THE EFFECT OF NITROGEN AND PHOSPHATE FERTILIZER MANAGEMENT ON THE PRODUCTION AND QUALITY OF TRUE POTATO (*Solanum tuberosum*, L.) SEEDS, FROM THREE COMMERCIAL VARIETIES GROWN IN KENYA.

BY

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DECLARATION

I hereby declare that this thesis is my original work and has not been presented for a degree in any other university.

..... 8/12/92

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

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ABSTRACT

Three experiments were conducted in the field to study the effect of fertilizer management on True potato (*Solanum tuberosum*, L.) seed (TPS) production and quality. In the first experiment, the effects of split applications of Nitrogenous fertilizer (112.5 Kg N ha^{-1}) on flowering, pollen quality, berry production and TPS quality, were studied. In Experiment II, the effect of time of nitrogenous fertilizer application of a single dose of 112.5 Kg ha^{-1} on flowering, pollen quality, berry production and TPS quality., was studied. Experiment III, involved three commercial varieties, Kenya Dhamana, Anett and Kenya Baraka under four levels of the nitrogenous fertilizer (0, 100, 200 and 300 Kg N ha^{-1}) and 3 levels (60, 120, 180 Kg ha^{-1}) of a phosphate (P_2O_5) fertilizer in factorial combination. The parameters studied in Experiment III were, flowering, pollen viability, berry and tuber yields.

In experiment I, additional split applications of N at hilling-up, and at flowering, gave a significantly higher mean flower number, pollen quality and berry yields. The treatments also had the highest mean number of TPS in 1000, in the large seed fraction. Tuber yields improved significantly, when N was split applied at planting and 30 days later at hilling-up.

In experiment II, application of N at hilling-up resulted in a significantly higher flower number, pollen viability, berry yields and TPS quality. However, application of the N fertilizer at the onset of flowering (50 days after planting) resulted in a significantly greater number of TPS in 1000, being in the larger seed Fraction (LSF). Both applications of N at hilling up and at flowering (30 and 50 days after planting) resulted in higher total

tuber yields, compared to application of N at planting or at berry development (75 days after planting).

In experiment III, outstanding varietal differences among the three commercial varieties were noted in almost all parameters studied, except mean tuber yields. Kenya Dhamana had outstanding performance in flowering, pollen quality and Berry production. Anett and Kenya Baraka were not significantly different from one another with regard to these TPS production parameters.

Variety and phosphate fertilizer interactions were significant. The general trend across all varieties was a decrease in flower numbers, pollen viability and berry yields.

Variety and nitrogen fertilizer interaction was significant across all varieties in pollen viability. The varieties showed a good response in pollen quality with the application of N. The general trend was increased viability at higher levels of N application.

Only the factor Nitrogen fertilizer levels showed significance in total tuber yield response. Kenya Dhamana showed highest yields at 300 Kg N ha^{-1}, and at 200 Kg N ha^{-1} level for Anett and Kenya Baraka.

Low levels (i.e < 180 Kg P_2O_5) combined with high levels of N may be useful in TPS production at Kabete.

Considerable seasonal differences ~~which~~ resulted in almost a total lack of flowering in the varieties Kenya Baraka and Anett.

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CHAPTER ONE

INTRODUCTION

General Introduction

The potato (*Solanum tuberosum*, L.) crop, has long been recognized as a major source of food. Its importance in recent years, has grown rapidly, especially in the developing countries. The crop is grown in over 130 countries where three-fourths of the world's population live. It ranks fourth in the world volume of production (290 million metric tons / year), after wheat, maize and rice (FAO, 1985). In Kenya, potatoes are now second to maize in terms of volume of production (Goverment Of Kenya (GOK), 1989)

The crop has been grown in Kenya for over eighty years. It was brought to this country from Europe, most likely by the British. Due to this origin, the potato is generally referred to as the English or Irish potato (Waithaka, 1976; Ballestrem and Holler, 1977; Durr and Lorenzl, 1980).

Nutritionally, the potato is a valuable food crop. In developing countries, where diets are often unbalanced, addition of the potato is a welcome improvement. It is estimated that 100 g of fresh weight of potatoes provide 335 Kilo joules, mainly from the starch which is about 70% of dry matter content (Smith, 1977). Further estimates indicate that 100 g of potatoes provide on average, 80% of the daily minimum protein requirements (but this needs to be supplemented with 10 g egg to improve the methionine and cystine content), 10% Fe, 20-50% vitamin C, 10% vitamin B1, (Talburt *et al.*, 1975; Smith, 1977; CIP, 1984 b.)

1.1.0 Potato Production in Kenya

In Kenya, potatoes play an important role in the economy. Potatoes contribute about 2% of the gross value of marketed agricultural product which amounts to about 5 million Kenya pounds every year (Durr and Lorenzl, 1980) On average, about 70% of the harvested crop does not get into the market but is used for dietary and subsistence needs of the farmers and as seed for the next season.

Estimates indicate that 3% of the total agricultural labour force - about 150,000 people - is employed in potato production (Durr and Lorenzl, 1980; Ngugi, 1983) Surveys show, that Kenya had in the late seventies , more than 50,000 ha of pure stand potato crop and more than 212,000 ha of potatoes as a component in mixed cropping systems. This resulted in a yield of over 480,000 tones of potatoes (GOK, 1978). Most of the production is concentrated around the central and eastern provinces each producing about 283,000 and 184,000 tons of potatoes respectively. The Rift Valley province areas of Mau Narok and Molo, have in the recent past, become important areas of production of the crop. Considerable potential exists for production in Western Province, notably Kakamega and Bungoma Districts.

Kenya has about 14 recommended commercial varieties, most of which originated from the northern latitude countries (Ballestrem and Holler, 1977; Waithaka, 1976). Recently two new varieties, Kenya Dhamana (CIP 800224) and Kenya Changuo, were selected and released officially but they are yet to be adopted by the farmers. There are also a number of 'Local varieties' with the farmers, that were not released officially through the National seed certification program.

Some estimates put the total number of these, at between 30 and 45 (Haugerund and Kimani, 1984). Most of these varieties have some resistance to late blight (*Phytopthora infestans*) and none to bacterial wilt (*Pseudomonas solanacearum*). Their maturity periods range from early (two and a half months as in Anett), medium (three and a half months as in Roslin Tana), to late (as in Kenya Baraka and Kenya Dhamana.)

1.2.0 Constraints to potato production in Kenya

Good quality potato seed is required in order to achieve high yields. The use of poor seed tubers is considered as the main cause of reduced potato crop yields (CIP, 1977; Durr and Lorenzl, 1980; Ngugi, 1983). Certified seed for potato ware production is scarce in Kenya and the few farmers who manage to get it, find the high cost prohibitive (Nyaga, 1976). It is often unavailable in adequate amounts, and at the right place and time. Hence, most farmers use their own seeds or buy from their neighbours or near by markets (Haugerund, 1985). These seed tubers are usually surpluses from previous seasons and are in most cases, physiologically degenerated in value as planting material due to a build-up of viral, bacterial and fungal pathogens, including pests like the potato tuber moth (*Phthorimaea operculella* (Zellar)).

Certified seed production is both expensive and time consuming. These are two of the most limiting factors to increased potato production in Kenya. The production of virus free seed starts at the National Plant Quarantine Station, Muguga, through the use of tissue culture and Thermo-therapy methods. Further multiplication is carried out at the National Potato Research Centre (NPRC), Tigoni, before the

final bulking to certified seed status at the various Agricultural Development Corporation (A.D.C.) farms in the Highlands. Pathogen freeing of degenerated varieties and multiplication to certified seed status takes several years, and involves costly manpower and expensive laboratory inputs. The final product - certified seed - is still very expensive to most Kenyan farmers. In Kenya, Durr and Lorenzl(1980), estimated the cost of certified seed per hectare to be about 30-45% of total production cost per hectare . These problems are not unique to Kenya; indeed good low cost seed has been one of the major limiting factors for use of the potato as food in many developing countries. Most tropical countries are presently relying on costly yearly importations of basic seed from Northern latitude countries, as the base for their potato production. Seed costs are from 50 to 70% of the total production costs under such conditions (Swaminathan and Sawyer, 1983).

Ideally, farmers need to replace their seed stocks of whatever variety they have, every two to three years in order to avoid excessive degeneration through viral build-up This has not been possible in Kenya, and may have led to farmers dropping out a number of previously high yielding varieties, that deteriorated over the years of growing, without the injection of clean certified seed. Indeed field surveys have shown the danger of loosing new released varieties such as Roslin Gucha and Roslin Tana which, due to continued lack of certified seed, have had low farmer adoption rates (Haugerund, 1985).

The demand for certified seed in Kenya per year is estimated at between 150,000 tons and 200,000 tons (Durr and Lorenzl, 1980). The quantity of the certified seed tubers available in Kenya is normally adequate for only about 10,000 ha and meets less than 1% of the total national yearly demand. This is despite the long existence of a well organized potato seed certification programme in Kenya. According to Ngugi (1983), and Haugerund and Kimani (1984), the reasons for the inadequacy of seed materials are:

1. Ware and seed grade prices are not rationalized and move freely depending on market forces. Ware potatoes have always been higher priced than seed and seed is consequently sold for consumption as Ware.

2. Certified seed production zones (above 2400 m) are far from potato growing areas. For example, Molo, a good potato seed area is 500 km away from important potato growing areas in Central and Eastern Provinces. The distribution system is also not efficient enough so as to supply seed to all the farmers in time and at a price that the average resource-poor farmer can afford.

1.3.0 Problem Definition

Potato production in Kenya is limited by the problems of poor seed tuber health, high cost, length of clearing diseased planting materials, high seed costs and the lack of adequate certified seed stocks. Given these, it may be argued that, any potato seed production programme, that could overcome these bottlenecks, would result in increased yields per unit area and an expansion of the areas under potato production

not only in Kenya but also in many other developing countries of the world, that are faced with a similar situation.

1.4.0 Objectives and justification of this Research Work

The availability of cheap and sufficient quantities of healthy seed stocks is one of the greatest problems in potato production in many developing countries of the world. This research work investigated the possibilities of producing cheaply, large quantities of True Potato Seeds (TPS) under mid altitude conditions in Kenya using local commercial varieties grown by farmers. True Potato Seed utilization has shown potential in producing large quantities of cheap seedling tubers that can be multiplied further by the farmer during the first and second clonal generations (F1 and F2). These seed tubers are of a high health status comparable to breeders and basic seed.

However the production of TPS in the mid-altitude areas of Kenya, is constrained by the following :-

1. The shy flowering of most of the European originated potato cultivars used by farmers in Kenya.

2. Lack of any documented information on the commercial cultivars behaviour of flowering and berry production ability.

3. Lack of cheaper technologies that could improve flowering and TPS production, from the commercial varieties already with farmers.

This research work was carried out to test the possibilities of managing Nitrogen and phosphate fertilizer applications under mid altitude conditions in Kenya, in order to produce cheaply, large quantities of open pollinated TPS. The objectives were :-

a) To investigate the effect of split application of lower nitrogen levels than those recommended (Pallais, 1985; CIP, 1986) for TPS production, on flowering, pollen quality, berry yields and TPS quality and find out how these would affect tuber yields.

b) To investigate the effect of applying the same lower level of N fertilizer at different potato crop stages on flowering, pollen quality, berry yields and TPS quality and find out how these would affect tuber yields.

c) To establish varietal response to different levels and combinations of nitrogen and phosphate fertilizers on flowering, pollen quality, berry yields and TPS quality and find out how these would affect tuber yields.

CHAPTER TWO

LITERATURE REVIEW

2.0.0 Seed tuber multiplication schemes

If the need is to produce seed stocks of a high health standard, for use in the production of ware potatoes for consumption, several methods of achieving this are available.

Whole tubers.

Clean, healthy seed tubers may be produced from basic seed, which in turn originate from breeders material. In this case whole tuber are used. The tuber multiplication rate of about 1:5 is low , and to obtain sufficient quantities of seed , several generations of clones need to be planted . This in turn increases the possibility of pathogen contamination and hence degeneration.

Sliced Tuber.

A slightly higher multiplication rate, may be achieved by planting sliced pieces of whole tuber. However, this may increase the risk of disease pathogen transfer between the seed tubers, during the slicing process. The cut pieces also require treatment with fungicides, before planting. This represents an appreciable increase in the cost of production of the seed tubers (Cole and Wright, 1967)

Plant cuttings

Stem cuttings, may be rooted and transplanted to produce more stem cuttings which give rise to the mother plants responsible for production of the seed tubers. This method has been used successfully in the near and far east countries like Philippines, Korea and Vietnam. It has been shown that eight plants derived from one tuber, could produce 5000 rooted cuttings in six months by cloning and recloning.

Single-node-cuttings may also be used to produce seed tubers rapidly. Godwin (1981) and Bryan *et al.* (1981), found that an infinite number of cuttings could be produced by recloning the cuttings and when these were transplanted to the field, yields of 0.5 kg seed tubers or more per plant, were realized.

Entire sprouts can, through a method of layering, be used to maximize production from a single tuber. The basis of this method is to maximize sprout growth and cut it into units consisting of single nodes. Hamann (1974), reported obtaining an increased ratio of up to 1:7,600.

Techniques such as the use of tiny tuberlets produced from leaf-bud cutting have been used to produce up to 0.5 kg of tubers per tuberlet in field trials (Bryan, 1985). Other techniques such as the use of stolon cuttings, "making" small tuber from mother plants and variations of these methods have been the subject of many studies (Bryan, 1985).

Most of these techniques require specialized technical knowledge and facilities like glass and screen houses. This is in addition to the use of growth hormones and expensive and elaborate phytosanitary procedures. The methods therefore, cannot be used efficiently and cheaply, by many farmers in the world, including those in Kenya. Infrastructural needs for these rapid propagation techniques is often lacking, especially, in the poor developing countries. Rapid propagation is therefore an extremely expensive alternative, although a large quantity of clean, healthy seed stocks can be build up, in a relatively short time.

True Potato Seeds

In the past decade or so, a method that has, albeit been used only on a small scale by breeders, has gained prominence and is increasingly becoming a promising alternative strategy in potato seed tuber production. This is the propagation of potatoes through botanical seeds, commonly referred to as True Potato Seeds (TPS).

True potato seeds fall into two broad categories; Hybrid TPS, result from controlled pollination between selected progenitors. For example Atzimba * DTO-28, Serrana * LT-7, LT-8 * LT-7. Open pollinated TPS (OP's) arises from natural pollination. Under field conditions about 15 % to 20 % of TPS formed will originate from natural cross pollination while 80 % to 85 % will be from selfing. The proportion of hybrid seeds may be much higher depending on the morphology of the floral structure, pollen fertility and the presence and activity of Bombus bee pollinators (Brown and Huaman, 1983, Glendinning, 1976).

Three methods of propagating TPS in order to produce a potato crop are used (Wiersema, 1984; CIP, 1987.)

(a) Direct Sowing

The TPS are sown directly into the field. The resulting seedlings are managed to produce tubers for consumption.

(b) Transplant Seedlings

The TPS are sown in a nursery and the seedlings are managed for about 28 days, until they are ready for transplanting into the open field. Here, tubers for consumption are produced.

(c) Seedling Tubers

The method involves propagation of tubers derived directly from TPS sown in a nursery. Tubers produced from TPS are generally smaller than ware size and hence are excellent for use as seed tubers

2.1.0 History of the use of TPS.

TPS have been used since time immemorial. Salaman (1949) reports that the South American Indians used TPS to rejuvenate their potato stocks from time to time. Haan (1953), reported that when the blight epidemics of 1845 wiped out the potato crop in Europe, most countries imported TPS from abroad. Similarly, potato breeding programmes have used TPS for many years by raising seedlings and subsequently propagating selected plants derived from the arising tubers (Howard, 1978; Dorset, 1964). In China potato production through TPS has been practiced on many communes and state farms since 1967 (Li, 1979,

1983). Similar diffusion of TPS use in potato production on a large scale, has been reported in Russia since 1961 (Kushnareva, 1976) and in India since the late 1940's (Upadhya, 1979). More recently, the International Centre of Potatoes (C.I.P.) has been spearheading research into possibilities of using TPS for potato production (Harris, 1983).

In Kenya limited work has been done to study methods of propagating potatoes from TPS. These studies have been carried out by researchers at the University of Nairobi and by CIP regional scientists working at Kabete, Muguga, Molo and Mau Narok areas (Alacho, 1986; CIP 1987, CIP, 1988). Alacho (1986) reports obtaining yields ranging from 17.8 to 58.3 tons /ha from a crop of TPS seedling transplants. This was in comparison to yields of 13.8 to 32.4 tons /ha obtained from clonal seed tubers.

2.1.2 History of Research Efforts in TPS

A number of reports show TPS yields similar to or even better than those obtained from tuber propagation. Of the three methods of propagating potatoes from TPS, direct sowing is the most unfavourable, while the use of seedling tubers has been proven better. Kunkel (1979) failed to obtain seedling emergence in an irrigated field of six hectares after direct sowing TPS that showed 87% germination in the laboratory. Accatino (1979) observed emergence in only 11 out of 52 lines of TPS directly sown with a maximum germination of 18%. However, Martin (1983) in the U.S.A. reported 50-80% emergence when TPS was direct sown with a precision planter. Emergence and establishment after field sowing is influenced by among other factors,

soil temperatures and soil conditions which determine aeration and surface crusting (Accatino, 1979; Martin, 1983). In addition, seed quality is a factor which must be taken into consideration in order to maximize on percent emergence, and seedling vigor.

2.2.0 Factors, favouring use of True Potato Seed in propagation.

Propagation of potatoes from TPS bears a number of advantages:

(a) tuber transmitted diseases are not found in TPS, except for a limited number of viruses and viroid. Only the viroid, is generally considered to pose a potential problem (Jones, 1982). Use of TPS would therefore represent a significant saving in production costs. Healthy seed stocks may be built-up quickly as seedling tubers. TPS has a great potential in cutting down on both the cost and the period of cleaning and rejuvenating virus degenerated seed stocks.

(b) TPS use would cut down on cost incurred by resource poor farmers, in the purchase of seeds tuber. These costs account for between 50-70% of the total production costs. The 2 to 2.5 tons (Ngugi, 1983; CIP, 1983; CIP, 1985) of seed tubers needed to propagate an hectare, is a considerable capital sacrifice on the part of the farmer. The use of the cheaper TPS alternative would be an important saving.

(c) Tubers are bulky and expensive to transport as compared to TPS. In Kenya, seed tubers have to be transported in lorries over a distance of over 500 km from Molo, the highland seed growing region, to the Central and Eastern Provinces, the ware growing areas. Future potato expansion programmes to Taita-Taveta and other Coastal Districts would have to consider transport as a major problem.

(d) Farmers would have smaller quantities of propagation materials to handle, by adopting the TPS alternative. Only between 100 - 200 g of TPS is required to sow one hectare, compared to between 2 and 2.5 tons of tubers required for the same unit area (CIP, 1980, 1982, 1983, 1985; Weirsemer, 1985; Ngugi, 1983).

(e) Since storage of TPS is relatively simple, transportation affords easier and efficient distribution to any distant potato growing area, thus making production of potatoes less dependent on infrastructure. TPS can be stored for longer durations under room temperature conditions with little loss in germination (Simmonds, 1968). This is not the case with storage of tubers which requires relatively more expensive well ventilated stores..

(f) Propagation of potatoes through TPS, also releases a considerable amount of tubers for family consumption and / or for marketing. Land that would normally be required by any farmer to maintain seed stocks is also released for other crops.

2.3.0 Tuber Yields from TPS

Few authors give yield information of direct sown TPS as a result of poor emergence. Bedi and Smale (1978) reported that they obtained total tuber yield of 20.2 - 47.2 tons/ha from several TPS lines, sown directly into the field. Yields obtained from Nursery seedling transplants are variable. Li (1983) in China reported yields similar to those of commercial varieties, while Kidane-Mariam (unpublished) in Peru obtained a mean marketable yield of 36 tons per hectare, from 40 lines of TPS.

Propagation through transplant seedling is more favourable than direct sowing in that, healthy vigorous seedlings are transferred to the field after selection at the nursery stage. Thus, a more uniform field establishment, is achieved. Current research in this method of propagation is focused on propagation medias and nutrient supply for the young seedlings in the Nursery, the optimal stage and method of transplanting (Accatino and Malagamba, 1982; Malagamba 1983; Wiersema, 1984, Upadhya, 1979). In general, these findings relate to better nursery fertility management.

2.4.0 Quantity and quality Parameters in TPS Production.

Clark and Lombard (1939) established a definite relationship of daylength to flowering and True Potato Seed production, in potato varieties. Their results showed that long photoperiods of 14 - 18 hours are optimal for maximizing flowering and berry set in the genotypes studied. Thus the location where the crop grows influences seed production, through latitude and season.

In large scale seed production schemes, the degree of flowering of the crop is important. Equally important is the amount and quality of pollen produced by the crop (Pallais *et al.*, 1985) The ultimate test to determine pollen fertility is its seed set capability. Hence any crop management practices that will improve the viabilityand quantity of pollen produced may also improve the degree of berry set and possibly increase the amount of TPS per berry.

One of the methods that has successfully been used to enhance flowering, and seed production has been the use of growth regulators (CIP, 1986; Pallais *et al.*, 1985). The hormones found effective include various combinations and levels of Benzyladinine (BA) and Gibberellic acid (GA_3). Combination of 500 ppm GA_3 and 500 ppm BA, produced not only a tenfold increase in the number of flowers, but also considerably improved pollen fertility.

Kidane-Mariam *et al.* (1985), pointed out the need of using appropriate TPS progenies in the production of both ware and seed tubers. TPS families for use in potato production may be either Hybrids or Open Pollinated (OP's) progenies. The hybrids, produced by controlled pollination, may be derived either by the conventional method of intermating tetraploid cultivars or by modified conventional breeding schemes employing meiotic mutants producing 2n gametes (Macaso-Khawaja and Peloquin, 1983). In contrast, OP's are the product of natural pollination and may be obtained from cultivars and advanced clones from the different kinds of Hybrids. Seeds of OP's are mostly selfs but may contain some hybrid seeds resulting from natural outcrossing (Glendinning, 1976).

Hybrid TPS are generally superior to OP's (Kidane-Mariam *et al.*, 1985; Macaso-Khawaja and Peloquin, 1983). This is to be expected since hybrids are products of two or more normally self-pollinated, highly heterozygous parents. Hence TPS hybrids, compared to OP's, may be expected to produce seedlings of higher vigour, survival rate, growth rate and yields However OP's of late maturing varieties have also shown superior vigour during seedling development. This may be an indication that a longer growing period of the mother plant, is favourable for seed development. (CIP, 1982, 1983, 1985).

The attractiveness of TPS technology depends a lot on the quality of the seeds and is decreased by low seedling vigour. If farmers are to adopt, on a wide scale, this method of propagating potatoes, then there is need to provide them with seeds that produce seedlings of high vigour , growth rate and survival The quality of TPS depends on a several factors whether they are OP's or hybrids. These include nutritional content of cotyledons which in turn depends on nutrient supply to the mother plant, potato embryo seed formation, seed size and seed weight. These factors have been used as parameters to sort out TPS into quality categories (Upadhya *et al.*, 1985; Kidane-Mariam *et al.*, 1985). Studies carried out by Upadhya *et al.* (1985), and Kidane-Mariam *et al.* (1985), indicate that considerable differences exist in the 1000 seed weight of TPS between and within the hybrid and OP categories. Generally hybrid seeds are heavier than OP's.

Seed size and weight are closely related to seed quality characteristics (Kidane-Mariam *et al.*, 1985). In general increased TPS size and weight is associated with high quality, (Dayal *et al.* 1985; CIP,

1983). TPS can be separated into several quality classes according to size by using a multi-size sieve. Large seeds are greater than 1.5 mm while small seeds are less than 1.2 mm.

Dayal *et al.* (1984), found a strong positive correlation between seed size/seed weight and tuber yield in field nursery conditions while Kidane-Mariam *et al.* (1985), did not. Later workers, however, contend that one possible reason they did not find a positive correlation could have been that the size difference in the seeds they studied was not wide enough.

Recent work in India by Uphadya *et al.* (1981), has associated seedling performance with potato seed embryo formation as evaluated through a dissecting microscope. The researcher ware able to show that A type seeds with a cercinnate embryo gave a higher germination than B-, C-, and D- types, and also that the seedlings from the A- type were vigorous and had higher fresh and dry weights than other types (Upadhya, 1983). Thus, by sorting TPS into embryo types, quality classes can be established.

Other quality parameters have been used to categorize TPS. Biochemical analysis carried out for certain TPS constituents such as carbohydrates, soluble proteins, total lipids and phospholipids have revealed that A type seeds have higher contents of these and especially soluble proteins while the C and D types showed the lowest amounts of total sugars and soluble proteins.

2.4.1 The influence of Time and partial application of N on TPS production.

Studies initiated by CIP have shown that improving the nutrient supply to a crop of potatoes not only improves the viabilityand quantity of pollen produced but also, the degree of flowering, berry set, size and number of true seeds per berry in addition to improving TPS quality (Upadhya *et al.*, 1983; Pallais *et al.*, 1985). Potatoes grown for TPS production have specific fertilizer needs Environments conducive to tuber bulking may be detrimental to flowering and perhaps to high quality seed formation (Pallais *et al.*, 1985). The stage of rapid tuber bulking coincides with flowering. The tuber has a stronger sink strength, and this may result decreased flow of assimilates to the developing floral shoots (CIP, 1977).

Pallais *et al.* (1985) reported that increasing levels of N increased flower production and pollen germinability in the clone DTO-33, but decreased flower production in DTO-28.

Apart from higher doses of nutrient supply to the mother plants, timing of fertilizer application and increased N fractioning seem to influence seed production and quality (Pallais *et al.*, 1985). Increased N fractioning was found to be superior in inducing flower production and pollen germinability in the clones DTO-33 and DTO-28. Waiting until flowering to apply N as a side dress was found to be disadvantageous. This may be due to a smaller percentage of flowers retained in both clones. Pollen germinability was observed to decrease slightly in DTO-33.

Similar work is reported (CIP, 1986) where additional N applications resulted in enhanced flowering, and lengthened period of Berry development. The increased flower production was an indication that N-rates greater than those required for tuber production might be essential to efficiently produce large quantities of TPS. Flower production was increased by 2.7 and 3.5 times, when three additional applications of 80 kg and six of 40 Kg N/ha were added to the normal 150 kg N/ha recommended for high tuber yields. Higher number of partial N applications were found to result in heavier seeds.

2.4.2 The influence of N and P_2O_5 application on TPS production.

Pallais *et al.* (1985), reported that increasing levels of N and K resulted in increased pollen germinability while P_2O_5 alone had the opposite effect.

Uphadya *et al.* (1985) evaluated the effect of applying higher doses of N and P to mother plants of TPS-3. Positive interaction between N and P doses were found to be significant at 5% level; whereas the effects on 100 seed weight due to P alone, were found to be highly significant at 1% level when data were subjected to Bartlett's test Uphadya *et al.* (1985), used six combinations of N and P fertilizers at rates of 120, 240 and 360 Kg ha^{-1} N, and 80 and 160 Kg ha^{-1} P. Trimming all flowering buds to retain only the initial flowering bunch per stem, they found that there were non significant differences among the treatments for the average berry weight and seeds per berry. They were also able to establish a positive interaction between N and P with regard to embryo types. Phosphorous alonea produced a highly significant effect on the 100 seed weight although higher doses of N and P

seemed to have a detrimental effect on 100 seed weight

CHAPTER THREE

MATERIALS AND METHODS

This research work was carried out at the university of Nairobi's field station farm at Kabete Campus. The station is located in a typical mid-altitude Potato growing area in Kenya It is situated at 1^0 14' S and 36^0 14' E grid and has an altitude of 1850 meters above sea level and an annual bimodal average rainfall of 925mm.

3.0.0 Weather

The weather conditions experienced at the site in the year of the experimental work are presented in appendix I. Tables I and II are extracts limited to the growing period only.

Table 1: Summary of weather conditions in season[1] I.

	Temperature (°C)			Rainfall	
Month	Minimum	Maximum	Average	(mm)	Days
November	14.0	23.6	18.8	182.1	16
December	13.4	23.8	18.4	25.2	3
January	13.6	25.1	19.4	96.2	8
Average	13.7	24.2	18.9	101.2	

Average Daylength: 11 Hours 55 minutes.

1./ Period between crop emergence and flowering

Table 2. Summary of weather conditions in season[2] II.

	Temperature (°C)			Rainfall	
Month	Minimum	Maximum	Mean	(mm)	Days
May	13.9	24.1	19.0	235.9	15
June	12.6	21.3	16.9	27.7	10
July	11.6	25.2	18.4	18.9	5
Mean	12.7	23.5	18.1	94.2	

Average Daylength: 12 Hours and 04 minutes

3.1.0. Soils

The soil at the field station farm has been described as comprising predominantly red friable kaolin clay mineral, and the parent material, as the Kabete Trachyte. The soil dominant on the farm has a top soil pH of between 5.2 to 7.2 and a sub-soil pH range of 5.2-7.7 (Nyandat and Michieka, 1970).

Soil analysis was performed on soil samples taken from the sites where the experiments were carried out. These are presented here as Appendix II.

2./ The period between crop emergence and flowering

3.2.0. Planting material

Over each of the two seasons of work, there were three experiments that were carried out in the field. Experiments I and II, were comparatively smaller insize and involved only the variety Kenya Dhamana. Experiment III involved three commercial varieties; Kenya Dhamana (CIP 800224), Anett, and Kenya Baraka

The selection of these varieties was on the basis of their varied flowering and berry production behaviour. Kenya Dhamana is an erect late maturing variety, with a bushy foliage. It produces, almost always, many pink flowers followed by a conisderable amount of berries.

Anett is an early to medium maturing variety (two and a half to three month) . It has many thin, sprawling stems, with light green leaves. Ocassionally, a few white flowers are produced. It is thus, considered to be a rare berry setter.

Kenya Baraka is late maturing (4 months), with very strong haulms and good foliage cover. It is sensitive to drought and low soil fertility. The buds and flower calyx are greenish, while the flowers are white. The variety shows erratic flowering characteristics. The flowers are also few. It is considered to be only an ocassional berry setter.

This work considered aspects related to the production of open pollinated TPS. This is because the production of TPS through self-pollination results in considerable reduction in seed costs compared to Hybrids. However, the same management aspects may apply to many TPS production schemes.

The planting seeds used in these trials, were from basic seed stocks from the National Potato Research Centre (N.P.R.C.), Tigoni. The seeds, were of the same physiological age and size . In season I (November, 1987 to March, 1988), the planting material had many strong sprouts, and crop establishment was good. In season II (April to August, 1988), sprouting was comparatively less and this resulted in uneven crop establishment.

3.3.0 Fertilizers.

All the three experiments, involved fertilizer applications as the main treatment. The fertilizers used were Calcium Ammonium Nitrate (C.A.N) (26:0:0) as the main source of N and Tripple Super Phosphate (T.S.P). (46% P_2O_5) as the main source of phosphorus, P.

The recommended fertilizer in Kenya is 517 kg D.A.P./ha (Ballestram and Holler, 1977) (D.A.P. is Diamonium Phosphate 18:46:0) for potatoes. However for this research work, C.A.N. and T.S.P. were used in combination, because it is easy with these to achieve various combination levels of both the N and the P components.

3.4.0. The Treatments

Experiment I was set to investigate the influence of N fractioning (i.e. split appliation) on TPS production parameters. The experiment had one variety and four fertilizer N application schedules. The treatments in this experiment I were as follows:-

TA - Full N rate (112.5 kg N Ha^{-1}) applied at planting.

TB - Half of the full N rate (56.25 kg N Ha^{-1}) applied at planting and half (56.25 kg N Ha^{-1}) at hilling (30 Days after planting) .

TC - Half of the full N rate (56.25 kg N Ha^{-1}) was applied at planting, a quarter (28.13 kg N Ha^{-1}) at hilling up (30 Days after planting) and a quarter (28.13 kg N Ha^{-1}) at flowering (50 Days after planting).

TD - Half of the full N rate (56.25 kg N Ha^{-1}) applied at planting and the rest at flowering (50 Days after planting).

P was applied as a basal treatment at planting at a rate of 180 kg P_2O_5 ha^{-1}.

Experiment II was set up to investigate the effect of applying N at different stages of the potato crop, on TPS production parameters.

The Treatments that were considered in experiment II were:

T I - Application of N rate (112.5 kg N ha^{-1}) at planting.

T II- Application of N rate (112.5 kg N ha^{-1}) at hilling up, 30 days after planting

T III- Application of N rate (112.5 kg N ha^{-1}) at flowering, 50 Days after planting .

T IV Application of N rate (112.5 kg N ha^{-1}) at berry development, 75 Days after planting.

P was applied as a basal treatment at 180 kg P_2O_5 ha^{-1}.

Experiment III was designed as a three factor factorial experiment, to investigate the influence of nitrogen and phosphate fertiliser levels and combinations, on True Potato Seed production parameters. The experiment had three varieties, Kenya Dhamana, Anett and Kenya Baraka. There were four levels of N (0, 100, 200 and 300 kg ha^{-1}) and three levels of P (60, 120, 180 kg P ha^{-1}). The factorial combinations are shown in appendix IV.

3.5.0 Experimental Design and Statistical Analysis

Each plot had seven plants in seven rows. The middle sample area, therefore had twenty five plants.

Data obtained from experiments I and II were analysed as Randomised complete block design in three replications, (Appendix III a) Experiment III, was analyzed also as a three factor Randomized complete block design. There were three replications The ANOVA model design table is presented as Appendix III b. The factors were, three commercially grown varieties, Kenya Dhamana, Anett, Kenya Baraka, four levels of N fertilizer and three levels of P_2O_5 fertilizer. The treatments combinations, and fertilizer levels, are shown in Appendix IV.

All data were analysed according to the methods laid out in Little and Hills (1977).

The means separation, where significance for the F test was found, were achieved through the Duncan's multiple range test (DMRT), and Least Significant Difference (LSD).

3.6.0 General Crop Management.

Fertilizer placement at planting was in the furrows. The N and P fertilizers were thoroughly mixed with the soil, 4-5 cm below the seed tubers, at planting. Where fertilizer application was required at post-emergence stage, the side-band placement method was used.

The crop was kept weed-free, throughout the season. Late blight control was achieved successfully by the use the of the fungicide, Dithane M45. Insect virus vectors like Aphids and White Flies were controlled by the use of Metasystox. Furadan a Nematicide was used for Nematode control, in both seasons.

In season I, all the three varieties showed a tendency of producing many haulms. This may have been due to the use of well sprouted tubers, during planting. In season II, the seeds used were not very well sprouted, and as such the stem count was lower.

During routine crop maintenance, it was noted that in season I, and II the average stem number per plant were 3.4 and 2.9, respectively.

3.7.0 Measurable TPS Production Parameters

In order to assess the influence of fertilizer manipulations, in all the experiments, several parameters involving flowering, pollen production, berry set, true potato seeds and tuber production, were considered. These parameters were used in assesing the influence of the various treatments, on true seed production.

The effect of these fertilizer manipulations, on the performance of the crop, was assessed through considering the following general parameters:

a) Flower production.

b) Pollen quality.

c) Berry yields.

d) TPS quality.

e) Tuber yields.

3.7.1 Flowering.

Experiments carried out in season I revealed that, only one thorough flower count was necessary. There are three stages that the floral reproductive structure undergo. In the first phase, flower buds and open flowers are seen, in the second open flowers and young berries are seen, while in the last, berries and flower stalks from which flowers aborted are observed. It proved easier and safer to make counts at the last of these flower stages. This is because less damage was done on the flowers and hence accidental flower abortion due to ruffling of the crop foliage was avoided at the stage when the flowers were most plentiful. The other advantage was that, during this last stage, a more exact number of berries could be established, without losing count of the total number of flowers expressed and aborted. By counting all berries and all flower stalks on the 25 plants, in each plot sample area , the total number of flowers formed was established

3.7.2 Pollen quality

At the initial stages of the experiments, Pollen viability was assessed through both the *in-vitro* germination and the differential staining techniques. However, only the staining technique was adopted because of its convenience in that the pollen samples could all be mounted on glass slides about the same time and counts taken later Pollen samples extracted from the flowers in the plot sample area, were utilized.

Pollen was collected into gelating capsules from the 25 flowering plants within the plot sample area, using battery powered vibrator buzzers. These pollen samples were then shaken thoroughly, in a vortex ginie machine, to achieve a complete mix. Afterwards pollen viability was assesed.

Differential pollen staining:

This method was adopted from that proposed by Alexander (l969). The method stains aborted non-viable pollen grains green, and non-aborted viable grains, red. Viable cells were expressed as a percentage of the total. Thus a fertilizer treatment which resulted in a lower percent count was considered to have been detrimental.

To make the stain the following method was used:

Addition of various constituents in the order given below, shaking after each addition and storing in coloured bottles:

(i) 95% alcohol, 10 mls.

(ii) Malachite green; 10 mg (1 ml of 1% solution in 95% alcohol).

(iii) Distilled water, 50 ml.

(iv) Glycerol, 25 ml

(v) Phenol, 5 gm

(vi) Chloral hydrate; 5 gm

(vii) Acid fuschin, 50 mg (5 ml of 1% solution in water).

(viii) Orange G; 5 mg (0.5 ml of 1% solution in water).

(ix) Glacial acetic Acid; 2 ml.

After the stain was prepared and made to the optimal pH for differentiation, a little potato pollen powder was mounted directly in a drop of the stain, covered with a cover slip, warmed over a small flame, and examined through a magnifying microscope.

Data were recorded by counting the number of red stained cells (viable non-aborted pollen) and expressing these over the total pollen grains.

3.7.3 Berry Production

Total berry yields were obtained by counting the total number of berries per plant from 25 plants, in the plot sample area.

The berry size was established by pouring the fruits through two sieves. Thus there were three sizes that were obtained; large (Size A >

30 mm), medium (Size B, 20-30 mm), small (Size C < 20 mm). The total number of fruits falling into each category size were counted and the final figures were percentages of the total.

3.7.4 TPS Data

The berries were harvested at full maturity and ripening. Afterwards they were crashed by hand onto a sieve separating the seeds from the the pulp. The seeds were covered in mucilage which was removed by first drying in the open at room temperatures and later rubbing in muslin cloth in order to achieve separation of the seeds from one another.

The seeds were then separated into lots of 1000's and 100's. Using an electronic scientific analytical balance, the 1000-seed weight's were obtained. Seed sizes were established by pouring the seeds through a series of 10 sieves of the following dimensions; 2.12 mm, 1.95 mm, 1.81 mm, 1.69 mm, 1.59 mm, 1 49 mm, 1.41 mm, 1.34 mm, 1.27 mm, < 1.27 mm (in inches respectively 1/12, 1/13, 1/14, 1/15, 1/16, 1/17, 1/18, 1/19, 1/20, and less than 1/20). All seeds in each sieve, were counted. Using Upadhya *et al.* (1984) classification, the 1000 seeds were put into three categories. Large seeds fell into 2.12 mm - 1.69 mm, medium size seeds fell into sieves 1.59 mm - 1.41 while small seeds fell into 1.34 mm - less than 1.27 mm. The total seeds in each of the three categories was expressed as a percentage of the total.

True Potato Seed from each treatment in all experiments were also assessed for viabilityby germinating them in glass houses. A hundred seeds were planted per tray. In addition further data were taken on the glass house experiments to asses the quality of the TPS in terms of

total germination, and vigour. Data on tuber size and yield were taken with the help of a top-load balance, in the field. The tubers were sorted into 3 sizes; greater than 45 mm, between 45 and 28 mm and chatts (less than 28 mm).

CHAPTER FOUR

RESULTS

4.1.0 EXPERIMENT I

The Influence Of N Split Application on True Potato Seed Production Parameters.

4.1.1 The Influence of N Split Application on Flowering

The number of flowers formed in season I, was about the same in TA, TB and TD. Although there was no significant (p = 0.05) difference between these treatments, applying the full amount of N at planting (TA) resulted in more flower formation. TA, and TB were significantly different from TC. Both outyielded TC by an average of 29 and 24%, respectively (Table 3).

Table 3: The effect of N Split application on Mean number of flowers per plot

TREATMENT	SEASON I	SEASON II
TA	3005.667 a	717.000 c
TB	2797.333 a	770.667 bc
TC	2132.667 b	893.333 ab
TD	2643.333 ab	989.000 a
MEAN	2644.7	842.5
LSD = 0.05	588.7	150.8
C.V (%)	11.14	8.96

In season II, flowering was inconsistent with that of the previous season. In all treatments the number of buds that developed into fully open flowers was 32% of that for season I's. Late application of part of the N at hilling and at flowering (TC and TD) proved beneficial. Application of Supplemental N at flowering (TD) was significantly higher ($P = 0.05$) than application of the full N at planting (TA) or application of half N at planting and hilling (TB).

4.1.2 The influence of N split application on pollen quality

Data obtained in season I indicated in general that pollen viability decreased the later the nitrogenous fertilizer was applied. There was no significant difference ($P = 0.05$) between treatments TA and TB. TA resulted in significantly higher pollen viablity compared to TC and TD (Table 4).

Table 4: The influence of N split application on pollen viability.

TREATMENT	Mean % viable pollen* cells. SEASON I	SEASON II
TA	73.9 a	48.7 c
TB	70.4 ab	76.6 a
TC	67.0 bc	80.7 a
TD	61.0 c	61.2 b
MEAN	68.1	66.8
LSD = 0.05	6.5	8.7
C.V (5)	4.8	6.5

*: Means calculated from the average of ten counts per treatment.

In season II, splitting N more than twice (TC) and late application of further N (TD) increased pollen viability by 9.2% and 17.4% compared to the control (TA). TA significantly depressed the pollen viability, compared to all other treatments. Split application of N proved advantageous and significantly higher (P = 0.05) pollen viability was achieved compared to applying all N amount at planting (TA).

Although there were no significant differences, TC had the highest pollen viability followed by TB Hence, further split applications of N at hilling and flowering proved better in increasing pollen quality.

4.1.3 Influence of N split Application on Berry Production .

This was established through three parameters; mean berries numbers, mean berries weight expressed in kilograms per plot, and size groups of the harvested berries.

4.1.3.1 Berry yields in numbers.

The mean number of berries in each of the treatments, is shows in Table 5.

Table 5: The effect of N split application on berry number per 25 plants.

TREATMENT	SEASON I	SEASON II
TA	1055.7 c	322.3 b
TB	2155.3 a	413.0 a
TC	1799.0 b	335.0 ab
TD	1789.3 b	308.3 b
MEAN	447.3	344.7
LSD = 0.05	352.8	83.5
C.V. (%)	10.4	12.1

The results, show that there was about 30% more berry production in season I than in season II. This difference is a reflection of the better flowering, prevalent during the first season. TB out-performed all the other treatments significantly. TC and TD produced almost a similar number of berries, but each was less than that of TA. The data, therefore show that , for the season, splitting N rather than applying the full dose at planting, was more beneficial to berry formation and retention.

The data obtained in season II, is comparable. TB again was the best treatment, significantly out-performing both TA and TD.

4.1.3.2 Berries Yields in Kilograms per plot.

All berries from 25 plants in the plot sample area were harvested and weighed, before an analysis of variance was done. Table 6 shows the result of this.

Table 6: Mean weight of berries in kilograms per 25 plants.

TREATMENT	Mean yield of berries (Kgs/plot) SEASON I	SEASON II
TA	4.72 b	2.65 b
TB	5.35 ab	3.01 ab
TC	5.90 ab	3.32 ab
TD	7.17 a	4.02 a
MEAN	5.78	3.25
LSD = 0.05	2.34	1.32
C.V (%)	20.3	20.3

In season I, application of supplemental N at the onset of flowering resulted in berries of the highest weight. The mean weight (in kgs), was not significantly different between treatments where N was applied any stage after planting (TB, TC, and TD). The apparent trend in this season was an increase in weight of berries , the later the supplemental N fertilizer applied.

The results obtained in both seasons compare well, although the mean treatment was higher in season I. In both seasons, TD gave the highest mean weight for berries. These means were significantly higher than those of TA where there was only one single application of N, at planting. There were no significant differences in mean berry weight between the other treatments and TD.

In season II, data showed a similar trend. Application of N at flowering (TD) resulted in the highest mean weight; this was significantly higher than that obtained in TA.

4.1.3.3 The influence of N split application on berry size

The berries considered large were those with a diametre greater than 25 mm. The results show (Table 7) that there were treatment differences in seasons II, unlike in season I.

In season II, application of the Nitrogenous fertilizer at hilling-up, resulted in the highest proportion of the berries in larger size category. This was significantly higher than that of TA, but not the other treatments. Overall, results that applications of N during the active growth stage, was benefitial to increasing the berry size.

Table 7: The effect of N Split application on Percent large berries.

TREATMENT	SEASON I	SEASON II
TA	36.1	27.0 b
TB	37.5	32.3 a
TC	33.1	28.0 ab
TD	39.7	29.7 ab
MEAN	36.59	29.25
LSD = 0.05	NS	4.55
C.V (%)	10.15	7.62

4.1.4 The influence of N split application on TPS quality

This was determined as 1000 seed weight (Swt) and as the number of Large seeds (Large seed fraction (LSF) in a sample of 1000 seeds.

4.1.4.1 The 1000 Seed Weight.

In both seasons, treatments were not significantly different due to treatments (Table 8).

Table 8: The effect of N split application on the 1000 seed weight (mg).

TREATMENT	Mean 1000 seed weight (mg) SEASON I	SEASON II
TA	885.67	868.33
TB	829.31	774.00
TC	880.46	840.33
TD	851.89	746.33
MEAN	861.83	761.75
LSD = 0.05	NS	NS
C.V. (%)	8.21	8.09

NS: Not significant

However, application of supplemental N at hilling (TB) and at flowering (TC) resulted in lighter seed. This effect was marked especially in season II.

4.1.4.2 Large Seed Fraction (LSF)

Applying N at either planting, and at hilling-up (TB) or additionally at onset of flowering (TC), significantly increased the number of seeds in the LSF (Table 9), in season I. Applying supplimental N at the onset of flowering (TD) resulted in significanly lower number of seeds in the LSF.

Table 9: The effect of N split application on the Large seed fraction (LSF)

TREATMENT	Mean number of seeds in 1000 in the LSF. SEASON I	SEASON II
TA	540.333 b	547 667
TB	620.333 a	592 667
TC	585.000 a	556.333
TD	430 667 c	492.333
MEAN	544.08	547.67
LSD = 0.05	52.94	NS
C.V. (%)	3.46	10.43

Although the treatment means were not significantly different in season II, TB and TC again were the better treatments and showed higher numbers of seeds in the LSF.

4.1.5 The Influence of N split Application On Tuber Yields

In season I, applying the full rate of N at planting (TA), or splitting it twice to apply at planting and at hilling (TB) did not produce any significant differences in tuber yields (Table 10). However, these two treatments significantly outyielded TC and TD. The results in season II, show that split application of the nitrogenous fertilizer (TB) led to the highest tuber yields and this was significantly higher than application at planting (TA). Further split applications (TC), and (TD) resulted in significantly lower tuber yields compared to TA and TB.

Table 10: The effect of N split application on tuber yields in tons / ha.

TREATMENT	Tuber yields (tons/ha) SEASON I	SEASON II
TA	43.65 a	32.65 b
TB	45.50 a	37.50 a
TC	34.71 b	25.04 c
TD	32.56 b	23.50 c
MEAN	39.10	29.61
LSD = 0.05	4.634	2.12
C.V (%)	5.93	5.86

The best treatment in both seasons was TB. Thus application of N at hilling-up, approximately 30 days after planting, was the best treatment and increased total tuber production compared to even the reccommended method of adding all fertilizer at planting (Figure 1).

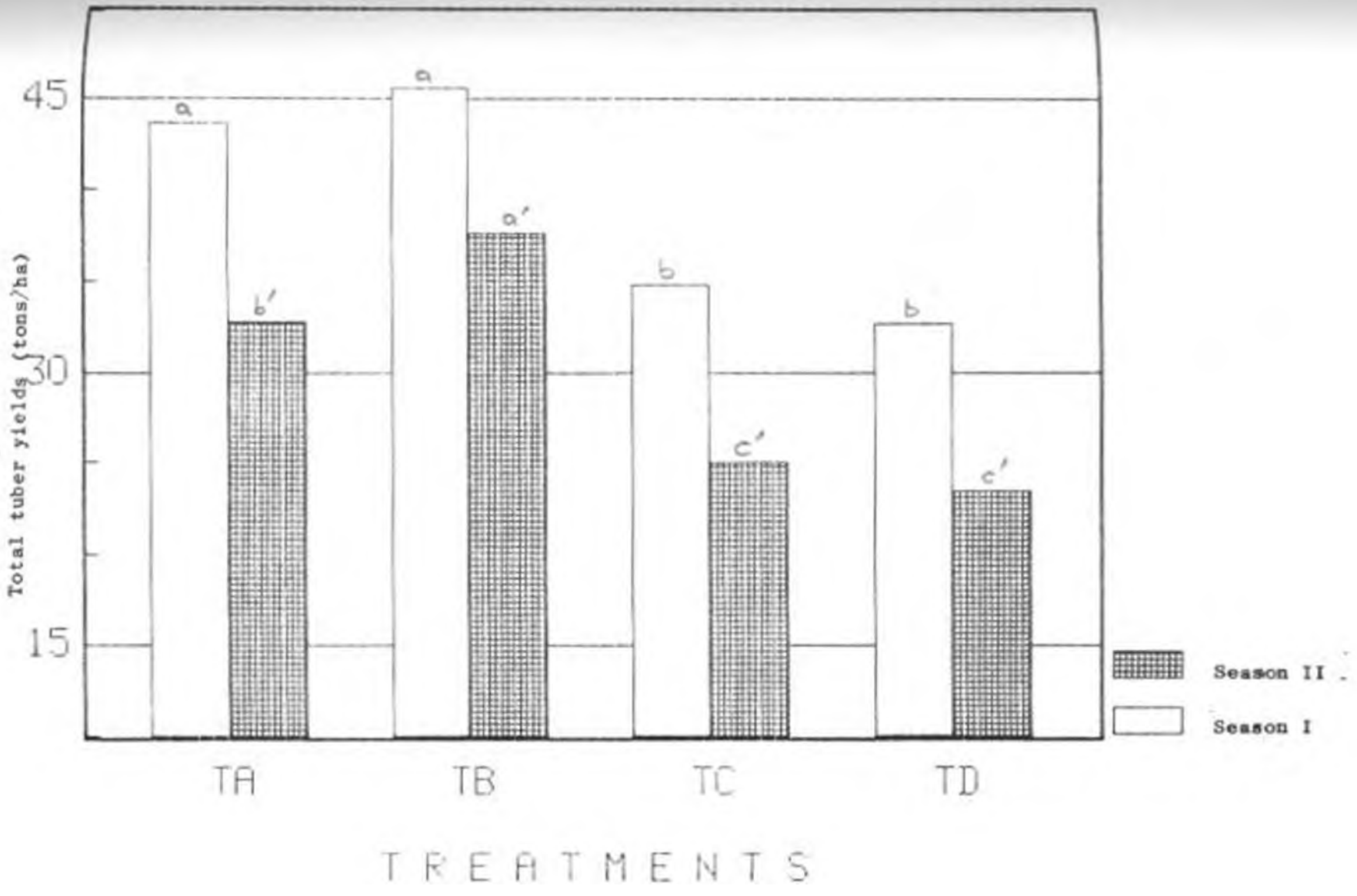

Figure 1 : The infulence of nitrogen split application on tuber production.

EXPERIMENT II

The influence of time of N application on TPS production parameters in the variety Kenya Dhamana.

4.2.1 The Influence Of Time Of N Application on Flowering.

Results obtained in the season I, showed that there was no significant difference in the number of flowers, when N was applied at planting (TI), hilling-up (TII) or just before flowering (TIII). However, applying N at berry development (TIV), resulted in a significantly lower number of flowers (Table 11).

Table 11: The effect of time of N application on flower production per plot

TREATMENT	Mean Flower Numbers SEASON I	SEASON II
TI	2758.3 a	1382.3 b
TII	2992.7 a	1304.7 b
TIII	3208.3 a	1639.3 b
TIV	2065.0 b	2115.0 a
MEAN	2756.1	1610.3
LSD = 0.05	477.2	475.1
C.V. (%)	10.0	17.1

Overall, in season I, application of N at flowering (TIII) was more conducive to increased flowering. This treatment was more outstanding compared to the others, by a margin of between 6.7% and 35%.

In season II, flower production was lower compared to the previous season. There was no significant difference between applying N at either planting, hilling or just before flowering; however application at berry development resulted in a significant increase in flower number. It was observed that, during this season only, the crop under TIV showed delayed senesence. More auxillary buds developed in secondery stems with flowering. Late application of N at the berry formation, thus forced the crop into a longer vegetative phase. This may account for the 31.8% increase in flowering in season II, this treatment compared to the average of the other three treatments.

4.2.2. The influence of time of N application on pollen quality

In general, the data obtained in season I indicates that the pollen quality decreased slightly, the later the N fertilizer was applied. Hence treatments I and II gave a better quality compared to III and IV . There was no significant difference between TII and TIII; pollen viability was about the same (Table 12). Waiting to apply N at flowering, (TIII) rather than at planting (TI), significantly reduced the pollen quality. Withholding N until berry setting (TIV), resulted in a significantly lower pollen viability compared to all other treatments, except TIII.

Table 12: The effect of N application on percent viable pollen cells.

TREATMENT	Mean Viable Cells (%) SEASON I	SEASON II
TI	73.87 a	67.67
TII	70.43 ab	71.67
TIII	67.03 bc	65.67
TIV	61.03 c	68.33
MEAN	68.09	68.33
LSD = 0.05	6.50	NS*
C.V. (%)	4.75	4.63

* : Not Significant.

When N was applied at berry development in season II, the response of the crop to the time of N application was slight but non significant. There was also a slight decrease in pollen quality, the later the N was applied (TIV).

4.2.3 The Influence of Time of N application on Berry Yields.

This was established from the mean number of fruits formed per plot sample area, irrespective of their size or consequent abortion.

Berry Production.

The data (Table 13) indicates that in the season I, there was no significant difference ($p=0.05$), whether N was applied at planting (TI), at hilling-up (TII), or at the onset of flowering (TIII).

However application of N at berry development proved disadvantageous and a significantly lower ($p = 0.05$) berry number was achieved.

In season II, TI resulted in the lowest number of berries formed; this treatment was significantly out-performed by late applied N as in TIII and TIV. There was no significant difference between these two treatments.

Table 13: The effect of time of N application on berry yields per 25 plant in plot sample area.

TREATMENT	Mean number of berries SEASON I	SEASON II
TI	2469.00 a	698.33 c
TII	2682.33 a	818.33 bc
TIII	2910.67 a	1034.00 b
TIV	1514.33 b	1398.67 a
MEAN	2394.08	987.33
LSD ($p = 0.05$)	512.1	319.0
C.V. (%)	12.36	18.67

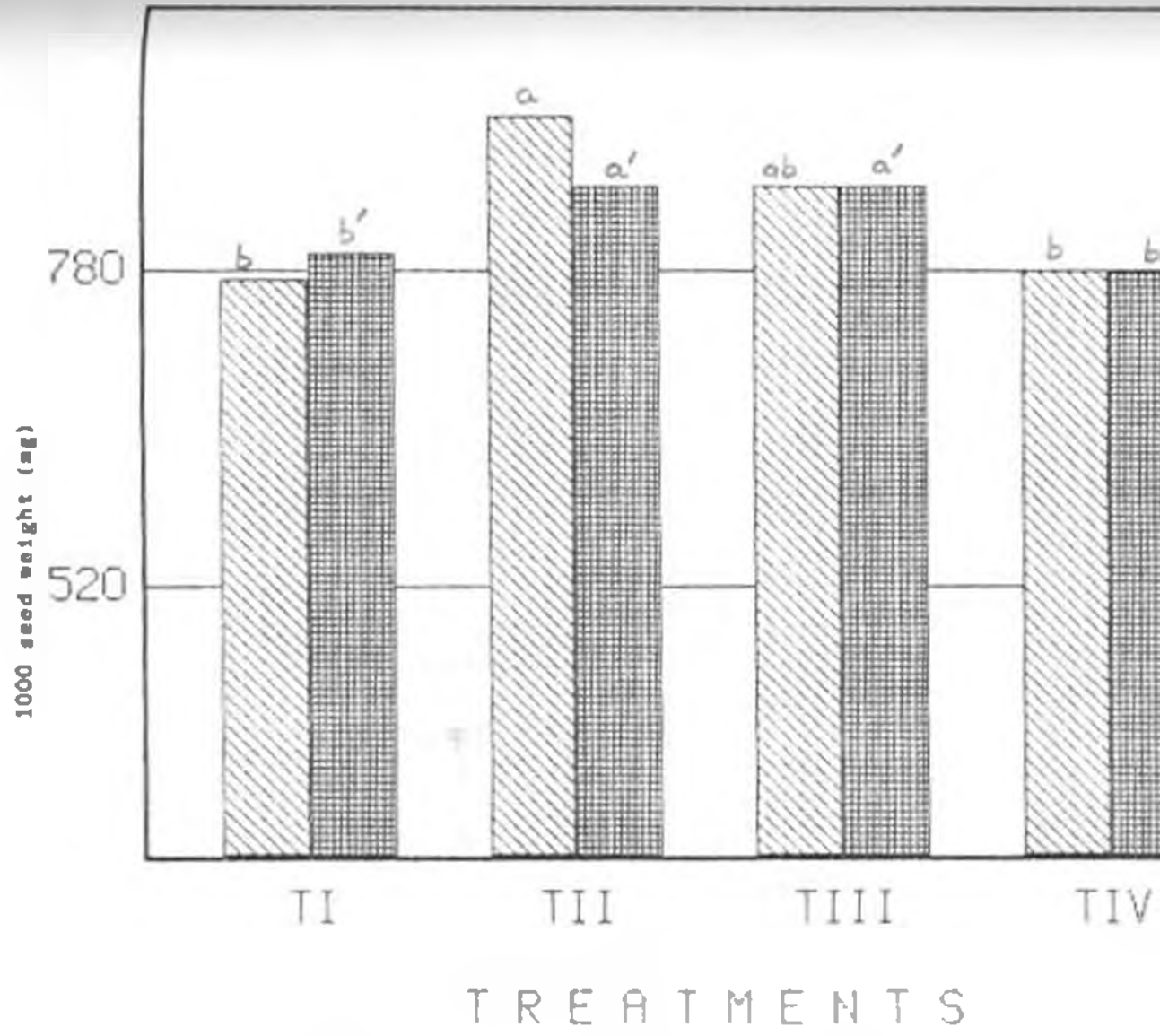

Figure 3: The influence of time of Nitrogen application on 100

4.2.4 The Influence of Time of N application on TPS Quality

4.2.4.1 1000 TPS Seed Weight.

Table 14: The effect of time of N application on 1000 seed mean weight (mg).

TREATMENT	SEASON I	SEASON II
TI	772.0 b	794.3 b
TII	906.4 a	850.0 a
TIII	849.3 ab	848.3 a
TIV	779.2 b	779.7 b
MEAN	826.7	818.1
LSD (p = 0.05)	101.6	50.4
C.V. (%)	6.2	3.1

The results obtained (Table 14), indicate that in both seasons, application of N at hilling up (TII) and at flowering (TIII), significantly increased the 1000 seed weight compared to the other treatments (Figure 3). Hence, N application at planting (TI), may have been too early, while application at berry development (TIV) may have been too late resulting in the lower 1000 seed weight obtained in both seasons.

In season I, TII produced TPS with the highest weight while TI, produced TPS of the lowest weight and therefore, quality.

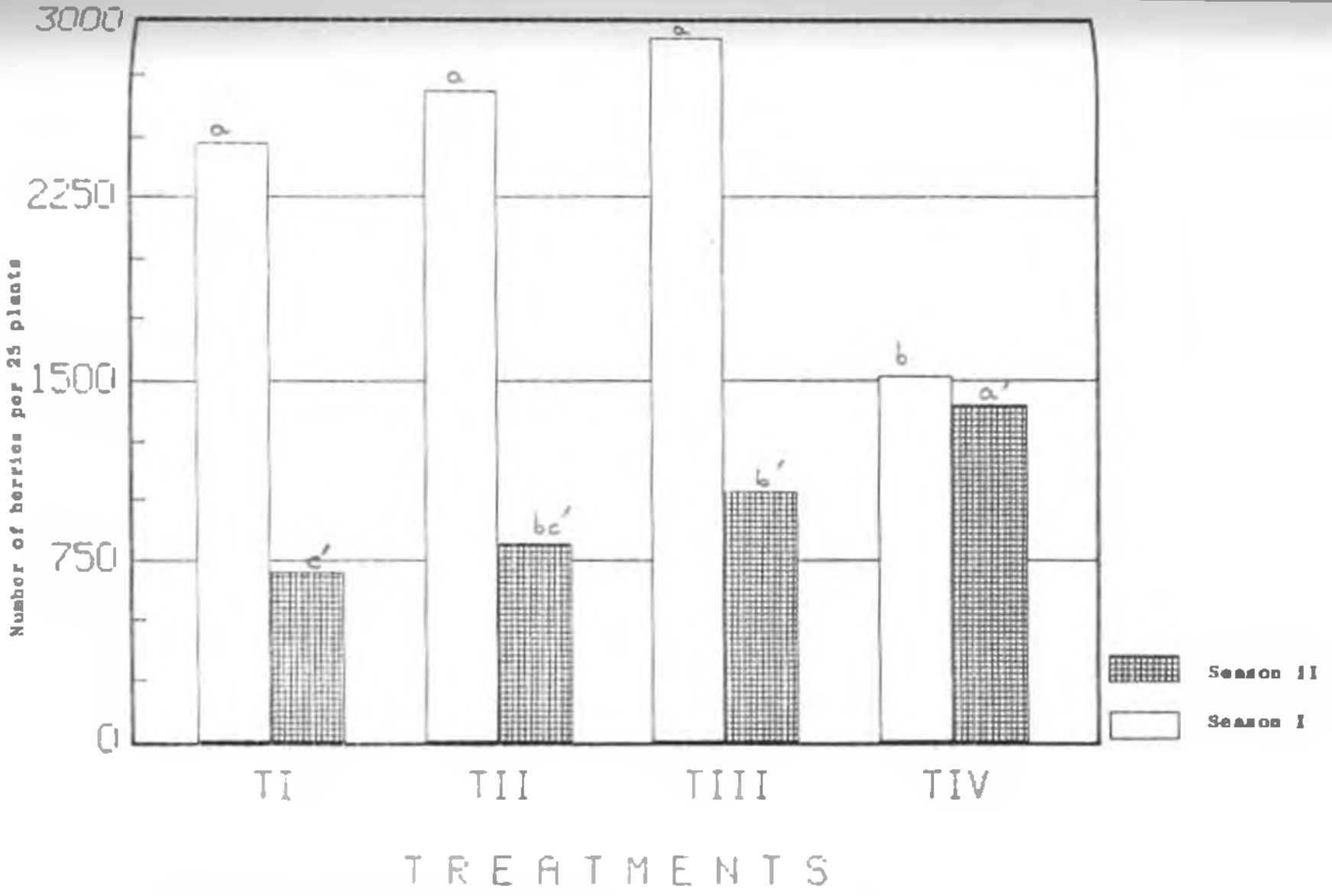

Figure 2: The influence of time of nitrogen application on berry production.

4.2.4.2. Large Seed Fraction (LSF)

In season I, application of N at late vegetative stage lead to Large seed formation. In season II, TIV resulted in the formation of TPS of a smaller size compared to to all other treatments. However the lower number of large sized seeds was not significant, except with that obtained through TIII

Table 15: The effect of time of N application on the Large Seed Fraction in 1000 seeds

TREATMENT	Number of large seeds SEASON I	SEASON II
TI	377.67 ab	257.00 ab
TII	330.00 b	258.00 ab
TIII	416.67 a	292.33 a
TIV	406.00 a	210.00 b
Mean	382.58	254 33
LSD	52.90	52.94
C.V (%)	8.16	10.42

In both seasons TIII, application of N at flowering proved useful in increasing the TPS size.

4.2.4.3. TPS germination quality.

Seedling vigour for season I seed only, was established 8 months after harvesting, when the seeds were expected to have broken dormancy naturally. 45 days were considered sufficient to allow all

viable TPS to germinate. Vigour was measured through germination tests in replicated trays. The results obtained are shown in Table 17.

Table 16: Percent germination 45 days after sowing.

Treatment	% seedling Emergence
TI	43.67 ab
TII	49.00 a
TIII	31.00 bc
TIV	19.00 c
Mean	35.67
LSD (P = 0.05)	17.12
C.V (%)	24.02

In general, seedling vigour decreased, the later the N fertilizer was applied. This, therefore would suggest that in order to assure production of vigorous seed, N fertilizer needs to be applied at hilling up and not later like at berry development.

4.2.5 The influence of time of N application on Tuber Yields.

The total tuber yield (Table 16), in both seasons, show that application of N at the onset of flowering (TIII), resulted in the highest yields.

In both seasons, the yields from TIII were significantly higher than those obtained from the traditional application of N at planting (TI). TIV gave the lowest yields in both seasons. This may be an indication that application of N at this stage may have been too late for it to be used in

increased tuber yields.

Table 17: Tuber yields in tons/ha of Kenya Dhamana

TREATMENT	Mean yields tons / ha SEASON I	SEASON II
TI	27.65 bc	19.17 c
TII	32.06 ab	31.00 a
TIII	34.99 a	35.27 a
TIV	23.61 c	27.40 b
MEAN	29.58	28.21
LSD = 0.05	6 493	7.49
C.V. (%)	10.99	13.3

EXPERIMENT III

4.3.0 The Effect of Fertilizer Combination Levels on TPS Production Parameters.

4.3.1 Variety and Phosphate Interaction in flowering

After data analysis, the results showed that the interaction of variety and phosphate fertilizer levels was significant (Appendix V).

Table 18: The effect of Variety, Phosphate fertilizer interaction on flowering in three commercial Varieties.

	Variety			
	Kenya Dhamana	**Anett**	**Kenya Baraka**	**P Mean**
Phosphate Level				
P_1	2126.0 a	174.4 c	246.9 c	849.1
P_2	2009.0 ab	182.1 c	220.9 c	804.0
P_3	1844 0 b	197.8 c	221.8 c	754.5
Variety Mean	1993.0	184.8	229.9	802.5
LSD (p = 0.05)		192.8		
CV (%)		= 29.5		

Means with the same letter(s) are not significantly different from one another across the table.

The results (Table 18) show that Kenya Dhamana had a significantly higher flower production, and that there were no differences in the flowering ability of Anett and Kenya Baraka

There was also no effect on flowering due to increasing Phosphate fertilizer levels in both Anett and Kenya Baraka Increasing levels resulted in a decrease in flower production in Kenya Dhamana , as indicated by a significantly lower value obtained for P_3 compared to that for the P_1 level.

4.3.2 Nitrogen fertilizer levels and pollen quality.

There were significant interaction effects of N levels and varieties on the pollen quality.

Table 19: The influence of variety and nitrogen fertilizer interaction on percent viable pollen cells.

	Variety			
	Kenya Dhamana	Anett	Kenya Baraka	N Level Mean
Nitrogen Level				
N_0	42.2 d	23.5 g	14.3 h	26.7
N_1	62.1 c	33.5 ef	23.4 g	39.7
N_2	72.0 b	40.1 de	28.5 fg	46.9
N_3	79.0 a	39.5 de	27.5 fg	48.7
Variety Mean	53.8	34.2	23.4	40.5
LSD (p = 0.05)		6.31		
CV (%)		16.59		

Means with the same letter(s) are not significantly different from one another across the table.

The results showed that Kenya Dhamana was superior to both Anett and Kenya Baraka. The interaction of the three varieties with N levels was significantly different. Thus, these results indicate that considerable differences exist in pollen viability between varieties.

The results (Table 19) show significant differences between the Nitrogen levels in the varieties. Kenya Dhamana had the highest mean percent viable pollen cells followed by Anett and Kenya Baraka. Pollen viability increased with increasing levels of N. Compared to Anett and Kenya Baraka at all N fertilizer rates, Dhamana showed significantly greater pollen viability at the N_1, N_2 and N_3 levels. These general trends are illustrated in figure 4.

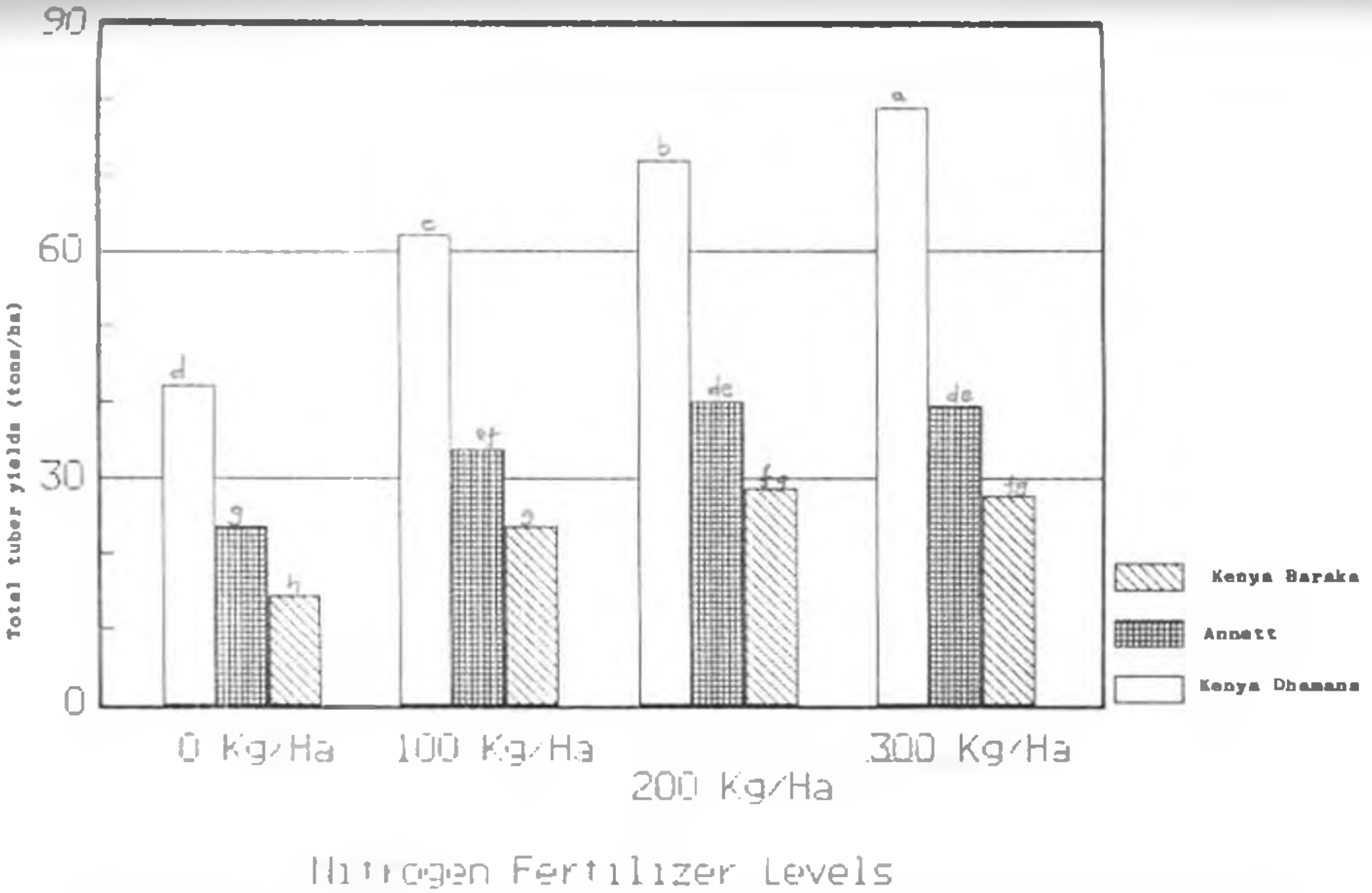

Figure 4: The influence of variety and Nitrogen fertilizer application on percent viable pollen cell.

All N levels in Kenya Dhamana were significantly different ($p = 0.05$). In Anett and Kenya Baraka, only the N_0 level gave significantly lower percent viable pollen cells in comparison to all other N levels (Table 19).

Kenya Dhamana was the most responsive variety to increasing levels of N fertilizer while Baraka was the least. The results also showed that lack of Nitrogen application in Kenya Dhamana resulted in pollen of comparable or better viability than all N applied treatments in both Kenya Baraka and Anett

4.3.3 Pollen viability and phosphate fertilizer levels.

After data analysis, the results showed that variety and phosphate level interaction was also significant (Appendix vi). The general trend was a slight decrease in pollen viabilty with each increasing level of the phosphate fertilizer (Table 20).

Table 20: The influence of variety and phosphate fertilizer interaction on mean percent pollen viability.

	Variety			
	Kenya Dhamana	**Anett**	**Kenya Baraka**	**P Mean**
Phosphate Level				
P_1	65.5 a	31.9 b	23.3 c	40.2
P_2	62.9 a	34.5 b	23.2 c	40.5
P_3	63.1 a	35.1 b	23.8 c	40.7
Variety Mean	63.8	34.1	24.4	40.5
LSD (p = 0.05)			5.47	
CV (%)			16.59	

Means with the same letter(s) are not significantly different from one another across the table.

All the three varieties showed significant differences (Table 20) from one another in their response in pollen viability. There were, however no differences in each variety , to increasing levels of the phosphate fertilizer. Pollen viability was observed to decrease slightly in the variety Kenya dhamana.

4.3.4 The Influence of Phosphate Fertilizer Levels on Berry Production.

After data analysis, only the phosphate and variety interactions were significant (Appendix vii). The results (Table 21) show that Kenya Dhamana was significantly superior in berry production compared to both Anett and Kenya Baraka.

Table 21: The influence of variety and Phosphate fertilizer interaction on Berry yields in numbers.

	Variety			
	Kenya Dhamana	**Anett**	**Kenya Baraka**	**P Mean**
Phosphate Level				
P_1	1358.0 a	121.4 b	143.4 b	540.9
P_2	1399.0 a	119.6 b	120.9 b	546.5
P_3	1238.7 a	119.3 b	118.0 b	492.0
Variety Mean	1331.9	120.1	127.4	526.5
LSD (p = 0.05)		108.8		
CV (%)		25.4		

Means with the same letter(s) are not significantly different from one another across the table.

The latter two were apparently not different from one another. There were also no differences between the phosphate fertilizer levels in each of the three commercial varieties. The trend was a general decrease in berry numbers with increasing levels of the phosphate fertilizer.

4.3.5 The Influence of Fertilizer Combination Levels on Tuber Yields.

The results did not show any significant difference in total tuber yields between the three varieties (Appendix viii). Only the nitrogen levels significantly influenced total yields.

Table 22: The influence of nitrogen fertilizer levels on total tuber yield (tons / ha)

Nitrogen Level	Mean yields (t/ha)
N_0	22.9 b
N_1	24.9 ab
N_2	26.4 ab
N_3	29.5 a
Mean	26.1
LSD (p = 0.05)	4.9
CV (%)	34.6

The results (table 22) show that only the factor Nitrogen had any significant influence on the varieties, in terms of total tuber yield production. Ther were no significant differences ($p = 0.05$) between all N fertilizer levels except between the highest level N_3, and the lowest level N_0.

CHAPTER FIVE

5.0 DISCUSSION

5.1.0 The effect of different fertilizer management strategies on flowering, pollen viability, and berry production.

According to Bodlaender (1963), flowering in the Potato (*Solanum tuberosum*, L.), is a function of the light period and temperatures. Flowering is accelerated by long day periods. Under short days, flower abortion is increased greatly. In both seasons when this research work was carried out, the daylength period, recorded by the meteorological station (Table 1 and 2), was about the same and typical of day neutral conditions (Table 1 and 2). The Daylength periods experienced may not be able to account for the large decrease in flower production in seasons II.

Day temperatures have been found to have little effect on flowering, but night temperatures around 12 ^{0}C have been found to be extremely unfavourable to flowering In warmer nights the potato crop flowers profusely; 18 ^{0}C night temperatures during the flowering months being optimal (Bodlaender, 1963). In season II when fewer flowers were formed, the mean night temperatures were lower than 12 ^{0}C, with the flowering month of July recording an average monthly low temperature of 11.6 ^{0}C (Table 2). This factor, coupled with a comparatively drier weather may account largely, for the depressed flower production (Malagamba, 1987) in all the three experiments, in season II. Anett and Kenya Dhamana were so severely affected by the seasonal temperature differences that flowering was reduced to negligible numbers, across all the fertilizer treatments in season II. From these results, Kabete may not be ideal site for TPS production through out the crop growing seasons

in the year. Physiological requirements at Kabete, particularly night temperature prevalent during the cold spells of June and July, are not conducive (Delouche, 1980).

In Experiment I, N application at planting and at the onset of flowering (TD) was the best treatment in both seasons Field observations showed this treatment, resulted in delayed crop senescence which may have led to increased flower production because of a longer vegetative phase.

The increase in flowering with split application of N confirms similar work (CIP, 1986) that indicated that additional split applications of N enhanced flowering, delayed plant maturity and lengthened period of berry development. Flower production was increased by 2.7 - 3.5 times, with up to six additional split applications of 40 kg N / ha.

The inference in Experiment I was that N applications at later stages other than at planting, were favourable to increased flowering. In season I , application of N at the onset of flowering was found to be the outstanding treatment by a margin of about 16 % compared to the control (TA). This favourable influence of late applied N on increased flowering may be due to the crop having a longer vegetative phase. However, in another trial (Pallais *et al*, 1985), applications of N at flowering were found to be disadvantageous to flower production. These differences may be attributed to the fact that in those trials, 80 and 40 Kg N / ha were used in three to six split applications. The trials at Kabete used much lower levels of 56.3 and 28.13 Kgs N / ha in only one or two split applications.

Genetic variability in TPS production is considerable and selection for this purpose has been found to give a rapid improvement (Malagamba, 1987). Of the three varieties used in experiment III, Kenya Dhamana showed outstanding performance. This may be attributable to its close relation with the Andigena clones of South America which flower profusely unlike many tuberosum varieties which normally produce few or no flowers (Howard, 1978). Anett and Kenya Baraka, are closely related to many of the tuberosum European cultivars, which underwent the process of selection for increased tuber production in the short days conditions, common in the Northern latitudes. The flowering data, pointed out that the type of TPS progenitors used in botanical seed production, is an extremely crucial factor. Kenya Dhamana showed a considerable inherent potential for producing comparatively larger quantities of flowers and hence TPS Appropriate, good flowering parental clones, need to be identified for economical routine TPS production. Northern Latitude adapted varieties and clones, may be season sensitive, under the tropical conditions in Kenya and therefore if these are to be used for TPS production, the appropriate planting dates need to be identified.

In all three varieties, it was noted that flowering decreased with increasing levels of the Phosphate fertilizer levels (Table 18). This decrease was significant in Kenya Dhamana. The results are in line with similar data (Pallais *et al*, 1985) where there was a marked decrease in flower production when P_2O_5 was increased from 0 to 200 Kg / ha. P_2O_5 is a basic plant nutrient required for increased tuber production. Hence in experiment III, increasing levels of the Phosphate fertilizer could have given tubers, which are a stronger sink, a greater capacity

to absorb most of the available Photosynthates, thus reducing flowering and consequently the production of the True Potato Seeds by the floral reproductive structures.

Reduced pollen viability may result from either high ambient temperatures and / or low nutrient supply to the mother plants (Malagamba, 1987), and this often leads to restricted berry and seed setting .

In Experiment I, supplemental applications of the Nitrogenous fertilizer at hilling up (TB) and at the onset of flowering (TC) were found to increase pollen viability significantly, especially in season II. Thus, the increased nutrient supply was a favourable factor (Malagamba, 1987) to increased pollen quality.

In Experiment II, significant treatment differences occurred only in season I, with applications of N at planting and at Hilling-up (TI and TII) being the best treatments. Application of N at hilling, in season II, was also the treatment with the highest per cent pollen viability. This may suggest that the N applied at this stage produced amenable nutritional environment in the crop, leading to increased pollen viability.

Data obtained in experiment III, showed that the variety Kenya Dhamana had pollen of a superior viability and thus may be likely to give more TPS, compared to Anett and Kenya Baraka. The general trend was increased pollen viability with each increasing N fertilizer level. The results compare well with those reported by Pallais *et al.* (1985), where an increase of N Fertilizer from 0 to 200 Kg / ha increased pollen viability by about 35 %. There was a marked but

significant downward trend in pollen viability (Table 20) with increasing levels of the phosphate fertilizer in Kenya Dhamana , and Anett. Kenya Baraka was the least responsive.

Berry numbers in Experiment I, increased appreciably when N was additionally applied at hilling-up and at the onset of flowering (TC). This may have been due to the nutrient supplied at this crop stage, resulting in reduced competition between the reproductive floral structures and the enlarging tubers (Dickson, 1980; CIP, 1977). Thus as a result of the increased flower production and pollen quality, there was a carry over effect which resulted in increased berry numbers. These results support other findings (CIP, 1986), which indicates that berry numbers increase with increasing levels of N.

In Experiment II, applications of N at the onset of flowering proved beneficial towards increased berry yields. The favourable nutrient situation may have reduced competition which in turn could have resulted in reduced flower abortion leading to increased berry production (Dickson, 1980; CIP, 1977).

Berry weights were found to increase with split N application. This may have been due to the extra nutrient supply, especially during the berry development stage. At this stage, tuberization is past and the bulking phase is almost at an end (Dickson, 1980). There is thus, less competition for the nutrient N. Application at this stage ensures that most of the N is channelled to berry development. The results obtained for TC, are supported by similar data (CIP, 1985) that indicated that berry weight did not vary significantly with increased partial applications of N.

Results in Experiment III, showed the superior ability of the closely related andigena variety Kenya Dhamana, in berry production. The tuberosum related Anett and Kenya Baraka had fewer berries due to the carry over effect in lower flower production and low pollen quality. The results of this experiment agree with those reported by Pallais *et al.* (1985), where increasing levels of P_2O_5 was found to result in decreased flowering and pollen quality and consequently low berry yields.

Experiment I showed that the split application of N resulted in increased berry weight. This increase may have been due to the N fertilizer applied, being made available at a period when it was required for pulp formation in berry development.

The time of N application was not found to affect the mean weight of berries formed. This would suggest that, berries may have a weaker sink strength compared to the other portions of the potato plant and especially the tubers. In another study (CIP, 1977) evidence for the presence and extent of nutrient competition within the crop was found. It was possible to increase tuber production by up to 60%, by pruning flowers and thus preventing berry production.

5.2.0 True Potato Seed quality as influenced by fertilizer management

Whereas no significant differences were shown by all the treatments in Experiment I in season II, the data showed an insignificant peak in the 1000 seed weight in treatment B where two additional applications of N (each 28.1 Kg/ ha) were used. Results from similar trials (CIP, 1986, Pallais, 1986) indicate that, where up to six times supplemental N

(40 kgs/ha each) was used, significant 100 seed weight was realized. In subsequent experiments, the highest TPS was found in plants receiving up to 600 kg N/ha. (Pallais, 1986). Supplimental application of N at hilling-up and at flowering, resulted in heavier seed as evidenced by the greater 1000 seed weight Heavier seeds were formed with two extra partial N fertilizer applications (TC) of 28.1 Kgs/ha each. The results though not significant, showed a pattern similar to previous work (Pallais *et al* 1985., CIP, 1986).

In Experiment II, applications of N at either hilling-up or at the onset of flowering, led to significant increases in the 1000 seed weight of the TPS. This may indicate that applications at these stages made N available for immidiate use during seed and cotyledon developement This in turn may have resulted in the increased seed weight.

Increased TPS size, a parameter related to seed weight, has been used for selecting high quality seed (Dayal *et al.*, 1984; CIP, 1983). In Experiment I, N application at hilling-up and at the onset of flowering resulted in increased seed size as shown by the LSF. This was more emphasized in season I than in II. The results compare well with those of previous work (CIP, 1986) where increased partial applications of N lead to significant increase in the large sized seeds.

The results of experiment II, show that, in season I, the large seed fraction (LSF), was significantly increased in TIII and TIV. Thus, the late N applied at the onset of flowering and at berry development, proved beneficial to the formation of large sized TPS. It may be that, at these stages, the N supplied increased nutrient availability and thus reduced competition, within the crop. Extra nutrient availability may have led to

seed enlargement with an accompanying increase in the LSF.

Application of the nitrogenous fertilizer as a split supplement (TB and TC in experiment I) and as the full dose (treatments III and IV) during the crops' active growth stage, result in N being utilized in increasing the cotyledon contents and hence led to the formation of large sized superior quality TPS (Upadhya *et al.*, 1985; Pallais *et al.*, 1985; CIP, 1986).

These results agree with those of previous studies which showed that the production of vigorous seed is generally associated with ideal growing conditions and the availability of high levels of nitrogen especially during the most active stage of growth of the crop. (Delouche, 1980; Garay, 1975; Hanington, 1971; Scoffer, 1974). Limiting conditions during berry development have been found to decrease the potential of the seed for field establishment (Pallais, 1987). This may account for the poor quality of seed under TIV. The N supply at this late stage, may have led to incomplete TPS development causing the observed low 1000 seeed weight Incomplete seed development, usually results in lack of uniform germination, loss of early seedling vigour and decreased seed performance under unfavourable conditions (Dickson, 1980; Perry, 1981).

TPS from treatment I had the highest emergence per cent count, although this was not significantly higher than that of TII. Thus, application at N at hilling-up, during this season, lead to the formation of TPS with a higher gemination rate.

The results on percent germination 45 days after sowing, show that the application of N during berry development (TIV), did not result in TPS with earlier and increased seed germination and establishment (Table 16). These results did not agree with the view (Pallais, 1987) that N application at seed development results in enhanced seedling establishment. Indeed the data obtained for both experiment I and II, show that when N was applied at hilling-up and at flowering, the TPS tended to be heavier and larger due probably to the improved nutrient status of the crop. This was less emphasized in TD in experiment I and TIV in experiment II. Decreased germination of True seeds resulting from treatments where N was applied at hilling-up and at flowering, probably suggests increased dormancy and not a low seed quality. Indeed, intensified seed dormancy may be attributed to dry matter accumulation in seeds, causing a thickening of the testa and thus imposing a physical restraint on germination (Gutterman, 1982).

Upadhya *et al.* (1985), and George, *et al.*(1980), found out that emergence and seedling vigour in the potato and the tomato, are related to the size and weight of the TPS.

5.3.0 Fertilizer management and tuber production

Total tuber yields in Experiment I were found to be significantly high when the nitrogenous fertilizer was applied at planting (TA) and more so if split applied at planting and at hilling up (TB). This may be an indication that N was made available when tuber initiation and bulking were to occur. Further split applications (TC) at the onset of flowering (TC) and at flowering and berry development (TD), resulted in yield reduction of about 20 % and 25 % in season I and about 23 % and 25 %

in season II, respectively. This may indicate that the N was applied too late when the stages of tuber initiation and bulking were past. The stage of rapid bulking usually coincides with flowering (CIP, 1977). In TC, the amount of split applied N may have been too little (28.1 Kg/ha) to increase tuber yields significantly. In TD, the second amount of N was comparatively low and could have been applied too late for it to be of use in increased tuber yields. In previous studies, split application of the nitrogenous fertilizer at half dose applied at planting in the furrow and a second dose applied 30 days after full emergence, was found to be beneficial especially in early maturing varieties. The results were more emphasized if the split application was as high as 80 kg N / ha (Sikka, 1982). However, according to Ngugi (1982), studies on the effect of further split applications have not shown marked advantage in total tuber yields From these results, the inference would be that the best yields are more likely to be realized, when N is applied not later than at flowering stage.

In experiment II, fertilizer application at hilling and onset of flowering resulted in high significant tuber yields. These were better than the control (TI) by about 16% and 27% in season I, and by over 60%, and 80% in season II, respectively. Overall, application of the nitrogenous fertilizer at the onset of flowering was the best treatment. This may have been due to a reduction in the competition for the macro-nutrient N. Competition becomes acute when tuberization coincides with flowering (Dickson, 1980; CIP, 1977).

In experiment III, only the main effect Nitrogen fertilizer levels, significantly influenced total tuber yields. Level N_0 was as good as N_1 and N_2. Thus the large expected difference between N_0 (0kg/ha) and N_1 and N_2 were not observed. This may have been due to the presence of substantial amount of N in the soil at planting (appendix II).

Studies (Maclean, 1983) on N fertilizer levels of between 135 - 170 Kg N ha_{-1} showed that there was a 50% increase in yield the higher the N levels. However, crop recovery of N applied seldom exceeds 50% efficiency. This may be an added reason why there were no significant differences in tuber yields between levels N_1 to N_3(100kg N/ha to 300 kg N/ha)

CHAPTER SIX.

6.0 CONCLUSIONS

The results obtained, although not entirely conclusive, point out that at the mid altitude conditions at Kabete, it was possible to produce sufficient quantities of quality True Potato seeds by managing the Nitrogen fertilizer application regimes, time and also the levels of the accompanying Phosphate fertilizer. From the studies conducted during the project, the following broad conclusions were reached:

1. Split application of N increased flowering. This was especially marked, if N was applied between 30 and 50 days after planting. Later split application threw the crop into a prolonged vegetative phase. Flowering increased, but this resulted in significantly depressed tuber yields.

2. Split application of N 112.5 kg / ha at the rates of half at planting a half at hilling-up and quarter 30 days later at hilling up and a quarter 50 days later at the onset of flowering, resulted in increased flowering , pollen viability and berry yields while at the same time increasing total tuber yields.

3. Application of N as single rate of 112.5 kg / ha at the hilling-up stage and flowering stages was found to significantly increase flowering, pollen viability and total berry yields. Tuber yields and 1000 swt were also increased significantly by this treatments.

4. The number of large sized seeds were significantly increased by single N fertilizer application around flowering.

5. Late applied N either as split (TD) or as single dose tended to result in more heavier seed with a comparatively larger size. However, these seeds showed poor germination which may be an indicator of deeper dormancy.

6. When N fertilizer was applied not later than the flowering stage, total tuber yields were significantly higher.

7. European selected varieties like Kenya Baraka and Anett may not be suitable for TPS production, especially in the mid altitude sites with near equatorial day neutral conditions such as in Kabete, because of their inherently lower flowering ability.

8. A decrease in flowering was noted with increasing levels of the phosphate fertilizer. This has implications on TPS production since high levels of the Phosphate fertilizer needed to assure reasonable tuber yields would result in decreased flowering and pollen viability which would result in restricted berry production and TPS quantity.

9. Physiological requirements such as night temperatures and photoperiod may limit the choice of Kabete as a good site for TPS Production.

CHAPTER SEVEN

7.0 RECOMMENDATIONS FOR FURTHER RESEARCH

More research should be carried out to establish varieties and clones that are adapted to mid altitude and highland areas in Kenya and that flower abundantly under the normal crop growing seasons common to the farmers.

Studies (Pallais *et al*, 1985) have shown that Potassium K^+, is an important nutrient in TPS production. Although many of the soils in Kenya are sufficient in K^+, the interaction of N, P and K is not known. Studies need to be made to establish whether the K^+ in the soil in Kenya, would be in sufficient quantities both to produce and sustain production of large quantities of TPS without jeorpadizing tuber production.

Organised and coordinated research should be carried out in areas that have the potential for the use of TPS technology so as to study the effect of enviroment on TPS production and the possible inbreeding depression associated with the utilization of the cheaper open pollinated seed..

Futher reaserch should be carried out to study the production needs of both hybrid and apomictic seeds which, although a bit more expensive, could be used in seedling tuber production schemes to assist resource poor farmers.

Seedling uniformity and vigour are important aspects that need to be studied in order to increase farmer adoption of TPS technology. TPS uniformity in germination and vigour could be increased through various

methods such as the use of potassium salts in seed priming and use of the charcoal instead of Gibberelic Acid (GA_3) in breaking TPS dormancy. Gametopytic screening techniques could be investigated in order to establish methods of increasing seedling uniformity and vigour.

CHAPTER EIGHT

8.0. LITERATURE CITED

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APPENDICES

Appendix I: Weather conditions at the University of Nairobi meteorological station Kabete field station from September 1987 to September 1988.

Period	Temperature (°C) Mean (max)	Mean (min)	Mean 24 hr	Rainfall (mm)	Rainy days
Sep 1987	24.0	12.1	18.1	17.4	3
Oct 1987	25.8	13.2	19.5	5.7	3
Nov 1987	23.6	14.0	18.8	182.1	16
Dec 1987	23.8	13 4	18.6	25.2	3
Jan 1988	25.1	13.6	19.4	96 2	8
Feb 1988	25.8	13.4	19.6	10.5	3
Mar 1988	25.8	14.6	20.2	172.0	15
Apr 1988	23.5	14.6	19.1	519.4	24
May 1988	24.1	13.9	19.0	235.9	15
June 1988	21.3	12 6	17.0	27.7	10
July 1988	25.2	11.6	18 4	18.9	5
Aug 1988	20.9	11.9	16.4	46.9	8
Sep 1988	22.6	13.5	18.1	27.1	11

Appendix II: Results of soil chemical analysis of the experimental fields.

	Season I	Season II	Recommended levels
pH in H_2O	6.50	6.30	-
pH in $CaCl_2$	5.90	5.40	-
N (%)	0.27	0.26	> 0.2
C (%)	2.59	2.70	> 0.3
K (m.e %)	1.80	0.70	0.2-1.5
Na (m.e %)	1.14	0.28	0-2.0
Ca (m.e %)	14.5	21.60	2.0-15.0
Mg (m.e. %)	3.0	5.8	1.0-3.0
CEC (m.e/100g)	14.0	28.19	
P (ppm)	4.8	0.13	20-80

Appendix III a: Anova model table for Experiment I & II.

K value	Source	Degrees of freedom
1	Replication	r-1
2	Factor A	a-1
-3	Error	(r-1)(a-1)

Appendix III b: Anova Model Table For Experiment III.

K Value	Source	Degrees of freedom
1	Replication	r-1
2	Factor A	a-1
4	Factor B	b-1
6	AB	(a-1)(b-1)
8	Factor C	c-1
10	AC	(a-1)(c-1)
12	BC	(b-1)(c-1)
14	ABC	(a-1)(b-1)(c-1)
-15	Error	(r-1)(abc-1)

Appendix IV: Experiment III: Treatments used in the experiment during season I and season II.

Factor V: Varieties

V_1 = Kenya dhamana (CIP 800224)
V_2 = Anett
V_3 = Kenya Baraka

Factor N: Nitrogen levels

N_1 = O Kg N/ha
N_2 = 100 Kg N/ha
N_3 = 200 Kg N/ha
N_4 = 300 Kg N/ha

Factor P: Phosphate levels.

P_1 = 60 Kg P_2O_5 Kg/ha
P_2 = 120 Kg P_2O_5 Kg/ha
P_3 = 180 Kg P_2O_5 Kg/ha

Factor N & P: Combinations of N and P205 levels.

1. N_0P_1	5. N_0P_1	9. N_0P_3
2. N_1P_1	6. N_1P_1	10. N_1P_3
3. N_2P_1	7. N_2P_1	11. N_2P_3
4 N_3P_1	8. N_3P_1	12. N_3P_3

Factor V & N: Variety and Nitrogen Level Combinations.

1. V_1N_0	4. V_1N_1	7. V_1N_2	10.$V_1N_3P_1$
2. V_2N_0	5. V_2N_1	8. V_2N_2	11.$V_2N_3P_1$
3. V_3N_0	6. V_3N_1	9. V_3N_2	12.$V_3N_3P_1$

Factor V & P: Variety and P_2O_5 Combinations.

1. V_1P_1	4 V_1P_2	7.V_1P_3
2. V_2P_1	5. V_2P_2	8.V_2P_3
3. V_3P_1	6. V_3P_2	9.V_3P_3

Factor V & N & P: Variety Combinations with fertilizer levels.

1. $V_1N_0P_1$	5. $V_1N_0P_2$	9. $V_1N_0P_3$
2. $V_1N_1P_1$	6. $V_1N_1P_2$	10. $V_1N_1P_3$
3. $V_1N_2P_1$	7. $V_1N_2P_2$	11. $V_1N_2P_3$
4 $V_1N_3P_1$	8. $V_1N_3P_2$	12. $V_1N_3P_3$

13. $V_2N_0P_1$	17. $V_2N_0P_2$	21. $V_2N_0P_3$
14. $V_2N_1P_1$	18. $V_2N_1P_2$	22. $V_2N_1P_3$
15. $V_2N_2P_1$	19. $V_2N_2P_2$	23. $V_2N_2P_3$
16. $V_2N_3P_1$	20. $V_2N_3P_2$	24. $V_2N_3P_3$
25. $V_3N_0P_1$	29. $V_3N_0P_2$	33. $V_3N_0P_3$
26. $V_3N_1P_1$	30. $V_3N_1P_2$	34 $V_3N_1P_3$
27. $V_3N_2P_1$	31. $V_3N_2P_2$	35. $V_3N_2P_3$
28. $V_3N_3P_1$	32. $V_3N_3P_2$	36. $V_3N_3P_3$

Appendix V: ANOVA table for Flower Production in Experiment III

K Value		Degrees of freedom	Sums of Squares	Mean Squares	F Value
1	Reps	2	413762.7	206881.4	3.69
2	Factor V	3	1956651.6	652217.19	11.6 *
4	Factor N	2	160944.6	80472.3	1.44
6	V * N	6	613351.9	102225.32	1.8
8	Factor P	2	76532212.5	38266106.23	682.73 *
10	V * P	6	2594882.9	432480.49	7.72 *
12	N * P	4	329090.6	82272.65	1.47
14	V * N * P	12	1407167.1	117263.926	2.09
-15	Error	70	3923390.6	56048.437	
	Total	107	87931454.5		

Coefficient of Variation: 29.5 %

Appendix VI: ANOVA table for Pollen Viability in Experiment III

K Value	Source	Degrees of freedom	Sums of Squares	Mean Squares	F Value
1	Reps	2	6.4	3.22	0.07
2	Factor V	3	8065.0	2688.3	59.67 *
4	Factor N	2	4.2	2.09	0.046
6	V * N	6	1831.3	305.2	6.77 *
8	Factor P	2	31581.5	15790.7	350.5 *
10	V * P	6	1574.4	262.4	5.82 *
12	N * P	4	139.1	34.76	0.77
14	V * N * P	12	1034.7	86.22	1.91
-15	Error	70	3153.7	45.05	
Total		107	87931454.5		

Coefficient of Variation: 16.59 %

Appendix VII: ANOVA table for Berry Production in Experiment III

K Value		Degrees of freedom	Sums of Squares	Mean Squares	F Value
1	Reps	2	95712.1	47856.03	2.68
2	Factor V	3	768326.0	256108.65	14.35 *
4	Factor N	2	64916.1	32458.03	1.82
6	V * N	6	90875.87	15145.98	0.85
8	Factor P	2	35035392.4	17517696.19	981.68 *
10	V * P	6	1353294.9	225549.15	12.64 *
12	N * P	4	106429.7	26607.43	1.49
14	V * N * P	12	234192.1	19516.01	1.09
-15	Error	7	1249123.9	17844.63	
	Total	107	47390.3		

Coefficient of Variation : 25.37 %

Appendix VIII: ANOVA table for total yields in experiment III.

K Value	Source	Degrees of freedom	Sums of Squares	Mean Value	F Prob
1	Reps	2	513.0	256.5	3.19
2	Factor V	3	631.2	210.4	2.62
4	Factor N	2	578.8	289.4	3.60 *
6	V * N	6	253.9	42.32	0.53
8	Factor P	2	176.0	87.97	1.09
10	V * P	6	579.8	96.63	1.20
12	N * P	4	413.6	103.41	1.29
14	V * N * P	12	338.0	28.16	0.35
-15	Error	69	5544.2	80.35	
	Total	106	90.2 8.4		

Cofficient of Variation: 34.61 %