THE EFFECT OF ALTITUDE OF SEED PRODUCTION ON POTATO 'SEED' VIGOUR

BY

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A thesis submitted in partial fulfilment of the requirements for the degree of Master of Science in Agronomy.

UNIVERSITY OF NAIROBI

1984

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

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

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Dedicated to My parents and to Sebastiano
and our Children, Victor and Anita.

ACKNOWLEDGEMENTS

I am very grateful to Prof. D.N. Ngugi for his support and advice during the course of this work. I thank Dr. C.L. Coulson who helped me alot in the preparation of my experiments. I am most grateful to DAAD/AFAA, whose financial support made this work possible. I would also like to extend my gratitude to the Directors of Thika Horticultural Research Station and the Potato Research Station, Tigoni for allowing me to use their facilities during my experiments. Lastly my thanks to the staff of the Department of Crop Science and Department of Soil Science for their technical assistance.

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ABSTRACT

Seed potatoes, variety Anett, were raised at three different altitudes: Thika (1440 m), Kabete (1800 m) and Limuru (2225 m) and at each site in soil transported from the other sites in large tins; in two seasons. The seed raised at all sites was planted the following season at Kabete for ware production.

In the first experiment, Limuru site yielded the highest number of tubers and fresh weight of tubers, followed by Thika site despite the fact that plants at Thika had shown a more vigorous vegetative growth than Limuru plants. In the second experiment, Thika site yielded the lowest number of tubers and fresh weight of tubers per plant. Limuru site yielded the largest number of tubers but Kabete yielded the highest fresh weight of tubers per plant..

In storage, seed tubers from Thika were the first to sprout, yet their sprout length and number of sprouts were the least. Limuru seeds sprouted last and had the highest sprout number and length, but these were not significantly different from those of Kabete seed.

In the field, plants from Limuru seed were the first to emerge, followed closely by plants from Kabete seed. Plants from Thika seed were the last to emerge and showed a poorer vegetative growth than plants from Limuru and Kabete seeds.

The plants from Thika seed senesced earlier than those from Limuru and Kabete seeds.

In the first experiment, the final ware yield was highest in plants descended from Limuru seed and lowest in plants from Thika seed. In the second experiment, plants from Limuru seed yielded the highest number of tubers, but plants from Kabete seed yielded the highest fresh weight of tubers. The lowest yield was obtained from plants descended from Thika seed.

It was concluded that in Kenya seed potatoes perform better if raised in the medium and high altitudes above 1400 m.

1. INTRODUCTION

1.1 History of the Potato

The original home of the potato (Solanum tuberosum) is the Andean plateau of South America (Pushkarnath, 1976) (Chapman, 1967). It was introduced to Europe in the second half of the sixteenth century (Pushkarnath, 1976) and to parts of Africa in the seventeeth century (Harris 1978). It gained recognition as an inexpensive and nutritive food only in the eighteenth century (Pushkarnath, 1976) (Harris, 1978).

1.2 Importance of the Potato

1.2.1 In the World

Potato is the most abundantly produced edible food in the world next only to cereals. The produce, when compared with the small area devoted to the crop is indeed very much higher than that of cereals (Pushkarnath, 1976). The ability of the potato to support a large number of people on a small acreage of land is a means of withstanding population pressure.

1.2.2 In Kenya

In Kenya, the Irish potato is a major food crop, particularly in the Central Province (Anon, 1976a) and (Anon 1978a). As a food crop it ranks only second to cereals (maize).

1.3 Food Value of the Potato:

Potato is a wholesome food (Pushkarnath, 1976). Apart from starch, of which it is a rich source, it provides essential body building substances such as vitamins, minerals and proteins (Talburt and Smith 1967). It contains practically all the essential dietary constituents except fat. It is one of the richest sources of calories needed to maintain day-to-day output of human energy. Constituents: (according to Talburt and Smith 1967) are:

	Total solids	22.5%
	Water	77.5%
Solids:	Proteins	2.0%
	Fat	0.1%
	Carbohydrates	19.4%
	Ash	1.0%

1.4 Limitations of the Potato:

The potato, despite its recognition as an inexpensive and nutritive food, is not yet widely grown in areas of the world where hunger and malnutrition are already realities, namely, the developing countries (Harris, 1978). Given its bulk, even though it is a cheap food, trade in potatoes will not be a means of directly alleviating the problems in the developing countries. It is important that the potato be established and its productivity be increased in such hunger stricken areas, especially in the tropics, including East Africa.

1.5 Problems of Potato Production in the Tropics.

The potato was first domesticated at high altitude in the Andes (Chapman, 1967) and is usually adapted in the tropics only to areas of land altitudes of 1000 metres above sea level or higher. In Kenya, for example the ideal potato growing areas are the highlands with altitudes ranging between 1600 and 2700 metres such as Kibirichia (Meru). At lower altitudes however potato crops have been successfully grown, under experimental conditions but disease problems are rampant at such altitudes (Chapman, 1967), and the yields are low.

1.6 Problems of Potato Production in Kenya:

In the potato growing areas of Kenya, the potential of potato cultivation has not been sufficiently exploited up to now. (Ballestrem and Holler, 1977). Thus, despite the increasing importance of potatoes in the diets of the people in Kenya potatoes have not always been available to the people at prices most consumers can afford, owing to the large fluctuation in production from season to season (Mbogoh, 1976). The high fluctuations indicate problems in production. These problems have been listed by Durr and Lorenzl, (1979) as:

(i) Diseases
(ii) Pests
(iii) Inadequate supply of certified seed
(iv) Poor husbandry practices
(v) Poor marketing system.

In the Central Province, much effort has been put into improving the expansion and development of potato production, but this expansion and development is still hampered by lack of certified seed material that is free from bacterial wilt (*Pseudomonas solanacearum*) and blight (*Phytophthora infestans*).

1.7 Importance of "Seed" Potato.

1.7.1 The "Seed" tuber

Unlike most crops where 'true' seed is used for raising a crop, potato is mostly propagated through tubers. On an average a tuber has twelve eyes distributed over the surface, the 'crow end' having a cluster of bud eyes. Each eye may have more than one bud and from each eye several sprouts may emerge. From these sprouts, new shoots are produced.

1.7.2 Seed quality

Seed quality is one of the most critical factors in raising potato productivity in developing countries. In fact in no other crop is the value of good seed so important as in the potato (Pushkarnath, 1976). With assured good seed, over 50% of the problems of production of the growers can be overcome (Pushkarnath, 1976). A detailed consideration of what is good seed and how it can be secured is therefore important.

1.7.3 Good Seed

A good quality seed is that which has the following attributes (Ricaud and Felix, 1980)

(i) Purity of variety
(ii) Right physiological age
(iii) Freedom from fungal and bacterial diseases.
(iv) Reasonable freedom from virus diseases.
(v) Freedom from nematodes.

These attributes are influenced by the way in which the seed crop is grown in the field, the area where it is grown, through the environmental factors e.g. temperature and rainfall, and the way in which it is stored. (Harris, 1978).

1.8 Seed Production Area.

It is well known that certain regions are more favourable for the production of high quality seed than others (Niederhauser, 1978). Experiences in different potato growing countries show yield differences between seed of the same variety originating in different locations. There have been several reports on the effect of altitude on performance of the seed thereof in subsequent crops. The best seed growing regions are usually characterised by lower temperatures (often provided by higher altitudes), freedom from certain disease (e.g. bacterial wilt and blight) and insect pests (e.g. tuber moth) and by isolation from contaminated areas.

In many tropical countries it should be feasible to establish disease-free areas for seed potato production and to apply strict plant quarantine restrictions to maintain disease freedom from such areas.

To establish such areas, further research is needed to study the so-called "place-effect" (Chapman, 1967) and to determine the probable causes. This "place effect" is sometimes attributed to differences in seed dormancy which can cause retarded or uneven emergence. Other possible influences are tuber-transmitted diseases differing in their virulence from place to place, variable soil and moisture conditions and possible natural selection of somatic mutations.

1.9 Seed production in Kenya.

Much effort has been put into improving the expansion and development of potato production through seed bulking exercises to increase the availability of planting material in all areas (Anon 1978a) with the aid of Agricultural Development Corporation (A.D.C.) farms, in Farmers Training Centres (F.T.C.) and by registered farmers, but the demand for good clean seed in Kenya has still to be met.

1.9.1 Problems limiting seed Production in Kenya.

1.9.1.1 Diseases

Bacterial wilt and late blight are still seriously hampering seed production (Anon. 1976a and Anon. 1978a).

1.9.1.2 Climate

Seed production is highly recommended in altitudes above 2300 metres, but potatoes are also grown in the Rift Valley Province and the Coast Province. These areas are characterised by high rainfall which is conducive to diseases such as bacterial wilt and late blight. (Ballestrem and Holler, 1977). Thus the demand for clean seed in all areas has yet to be met (Anon. 1976a), (Anon. 1978a).

1.9.1.3 Land availability

The areas of Kibirichia (Meru) and Kinangop are the only areas of concentrated potato growing (Ballestrem and Holler, 1977). In other areas the potential of potato cultivation has not been sufficiently exploited up to now. Seed propagation is highly recommended at high altitudes above 2300 m; and yet these are areas of ware crop production. The land area available at such altitudes is limited and there has been much discussion within Kenya concerning the scope and size of the seed industry. At one extreme, certified seed could not be used for every potato crop every season. Given a final annual ware production of 104,000 ha, this would require 10,400 ha of certified seed crop each year. If every tenth crop were planted with certified seed 1,040 ha of certified seed crop would be necessary. This last figure represents about ten times the current certified seed production (Robinson, 1973).

1.9.1.4 Market structure

The marketing and transport infrastructure existing in Kenya is limiting to the distribution of seed potatoes produced at the higher altitudes to the rest of the growing areas e.g. Coast Province.

As soon as some marketing problems are solved Kenya will be able to figure prominently in seed potato production in East Africa (Ballestrem and Holler, 1977).

1.9.1.5 Limited Research

Very little documental evidence exists in Kenya on the effect of location of seed production on its quality and subsequent performance. The reports from other countries on the effect of altitude and other factors on seed vigour vary widely and are not reconcilable. Yet seed potato production cannot be carried out everywhere, since not all regions are suitable for such production.

1.10 Objective of this study.

The aim of this study is to find out the effect of altitude of seed production on potato seed vigour as expressed by:

(i) the number of eyes per seed tuber.

(ii) the rate and amount of sprouting of seed tubers.

(iii) the rate of emergence in the field

(iv) the final ware yield of the subsequent crop.

Since most of the ware crop is grown in the higher altitudes (e.g. Kibirichia in Meru, North and South Kinangop) it would be of interest to find out if there is any advantage in raising seed at a certain altitude so as to enable planners to rationalise where best to concentrate seed production for the country.

2. LITERATURE REVIEW

SECTION A.

2.1 Effect of Altitude on:

2.1.1 Subsequent Yield.

There have been several reports of the altitude at which seed tubers were produced affecting subsequent ware yield. Rønsen (1971) found that the yield from seed grown in the previous year at low altitude was greater than that from seed produced at higher altitude, while Staikov and Chavdarov (1971) found the reverse to be true.

However, Kozlowska (1963) showed that ware yield increased progressively as the altitude of seed production increased from sea level to 939 m above sea level but that further increase in altitude gave a reduction in yield.

In 1974-1975 certified Scottish seed tubers were multiplied at four sites of different altitudes 46 m, 15-30 m, 213-244m and 366 m, the progeny tubers were subsequently grown to produce a ware crop at Wellsbourne, England, 46 m in 1975 and 1976 (Wurr, 1979). In 1975 the effects of the site of seed production on tuber yield of the ware crop were small, though there was an indication of a negative relationship between total tuber yield and the temperature at each site (Wurr, 1979). In 1976 the effect of site of seed production was more marked. In the field the final yield by both varieties was lowest from seed initially raised at the lowest altitude and highest from seed initially raised at the highest altitude. There was no indication that the effect of the site of seed production on tuber yield occurred as a result of differences in stem density (Wurr, 1979).

In Cyprus, Vakis (1980) found that seed performed equally well whether produced at low or high altitude sites.

In the 1974-75 experiment with certified Scottish seed tubers, Wurr (1979) found that the effects of site of seed production on sprout growth were small in 1975. In 1976, however, he found that the effect was more marked. The total sprout length per tuber of both varieties used was greater from the lowest and least from the highest site. However, Wurr (unpublished) found that seed tubers of two out of four varieties grown at 365 m. above sea level sprouted earlier than the tubers of the same size grown in the same way at three sites of lower altitude.

2.1.2 Chemical composition of tubers.

Moreno (1978) grew potato plants at (a) low altitude on the coast of Peru (100 m) and (b) high altitude in the Andes (3000 m) in the open and in each locality in soil transported from the other locality in large pots. Potato tubers of a particular cultivar grown on the coast differed in chemical composition from those grown in the Andes. His findings showed that, in general, tubers from the low altitudes had a lower content of soluble nitrogen than tubers from the higher altitudes. Asparagine: Glutamine ratio in tubers from low altitude was greater than I and almost three times higher than in tubers from the high altitude. Electrophoretic patterns of soluble basic and acidic proteins were higher in (a) than in (b). It was clearly shown that potato tubers from the Andes differed in metabolism and quality from those from the coast of Peru (Moreno, 1978). This difference in metabolism is likely to affect the quality of tubers as seeds.

3.1.3 Root Anatomy:

In a study of ten varieties grown for several years at 595 m and 1450 m. above sea level, Nikolayevskii and Nikolayevska (1977) reported that the varieties differed in the changes which occurred in root anatomy at higher altitudes. In five varieties the area of the root cross section did not change at all at higher altitudes, while in three varieties it fell by 8-11% and in two varieties it rose by 25-65%. Three groups of varieties were distinguished:

(i) those in which the relative development of the phloem was reduced by 9-15% at higher altitudes while the development of other tissues was not affected e.g. Lorkh.

(ii) those in which the development of the xylem increased by 15-43% while that of the other tissue remained the same or decreased e.g. Atlanta.

(iii) those in which there was a reduction in the relative development of all the vascular tissue including a 9-33% reduction in xylem development e.g. Agra.

Thus, in general, the altitude affected root anatomy of all the varieties in one way or another. It was not shown whether the differences in root anatomy had any effect on the yield of tubers. However other studies have shown differences in tuber development and subsequent yield of potatoes grown at different altitudes. The changes in root anatomy could be one of the factors influencing tuber growth and therefore could affect subsequent performance of seed tubers grown at different altitudes.

Also differences in sprout development and in chemical composition of tubers raised at different altitudes account for the differences in subsequent performance of seed tubers raised from these altitudes. Therefore it is necessary to find the altitude at which these factors combine in the best way to give maximum subsequent performance of seed.

SECTION B

2.2 Altitudes of seed Production in Various Countries.

2.2.1 Peru Seed is mainly produced in the Central highlands at 3200-3450 m. above sea level. At higher altitudes of 3950-4200 m. above sea level yields are lower (Anon. 1978b) (Horton, 1981). This implies that seed production is more favoured at the intermediate altitudes, not in the low altitudes nor the very high altitudes.

2.2.2 Romania: Seed potatoes are initially grown at Gheorghieni at an altitude of 1400 m., then multiplied at Brasnov (800 m. above sea level) before being grown commercially in the Danube basin (Vender, 1981). This indicates that although potatoes can be successfully grown at low altitudes (Danube basin, i.e. below 800 m.) it is preferable to raise seed at the higher altitude.

2.2.3 Britain: Great advantage is taken of the relatively cool, windy and comparatively aphid-free conditions of Northern Ireland, Scotland and Northern England, to produce seed with minimal virus infection (Wurr, 1978).

2.2.4 United States of America: In general seed area extends along the Northern tier of states adjoining Canada and includes certain areas of high altitude

(1000 m.) in many Western states; where diseases spread slowly, soil is productive, volunteer plants are not a problem and the tubers can be stored economically due to the low temperatures prevalent in these areas (Smith, 1977). (Jehle et al, 1952).

2.2.5 Israel: Seed potatoes are grown in the Golan heights at an altitude of 950 m. above sea level (Oppenheimer, 1981). The growth is rapid due to length of day and age of material planted. (Oppenheimer, 1981). This is particularly desired to give a quicker maturity period in the shorter growing season of spring.

It can be seen from the foregoing that altitude of seed production varies from country to country (e.g. 3200 m in Peru, 1400 m. in Romania and 950 m. in Israel). In Kenya, seed propagation is highly recommended in altitudes above 2300 m. above sea level (Ballestrem and Holler, 1977).

The common factor in all these countries cited is that seed is preferably grown at altitudes higher than those generally used for ware production. In Kenya for example, ware production is generally in altitudes ranging from 1600 m. to 2700, while seed is recommended above 2300 m and in Romania, seed in produced at 1400 while ware production is below 800 m above sea level. It is necessary to find out how altitude affects the seed quality so as to establish an area best suited for seed production. In Kenya little research has been done to this effect.

SECTION C

2.3 Factors through which altitude affects potato growth.

2.3.1 Air temperature

Increasing altitude in general reduces the average temperature during the growing season so that seed grown at high altitude should be physiologically younger than that grown at a lower altitude (Harris, 1978) (Accatino, 1978). By using physiologically old seeds, less foliage growth occurs while tuber initiation occurs earlier (Accatino, 1978). In many areas, yield and quality of potatoes are kept below maximum by the prevalence of high temperatures at the stage of tuber initiation (Borah and Milthorpe, 1959). Higher temperatures, however, are desirable at emergence and early development up to tuber initiation, when low temperature results in slow emergence and growth. During the rapid tuber enlargement stage and beginning of maturation also high temperatures increase yield (Borah and Milthorpe, 1959). Low temperatures are desirable during early storage when earlier break of dormancy is required. This effect of temperature refers to potatoes in general, but it is bound to affect the quality of the seed tuber through its influence on tuber growth.

Went (1959) and Iritani (1968) reported that tubers produced under cool conditions gave a higher final yield than those produced in warm conditions. They atributed this effect to the fact that seed produced at a higher temperature tends to break dormancy early and therefore becomes physiologically older than seed produced under cooler conditions, hence it gives a lower final yield at maturity. This contradicts the contention by Borah and Milthorpe (1959) and Wurr (unpublished) that low temperatures induce earlier break of dormancy, but all concluded that high temperatures reduce subsequent yield.

In this study, it will be seen whether in Kenya, seed from the cooler environments has more yield potential than comparable seed from the warmer environments.

2.3.2 Soil Temperature.

Influence of soil temperature on growth of tubers is greatest when air temperature is not conducive to tuber growth.

Jones, McKinney and Fellows (1922) found that potatoes give maximum yields at a soil temperature of 15 - 18^{o}C. A lower soil temperature slows the growth of the epigenous part of the plant and decreases starch content of the tubers, and below 4.4^{o}C growth ceases. The contents of phosphorus and nitrate were found to be much lower at 10 - 12^{o}C than at 15 - 20^{o}C (Barskaya, Novitskaya and Sycheva, 1960). One of the principal causes of nutrient decrease of potatoes in lower soil temperature is the reduced mineral uptake (Barskaya et al, 1960). When potatoes were grown at soil temperature of 10^{o}C and 30^{o}C for three weeks, the dry matter of tubers and rate of storage of carbohydrates in roots increased as the soil temperature decreased to 10°C (Sekioka, 1964).

In California, earliest emergence and best plant growth was obtained at 22-24°C soil temperature, and the poorest emergence and growth at 10-13°C. (Yamaguchi, Timm and Spurr, 1964). Many stolons are formed at 10-13°C and a large number are six inches more in length with delayed tuber enlargement. At the intermediate and high temperatures (22-24°C) most stolons were short or tubers were sessile to the stems. At 27-29°C, some multiple tuber initiations on simple thick stolons developed close to the soil surface. Largest tubers were produced at a soil temperature of 15.5-18°C (Yamaguchi *et al.*, 1964).

Went (1959) found greater tuber initiation at lower soil temperature. He suggested that a tuber forming hormone may be present in plants grown at low night temperatures. Plants grown at intermediate soil temperatures (15.5-18°C, 22-24°C) produced higher yields than those grown at lower or higher soil temperatures. Specific gravity, dry weight and starch content of tubers were higher at the intermediate temperatures than at lower or higher temperatures (Yamaguchi et al, 1964). It was found that potatoes suffered from "heat" or"drought" necrosis near the time of harvesting at soil temperatures above 22°C in Kern county, California (Lorenz, 1950).

2.3.3 Rainfall.

Amount of rainfall is another major factor limiting potato yield, therefore potato growth and consequently seed tuber quality. The optimum rainfall distribution for an early variety like Anett 3-3½ months) is a monthly mean of 150 mm. (Ballestrem and Holler, 1977). The distribution of rainfall during the growth period is more decisive for the final crop yield than the amount of rain. A well distributed rainfall of 220 mm during the growth period is better than 350 mm in only two months at altitude 1500 m above sea level (Ballestrem and Holler, 1977). A minimum monthly rainfall of 80 mm is necessary in areas above 1500 m if a potato crop (variety Anett) is to be economical. Generally Kenya soils are well drained so that the potato crop is not negatively affected by higher rainfall (Ballestrem and Holler, 1977).

2.3.4 Pests and Diseases.

There is greater occurrence of insect pests e.g. tuber moth (*Phthorimaea operculella*) and diseases e.g. bacterial wilt (*Pseudomonas solanacearum*) and blight (*Phytophthora infestans*) in the lower altitudes than in the higher altitudes in Kenya (Ballestrem and Holler, 1977). These greatly affect the choice of seed area, as the seed is required to be free from these pests and diseases.

SECTION D

2.4 Potato Properties through which the above climatic conditions may influence seed vigour.

2.4.1 Chronological age.

Kawakami (1953) considered that the value of seed tuber was not affected by its source other than through the effect of the source on the chronological age. He suggested that the optimum chronological age of seed was approximately five months from harvesting to planting. He ignored any influence of the conditions under which the seed was produced and stored. This implies that seed from high altitude will give the same subsequent yield with seed from the low altitude if both were harvested at the same time and then planted at the same time. It also implies that seed from low altitude stored for five months will give higher ware yield than seed from high altitude stored for only two months or seven months, and vice versa.

2.4.2 Physiological age.

There are nevertheless many reports of seed of the same chronological age from harvest to planting giving differences in performance in the field, which were attributed to physiological age (Wurr, 1978). He maintained that the health of the seed tuber, its physiological age and the way in which the seed crop was grown in the field and the way in which it was stored determined its certification grade and its subsequent ware yield. Seed grown at high altitude or low temperature should be physiologically younger than that grown at lower altitude or higher temperatures (Harris, 1978 ; Accatino, 1978).
The effect of physiological age on yield depends on the stage of growth of the crop at harvest

(Harris, 1978). In a short growing season the use of physiologically old seed may lead to higher yields whereas in a longer growing season this is often not the case (Accatino, 1978). Thus in Israel, seed for the spring season is raised in the Golan heights at an altitude of 950 m. in order to get physiologically old seed which will give quicker maturity period in the short growing season of spring. (Oppenheimer, 1981). Yet in Peru, seed is raised at 3200-3450m. above sea level because the growing period is longer and physiologically younger seed is more desirable. Plants grown from too old seeds are often weak and their yield low. Old seeds give weak sprouts, frequently giving less abundant growth of potatoes, especially when the seeds are planted in cold wet soil (Accatino, 1978).

2.4.3 Dormancy.

It is believed that low temperatures during tuber initiation and early storage cause an earlier break of dormancy. There may be a similar effect on tubers subjected to low soil temperatures prior to harvest (Borah and Milthorpe, 1959). Yet Went, (1959) and Iritani (1968) reported that seed produced at higher temperatures tends to break dormancy early and therefore becomes physiologically older than seed produced under cooler conditions. In either case the result is a lower yield by seed from warm environments and higher yield in seed from the cooler environments. In Kenya, high temperature is synonymous with low altitude and low temperature with high altitude.

2.4.4 Sprout length.

Wurr (1979) found that seed tubers raised at low altitude or high temperature gave greater sprout length per tuber than those raised from higher altitude or lower temperature, and sprout length had a negative relationship to subsequent yield in the field.

2.4.5 Freedom from Diseases.

Generally, seed raised at higher altitude is more free from bacterial, fungal and virus diseases than seed from the lower altitude, especially in the tropics, since these diseases have higher occurrence at lower than at higher altitudes. (Chapman, 1976).

The above five conditions of the potato tuber partly determine the certification grade of the seed and its subsequent yield (Wurr, 1978). The prime aim of a seed certification system is to maintain the varietal purity of seed stocks and to control the spread of disease by presenting tolerances and suitable growing conditions. To this end, most countries are selective in their choice of seed production area, as cited in Section B of this chapter. In Kenya, too, a choice of seed area needs to be selected, with suitable climatic conditions to produce healthy and vigorous seeds. It has been assumed that in Kenya seed is best produced in the higher altitudes above 2300 m. above sea level (Ballestrem and Holler, 1977) because it is at these altitudes that occurrence of fungal and bacterial and virus diseases is less. But there has been little research into the effect of altitude on the vigour of the seeds produced thereof. The objective of this study therefore is to investigate the effect of altitude on seed vigour as reflected by performance of the seed in subsequent season. By elucidating possible yield advantages to be gained from seed raised at a certain altitude it will then enable planners rationalise where best to concentrate the growing of potato seed for the country.

3. MATERIALS AND METHODS

Two experiments were conducted. In the first experiment, seed was produced in October 1982 - January 1983 and tested in April - August 1983. In the second experiment seed was produced in May - August 1983 and tested in December 1983 - March 1984.

3.1 Experiment 1.

3.1.1 Seed Production.

3.1.1.1 Seed Preparation. The variety Anett was used. Seed tubers of the same size and age were pre-sprouted using the natural method. The average number of sprouts per tuber varied from four to seven.

3.1.1.2 Sites. Three sites of different altitudes were used for seed production: Thika (1440 m), Kabete (1820 m) and Limuru (2225 m).

3.1.1.3 Soil. Soil from each site was transported to all sites in large tins, each containing 22.5 kg. of soil dug from a depth of 15 cm. to the surface.

3.1.1.4 <u>Experimental design</u>. A split plot design was used. The three different sites formed the main plots or treatments, while the different soils formed the subplots at each site. Each soil was replicated four times at each site. Spacing was 75 cm between rows and 30 cm within rows. Two guard rows were planted around the perimeter, with the same spacing of 75 x 30 cm.

3.1.1.5 <u>Planting</u>. This was done from 26 - 27 October, 1982, starting with Thika, then Limuru and lastly Kabete. Seed tubers were planted in tins which were previously washed, perforated for drainage and filled with 22.5 kg of soil. The tins were dug into the ground to ensure that soil temperature in the tins was the same as that of the surrounding soil. Tins were used (Instead of plastic buckets or pots) because tins conduct the temperature from the surrounding soil to the soil inside the tins. One tuber was planted in each tin. Diammonium Phosphate (DAP) fertiliser was added at the rate of 500 kg/ha or 14 g. per plant. Aldrin (40% W.P.) dust was applied for protection against tuber moth. All the plants were well watered immediately after planting. For the rest of the season the plants were to depend on rainfall for water.

3.1.1.6 Management in the Field. Three weeks after plant emergence, up to the end of the season, the plants were sprayed with Dithane M45 once a week and Ridomil every fortnight, to control early blight (Phytophthora infestans) and late blight (Alternaria solani) respectively. Weeding was done two months after planting.

3.1.1.7 Parameters measured.

Weather. In addition to the weather data recorded daily by the meteorological stations at the three sites, soil moisture and soil temperature at each site were monitored every week using the methods described below:

Soil Moisture. Calibrated gypsum blocks were placed in the soil at 5 and 15 cm depths. A resistance meter was used to relate the change in soil water status via the change of resistance of the block to soil water potential by the use of calibration curves.

Soil Temperature. Previously calibrated thermistors were placed into the soil at a depth of 5 cm and 15 cm.

The themistor connections were insulated with araldite to prevent spurious resistance readings due to soil water. A resistance meter was used to take readings which were then transformed into temperature readings (^{o}C) using calibration curves. The calibration curves of thermocouplee resistance against temperature of water (^{o}C) had previously been produced in the laboratory.

Soil Chemical Analysis. A soil sample from each site was analysed for pH, Carbon, Nitrogen, Phosphorus, Calcium, Magnesium, Potassium, Sodium, Cation Exchange Capacity (C.E.C.) and water retaining capacity.

Plant Parameters.

Stems and leaves. Three weeks after emergence and two months after emergence, the number of stems and leaves per plant were determined. The stems included the main stems and axillary branches. Two months after emergence the number of nodes and internodes per main stem were counted.

After harvesting the following parameters were determined:

(i) Number of tubers per plant.

(ii) Fresh weight of tubers per plant.

(iii) The mean fresh weight per tuber per plot was calculated.

3.1.1.8 Harvesting. Plants from Thika were harvested first, then plants from Limuru were harvested later the same day and those from Kabete were harvested last on the following day i.e.from 20 - 21st January, 1983.

3.1.1.9 Storage. The tubers were treated with pyrethrin dust and put in wooden trays in a well ventilated store to sprout naturally for planting the following season.

3.1.2 Testing of Seeds raised at different sites.

3.1.2.1 Number of Eyes. After three months in storage, the number of eyes for 20 medium size tubers (2-4 cm diameter) were counted and the average number of eyes per tuber determined.

3.1.2.2 Sprout length. This was determined for 20 medium size tubers from each seed batch and expressed as the number of sprouts per tuber 3 mm long or longer.

3.1.2.3 Planting. Seed from all sites was planted at Kabete during April-August 1983 to test its performance. Seed tubers from a particular site and soil combination were planted in rows of eight plants in a completely randomised design on 28th April. Three guard rows were planted around the experimental plot. Management of the crop in the field was identical to the first season.

3.1.2.4 Harvesting. All the plants were harvested on 10th August 1983. Each row of eight plants was harvested separately and the resultant tubers counted and weighed separately. From this, the fresh weight and number of tubers per plant were derived.

3.2 Experiment 2.

3.2.1 Seed production. This was done during the season of April - August 1983, using the same variety, seed preparation and sites as in the first experiment. Experimental design was the same as in the first experiment except there were 12 replications of each soil at each site.

Planting. Was done on 29-30 April, starting with Thika and Limuru on the same day and then Kabete the next day, in the same way as in experiment 1.

Plant management in the field and the parameters measured were as in the first experiment.

Harvesting. Plants from Thika and Limuru were harvested on 8th August starting with Thika in the morning and Limuru in the afternoon. Plants from Kabete were harvested on 9th August 1983. Tubers from each plant were harvested, counted and weighed separately.

Storage. Tubers of twelve replications representing one site and soil combination were pooled together and stored together in wooden trays in a well ventilated store. The tubers were treated with pyrethrin dust and sprouted naturally.

3.2.2 Seed Testing. Was done during December 1983-March 1934.

3.2.2.1 Number of Eyes. Was determined as in the first experiment.

3.2.2.2 Number of Sprouts. Was determined as in the first experiment.

3.2.2.3 Planting. As in the first experiment, seed from all sites was planted at Kabete to test its performance. Small seeds, medium size seeds and large seeds from each batch were planted separately. Planting was on December 8th 1983. Seeds of a particular site, soil and size combination were planted in one row in a completely randomised design. Crop management in the field was as in the first experiment. Two months after planting, photographs were taken in the field to show differences in vegetative growth.

3.2.2.4 Harvesting. All the plants were harvested on March 12th 1984. Plants from each seed batch were harvested separately, counted and weighed. Then the number and fresh weight of tubers per plant were derived.

4. RESULTS

4.1 Experiment 1.

4.1.1 Seed Production.

4.1.1.1 Emergence and vegetative growth.

The first plants to emerge were those in Thika, ten days after planting. Those in Limuru emerged twelve days after planting, three days after those in Kabete, and four days after those in Thika.

At all sites, plants in Kabete soil were the first to emerge, followed by those in Limuru soil and lastly those in Thika soil.

Three weeks after planting, at Kabete site, two plants in Kabete soil and one in Thika soil had not emerged and had to be replaced by new seed tubers.

Vegetative growth, measured in terms of number of stems, leaves and internodes was as shown in Tables 1, 2 and 3.

Table 1: Effect of site and soil on Number of stems per plot. (Totals based on 4 replications).

	SITE				
Soil	Thika	Limuru	Kabete	Total	Mean
Thika	42	29	18	89	29.6
Limuru	62	35	22	119	39.6
Kabete	45	43	27	115	38.3
Total	149	107	67		
Mean.	49.6	35.6	22.3		

<u>NB</u> Numbers of stems includes the main stems and axillary branches.

F (site) = 60.59^{**}

F (soil) = 9.59^{**}

LSD ($P = 0.05$) = 2.50

The mean for Thika soil was significantly lower than that of Kabete and Limuru soils. The mean for Kabete and Limuru soils were not significantly different.

Table 2: Effect of site and soil on Number of Leaves per plot. (Totals based on 4 replications).

	SITE				
Soil	Thika	Limuru	Kabete	Total	Mean
Thika	261	216	112	589	196.33
Limuru	366	288	206	860	286.66
Kabete	345	327	194	866	288.66
Total	972	831	512		
Mean	324	277	170.66		

F (site) = 540.86**

F (soil) = 243.79**

L.S.D. (P = 0.05) = 8.54

The mean for Thika soil was significantly lower than those of Kabete and Limuru soils. The means for Kabete and Limuru soils were not significantly different.

Table 3: Effect of site and soil on Number of Internodes per plant (Totals based on 4 replications).

	SITE				
Soil	Thika	Limuru	Kabete	Total	Mean
Thika	226	197	134	557	185.6
Limuru	246	289	135	670	223.3
Kabete	233	274	138	645	215.0
Total	705	760	407		
Mean.	235	253.3	135.6		

F (site) = 13.82**

F (soil) = 0.48 NS.

LSD (P = 0.05) = 1.04

All the means for sites were significantly different, whereas soil had no significant effect on the number of internodes.

Plants at Thika showed the most vigorous vegetative growth, having the largest number of stems and leaves, while plants at Kabete showed the least vigorous vegetative growth, with the least number of stems and leaves. Limuru site had more vigorous vegetative growth than Kabete site, but less than Thika site. Plants at Limuru had significantly more internodes than the plants at Kabete and Thika.

At all sites, plants growing in Thika soil showed the least vigorous vegetative growth, with the least number of stems and leaves. Kabete soil gave the most vigorous vegetative growth.

4.1.2 Flowering.

At Limuru site no flowering occurred at all. At Thika site, two plants in Limuru soil had flowered by November 26 1982, that is, one month after planting. The other plants did not flower. At Kabete site all plants flowered by November 30th, 1982, and later produced fruits.

4.1.3 Diseases.

The first signs of disease appeared at Kabete on 25th November 1982, one month after planting. There was virus infection on one plant in the guard rows and one plant in Thika soil. There were also symptoms of blight (*Phytophthora infestans*) in the guard rows. However these did not spread as the plants were sprayed regularly. Limuru site was the second to show symptoms of late blight; these were confined to the guard rows and did not spread. At Thika site the blight symptoms showed latest and spread very fast, but this was near the time of harvesting.

4.1.4 Pests.

There were no pests at Limuru site. At Kabete there were patridges which ate some plants from the guard rows. There was also tuber moth infestation by the time of harvesting. At Thika there were porcupines and tuber moth infestations were more marked than at Kabete.

4.1.5 Seed Tuber Yield.

The highest tuber yield was obtained from Limuru and the lowest from Kabete as shown in Tables 4 and 5.

Table 4: Effect of site and soil on Number of Tubers per plot (Totals based on 4 replications).

	SITE				
Soil	Thika	Limuru	Kabete	Total	Mean.
Thika	55	59	27	141	47
Limuru	20	66	54	140	46
Kabete	75	89	53	217	72
Total	150	214	134		
Mean	50	71	44		

F (site) = 36.7^{**}

F (soil) = 33.7^{**}

LSD (P = 0.05) = 5.6

There was significant difference in mean number of tubers between Limuru and the other sites; there was no significant difference between Kabete and Thika sites in Number of tubers. There was significant difference in number of tubers between Limuru and Thika soils.

Limuru site gave the largest number of seed tubers, followed by Thika. The lower yield at

Kabete was attributed to the fact that three plants had to be replaced three weeks after planting after the planted seed failed to emerge. By the time of harvesting the plants were three weeks younger than the other plants and had not matured and tuber growth was not complete.

Table 5: Effect of Site and Soil on Fresh Weight of Tubers per plot (g) (based on 4 replications).

	SITE				
Soil	Thika	Limuru	Kabete	Total	Mean
Thika	1193	1393	5789	3165	1055
Limuru	825	1638	11334	3597	1199
Kabete	1875	2000	1077	4953	1651
Total	3893	5031	2790		
Mean	1298	1677	929		

F (site) = 210.22**

F (soil) = 120.59**

LSD (P = 0.05) 55.45

The fresh weights of the seed tubers produced were significantly different at all sites and in all soils (Table 5).

Limuru site gave the highest yield of seed tubers and Kabete site the lowest. Kabete soil yielded highest, followed by Limuru soil and lastly Thika soil.

The three sites and soils showed significant differences in the size of tubers produced, with Limuru site having the largest tubers and Kabete the smallest tubers. Limuru soil also gave the largest tubers and Kabete soil the smallest (Table 6).

Table 6: Effect of Site and Soil on Tuber size (fresh weight per tuber) (g).

	SITE				
Soil	Thika	Limuru	Kabete	Total	Mean.
Thika	26.7	20.0	21.6	68.5	22.8
Limuru	25.5	42.5	21.3	89.3	29.8
Kabete	21.7	25.7	17.7	65.1	21.7
Total	73.1	88.2	60.6		
Mean	24.4	29.7	20.2		

F (site) = 10.73**
F (site) = 10.59**
LSD (P = 0.05) = 5.55

There were significant differences in tuber size between all the sites. There was no significant difference in tuber size between Thika and Kabete soils; but Limuru soil gave significantly larger tubers than Thika and Kabete soils (Table 6).

4.1.6 <u>Seed Testing</u>.

4.1.6.1 <u>Effect of Site and Soil on Number of Eyes and Sprouting</u>.

<u>Number of Eyes</u>.

Seed from Limuru had the largest number of eyes per tuber and seed from Thika had the lowest number of eyes. (Table 7).

Table 7: Mean Number of Eyes per Tuber.

	SITE				
Soil	Thika	Limuru	Kabete	Total	Mean.
Thika	9.35	10.15	9.97	27.47	9.82
Limuru	9.55	10.24	10.10	29.89	9.96
Kabete	7.60	11.90	10.62	32.12	10.70
Total	28.40	32.29	30.69		
Mean	7.46	10.76	10.23		

Sprouting.

Although all the seed was sprouted in the same place, under the same conditions, seed tubers from Thika sprouted about two days earlier than those from Kabete and Limuru. There were differences in the number and length of sprouts, with Limuru seed having slightly more and larger sprouts than Kabete seed (Table 8). There were significant differences in the number of sprouts per seed tuber 3 mm long or longer. Limuru seed tubers had the largest number of sprouts of 3 mm length, followed by Kabete seed. Seed tubers from Thika, though the first to sprout had the fewest sprouts per tuber of 3 mm length or longer (Table 8).

Table 8: Number of sprouts per tuber with sprouts 3 mm. or longer.

	SITE				
Soil	Thika	Limuru	Kabete	Total	Mean.
Thika	2.5	5.5	5.5	13.5	4.5
Limuru	3.5	6.0	4.5	14.5	4.6
Kabete	2.5	9.0	7.0	18.5	6.2
Total	8.5	20.5	17.0		
Mean	2.8	6.8	5.7		

4.1.6.2 <u>Emergence and Vegetative Growth in the Field</u>.

Plants from Limuru seed were the first to emerge, followed by those from Kabete seed two days later. Of the plants from Limuru seed and Kabete seed, those from seed previously raised in Thika soil and Limuru soil emerged before those from seed produced in Kabete soil. Plants from Thika seed emerged last.

Generally, plants from Thika seed had less vigorous vegetative growth than plants from Kabete and Limuru seed. The least vigorous vegetative growth was shown by plants from Thika seed produced in Thika soil. The most vigorous vegetative growth was shown by plants from Limuru and Kabete seeds raised in Kabete soil.

At maturity, that is three months after planting, plants from Thika seed were the first to show signs of senescence. Plants from Limuru and Kabete seeds raised in Kabete soil were the last to senesce.

4.1.6.3 Tuber Yield of Subsequent Crop.

Number of Tubers.

Seed from Limuru site gave a significantly larger number of tubers per plant in the subsequent season than seed from Thika and Kabete. There was no significant difference in subsequent number of tubers between Kabete seed and Thika seed. (Table 9).

Seed raised in Thika soil gave a significantly larger number of tubers per plant than that raised in Limuru and Kabete soils (Table 9).

Table 9: Effect of seed origin on subsequent Number of Tubers per Plant.

	SITE				
Soil	Thika	Limuru	Kabete	Total	Mean.
Thika	6.0	7.0	7.1	20.1	6.6
Limuru	5.2	6.0	5.3	16.5	5.5
Kabete	5.4	6.2	5.4	17.0	5.6
Total	16.6	19.2	17.8		
Mean	5.5	6.4	5.9		

$F \text{ (site)} = 16.45^{**}$

$F \text{ (soil)} = 47.94^{**}$

LSD ($P = 0.05$) = 0.9

Fresh Weight of Tubers.

There were significant differences in subsequent fresh weights of tubers per plant between all the three sites of seed origin. Seeds originating from Kabete gave the highest subsequent yield in fresh weight, followed by Limuru seed. Seeds from Thika site gave the lowest subsequent fresh weight.

Seeds previously grown in Thika soil gave the highest subsequent fresh weight of tubers per plant, and seeds from Limuru soil the lowest.

Table 10: Fresh Weight of Tubers per Plant (g)

	SITE				
Soil	Thika	Limuru	Kabete	Total	Mean
Thika	340.4	408.8	554.2	1303.4	427.8
Limuru	419.0	504.6	451.0	1374.6	458.2
Kabete	506.2	479.0	487.1	1492.3	490.8
Total	1262.6	1392.4	1492.1		
Mean	421.5	464.1	497.4		

$F\ (\text{site}) = 3.93^{**}$

$F\ (\text{soil}) = 3.03^{**}$

LSD (P = 0.05) = 15.5

4.2 Experiment 2.

4.2.1 Seed Production.

4.2.1.1 Emergence and Vegetative growth.

Plants at Limuru were the first to emerge two weeks after planting, followed by those at Kabete two days later. Plants at Thika emerged three weeks after planting.

Plants at Limuru showed the most vigorous vegetative growth and those at Thika the least vigorous vegetative growth as shown by the number of stems, leaves, and nodes (Tables 11, 12 and 13).

Table 11: Effect of site and soil on Number of main stems per plot (Totals based on 12 replications).

	SITE				
Soil	Thika	Limuru	Kabete	Total	Mean.
Thika	33	41	40	114	38.0
Limuru	40	52	54	146	48.6
Kabete	43	70	58	171	57.0
Total	116	163	152		
Mean	38.6	54.3	50.6		

F (site) = 179.2**
F (soil) = 242.0**
LSD (P = 0.05 = 1.0

NB. Number of Main Stems does not include the axillary branches.

The means for Number of stems were significantly different for all sites and all soils, with Limuru site giving the largest number of stems and Thika site the least (Table 11).

As in the first season, Kabete soil had the largest number of stems and Thika soil the least.

There were also significant differences in mean number of leaves between all the sites and all the soils (Table 12).

Limuru site showed the most vigorous growth, with the largest number of leaves, and Thika site the least vigorous growth, with the least number of leaves.

Again Kabete soil showed the most vigorous growth and Thika soil the least.

Table 12: Effect of Site and Soil on Number of leaves per plot (Totals based on 12 replications).

	Site				
Soil	Thika	Limuru	Kabete	Total	Mean
Thika	239	315	291	845	281.6
Limuru	294	406	438	1138	379.3
Kabete	302	663	470	1435	478.3
Toral	835	1384	1199		
Mean	278.3	461.3	399.6		

F (site) = 96.7**

F (Soil) = 107.9**

LSD (P = 0.05) = 15.67

Table 13: Effect of Site and Soil on Number of Nodes per Plot (based on 12 replications).

	Site				
Soil	Thika	Limuru	Kabete	Total	Mean
Thika	129	122	123	374	124.6
Limuru	114	117	126	357	119.0
Kabete	119	117	132	368	122.6
Total	362	356	381		
Mean	120.2	118.6	127		

F (Site) = 48.27**

F (Soil) = 21.07**

LSD (P = 0.05) = 5.036

All sites showed significant differences in number of nodes, with Kabete site giving the largest number followed by Thika site, and Limuru site giving the least number of nodes. Thika soil gave the largest number, followed by Kabete soil, and Limuru soil gave the least number of nodes. (Table 13). There does not seem to be a definite relationship between the number of nodes or internodes and vegetative growth.

4.2.1.2 Seed Tuber Yield.

Tuber Number per Plant

The largest number of tubers was again obtained from Limuru site, and the lowest was from Thika site (Table 14). There were significant differences in number of tubers per plant between all sites.

Limuru soil gave the largest number of tubers and again Thika soil gave the least number

(Table 14). There were significant differences between all soils.

Table 14: Effect of site and soil on Number of Tubers per plant: (Means for 12 replications).

	SITE				
Soil	Thika	Limuru	Kabete	Total	Mean.
Thika	2.2	7.0	7.2	16.4	5.5
Limuru	4.2	10.0	8.7	22.9	7.6
Kabete	4.1	9.8	8.0	21.1	7.0
Total	10.5	26.8	23.9		
Mean	3.5	8.9	7.9		

F (site) = 244.78**
F (soil) = 39.52**

LSD (P = 0.05) = 0.976

Fresh Weight of Tubers.

There were significant differences in fresh weight of tubers per plant between all the sites.

Kabete site gave the highest yield in fresh weight, followed by Limuru site, and Thika site gave the lowest yield (Table 15).

Table 15: Effect of Site and Soil on Fresh Weight of Tubers per plant (g) (Means for 12 replications).

Soil	SITE Thika	Limuru	Kabete	Total	Mean.
Thika	96.6	169.5	257.8	523.9	174.7
Limuru	406.8	260.7	317.4	984.9	328.3
Kabete	112.7	295.3	326.8	732.7	244.9
Total	585.1	725.5	906.0		
Mean	195.0	241.8	300.7		

F (site) = 19.45**

F (site) = 49.77**

LSD = (P = 0.05) = 21.6

There were significant differences in fresh weight of tubers per plant between all the soils, with Limuru soil giving the highest yield followed by Kabete soil. Again Thika soil gave the lowest yield.

Comparing the data in Tables 14 and 15, it is clear that although Limuru site gave significantly more number of tubers per plant, Kabete site gave the highest fresh weight of tubers, implying that the tubers produced at Kabete were larger in size than those produced at Limuru. From these data the average size of tubers can be derived (Table 16).

Table 16: Effect of Site and Soil on Tuber size (average fresh weight per tuber (g)).

	SITE				
Soil	Thika	Limuru	Kabete	Total	Mean.
Thika	44.0	24.2	35.7	103.9	34.6
Limuru	97.0	26.1	36.5	159.6	53.2
Kabete	27.5	30.1	40.9	98.5	32.8
Total	168.5	80.4	113.1		
Mean	56.2	27.0	37.7		

It is indicated that Thika site gave the largest tubers, though fewest, while Limuru site gave the smallest tubers but the largest number. The differences between all sites are significant.

Limuru soil gave significantly larger tubers than Kabete and Thika soils, which were not significantly different.

4.2.2 Effect of Site and Soil on Number of Eyes and Sprouting.

Number of Eyes: There was no significant difference in the number of eyes per tuber between sites, but Kabete seed had the largest number of eyes per tuber on average, followed by Limuru seed. Seed tubers from Thika had the fewest number of eyes per tuber (Table 17). There was no significant difference between soils of seed origin. (Table 17).

Table 17: Mean Number of Eyes per tuber (for 20 medium size tubers).

	SITE				
Soil	Thika	Limuru	Kabete	Total	Mean
Thika	9.0	9.9	10.9	30.8	10.2
Limuru	9.1	9.4	10.1	26.6	8.9
Kabete	9.9	10.9	10.9	32.1	10.7
Total	20.95	30.2	38.3		
Mean	6.98	10.1	12.7		

<u>Sprouting</u>: Seed tubers from Thika sprouted earlier than those from Limuru and Kabete by about 4 days. There was no significant difference in time of sprouting between Kabete and Limuru seed and their sprout length was not significantly different. (Table 18). Soil had no significant effect on sprouting.

Table 18: Mean Number of Sprouts per tuber 3 mm. or longer.

	SITE				
Soil	Thika	Limuru	Kabete	Total	Mean.
Thika	5.7	7.0	6.9	19.6	6.5
Limuru	6.1	7.7	7.2	21.0	7.0
Kabete	6.4	7.9	7.4	21.7	7.2
Total	18.2	22.6	21.5		
Mean	6.0	7.5	7.1		

4.2.3 <u>Effect of Seed Origin on Seed Performance</u>.

4.2.3.1 <u>Emergence and Vegetative Growth</u>.

The following plants were the first to emerge, two weeks after planting, in that order:

1. Seed from Limuru site, Kabete soil.
2. Seed from Kabete site, Kabete soil.
3. Seed from Limuru site, Limuru soil.
4. Seed from Kabete site, Limuru soil.

Four weeks after planting, all plants had emerged, but all plants from Thika seed were visibly smaller than the rest (Plates: 1, 4 and 7 indicating that they had emerged last while the first ones to emerge were visibly taller and more leafy than the rest. (Plates 5b, 8a and 9.

Generally, plants from Limuru and Kabete seed had thicker and more main stems and branches and more leaves than plants from Thika seed. At maturity, plants from Thika seed were the first to senesce while plants from Kabete and Limuru seeds were the last.

4.2.3.2 Tuber Yield.

Number of Tubers. There were no significant differences in the number of tubers per plant between the sites of seed origin, though seed originating from Kabete gave the largest number of

Plate 1. Plants from seed of Thika site Thika soil.

Plate 2. Plants from seed of Limuru site Thika soil.

Plate 3. Plants from seed of Kabete site Thika soil.

Plate 4. Plants from seed of Thika site Limuru soil.

Plate 5. Plants from seed of Limuru site Limuru soil.

Plate 6. Plants from seed of Kabete site Limuru soil.

Plate 7. Plants from seed of Thika site Kabete soil.

Plate 8. Plants from seed of Limuru site Kabete soil.

Plate 9. Plants from seed of Kabete site Kabete soil.

tubers per plant, and seed from Thika the lowest (Table 19).

Soil origin had no significant effect on subsequent number of tubers per plant though seed from Limuru soil gave the largest number of tubers per plant and Thika soil the lowest (Table 19).

Table 19: Effect of Seed Origin on Subsequent number of tubers per plant.

	SITE				
Soil	Thika	Limuru	Kabete	Total	Mean
Thika	4.3	6.0	5.0	15.3	5.1
Limuru	9.3	6.6	13.0	28.9	9.6
Kabete	5.0	9.0	10.0	24.0	8.0
Total	18.6	21.6	28.0		
Mean	6.2	7.2	9.3		

Fresh Weight of tubers.

There were significant differences in fresh weight of tubers between the sites of seed origin. Plants from Limuru seed gave the highest subsequent yield in fresh weight, followed by those from Kabete seed, and the lowest fresh weight was from plants originating from Thika seed (Table 20).

Soil origin had some effect on tuber fresh weight, with seed originating from Kabete and Limuru soils yielding significantly higher than seed from Thika. There was no significant difference in Limuru and Kabete soils (Table 20).

Table 20: Effect of Seed origin on subsequent Fresh weight of tubers per plant: (g).

	SITE				
Soil	Thika	Limuru	Kabete	Total	Mean
Thika	1707.6	2961.3	2842.6	7511.5	2503.8
Limuru	1885.3	3623.0	3010.0	8518.3	2839.4
Kabete	1938.0	3147.6	3364.0	8449.6	2816.5
Total	5530.9	9731.9	9216.6		
Mean	1844.0	3244.0	3076.0		

F (site) = 84.0**

F (soil) = 6.379*

LSD (P = 0.05) = 41.33

5. DISCUSSION OF RESULTS

5.1 Emergence.

5.1.1. Effect of site on Emergence.

In the first experiment, plants at Thika were the first to emerge, followed by those at Limuru, and lastly, those at Kabete. This was probably due to the fact that the three sites were planted in that order, with a difference of one day in between planting. But in the second season of seed production (April-August 1983) plants at Limuru were the first to emerge, followed by those at Kabete, despite the fact that Thika and Limuru sites were planted on the same day and Kabete site was planted one day later than Thika site. It is clear that it is not merely altitude which influenced the emergence of the plants. The three locations showed significant differences in air temperature, soil temperature and rainfall (Appendix Tables i, ii, iii, iv, v, vi, vii, and viii). Thika had the highest air and soil temperature while Limuru had the lowest in both seasons. Thika had the highest air and soil temperatures while Limuru had the lowest in both seasons (Appendix tables (iv to ix) and (xiv to xviii)). Thika had the lowest rainfall and Limuru the highest in both seasons (Appendix tables (i to iii) and (xi to xiii)). However, in the first season, all the sites had sufficient rainfall, well above the minimum required for potato growth (Tables (i), (ii) and (iii)). In the second season the rainfall at Thika was well below the minimum required for potato growth. (Table (xiv)). Thus in the first season, emergence at Thika was first, probably partly because of enough rainfall and high air and soil temperatures (Tables (i), (iv) and (vii)). High air and soil temperatures are known to quicken emergence (Borah and Milthorpe, 1959). In the second season, emergence at Thika was delayed despite the high soil and air temperatures (Tables (iv) and (vii)) because of low rainfall which resulted in low soil moisture (Table (xx)). In the first season emergence at Limuru and Kabete was later than at Thika because of the lower temperatures which are known to delay emergence (Borah and Milthorpe, 1959). In the second season, plants in Limuru and Kabete had 1-2 days difference in emergence because of the difference in planting time, since both had enough rainfall for emergence to take place (Tables (xii) and (xiii)). Emergence at these two sites was faster in the first season (10-12 days after planting) than in the second season (2 weeks after planting) probably due to less rainfall in the second season (Tables (ii), (iii) (xii) and (xiii)).

5.1.2 Effect of Soil on Emergence

Plants emerged first in Kabete soil at all sites in both seasons, yet all soils at a given site were having similar soil temperatures, and rainfall. The quicker emergence in Kabete soil may be attributed to its better chemical content (Table (vii)) and water holding capacity. Increased supply of Nitrogen, Phosphorus and Potassium is known to increase rate of sprouting and shoot emergence (Headford, 1962; Morris, 1967). Kabete soil had the highest percent Nitrogen, followed by Limuru soil and Thika soil had the lowest. Potassium was the same for Kabete and Limuru soils but less in Thika soil. Phosphorus was highest in Limuru soil and lowest in Thika soil (Table (vii). Percent carbon and Cation Exchange Capacity were highest in Kabete and Limuru soils and lowest in Thika soil (Table (vii)). This may be the explanation for the quicker emergence in Kabete soil, then Limuru soil and the delay in emergence in Thika soil. Also there may be differences in the specific heat for the different soils which may have caused differences in rate of emergence.

5.2 Vegetative Growth.

5.2.1 Effect of Site on Vegetative Growth.

In the first season, vegetative growth was most vigorous at Thika, followed by Limuru, then Kabete. This can be partly explained by the emergence having been faster in Thika and last in Kabete. It was also partly due to higher air and soil temperatures in Thika, which are known to promote vegetative growth (Harris, 1978; Borah and Milthorpe, 1959), since all the sites had sufficient rainfall to support potato growth, and top growth is not affected by moisture content as long as available moisture is present for growth (Smith, 1977). The less vigorous growth in Kabete, though the temperatures were higher than in Limuru, was due to some plants failing to emerge and being replaced after three weeks. The plants which emerged first at Kabete were as vigorous as those in Limuru.

In the second season, vegetative growth was most vigorous at Limuru and least at Thika, probably due to the rainfall being highest in Limuru and lowest in Thika (Tables (xii) and (xi)). The vegetative growth in Thika was very poor, because there was hardly enough rain to sustain potato growth. The minimum amount of rainfall for an early maturing variety like Annet (3-3½ months) is 80 mm per month (Ballestrem and Holler, 1977). In Thika, the rainfall was not only below 80 mm per month, it also stopped much earlier than at Kabete and Limuru (Tables (xi), (xii), and (xiii)), thus causing the plants at Thika to senesce one week earlier than expected.

Vegetative growth at Kabete and Limuru was less vigorous in the second season than in the first season because of less rainfall in the second season. (Tables (ii), (iii) (xii) and (xiii)).

5.2.2 Effect of Soil on Vegetative growth.

In both seasons, plants in Kabete soil at all sites showed more vigorous vegetative growth than those in Limuru and Thika soils.

Those in Thika soil showed the least vigorous vetetative growth, because of the lowest content of Nitrogen, Phosphorus and Potassium, which is known to reduce rate of emergence, and therefore vegetative growth (Headford, 1962; Morris, 1967). The carbon content and Cation Exchange Capacity (CEC), were also less in Thika soil, thus reducing the vegetative growth. Water holding capacity of the soil was also important, especially in the second season at Thika where rainfall was so little that the soil which could retain more moisture had an advantage over the others. Thika soil had the lowest water holding capacity and Kabete soil the highest (Tables(xix), (xx)). Thus the differences in vegetative growth.

5.2.3 Effect of Site on Senescence.

Plants at Thika in all seasons senesced earlier than at the other sites. In all seasons, plants at Limuru and Kabete senesced at the same time, and some plants had not fully senesced at both sites by the time of harvesting. The earlier senescence at Thika was atributed to the rainfall stopping earlier, and combined with the higher air temperatures, caused the plants to mature earlier.

Plants in Kabete soil at each site were the last to senesce, while those in Thika soil were the first to senesce, probably due to the higher moisture content in Kabete soil. (Tables (xix) and (xx)).

5.3 Tuber Yield.

5.3.1 Effect of Site on Number of Tubers.

In the first experiment, though Thika site had the most vigorous vegetative growth, it is Limuru site which yielded the highest number of tubers per plant. Thika site yielded more tubers per plant than Kabete site which had the least vigorous vegetative growth, but the difference in number of tubers was not statistically significant. The lower yield in Thika despite the vegetative growth was probably due to the high air and soil temperatures; which are conducive to more vegetative growth but undesirable at the time of tuber initiation (Borah and Milthorpe, 1959). Tuber initiation and early tuber growth requires low temperatures between 18 and 22^{o}C (Yamaguchi et al. 1964 and Went, 1959). The young sprouts develop best at soil temperatures of 18^{o}C. Tuber initiation is retarded at soil temperature above 20^{o}C and completely inhibited at 29^{o}C (Martin and Leornard, 1967). Though the mean air temperatures at Thika were not above the required 22^{o}C, the soil temperatures were above the ideal at the time of tuber initiation, and sometimes reached the critical 29^{o}C. (Table(viii)) thus retarding tuber production and causing tuber initiation to stop early and so produce a lower number of tubers per plant.

The lower yield at Kabete was attributed to the fact that the three plants (out of twelve) which had been replaced three weeks after planting were not fully mature at the time of harvesting. Those which had emerged first had the same number of tubers per plant as those at Limuru and more than those from Thika.

In the second season, Thika gave the lowest number of tubers per plant corresponding to the poor vegetative growth. The largest number of tubers per plant was again obtained from Limuru, corresponding to the most vigorous vegetative growth. The higher the number of stems per plant the higher the number of tubers produced (Smith, 1977). The higher the number of stems, the greater the assimilation area and the higher the yield (Smith, 1977). The lowest number of tubers per plant was from Thika due to the lowest number of stems. Kabete site had the second largest number of stems per plant, and consequently the second largest number of tubers per plant.

5.3.2 Fresh Weight of Tubers.

In the first season, yield in terms of fresh weight of tubers per plant was highest in Limuru and lowest in Kabete, like the number of tubers per plant. The fresh weight of tubers from Thika was higher than in Kabete and lower than in Limuru. Yet in Limuru vegetative growth was less vigorous than in Thika. The lower temperatures in Limuru were more conducive to tuber production and the longer period of rainfall provided a longer growing season (13 days between rain cessation in Thika and Limuru - Tables(i)-(iii)). Also the higher rainfall in Limuru meant a higher soil moisture content (Table(xix)) and more absorption of nutrients during the growing season. Thus there was a longer period when tuber bulking rate remained high resulting in production of more and larger tubers in Limuru. In Kabete the low temperatures were conducive to tuber initiation and bulking but the rainfall ended 9 days earlier than in Limuru so that the bulking period was shorter by 9 days. Also the plants which had been planted three weeks later had not matured. This resulted in smaller tubers and less yield. In Thika, the high air and soil temperatures may have reduced tuber initiation, and the shorter rainfall season (Table i) meant a shorter bulking period, leading to smaller tubers and less yield. At soil temperature above 29^{o}C the carbohydrates consumed by respiration in the tuber exceed those produced by photosynthesis, (Martin and Leornard, 1967) leading to less storage of carbohydrates, hence, less bulking leading to smaller tubers and less yield.

In the second season, though the highest number of tubers per plant was from Limuru, it is Kabete site which gave the highest fresh weight of tubers per plant. The lower fresh weight in Limuru was attributed to interplant competition, for nutrients, air and moisture, as the number of stems increased. Also as the number of tubers per plant increases, average tuber size decreases (Smith, 1977). Thus, in Limuru there were more tubers per plant but of smaller size and less weight than in Kabete. In Kabete the fewer stems meant less interplant competition, resulting in fewer but larger tubers. Thus the total fresh weight of tubers produced and the average fresh weight of tubers per plant was higher in Kabete than in Limuru. In Thika the number of tubers and the fresh weight of tubers per plant were the lowest, because of fewer stems producing fewer and smaller tubers due to lack of rainfall and high temperatures.

5.4 Sprouting and Number of Eyes.

5.4.1 Effect of Site on Number of Eyes per tuber.

In both seasons seed tubers from Thika had the fewest average number of eyes per tuber and Limuru had the highest average, but the differences were not significant. The small differences may be due to altitude effect, as O'Brien and Allen (1977) found that seed produced at lower altitude (30 m above sea level) had slightly less number of eyes per tuber than comparable seed tubers produced at higher altitude (270 m above sea level).

5.4.2 Effect of Site on Sprouting.

Seed from Thika was the first to sprout in both seasons, but had the lowest number of sprouts per tuber 3 mm long or above. The difference between sprout length between Kabete and Limuru seeds was not significant. Thika seed sprouted earlier yet had fewer and shorter sprouts may be due to the seed being physiologically older than Limuru and Kabete seed, being raised in a warmer environment.

Seed produced in a warmer environment is physiologically older than comparable seed produced in a cooler environment (Wurr, 1978). Thika seed being physiologically older may have been at the stage of dormancy break at the time of storage. At this stage tubers are known to produce few or even single sprouts as the growth of the apical bud occurs rapidly and suppresses the growth of the other buds, producing the apically dominant (or single sprout) condition (Allen, 1978). It may also be due to less amount of tuber substrate which is linearly related to sprout growth (Headford, 1962). The less amount of tuber substrate could be due to a shorter growing period and also consumption of more carbohydrates by respiration than are produced by photosynthesis under higher air and soil temperatures (Martin and Leonard, 1962). The early sprouting in Thika seed was due to being physiologically older than seed from Kabete and Limuru, and this resulted in earlier senescence of the plants grown from Thika seed in the subsequent season.

There was little difference in time of sprouting between Limuru and Kabete seed but there were slight differences in sprout length, with Limuru seed having more sprouts per tuber 3 mm or longer. The small difference may be due to Limuru seed being physiologically younger than Kabete seed because of the lower temperatures at Limuru, therefore having less apical dominance and sprouting later. Late sprouting results in more sprouts per seed piece (Toosey, 1962). It may also be that Limuru seed had more tuber substrate due to a longer growing period under cool conditions, which meant that no more carbohydrates were consumed by respiration than were produced by photosynthesis, and probably there was more storage of starch in the tubers since by the time of harvesting the plants in Limuru had not fully senesced.

5.5 Effect of Site of Seed Production on Subsequent Seed performance in the field.

5.5.1 Effect of Site of Seed Production on subsequent Emergence.

In both seasons, plants from Limuru seed emerged first, followed by those from Kabete seed with no significant difference. Plants from Thika seed were always the last to emerge, 2-3 days after those from Kabete seed in the first season and a week later in the second season. This indicated that sprouts of seeds from Thika were weaker than those from Limuru and Kabete, whereas seeds from Limuru and Kabete were almost equally vigorous. Limuru and Kabete seeds had more sprouts per tuber of 3 mm or longer and it is known that increase in sprout size at planting time results in earlier emergence and tuber initiation (Headford, 1962).

5.5.2 Effect of Site of Seed Production on subsequent Vegetative Growth.

In both seasons, plants from Limuru seed had the largest number of stems per plant, though this was not significantly different from that of plants from Kabete seed. The large number of stems per stem in plants resulting from Limuru and Kabete seed was due to the higher number of eyes per tuber. Seed tubers with a larger number of eyes produce more stems per plant (Smith, 1977). Also seed from Limuru and Kabete had more and larger sprouts having sprouted later than Thika seed. Late sprouting produces more sprouts and results in more plants per hill than early sprouting (Toosey, 1962). Plants from Thika seed had the fewest number of stems and leaves per plant (Plates 1, 4 and 7) because it had the lowest number of eyes and sprouts

Plants resulting from Limuru seed had the largest leaf cover (Plates 2, 5 and 8) and plants from Thika seed the lowest (Plates 1, 4 and 7).

5.5.3 Effect of Site of Seed Production on Senescence of Subsequent crops.

During both the first and second seasons, plants from Thika seed were the first to senesce, about one week earlier than those from Limuru and Kabete seeds. This may be due to the seed from Thika being physiologically older and therefore maturing earlier. There was no significant difference in the time of senescence in Limuru and Kabete seeds but plants from Limuru and Kabete seeds raised in Kabete soil were the last to senesce. Seed from the higher altitudes is physiologically younger. This allowed the plants a longer growing period, making better use of the growing conditions.

5.5.4 Effect of Site of Seed Production on Subsequent Tuber Yield.

5.5.4.1 Number of Tubers.

In the first season, plants from Limuru seed gave the largest number of tubers per plant, followed by plants from Kabete seed, and lastly plants from Thika seed, though the differences were not statistically significant. The larger number of tubers per plant in plants from Limuru seed were due to the larger number of stems per plant which resulted from the larger number of eyes and sprouts per seed tuber. As number of stems increases, the number of tubers formed also increases (Smith, 1977). Also the number of sprouts per seed piece is directly related to the number of tubers produced (Toosey, 1962). Limuru seed had the largest number of sprouts longer than 3 mm (Table 18). Thika seed gave the lowest number of tubers in the subsequent season because of the lowest number of eyes per seed tuber and the lowest number of sprouts, and then stems per plant. In the second season Kabete seed yielded the highest number of tubers per plant, and Thika seed yielded the lowest, for the same reasons as in the first season. Kabete seed, though it had fewer eyes and sprouts per medium sized tuber, than Limuru seed, it had the highest fresh weight of tubers per plant, which meant larger seed tubers on the average. The larger tubers resulted in more eyes per tuber, and subsequently more stems per plant. This is why it gave the largest number of tubers subsequently.

In both seasons, Thika seed suffered from "heat" or "drought" necrosis, which is attributed to high soil temperatures towards the time of harvesting (Lorenz, 1950). This may have reduced the seed vigour, partly contributing to the lower yield by Thika seed in the subsequent crop.

5.5.4.2 Fresh Weight of Tubers.

In the first season, plants from Kabete seed yielded the highest fresh weight of tubers per plant, though they had yielded fewer tubers per plant than those from Limuru seed. This indicated that tubers resulting from Kabete seed were larger in size than those from Limuru seed. The larger tubers may be due to less interplant competition because plants from Kabete seed had less number of stems per plant than Limuru seed. As the number of tubers per plant increases, the average weight per tuber decreases (Toosey, 1962). Plants from Limuru seed had more stems than those from Kabete seed, and therefore had more interplant competition. They also produced more tubers per plant, reducing the average size of each tuber, hence, less fresh weight of tubers per plant than plants from Kabete seed. Plants from Thika seed, although they gave the least subsequent number of stems, did not produce as much fresh weight as those from Kabete seed. This indicated that Thika seed was less vigorous, may be due to its physiological age, and also its previous poorer nutrition or tuber growth due to higher temperatures and lower rainfall in Thika.

In the second experiment, the highest fresh weight of tubers per plant was given by plants resulting from Limuru seed. This was because in the second season, plants from Limuru seed had a lower number of tubers per plant than plants from Kabete seed, therefore the average weight per tuber was increased. The larger number of tubers per plant from Kabete seeds meant less weight per tuber and this may account for the less fresh weight of tubers per plant in plants resulting from Kabete seed. Kabete seed had a larger number of eyes per tuber because of larger tubers, so they produced more stems and tubers per plant, more competition, and therefore smaller tubers. Plants from Thika seed generally had poor vegetative growth and so yielded the lowest fresh weight of tubers per plant.

5.6 Conclusion.

Comparing the first and second experiments, it can be seen that seed from Thika performed poorly in both seasons, although in the first season vegetative growth at Thika was better than at the other sites and even seed tuber yield was better than at Kabete. In both seasons, seed from Kabete performed better than seed from Thika, despite the fact that in the first season seed yield in Kabete was low.

Seed from Kabete and Limuru performed better than seed from Thika, and the differences in subsequent number of tubers between them in both seasons were not significant. However, they varied in the fresh weight of tubers produced, depending on which site had produced larger seed tubers. The larger seed tubers subsequently yielded more tubers but less weight and the smaller seed tubers yielded less tubers but more weight. In the first season, seed from Kabete produced higher subsequent fresh weight of tubers and in the second season Limuru seed performed better. This may be because in the first season there was a longer rainy season in Limuru than Kabete, and it being colder in Limuru the seed produced and harvested at the same time with Kabete seed was not yet physiologically mature in Limuru. Kabete, being warmer and the rain having stopped earlier, had physiologically more mature seeds, which gave a higher subsequent yield since it was not too old as that from Thika. Then in the second season, the rainy period at Limuru and Kabete was equally short, so seed from Limuru was as mature as that from Kabete, but Kabete seed tubers were fewer and larger, may be because of higher temperatures, so the subsequent number of tubers was higher than from Limuru seed but the fresh weight of tubers was less because of the larger numbers.

It can be concluded that altitudes 1400 m. above sea level or lower are not suitable for potato seed production in Kenya, because they are characterised by high soil and air temperatures and low rainfall which are not suitable for potato growth. Altitudes of 1600 m. above sea level and higher are equally suitable for seed production if bacterial and fungal diseases are controlled. The rainfall at these altitudes is sufficient for potato growth, and both the soil and air temperatures are not limiting. However, the suitability of each altitude varies from season to season and depends on the farmers' seed requirements. If seed is required in a short time, the lower altitudes are more suitable for early maturing of seed. Also if physiologically older seed is required, the lower altitudes are more suitable.

In the higher altitudes above 2000 m, the growing period is longer and plants take longer to reach physiological maturity, so that the seed yield is less in weight if harvested early. In the medium altitudes about 1800 m. the growing period is shorter and plants take a shorter time to reach physiological maturity. Seeds produced at both altitudes at the same time and with the same chronological age in the long rains will vary in their physiological age, seed from the lower, warmer altitudes being physiologically more mature and higher yielding. In a situation where seed is required in a shorter time the medium altitudes, like Kabete, should be utilised for seed production. If seed is not required in a short time then the higher altitudes are more suitable for seed production. In this case more tubers per plant can be obtained and most seed producers aim at getting more seed tubers of smaller size.

Seed of varieties which are late maturing are more suitably produced in the higher altitudes above 2000 m. while seed of the early maturing varieties, like Anett, can be produced in the medium altitude about 1800 m.

REFERENCES

Anonymous, 1976a. Kenya Ministry of Agriculture, Central Province, Annual Report, 1976. pp 25.

Anonymous, 1976b. Kenya Ministry of Agriculture, Western Province, Annual Report, 1976. pp 20.

Anonymous, 1978a. Kenya Ministry of Agriculture, Central Province, Annual Report 1978. pp 34.

Anonymous, 1978b. CIP (International Potato Centre) Annual Report, 1978. Lima, Peru. pp 82.

Accatino, P. 1978. The Potato in the Arab Countries by International Potato Centre (CIP), Lima, Peru and Arid Lands Agriculture Development Programme, The Ford Foundation, Beirut, Lebanon, pp 13-14.

Allen, E.J. 1978. Plant Density in The Potato Crop: The Scientific Basis for Improvement by P.M. Harris. Edited by P.M. Harris. Dept. of Agric. and Horticulture. Reading University 1978 pp. 279.

Ballestrem, C.G. and H.J. Holler, 1977. Potato Production in Kenya. Experiences and Recommendations. Eischborm, 1977.

Barskaya, T.A., Yu. E. Novitskaya, and Z.F. Sycheva, 1960. Growth of Potato Plants in Cold Soil in Potatoes: Production, Storing and Processing by Ora Smith. Second Edition, 1977. The Avi Publ. Inc. Westport, Connecticut.

Borah, M.N. and F.L. Milthorpe, 1959. Growth of the Potato, P.E.E. Sch. Agric. Univ. Nottm. pp 41-45.

Chapman, H.W., 1967. Some Experiments with Potatoes S. tuberousm in Trinidad, 1963-64. In Proceedings 1st International Symposium Tropical Root Crops, Trinidad. 1. pp. 171-179.

Chapman, H.W. 1976. In Food Crops of the Lowland Tropics by C.C.A. Leakey and J.B. Willis, 1976.

Durr, G. and G. Lorenzl, 1980. Potato Production and Utilisation in Kenya. CIP (International Potato Centre) Publication. 1980. Apartado Postal 5969. Lima Peru.

Franco, F., D. Harton and F. Tardieu. 1981. Potato Production and Utilisation in the Montaro Valley, Peru, in Potato Abstracts, 1981. Vol. 6. No. 6. 792.

Horton, D. 1981. Farm Level Research on Agronomic Constraints to Potato Production: Some lessons From The Montaro Valley. Social Science Research at the International

Potato Centre (CIP). Report of the Second Social Science Planning Conference. CIP. 1981. pp. 32.

Harris, P.M. 1978. The Potato Crop: The Scientific Basis for Improvement. Edited by P.M. Harris, Dept. of Agric. and Horticulture, Reading University. 1978.

Headford, D.W.R. 1962. Sprout Development and subsequent Plant Growth. Eur. Pot. J. Vol. 5. pp. 14-22.

Iritani, W.M. 1968. In the Potato Crop: The Scientific Basis for Improvement by P.M. Harris. Edited by P.M. Harris, Dept. of Agric. and Horticulture, Reading University 1978.

Jehle, R.A., C.E. Cox and J.E. Moore (1952). Early Home grown seed for Planting the late Potato crop in Maryland. American Potato J. Vol. 29, 1952. pp. 1.

Jones, R.L., H.H. Mckinney and H. Fellows., 1922. The Influence of Soil Temperature on Potato Scab. Wisconsin Agric. Experimental Station Bulletin. 53.

Kawakami, A. 1953. Physiological Aspects of Potato Seed Tubers. Eur. Pot. J. Vol. 5 pp. 5.

Kozlowska, A., 1963. Differences in Growth in the Metabolism of Potatoes Grown in the Mountains and in the lowlands. Eur. Pot. J. Vol. 6 pp. 143-159.

Lorenz, O.A., 1950. Air and Soil Temperatures in Potato Fields, Kern country, California, During Spring and Early Summer. American Potato J. 1950. Vol. 27. pp 396.

Martin, J.H. and W.H. Leonard, 1967. Principles of Field Crop Production. pp 847. The Macmillan Company, Collier Macmillan Ltd. London.

Mbogoh, S.G. 1976. The Economics of Production and Marketing Potatoes in Meru District, Kenya. M.Sc. Thesis. University of Nairobi. 1976.

Moreno, U., 1979. Response of the Potato Plant to Soil and Climatic Factors on the Coast and the Andes of Peru. In Potato Abstracts. 1978. Vol. 13 No. 4. 648.

Morris, O.A. 1967. Eur. Pot. J. 10, 296-311. In The Potato Crop: The Scientific Basis for Improvement, by P.M. Harris. Dept. of Agric. and Horticulture, Reading University, 1978.

Niederhouser, J.E. 1978. In Potato Improvement: Some Factors and Facts. by H.P. Beukema and D.E. van Der Zaag. Int. Agric. Centre (I.A.C.), Wageningen, The Netherlands, 1978.

Nikolayevskii, V.G. and L.O. Nikolayevska, 1977. Features of the Anatomical Structure of Potato Roots in Different Altitude Zones of the North Ossentia Mountains. In Potato Abstracts, 1977. Vol. 2, No. 9. 985.

O'Brien, P.J. and E.J. Allen, 1975. Effect of Area of Seed Production and Date of lifting of Seed Crops on the Performance of the Progeny Tubers. Proc. 6th Triennial Conference of the European Association for Potato Research, 1975, pp. 41-42.

Oppenheimer, J., 1981. Seed Potato Certification in Israel. News and Reviews. American Potato J. 1981. Vol. 58. pp 489-490.

Pushkarnath, 1976. Potato in Sub-tropics. by Pushkarnath. Published by Ravi Vyas, Orient Longman Ltd. New Delhi, 1976.

Ricaud, C. and S. Felix, 1978. Growers Guide to Seed Potato Production. Mauritius Sugar Research Institute.

Robinson, R.A., 1973. FAO (Food and Agriculture Organisation) Report to the Government of Kenya on Potato Development. UNDP. Kenya 68/023. FAO of the UN. Rome, 1973.

Ronsen, K. 1971. Seed Potatoes Grown at Different Altitudes and Different Temperatures. Forskning of Forsok i Landruket. 22. pp. 241-266.

Sekioka, H. 1964. In Potatoes: Production, Storing and Processing by Ora Smith. The Avi Publ. Inc. Westport, Connecticut, 1977. pp. 347.

Smith , O. 1977. In Potatoes: Production, Storing and Processing by Ora Smith. The Avi. Publ. Inc. Westport, Connecticut, 1977.

Staikov, G. and C.H. Chavdarov, 1971. In the Potato Crop. by P.M. Harris. Dept. of Agric. and Horticulture, Reading University. pp. 339.

Talburt, W.F. and O. Smith, 1967. Potato Processing. 2nd Edition. pp. 558. The Avi. Publ. Inc. Westport, Connecticut, U.S.A.

Toosey, R.D. 1962. Influence of Pre-sprouting on Tuber Number, Size and Yield of King Edward Potatoes. Eur. Pot. J. Vol. 5 pp. 23-27.

Vakis, N.J. 1980. Production of Seed Potatoes in Cyprus. Tech. Bulletin. Agric. Research Institute, Nicosia. 1980. No. 34. pp 16.

Vender, C. 1980. Seed Potatoes in Romania. In Potato Abstracts, 1980. Vol. 5. No. 12. 1771.

Went, F.W., 1959. Effects of Environment of Parent and Grandparent Generations on Tuber Production by Potatoes. American Journal of Botany. Vol. 46. pp. 277-282.

Wiersema, S.G., 1979. Seed Potato Production in East Africa: Principles and Techniques. pp. 5. CIP. Apartado, Lima, Peru.

Wurr, D.C.E. 1978. The Effects of the Date of Defoliation of the Seed Potato Crop and the Storage Temperature of the Seed on Subsequent growth. 2. Field Growth. Journal of Agric. Sci, Camb. Vol. 91 pp. 747-756.

Wurr, D.C.E., 1979. The Effect of the Site of Seed Potato Production on Tuber Yield. Journal of Agric. Sci. Camb. 1979. Vol. 92. pp. 227-233.

Yamaguchi, M., H.M. Timm and A.R. Spurr, 1964. Effects of Soil Temperature on Growth and Nutrition of Potato Plants and Tuberisation, Composition and Periderm Structure of Tubers. Proc. American Soc. Horticultural Science. 84. pp. 412-413.

7. APPENDIX

Table i : Rainfall at Thika in the 1st Season (October 25th 1982 - January 11th 1983)(mm)

		MONTH		
Date	October	November	December	January
1		12.4	0.8	0.0
2		0.0	17.9	0.0
3		3.0	18.1	0.0
4		0.0	6.3	0.0
5		0.0	0.0	0.0
6		0.0	12.2	1.0
7		0.0	8.4	
8		0.0	0.0	
9		0.0	3.0	
10		0.4	0.0	
11		6.3	0.0	
12		0.0	0.0	
13		4.2	0.0	
14		8.1	0.3	
15		1.0	0.0	
16		11.0	0.0	
17		18.0	0.0	

Table i: cont.

	MONTH			
Date	October	November	December	January
18		8.1	0.8	
19		0.8	0.0	
20		0.0	0.0	
21		8.7	0.0	
22		0.0	0.0	
23		7.4	0.0	
24		8.9	0.0	
25	0.0	31.7	0.0	
26	0.0	44.2	0.0	
27	0.0	15.1	0.0	
28	5.4	5.8	0.0	
29	19.2	0.0	0.0	
30	14.0	11.5	0.0	
31	8.6		0.0	

Total for the season = 313 mm.

Total for 1st 1st week after planting = 47.2mm

Monthly mean for season = 101 mm.

Table ii: Rainfall in Limuru in 1st Season
(25th Oct. 1982 - Jan. 11th 1983)(mm)

	MONTH			
Date	October	November	December	January
1		20:2	18.0	0.0
2		9.6	21.0	0.0
3		48.6	6.8	0.0
4		23.8	4.4	0.0
5		4.4	7.0	0.1
6		1.0	0.0	0.0
7		0.0	0.0	0.0
8		0.0	2.4	
9		4.8	1.0	
10		23.8	0.0	
11		0.0	1.8	
12		1.0	15.4	
13		0.0	0.0	
14		19.4	0.0	
15		2.6	0.0	
16		2.0	0.0	
17		0.0	0.0	
18		7.0	0.0	
19		3.0	0.0	

Table ii: cont.

	MONTH			
Date	October	November	December	January
20		5.4	0.0	
21		0.0	0.0	
22		0.0	18.2	
23		0.0	0.0	
24		4.4	0.0	
25	0.0	12.0	0.0	
26	0.0	54.0	0.0	
27	0.0	8.2	0.0	
28	0.0	11.0	0.0	
29	8.0	22.0	0.0	
30	28.2	8.2	0.0	
31	6.0		0.0	

Total for the Season = 434.1 mm.

Total for the 1st week after planting = 62.4 mm.

Monthly mean for the season = 144.6 mm.

Table iii: Rainfall in Kabete in 1st season
(Oct. 25th 1982 - Jan. 11th 1983)(mm)

		MONTH		
Date	October	November	December	January
1		30.3	8.2	0.0
2		2.4	17.5	0.0
3		0.0	65.0	0.0
4		0.0	8.3	0.0
5		0.0	0.0	0.0
6		0.0	0.6	0.1
7		0.0	3.1	0.0
8		18.2	0.0	0.0
9		1.6	2.9	0.0
10		0.0	4.4	0.0
11		4.2	0.0	0.0
12		0.0	0.8	0.0
13		21.0	1.4	
14		11.1	0.0	
15		8.9	0.1	
16		0.6	0.0	
17		13.9	0.0	
18		5.6	0.0	
19		1.4	0.0	

Table iii: cont.

	MONTH			
Date	October	November	December	January
20		0.0	0.0	
21		0.0	0.0	
22		0.0	0.0	
23		0.0	0.0	
24		15.0	0.0	
25	0.0	12.9	0.3	
26	0.0	13.5	0.0	
27	0.0	19.0	0.0	
28	14.0	18.4	0.0	
29	0.9	2.6	0.0	
30	8.1	22.4	0.0	
31	0.2		0.0	

Total for the season = 372 mm.

Total for the 1st week after planting = 59.3 mm.

Monthly mean for the season = 124 mm.

Table iv: Mean Air Temperature for Thika from Oct. 25th 1982 to Jan. 11th 1983. (^{o}C)

	MONTH			
Date	October	November	December	January
1		20.1	20.2	18.9
2		21.0	20.9	18.8
3		21.0	21.0	17.9
4		21.7	19.5	18.3
5		21.5	19.9	20.0
6		21.4	18.6	20.9
7		21.5	17.8	20.9
8		20.5	18.8	17.8
9		21.2	18.5	20.2
10		20.2	19.9	20.6
11		19.5	18.9	22.1
12		19.7	19.7	
13		19.7	19.7	
14		20.5	18.6	
15		19.9	19.0	
16		20.0	19.3	
17		20.2	19.9	
18		18.2	19.5	
19		19.2	19.5	

Table iv: cont.

	MONTH			
Date	October	November	December	January
20		19.4	17.7	
21		18.9	19.5	
22		20.2	19.9	
23		19.5	20.2	
24		19.8	20.4	
25	19.9	19.7	18.5	
26	19.8	20.3	19.3	
27	19.0	19.4	19.8	
28	20.6	16.3	20.5	
29	20.1	18.3	17.9	
30	19.9	20.3	18.3	
31	18.0		17.7	

Mean for the season = 19.7^{o}C.

Mean around tuber initiation = 20.0^{o}C.

Table v : Mean air Temperature for Limuru from Oct. 25th 1982 to Jan. 11th 1983. (^{o}C)

	MONTH			
Date	October	November	December	January
1		14.5	15.5	16.0
2		16.0	15.5	16.0
3		16.0	16.0	14.0
4		15.5	15.5	16.5
5		16.5	15.0	15.2
6		16.0	14.5	16.0
7		17.0	14.5	16.5
8		15.5	13.5	15.5
9		17.0	14.0	15.5
10		16.0	16.0	16.5
11		17.0	15.7	16.0
12		15.5	16.0	
13		15.5	15.5	
14		16.0	15.0	
15		15.0	15.0	
16		15.0	15.7	
17		15.5	16.0	
18		15.5	15.5	

Table v˙: cont.

	MONTH			
Date	October	November	December	January
19		14.0	15.0	
20		14.5	13.5	
21		14.0	14.5	
22		16.0	15.5	
23		16.0	15.5	
24		15.5	16.0	
25	15.0	14.5	15.0	
26	15.0	16.0	16.0	
27	15.5	15.0	15.0	
28	15.5	15.5	16.5	
29	16.0	15.0	14.5	
30	15.2	16.0	14.0	
31	15.5		14.5	

Mean for the season = 15.6^{o}C

Mean at and after tuber initiation = 15.6^{o}C

Table vi : Mean air Temperature for Kabete from Oct. 25th 1982 to Jan. 11th 1983. (^{o}C)

	MONTH			
Date	October	November	December	January
1		18.0	18.1	18.2
2		19.1	19.2	19.0
3		19.6	19.1	17.5
4		18.9	18.0	17.7
5		19.5	17.3	19.1
6		20.2	16.7	18.2
7		19.3	15.6	18.1
8		19.2	17.7	19.2
9		19.4	16.9	18.7
10		18.5	18.2	18.2
11		17.3	18.0	17.0
12		17.9	17.9	
13		18.4	17.2	
14		18.1	17.2	
15		17.6	17.1	
16		18.4	17.7	
17		18.1	18.4	
18		16.9	18.4	
19		17.5	17.2	

Table vi: cont.

	MONTH			
Date	October	November	December	January
20		17.5	18.9	
21		18.1	18.8	
22		18.6	19.1	
23		17.6	18.9	
24		18.5	17.9	
25	17.5	18.0	18.7	
26	17.8	17.2	19.7	
27	18.0	19.1	19.0	
28	19.0	16.5	18.1	
29	18.1	17.0	19.4	
30	18.9	18.6	18.3	
31	16.7		18.8	

Mean for the season = 18.4^{o}C

Mean around tuber initiation = 18.3^{o}C

Table vii:Soil Chemical Analysis Resultus

Soil	pH		%C	%N	PPM	Me/100 g.				CEC
	$CaCl_2$	H_2O				Ca	Mg	K	Na	
Thika	5.10	5.80	1.71	0.20	1.90	3.40	1.40	1.40	1.00	9.6
Limuru	5.90	6.70	3.51	0.30	15.42	15.70	1.40	1.90	0.80	20.80
Kabete	5.40	5.90	3.51	0.33	3.20	14.70	1.20	1.90	0.90	19.70

Table viii: Mean Monthly Soil Temperature at Thika from October 25th 1982 to January 11th 1983 (^{o}C)

Month	October	November	December	January
Depth 5 cm	25.0	24.6	25.0	26.5
10 cm	22.8	22.6	22.0	24.0

Minimum for the Season = 17.0^{o}C

Maximum for the Season = 36.2^{o}C

Table ix: Mean Monthly Soil Temperature at Kabete from October 25th 1983 to January 11th 1983. (^{o}C)

Month	October	November	December	January
Dept 5 cm	22.2	22.0	22.3	25.2
10 cm	20.6	20.5	20.8	23.5

Minimum for the Season = 17.0^{o}C

Maximum for the Season = 31.7^{o}C

Table x : Soil Temperatures for Kabete, Limuru and Thika on certain days between 25th Oct. 1982 to 11th Jan. 1983.

	SOIL TEMP. (^{o}C)		
Date of Reading	Thika	Limuru	Kabete
1	21.0	17.1	18.2
2	23.2	17.4	20.7
3	24.6	18.0	22.0
4	23.0	17.8	22.3
5	23.6	19.1	22.8
6	24.2	20.0	23.1
7	26.8	21.0	21.1
8	26.8	20.2	24.3
9	26.9	26.0	26.6
10	30.7	17.3	20.2
Total	8250.8	193.9	221.3
Mean	25.1	19.4	22.13

Table xi: Rainfall at Thika from April 28th to August 11th 1983 (mm).

		MONTH			
Date	April	May	June	July	August
1		0.2	0.0	0.0	0.0
2		0.0	0.0	0.0	0.0
3		0.0	0.0	0.0	0.0
4		0.0	2.1	0.0	0.0
5		0.0	2.0	0.0	0.0
6		0.0	0.0	0.0	0.0
7		0.0	0.0	0.0	0.0
8		0.0	0.0	0.0	0.0
9		0.0	0.0	0.0	0.0
10		1.7	0.0	0.0	0.0
11		0.4	0.0	0.0	0.0
12		3.5	0.0	0.0	
13		0.0	0.0	0.0	
14		0.0	0.0	0.0	
15		0.0	0.0	0.0	
16		0.6	0.0	0.0	
17		0.0	0.0	0.0	
18		0.0	0.0	0.0	
19		0.0	0.5	0.0	

Table xi: cont.

		MONTH			
Date	April	May	June	July	August
20		0.0	0.0	0.0	
21		0.0	0.4	0.0	
22		0.0	8.7	0.0	
23		0.0	1.0	0.0	
24		0.9	0.0	0.0	
25		7.7	0.0	0.0	
26		0.0	0.0	0.0	
27		0.0	14.5	0.0	
28	14.1	0.0	0.2	0.0	
29	1.3	0.0	0.5	0.0	
30	0.0	0.0	0.4	0.0	
31		0.0			

Total for the Season = 59.4 mm

Total for 1st week after planting = 15.6 mm

Monthly mean for the Season = 19.8 mm

Table xii: Rainfall at Limuru from April 28th 1983 to August 11th 1983. (mm)

		MONTH			
Date	April	May	June	July	August
1		4.2	0.0	1.0	2.0
2		3.0	0.0	0.0	0.0
3		4.8	0.0	0.0	0.0
4		0.0	0.0	0.0	0.0
5		2.4	11.0	0.0	0.0
6		7.6	0.4	0.0	0.0
7		36.8	0.0	0.0	0.0
8		0.0	0.0	0.0	0.0
9		3.4	0.0	0.0	0.0
10		0.0	0.0	0.0	0.0
11		6.6	0.0	0.0	0.0
12		3.8	0.0	0.0	
13		3.4	0.0	0.0	
14		2.4	0.0	0.0	
15		0.0	1.0	3.2	
16		0.0	0.0	28.0	
17		2.5	0.0	16.6	
18		0.2	0.0	0.0	
19		0.0	0.0	0.0	

Table xii: cont.

	MONTH				
Date	April	May	June	July	August
20		0.0	9.2	0.0	
21		0.0	1.0	0.0	
22		0.0	8.0	0.0	
23		0.0	12.2	0.0	
24		0.0	2.4	0.0	
25		4.5	0.0	0.0	
26		0.0	0.0	0.0	
27		0.0	0.0	0.0	
28	41.0	0.0	15.2	0.0	
29	15.0	0.0	1.4	0.0	
30	12.8	4.8	9.0	0.0	
31		0.0		0.0	

Total for the Season = 280.2 mm.

Total for the first week after planting = 68 mm.

Monthly mean for the Season = 93.4 mm.

Table xiii: Rainfall at Kabete from 28th Aptil to 11th August 1983. (mm)

	MONTH				
Date	April	May	June	July	August
1		3.0	0.0		0.0
2		2.0	0.0		0.0
3		0.0	0.0		0.0
4		1.3	35.0		0.0
5		0.0	1.7		0.0
6		4.6	0.4		0.0
7		0.6	0.0		0.0
8		0.1	0.0		0.0
9		11.4	0.0		0.0
10		0.4	0.0		10.8
11		0.0	0.0		
12		4.1	0.0		
13		0.1	0.0		
14		0.0	0.4		
15		0.0	0.0	12.7	
16		9.4	0.0	3.4	
17		1.9	0.0	0.0	
18		0.0	0.0	0.0	
19		0.0	3.4	0.0	

Table xiii: cont.

	MONTH				
Date	April	May	June	July	August
20		0.0	1.3	0.0	
21		0.0	1.3	0.0	
22		0.2	0.9	0.0	
23		2.5	0.1	0.0	
24		0.4	0.0	0.2	
25		2.8	0.0	0.0	
26		0.0	1.7	0.1	
27		0.0	0.0	1.1	
28	33.1	0.0	5.9	0.2	
29	39.7	1.0	0.6	0.0	
30	5.2		0.0	0.0	
31			0.0		

Total for the Season = 241.1 mm.

Total for the first week after planting = 84.0 mm.

Monthly mean for the Season = 80.4 mm.

Table xiv: Mean Air Temperature at Thika from April 28th to August 11th 1983 (^oC)

		MONTH			
Date	April	May	June	July	August
1		21.0	18.8	17.8	19.5
2		21.4	19.9	18.0	19.3
3		21.3	18.0	19.1	19.4
4		20.3	18.9	18.9	19.6
5		20.0	19.3	18.4	17.9
6		20.8	20.4	19.2	19.6
7		21.0	19.6	19.3	19.0
8		20.1	19.1	18.7	20.0
9		20.4	18.2	18.6	18.8
10		21.5	20.8	18.7	18.3
11		21.1	19.6	19.2	18.4
12		19.7	19.6	18.2	
13		20.4	19.1	20.1	
14		19.2	20.2	17.1	
15		19.5	17.6	20.9	
16		20.5	20.2	20.0	
17		21.0	20.4	18.7	
18		20.2	20.4	17.3	
19		20.4	18.4	17.3	

Table xiv: cont.

	MONTH				
Date	April	May	June	July	August
20		20.6	17.1	17.6	
21		19.9	18.7	18.1	
22		20.5	19.2	18.7	
23		21.1	20.2	18.3	
24		21.3	21.1	15.6	
25		19.7	19.2	19.6	
26		20.1	19.0	18.6	
27		20.9	19.0	19.7	
28	21.0	20.7	18.8	19.8	
29	20.8	20.7	19.7	19.7	
30	20.9	20.5	18.9	17.9	
31		20.7		19.3	

Mean for the Season = 18.4^{o}C.

Mean at tuber initiation = 20.5^{o}C.

Table xv: Mean Air Temperature at Limuru from April 28th to August 11th 1983. (^{o}C)

	MONTH				
Date	April	May	June	July	August
1		16.5	15.0	13.0	14.5
2		16.5	14.5	13.0	14.5
3		18.5	15.0	12.5	14.0
4		16.0	15.0	13.5	14.0
5		15.5	14.5	12.0	14.0
6		16.0	14.0	14.0	14.0
7		16.5	15.0	14.0	15.5
8		16.5	14.0	13.7	14.5
9		15.5	16.0	14.0	14.0
10		16.5	15.5	14.0	16.0
11		16.5	15.5	14.0	15.5
12		15.5	15.5	15.0	
13		16.0	15.0	14.0	
14		14.0	15.0	13.5	
15		13.5	14.0	15.5	
16		13.5	13.0	15.5	
17		13.5	15.0	15.5	
18		15.5	15.5	13.0	
19		16.0	16.0	12.5	

Table xv: cont.

	MONTH				
Date	April	May	June	July	August
20		15.0	16.0	11.0	
21		15.5	14.5	13.5	
22		16.0	14.5	12.0	
23		16.5	15.5	12.0	
24		16.5	15.0	12.5	
25		16.5	16.0	12.5	
26		18.0	16.0	13.5	
27		16.0	15.0	15.0	
28	16.5	16.5	15.5	14.7	
29	17.0	16.5	15.5	15.0	
30	16.5	15.5	14.5	15.0	
31		16.0		15.0	

Mean for the Season = 14.9°C

Meat at and after tuber initiation = 15.9°C

Table xvi: Mean Air Temperature at Kabete from April 28th to August 11th 1983. (^{o}C)

	MONTH				
Date	April	May	June	July	August
1		18.9	17.3	15.8	17.3
2		18.8	17.4	16.1	17.4
3		19.1	17.4	16.3	17.5
4		18.5	16.9	15.7	17.2
5		18.8	18.3	14.8	15.8
6		18.3	17.4	16.2	17.6
7		18.8	17.4	17.3	17.7
8		18.4	16.7	16.0	18.7
9		18.9	18.9	16.1	19.2
10		19.3	17.6	17.1	17.1
11		19.7	18.0	17.3	16.3
12		17.8	17.9	17.0	15.8
13		17.8	18.4	18.2	15.1
14		16.8	16.0	16.4	13.0
15		18.1	18.0	19.9	16.2
16		18.6	17.7	18.0	16.7
17		18.3	18.1	15.4	17.0
18		17.8	17.5	14.4	17.9
19		17.8	16.7	15.8	17.8

Table xvi: cont.

	MONTH				
Date	April	May	June	July	August
20		17.4	16.1	15.3	18.5
21		18.5	16.1	14.5	16.9
22		18.3	18.2	17.7	17.8
23		19.5	18.3	17.1	16.6
24		18.7	18.3	14.3	16.8
25		19.0	17.9	17.5	15.7
26		18.4	18.2	16.1	18.1
27		18.8	17.2	16.0	16.4
28	18.7	18.9	1717	18.3	18.4
29	18.7	18.6	16.1	16.6	17.7
30	17.7	18.5	17.1	16.2	16.6
31		18.0		16.9	16.9

Mean Temperature for Season = 17.5°C

Mean Temperature at and after tuber initiation = 18.5°C.

Table xvii: Mean Monthly Soil Temperature at Thika from April 28th to August 11th 1983. (^{o}C)

Month	April	May	June	July	August
Depth 5 cm	26.0	24.4	23.5	21.2	24.3
10 cm	23.0	24.2	22.4	21.4	22.2

Minimum for the Season = 16.8^{o}C

Maximum for the Season = 33.9^{o}C

Table xviii: Mean Monthly Soil Temperature at Kabete from April 28th to August 11th 1983.

Month	April	May	June	July	August
Depth 5 cm	25.4	25.2	24.0	22.6	25.3
10 cm	22.8	23.2	22.0	20.3	22.0

Minimum for the Season = 17.7^{o}C

Maximum for the Season = 30.7^{o}C

Table xix: Soil water potential (bars) at weekly intervals at the three sites in the 1st season: (Oct. 25th 1982 to Jan. 11th 1983).

	SITE		
WEEK	THIKA	LIMURU	KABETE
1	-0.10	-0.70	-0.60
2	-0.50	-0.50	-0.65
3	0.00	-0.45	-0.40
4	-0.10	-0.40	-0.40
5	-0.50	-0.39	-0.35
6	0.00	-0.40	-0.30
7	0.00	-0.20	-0.30
8	2.00	-0.15	-0.10
9	1.00	-0.18	0.10
10	5.00	-0.18	0.10
11	7.00	0.10	0.10
12	10.00	0.20	0.10
TOTAL	23.80	-3.25	-2.70
Mean	1.98	-0.27	-0.22

Table XX: Soil water potential (bars) at weekly intervals at the three sites in the second season (April 28th to August 11th 1983)

	SITE		
WEEK	THIKA	LIMURU	KABETE
1	-0.50	-0.80	-0.45
2.	-0.50	-0.60	-0.60
3	-0.20	-0.60	-0.60
4	0.00	-0.50	-0.65
5	0.10	-0.45	-0.25
6	0.00	-0.40	-0.15
7	0.00	-0.40	-0.10
8	0.50	-0.43	-0.30
9	0.60	-0.43	-0.20
10	2.50	-0.10	0.19
11	5.00	0.15	0.10
12	10.00	0.09	0.10
Total	17.40	-4.47	-2.91
Mean	1.45	-0.37	-0.24