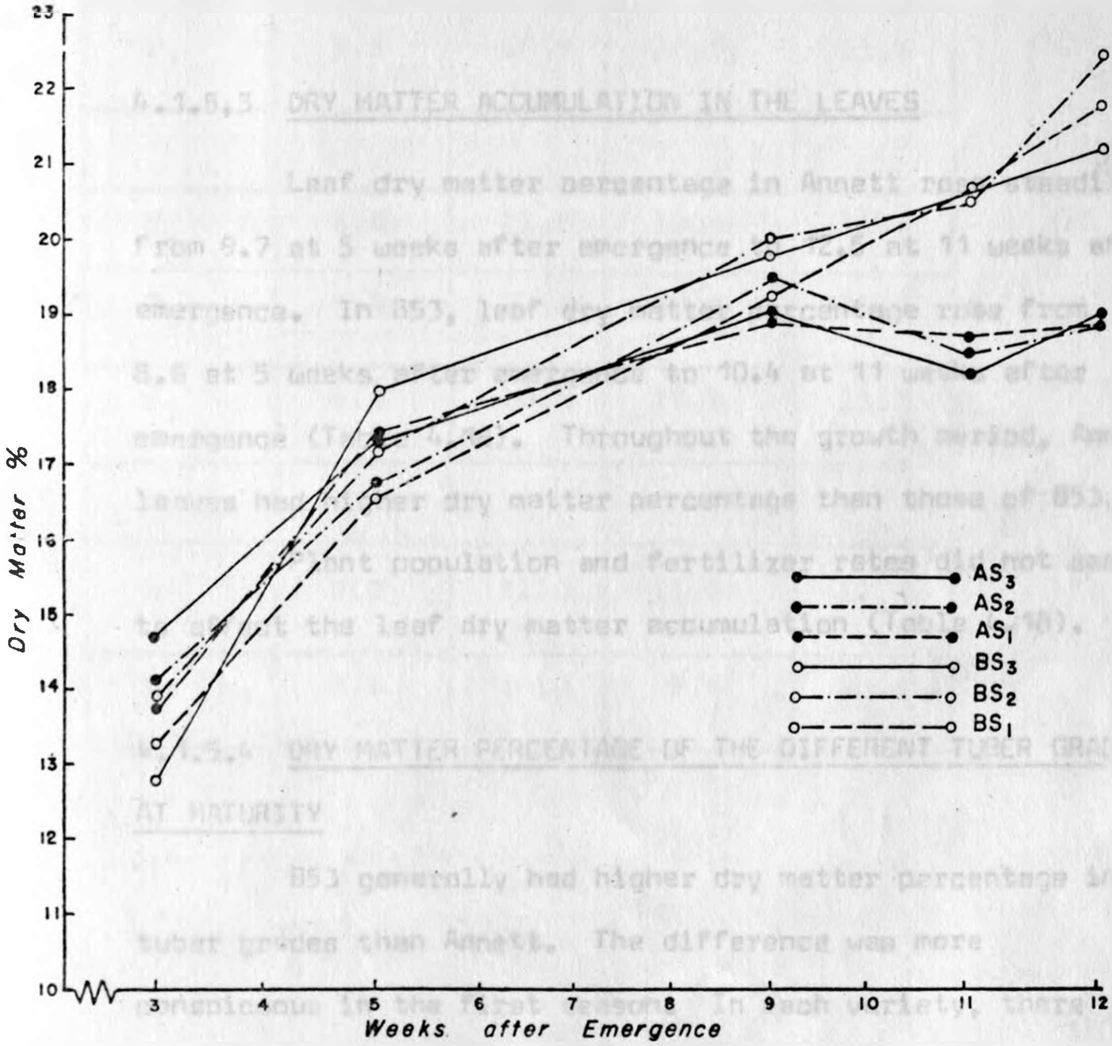


Fig. 4N EFFECT OF SPACING ON DRY MATTER ACCUMULATION IN TUBERS (SEASON I)

4.1.5.2 DRY MATTER ACCUMULATION IN THE TUBERS

In the first season, tuber dry matter % of the two varieties did not differ much until after 9 weeks after emergence when the dry matter percentage of Annett almost stagnated but that of B53 continued rising (Figs. 4.N and 4.O) In the second season, Annett accumulated more tuber dry matter than B53 until 11 weeks after emergence when tuber dry matter % of B53 continued rising whilst Annett had no change in tuber dry matter percentage, as it was almost mature (Fig. 4.M). These graphs do not show any fertilizer rate and plant population effects on dry matter accumulation.

4.1.5.3 DRY MATTER ACCUMULATION IN THE LEAVES

Leaf dry matter percentage in Annett rose steadily from 9.7 at 5 weeks after emergence to 12.5 at 11 weeks after emergence. In B53, leaf dry matter percentage rose from 8.6 at 5 weeks after emergence to 10.4 at 11 weeks after emergence (Table 4.18). Throughout the growth period, Annett leaves had higher dry matter percentage than those of B53.

Plant population and fertilizer rates did not seem to affect the leaf dry matter accumulation (Table 4.18).

4.1.5.4 DRY MATTER PERCENTAGE OF THE DIFFERENT TUBER GRADES AT MATURITY

B53 generally had higher dry matter percentage in all tuber grades than Annett. The difference was more conspicuous in the first season. In each variety, there

TABLE 4.18 - MEAN EFFECTS OF PLANT POPULATION, FERTILIZER RATE AND VARIETY ON DRY MATTER ACCUMULATION (%) IN LEAVES (SEASON II)

	Weeks after emergence			
	5	7	9	9
F_1	9.2	10.6	10.8	11.6
F_2	9.3	10.8	10.6	11.7
F_3	9.1	10.9	10.9	11.6
S_1	8.8	11.0	10.9	11.6
S_2	9.3	10.8	10.8	11.7
S_3	9.4	10.5	10.5	11.5
A	9.7	11.2	11.8	12.5
B	8.6	10.3	9.8	10.4

TABLE 4.19 - MEAN EFFECT OF PLANT POPULATION, FERTILIZER RATE AND VARIETY ON DRY MATTER PERCENTAGE IN TUBERS AT MATURITY (SEASON I)

Treatment	Tuber grade				
	Ware 50 mm	Big seed 45-50 mm	Medium seed 35-45 mm	Small Seed 25-35mm	Chat 25 m
F_1	21.5	22.8	21.4	21.7	20.1
F_2	22.1	23.1	22.0	21.2	20.1
F_3	22.5	20.9	21.9	20.9	19.3
S_1	22.4	22.1	22.3	21.8	
S_2	22.4	23.0	21.5	21.0	
S_3	21.3	21.8	21.5	21.0	
A	19.3	19.9	19.5	19.5	
B	24.8	24.7			

TABLE 4.20 - MEAN EFFECTS OF PLANT POPULATION, FERTILIZER RATE AND VARIETY ON DRY MATTER PERCENTAGE IN TUBERS AT MATURITY (SEASON II)

Treatment	Tuber grade				
	Ware	Big seed	Medium seed	Small seed	Chats
F_1	21.1	20.5	20.6	19.8	18.3
F_2	20.3	20.2	20.2	19.3	17.6
F_3	20.9	20.1	19.5	19.6	17.8
S_1	20.9	20.3	19.8	20.0	17.9
S_2	20.9	20.5	20.7	19.1	18.5
S_3	20.6	19.9	19.8	19.6	17.3
A	19.5	18.6	18.7	19.0	18.6
B	22.0	21.9	21.5	20.1	17.2

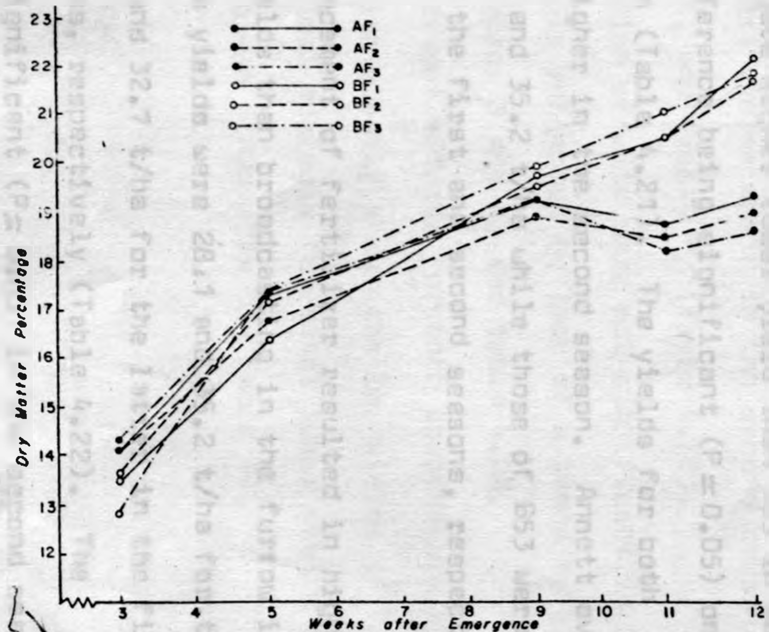


Fig. 4.0 EFFECT OF FERTILIZER LEVEL ON TUBER DRY MATTER ACCUMULATION IN ANNETT AND B 53 (SEASON I)

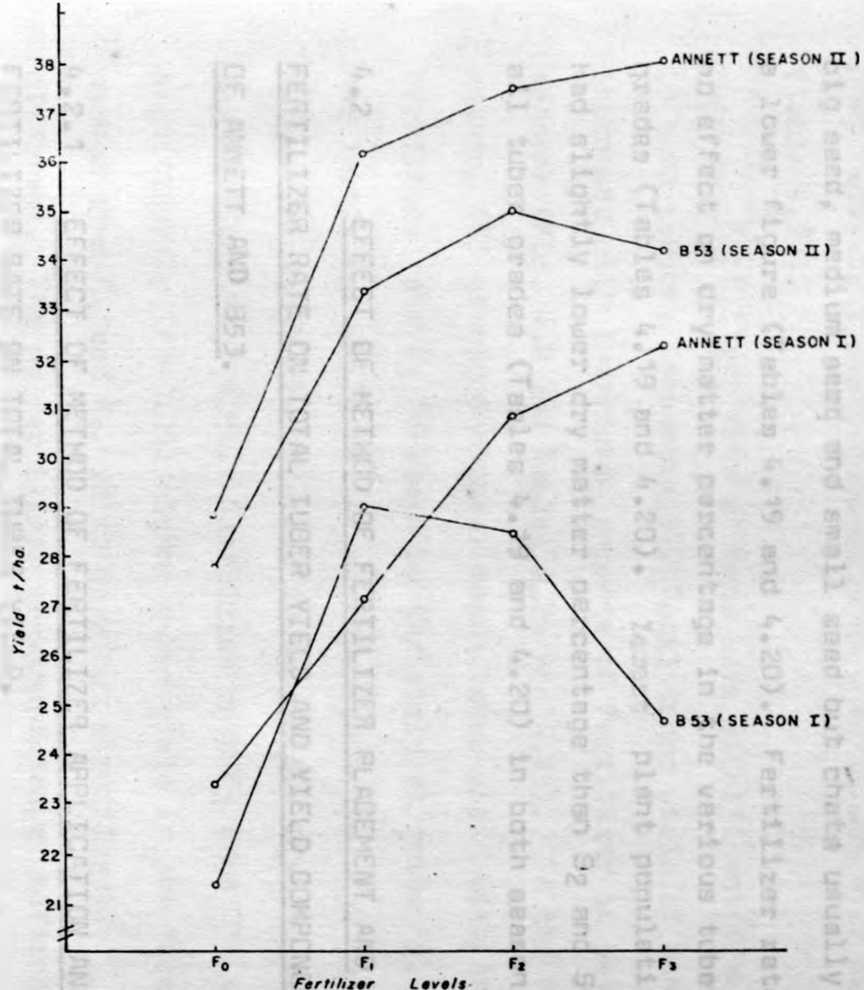


Fig. 4P EFFECT OF FERTILIZER LEVEL ON TOTAL TUBER YIELD OF ANNETT AND B53 was little difference in dry matter percentage between ware, big seed, medium seed and small seed but chats usually had a lower figure (Tables 4.19 and 4.20). Fertilizer rate had no effect on dry matter percentage in the various tuber grades (Tables 4.19 and 4.20). Lowest plant population S_1 had slightly lower dry matter percentage than S_2 and S_3 in all tuber grades (Tables 4.19 and 4.20) in both seasons.

4.2 EFFECT OF METHOD OF FERTILIZER PLACEMENT AND FERTILIZER RATE ON TOTAL TUBER YIELD AND YIELD COMPONENTS OF ANNETT AND B53.

4.2.1 EFFECT OF METHOD OF FERTILIZER APPLICATION AND FERTILIZER RATE ON TOTAL TUBER YIELD.

Annett gave higher tuber yield than B53 in both seasons, the difference being significant ($P = 0.05$) only in the second season (Table 4.21). The yields for both varieties were higher in the second season. Annett average yields were 28.5 and 35.2 t/ha while those of B53 were 25.9 and 32.6 t/ha in the first and second seasons, respectively (Table 4.21).

Hill placement of fertilizer resulted in higher overall tuber yields than broadcasting in the furrow in both seasons, the mean yields were 28.1 and 35.2 t/ha for the former and 26.3 and 32.7 t/ha for the latter in the first and second seasons, respectively (Table 4.22). The difference was significant ($P = 0.05$) in the second season

(Table 4.22). In the first season, B53 gave higher yields when fertilizer was broadcast than when it was hill placed (Table 4.23).

Fertilizer rate effects were significant ($P = 0.05$) in both seasons (Appendix 5). Total tuber yield of Annett increased with increasing amounts of fertilizer in both seasons (Fig. 4.P and Tables 4.24 and 4.25). In the first season, B53 attained highest total tuber yield with the fertilizer rate F_1 followed by the yield at rates F_2, F_3 and lastly F_0 while in the second season, F_2, F_3, F_1 and F_0 gave declining tuber yield in that order (Tables 4.24 and 4.25 and Fig. 4.P). Fertilizer rate F_2 gave significantly ($P = 0.05$) higher tuber yield in the first season than F_1 and F_3, which were not significantly different. The no fertilizer treatment had significantly ($P = 0.05$) lower yields than F_1, F_2 and F_3 (Table 4.26). F_2 gave the highest yields again in the second season followed by F_3, F_1 and lastly F_0 (Table 4.26).

Interaction effects were not significant in both seasons and this is reflected by lack of a trend by yields in Appendix 5 (Tables 3 and 4) and table 4.23.

All treatment effects for both seasons are shown in Table 4.27 which clearly shows the low yields of F_0.

Statistical analysis for total tuber yields for both seasons is given (Appendix 5 - Table 1).

TABLE 4.21 - MEAN EFFECT OF VARIETY ON TOTAL TUBER YIELD (T/HA) (EX II)

Variety	Yield*	
	First Season	Second Season
Annett	28.5 a	35.2 a
B53	25.9 a	32.6 b

* Similar letter after figures in same column depicts non-significance (P = 0.05)

TABLE 4.22 - MEAN EFFECT OF METHOD OF FERTILIZER PLACEMENT ON TOTAL TUBER YIELD (T/HA)

Method	Yield*	
	First Season	Second Season
M_1	28.1 a	35.2 a
M_2	26.3 a	32.7 b

* Similar letter after figure in the same column depicts non-significance (P=0.05).

TABLE 4.23 MEAN EFFECT OF METHOD OF FERTILIZER PLACEMENT ON TOTAL TUBER YIELD (t/ha).

VARIETY	METHOD				VARIETY MEAN	
	M_I		M_2			
	Season I	Season II	Season I	Season II	Season I	Sea II
ANNETT	30.5	35.5	26.4	34.9	28.5	3
B53	25.8	34.8	26.I	30.4	25.9	3
METHOD MEAN	28.I	35.I	26.3	32.7		

TABLE 4.24 MEAN EFFECT OF FERTILIZER RATE ON TOTAL TUBER YIELD (t/ha)(Season I)

VARIETY	FERTILIZER RATE				VARIETY MEAN
	F_o	F_I	F_2	F_3	
ANNETT	23.4	27.2	3I.0	32.4	28.5
B53	2I.4	29.I	28.5	24.7	25.9
FERTI-LIZER MEAN	22.4	28.I	29.7	28.5	27.2

TABLE 4.25 MEAN EFFECT OF FERTILIZER RATE ON TOTAL TUBER YIELD (t/ha) (Season II)

VARIETY	FERTILIZER RATE				VARIETY MEAN
	F_o	F_I	F_2	F_3	
ANNETT	29.0	36.2	37.5	38.0	35.2
B53	27.8	33.4	35.0	34.3	32.6
FERTILIZER MEAN	28.4	34.8	36.3	36.2	33.9

TABLE 4.26 MEAN EFFECT OF FERTILIZER LEVEL ON TOTAL TUBER YIELD (t/ha)

FERTILIZER LEVEL	YIELD*	
	FIRST SEASON	SECOND SEASON
F_o	22.4 a	28.4 a
F_I	28.I b	34.8 b
F_2	29.7 c	36.3 c
F_3	28.5 b d	36.2 c d

* Similar letter after the figure in the same column indicates non-significance (p = 0.05)

TABLE 4.27 - MEAN EFFECT OF METHOD OF FERTILIZER PLACEMENT ON TOTAL TUBER YIELD OF ANNETT AND B53 AT DIFFERENT FERTILIZER RATES

Variety	Fertilizer Rates	Method of placement				Fertilizer means	
		M		M2			
		Season I	Season II	Season I	Season II	Season I	Season II
Annett	F_0	26.8	28.1	19.9	29.8	23.4	29.0
	F_1	29.0	36.6	25.5	35.9	27.2	36.2
	F_2	32.5	38.2	29.4	36.9	31.0	37.5
	F_3	33.8	39.0	30.9	37.1	32.4	38.0
B53	F_0	23.2	29.1	19.6	26.6	21.4	27.8
	F_1	29.9	36.1	28.3	30.6	29.1	33.3
	F_2	27.5	35.6	29.5	34.3	28.5	35.0
	F_3	22.4	38.4	27.0	30.3	24.7	34.5
Method Means		28.1	35.1	26.3	32.7	-	-

4.2.2 EFFECT OF METHOD OF FERTILIZER PLACEMENT AND FERTILIZER RATE ON TUBER GRADES AT MATURITY.

Annett yielded more ware, as percentage of total tuber yield, than B53 in both seasons whilst B53 had a higher proportion of its yield as seed (big and medium) than Annett. The varietal difference in the proportions of these two tuber grades were highly significant ($P=0.01$) in the second season (Appendix 6). Statistical analysis was not carried out in the first season. Mean ware yield of Annett was 34% and 65.3% of the total tuber yield in the first and second seasons, respectively. Mean ware yield of B53 was 15% and 36% of the total tuber yield in the first and second seasons, respectively (Tables 4.28 and 4.29). Mean yield of seed in Annett was 55% and 29.7%of the total tuber yield and that of B53 was 70.2% and 57.8 of the total tuber yield, in the respective seasons.

Method of fertilizer placement did not influence tuber grades of Annett and B53 in both seasons (Tables 4.28 and 4.29).

In the first season, fertilizer rate did not influence tuber grades (Table 4.30). Fertilizer rate significantly ($P=0.05$) affected the proportions of ware yield in the second season as shown by the relatively larger difference in each grade due to fertilizer rates (Table 4.31). The fertilizer rate F_2 gave a higher ware percentage than rates F_1, F_3 and F_0 in that order. Ware percentage of the total tuber yield for F_1, F_2 and F_3 were not significantly different but were much higher than the

TABLE 4.28 - MEAN EFFECT OF METHOD OF FERTILIZER PLACEMENT ON TUBER GRADES (AT HARVEST SEASON I)

Variety	Method	% of total tuber fresh weight	
		Ware	Big and medium seed
Annett	M_1	33.3	54.9
	M_2	34.6	55.1
B53	M_1	15.7	69.3
	M_2	14.2	71.2

TABLE 4.29 - MEAN EFFECT OF METHOD OF FERTILIZER PLACEMENT ON TUBER GRADES AT HARVEST (SEASON II)

Variety	Method	% of total tuber fresh weight	
		Ware	Big and medium seed
Annett	M_1	64.4	30.0
	M_2	66.3	29.4
B53	M_1	36.7	56.8
	M_2	35.2	58.8

TABLE 4.30 - MEAN EFFECT OF FERTILIZER RATE ON TUBER GRADES AT HARVEST (SEASON I)

Variety	Fertilizer rates	% of total tuber fresh weight	
		Ware	Big and medium seed
Annett	F_0	33.2	55.6
	F_1	35.4	53.5
	F_2	31.9	56.7
	F_3	35.3	54.2
B53	F_0	16.1	72.4
	F_1	15.7	67.5
	F_2	14.1	73.9
	F_3	13.9	67.3

TABLE 4.31 - MEAN EFFECT OF FERTILIZER RATE ON TUBER GRADES AT HARVEST (SEASON II)

Variety	Fertilizer rate	% of total tuber fresh weight	
		Ware	Big and medium seed
Annett	F_0	60.7	32.5
	F_1	65.9	29.4
	$F_{2'}$	69.2	27.4
	F_3	65.6	29.2
B53	F_0	35.0	58.6
	F_1	31.8	61.5
	F_2	37.3	56.7
	F_3	39.7	54.4

Table 4.32: Mean Effects of method of fertilizer placement fertilizer rate and variety on tuber grades at Harvest (Season I).

Treatment	% of total tuber fresh weight				
	Ware >50mm	Big Seed 45-50mm	Medium Seed 35-45mm	Small Seed 25-35mm	chats <25mm
M_1	24.5	25.9	36.2	11.2	2.1
M_2	24.4	25.2	37.9	10.3	
F_o	24.7	28.1	35.9	9.6	
F_1	25.6	24.1	36.3	11.4	
F_2	23.0	26.6	38.7	9.7	1.9
F_3	24.6	23.6	37.2	12.2	
A	34.0	24.2	30.9	8.9	
B	15.0	27.1	43.2	12.6	

Table 4.33: Mean Effects of method of fertilizer placement, fertilizer rates and variety on tuber grades at harvest (Season II)

Treat-ment	% of total tuber fresh weight				
	Ware 50mm	Big Seed 45-50mm	Medium Seed 35-45mm	Small Seed 25-35mm	Chats 25mm
M_1	50.5	20.7	22.7	5.0	1.0
M_2	50.8	20.5	23.6	4.3	0.8
F_o	47.8	21.8	23.7	5.5	1.0
F_1	48.8	21.7	23.8	4.7	0.9
F_2	53.2	20.3	21.8	3.9	0.7
F_3	52.7	18.5	23.3	4.5	0.9
A	65.3	16.0	13.7	4.1	0.8
B	36.0	25.2	32.6	5.2	1.0

ware percentage in F_0.

In both varieties, yield of small seed and chats accounted for a small proportion of the total tuber yield as shown in Tables 4.32 and 4.33. These two tables show tuber size distribution and it is apparent that for both varieties, ware % is greater in the second season and that Annett has a higher ware % than B53, and vice-versa in the seed grades. It is also clear that the method of fertilizer placement and fertilizer rate do not markedly affect tuber size distribution.

4.2.3 EFFECT OF METHOD OF FERTILIZER PLACEMENT AND FERTILIZER RATE ON LEAF AREA DEVELOPMENT.

In the first season, Annett reached peak L between three and four weeks after emergence whereas B53 reached the peak much later, around six weeks after emergence (Figs. 4.Q and 4.R). Annett LAI fell drastically after the peak whilst B53 sustained high L until 11 weeks after emergence after which it dropped sharply to zero values by 13 weeks after emergence. Between three and four weeks after emergence, Annett had much higher L than B53 but from six weeks after emergence up to maturity, B53 had higher L (Figs. 4Q and 4.R). At six and eleven weeks after emergence, B53 had significantly ($P = 0.001$) higher L than Annett.

Fertilizer rate effects on L were only significant at six weeks after emergence. This is clear from the graph for variety B53 (Fig. 4.Q) where the no fertilizer treatment

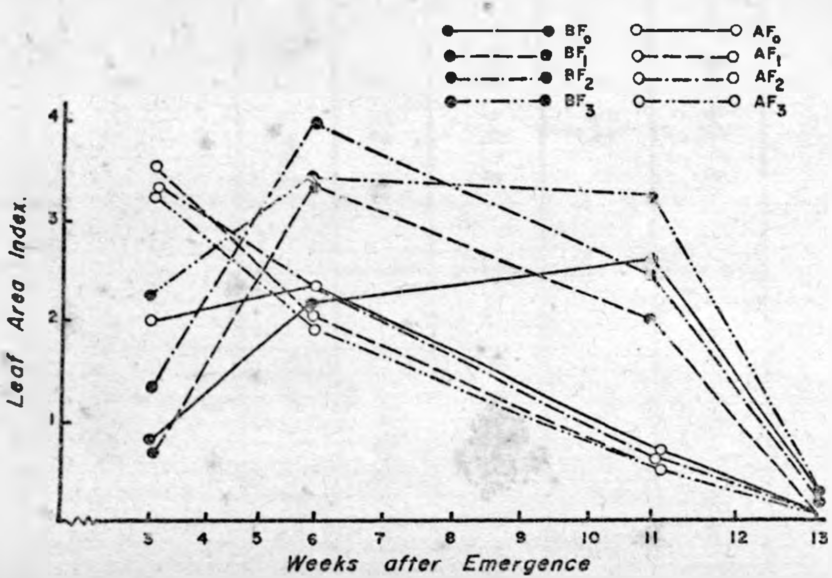


Fig. 4Q. EFFECT OF FERTILIZER RATES ON LEAF AREA DEVELOPMENT IN ANNETT AND B53 (SEASON I).

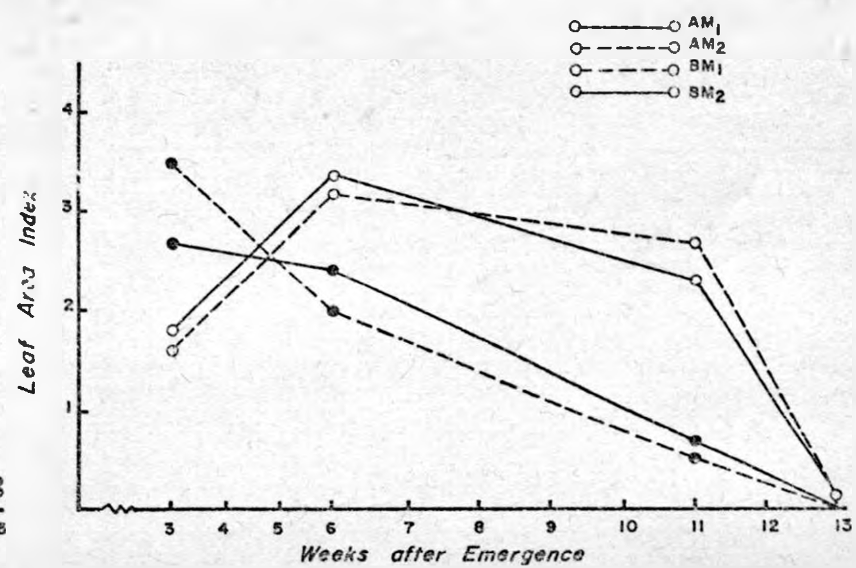


Fig. 4R. EFFECT OF METHOD OF FERTILIZER PLACEMENT ON LEAF AREA DEVELOPMENT IN ANNETT AND B53 (SEASON I).

Table 4.34: Mean Effect of fertilizer rates on leaf area index (L) at six weeks, after emergence.

Fertilizer rate	Mean L.*
F_o (0kg DAP/ha)	2.25 a
F_1 (344 " " ")	2.84 ab
F_2 (430 " " ")	3.15 b
F_3 (517 " " ")	2.64 ab

* Similar letter after value depicts non-significant difference ($P \leq 0.05$)

Table 4.35: The interaction effect of variety and fertilizer on leaf area index (L.A.I.) at six weeks after emergence.

Treatment	Mean L.A.I.*
AF_o	2.36 a
AF_1	2.08 a
AF_2	2.32 a
AF_3	1.87 a
BF_o	2.15 a
BF_1	3.59 b
BF_2	3.97 b
BF_3	3.41 b

* Similar letter after value depicts non-significant difference ($P \geq 0.05$)

had a conspicuously lower L than the other three fertilizer rates (Table 4.35). Between three and four weeks, F_1, F_2 and F_3 reached peak L of 3.5 whilst the F_0 had L as low as 2.0

Variety and fertilizer rate interaction was significant (P 0.01) at six weeks after emergence (Table 4.35). B53 interacted with fertilizer positively and all F_1, F_2 and F_3, had significantly (P = 0.05) higher L than Annett at F_0, F_1, F_2 and F_3. At six weeks after emergence, there was no difference in Annett L between F_1, F_2, F_3 and the no fertilizer treatment (Table 4.35).

4.2.4 <u>EFFECT OF METHOD OF FERTILIZER PLACEMENT AND FERTILIZER RATE ON THE NUMBER OF STEMS/PLANT (HILL) AND NUMBER OF TUBERS/PLANT (HILL)</u>.

Annett had a significantly higher mean number of stems/plant than B53 : 5.4 and 3.7, respectively in the first season. The difference in the mean number of stems/plant was non-significant in the second season and Annett and B53 had 3.3 and 3.4 stems/plant respectively.

Method of fertilizer placement and fertilizer rate had no effect on the number of stems/plant in both seasons (Appendix 8).

Annett and B53 had almost equal mean numbers of tubers/plant in the first season but B53 had significantly (P = 0.05) more tubers/plant than Annett in the second season (Appendix 8).

The method of fertilizer placement had no significant effect on the number of tubers/plant in the first season but hill placement resulted in significantly (P = 0.05) more tubers/hill than broadcasting in the furrow, in the second season. ?

Fertilizer rates significantly (P = 0.05) influenced the number of tubers/plant in both seasons. Fertilizer rates F_3, F_2 and F_1 were not significantly different but had significantly more tubers/hill than Fo.Fo had the lowest mean number of tubers/plant in both seasons.

4.2.5 Effect of Method of Fertilizer Placement and Fertilizer Rate on Tuber Dry Matter at Maturity.

853 generally had higher dry matter percentage than Annett in all tuber grades. The difference was larger in the first season. In each variety, there was little variation in dry matter percentage of ware, big seed and medium seed but small seed and chats had slightly lower dry matter percentage in both seasons (tables 4.36 and 4.37).

Method of fertilizer placement did not influence dry matter percentage of the tubers at maturity but dry matter percentage in each tuber grade generally decreased with increasing fertilizer rate (Tables 4.36 and 4.37).

Table 4.36: Mean Effects of method of fertilizer placement, fertilizer rate and variety on dry matter percentage (%) in tubers at maturity (Season I)

Treatment	Tuber grade				
	Ware > 50mm	Big Seed 45-50mm	Medium seed 35-45mm	Small Seed 25-35mm	Chats < 25mm.
M_1	22.8	22.9	22.5	21.7	21.1
M_2	22.7	22.1	22.2	21.5	20.4
F_o	23.2	23.3	23.4	22.5	21.6
F_1	22.2	22.4	22.5	20.8	20.1
F_2	22.9	23.7	21.7	22.0	20.7
F_3	22.8	20.7	21.8	21.0	20.3
A	21.6	20.3	20.0	19.5	20.3
B	24.0	24.7	24.7	23.7	21.2

TABLE 4.37 - MEAN EFFECTS OF METHOD OF FERTILIZER PLACEMENT, FERTILIZER RATE AND VARIETY ON DRY MATTER PERCENTAGE (%) OF TUBER MATURITY (SEASON II)

	Ware	Tuber grade			
	Ware	45-50 mm	35-45 mm	25-35 mm	25 mm
M_1	20.9	19.5	18.9	18.0	18.0
M_2	21.2	19.7	18.9	18.5	17.4
F_0	22.3	20.2	19.7	19.1	18.4
F_1	21.0	20.2	19.1	18.4	18.6
F_2	19.8	18.9	18.4	17.7	16.5
F_3	21.0	19.0	18.5	17.7	16.9
A	20.2	18.9	18.2	17.8	18.6
B	21.9	20.3	19.7	18.7	16.7

CHAPTER FIVE

5. DISCUSSION

5.1 Effect of plant population and fertilizer rate on total tuber yield and yield components of Annett and B53.

5.1.1. Effect of plant population and fertilizer rate on total tuber yield.

Annett outyielded B53 in both seasons (Table 4.1.). This is consistent with their varietal descriptions (Ballestrem and Holler, 1974) and results from various trials conducted at low rainfall Thika and higher rainfall Molo (Holler, 1973). The tuber yields were higher in the second season for both varieties, probably because there was more rain and the rainy season was longer then: the amounts were 408 and 590 mm in the respective seasons. + 30 mm irrigation

Total tuber yield from the three plant populations: 44444, 53333 and 66666 plants/ha did not differ significantly in both seasons but tuber size decreased with increasing plant population. There was no consistent relationship between spacing and total tuber yield (Table 4,2 and 4,3; Fig. 4,A).

The result from this experiment suggests it is not economically efficient to plant Annett and B53 at plant populations higher than the recommended 44444 plants/ha at Kabete as that will increase input by way of extra seed tubers without any appreciable gain in tuber yield.

It is possible that adverse weather in both seasons resulted in stiff competition for moisture at the higher plant population. The early termination of rains in the first season and the long dry spell from the seventh week after emergence in the second season must have adversely affected B53 more than Annett. In both seasons, Annett attained peak L earlier (Figs 4.c,-4.F) than B53 and as shown in Fig 4.k ; by the time the dry spell struck in the second season, tubers in Annett already accounted for 70% of total plant dry weight whereas they only accounted for only 56% of total plant dryweight in B53.

Total tuber yield generally increased with fertilizer rate in Annett in both seasons and in B53 during the second season (Tables 4.4 and 4.5; Fig. 4B). Annett may have responded to fertilizer because its growth cycle was almost completed when moisture supply was still adequate and this may have been the case for B53 in the second season: the plants extracted nutrients more efficiently when there was adequate soil moisture. The fertilizer levels tested: 344 Kg DAP/ha, 430Kg DAP/ha and 517Kg DAP/ha did not differ significantly in total tuber yield. This suggests that under Kabete conditions, using the recommended rate, which was the highest rate used in this work, was wasteful. Before the experiment in the first season, soil analysis showed moderate nitrogen, high magnesium, carbon and calcium; extremely low phosphorus and abnormally high potassium and sodium. In the second season, soil analysis before the experiment showed moderate nitrogen, high carbon% and calcium, extremely low phosphorus, magnesium, potassium and sodium. The soil was slightly acidic in both seasons.

It is likely that at Kabete the most economic fertilizer rate lies between 344Kg DAP/ha and 517Kg DAP/ha. The differences in yield between fertilizer rates F_1, F_2, and F_3 of experiment 1(VXSXF)rate at plant population S_1(same as used in experiment 2) and the rate Fo of experiment 2 were greater than the differences in tuber yields between fertilizer rates F_1,F_2 and F_3 and fertilizer rate Fo in experiment 2. The latter difference was significant ((P=0.05) therefore the former difference could also be significant. That then shows that fertilizer application was necessary for high potato yields under Kabete conditions (Tables 4.6 and 4.27).

It should be noted that the three fertilizer rates used in this experiment approximate levels which gave the highest tuber yields in different seasons at Thika (Holler, 1973), though the yields there were much lower, about 19t/ha, probably because of considerably lower rainfall.

5.1.2. <u>Effect of plant population and fertilizer rate on tuber grade</u>.

Annett gave a greater % of its tuber yields as ware compared to B53 in both seasons while B53 had a higher portion of its yield as seed (big and medium) than Annett in both seasons (Tables 4.9 - 4.12). Annett would thus appear to be more suited for ware production whilst B53 would be of more interest to seed growers in the Kabete Area. It is possible that in B53 tubers did not grow to their maximum because of adverse weather conditions.

For both varieties, ware percentage of total tuber yield increased with decreasing plant population whilst percentage of seed grades increased with increasing plant population, the highest plant population giving the highest seed percentage. Lowering plant populations below 44444 plants/ha would increase ware percentage but would give uneconomically low total tuber yields as was reported by Holler (1973) of a plant population of 33333 plants/ha which gave a significantly ($P = 0.05$) lower yield than 44444 plant/ha. Annett and B53 were among the varieties used in that study.

Generally, low plant populations reduce inter-plant competition for light, moisture and nutrients and hence results in healthier plants with a long and high bulking rate culminating in dominance of large tubers in the yield. The results from this experiment agree with three reported by Mundy and Bowles (1972), Egorov and Fillipov (1975), Bremner and Taha (1966), Jarvis and Shotton (1971), Gurnah (1974), but differ from the results of Jarvis and Roger-Lewis (1974), Jarvis and Roger-Lewis (1976) and Ifenkwe and Allen (1978) who had yield of saleable ware increasing with increasing plant density. The relevance of these findings depends on the plant densities used, the varieties, the sieve size standard for ware and the weather.

It can therefore be said that a plant population higher than 44444 plants/ha is more suited for seed production and in this experiment 66666 plants/ha was most suited. But since total tuber yield did not differ significantly with plant population, the extra cost of additional seed tubers will have to be weighed against the returns from the higher 'selling' price of seed potatoes.

The non-significance of fertilizer levels and interaction effects suggests that there is no need to increase fertilizer with increasing plant population for seed and ware production at least within the tested population range (Tables 4.7, 4.8, 4.11 and 4.12). Influence of seasons on potato response to plant population and fertilizer rate may invalidate this inference.

5.1.3. Effect of plant population and fertilizer rate on leaf area development.

Annett quickly developed leaf area compared to B53 (Figs 4.C-4.F) and this suggests that in situations of forced early lifting, due to disease or when the rains are short-lived, Annett would give a reasonable and much higher yield than B53. Annett was thus observed to be drought escaping.

B53 sustained its leaf area for longer periods than Annett (Figs 4.C-4.F). This may explain the higher dry matter % in the B53 tubers at maturity. The fact that Annett had a shorter bulking period than B53 but ended up with higher yields suggests that Annett had a relatively higher bulking rate, as was the case in the second season (Fig. 4.k

The haulm in B53 competes for assimilates with the tubers more than is the case in Annett since the contribution of leaves, stems and petioles to total plant dry weight decreases more markedly in Annett than in B53 (Fig 4.K

The more developed haulm of B53 is maintained at the expense of tuber bulking. Also the high initial L in Annett favourshigh bulking rate of the tubers. B53, with its longer growth cycle, had its bulking period shortened by dry weather, particularly in the short rainy season, hence the lower yields.

Plant population and fertilizer effects did not affect the general pattern of L development (Figs 4.C-4.F) but the significantly higher L of the highest plant population at five weeks after emergence in the second season and the significantly higher L of the lowest plant population at 9 weeks after emergence in the first season is due to the fact that high plant population initially raises a larger L but the lower plant population maintains L longer probably because of reduced shading effects.

5.1.4. Effect of plant population and fertilizer rate on the on the number of stems/plant(hill) and tubers/plant (hill).

Annett had a higher mean number of stems/hill than B53 in both seasons, the difference being only significant in the first season. Both varieties had higher mean numbers of stems/hill in the first season than in the second season. This may be because the seed tubers were well sprouted at the time of planting in the first season.

Fertilizer rates did not affect the number of stems/ hill. In the second season, the highest plant density had significantly more stems/hill than S_1 and S_2, the numbers being 3.1 for S_3 and 2.5 for S_1 and S_2.

B53 had more tubers/hill at maturity than Annett in both seasons. Since B53 had less tuber yield than Annett in both seasons, this may explain why B53 tuber yield was dominated by seed grades as opposed to ware Annett.

The peak number of tubers/hill was reached by 5 weeks after emergence. There was little variation in the mean number of tubers/hill in both varieties in the sampling period: 3-12 weeks after emergence in the first season and 5-13 weeks after emergence in the second season, except for B53 which had markedly low tuber numbers at 3 weeks after emergence in the first season (Figs. G-J; Tables 4.15 and 4.16) probably because its initial development was slow. About 90% of the tubers initiated by peak tuber number survived to final harvest. Resorption of small tubers was observed very clearly from 9 weeks after emergence onwards. This is consistent with the description of Moorby and Milthorpe (1973) who observed that all the tubers formed after the initial two to four weeks as also stated by MacGillivray (1961), Bremner and Taha (1966) and Beukema and Zaag (1979), will continually be resorbed. Resorption took place in all treatments and did not reflect any treatment effects.

In the first season, variety, fertilizer rate and plant population effects had no significant effects on the number of tubers/hill. In the second season, they had. The number of tubers/hill increased with increasing fertilizer level.

The number of tubers/hill increased with decreasing plant population. This means that the number of tubers/stem increased with decreasing plant population (since S_1 and S_2 had 2.5 stems/hill while S_3 had 3.1 stems/hill) and this agrees with Allen and Wurr (1974), Wurr (1974), Ifenkwe and Allen (1978) and Allen (1978) who reported that the number of tubers/stem was reduced with increasing plant density.

From the foregoing, B53 had more tubers/stem than Annett in both seasons and this should have had a bearing on its tuber sizes.

5.1.5. Effect of plant population and fertilizer rate on dry matter accumulation and partitioning.

5.1.5.1 Dry matter partitioning in Annett and B53

Dry matter partitioning into tubers was more pronounced in Annett than in B53 while dry weight of leaves, stems and petioles as percentage of total plant dry weight declined sharper in Annett than in B53 (Table 4.17; Fig. 4.K This is consistent with the duration of the growth cycles of the two varieties.

5.1.5.2 Tuber dry matter at maturity.

Ware, big and medium seed tubers had about the same dry matter percentage whilst small seed and chats had a slightly lower dry matter content (Tables 4.19 and 4.20).

This has importance when choosing potato seed: planting small seed grade or chats, which have low food reserves, will give weak plants and ultimately low yields. Plant population and fertilizer rate did not seem to affect the rate of dry matter accumulation (Figs 4.N and 4.O) nor influence the dry matter contents of the various tuber grades at maturity (Tables 4.19 and 4.20). It is possible that the population range tested in this experiment was not high enough to have an effect on dry matter as was reported by Wurr and Allen (1974) and Ifenkwe and Allen (1978) that tuber dry matter decreased as plant density increased or Mazur and Ciecko (1976) who reported increased tuber dry matter and starch yields with increased plant density.

The continued increase in tuber dry matter percentage 9 weeks after emergence by B53 when Annett tuber dry matter percentage remained more or less stagnant (Figs 4.N and 4.O) can be explained by leaf area differences then. B53 had signigicantly higher leaf area at 9 weeks after emergence than Annett, whose LAI values were approaching zero as it reached maturity, in both seasons.

At the highest fertilizer rate, F_3, the dry matter percentage of the seed grade tubers tended to be lower than those of the lower fertilizer rates. The higher nitrogen may have delayed maturity but it would appear that under tropical conditions, like those at Kabete, Nitrogen does not adversely affect dry matter percentage as reported to happen in the temperates (Ngugi, 1972).

5.2 Effect of method of fertilizer placement and fertilizer rate on total tuber yield and yield components of Annett and B53.

5.2.1 Effect of Method of fertilizer placement and fertilizer rate on total tuber yield.

Annett outyielded B53 in both seasons. This conforms to the varietal descriptions (Ballestrem and Holler, 1974) based mostly on work done at Thika. Even in trials carried out at Molo, a higher rainfall area, Annett has always outyielded B53 (Holler, 1973). The yields of both varieties were higher in the secondseason probably because the growth conditions, particularly soil moisture, were better then (Table 4.21). In the first season, short rains, the rains stoppedearly whilst in the second season there was a persistent dry spell from about seven weeks after emergence which necessitated irr igation in the 9th week after emergence. In both seasons, adverse weather was bound to affect B53 more than Annett as there was relatively less leaf area on Annett (nearin g maturity) when those adverse conditions set in.

Hill placement generally gave higher yields than broadcasting in the furrow in both seasons (Table 4.22). This agrees with the results of Batey and Boyd (1967) and Harris (1978) who reported more pronunced fertilizer response curves when fertilizer had been placed than when it had been broadcast. Related work of Varis and Laneta (1975) showed that drilling and placing fertilizer gave higher yields than broadcasting while Nikitina (1976) also reported higher yields by drilling than by broadcasting.

To much repitition from literature review.

Even though the mean yield from hill placement was not significantly higher than that from broadcasting in the furrow in the first season, the difference of 1.7 t/ha (ware and seed grades) is quite substantial. In the second season the difference was higher and significant at 2.2 t/ha (ware and seed grades). B53 had slightly higher yield with broadcasting fertilizer than with placed fertilizer in the first season but had a great difference in total tuber yields vice-versa in the second season (Tables 4.23). Prolonged moisture supply may effectively enhance B53, with its longer growth cycle, to more efficiently extract nutrients and raise its tuber yield.

Total tuber yield of Annett increased with increasing amounts of fertilizer in both seasons (Table 4.24 and 4.25). In the first and second season, B53 attained the highest total tuber yield with fertilizer rates 340 Kg DAP/ha and 430 Kg DAP/ha, respectively. In both seasons, F_1, F_2 and F_3 had significantly higher tuber yields than Fo indicating the need for fertilizer application but since F_2 gave the highest overall tuber yield in both seasons, (Tables 4.24 and 4.25) this suggests that the most efficient fertilizer rate for Kabete is lower than the recommended 517 Kg DAP/ha. In the first season, the soil analysis before the experiment showed that soil nitrogen levels were moderate, carbon, percentage high, phosphorus very low, potassium and sodium abnormally high. Magnesium and calcium levels were high.

5.2.2 Effect of method of fertilizer placement and fertilizer rate on tuber grades.

Annett gave a greater portion of its yield as ware than B53, but B53 had a greater percentage of its tuber yield as seed (big and medium) than Annett in both seasons (Tables 4.32 and 4.33). This may be expected since B53 with its long growth cycle and much bigger haulm development must have suffered from the adverse weather conditions more than Annett. The haulm in B53 competes with the tubers for assimilates longer than in Annett and it also had greater mean number of tubers/plant in both seasons. These factors may have prevented tubers in B53 to grow to full size.

Tuber size distribution in Annett and B53 was not influenced by method of fertilizer application.

The three fertilizer rates F_1, F_2 and F_3 did not differ much in the proportions of their ware and seed grades yield but the unfertilized treatment, Fo, gave significantly lower ware percentage than F_1, F_2 and F_3 suggesting that poor soil nutritional conditions result in dominance by smaller tubers.

In both varieties, the yield of small seed and chats accunted for about 8-10% of the total tuber yield.

5.2.3 Effect of Method of fertilizer placement and fertilizer rate on leaf area (L) development.

Annett developed high L compared to B53 at the beginning of the crop growth but B53 maintained significantly higher L for longer time than Annett (Figs 4.Q and 4.R).

This suggests that Annett will do better than B53 in short rainy seasons or will give better yields in situations of forced early lifting such as avoiding disease contamination. This growth habit of Annett and B53 conforms to their varietal descriptions (Ballestrem and Holler, 1974).

F_1, F_2 and F_3 did not differ signigicantly but Fo had a significantly lower L at the time of peak L. This result was expected since poor soil nutritional status normally results in plants which are not well developed and in this experiment all Fo plots could be visually singled out because of relatively stunted growth. The fertilizer rate and variety interaction effects on L were significant indicating that L development of Annett and B53 is sensitive to the fertility of the soil. Decline in L followed general patterns influenced by variety and not fertilizer rate or method of application.

5.2.4. Effect of method of fertilizer application and fertilizer rate on the number of stems/hill and tubers/hill.

Annett had significantly more stems/hill than B53 in the first season, but the numbers of stems/hill were not significantly different in the second season. B53 had significantly more tubers/hill than Annett in the second season and thus had more tubers/stem in both seasons since it had more tubers/hill in the first season. It would thus appear that lack of moisture, due to early termination of the rains suffered by B53 in the first season affected growth of tubers more than their numbers.

Hill placement resulted in more tubers/hill than broadcasting in the furrow in the second season. This result agrees with the observation of Varis and Laneta (1975) who reported an increased number of tubers/hill when fertilizer was placed than when it was broadcasted. Hill placement of fertilizer may have improved plant nutrition particularly of nitrogen and thus caused an increased tuber formation as was also reported by Hanley et al (1965) and Dubetz and Bole (1975).

Fo had the lowest number of tubers/hill and thus the lowest number of tuber/stem compared to F_1,F_2 and F_3 which were not significantly different, suggesting that soil fertility is a factor in the number of tubers formed by the potato plant.

5.2.5. Effect of method of fertilizer placement and fertilizer rate on tuber dry matter at maturity.

Method of fertilizer placement and fertilizer rate seemed not to influence dry matter content of the tubers although it has been reported by Ionas (1975) and Painter et al (1978) that increased rates of applied nitrogen caused lowering of tuber specific gravity. In this work, even fertilizer rate Fo did not differ in dry matter percentage of the various tuber grades from F_1,F_2 and F_3. It would appear that under tropical conditions (like at Kabete) nitrogen does not adversely affect tuber dry matter percentage as it does in the temperate as reported by Ngugi (1972).

There was little variation in dry matter percentage between ware, big seed and medium seed but small seed and chats had a lower dry matter percentage. This has a strong bearing on choice of tuber grades to use as "seed" since it would mean planting chats and small seed, which have small energy reserves, will produce weak plants and ultimately result in low yields.

This already was told!

CHAPTER SIX

6. CONCLUSIONS

The results from the variety x plant population x Fertilizer level and Variety x Method of fertilizer application x Fertilizer level experiments carried out in two seasons at Kabete lead to the following conclusions and suggestions:

1) Annett yields more than B53 and has a higher percentage of its tuber yield as ware compared to seed grades. B53 has most of its yield in the seed grades.

2) Annett can be more suited to areas with short rainy seasons than B53.

3) In potato cultivation, hill placement facilitates more efficient fertilizer use than broadcasting in the furrow.

4) Under Kabete conditions, addition of fertilizer to potato is necessary but the current recommendation seems to be higher than the most efficient fertilizer rate.

5) Plant populations higher than 44444 plants/ha do not significantly increase tuber yield but increase the proportion of the seed grades. For seed production plant a population higher than 44444 plants/ha is better. (Suggestion 2)

THE FOLLOWING SUGGESTIONS ARE MADE:

1) A fertilizer trial with a wider range of fertilizer levels is necessary to determine the most economic fertilizer level at Kabete.

2) A more sensitive spacing experiment to determine the most ideal plant populations for ware and for seed production, taking into account the economics of the production, is necessary. (Conclusion 5)

3) Testing the effectiveness of hill placement at high fertilizer levels to establish when scorching becomes a threat and pot experimentsto establish the relative efficiency of hill placement compared to broadcasting, with the aim of recommending different fertilizer rates depending on the method of application.

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Appendix 1 :

Mean Squares for total tuber yield (Kg/M^2)

Source of Variation	D.F.	Mean Square	
		Season I	Season II
Total	53		
Block	2	1.3275ns	0.5698*
Variety,V	1	5.0539**	1.7388**
Spacing,S	2	0.0939ns	0.1089ns
Fertilizer,F	2	0.1721ns	0.1198ns
VXS	2	0.2050ns	0.487ns
VXF	2	0.7665ns	0.0393ns
SXF	4	0.5600ns	0.2119ns
VXSXF	4	0.5367ns	0.2492ns
ERROR	34	0.6172	0.1657

S.E. of the mean 0.1069 0.0554

Coefficient of variation 25.55% 11.87%

* (P = 0.05)

** (P = 0.01)

Appendix 2

Mean Squares for tuber grades (Season II)

Source of Variation	D.F.	Mean Squares	
		Ware (Kg/M^2)	Big and Medium Seed (Kg/M^2)
Total	53		
Block	2	0.0160ns	0.3531ns
Variety, V	1	17.4160**	7.3667**
Spacing, S	2	2.071**	0.9964**
Fertilizer, F	2	0.0600ns	0.2732ns
VXS	2	0.6450ns	0.2537ns
VXF	2	0.0450ns	0.0168ns
SXF	4	0.2050ns	0.1266ns
VXSXF	4	0.156ns	0.1780ns
ERROR	34	0.183	0.1165

S.E. of the mean 0.008 0.006

C.V. 26.46 21.66

** (P = 0.01)

Appendix 3: Mean Squares for leaf area index

Source of Variation	D.F.	Mean Squares			
		Season I		Season II	
		L.A.I -5 weeks from Emergence	L.A.I - 9 weeks after Emergence	L.A.I - 5 weeks after Emergence	L.A.I - 9 weeks after Emergence
Total	53				
Block	2	1.546ns	3.354**	6.307**	2.515**
Variety,V	1	0.006ns	57.330**	9.951**	6.448**
Spacing,S	2	2.125ns	2.611*	3.603*	0.571ns
Fertilizer,F	2	1.397ns	0.173ns	0.478ns	0.137ns
VXS	2	0.270ns	1.661ns	1.984ns	0.051ns
VXF	2	2.231ns	0.272ns	0.059ns	0.091ns
SXF	4	1.222ns	0.879ns	2.567ns	0.274ns
VXSXF	4	0.635ns	1.044ns	0.438ns	0.262ns
ERROR	34	1.218	0.740	1.011	0.522
S.E. of the mean		0.1502	0.1171	0.1368	0.0983
Coefficient of Variation		27.77%	39.42%	27.33%	28.60%

Appendix 4

Table 1: Mean Squares for number of stems/plants at Maturity

Source of Variation	D.F.	Mean Squares	
		Season I	Season II
Total	53		
Block	2	1.6250ns	0.1791ns
Variety,V	1	11.8067*	0.0090ns
Spacing,S	2	0.3160ns	1.9457*
Fertiliser,F	2	2.4687ns	0.0601ns
VXS	2	0.5567ns	0.6080ns
VXF	2	0.1008ns	0.7635ns
SXF	4	0.5712ns	1.3393*
VXSXF	4	2.0376ns	0.3515ns
ERROR	34	0.9131	0.4654

S.E. of the mean	0.1300	0.0928
C.V.	22.86%	25.08%
*	(P=0.05)	

Appendix 4

Table 2: Mean Squares for number of tubers/plant at maturity

Source of Variation	D.F.	Mean Squares	
		First Season	Second Season
Total	53		
Block	2	20.08	12.38**
Variety,V	1	18.97ns	15.36**
Spacing,S	2	29.09ns	7.65**
Fertilizer,F	2	6.91ns	6.36*
VXS	2	7.22ns	2.81ns
VXF	2	17.79ns	3.20ns
SXF	4	5.28ns	0.75ns
VXSXF	4	4.29ns	2.71ns
ERROR	34	9.88	1.38

S.E. of the mean	0.43	0.16
C.V.	8.41%	12.71%

* (P = 0.05)
** (P = 0.01)

Appendix 5

Table 1: Mean Squares for total tuber yield (Kg/m^2)

Source of Variation	D.F.	Mean Squares	
		First Season	Second Season
Total	47		
Block	2	0.0104ns	0.1227
Variety,V	1	0.7726ns	0.7873*
Method, M	1	0.4275ns	0.7276*
Fertilizer,F	3	1.2923*	1.6764***
VXM	1	0.5875ns	0.4506ns
VXF	3	0.4544ns	0.0345ns
MXF	3	0.2059ns	0.1258ns
VXMXF	3	0.0630ns	0.0548ns
ERROR	30	0.3267	0.1133

S.E. of the mean 0.0825 0.0486

Coefficient of Variation 21.0% 9.93%

* ($P = 0.05$)

*** ($P = 0.001$)

Appendix 5

Table 2: Mean effect of Fertilizer rate and method of placement on total tuber yield (Kg/ha) of Annett and B53 (Season I)

Method	Fertilizer rate				Method Mean
	F_o	F_1	F_2	F_3	
M1	25012	29419	30051	28134	28154
M2	19788	26878	29437	28970	26268
Fertilizer Mean	22400	28148	29744	28552	28216

Table 3: Mean effect of fertilizer rate and method of placement on total tuber yield (Kg/ha) of Annett and B53 (Season II)

Method	Fertilizer rate				Method Mean
	F_o	F_1	F_2	F_3	
M1	28560	36351	36913	38692	35129
M_2	28220	33223	35607	33690	32685
Fertilizer Mean	28390	34787	36260	36191	33907

Appendix 6

Table I: Mean Squares for tuber grades (Season II)

Source of Variation	D.F.	Mean Squares	
		Ware -(Kg/plot)	Big and Medium seed (Kg/Plot)
Total	47		
Block	2	0.0900ns	0.2416
Variety,V	1	49.6845**	27.6397**
Method,M	1	0.4523ns	0.3461ns
Fertilizer,F	3	2.6293*	0.6126ns
VXM	1	0.5286ns	0.1928ns
VXF	3	0.4837ns	0.1549ns
MXF	3	0.5693ns	0.1813ns
VXMXF	3	0.0303ns	0.1913ns
ERROR	30	0.7954	0.4696

S.E. of the mean	0.1287	0.0989
Coefficient of variation	28.56%	26.37%

* $(P \simeq 0.05)$

** $(P \simeq 0.01)$

Appendix 7

Mean Squares for Leaf Area Index

Source of Variation	D.F.	Mean Squares (First Season)	
		L.A.I - 6 weeks after emergence	L.A.I - 11 weeks after emergence
Total	47		
Block	2	1.494ns	0.354ns
Variety, V	1	15.098***	43.434***
Method, M	1	0.103ns	0.644ns
Fertilizer,F	3	1.674ns	0.374ns
VXM	1	1.197ns	0.077ns
VXF	3	2.351**	0.255ns
MXF	3	0.130ns	0.122ns
VXMXF	3	0.223ns	0.149ns
ERROR	30	0.534	0.195

S.E. of the mean	0.1055	0.637
C.V.	26.87%	31.87%

** (P = 0.01)

*** (P = 0.001)

Appendix 8

Table 1: Mean Squares for number of stems/plant at Maturity.

Source of Variations	D.F.	Mean Squares	
		Season I	Season II
Total	47		
Block	2	0.0247NS	0.5109NS
Variety,V	1	35.4493**	0.1102NS
Method,M	1	3.3868NS	0.1752NS
Fertilizer,F	3	1.7826NS	2.8391NS
VXM	1	3.9387NS	0.0352NS
VXF	3	0.9075NS	1.0052NS
MXF	3	0.1297NS	0.5691NS
VXMXF	3	0.9177NS	0.2157NS
ERROR	30	0.9873	1.0542

S.E. of the mean 0.1434 0.1482

C.V. 21.95% 30.86%

** (P = 0.01)

Appendix 8

Table 2: Mean Squares for number of tubers/plant at Maturity

Source of Variation	D.F.	Mean Squares	
		Season I	Season II
Total	47		
Block	2	8.3014NS	2.3509
Variety, V	1	0.1200NS	28.0622 **
Method,M	1	1.6875NS	16.2168*
Fertilizer,F	3	54.5431*	11.0391*
VXM	1	24.0834NS	3.9103NS
VXF	3	16.2467NS	1.9202NS
MXF	3	8.5786NS	1.2367NS
VXMXF	3	0.0922NS	1.0735NS
ERROR	30	11.8055	3.4584

S.E. of the mean 0.4959 0.2684

C.V. 24.27% 16.70%

* ($P \simeq 0.05$)

** ($P \simeq 0.01$)

Appendix 8

Table 3: Effects of Treatments on number of stems/plant (Final harvest) in Exp. II, Season I.

Variety	Treatment		Blocks I	Blocks II	Blocks III	Total	Mean
Annett	M_1	F_o	3.50	3.75	5.75	13.00	4.33
		F_1	4.25	4.00	6.25	14.50	4.83
		F_2	5.25	4.50	5.25	15.00	5.00
		F_3	4.25	6.50	4.75	15.50	5.17
	M_2	F_o	6.75	3.50	4.00	14.25	4.75
		F_1	6.00	7.50	5.25	18.75	6.25
		F_2	6.00	5.75	6.25	18.00	6.00
		F_3	6.75	5.75	7.75	20.25	6.75
B53	M_1	F_o	3.50	3.25	2.75	9.5	3.17
		F_1	4.50	3.75	2.50	10.75	3.58
		F_2	3.00	3.50	5.00	11.50	3.83
		F_3	3.75	5.00	3.75	12.50	4.17
	M_2	F_o	4.50	4.25	3.50	12.25	4.08
		F_1	3.25	3.25	3.00	9.50	3.17
		F_2	3.75	3.00	3.25	10.00	3.33
		F_3	2.75	5.25	4.00	12.00	4.00

Appendix 8

Table 4: The Effect of Treatments on number of tubers/plant (Final Harvest) Expt. II, Season I.

Variety	Treatments		Blocks			Total	Mean
			I	II	III		
Annet	M_1	F_o	12.2	13.2	16.2	41.6	13.9
		F_1	10.00	19.50	11.0	40.5	13.5
		F_2	16.0	13.2	19.5	48.7	16.2
		F_3	18.7	17.2	14.5	50.4	16.9
	M_2	F_o	8.2	7.2	14.0	29.4	9.8
		F_1	14.7	10.5	14.2	39.4	13.1
		F_2	15.2	20.0	11.0	46.2	15.4
		F_3	16.2	11.5	17.0	44.7	14.9
B53	M_1	F_o	9.5	13.0	10.0	32.5	10.8
		F_1	19.2	10.2	16.7	46.1	15.4
		F_2	13.5	10.7	14.0	38.2	12.7
		F_3	11.5	18.2	16.5	46.2	15.4
	M_2	F_o	10.2	9.5	9.0	28.7	9.6
		F_1	17.0	21.5	14.5	53.0	17.7
		F_2	12.2	13.5	20.0	45.7	15.2
		F_3	12.7	14.2	21.2	48.1	16.0

Appendix 8

Table 5: Effect of Treatments on number of stems/plant (final harvest) in Expt. II, Season II.

Variety	Treatments		Blocks I	Blocks II	Blocks III	Total	Mean
Annett	M_1	F_o	2.5	5.5	2.0	10.0	3.3
		F_1	3.0	1.7	1.7	6.4	2.1
		F_2	3.5	4.0	3.0	10.5	3.5
		F_3	3.7	3.2	4.5	11.4	3.8
	M_2	F_o	3.0	3.0	2.2	8.2	2.7
		F_1	2.7	3.7	2.5	8.9	3.0
		F_2	4.2	4.5	3.2	11.9	4.0
		F_3	5.2	3.0	3.2	11.4	3.9
B53	M_1	F_o	1.7	4.5	2.5	8.7	2.9
		F_1	4.5	2.0	3.7	10.2	3.4
		F_2	3.0	4.5	4.0	11.5	3.8
		F_3	4.5	2.5	2.7	9.7	3.2
	M_2	F_o	3.5	2.2	1.7	7.4	2.5
		F_1	2.2	4.0	4.0	10.2	3.4
		F_2	4.0	4.2	4.2	12.4	4.1
		F_3	2.7	3.2	5.0	10.9	3.6

Appendix 8

Table 6: Effect of Treatments on number of tubers/plant (Final harvest) in Expt. II, Season II.

Variety	Treatments		Blocks I	Blocks II	Blocks III	Total	Mean
Annett	M_1	F_o	11.4	9.1	8.6	29.1	9.7
		F_1	9.0	11.5	13.5	34.0	11.3
		F_2	11.2	9.2	11.6	32.0	10.7
		F_3	9.6	14.2	9.1	32.9	11.0
	M_2	F_o	10.2	8.1	7.6	25.9	8.6
		F_1	9.1	11.1	9.4	29.6	9.9
		F_2	9.5	8.0	11.9	29.4	9.8
		F_3	9.4	15.9	10.7	36.0	12.0
B53	M_1	F_o	14.6	8.9	10.7	34.2	11.4
		F_1	12.6	14.0	13.5	40.1	13.4
		F_2	12.6	13.5	13.6	39.7	13.2
		F_3	13.5	13.7	12.0	39.2	13.1
	M_2	F_o	10.5	8.5	8.4	27.4	9.1
		F_1	11.7	12.4	10.2	34.3	11.4
		F_2	10.6	13.6	12.6	36.8	12.3
		F_3	11.2	13.2	9.5	33.9	11.3