THE CRITICAL PERIOD FOR WEED COMPETITION IN POTATO (Solanum tuberosum L.)

BY

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DECLARATION

This thesis is my original work and has not been presented for a degree in any other university.

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

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ABSTRACT

This thesis reports on experimental work carried out on Irish potato (*Solanum tuberosum* L.) during the 1980-81 short rains and 1981 long rains. The work was conducted at Kabete, Faculty of Agriculture Field Station, located at an altitude of 1850 m and within 1^{o} 15'S and 36^{o} 44'E. The average annual rainfall for the area is about 925 mm.

The objective of the study was to determine the stage at which weed competition affects potato growth and tuber yield most. This was done by looking at the effect of weed competition throughout the growing season on potato plant growth and tuber yield, both at various stages of growth, and at final harvest, tuber dry matter content and leaf area development.

A randomised complete block design was used with four replicates. The treatments were 16 weeding frequencies combined factorially with two potato varieties - Anett and B53 (Roslin Eburu), making a total of 32 treatment combinations.

In the 1980 short rains, due to low weed density and vigorous initial crop growth, there was no significant reduction in the final tuber yield by a delay in weeding from the 15th up to the 30th day. However, a further delay from the 30th up to the 45th day caused a final tuber yield reduction of 20% in Anett and 16% in B53. During the long rains of 1981, where weed density was very high, a delay in weeding from the 15th up to the 30th day caused a decrease in the final tuber yield of 18% in Anett and 16% in B53. A further

delay from the 30th up to the 45th day caused a yield reduction of 32 and 38% in Anett and B53 respectively.

Leaf area index showed a similar trend to the one shown by the final tuber yield. A delay in weeding up to the 45th day caused a significant drop in leaf area index during the two seasons.

The percent tuber dry matter was not significantly affected by weed competition in the two seasons.

Anett outyielded B53 during the 1980 short rains. It yielded a greater proportion of ware than B53, whose tuber yield was predominantly seed size grade.

Anett developed a peak leaf area earlier but maintained it for a shorter period than B53 in both seasons. B53 had a more developed haulm, attained peak leaf area later but maintained it for a longer duration.

B53 tubers had a significantly higher percent dry matter than Anett.

The critical weed competition period in potatoes at Kabete was found to be between the 14th and 45th day after crop emergence. During this period, the crop was growing vigorously and any weed competition adversely interfered with crop growth and tuber yield.

One weeding at 15 days after crop emergence was as good as clear weeding, giving the highest leaf area and final tuber yield which also contained the highest percentage of ware size tubers. At Kabete, one weeding at 15 days after crop emergence was therefore found to be enough and any more weedings appeared to be an unnecessary addition to the production costs.

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CHAPTER I

INTRODUCTION

THE ORIGIN OF THE POTATO (*Solanum tuberosum* L.)

The potato, which is generally known as the Irish or English potato, is an introduced crop in Kenya. It is believed to have originated in the Andean highlands of South America (Burton, 1966; Smith, 1968; Hawkes, 1978). Several species of tuber bearing wild solanum species grow in the Andean highlands, from Colombia in the north to Chile in the south. The present stock of our domestic potato was among these. It is in the highland areas of Callao in Bolivia where man first made use of the potato (Smith, 1968).

INTRODUCTION AND DEVELOPMENT OF THE POTATO IN KENYA

There are no clear records of the introduction of the potato into Kenya, but it is definite that it was introduced at the end of the nineteenth century by the British East African Trading Company.

It was first grown in the then "White Highlands" (today's Kenya Highlands) by the early settlers mainly of South African origin (Waithaka, 1976; Ballestrem and Holler, 1977). After introduction, potatoes continued to be grown only by the Europeans until about 1917/18 when Africans started growing them, but purely for home consumption, as there was no provision for marketing their produce. By the year 1921 (Waithaka, 1976), a total of about 93 hectares of potatoes were grown by the White settlers and an export crop of about 3,648 kg was sold (Waithaka, 1976). In 1938, potato export shipped from Mombasa reached a peak of 8,128 tonnes (Anon., 1938).

From this small beginning, the potato, both as food and cash crop, has today become a very popular crop in the country, playing an increasingly important role in the agricultural production and consumption pattern. By 1979, the total number of potato growers amounted to 480,000 holdings and the production area to more than 200,000 ha in pure and mixed stands. Production was estimated at 335,280 tonnes, of which more than two thirds were retained for home consumption (Homann, Wiersema, Zettelmeyer, 1979).

POTATO PRODUCTION IN KENYA

Potatoes are produced mainly on small farms in Central, Eastern and Rift Valley provinces (Homann *et. al.*, 1979). The Kenya highlands with altitudes between 1,600 m and 2,700 m are the ideal growing areas for potatoes. This range of altitude coincides with areas of Kibirichia, Molo, South and North Kinangop, Nyahururu, Nyeri, Embu, Limuru, Kiambu and Taita (Ballestrem and Holler, 1977). Such areas have adequate rainfall and low temperatures suitable for potato growth.

The importance of the crop as a cash crop is on the increase as the production area expands. Since potatoes will do well in the high potential higher altitudes where maize does not do well, there is a chance of expanding the cultivation of the crop, partly to meet the ever mounting local demand and export. Kenya possesses some 7.5 million hectares of high potential land which is suitable for the cultivation of maize (FAO, 1973). In addition, Kenya possesses 2 to 5 million hectares of high potential land which is at too high an altitude for the successful cultivation of maize. On this land, potato constitutes an alternative crop (FAO, 1973).

Despite the increased interest in potatoes and expansion in both area and production, the potato yield has remained extremely low, and production fluctuates markedly over the years. The yield per hectare varies considerably from one area to another (Table 1). The national average is about 5 t/ha. This is far below average yield in other countries (Table 2). Research trials in Kenya have recorded very high yields of over 40 t/ha (Annual Reports, 1974-1977; Holler, 1973).

Table 1: Average yields of potatoes in different areas in Kenya

Area	Average yield (tonnes/ha)
Kibirichia (Meru)	9.4
Ol Kalou	5.2
South Kinangop	5.2
Nyeri/Muranga	5.1
Kiambu	4.8
Molo area	4.5

After George Duerr, 1976/77 "Studies on the potato sector in Kenya" Interim Report Nos 1-6, International Potato Centre.

Table 2: Average yield of potatoes in different countries

Country	Average yield (tonnes/ha)
The Netherlands	33.5
United Kingdom	24.5
United States of America	24.0
Colombia	10.7
Sri Lanka	8.5
India	8.0
Venezuela	8.0
Peru	6.2
Uganda	5.0

(From D. E. Kay, 1973 "TPI Crops and Product Digest No. 2 Root Crops, p.109").

Varieties:

The potato varieties grown in Kenya can be grouped according to their maturity periods: Early maturing, 3 to 3½ months (for example Anett and Kerr's Pink), medium late maturing, 3½ to 4 months (for example Roslin Eburu (B53) and Desiree) and late maturing, 4 to 5 months (for example Kenya Baraka).

Many potato varieties exist in Kenya, but the most popular of the recommended ones are: Kerr's Pink, Anett, Kenya Baraka, Roslin Eburu (B53) and Desiree (Ballestrem and Holler, 1977).

COMPOSITION AND USE OF THE POTATO

The tuber is characterised by a starchy energy rich food. On world scale it is the fourth leading world food commodity of this type after wheat, rice and maize (Ngugi, 1978). On the world wide basis the crop produces more dry matter and protein per hectare than the major cereal crops (Gray and Hughes, 1978).

The average composition of the potato tuber is: 75 to 78% water, 1.8 to 2% protein, 17 to 20% carbohydrates, 1.2% fibre, 1.0% ash and less than 1% fat (Litzenberger, 1974). The chemical composition varies with variety, soil type, location, cultural practices, maturity time, method of vine kill, storage, environment, method of analysis used and other factors (Smith, 1968).

The above qualities make the potato a very important food crop in Kenya where the rapidly growing population must be fed. In Kenya, potatoes are prepared in various ways. In urban areas for instance, the potato chips and crisps are very popular. The potatoes are also boiled and eaten with meat and vegetables. Sometimes they are cooked, mashed and mixed with pulses and leafy vegetables.

The average potato consumption in urban areas is estimated at 14.7 kg/head/year. In Nairobi, consumption is estimated at between 18 to 60 kg/head/year. In rural areas the average consumption is estimated at 20.6 kg/head/year (Homann et. al., 1979).

The potato is also a crop for industry. It has a number of industrial uses which could make a significant contribution to Kenya's economy. These include: starch extraction, alcohol manufacture, potato crisps and instant mashed potatoes (FAO, 1973).

PROBLEMS IN POTATO PRODUCTION

The potato farmer is faced with many and variable problems most of which contribute greatly to the low yields experienced in Kenya. Some of the major problems in potato production are lack of good husbandry practices: timely weeding, seed chitting, spacing, fertilizer applications, disease and pest control methods.

While the other aspects of husbandry practices are widely talked about and crop losses from them are easily assessed, timely weeding is an aspect which is rarely remembered. It is a normal practice to clean-weed a crop in order to get a good yield. Weeding is, however, an expensive practice and therefore it is important to know the effect of weeds on the crop and the best time to weed the crop in order to get maximum returns.

Weeds:

A weed is usually defined as a plant growing where it is not wanted (Pearson, 1966). Weeds are not as spectacular as plant diseases and insects in their manner of crop destruction. Nevertheless, they cost farmers as much as both insects and diseases combined. The losses caused by weeds are manifold, some of them being so subtle as almost to escape detection. The chief losses are:

i Reduction in yield due to competition by weeds with the crop for light, water and mineral nutrients;

ii decrease in crop quality;

iii increased costs of weed control including all or nearly all of the costs of cultivation and of chemicals;

iv losses due to plant diseases and insects that are harboured and protected by the weeds;

v losses of livestock poisoned by chemicals used in weed control. Some weeds are also poisonous to the animals when eaten;

vi decrease in land value.

Weeds also interfere with harvesting, particularly weeds with tough wiry rhizomes, e.g. couch grass (Digitaria scalarum Chiov).

Other problems in potato production include lack of certified seed where up to now it has not been possible to supply all farmers with certified seed. This forces them to plant unclean seed infected with viral and other seed borne diseases like bacterial wilt (Pseudomonas solanacearum, Smith).

Potato production is also faced with a strong seasonality. Immediately after harvest there are large quantities of potatoes in the market which forces the producer to fetch extremely low prices during harvesting periods. This problem is magnified by the poor storage facilities presently available for this highly perishable crop since it is not possible to store the crop until the next harvest. Furthermore, the production costs are very high depending on the costs of inputs and the husbandry techniques applied.

It is therefore of utmost importance to find out ways and means of raising the potato yield per unit area and reducing the production costs as much as possible.

OBJECTIVE OF THE STUDY

The objective of this study was to determine the stage at which weed competition affects potato growth and tuber yield most.

CHAPTER II

LITERATURE REVIEW

The Potato Plant

The potato is usually vegetatively propagated by means of tubers normally referred to as the 'seed'.

The plant is herbaceous with spiral phylotaxis (artschwager, 1918).

The potato has a fibrous root system formed either by the seedling tap root or by adventitious roots in plants raised from tubers (Weaver, 1922).

The plant develops stolons from the most basal nodes below soil level (Kumar and Wareing, 1972). When tubers develop, they do so from the sub-apical region of stolons. However, tuber formation is regarded as the sum total of two separate processes: stolon formation and tuberization of the stolon tip (Booth, 1959, 1963). Stolon formation usually begins at the lower nodes and progresses acropetally. The first tubers, in turn, usually develop from the lower stolons and tend to become dominant over those formed later (Plaisted, 1957). The importance of the tubers is indicated by the fact that 75 to 85% of the total dry matter produced by the plant accumulates there (Ivins and Bremner, 1964).

Morphologically, the potato tuber is a modified stem with a shortened and broadened axis and rather poorly developed leaves (Artischwager, 1924).

Growth pattern:

Three main phases can be distinguished in the growth pattern of the potato (Ngugi, 1972; Moorby, 1978; Beukema and Zaag, 1979):

- Pre-emergence
- haulm growth
- tuber growth

Pre-emergence growth:

This is the time between planting and emergence of the shoots above ground (Ngugi, 1972). When the sprouted tuber is planted, the rate of sprout growth increases rapidly (Moorby, 1978). The rate of shoot and leaf formation is determined by the size of sprouts before planting, soil moisture and soil temperature (Ngugi, 1972; Beukema and Zaag, 1979). Throughout the period of emergence growth, the plant is dependent on carbohydrate reserves of the mother tuber (Moorby, 1978).

Haulm growth:

This extends from the time the shoot emerges above the ground to the time when maximum haulm growth is achieved after which foliage senesces (Ngugi, 1972). During this phase haulms and roots develop simultaneously (Beukema and Zaag, 1979). As the plant becomes autotrophic, its sensitivity to environmental factors, such as temperature, radiation, water and mineral nutrients increases (Moorby, 1978).

Tuber growth:

Tuber growth overlaps with haulm growth. Tubers may be initiated by plants over a very wide range of developmental stages varying from very early, in plants from tubers with well developed sprouts, to late, in plants with excessive haulm growth. Most tubers which grow to harvestable size are formed within a period of two weeks after tuber initiation starts (Moorby and Milthorpe, 1975).

Tuberization is hastened by short days, low temperatures, high daily radiation and low mineral nutrient supply (Slater, 1963, 1968). It is generally accepted that there is an inverse relationship between haulm and tuber growth (Moorby, 1978). For example, if haulm growth is encouraged by application of large quantities of nitrogen or early irrigation, tuber initiation is delayed. The eventual rate of tuber growth and its duration are, however, greater because of the increased size and longer persistence of the haulm (Ivins and Bremner, 1964; Gunasena and Harris, 1968; Dyson and Watson, 1971). In contrast, tuberization is encouraged if haulm growth is inhibited, for example by low temperatures (Horah and Milthorpe, 1962; Bodlaender, 1963; Burt, 1964, 1965; Gregory, 1965; Slater, 1968). The available evidence suggests that before tuber initiation the haulm is the dominant sink for assimilates but that at the time of tuber initiation there is a major diversion of assimilates to the stolons and tuber initials (Moorby, 1978).

Tuber yield is determined by rate of tuber growth (bulking rate) and the duration of bulking (Bremner and Taha, 1966). According to Bremner and Taha (1966), the duration of bulking is a function of the time of tuber initiation and the time of haulm senescence. Tuber bulking rate is also a function of leaf area index, 'L', and increases with values of 'L' up to a maximum value of about 3 (Ivens and Bremner, 1964). In their field trials, Bremner and Radley (1966) found that the rates of dry matter accumulation and tuber bulking were similar in those treatments in which the leaf area index was maintained at or above 3 for two or three weeks. Below this level growth rates and tuber bulking rates were closely related to the size of the leaf surface.

The bulking rate is exponential for the first two to three weeks after which it becomes almost linear (Moorby and Milthorpe, 1975). Soon after the assumption of this constant rate of bulking the rate of axillary branch production decreases and this leads to a decrease in the rate of production of new leaves. There is also a gradual increase in the rate of senescence of older leaves, a substantial net migration of nitrogen, phosphorus and potassium from haulm to tubers and a decrease in the dry weight of the haulm. At this time the rate of increase of the dry weight of the tubers often exceeds that of the total dry weight made by the plant. The senescence of the haulm accelerates as the tuber bulking increases and eventually becomes complete. Once the bulking rate enters its constant phase, it appears to be very insensitive to short term fluctuations of temperature and radiation. It starts to decrease when the leaf area index has decreased to about one (Moorby and Milthorpe, 1975).

Ecological Requirements

Rainfall:

An average annual rainfall of 500 to 750 mm well distributed over the growing period is required for a good crop. In water use, the potato is twice as efficient as maize, wheat, sorghum and beans in the production of food calories per litre of water (Ngugi, 1978). The water requirement of a potato crop varies with different varieties (Ballestrem and Holler, 1977). Irregular rainfall and abnormal dry weather leads to secondary tuber formation (Grosmer and Grison, 1976).

Temperature and daylength:

Generally potatoes do well in cool conditions found in the high altitude areas. Many workers have reported different ideal temperatures for potato growth. After emergence of the plants, the minimum and optimum temperatures for leaf expansion are about 7°C and 20°C respectively, whereas the optimum for stem elongation and branch production is about 25°C (Borah and Milthorpe, 1962; Bodlaender, 1963). Tuberization is best at soil temperatures of 17-18°C (McGillivray, 1961). According to Winters and Miskimen (1967), the ideal temperature range for tuberization is between 15.6 and 23.9°C. At temperatures above 26.7°C, there is little or no tuberization. Nagaich (1977) gave a temperature of 20°C as the ideal one for tuber development. The difference between day and night temperature is very important. High temperatures of up to 35°C have no negative effects if the night temperatures go down to 20°C (Ballestrem and Holler, 1977). Very high soil temperatures of above 30°C inhibit tuber growth (Moorby and Milthorpe, 1975).

Tuber initiation occurs under short day conditions (Beukeman and Zaag, 1979). The generative phase of a potato plant reaches its optimum under long day conditions. Therefore we find that most varieties do not flower under Kenyan conditions which are characterized by short day conditions (Ballestrem and Holler, 1977). There is an interaction between temperature and day length. Short day conditions and low temperatures stimulate tuber initiation (Mendoza and Haynes, 1977), while long days and high temperatures restrict tuber formation (Beukema and Zaag, 1979). High temperature and short day conditions result in an earlier initiation and development of tubers by early maturing varieties than by late maturing ones (Beukema and Zaag, 1979).

Soil:

Potatoes do well in all types of soil except the water logged ones. An ideal potato soil is deep and well drained, has a silt loam or a sandy loam texture and is slightly acidic (Smith, 1968).

<u>Competition Between Weeds and Potatoes</u>

Weeds compete with the potato crop for light, nutrient and water. Yield of tubers can be severely reduced, the size of the reduction being dependent on the density and competitive ability of the particular weed population and the availability of supplies of light, nutrients and water. The yield reductions brought about in herbicide experiments which included non-weeded and hand weeded controls typically range from 16 to 76% (Nield and Proctor, 1962). The earlier the weeds emerge in relation to the crop, the greater their competitive advantage (Makepeace and Holroyd, 1975) and yields are seriously reduced if weeds are not controlled at an early stage (Nield and Proctor, 1962;

Greig and Ap-Tikriti, 1967; Becker, 1962). Pereira (1941) showed that even small weeds at the time of potato emergence can cause a reduction in potato yield. If potatoes are chitted before planting, they emerge earlier in relation to the weeds and thus compete more effectively against them. Potato plants which are fairly large and growing actively are more capable of competing with weeds than they are at the time of emergence (Kawatei, Kitano and Shirasawa, 1958).

Annual broad leaved weeds, because of their growth habit, tend to be more competitive than annual grass weeds, and because of their speed of germination and emergence they are more competitive than perennial weeds, particularly in the earlier stages of crop development. Once the potato canopy has closed, annual weeds are effectively suppressed. Hence weeding or herbicide application is only necessary between planting and closure of the leaf canopy. The rapidly growing perennial weeds, such as creeping thistle (Cirsium arvense L. (Scop) and perennial sow-thistle (Sonchus arvense L.) can penetrate the canopy once it has closed but rarely provide serious competition. They generally emerge later than annual weeds after the crop has emerged and thus they are difficult to control with herbicides or cultivations within the growing crop. The perennial broad leaved weeds and the perennial grasses, e.g. couch grass, often make most of their growth when the potatoes begin to senesce and the canopy becomes more open (Makepeace and Holroyd, 1975).

Post Planting Cultivations in Potatoes

There is much evidence to indicate that intensive cultivations in potatoes is often unnecessary and indeed, may be harmful. In 1937, Moore, working in New York, found that there was no advantage in cultivating potatoes except for the control of weeds. Pereira (1941) and Russel (1949) found the same thing to be true in England. Aldrich, Blake and Campbell, (1954) found that more than 2 or 3 cultivations reduced potato yields.

Cultivating immediately after planting, especially if the soil is wet, results in soil compaction with a reduction in air space and destroys the soil particle aggregates necessary for good tilth. Cultivation during wet weather may be difficult or ineffective for weed control (Ingram, 1964). It stimulates germination of weed seeds (Roberts, 1963; Chancellor, 1964). Much of the effectiveness of pre-emergence application of herbicides is dependent upon this principle.

Post planting cultivations are usually aimed at increasing the amount of tilth available for incorporation into the ridge as well as controlling weeds. This objective is not always achieved (Kouwenhoven, 1967) and if an adequate ridge can be built at or immediately after planting, further inter-row cultivations can be avoided and residual herbicides used to control weeds.

However, the solution in Kenya is not really the use of herbicides. For one reason, these herbicides are very expensive and the present potato yields are very low compared to those in temperate countries where the use of herbicides is very advanced. The other reason is that cash returns from crops in the tropics are low and cannot support the expensive chemicals to replace manual work (Wrigley, 1968). Any money available for crop protection is used to buy insecticides and fungicides before herbicides (Almond and King, 1955). In fact, in some experiments carried out in India, hand weeding was found to be more economical where maximum net return is aimed at (Panje, 1968).

Critical Period of Weed Competition

There is much evidence to show that there are certain stages of crop growth when the presence of weeds no longer affect the growth and yield of a crop adversely (Gurnah, 1974). Each crop has its own critical weed competition period. "This is the period during the growth of the crop when the presence and competition of weeds is harmful to the crop" (Nieto Brando and Gonzalez, 1968; Gurnah, 1974). Nieto *et. al*. (1968) observed that in some parts of the world, farmers lay a great deal of money on continuous weed control under the impression that, the more cultural care is taken, the higher the production will be, but they forget that yield is a genetic factor which cannot be modified by further weeding; it only results into higher production costs. Thus weeding costs can be reduced by keeping the crop weed free only during the critical period.

The exact time and duration of critical weed competition differs very much in crops. Some crops are better weed competitors than others. In Mexico, work on maize and beans showed that if the crops are kept weed free during the first 30 days, maximum yields may be obtained (Nieto *et al*., 1968). They found maize to be a better weed competitor than beans.

In West Indies, Kasasian and Seeyave (1969), working with several crops, found optimum yield in beans when kept weed free during the period between second and fourth week after germination. For tomatoes, they found the critical weed competition period to be the first month after transplanting. In sweet potatoes, it was found that keeping the crop weed free for the first three weeks was as good as keeping it weed free for all the time. Pigeon pea gave near optimum yield when kept weed free for the first seven weeks. All these crops give a good ground cover eventually which suppresses weeds. In yams, they found that weeds continue to depress the yield for a longer period than in other crops since the crop does not give a full ground cover.

In Trinidad, work on sugarcane indicated that weed infestation during the first 12 weeks after planting reduced the yield of cane significantly but those weeds that germinated after that seemed to have little effect (Lamuse, 1965). Experiments with the same crop in Kenya at the Associated Sugar Company, Ramisi, showed a significant reduction in cane yield due to weed competition between 30 and 90 days after planting (Abubaker, 1978).

In Zimbabwe, an experiment with cotton showed that this crop needed to be weeded only between the sixth and eighth weeks after emergence (Schwerzel and Thomas, 1971).

In Tanzania, Enyi (1973), analysing the effect of weed competition on growth and yield attributes in Sorghum (<u>Sorghum vulgare</u> Pers.), cow peas (<u>Vigna unguiculata</u> L.) and green gram (<u>Phaseolus aureus</u> Roxb.) found that in each of the crops studied, weeding increased grain yield; weeding 2 weeks after sowing was better than weeding 4 or 8 weeks after sowing and weeding at two and four weeks after sowing was better than weeding either two or 4 weeks only or 4 and 8 weeks only after sowing. Weeding thrice (2, 4 and 8 weeks after sowing) was significantly superior to all the other weeding treatments. Weeding increased leaf area, dry weight of side and main stem and number of mature pods at harvest in green gram and cow peas. In sorghum, apart from increasing leaf area index, it also increased the length of ears and grain weight per unit length of ear.

In the Sudan, Gezira, two weedings at 30 and 60 days after planting were enough to give the best yields in groundnuts (Ishag, 1971).

In Nigeria, the critical weed competition period in cassava was found to be during the third month after planting (Onochie, 1975).

In an experiment with sugarbeets, weeds were allowed to grow for different periods after sowing the sugar beet; they were then removed and the beets hand-weeded until harvest. They were also hand-weeded for different periods after planting and then no more weeding was done. Weed competition reduced beet yields by up to 94%. Weeds that emerged soon after the beet was sown reduced yields the most. Those weeds that emerged later were controlled by crop competition (Dawson, 1965).

The extent of yield reduction by weed competition is dependent on weed density. This was shown in an experiment conducted by Reeves in 1976, in which he analysed the effect of annual rye grass (<u>Lolium rigidum</u> Guad) on the yield of wheat. He found that the presence of rye grass decreased the dry matter production and grain yield of wheat by reducing the number of fertile tillers and spikelets. Significant reduction in dry matter occurred within the third week in 1972 and within the sixth week in 1973. Thus competition occurred early in the growing season. The extent of yield reduction was dependent on the rye grass density.

The intensity of competition is also dependent upon the species of weeds. This was concluded in an experiment on the nature of competition between cereal crops and annual weeds by Blackman and Templeman (1938). They analysed the effect of different weed species on cereal crops and found that in all, weeds depress cereal yields, but the extent of yield reduction was dependent upon the weed species. In another experiment by Swain, Nott and Trouch (1975), it was found that where high population of Cyperus difformis L. competed with rice, yields were reduced by 22 to 43%. When maize was seeded into plots with six week old Grant Foxtail, corn height, fresh weight and dry weight were reduced by as much as 90%, when compared to the comparable plants grown in monoculture (Bell and Koeppe, 1972).

The results of field trials conducted in Poland to determine the effect of the final level of weed infestation on the yield of potatoes showed that, at a level of weed infestation of 0.5 t dry matter per hectare (DM/ha), a linear relationship existed between the tuber yield and the weight of weeds. An increase in weight of weeds of 0.1 t/ha resulted in a tuber yield decrease of 0.5 to 0.7 t/ha. With increasing weight of weeds, there was a significant increase in the number of small tubers (less than 40 g) in the yield and a decrease in the number of large tubers (over 100 g). No significant change in the starch content of the tubers was found but the number of tubers per plant and average tuber weight significantly decreased. At a level of infestation of 2.0 tonnes of weed DM/ha, as much nitrogen, phosphorus and potassium was taken up by the weeds as was contained in 10.0 tonnes of the tuber yield. Contents of phosphorus and potassium in weeds were much higher than those in potatoes (Radecki, 1979).

Sonmex and Karaca (1975) carried out trials on a clay loam soil in Bolu (Turkey) infested with 238 and 423 weeds/m^2; the main species were Sinapis arvensis L., Chenopodium album L. and Avena fatua L. Weed counts were made seven times at 15 to 110 days after crop emergence; weeding from the 15th to the 45th or 49th day increased the yield by 93 to 215% compared with unweeded controls.

In several potato growing areas of lower Saxony (Germany), results of field trials showed that potato tuber yield were correlated with weed density. The economic threshold for weed control was less than 2% weed infestation or 2.9 to 6.0 weeds/m^2 (Funch, Reschke and Heitefuss, 1975).

In Wageningen (Netherlands) studies were made to find out the effect on potato yields when weed growth in the crop is permitted during the early stages of growth. Where weeds were permitted to grow during the first month after planting tuber yields were reduced by an average of 20% compared with controls in which no weeds were allowed to grow during the entire growing season. Where all weed control was omitted throughout the growth of the potatoes, yields were reduced by 30%

compared with controls weeded for the first month only after planting. In other trials, where application of 46 kg nitrogen and 28 kg P_2O_5 per hectare were made at the time of planting, the yield reductions caused by weed growth were largely eliminated (Van Hiele, 1952).

CHAPTER III

MATERIALS AND METHODS

EXPERIMENTAL SITE

The experiment was conducted at the Faculty of Agriculture Field Station of the University of Nairobi at Kabete. The station is at an altitude of about 1850 m above sea level. It is within latitude 1° 1'S and longitude 36° 44'E.

The soil in this area has been described as red to strong brown, friable clay, with laterite (Gethin-Jones and Scott, 1958) - cited by Nyandat and Michieka (1970). Scott (1961) - cited by Nyandat and Michieka (1970) - placed the soil under a red friable clay. According to Nyandat and Michieka (1970), the clay mineral is predominantly kaolin and the parent material is the Kabete Trachyte. The pH of the top soil ranges between 5.2 and 7.2 and that of the subsoil 5.2 to 7.7. The available nutrients - potassium, calcium, magnesium and phosphorus - range from deficiencies to fairly high levels. The soil is well drained.

The data from laboratory analysis of soil samples taken from the sites of both experiments are presented in Appendix I.

On the first site the soils were moderately acidic with adequate levels of bases (potassium, calcium and magnesium). Available phosphorus was just above the threshold level (20 ppm). Organic carbon (and hence total nitrogen) was adequate. The second site had slightly acid soils with ample contents of bases. Available phosphorus was deficient to just adequate.

Organic carbon was moderate.

The field is usually under rotational cropping and before this experiment it was under grass.

RAINFALL

The average rainfall for Kabete is 925 mm. There are two rainy seasons. The long rains occur during the months of March, April and May and the short rains in October, November and December. The same trial was planted twice; first during the short rains of 1980 and again during the long rains of 1981. The rainfall data is presented in Appendix II.

PLANTING MATERIAL

Two potato varieties were planted: Anett and Roslin Eburu (B53). These two varieties are very popular and widely grown in Kenya.

Anett is a variety of German origin. It is early maturing (3-3½ months) and high yielding. B53 is of Scottish origin, which is medium to late maturing (3½-4 months) and medium to high yielding.

During the first season 'seed' tubers were chitted with rindite at the rate of 0.5 cc/kg. Rindite is a growth stimulant made by mixing: Ethylene chlorohydrin, Ethylene Dichloride and Carbon Tetrachloride in the ratio of 7:3:1 respectively. Potato tubers of known weight were put in a polythene bag and the correct amount of rindite was soaked in cotton waste and put in the polythene bag. The bag was tied airtight and left for about thirty hours for the chemical to diffuse into the tubers. After this period the tubers were spread on a floor and in about two weeks time they had developed sprouts approaching 2 cm in length. Planting was done at this stage of sprout development.

During the second season, there was a 'seed' shortage in the country. The only available seed which also came very late in the season was not properly sprouted. This was naturally sprouted as there was no time to treat it with rindite for proper sprouting.

All the seed tubers planted during the two seasons were 35-45 mm (medium size) basic seed from the National Potato Research Station, Tigoni.

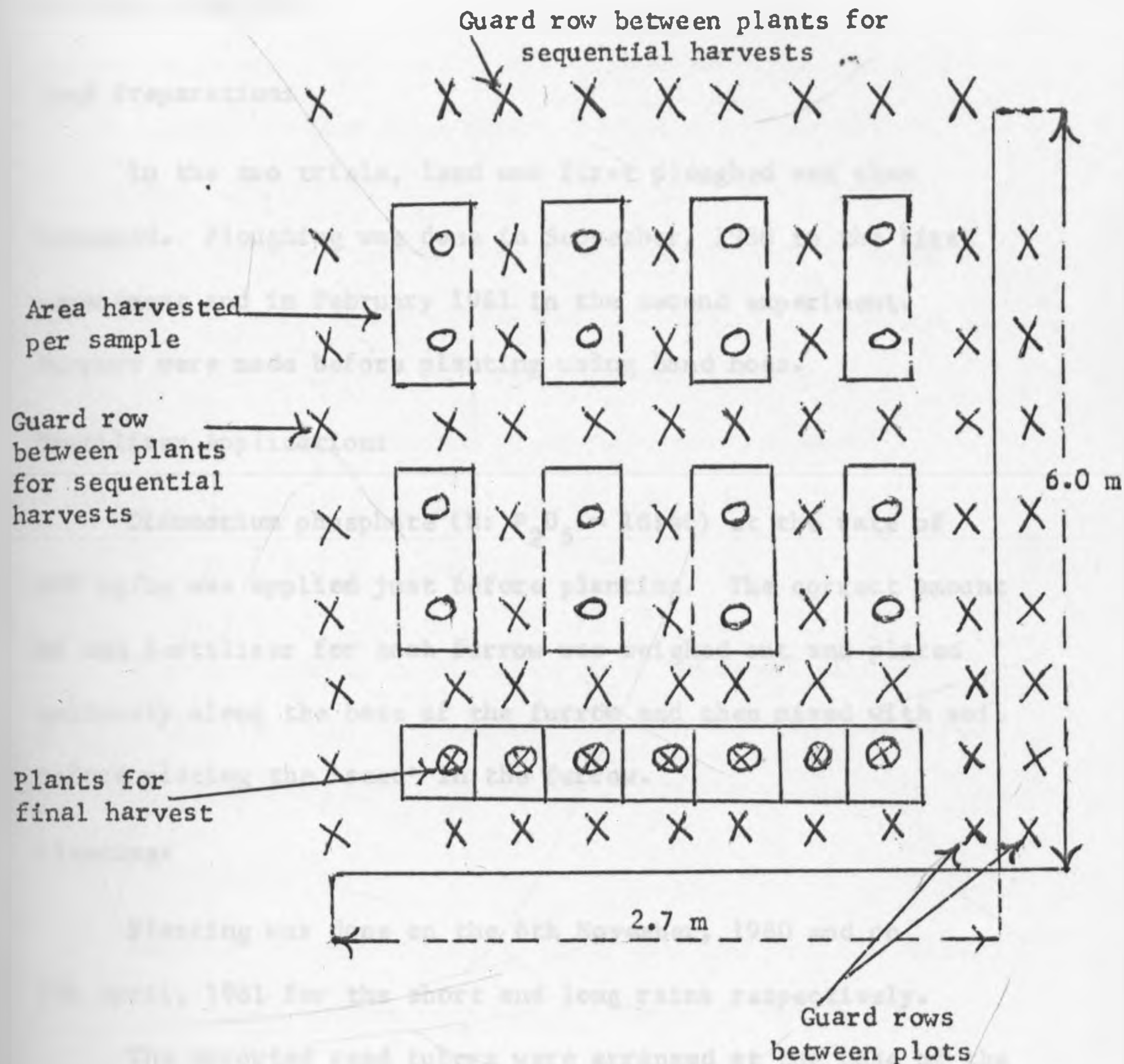
EXPERIMENTAL DESIGN

A randomised complete block design was used with four replicates. There were two varieties, Anett and B53 and 16 weeding frequencies (Table 3). This gave 32 treatment combinations of variety and weeding frequencies. The total number of plots was therefore 128.

Each block had 32 plots each of which consisted of 81 plants which comprised 16 plants for 8 sequential harvests (one harvest consisting of 2 plants) and 7 plants for final harvest at the end of the season. The rest were guard rows. Each of the 2 plants for one harvest was surrounded by one guard row. The 7 plants for the final harvest were also surrounded by a guard row. Each plot was surrounded by its own guard row, such that there were 2 guard rows between 2 plots (fig. 1).

Table 3: Weeding frequencies

Weeding treatment	Time of weeding (days after crop emergence)
1	- (unweeded control)
2	15
3	30
4	45
5	60
6	15, 30
7	15, 45
8	15, 60
9	30, 45
10	30, 60
11	45, 60
12	60, 75
13	15, 30, 45
14	45, 60, 75
15	15, 30, 45, 60
16	15, 30, 45, 60, 75



Key X plants for guard rows

0 plants for sequential harvesting

⊗ plants for final yield

Fig. 1: Diagramatic representation of plant arrangement and sampling areas in one plot

CULTURAL PRACTICES

Land Preparation:

In the two trials, land was first ploughed and then harrowed. Ploughing was done in September, 1980 in the first experiment and in February 1981 in the second experiment. Furrows were made before planting using hand hoes.

Fertilizer Application:

Diammonium phosphate (N: P_2O_5 = 18:46) at the rate of 500 kg/ha was applied just before planting. The correct amount of the fertilizer for each furrow was weighed out and placed uniformly along the base of the furrow and then mixed with soil before placing the 'seed' in the furrow.

Planting:

Planting was done on the 6th November, 1980 and on 7th April, 1981 for the short and long rains respectively.

The sprouted seed tubers were arranged at the base of the furrow at a spacing of 30 cm within the row. The furrows were 75 cm apart.

Management:

Weeding was one of the treatments; so this was done according to the given frequencies (Table 3). All weedings were done by hand one day after the sampling.

Late blight (<u>Phytophthora</u> <u>infestans</u>. Mont.) were the major disease problem in the field, but this was adequately controlled by spraying with Dithane M45. Insect pests were not a major problem. However, Rogor-L, mixed with Dithane M45 was used during the spraying to control the insects using a knapsack sprayer. Dithane M45 was sprayed at a rate of 2 kg in 500 litres of water per hectare. Rogor-L was mixed with the Dithane solution at the rate of 1.25 ml/litre. During the first season it was possible to control blight by spraying once every 14 days as the season was not very wet. However, during the second season, it was found necessary to spray at an interval of 7 days because it was very wet and such conditions are known to favour the growth of the fungus.

WEED FLORA

As the intensity of competition is dependent upon the species of weeds, the weed species from the experimental plots were collected and identified during the two seasons.

SAMPLING PROCEDURE

Sampling started two weeks after emergence of the crop. On average, the potatoes took about 2 weeks to emerge in season I and 4 weeks in season II. Emergence dates were taken when about 75% of the potatoes had emerged. Due to varietal differences, Anett emerged 3 days earlier than B53. Consequently, Anett was throughout sampled 3 days earlier than B53.

In order to determine the exact stage at which weed competition affect potato growth, both potato plants and the weeds were sampled at an interval of 2 weeks. Each sample consisted of 2 potato plants per plot and all the weeds within that particular area covered by the 2 plants. For weed sampling, a quadrant, measuring 150 by 30 cm, was used. This was the area covered by two plants in two different rows. The quadrant was placed on the ground with the two plants and all the weeds within that area. The weeds were then uprooted, roots discarded and the aerial growth put in a properly labelled paperbag. The two potato plants were finally lifted using hand forks. The roots were removed and discarded and the aerial parts put in a paperbag. The tubers were put in a separate paperbag.

The samples were taken to the laboratory where the aerial parts were separated into stems and leaves. All dead leaves were thrown away. The leaves were used for the determination of leaf area index. The disc method (Watson and Watson, 1953) was used, with some modifications from the original method. From each lot of leaves for the two plants, leaves were picked at random and punched using punches of known cross sectional area. One hundred discs were punched from each lot, put in a small paperbag and placed in an oven to dry. Only whole discs were included as per Bremner and Taha (1966). The rest of the leaves were also put in a paperbag and dried in the same oven. The potato stems and the big weed stems were cut into small pieces to enhance drying for dry matter determination.

During the 1980 short rains, tuber fresh weights were not taken due to much work and labour shortage. However, in the 1981 long rains tuber fresh weights were taken at every sampling. After taking the fresh weights, the tubers were cut into thin slices to facilitate quick and even drying.

All these organs: leaves, stems and tubers, along with the weeds, were dried in ovens and when completely dry, their dry weights were taken. The drying was done in different ovens all set at 100°C. The leaves, stems and weeds took 3 days to dry while the tubers took 5 to 6 days.

The dry weights of the leaves and the 100 leaf-discs were used to calculate the leaf area by simple proportion.

Final Harvest:

During the plan of the experiment, eight samplings had been planned for, but by the end of the 5th sampling during the two experiments, the crop was mature and most of the haulms dry. The final harvest was then taken after the 5th sample.

At the final harvest the following measurements were taken:

i The total tuber weight from which tuber yield/ha was calculated;

ii the tubers were then divided into 3 size grades:

- large: over 55 mm in diameter
- medium: between 45 and 55 mm diameter
- small: under 45 mm

The fresh weights of individual grades were taken. Samples were then taken from these grades, sliced and oven dried for dry matter determination.

STATISTICAL ANALYSIS -

All the data was subjected to analysis of variance (ANOVA). The Duncan's New Multiple Range Test was used for the separation of means (ANOVA tables are given in the appendices).

CHAPTER IV

RESULTS

GENERAL OBSERVATIONS

In general, the 1980 short rains crop was more vigorous in growth than that of the 1981 long rains. This can best be explained by the condition of the planting material. During the short rains of 1980, the seed was properly chitted before planting and consequently the emergence was very good. In two weeks' time after planting, about 75% of the potatoes had already emerged.

In the 1981 long rains, there was a seed shortage in the country and the only available ones, which also came very late, were not properly sprouted before planting. Consequently, this crop took about four weeks to attain 75% emergence.

Weed density was much higher during the 1981 long rains than in the 1980 short rains. Before ploughing to plant the potato crop, each field was under natural grass. The grass in the field of 1981 experiment, however, was mixed with large quantities of broad leaved weeds which left their seeds in the ground. These germinated in great masses after ploughing.

In some cases, high coefficients of variation (CVs) have occurred, for example in the analysis of leaf area index ('L'), tuber fresh weight, leaf and stem dry matter. A lot of care was of course taken during sampling and the processing of the materials in various ways. However, it should be realised that the experiment was quite big and involved a lot of seed tubers. It was therefore not easy to have a very uniform seed all the way through. This led to some age variations in plants sampled at the same time. This situation was worse in season II where emergence was not good.

It should also be noted that the samples were very many and some processes were quite tedious, for example the disking process to get leaf area index. All these factors put together might have contributed to the high CVs.

EFFECT OF VARIETY AND WEEDING TREATMENTS ON TUBER FRESH WEIGHT (T/HA)

Due to much work and labour shortage during the 1980 short rains, it was not possible to take tuber fresh weights. Tuber fresh weights were, however, taken in the 1981 long rains experiment.

Varietal effects:

In the 1981 long rains, varietal effects on tuber fresh weight were only significant ($P = 0.05$) at the 1st and 2nd harvests (15 and 30 days after crop emergence) as can be seen in Appendix III. During these harvests, Anett had a significantly ($P = 0.01$) higher tuber fresh weight than B53 (Table 4).

It had started tuberization earlier than B53 and therefore it had more tubers than B53 during the first two harvests. After the two harvests, B53 caught up with Anett and during the last three harvests (at 45, 60 and 75 days after crop emergence), the differences in tuber fresh weight in Anett and B53 were not significant.

Table 4: Effect of weeding treatments on tuber fresh weight (t/ha) of Anett and B53 during the long rains, 1981

Weeding treatment	Anett					B53				
	Days after crop emergence					Days after crop emergence				
	15	30	45	60	75	15	30	45	60	75
1	0.90	7.51	10.01	10.01	10.60	0.30	5.42	9.59	10.20	10.79
2	0.89	7.78	15.79	18.80	18.81	0.34	6.51	16.21	18.00	18.40
3	1.00	7.20	13.38	15.36	15.38	0.33	5.47	13.00	15.00	15.40
4	0.90	7.31	9.99	10.43	10.60	0.31	5.60	9.45	10.33	10.82
5	0.89	7.42	10.02	10.55	10.59	0.29	5.40	9.63	10.29	10.68
6	1.01	8.89	16.00	18.79	18.84	0.35	6.69	16.25	18.09	18.10
7	0.92	9.00	16.01	18.62	18.80	0.34	6.48	15.98	17.90	18.49
8	0.98	8.80	13.99	18.80	18.79	0.29	6.51	16.45	18.10	18.21
9	0.98	8.80	15.99	18.80	18.79	0.29	6.51	16.45	18.10	18.21
10	1.00	7.80	13.20	15.40	15.46	0.30	6.69	13.01	14.99	15.20
11	0.91	7.78	10.20	10.33	10.63	0.29	5.60	9.55	10.29	10.79
12	0.88	6.99	9.89	10.65	10.65	0.31	5.51	9.60	10.40	10.81
13	1.01	8.79	16.01	18.76	18.79	0.31	6.60	15.99	18.08	18.50
14	0.92	7.21	10.13	10.57	10.66	0.29	5.69	9.63	10.43	10.80
15	0.89	8.97	15.69	18.82	18.86	0.35	6.67	16.31	17.98	17.99
16	1.01	9.01	16.02	18.84	18.83	0.36	6.70	16.38	18.00	18.47
Variety mean	0.94	8.09	13.22	15.04	15.11	0.32	6.01	13.13	14.58	14.93

Weeding effects:

At the first harvest (15 days after crop emergence), weeding treatments had not started since weeding was always done one day after potato harvest. At this time, tuber fresh weights were fairly uniform for all the treatments in both Anett and B53 (Table 4).

At 30 days after crop emergence (2nd harvest), weeding treatment effects on tuber fresh weights were not significant (Table 4). However, some slight differences could be noted in the tuber fresh weight among the treatments. In both Anett and B53, all those plots which were weeded at 15 days after crop emergence (treatments 2, 6, 7, 8, 13, 15 and 16) had a slightly higher tuber fresh weight at 30 days than the remaining plot (treatments 1, 3, 4, 5, 9, 10, 11, 12 and 14) whose weeding treatments had not commenced as yet.

At 45, 60 and 75 days after crop emergence (3rd, 4th and 5th harvests) the effects of weeding treatments on tuber fresh weights were significant (P = 0.05). The weeding x variety interactions were not significant and therefore only the means of the two varieties (Table 5) were considered.

During those three harvests, treatment 1 (the zero weeding) and treatments 4, 5, 11, 12 and 14 weeded once at (or with other weedings after) 45 or 60 days after crop emergence did not have any significant (P = 0.05) difference in tuber fresh weight and had the lowest (P = 0.05) tuber fresh weight at each of the three harvests (Table 5 and fig. 2).

Treatments 2, 6, 7, 8, 13, 15 and 16 weeded once at (or with other weedings after) 15 days did not have any

Table 5: Mean effect of weeding treatments on tuber fresh weight (t/ha) at 45, 60 and 75 days after crop emergence during the long rains, 1981

Weeding treatment	Days after crop emergence 45	60	75
1	9.80a	10.40a	10.71a
2	16.00b	18.40b	18.61b
3	13.19c	15.18c	15.39c
4	9.72a	10.38a	10.71a
5	9.83a	10.42a	10.64a
6	16.13b	18.44b	18.47b
7	16.00b	18.26b	18.65b
8	16.22b	18.45b	18.50b
9	13.10c	15.29c	15.40c
10	13.11c	15.20c	15.33c
11	9.88a	10.31a	10.71a
12	9.75a	10.53a	10.73a
13	16.00b	18.39b	18.65b
14	9.88a	10.50a	10.73a
15	16.00b	18.40b	18.43b
16	16.20b	18.42b	18.65b

Means under the same column with letter 'a' are significantly (P = 0.05) different from those means with letter 'b'. Means under the same column with letter 'c' are not significantly (P = 0.05) different from either those means with letter 'a' or those with letter 'b'.

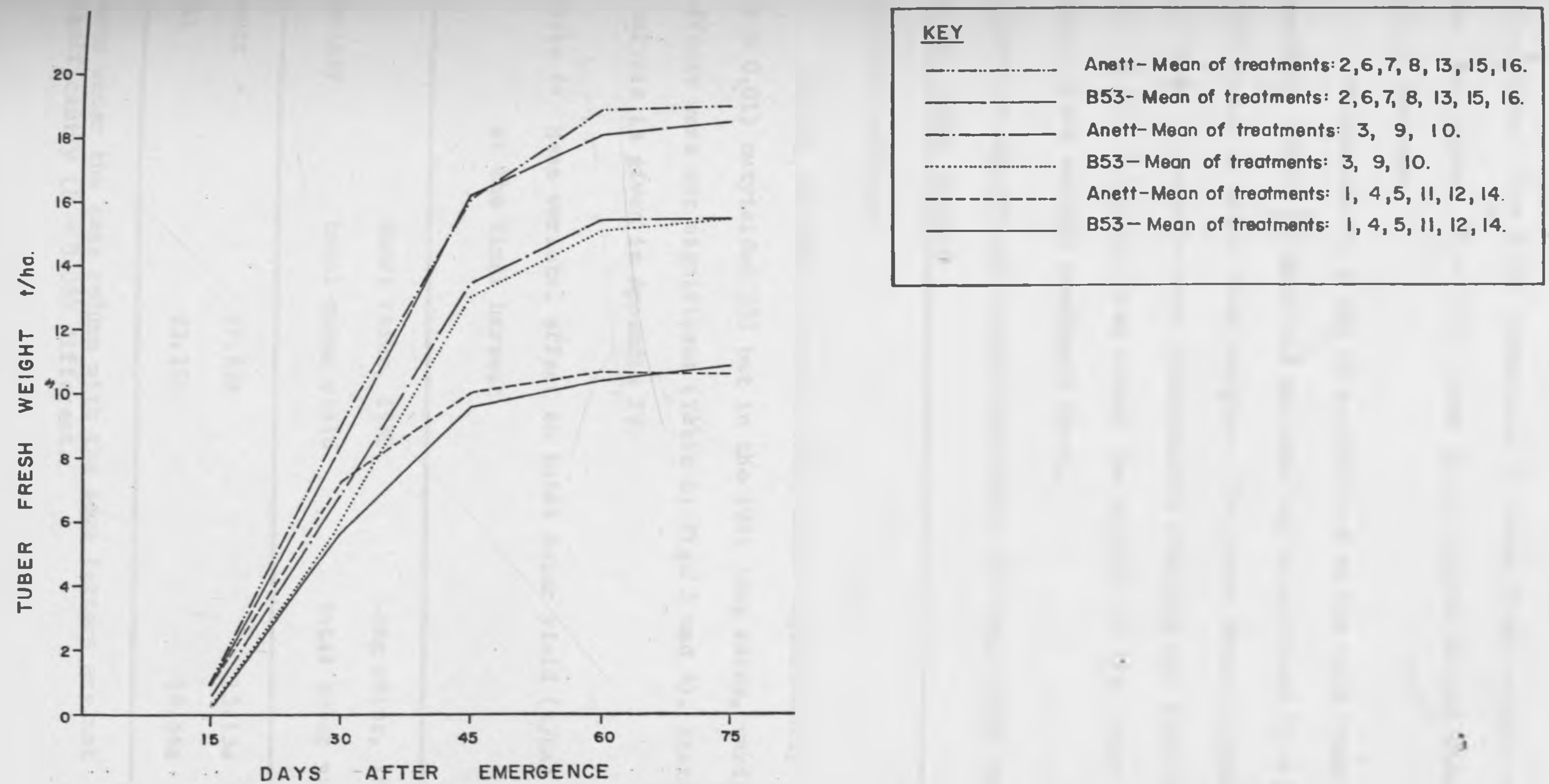


Fig. 2 : EFFECT OF TREATMENT ON TUBER FRESH WEIGHTS DURING LONG RAINS, 1981.

significant (P = 0.05) difference in tuber fresh weights and had the highest (P = 0.05) tuber fresh weights during these three harvests.

Treatments 3, 9 and 10 weeded once at (or with other weedings after) 30 days did not have any significant (P = 0.05) difference in tuber fresh weights. The tuber fresh weights of these treatments were intermediate and were not significantly (P = 0.05) different from either the highest or the lowest tuber fresh weights mentioned above.

EFFECT OF VARIETY AND WEEDING TREATMENTS ON TOTAL TUBER YIELD AT THE FINAL HARVEST

Varietal effects:

During the short rains of 1980, Anett significantly (P = 0.01) outyielded B53 but in the 1981 long rains, varietal effects were not significant (Table 6; Figs 3 and 4). Statistical analysis is given in Appendix IV.

Table 6: Mean varietal effect on total tuber yield (t/ha) at the final harvest

Variety	Short rains, 1980 total tuber yield	Long rains, 1981 total tuber yield
Anett	27.85a	15.13a
B53	23.15b	14.54a

Means under the same column with the same letters are not significantly (P = 0.05) different.

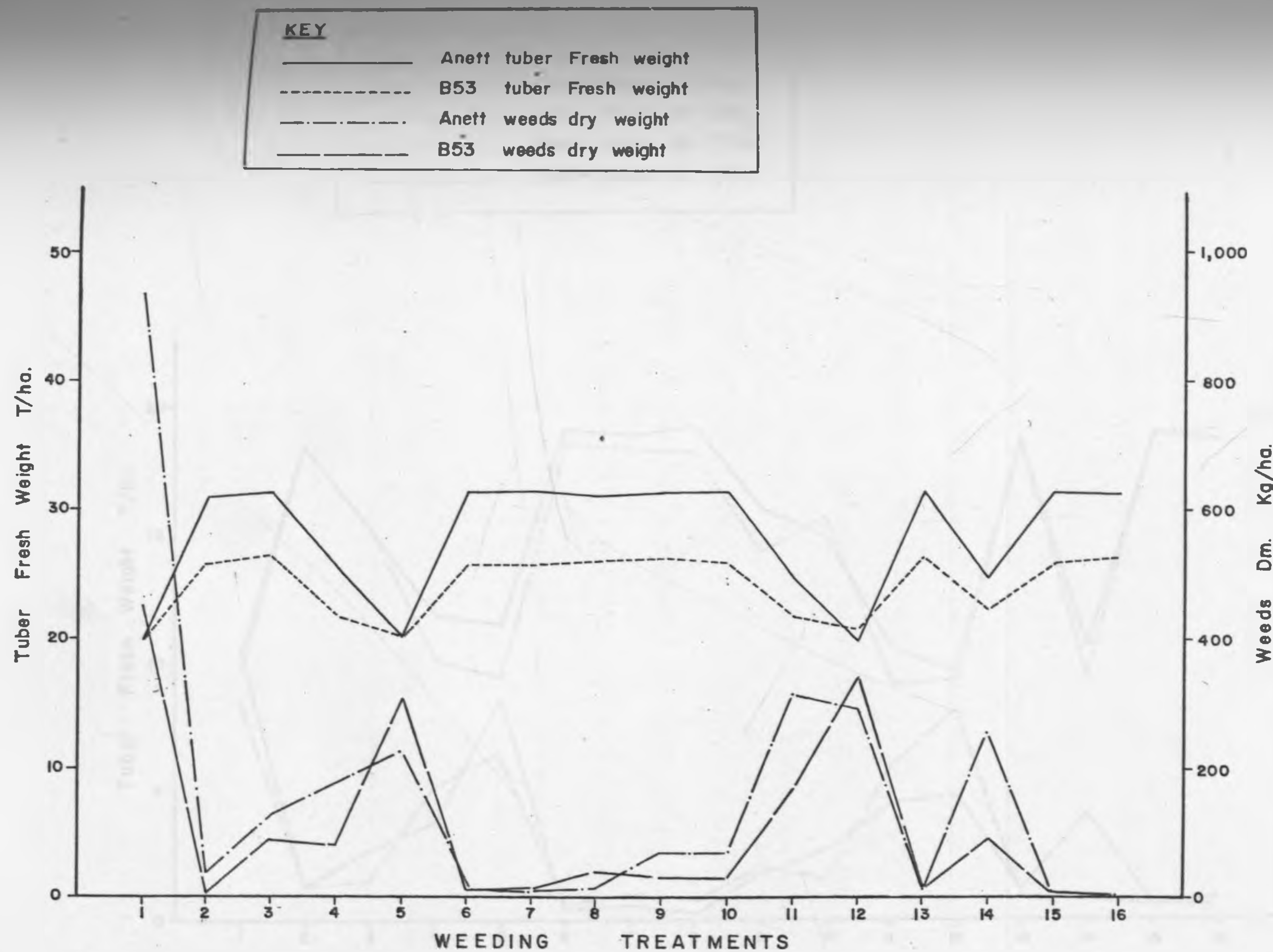


Fig. 3 : EFFECT OF TREATMENTS ON TUBER FINAL YIELD AND WEED DRY MATTER: SHORT RAINS, 1980.

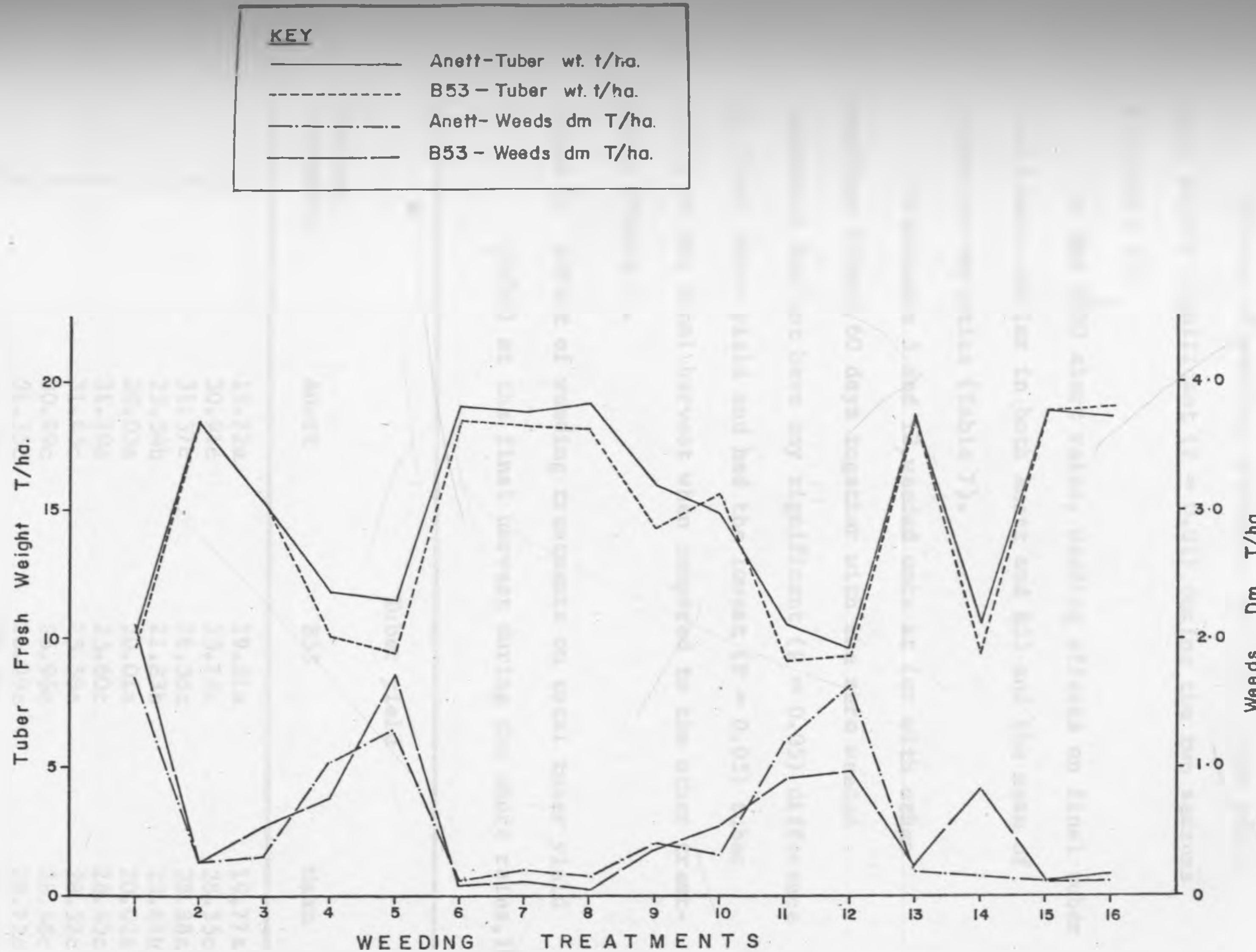


Fig. 4 : EFFECT OF TREATMENTS ON TUBER FINAL YIELD AND WEEDS DRY MATTER : LONG RAINS, 1981.

Weeding effects:

Effects of weeding treatments on final tuber yield were highly significant (P = 0.01) during the two seasons (Appendix IV).

In the 1980 short rains, weeding effects on final tuber yield were similar in both Anett and B53 and the mean of these two varieties (Table 7).

Treatments 5 and 12, weeded once at (or with other weedings after), 60 days together with the zero weeded treatment did not have any significant (P = 0.05) difference in final tuber yield and had the lowest (P = 0.05) tuber yield at the final harvest when compared to the other treatments (Table 7).

Table 7: Effect of weeding treatments on total tuber yield (t/ha) at the final harvest during the short rains, 1980

	Tuber yield		
Weeding treatment	Anett	B53	Mean
1	19.72a	19.81a	19.77a
2	30.91c	25.78c	28.35c
3	31.37c	26.38c	28.88c
4	25.54b	21.83b	23.69b
5	20.03a	20.01a	20.02a
6	31.30c	25.60c	28.45c
7	31.45c	25.58c	28.52c
8	30.99c	25.96c	28.48c
9	31.35c	26.09c	28.72c
10	31.37c	29.90c	28.64c
11	24.76b	21.72b	23.24b
12	19.91a	20.13a	20.02a
13	31.27c	26.44c	28.86c
14	24.89b	22.14b	23.52b
15	31.37c	25.90c	28.64c
16	31.33c	26.42c	28.88c

Yields with the same letters under the same column are not significantly (P = 0.05) different.

Treatments 4, 11 and 14 weeded once at (or with other weedings after) 45 days after crop emergence did not have any significant (P = 0.05) difference in final tuber yield. These treatments significantly outyielded (P = 0.05) treatments 1, 5 and 12 mentioned above, in the 1980 short rains.

Treatments 2, 3, 6, 7, 8, 9, 10, 13, 15 and 16 weeded once at (or with other weedings after) 15 or 30 days after crop emergence did not have any significant difference in final tuber yield and had the highest (P = 0.05) tuber yield at the final harvest of the 1980 short rains.

During the long rains of 1981 weeding effects on final tuber yield were similar in both Anett and B53 (Table 8). The effects were as follows:

Table 8: Effect of weeding treatments on total tuber yield (t/ha) at the final harvest during the long rains of 1981

	Tuber yield		
Weeding treatment	Anett	B53	Mean
1	10.39a	9.71a	10.05a
2	18.85b	18.48b	18.67b
3	15.38b	15.25b	15.32b
4	11.14a	10.10a	10.62a
5	11.05a	9.42a	10.24a
6	19.10b	18.45b	18.78b
7	18.78b	18.25b	18.52b
8	19.13b	18.05b	18.59b
9	15.96b	15.20b	15.58b
10	15.27b	15.60b	15.44b
11	10.51a	9.18a	9.85a
12	9.72a	9.33a	9.53a
13	18.60b	18.57b	18.59b
14	10.59a	9.39a	9.99a
15	18.92b	18.68b	18.80b
16	18.61b	19.05b	18.83b

Yields with the same letters under the same column are not significantly (P = 0.05) different.

Treatments 4, 5, 11, 12 and 14 weeded once at (or with other weedings after) 45 or 60 days together with the zero weeding treatment 1 did not have any significant (P = 0.05) difference in final tuber yield and had the lowest (P = 0.05) tuber yield in the 1981 long rains.

Treatments 2, 3, 6, 7, 8, 9, 10, 13, 15 and 16 weeded once at (or with other weedings after) 15 or 30 days after crop emergence did not have any significant (P = 0.05) difference in final tuber yield and had the highest tuber yield in the 1981 long rains. Although yields from these treatments were not significantly (P = 0.05) different from each other during this season, yields from treatments 2, 6, 7, 8, 13, 15 and 16 weeded once at (or with other weedings after) 15 days were slightly higher than yields from treatments 3, 9 and 10 weeded at 30 days after crop emergence as shown in Table 8.

EFFECT OF VARIETY AND WEEDING TREATMENTS ON TUBER GRADING AT THE FINAL HARVEST

Varietal effects:

During the two seasons, Anett had a significantly (P = 0.01) higher percentage of its yield in the large grade than B53, while B53 had a significantly (P = 0.01) higher percentage of its yield in the small grade than Anett. In the 1980 short rains, B53 had a significantly (P = 0.05) higher percentage of its yield in the medium grade than Anett. In the long rains of 1981 varietal differences on the medium grade were not significant (Table 9).

Table 9: Mean effect of varieties on tuber grades at the final harvest

	Short rains 1980			Long rains 1981		
	% of total tuber fresh wt			% of total tuber fresh wt		
Variety	Large	Medium	Small	Large	Medium	Small
Anett	34.73a	35.09a	30.23a	24.37a	27.76a	47.91a
B53	9.97b	40.31b	49.84b	18.84b	29.02a	52.16b

Means with the same letters under the same column are not significantly (P = 0.05) different.

Weeding effects:

During the short rains of 1980 weeding effects on tuber grading were not significant (Appendix V and Table 10).

In the 1981 long rains, weeding effects on tuber grading were significant (P = 0.05). The results are given in Table 11.

In both Anett and B53 treatments weeded once at (or with other weedings after) 15 or 30 days after crop emergence did not have any significant (P = 0.05) difference in their tuber grading. These treatments had a higher percentage of their tuber yield in both large and medium grades when compared to the other treatments.

The zero weeding and those treatments which were weeded once at (or with other weedings after) 45 or 60 days did not have any significant (P = 0.05) difference in their tuber grading and had a higher percentage of their tuber yield in the small grade. Consequently, these treatments had a lower percentage of their yields in both large and medium grades when

Table 10: Effect of weeding treatments on tuber grades at the final harvest during the short rains of 1980

Weeding treatment	Anett % of total tuber fresh weight			B53 % of total tuber fresh weight		
	Large	Medium	Small	Large	Medium	Small
1	34.92	35.72	30.72	8.99	40.40	50.61
2	34.55	34.55	30.91	8.93	40.68	50.39
3	35.19	35.36	29.13	10.78	40.33	48.90
4	35.34	35.05	29.61	9.88	39.62	50.49
5	35.87	34.83	29.30	10.24	40.53	49.21
6	34.68	35.76	29.56	9.01	39.55	51.44
7	33.28	36.44	30.28	8.91	40.10	50.99
8	34.32	35.06	30.62	10.55	41.02	48.43
9	33.86	34.66	31.48	10.39	39.64	51.97
10	34.65	34.44	30.91	9.94	40.91	49.15
11	35.41	34.95	29.65	10.46	41.00	48.54
12	33.88	35.72	30.40	10.88	40.36	49.75
13	35.22	34.35	30.44	10.11	41.13	48.76
14	35.03	34.09	30.47	10.92	38.22	50.86
15	34.79	35.99	29.22	9.65	41.06	49.29
16	34.67	34.41	30.92	10.91	40.44	48.65

Table 11: Effect of weeding treatments on tuber grades at the final harvest during the long rains of 1981

Weeding treatment	Anett % of total tuber fresh weight			B53 % of total tuber fresh weight		
	Large	Medium	Small	Large	Medium	Small
1	8.39a	17.16a	74.45a	9.91a	19.92a	70.18a
2	34.98b	32.10b	32.92b	25.31b	36.50b	38.19b
3	33.18b	32.77b	34.05b	25.55b	33.92b	40.53b
4	10.75a	18.75a	70.50a	8.30a	19.01a	72.69a
5	10.58a	18.25a	71.67a	9.43a	19.13a	71.44a
6	33.54b	33.78b	32.69b	27.03b	33.01b	39.96b
7	31.04b	35.32b	33.64b	23.87	34.53b	41.60b
8	33.53b	33.44b	33.04b	23.22b	35.38b	41.42b
9	32.34b	33.20b	34.47b	23.14b	33.98b	41.88b
10	31.95b	33.74b	34.31b	25.03b	35.33b	39.64b
11	9.44a	18.25a	72.31a	9.85a	18.12a	72.03a
12	10.34a	18.34a	71.32a	8.72a	18.62a	73.26a
13	32.64b	33.41b	33.95b	25.02b	35.67b	39.31b
14	8.42a	19.20a	72.39a	8.33a	19.74a	71.93a
15	34.53b	33.05b	32.42b	23.28b	36.82b	39.90b
16	34.22b	33.43b	32.35b	25.39b	34.65b	39.96b

Grades under the same column with the same letters are not significantly (P = 0.05) different.

compared to those treatments weeded at 15 or 30 days.

EFFECT OF VARIETY AND WEEDING TREATMENTS ON WEEDS DRY MATTER (KG/HA)

Varietal effects:

During the two seasons, varietal effects on weeds dry matter were not significant for all the five harvests (Appendices VI and VII; Tables 12 and 13).

Weeding effects:

At the first harvest (15 days after crop emergence) weeding treatment effects on weeds dry matter were not significant during the two seasons. At that time the weeding treatments had not commenced as yet since the harvesting of weeds was always done one day before weeding.

During all the other harvests (2nd, 3rd, 4th and 5th) in the two seasons, weeding effects on weeds dry matter were very significant ($P = 0.01$) as indicated in Tables 12 and 13.

At the 2nd harvest (30 days after crop emergence) during the two seasons, all those plots which were weeded at 15 days had no weeds while all the remaining plots had weeds since their weeding treatments had not commenced as yet. Therefore the weeds dry matter from treatments weeded at 15 days was significantly ($P = 0.05$) different from the weeds dry matter from the remaining treatments.

At the 3rd harvest (45 days after crop emergence) during the two seasons, all the plots weeded at 15 and/or 30 days

Table 12: Effect of treatments on weeds dry matter (kg/ha) during the short rains of 1980

Varieties	Weeding treatment	Days after crop emergence 15	30	45	60	75	Mean
	1	70	340	600	510	740	452.0
	2	6	0	0	0	40	9.2
	3	60	380	0	0	0	88.0
	4	20	270	120	0	0	82.0
	5	40	240	540	710	0	306.0
	6	60	0	0	0	0	12.0
	7	30	0	0	0	0	6.0
Anett	8	180	0	0	0	0	36.0
	9	20	110	0	0	0	26.0
	10	30	120	0	0	0	30.0
	11	50	130	650	0	0	166.0
	12	200	190	440	880	0	342.0
	13	70	0	0	0	0	14.0
	14	30	160	260	0	0	90.0
	15	40	0	0	0	0	8.0
	16	30	0	0	0	0	6.0
Mean		58.5	121.3	163.1	131.3	48.8	104.6
	1	70	390	980	1030	2220.	938.0
	2	90	0	0	9	80	35.8
	3	50	210	0	90	270	124.0
	4	60	220	580	0	0	172.0
	5	60	220	850	0	0	226.0
	6	60	0	0	0	0	12.0
	7	30	0	0	0	0	6.0
B53	8	60	0	0	0	0	12.0
	9	60	280	0	0	0	68.0
	10	20	320	0	0	0	68.0
	11	70	620	880	0	0	314.0
	12	80	240	380	770	0	294.0
	13	60	0	0	0	0	12.0
	14	80	260	850	0	0	258.0
	15	50	0	0	0	0	10.0
	16	40	0	0	0	0	8.0
Mean		58.8	172.5	282.5	118.7	160.6	159.9

Table 13: Effect of treatments on weeds dry matter (kg/ha) during the long rains of 1981

Variety	Weeding treatment	Days after crop emergence 15	30	45	60	75	Mean
	1	600	1160	2080	3460	3080	2076.0
	2	970	0	0	270	1000	448.0
	3	940	1790	0	0	0	546.0
	4	280	1260	2190	0	0	764.0
	5	840	1480	2980	3370	0	1734.0
	6	360	0	0	0	0	72.0
	7	450	0	0	0	0	90.0
Anett	8	190	0	0	0	0	38.0
	9	540	1230	0	0	0	354.0
	10	610	2110	0	0	0	542.0
	11	320	1450	2780	0	0	910.0
	12	650	920	1630	1690	0	978.0
	13	1080	0	0	0	0	216.0
	14	560	1060	2520	0	0	828.0
	15	590	0	0	0	0	118.0
	16	780	0	0	0	0	156.0
Mean		610.0	778.1	886.3	549.4	255.0	615.8
	1	390	1550	2310	2080	2220	1710.0
	2	580	0	0	300	400	256.0
	3	630	920	0	0	0	310.0
	4	700	1350	3080	0	0	1026.0
	5	580	960	1880	2990	0	1282.0
	6	610	0	0	0	0	122.0
	7	1060	0	0	0	0	212.0
B53	8	750	0	0	0	0	150.0
	9	620	1390	0	0	0	402.0
	10	420	1090	0	0	0	302.0
	11	540	2000	3330	0	0	1174.0
	12	1080	1720	2420	2910	0	1626.0
	13	870	0	0	0	0	174.0
	14	790	900	2240	0	0	786.0
	15	480	0	0	0	0	96.0
	16	660	0	0	0	0	132.0
Mean		672.0	742.5	953.7	517.5	163.7	624.9

after crop emergence had no weeds. Weeds dry matter from these treatments was therefore significantly (P = 0.05) different from that of the remaining treatments 1, 4, 5, 11, 12 and 14 which had not been weeded by this time.

At the 4th harvest (60 days after crop emergence) during the two seasons, all the plots which were weeded at 15, 30 or 45 days had either no weeds dry matter or had very low weeds dry matter. The dry matter from treatments weeded at 15, 30 and/or 45 days was therefore significantly (P = 0.05) lower than that of the remaining treatments 1, 5 and 12.

At the 5th harvest (75 days after crop emergence) during the two seasons all the plots which were weeded at 15, 30, 45 and/or 60 days had no weeds dry matter or had very low weeds dry matter. Their weeds dry matter was therefore significantly (P = 0.05) lower than the weeds dry matter of the remaining treatment 1, the zero weeding.

Comparing the two seasons, weed density was much higher during the long rains of 1981 than in the short rains of 1980. However, the weed species identified on the two sites were similar during the two seasons. Table 14 gives the species of weeds which were identified on those two sites.

Table 14: Weed flora identified on the experimental sites during the two seasons

Scientific name	Common name
Tagetes minuta L.	Mexican marigold
Bidens pilosa L.	Blackjack
Galinsoga parviflora Cav	Macdonaldi
Sonchus oleraceus L.	Snow thistle
Schkuhria pinnata (Lam) Thell	Dwarf marigold
Datura stramonium L.	Thorn apple
Nicandra physalodes L. Gaertn	Chinese lantern
Commelina benghalensis L.	Wandering Jew
Oxygonum sinuatum Meisn Dammer	Double thorn
Amaranthus hybridus L.	Pig weed

EFFECT OF VARIETY AND WEEDING TREATMENTS ON PERCENT TUBER DRY MATTER CONTENT

During the short rains of 1980, tuber fresh weight was not taken and therefore the percent tuber dry matter could not be calculated. The percent tuber dry matter given below is only for the long rains of 1981.

Varietal effects:

At each of the five harvests, B53 had a significantly (P = 0.01) higher percent tuber dry matter than Anett (Appendix VIII; Table 15).

Weeding effects:

Weeding treatments did not affect the percent tuber dry matter in any of the five harvests (Table 16).

Table 15: Mean varietal effect on percent tuber dry matter during the long rains of 1981

	Days after crop emergence				
Variety	15	30	45	60	75
Anett	16.82a	19.84a	20.93a	20.70a	20.63a
B53	17.11b	20.88b	23.98b	23.96b	24.01b

Means with different letters under the same column are significantly (P = 0.05) different.

Table 16: Effect of treatments on percent tuber dry matter during the long rains, 1981

		Days after crop emergence				
Variety	Weeding Treatment	15	30	45	60	75
	1	16.28	20.29	20.95	20.83	20.00
	2	17.16	20.02	21.43	20.52	20.56
	3	16.06	19.97	20.21	20.84	20.51
	4	16.28	20.03	20.53	20.61	21.73
	5	17.43	20.87	20.58	21.37	20.05
	6	16.63	20.48	20.65	20.56	20.69
	7	16.66	19.43	21.62	20.04	20.88
Anett	8	16.76	19.14	20.88	20.50	21.09
	9	16.55	19.48	20.49	21.41	20.61
	10	17.91	20.14	20.84	20.38	20.13
	11	17.34	19.28	21.43	20.81	20.56
	12	16.52	19.42	20.18	21.73	21.02
	13	16.90	19.46	21.69	20.18	20.38
	14	16.85	20.21	20.80	20.68	20.41
	15	17.18	19.84	21.97	20.07	20.73
	16	16.72	19.38	20.77	20.63	20.78
	1	16.72	19.84	23.01	23.62	23.45
	2	16.83	21.10	23.83	23.71	23.34
	3	16.60	20.71	24.77	23.57	24.51
	4	17.42	20.00	23.83	23.76	24.73
	5	16.79	20.91	24.05	24.06	24.93
	6	17.13	20.24	24.52	24.21	23.77
	7	17.48	20.87	24.42	23.42	23.75
B53	8	17.53	21.00	23.75	23.65	24.20
	9	16.76	20.53	24.50	24.00	24.49
	10	17.68	20.23	23.65	24.02	24.52
	11	17.11	21.42	23.93	23.72	23.68
	12	17.09	21.50	23.97	23.97	23.24
	13	17.33	21.33	24.50	24.70	23.88
	14	16.69	20.92	23.87	23.68	23.58
	15	17.27	21.20	23.80	24.11	24.28
	16	17.32	20.53	23.26	24.14	23.91

EFFECT OF TREATMENTS ON PERCENT TUBER DRY MATTER CONTENT AT THE FINAL HARVEST

Varietal effect:

B53 had a significantly ($P = 0.01$) higher percent dry matter in its tubers than Anett during the two seasons (Table 17).

Table 17: Effect of treatments on percent tuber dry matter at the final harvest

Weeding treatment	Short rains, 1980 Anett	Short rains, 1980 B53	Long rains, 1981 Anett	Long rains, 1981 B53
1	21.71	24.29	20.79	24.17
2	22.07	25.15	23.97	25.14
3	21.60	24.30	22.27	24.53
4	20.67	24.16	21.86	25.00
5	21.91	25.80	22.28	25.71
6	20.80	21.98	22.41	25.81
7	20.85	23.92	22.73	25.45
8	19.92	25.77	22.87	23.46
9	20.06	21.83	22.61	23.97
10	20.33	21.81	23.12	23.39
11	20.96	20.96	22.81	25.65
12	20.58	23.39	22.35	22.51
13	19.61	23.87	23.63	23.41
14	20.80	25.05	23.10	23.58
15	21.30	24.09	25.33	23.06
16	20.66	24.10	22.36	25.14
Variety mean	20.86	23.78	22.78	24.50

Weeding effects:

During the two seasons, weedings did not have any effect on percent tuber dry matter (Appendix IX, Table 17).

EFFECT OF TREATMENTS AND TUBER GRADES ON PERCENT TUBER DRY MATTER AT THE FINAL HARVEST

Varietal effects:

B53 had a significantly (P = 0.05) higher percent tuber dry matter in all the three grades (large, medium and small) than Anett during the two seasons (Table 18).

Table 18: Mean varietal and tuber grades effect on percent tuber dry matter at the final harvest

	Short rains 1980				Long rains 1981			
Variety	Large	Medium	Small	Mean	Large	Medium	Small	Mean
Anett	20.82	20.83	20.77	20.81	20.53	20.81	20.82	20.72
B53	23.22	23.77	23.86	23.62	23.76	23.86	23.73	23.78
Mean	22.02	22.30	22.32	22.22	22.15	22.34	22.28	22.25

Tuber grades:

During the two seasons, the percent tuber dry matter was not significantly (P = 0.05) different in all the 3 grades (large, medium and small) in both Anett and B53 (Table 18).

Weeding effects:

Weeding treatments did not affect the percent tuber dry matter (Table 19 and Appendix X).

Table 19: Effect of weeding treatments on percent tuber dry matter in different tuber grades

Variety	Weeding treatment	Short rains 1980 Large	Short rains 1980 Medium	Short rains 1980 Small	Long rains 1981 Large	Long rains 1981 Medium	Long rains 1981 Small
	1	20.36	21.31	19.39	20.64	20.08	19.54
	2	20.32	22.02	20.26	20.55	22.15	22.34
	3	21.70	21.77	21.60	21.14	19.78	22.02
	4	20.67	19.96	19.67	19.67	21.68	20.91
	5	21.14	20.15	21.83	21.23	20.75	19.09
	6	20.26	20.38	20.43	19.14	20.54	22.51
	7	22.06	20.71	20.40	21.81	21.50	21.39
Anett	8	19.85	20.86	21.36	19.16	19.06	20.93
	9	19.83	21.41	19.64	19.80	19.88	19.63
	10	20.00	19.61	20.08	20.78	21.74	20.87
	11	20.64	20.44	20.27	19.63	22.76	20.16
	12	20.62	21.61	22.11	21.31	20.93	21.47
	13	21.78	20.48	20.80	20.98	20.04	19.00
	14	19.29	21.30	20.84	20.14	20.75	21.11
	15	22.86	20.21	22.49	21.78	20.91	20.37
	16	21.81	21.11	21.16	20.74	20.41	21.88
Mean		20.82	20.83	20.77	20.53	20.81	20.82
	1	22.78	22.73	23.07	22.00	23.11	22.20
	2	20.25	24.74	24.17	24.94	24.65	24.86
	3	24.48	24.37	23.18	23.53	23.88	24.55
	4	23.42	24.54	24.33	23.01	23.92	23.43
	5	22.67	24.45	23.43	23.49	24.74	24.07
	6	24.35	23.04	23.91	24.94	24.70	24.77
	7	23.32	23.90	23.95	23.08	22.29	22.85
B53	8	24.51	22.20	24.36	23.44	23.74	24.03
	9	23.64	24.92	23.22	23.58	23.05	22.15
	10	23.76	23.81	24.25	23.07	23.11	24.66
	11	22.51	23.08	23.91	24.10	23.75	24.43
	12	23.13	23.23	24.03	24.49	23.26	23.00
	13	24.22	24.84	24.86	24.95	24.74	22.39
	14	22.55	23.26	23.29	23.54	23.78	24.02
	15	23.77	22.49	23.97	23.94	24.35	23.85
	16	21.07	24.66	23.80	24.04	24.76	24.51
Mean		23.22	23.77	23.86	23.76	23.81	23.78

EFFECT OF VARIETY AND WEEDING TREATMENTS ON LEAF AREA INDEX 'L'

During the short rains of 1980, 'L' was very high compared to the long rains of 1981 (Tables 20 and 21). During the short rains of 1980, all the treatments attained a peak 'L' of above three while during the long rains, only a few treatments managed to attain an 'L' of 3.

All Anett treatments attained a peak 'L' at 30 days after crop emergence in both seasons. B53 treatments varied depending on the weeding treatment. During the short rains of 1980, B53 treatments weeded once at (or with other weedings after) 45 or 60 days together with the zero weeded control attained peak 'L' at 30 days. All the other treatments attained peak 'L' at 45 days. During the long rains of 1981, B53 treatments weeded once at (or with other weedings after) 30, 45 or 60 days and the zero weeded control attained peak 'L' at 30 days, while the rest of the treatments attained peak 'L' at 45 days.

During the two seasons, B53 maintained a high 'L' for a longer time than Anett. In B53 high 'L' was maintained for 30 days between 30 and 60 days, while in Anett high 'L' was only maintained for 15 days between 30 and 45 days. From peak 'L', there was a sharp drop in 'L' of Anett while that of B53 was gradual up to 60 days. After 60 days, a reverse in 'L' behaviour occurred in both varieties, dropping sharply in B53 and gradually in Anett. That is why in the long rains, at 75 days, 'L' was higher ($P = 0.01$) in Anett than in B53, although Anett matured earlier (Table 21). Thus Anett tended to keep

Table 20: Effect of weeding treatments on leaf area index of Anett and B53 during the short rains of 1980

Weeding treatment	Anett: Days after crop emergence 15	30	45	60	75	B53: Days after crop emergence 15	30	45	60	75
1	0.98	3.52	2.00	1.30	0.89	1.11	4.80	2.75	1.96	0.58
2	0.71	4.52	4.49	2.40	0.80	0.89	4.18	5.11	3.87	1.56
3	1.11	4.53	4.40	1.33	1.00	1.42	4.13	5.42	4.22	0.93
4	1.38	3.78	2.09	1.73	0.89	1.20	3.82	2.58	2.26	1.24
5	1.02	4.36	2.13	1.38	0.98	0.89	5.51	2.89	1.73	1.16
6	1.07	5.07	4.98	1.51	0.44	1.24	5.20	5.33	4.09	1.51
7	1.20	5.64	4.53	1.38	1.07	1.02	4.36	5.42	3.69	1.20
8	0.62	5.16	4.89	2.53	0.67	1.33	4.84	4.84	4.27	1.87
9	0.93	5.22	4.44	1.82	0.49	1.47	5.30	5.33	3.29	0.84
10	1.24	3.64	3.60	1.42	1.16	0.80	4.44	5.29	3.42	1.02
11	1.42	4.97	2.40	1.16	0.89	0.89	4.44	2.84	2.80	1.42
12	1.24	4.98	2.36	1.45	0.93	0.84	3.96	2.53	2.03	1.11
13	0.89	5.24	4.80	1.56	0.76	0.98	4.22	4.93	3.24	0.84
14	1.47	4.53	2.22	1.09	0.58	0.80	4.00	2.67	1.78	0.40
15	0.89	4.80	4.62	2.00	0.40	0.76	4.09	4.89	4.09	1.11
16	1.24	5.16	4.89	1.29	1.16	0.76	5.22	5.38	4.36	1.24
Means	1.09	4.70	3.68	1.58	0.82	1.03	4.53	4.26	3.19	1.13

Table 21: Effect of weeding treatments on leaf area index of Anett and B53 during the long rains of 1981.

Weeding treatment	Anett					B53				
	Days after crop emergence					Days after crop emergence				
	15	30	45	60	75	15	30	45	60	75
1	1.07	1.44	1.34	0.25	0.18	1.81	1.82	1.64	0.60	0.11
2	1.55	3.01	3.00	1.38	0.36	1.51	2.50	2.60	1.51	0.17
3	1.82	2.30	2.11	1.12	0.41	1.57	2.29	2.21	1.22	0.15
4	1.28	2.05	1.50	0.81	0.65	1.99	2.42	1.76	1.27	0.26
5	1.60	2.00	1.30	0.22	0.15	1.29	1.88	1.84	0.73	0.18
6	1.80	2.50	2.44	1.11	0.47	1.52	2.90	3.60	1.56	0.29
7	1.91	2.61	2.53	1.28	0.25	1.38	2.89	3.45	1.57	0.45
8	1.92	3.26	3.25	1.50	0.83	1.30	2.50	2.75	1.56	0.29
9	1.80	2.18	2.00	1.04	0.65	1.56	2.28	2.25	1.32	0.03
10	1.70	2.78	2.52	1.06	0.16	1.82	2.40	2.01	1.21	0.02
11	1.52	2.10	1.07	0.83	0.24	1.38	2.54	2.02	1.22	0.13
12	1.36	1.53	1.52	0.25	0.11	1.74	2.53	1.62	0.58	0.01
13	1.09	3.06	3.00	1.50	0.62	1.35	2.90	3.01	1.50	0.35
14	1.73	1.80	1.68	0.90	0.51	1.01	2.50	1.32	1.23	0.10
15	1.87	3.09	3.04	1.29	0.44	1.74	2.80	3.06	1.66	0.35
16	1.55	3.10	3.05	1.35	0.29	1.12	2.90	3.06	1.58	0.15
Means	1.60	2.43	2.21	0.99	0.40	1.51	2.50	2.39	1.27	0.19

its leaves after maturity while B53 leaves died immediately after maturity.

Varietal effects:

During the short rains, varietal effects on 'L' were only significant (P = 0.05) at 45, 60 and 75 days after crop emergence, during which times B53 had a higher 'L' than Anett (Table 20).

During the long rains, varietal effects on 'L' were significant (P = 0.05) at 30, 60 and 75 days after crop emergence. At 30 and 60 days, B53 had a significantly (P = 0.05) higher 'L' than Anett while at 75 days, Anett had a significantly (P = 0.01) higher 'L' than B53 (Table 21).

Weeding effects:

Tables 20 and 21 also show the effect of weeding treatments on 'L' of Anett and B53 during the two seasons.

At 15 and 30 days after crop emergence (1st and 2nd harvests) during the two seasons 'L' was fairly uniform in all the treatments in the two varieties and therefore weeding effects on 'L' were not significant (Appendices XI and XII).

At 45 days after crop emergence (3rd harvest) weeding effects on 'L' were significant (P = 0.05) in both seasons.

During the short rains, at 45 days after crop emergence, weeding effects on 'L' in both Anett and B53 were as follows: treatments weeded once at (or with other weedings after) 45 or 60 days, together with the zero weeded control did not have any significant (P = 0.05) difference in 'L' and had the lowest 'L' at 45 days (Table 22).

Table 22: Effect of weeding treatments on 'L' of Anett and B53 at 45 days after crop emergence during the short rains of 1980

Weeding treatment	Leaf area index		
	Anett	B53	Mean 'L'
1	2.00a	2.75a	2.38a
2	4.49b	5.11b	4.80b
3	4.40b	5.42b	4.91b
4	2.09a	2.58a	2.34a
5	2.13a	2.89a	2.51a
6	4.98b	5.33b	5.16b
7	4.53b	5.42b	4.98b
8	4.89b	4.84b	4.87b
9	4.44b	5.33b	4.89b
10	4.36b	5.29b	4.83b
11	2.40a	2.84a	2.62a
12	2.36a	2.53a	2.45a
13	4.80b	4.93b	4.87b
14	2.22a	2.67a	2.45a
15	4.62b	4.89b	4.76b
16	4.89b	5.38b	5.14b

'L' values with the same letters under the same column are not significantly (P = 0.05) different.

Treatments weeded once at (or with other weedings after) 15 or 30 days after crop emergence did not have any significant ($P = 0.05$) difference in 'L' and had the highest 'L' at 45 days during the short rains of 1980.

In 1981 long rains, the variety x weeding interaction was not significant at 45 days after crop emergence, and therefore only the mean of the two varieties was considered (Table 23). Treatments weeded once at (or with other weedings after) 15 days had the highest ($P = 0.05$) 'L' at 45 days.

Treatments weeded once at (or with other weedings after) 45 or 60 days together with the zero weeding did not have any significant ($P = 0.05$) difference in 'L' and had the lowest 'L' at 45 days.

Table 23: Mean effect of weeding treatments on 'L' at 45 days after crop emergence during the long rains of 1981

Weeding treatment	Mean 'L'
1	1.49a
2	2.80b
3	2.16c
4	1.63a
5	1.57a
6	3.02b
7	2.99b
8	3.00b
9	2.13c
10	2.25c
11	1.54a
12	1.57a
13	3.00b
14	1.50a
15	3.05b
16	3.06b

Means with letter 'a' are significantly ($P = 0.05$) different from means with letter 'b'. Means with letter 'c' are not significantly ($P = 0.05$) different from either those with letter 'a' or those with letter 'b'.

Treatments weeded once at (or with other weedings after) 30 days had intermediate 'L' which was not significantly ($P = 0.05$) different from either the highest or the lowest 'L' mentioned above.

At 60 days after crop emergence (4th harvest) weeding effects on 'L' were not significant during the short rains of 1980.

In 1981 long rains, at 60 days, weeding treatment effects on 'L' were highly significant ($P = 0.01$), but the variety x weeding interaction was not significant. Therefore, only the mean of the two varieties was considered (Table 24).

Table 24: Mean effect of weeding treatments on 'L' at 60 days after crop emergence during the long rains of 1981

Weeding treatment	Mean 'L'
1	0.43a
2	1.45b
3	1.17c
4	1.04c
5	0.48a
6	1.34b
7	1.43b
8	1.53b
9	1.18c
10	1.14c
11	1.03c
12	0.42a
13	1.50b
14	1.07c
15	1.48b
16	1.47b

Means with letter 'a' are significantly ($P = 0.05$) different from means with letter 'b'. Means with letter 'c' are not significantly ($P = 0.05$) different from either those with letter 'a' or those with letter 'b'.

The zero weeded control and those treatments weeded once at (or with other weedings after) 60 days did not have any significant (P = 0.05) difference in 'L' and had the lowest 'L' at 60 days after crop emergence.

Treatments weeded once at (or with other weedings after) 15 days did not have any significant (P = 0.05) difference in 'L' and had the highest 'L' at 60 days.

Treatments weeded once at (or with other weedings after) 30 or 45 days were intermediate in 'L' and they did not have any significant (P = 0.05) difference in 'L' from either those treatments with the highest or those with the lowest 'L' mentioned above.

At 75 days after crop emergence (5th harvest) during the two seasons, weeding treatment effects on 'L' were not significant. The crop was mature and the leaf area index was very low.

DRY MATTER PARTITIONING IN THE POTATO PLANT (% OF WHOLE PLANT DRY MATTER) DURING THE SHORT RAINS OF 1980

Figure 5 and Table 25 show the dry matter partitioning in Anett and B53 during the short rains of 1980 (chosen because of the consistent sampling interval and good crop emergence).

In Anett, at 15 days after crop emergence, tubers accounted for 2.99% of the total plant dry matter. This rose sharply to 39.8, 66.17 and 83.28% at 30, 45 and 60 days after crop emergence respectively. After 60 days, the rise was steady up to 88.28% at 75 days. The difference in dry matter in the two weeks between 60 and 75 days was only 5%.

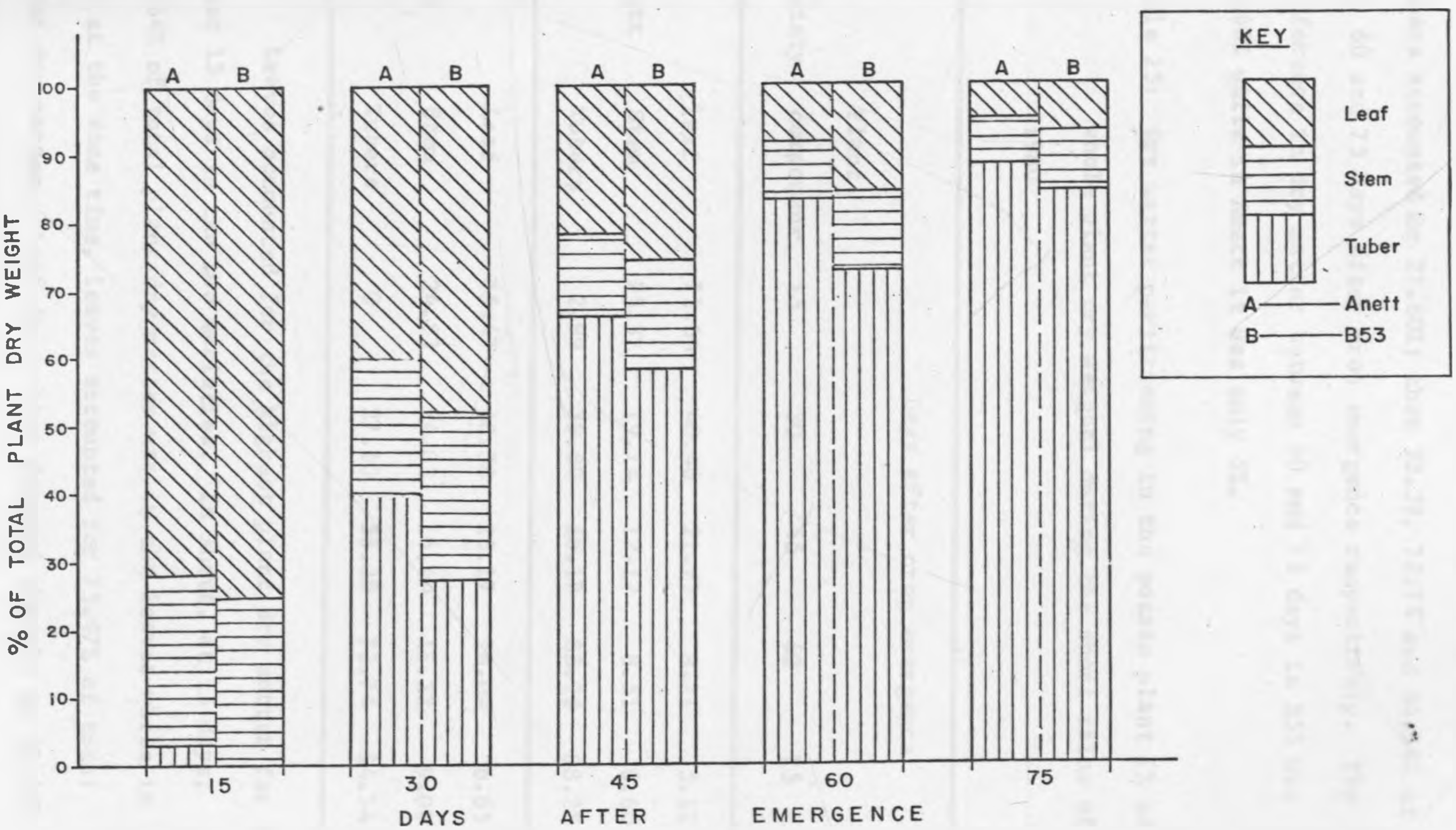


Fig. 5 : DRY MATTER PARTITIONING IN ANETT AND B53 (% OF WHOLE PLANT DRY WEIGHT) DURING THE SHORT IRAINS, 1980.

At 15 days B53 had not initiated any tubers. At 30 days, tubers accounted for 27.60%; then 58.39, 72.74 and 84.34% at 45, 60 and 75 days after crop emergence respectively. The difference in dry matter between 60 and 75 days in B53 was 11.60% while in Anett it was only 5%.

Table 25: Dry matter partitioning in the potato plant (% of whole plant dry weight) during the short rains of 1980

Variety	Plant component	Days after crop emergence 15	30	45	60	75
Anett	leaf	71.64	40.46	21.67	8.21	5.12
	Stem	25.37	19.74	12.17	8.51	6.60
	Tubers	2.99	39.80	66.17	83.28	88.28
B53	Leaf	75.47	48.38	25.17	16.04	6.65
	Stem	24.53	24.03	16.44	11.22	9.01
	Tubers	0	27.60	58.39	72.74	84.34

Leaves accounted for the highest plant dry matter for the first 15 days in the two varieties. In Anett, at 15 days, 71.64% of total plant dry matter was in the leaves while in B53 at the same time, leaves accounted for 75.47% of total plant dry matter. Leaf dry matter dropped sharply to 40.46% in Anett and 48.38 in B53 in two weeks' time and then to 21.67, 8.21 and 5.12% in Anett and 25.17, 16.04 and 6.65% in B53 at 45, 60 and 75 days respectively.

Stems accounted for 25.37, 19.74, 12.17, 8.15 and 6.60% in Anett and 24.53, 24.03, 16.44, 11.22 and 9.01% in B53 at 15, 30, 45, 60 and 75 days respectively.

EFFECT OF VARIETY AND WEEDING TREATMENTS ON LEAF DRY MATTER (T/HA)

Leaf dry matter behaviour was quite close to that of leaf area index during the two seasons. Leaf dry matter was higher during the short rains of 1980 than during the long rains of 1981 (Tables 26 and 27).

Varietal effects:

During the short rains of 1980, varietal effects on leaf dry matter were significant(P = 0.05) during each of the five harvests (Appendix XIII. At 15 days after crop emergence, Anett had a significantly (P = 0.05) higher leaf dry matter than B 53 while at 30, 45, 60 and 75 days after crop emergence, B 53 had a significantly (P = 0.05) higher leaf dry matter than Anett (Table 26).

During the long rains of 1981 varietal effects on leaf dry matter were significant (P = 0.05) at 15, 45, 60 and 75 days. At 15 and 75 days Anett had a significantly (P = 0.05) higher leaf dry matter than B 53 while at 45 and 60 days B 53 hnd a significantly (P = 0.05) higher leaf dry matter than Anett (Table 29).

Weeding effects:

In the 1980 short rains, weeding treatment effects on leaf dry matter were not significant (Appendix XIII) in all the five harvests in the two varieties (Table 26).

In the 1981 long rains, weeding treatment effects on

Table 26: Effect of weeding treatments on leaf dry matter (t/ha) of Anett and B53 during the short rains of 1980

Weed-ing treat-ment	Anett					B 53				
	Days after crop emergence					Days after crop emergence				
	15	30	45	60	75	15	30	45	60	75
1	0.44	1.10	1.09	0.53	0.15	0.38	1.33	1.30	1.00	0.38
2.	0.40	1.21	1.23	0.73	0.20	0.38	1.31	1.52	1.33	0.42
3	0.49	1.22	1.20	0.57	0.19	0.42	1.40	1.45	1.16	0.47
4	0.49	1.24	1.23	0.57	0.20	0.43	1.48	1.46	1.00	0.45
5	0.47	1.25	1.22	0.54	0.17	0.42	1.37	1.36	1.01	0.42
6	0.51	1.34	1.33	0.46	0.16	0.47	1.53	1.56	1.24	0.37
7	0.47	1.26	1.24	0.51	0.17	0.37	1.44	1.45	1.45	0.35
8	0.41	1.37	1.36	0.56	0.15	0.45	1.48	1.52	1.17	0.45
9	0.43	1.32	1.30	0.65	0.19	0.40	1.50	1.54	1.94	0.36
10	0.50	1.20	1.19	0.59	0.16	0.41	1.30	1.34	1.85	0.37
11	0.51	1.36	1.24	0.49	0.17	0.44	1.36	1.32	1.03	0.47
12	0.49	1.36	1.29	0.52	0.18	0.38	1.38	1.31	1.15	0.42
13	0.40	1.25	1.24	0.62	0.16	0.39	1.51	1.54	1.01	0.37
14	0.50	1.28	1.27	0.52	0.15	0.37	1.46	1.41	1.00	0.42
15	0.42	1.44	1.34	0.57	0.17	0.39	1.47	1.49	1.04	0.48
16	0.49	1.36	1.30	0.54	0.15	0.40	1.60	1.63	1.09	0.45
Means	0.46	1.29	1.25	0.56	0.17	0.41	1.43	1.45	1.19	0.42

Table 27: Effect of weeding treatments on leaf dry matter (t/ha) of Anett and B53 during the long rains of 1981

Weeding treatment	Anett					B53				
	Days after crop emergence					Days after crop emergence				
	15	30	45	60	75	15	30	45	60	75
1	0.37	0.71	0.42	0.09	0.03	0.35	0.72	0.63	0.13	0.01
2	0.48	0.88	0.78	0.38	0.10	0.39	0.88	1.03	0.50	0.07
3	0.39	0.72	0.60	0.25	0.04	0.40	0.73	0.83	0.35	0.03
4	0.48	0.74	0.40	0.12	0.05	0.36	0.75	0.70	0.15	0.04
5	0.40	0.76	0.41	0.11	0.03	0.33	0.74	0.68	0.14	0.02
6	0.47	0.87	0.79	0.40	0.09	0.41	0.88	1.00	0.51	0.06
7	0.46	0.90	0.80	0.41	0.12	0.42	0.87	0.95	0.49	0.05
8	0.48	0.89	0.78	0.39	0.10	0.38	0.86	0.99	0.47	0.08
9	0.41	0.75	0.61	0.26	0.05	0.37	0.72	0.85	0.37	0.03
10	0.38	0.73	0.59	0.24	0.07	0.36	0.73	0.84	0.36	0.04
11	0.40	0.76	0.40	0.09	0.06	0.42	0.77	0.64	0.14	0.01
12	0.43	0.72	0.43	0.11	0.03	0.40	0.73	0.67	0.12	0.03
13	0.38	0.91	0.79	0.39	0.12	0.34	0.88	1.01	0.48	0.06
14	0.37	0.73	0.41	0.14	0.04	0.38	0.79	0.65	0.15	0.02
15	0.45	0.88	0.80	0.38	0.09	0.41	0.89	0.99	0.49	0.08
16	0.44	0.91	0.79	0.41	0.10	0.39	0.90	1.02	0.51	0.07
Means	0.42	0.80	0.61	0.26	0.07	0.38	0.80	0.84	0.34	0.04

leaf dry matter were only significant ($P = 0.05$) at 45 and 60 days after crop emergence. These effects were as follows: at 15 days after crop emergence (1st harvest) weeding effects on leaf dry matter were not significant.

At 30 days after crop emergence (2nd harvest), although weeding effects on leaf dry matter were not significant, treatments 2, 6, 7, 8, 13, 15 and 16 which were weeded at 15 days, seemed to have slightly higher leaf dry matter than the remaining treatments (Table 27).

At 45 and 60 days after crop emergence (3rd and 4th harvests), the effects of weeding treatments on leaf dry matter were significant ($P = 0.05$). The interaction (variety x weeding) was not significant and therefore only the means of the two varieties were considered (Table 28).

During the two harvests (3rd and 4th), treatments 2, 6, 7, 8, 13, 15 and 16, weeded at (or with other weedings after) 15 days, had the highest ($P = 0.05$) leaf dry matter at 45 and 60 days after crop emergence. Treatments 4, 5, 11, 12 and 14 weeded at (or with other weedings after) 45 or 60 days including the zero weeding (treatment 1) had the lowest ($P = 0.05$) leaf dry matter. Treatments 3, 9 and 10 weeded at 30 days had intermediate leaf dry matter which was not significantly ($P = 0.05$) different from either the highest or the lowest leaf dry matter mentioned earlier.

At 75 days after crop emergence (5th harvest) in the long rains, weeding effects on leaf dry matter were not significant. Although weeding effects on leaf dry matter were not significant at this harvest, treatments 2, 6, 7, 8, 13, 15 and 16 appeared to have a slightly higher leaf dry matter than the remaining treatments (Table 27).

Table 28: Mean effect of weeding treatments on leaf dry matter (t/ha) at 45 and 60 days after crop emergence during the long rains of 1981

Weeding treatment	Days after crop emergence 45	60
1	0.53a	0.11a
2	0.91b	0.44b
3	0.72c	0.30c
4	0.55a	0.14a
5	0.55a	0.13a
6	0.90b	0.46b
7	0.88b	0.45b
8	0.89b	0.43b
9	0.73c	0.32c
10	0.72c	0.30c
11	0.52a	0.19a
12	0.55a	0.12a
13	0.90b	0.44b
14	0.53a	0.15a
15	0.90b	0.44b
16	0.91b	0.46b

Means under the same column with letter 'a' are significantly (P = 0.05) different from means with letter 'b'.

Means under the same column with letter 'c' are not significantly different from either those with letter 'a' or those with letter 'b'.

EFFECT OF VARIETY AND WEEDING TREATMENTS ON STEM DRY MATTER (T/HA)

Varietal effects:

During the short rains of 1980, varietal effects were significant (P = 0.01) at each harvest (Appendix XV). At 15 days after crop emergence (1st harvest) Anett had a significantly (P = 0.01) higher stem dry matter than B53 (Table 29). At 30, 45, 60 and 75 days after crop emergence (2nd, 3rd, 4th and 5th harvests) B53 had a significantly (P = 0.01) higher stem dry matter than Anett. Thus, stem dry matter was higher in Anett than in B53 at the first harvest only and during all other harvests B53 had a higher stem dry matter than Anett.

During the long rains of 1981, varietal effects were only significant (P = 0.05) at 60 days after crop emergence (4th harvest) as indicated in Appendix XVI. At this harvest B53 had a significantly (P = 0.05) higher stem dry matter than Anett (Table 30).

Weeding effects:

During the two seasons, weeding treatment effects on stem dry matter were not significant in any of the five harvests.

Table 29: Effect of weeding treatments on stem dry matter (t/ha) of Anett and B53 during the short rains of 1980

Weeding treatment	Anett					B53				
	Days after crop emergence					Days after crop emergence				
	15	30	45	60	75	15	30	45	60	75
1	0.19	0.62	0.56	0.42	0.35	0,13	0.73	0.86	0.65	0.50
2	0.17	0.61	0.59	0.54	0.43	0.14	0.71	0.89	0.61	0.51
3	0.16	0.62	0.58	0.43	0.37	0.15	0.74	0.89	0.64	0.52
4	0.17	0.65	0.59	0.51	0.35	0.13	0.74	0.88	0.65	0.45
5	0.16	0.62	0.57	0.44	0.32	0.12	0.69	0.83	0.53	0.44
6	0.20	0.65	0.63	0.42	0.37	0.17	0.79	0.84	0.58	0.50
7	0.17	0.70	0.57	0.46	0.36	0.11	0.79	0.90	0.52	0.51
8	0.16	0.73	0.69	0.50	0.32	0.17	0.78	0.83	0.62	0.42
9	0.16	0.72	0.62	0.51	0.39	0.15	0.80	0.85	0.53	0.43
10	0.21	0.71	0.63	0.48	0.43	0.12	0.77	0.88	0.63	0.49
11	0.17	0.72	0.63	0.51	0.40	0.13	0.74	0.87	0.51	0.46
12	0.15	0.71	0.64	0.49	0.36	0.17	0.75	0.89	0.56	0.47
13	0.16	0.67	0.57	0.46	0.41	0.15	0.74	0.90	0.60	0.41
14	0.18	0.74	0.64	0.45	0.39	0.13	0.82	0.84	0.50	0.45
15	0.15	0.73	0.65	0.49	0.38	0.12	0.76	0.82	0.61	0.48
16	0.20	0.74	0.64	0.46	0.40	0.16	0.80	0.90	0.59	0.50
Means	0.17	0.68	0.61	0.47	0.38	0.14	0.76	0.87	0.58	0.47

Table 30: Effect of weeding treatment on stem dry matter (t/ha) of Anett and B53 during the long rains of 1981

Weeding treatment	Anett					B53				
	Days after crop emergence					Days after crop emergence				
	15	30	45	60	75	15	30	45	60	75
1	0.18	0.34	0.34	0.08	0.03	0.20	0.36	0.38	0.24	0.05
2	0.20	0.35	0.30	0.07	0.02	0.19	0.33	0.35	0.26	0.02
3	0.23	0.37	0.32	0.10	0.03	0.19	0.32	0.33	0.23	0.03
4	0.22	0.36	0.33	0.09	0.04	0.18	0.34	0.35	0.26	0.04
5	0.18	0.33	0.33	0.05	0.05	0.18	0.30	0.32	0.30	0.06
6	0.21	0.34	0.31	0.10	0.04	0.20	0.32	0.33	0.28	0.07
7	0.21	0.37	0.36	0.08	0.04	0.19	0.31	0.35	0.26	0.04
8	0.23	0.36	0.35	0.06	0.02	0.17	0.34	0.36	0.30	0.02
9	0.21	0.34	0.33	0.08	0.04	0.18	0.37	0.38	0.29	0.03
10	0.18	0.33	0.32	0.07	0.03	0.18	0.38	0.40	0.25	0.06
11	0.19	0.32	0.31	0.06	0.03	0.19	0.36	0.38	0.24	0.03
12	0.17	0.36	0.36	0.09	0.05	0.19	0.34	0.34	0.28	0.05
13	0.18	0.38	0.35	0.06	0.03	0.17	0.38	0.39	0.27	0.02
14	0.22	0.35	0.34	0.05	0.02	0.20	0.35	0.37	0.24	0.06
15	0.19	0.33	0.32	0.07	0.04	0.19	0.36	0.39	0.25	0.04
16	0.18	0.33	0.31	0.08	0.05	0.21	0.34	0.36	0.29	0.07
Means	0.20	0.35	0.33	0.07	0.04	0.19	0.34	0.36	0.27	0.04

CHAPTER V

DISCUSSION

EFFECT OF VARIETY AND WEEDING TREATMENTS ON POTATO TUBER YIELD

During the short rains of 1980, Anett outyielded B53 while in the 1981 long rains, the two varieties were not significantly different in their final tuber yield.

At the first and second harvests in the 1981 long rains, Anett had a higher tuber yield than B53, but during the last three harvests, the two varieties were not significantly different in their tuber yield.

The short rain results are consistent with varietal descriptions of the two varieties (Ballestrem and Holler, 1974) and also the results of work at Kabete by Mariga (1980).

The long rain results at the first and second harvests indicate clearly that Anett starts bulking earlier than B53. The short rain season was, therefore, more suitable for an early maturing variety, like Anett, which starts bulking early in the season. B53 with its longer growth cycle, had its bulking period shortened by the dry weather. The long rains, on the other hand, favoured the long growth cycle of B53 and this enabled B53 to catch up with Anett in terms of tuber yield. These results indicate that given enough rainfall over its growing period, B53 would perhaps not be outyielded by Anett.

The final tuber yield was very high in the short rains of 1980 when compared to the yield during the long rains of

1981 (Tables 7 and 8). In fact, the highest yield in the long rains was less than the lowest yield in the short rains. This can best be explained by the condition of the planting material and the growth characteristics of the crop after emergence during the two seasons. During the short rains, plant emergence was very good; the crop grew very vigorously and attained a very high leaf area (Table 20). In the long rains of 1981, the plant emergence was slow and, besides, the growth during the season was not as vigorous as in the short rains of 1980. The peak 'L' attained during the long rains was very low('L' of about 3) compared to that of the short rains('L' of about 5) - Table 20 and 21. These differences in crop growth during the two seasons should have caused the differences in the final tuber yield for tuber bulking rate is a function of leaf area index and the leaf area duration (Ivins and Bremer, 1964). The leaf area duration was, however, not different in the two seasons.

From the results it appears that the losses in tuber yield caused by weeds are appreciable. In the control treatment where no weeding was done throughout the growth of the potatoes, yield was reduced by 37 and 44% in Anett during the short and long rains respectively and by 25 and 49% in B53 in the short and long rains respectively compared to the clean weeded treatment. These yield reductions due to weed competition fall within the range observed by Nield and Proctor (1962) where, in herbicide experiments, potato yield reduction due to weeds ranged between 16 and 76 percent. Also in Wageningen (in The Netherlands), yields were reduced by 20% where weeds were allowed to grow during the first month after planting when compared to clean weeded controls (Van Hiele, 1952).

The percentage yield reduction due to weed infestation was higher in the long rains than in the short rains. This can be explained by the fact that weed density was higher in the long rains than in the short rains (Table 12 and 13). This is in accordance with the findings in Lower Saxony (Germany) where the results of field trials showed that potato tuber yield were correlated with weed density (Funch, Reschke and Heitefuss, 1975).

The period between planting and emergence of the crop during the two seasons also contributed to the differences in percentage yield reductions. During the short rains of 1980, potatoes took half the period that potatoes in the long rains took to emerge. Therefore, by the time the long rains crop emerged, weeds had already established themselves and were able to compete more favourably against the crop than was the case in the short rains. The short rains crop emerged before weeds established themselves. This is in accordance with the results obtained by Makepeace and Holroyd, 1975, who noted that, the earlier the weeds emerge in relation to the crop, the greater their competitive advantage is.

The results indicate clearly that it is the first weeding and the time it is done that counts in regard to tuber yield. During the two seasons, weeding at 15 days was as good as weeding at 30 days and these two weedings were not significantly different from the clean weeding. During the long rains, however, there was some yield reduction in those treatments weeded at

30 days (or with other weedings after) when compared to clean weeding. This was not the case in the short rains where the yields of treatments weeded at 15 and those weeded at 30 days were very similar. In the short rains also, a weeding at 45 days gave a significantly higher yield than a weeding at 60 days; but in the long rains these two weedings yielded the same. In the short rains only a weeding at 60 days was as bad as the zero weeded control, whereas in the long rains the two different weedings at 45 and at 60 days were as bad as the zero weeding.

The difference in yield between treatments weeded at 15 days and those weeded at 30 days, in the long rains, can be explained by the difference in weed density and the period between planting and emergence explained earlier. By the end of 30 days in the long rain season, weed density was already high and competition between potatoes and the weeds had started before the weeds were removed at the end of the 30 days. The competition caused the slight yield reduction found in those treatments weeded at 30 days during the long rains. This was not the case in the short rain season where, even by the end of the 30 days, weed density was too low to cause serious competition against the crop. The same argument goes for the similarity in yield between weeding at 45 and 60 days during the long rains; but in the short rains, weeding at 45 days was better than weeding at 60 days. In the long rains, by the end of 45 days, the unweeded crop had already been affected by the weed competition and weeding at this time produced as poor a yield as the zero weeded control.

From the results, it appears that the best time for weeding potatoes at Kabete is at 15 days after crop emergence and that one weeding at this time is enough to give the best yields in potatoes. From emergence up to 15 days, both the crop and the weeds are growing vigorously without much competition. After 15 days, the crop and the weeds are just about to cover the empty space and start competing for light, moisture and nutrients. If the weeds are removed at 15 days or around this time, the crop grows vigorously and smothers most of the weeds which come up afterwards. The crop will also have established itself by the time weeds come up and these weeds will not therefore affect the crop. In 1958, Kawatei et al. observed that at the stage where potato plants are fairly large and growing actively they are more capable of competing with weeds than at the time of emergence. It is actually between 15 and 30 days after crop emergence that the potato builds up a high leaf area which helps to suppress most of the weeds. This explains why more weedings after the first one at 15 days are not necessary. Makepeace and Holroyd (1975) also noted that weeding in a potato crop is only necessary between planting and the closure of leaf canopy. The period between planting and closure of leaf canopy depends on factors like season, weed density, seed quality and the quality of seed bed at planting.

The above findings are similar to the results found in Bolu (Turkey), where weedings done from the 15th up to the 45th or 49th day increased tuber yield by 93-216% compared to the unweeded controls (Sonmez and Karaca, 1975). The yield increase in Bolu was very large but this depended on the weed density (Funch *et al.*, 1975; Reeves, 1976) and the species of weeds present (Blackman and Templeman, 1938).

From the results it was found that one weeding at 15 days after crop emergence produced tuber yield similar to yield from clean weeded treatment which was composed of five cultivations at 15, 30, 45, 60 and 75 days. This finding conflicts with the finding of Aldrich *et al.* (1954) who found that more than two or three cultivations reduced potato yields. This difference might be due to the differences in the area, soil and climatic conditions under which the experiments were carried out. The effect of several weedings will also depend on the method of weeding employed and the effect they had on the soil moisture.

EFFECT OF VARIETY AND WEEDING TREATMENTS ON TUBER GRADES AT THE FINAL HARVEST

During the two seasons, Anett had a higher percentage of its tuber yield in the large grade than B53. The latter variety had a higher percentage of its tuber yield in the small grade. It might be possible that the growing conditions during the two seasons were not good enough for B53. During the short rains of 1980, weeding treatments did not affect tuber grades while in the long rains of 1981 there were significant effects. It has already been noted that weed density was very high in the long rains compared to the short rains. It could therefore be possible that the weed density in the short rains was not high enough to affect tuber grades but just enough to reduce the total tuber yield.

During the long rains, weedings at 15 and at 30 days had a higher percentage of their yields in the large and medium grades than those treatments weeded at 45 or at 60 days. These results are consistent with the results of field trials conducted in Poland, where, with increasing weight of weeds, there was a significant increase in the number of small tubers (less than 40 g) in the yield and a decrease in the number of large tubers - over 100 g (Radecki, 1979).

Under the conditions of this study at Kabete, one weeding at 15 days is therefore enough to give a high potato yield which also contains a high percentage of large size tubers.

EFFECT OF VARIETY, WEEDING AND TUBER GRADES ON PERCENT TUBER DRY MATTER

During the two seasons, B53 had a higher percent dry matter in tubers than Anett. This might be explained by the fact that B53 sustained a high leaf area for a longer time than Anett (Tables 20 and 21) and this might have enabled it to accumulate more dry matter in its tubers than Anett.

Tuber grading and weeding treatments did not affect the percent dry matter in tubers. According to Mariga (1980), working at Kabete, ware, big and medium seed had the same dry matter percentage whereas the small seed and chatts had a slightly lower dry matter content. It should, however, be noted that the grading method used in the present study was different from that used by Mariga. In the present study, the large grade is equivalent to Mariga's ware size while his big seed is equivalent to medium grade. In this study, medium seed, small seed and chatts are all in the small size grade. Therefore the medium seed which has a high dry matter content and is included in the small grade might have played a role in raising the percent dry matter in the small grade. In any case, the difference in dry matter in Mariga's case was very small.

EFFECT OF VARIETY AND WEEDING TREATMENTS ON LEAF AREA INDEX, 'L'

During the short rains of 1980 leaf area index was very high compared to the long rains of 1981 (Table 20 and 21). This might be explained by the condition of the seed at planting time and the density of weeds as explained earlier.

The difference in 'L' might account for the big difference in the final tuber yield found during the two seasons. Ivins and Bremner (1964) observed that tuber bulking rate is a function of leaf area index and increases with values of 'L' up to a maximum value of 3. In fact, in the long rain season, most treatments had their peak 'L' below 3 whereas in the short rains all treatments had a peak 'L' above 3.

During the two seasons, Anett emerged earlier and had a higher 'L' than B53 in the beginning. However, soon after 15 days, B53 caught up and passed Anett in 'L'. During most of the growing period, B53 had a higher 'L' than Anett. B53 also maintained a high leaf area for a longer period than Anett. The two varieties did not, however, differ in their leaf area duration.

The fact that Anett emerged earlier and maintained a high 'L' for a shorter time than B53 suggests that Anett will do better than B53 in a short rain season. This was very true in the short rain season of 1980 where Anett outyielded B53. This agrees with their varietal descriptions: Anett is an early maturing variety (Ballestrem and Holler, 1974). The early initial 'L' in Anett favoured an early bulking and the fact that Anett had a shorter bulking period than B53 but ended up with a higher yield than B53 in the short rains shows that Anett has a higher bulking rate earlier in the season than B53. The later, but longer bulking period in B53 was interrupted by the dry weather in the short rain season and hence the low yields. The more developed haulm in B53 might also have been maintained at the expense of tuber bulking. This might explain why in the long rain season, B53 did not outyield Anett although B53 might have had enough time to complete its long bulking period.

After maturity (when tuber fresh weight stopped increasing) Anett tended to keep its leaves while B53 leaves dried immediately after maturity. This is seen in the gradual drop in 'L' of Anett and a sharp drop in 'L' of B53 after 60 days (Table 20 and 21). Also in the long rains at 60 days, B53 had a higher 'L' than Anett but at 75 days Anett had a higher 'L' than B53 although Anett had matured earlier. This is why although Anett matured earlier than B53 their haulms dried around the same time.

When the effects of weeding treatments on 'L' were significant, treatments weeded at 15 days had the highest 'L'. This showed a similar trend to the one shown by the final tuber yield. Weed competition therefore starts by affecting the leaf area which is built up early in the season, and this affects both the tuber bulking rate and the duration of bulking. These will consequently affect the final tuber yield. The period of highest 'L' was between 30 and 45 days and this coincided with the period of highest tuber bulking rate (Figure 2).

DRY MATTER PARTITIONING IN ANETT AND B53 DURING THE SHORT RAINS OF 1980

Throughout the growing period, Anett had a higher percentage of total dry matter in tubers than B53. On the other hand, B53 had a higher percentage of its total dry matter in leaves and stems than Anett (Figure 5 and Table 25). B53 haulms must therefore be competing with tubers for assimilates more than Anett haulms. This might explain why Anett had more tubers in the large grade than B53.

EFFECT OF VARIETY AND WEEDING TREATMENTS ON LEAF AND STEM DRY MATTER (T/HA)

In the two varieties, leaf and stem dry matter followed a similar trend during the two seasons only that leaf dry matter was higher than stem dry matter (Tables 26, 27, 29 and 30).

Haulm growth followed a similar trend as the leaf area index and the highest rate of haulm growth was between 15 and 30 days during which time 'L' was increasing at its highest rate.

During the short rains of 1980, both leaf and stem dry matter were not affected by weeding treatments. In the 1981 long rains, stem dry matter was also not affected by the weeding treatments. Effects of weeding treatments on leaf dry matter were, however, significant at the third and fourth harvests during the long rains of 1981.

During these two harvests in the long rains, treatments weeded at 15 days had the highest leaf dry matter while treatments weeded at 45 or 60 days had the lowest leaf dry matter. Treatments weeded at 30 days after emergence had intermediate leaf dry matter.

The difference in weed density (explained earlier) during the two seasons may help to explain why weeding treatment effects on leaf dry matter were significant during the long rains of 1981 but were not significant in the 1980 short rains. The initial haulm growth in the short rains was perhaps too vigorous to be badly affected by competition from the low weed density found in the short rain season.

A weeding at 15 days removed weeds in time before the period of highest haulm growth. Weeding at 30 days was done towards the end of maximum haulm growth. However, there was still some haulm growth between 30 and 45 days and therefore this weeding managed to increase haulm dry matter slightly in the long rains where weed density was very high. Weeding at 45 or 60 days in the long rains was too late as the crop had already been badly affected by the competition and could not resume growth.

While the highest growth rate in haulms was between 15 and 30 days, high tuber bulking rate continued from 15 days up to 45 days (Figure 2). The highest growth rate in a potato plant is therefore between 15 and 45 days after crop emergence.

From the above findings under Kabete conditions and during conditions pertaining to the seasons, the critical weed competition period in potatoes appears to be between the 15th and the 45th day after crop emergence. This period coincides with the period of highest growth rate in a potato plant. The presence and competition of weeds during this period proved to be harmful to the potato crop. This agrees with the definition of the critical weed competition period of a crop that "it is that period during the growth of the crop when the presence and competition of weeds is harmful to the crop" (Nieto et al., 1968; Gurnah, 1974).

CHAPTER VI

CONCLUSIONS AND SUGGESTIONS FOR FUTURE WORK

The critical weed competition period in potatoes at Kabete is between the 15th and the 45th day after crop emergence. During this period, the crop was growing vigorously and any weed competition interfered with the crop growth. The effect of weed competition was reflected in the final tuber yield where a delay in weeding after the 15th day caused a significant drop in tuber yield.

During the short rains of 1980, due to low weed density and a vigorous initial crop growth, there was no significant reduction in the final tuber yield by a delay in weeding from the 15th up to the 30th day. However, a further delay from the 30th up to the 45th day caused a final tuber yield reduction of 20% in Anett and 16% in B53.

During the long rains where weed density was very high, a delay in weeding from the 15th up to the 30th day caused a decrease in the final tuber yield of 18% in Anett and 16% in B53. A further delay from the 30th up to the 45th day caused a yield reduction of 32% in Anett and 38% in B53.

At Kabete, one weeding in potatoes done at 15 days after crop emergence was found adequate and any more weedings were unnecessary addition to the production costs.

These findings should be taken with caution as they are only true at Kabete and they may differ in other areas. This leaves a lot of room for more work of the same nature in other areas.

In hot areas, such as the marginal rainfall areas, e.g. Machakos, the rate of both weeds and potato growth is very high. It might therefore be necessary to weed at an earlier date than the 15th day.

It is also necesssry to investigate the situation in areas of higher altitude than Kabete. Such an area would be colder than Kabete and the plant growth rate would be lower. It is very likely that at such an area the first weeding would need to be delayed until after the 15th day - perhaps up to the 30th day. These possibilities need more work to be carried out.

It is also important to include more varieties of varying growth habits in a similar experiment and find out whether their critical weed competition periods will differ.

The intensity of competition depends on weed species and therefore a similar experiment can be repeated under different weed species.

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APPENDICES

Appendix Table I: Soil test data during the experiments

	Short rains 1980 (1st site) BLOCK				Long rains 1981 (2nd site) BLOCK			
	I	II	III	IV	I	II	III	IV
pH	5.6	5.3	5.7	5.4	6.2	6.2	6.2	6.1
Na m.e. %	0.18	0.18	0.26	0.18	0.24	0.18	0.19	0.14
K m.e. %	1.22	1.11	1.00	1.00	0.75	0.77	0.81	0.81
Ca m.e. %	8.0	8.7	9.4	8.4	9.4	9.0	8.4	8.6
Mg m.e. %	2.4	2.3	2.5	2.2	2.2	2.2	2.2	2.1
Mn m.e. %	1.60	1.64	1.54	1.57	1.32	1.38	1.28	1.18
P ppm	21	21	21	22	<u>16</u>	27	25	23
C%	2.15	2.09	2.12	2.03	1.83	1.92	1.86	1.86
Hp m.e.%		0.1		0.1				

Key: Underlined are deficiencies

Analysis by the National Agricultural Laboratories, Ministry of Agriculture.

Appendix table II: Rainfall data during the experiments

	Month	Total rainfall (mm)	Long term average (10 years) - mm
1st experiment	November, 1980	254.7	132.0
	December, 1980	73.7	77.2
	January, 1981	2.7	54.8
	February, 1981	6.7	59.0
2nd experiment	March, 1981	123.8	95.5
	April, 1981	506.0	247.3
	May, 1981	213.7	169.6
	June, 1981	10.5	44.7
	July, 1981	18.00	25.9

Appendix table III: Analysis of variance, F values and CVs for treatment effects on tuber fresh weight (t/ha) at different sampling dates during the long rains of 1981

		F values				
		Days after crop emergence				
Source	DF	15	30	45	60	75
Total	127					
Blocks	3					
Treatments:						
Varieties (v)	1	14.8349***	5.1888*	2.7710 NS	1.2554 NS	0.0454 NS
Weedings (w)	15	1.0781 NS	1.7220 NS	3.6028***	2.6828**	2.0121*
v x w	15	1.1707 NS	1.0591 NS	1.4397 NS	1.0369 NS	0.7371 NS
Error	93					
CV (%)		49.119	47.8251	39.5826	39.1088	39.9013

Appendix table IV: Analysis of variance, F values and CVs for treatment effects on final tuber yield fresh weights (t/ha)

Source	DF	F values: Short rains 1980	F values: Long rains 1981
Total	127		
Blocks	3	51.5905***	8.3024***
Treatments:	31		
Varieties (v)	1	540.5309***	1.9194 NS
Weedings (w)	15	107.7705***	16.2941***
v x w	15	11.7595***	0.6536 NS
Error	93		
CV (%)		3.6365	18.6482

Appendix table V: Analysis of variance, F values and CVs for treatment effects on tuber grades (% fresh weights)

Source	DF	F values					
		Short rains, 1980			Long rains, 1981		
		Large	Medium	Small	Large	Medium	Small
Total	127						
Blocks	3						
Treatments:	31						
Varieties (v)	1	125.2209***	8.6132**	104.4867***	8.8521***	2.4871 NS	17.2191**
Weedings (w)	15	0.8480 NS	1.2100 NS	0.9113 NS	9.2905***	1.8162*	9.3116***
v x w	15	0.8889 NS	0.8693 NS	1.0245 NS	0.6525 NS	1.3379 NS	0.5726 NS
Error	93						
CV (%)		45.2498	24.7918	29.2248	31.1061	33.8924	27.4144

Appendix table VI: Analysis of variance, F values for treatment effects on weeds dry matter (t/ha) during the short rains of 1980

		F values				
		Days after crop emergence				
Source	DF	15	30	45	60	75
Total	127					
Blocks	3					
Treatments:	31					
Varieties (v)	1	3.3976 NS	2.8483 NS	3.0892 NS	0.7024 NS	1.9658 NS
Weedings (w)	15	1.2630 NS	3.6295***	6.4161***	7.2007***	12.6291***
v x w	15	0.5811 NS	0.9576 NS	0.6043 NS	0.6877 NS	1.4649 NS
Error	93					

Appendix table VII: Analysis of variance, F values for treatment effects on weeds dry matter (t/ha) during the long rains of 1981

Source	DF	F values Days after crop emergence 15	30	45	60	75
Total	127					
Blocks	3					
Treatments	31					
Varieties (v)	1	1.0690 NS	0.0247 NS	0.0723 NS	1.1148 NS	3.7251 NS
Weedings (w)	15	0.7812 NS	15.2849***	26.0567***	40.3735***	50.3842***
v x w	15	0.9605 NS	1.2382 NS	0.8938 NS	2.3117**	3.1490***
Error	93					

Appendix table VIII: Analysis of variance, F values and CVs for treatment effects on percent tuber dry matter during the long rains of 1981

		F values				
		Days after crop emergence				
Source	DF	15	30	45	60	75
Total	127					
Blocks	3					
Treatments	31					
Varieties (v)	1	78.5472***	17.4579*	310.8755***	324.6288***	553.5215***
Weedings (w)	15	0.3581 NS	1.4057 NS	0.5653 NS	0.6146 NS	1.1033 NS
v x w	15	0.4881 NS	0.8362 NS	1.3152 NS	1.1559 NS	1.0636 NS
Error	93					
CV (%)		4.0885	4.2800	3.4066	3.2984	3.1724

Appendix table IX: Analysis of variance, F values and CVs for treatment effects on percent tuber dry matter at the final harvest

		F values	
Source	DF	Short rains 1980	Long rains 1981
Total	127		
Blocks	3		
Treatments	31		
Varieties (v)	1	58.4222***	34.9109***
Weedings (w)	15	1.3730 NS	1.4233 NS
v x w	15	0.79307 NS	0.9023 NS
Error	93		
CV (%)		9.5602	7.8812

Appendix table X: Analysis of variance, F values and CVs for treatment effects and tuber grades on percent tuber dry matter at the final harvest

		F values					
		Short rains, 1980			Long rains, 1981		
Source	DF	Large	Medium	Small	Large	Medium	Small
Total	127						
Blocks	3						
Treatments:	31						
Varieties (v)	1	4.0330*	89.7466***	150.0092***	4.0808*	26.950***	132.0856***
Weedings (w)	15	0.5059 NS	1.1011 NS	0.0119 NS	0.6075 NS	1.0569 NS	1.4503 NS
v x w	15	0.5432 NS	0.6219 NS	0.9845 NS	0.6291 NS	1.3502 NS	1.0871 NS
Error	93						
CV (%)		22.1403	7.4901	6.4102	33.7410	10.9102	4.9514

Appendix table XI: Analysis of variance, F values and CVs for treatment effect on leaf area index during the short rains of 1980

		F values				
		Days after crop emergence				
Source	DF	15	30	45	60	75
Total	127					
Blocks	3					
Treatments:	31					
Varieties (v)	1	0.7371 NS	0.0106 NS	8.8284**	79.5964***	4.2793*
Weedings (w)	15	0.6018 NS	1.5398 NS	2.0993*	1.1506NS	0.9365 NS
v x w	15	1.1884 NS	0.5656 NS	2.4861*	0.9204	1.0107 NS
Error	93					
CV (%)		46.7714	30.5523	27.9501	46.5413	41.0620

Appendix table XII: Analysis of variance, F values and CVs for treatment effects on leaf area index during the long rains of 1981

		F values				
		Days after crop emergence				
Source	DF	15	30	45	60	75
Total	127					
Blocks	3					
Treatments:	31					
Varieties (v)	1	0.3523 NS	5.2675*	2.4948 NS	5.5398*	21.3163***
Weedings (w)	15	1.2211 NS	1.0958 NS	9.5119***	6.5028***	1.7299 NS
v x w	15	1.5539 NS	1.2117 NS	1.5437 NS	0.5872	1.2112 NS
Error	93					
CV (%)		32.4021	33.4000	28.9000	46.3000	49.1231

Appendix table XIII: Analysis of variance, F values and CVs for treatment effects on leaf dry matter (t/ha) during the short rains of 1980

Source	DF	F values Days after crop emergence 15	30	45	60	75
Total	127					
Blocks	3					
Treatments:	31					
Varieties (v)	1	192.9836***	41.4960***	25.8563***	224.0847***	12.4252***
Weedings (w)	15	0.4323 NS	0.6488 NS	0.5229 NS	1.5434 NS	0.8700 NS
v x w	15	0.5650 NS	1.3110 NS	0.2943 NS	1.5829 NS	0.6867 NS
Error	93					
CV (%)		33.8200	14.5801	11.6618	22.5165	20.6617

Appendix table XIV: Analysis of variance, F values and CVs for treatment effects on leaf dry matter (t/ha) during the long rains of 1981

		F values				
		Days after crop emergence				
Source	DF	15	30	45	60	75
Total	127					
Blocks	3					
Treatments:	31					
Varieties (v)	1	42.4015***	0.4041 NS	4.3043*	4.5820*	21.2997***
Weedings (w)	15	0.9192 NS	1.0441 NS	8.0728***	6.0296***	1.7337 NS
v x w	15	1.6328 NS	1.3170 NS	1.3694 NS	0.5356 NS	1.2247 NS
Error	93					
CV (%)		30.1345	31.3309	32.0687	47.9939	49.0676

Appendix table XV: Analysis of variance, F values and CVs for treatment effects on stem dry matter (t/ha) during the short rains of 1980

Source	DF	F values Days after crop emergence 15	30	45	60	75
Total	127					
Blocks	3					
Treatments:	31					
Varieties (v)	1	19.0980***	65.3829***	22.1152***	63.9321***	89.0729***
Weedings (w)	15	1.0924 NS	0.7971 NS	0.7682 NS	1.3786 NS	1.4433 NS
v x w	15	0.7851 NS	0.1915 NS	0.6345 NS	1.2611 NS	0.9560 NS
Error	93					
CV (%)		34.7559	15.1640	13.8561	18.9375	22.3395

Appendix table XVI: Analysis of variance, F values and CVs for treatment effects on stem dry matter (t/ha) during the long rains of 1981

Source	DF	F values Days after crop emergence 15	30	45	60	75
Total	127					
Blocks	3					
Treatments:	31					
Varieties (v)	1	2.0549 NS	0.7111 NS	1.6124 NS	5.0942*	3.6143 NS
Weedings (w)	15	1.6732 NS	0.9523 NS	1.6762 NS	1.8081 NS	1.3738 NS
v x w	15	0.9212 NS	1.2622 NS	0.8277 NS	1.0981 NS	1.9190*
Error	93					
CV (%)		39.8613	42.9518	46.0274	46.0819	43.0837