COMPARISON OF VEGETATIVE GROWTH AND TUBER YIELD OF POTATO *(Solanumtuberosum L.)* FROM SEEDLING TUBERS DERIVED FROM TRUE POTATO SEED (TPS) WITH THOSE FROM CONVENTIONAL SEED TUBERS OF PARENTAL CLONES

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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.

22nd-10-98

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This thesis has been submitted for examination with my approval as University supervisor.

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DEDICATION

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ABSTRACT

A study to show potato *(Solanum tuberosum)* tuber yield from seedling tubers derived from true potato seeds (TPS) as planting material was carried out between March 1994 and January 1995 at the Kabete Field Station University of Nairobi. Seedling tubers of hybrids and open-pollinated progenies were compared with the conventional seed tubers of the parental lines and local standard clones on the basis of vegetative growth, total and marketable tuber yields and tuber characteristics (size, shape and colour). A split plot design experiment with three replicates was used in the study.

Vigour of plants from local standard clones was higher at the early stage of growth, whereas plants from the advanced imported varieties had higher vigour in the later stages of growth.

Seed tuber size, sprout uniformity and seasonal changes had significant effects on the number of main stems per hill. Plants derived from hybrid seedling and conventional seed tubers showed significantly higher number than the rest.

Tuber yields from hybrid seedling tubers were significantly (P=O.O5) higher than those from the open pollinated seedling tubers and conventional seed tubers. Marketable yield indicated that conventional seed tubers outyielded seedling tubers. However, local standard clones gave significantly (P=0.05) lower yield than seedling tubers despite their tuber uniformity.

Results of tuber characteristics showed that there was segregation for skin colour, size and shape of the tubers from seedling tubers. The uniformity of the tubers from conventional seed tubers was better than that from seedling tubers. Tuber uniformity from the hybrids tended to be better than that from open pollinated progenies.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Nutritive Value of Potato Tubers

The cultivated potato (*Solanum tuberosum L.*), often referred to as Irish potato, has become an important food and cash crop in Kenya and other developing countries. Its ability to grow in the high altitude (>2000 m) areas where maize (major food crop in Kenya) does not do well and its high nutritive value make it an important food crop in Kenya.

In developing countries, where diets are often unbalanced, addition of potatoes to the diets is an improvement. The balance between proteins and calories in a potato is excellent. Potentially more nutritive value (calories and proteins) can be produced per unit of time, land and water with potato than with any other major food crop (Sawyer, 1978). As a starchy, energy rich food, potato is ranked fourth after wheat, rice and maize in the world (Ngugi, 1982). In terms of calory production per unit of land, it is second only to sugarcane Similarly, it is second only to soybean in vegetable protein production per unit area. Furthermore, its use as a complement to maize is on the increase in developing countries (Asia and Africa) as a whole, and has a bright future (CIP, 1979; Horton, 1987). This means that expansion of potato production to meet the ever mounting local food demand is inevitable.

1.2 Potato Production in Kenya

Kenyan Government is doing as much as it can to streamline all that goes into production of potato as was portrayed in the 1989-1993 Development plan (GOK, 1989). During the plan period, the

Government was to take steps to ensure that the area under potato seed production was increased not only for the major crops such as maize and wheat but also for barley, grasses, horticultural crops, beans and potatoes.

A survey conducted in 1988 (GOK, 1989) showed that demand for potato was 760,000 tonnes while production was 821000 tonnes showing 8.03% excess in production. Demand has since increased by 21.7%. Therefore, production is to be increased in order to feed the fast growing population.

As a result of the increasing importance of the agricultural sector in Kenya, the value of potatoes is also increasing. In 1975, potatoes accounted for 2% of the gross value marketed agricultural production which was about K£ 2.5 million (GOK. 1989). In 1981, potatoes accounted for only 1.1% of the gross value of marketed agricultural production which was about K£ 3.5 million (Anon 1993). This shows an increase in the value and hectarage under potatoes. On the 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's crop (GOK, 1989). Utilization of the crop however, may vary from place to place (Table 1). Estimates indicate that 3%, approximately 15000 people, of the total agricultural labour force, is employed in potato production (Durr and Lorenzl, 1980; Ngugi, 1982).

Table 1: Utilization of potato crop as percentage of total production in Kenya (Durr and Lorenzl, 1980)

Area	% Sale	% Home Consumption	% Seed
Molo	39	36	25
OlKalou	32	41	25
Kinongop	27	48	25
Kiambu	14	54	32
Nyeri/Muranga	18	54	27
Meru	60	19	21

1.2.1 Constraints of potato production in Kenya

Although potatoes have been grown in Kenya for well over 70 years on a commercial basis, the crop has never been cleared of its wide range of major problems. Pest control has continued to be a major drawback. Similarly, the provision of clean seed in adequate quantities at the right time has not been satisfactory. These factors have contributed to poor crops being grown every year (Waithaka, 1976).

The yield per hectare varies considerably from one area to another while the national average yield is about 8-9 t/ha (Anon 1994). This is far below the average yields of 88-100 t/ha in developed potato growing countries (Iritani *et al*, 1983). Maximum potential in the tropics can be 65 t/ha if management of water, pests, fertilizers, etc. are well looked after (Burton, 1980).

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 yield (CIP, 1977; Durr and Lorenzl, 1980; Ngugi

1982). Certified seed for potato ware production is scarce in Kenya and the few farmers who manage to get it find the high cost prohibitive. It is often unavailable in adequate amount and at the right place and time. Hence, most farmers use their own "seeds" or buy from their neighbours or nearby markets (Haugerund, 1984; Anon, 1993). These seed tubers are usually surpluses from previous seasons and are in most cases, physiologicaly degenerated in value as planting material due to a build up of viral, bacterial and fungal pathogens, including pests like the potato tubermoth (*Phthorimoea perculella,* Zellar).

Certified "seed" production is both expensive and time consuming. The cost of seed production and the time needed are two of the most limiting factors to potato production in Kenya. Durr and Lorenzl (1980) estimated the cost of certified seed per hectare to be 30-45% of total production cost. 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, the certified seed tubers, is still very expensive to most Kenyan farmers. These problems are not unique to Kenya. Indeed availability of good low cost seed has been one of the major limiting factors for the use of the potato as food in many developing countries. Most tropical countries are presently relying on costly yearly importations of basic seed from developed countries as base for potato production. 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 this may have led to farmers dropping out a number of previously high yielding varieties that deteriorated over the years of growing. 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 and Kimani, 1984).

Most cultivated potatoes are extremely heterozygous. Offsprings or progeny resulting from a cross of two parents even within the same varieties are usually highly varied compared with clones in terms of uniformity. Studies have indicated, however, that uniformity is important not only with regard to phenotype in the field, but also with regard to maturity, pest and disease resistance and cooking quality. Due to this, with few exceptions (India and China), worlds potato growers use tubers (CIP, 1977).

Therefore, in relation to the use of clonal seed tubers, true potato seeds (TPS) for seed tuber production may have advantages. Work done in the Republic of China, shows that the use of TPS for seed potato production would be a feasible and economical method for controlling virus disease (Malagamba, 1983). This is because TPS do not transmit most viral diseases.

Additionally, the use of TPS eliminates the need for large storage requirements for seed tubers and costly transport. For example, 200 grams of TPS are needed to plant 1 ha of land and no more than 80 potato plants could produce this amount of seed (Burton, 1980). Moreover, TPS stores readily at room temperature for several years with little loss of viability. CIP (1977) reported that 70% germination can be expected after ten years of storage of TPS at room temperature with little loss in vigour.

There are two alternative methods by which TPS can be used to raise potatoes (Bedi *et al.*, 1979): One could use seedling transplants or seedling tubers. Use of TPS for seed tuber production is a promising alternative to avail cheaper pathogen free seeds to the resource poor farmers in many developing countries. The initial seedling tubers derived from TPS have a higher sanitary status than those from virus degenerated tubers that many farmers use. TPS would allow the expansion of potato cultivation into farming areas that previously were unable to produce potatoes, because of the lack of good quality potato seed, or into warm humid tropical areas where potato tuber seed cannot be produced or stored.

Based on the constraints of potato production in Kenya, the objectives of this study were therefore to determine the differences between:

1) vegetative growth and other important tuber charateristics of plants from seedling tubers derived from TPS progenies and conventional seed tubers.
2) the total and marketable potato tuber yields from the various seed sources.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 The Potato Plant Botanical Aspects

The potato is an annual, herbaceous dicotyledonous plant belonging to the family Solanaceae (which includes crop plants such as tobacco, tomato, eggplant and pepper) and genus *Solanum*. The genus *Solanum* contains 2000 species but only 150 are tuber-bearing close relatives of the cultivated potatoes. Howard (1970) stated that cultivated potatoes may be diploid, triploid, tetraploid and pentaploid with somatic chromosomic numbers (2n) of 24, 36, 48 and 60, respectively. The most important potato cultivars are tetraploids. The Russian botanists in the 1925-1928 period recognized two main species of cultivated tetraploids, *Solanum tuberosum* and *Solanum andigena* Juz et Buk (Horton, 1987). However, most workers now only recognize a single species called *Solanum tuberosum* and two subspecies, *tuberosum* and *andigena* (Howard, 1970).

Stolons and tubers are the most important tissue components of a potato plant. A potato stolon may be defined as an underground stem, commonly a lateral stem, showing negligible leaf expansion, which grows diageotropically and become aerial if they reach the soil surface (Booth, 1963). Stolons normally appear within seven to ten days after emergence in cultivated species having similar functions as stems. Stolon length varies from less than 2.5 to 45 cm or more (Smith, 1977).

The potato tuber is an enlarged portion of an underground stem adapted to storage of photosynthates and reproduction of the plant (Horton, 1987). The tubers, which originate from the tips of called stolons, contain all the characteristics of normal stem, including dormant buds (the "eye") formed at the base of a leaf (rudimentary in this case) with detectable leaf scars (the "eyebrows"). Lenticels or stempores through which air penetrates to the stem interior are found on tubers.

Under suitable environmental conditions, a potato plant can produce flowers and set berries. Inside the berries of the potato plant seeds may develop. These seeds can be extracted from a mature berry and air dried for use in a true potato seed planting programme.

2.2 Factors Affecting Potato Vegetative Growth and Yield.

Inorder for the farmer to obtain optimum growth (vegetative growth) and high yields from a potato crop, many factors are involved. These include use of certified seed tubers of locally adapted varieties, good nutrient supply, use of appropriate plant population, good disease and weed control, and also use of the right size of seed tubers (Ballestrem and Holler, 1977).

The health of seed tubers is an important factor that influences the potential yield of a crop. Several diseases and pests are transmitted by tubers resulting in degeneration during their subsequent multiplication (CIP, 1982). Disease may reduce the potato crop in four ways: (a) by causing the premature death of foliage (b) by stunting plants (c) by reducing plants photosynthetic efficiency by causing break down in the transport of photosynthates to the tubers, or (d) by causing tubers to rot before they are lifted (Hooker, 1981).

Blight (caused by *Phytophthora infestans*) is, on a world wide basis, probably the most important and destructive potato disease. The fungus is parasitic on solanaceous plants during the growing season, which in the high land tropics may mean the whole year (Berkely, 1846). Elsewhere it overwinters mainly as mycelium in diseased tubers (seed ground keepers or culls) though there has been a report of the fungus surviving for several years in soil containing infected plant remains (Yurova, 1960). These diseased tubers produce diseased sprouts, from the lesions on which the disease is spread when conditions become favourable for sporulation during the next growing season.

Large seed tubers have more reserve material and this can result in higher relative growth rates than in small seed tubers during the pre-emergence and early post-emergence periods. Large seed tubers give rise to larger plants than do small seed tubers in the establishment phase, though the difference in plant size is relatively smaller than in seed size (Taha, 1966). After establishment, seed tuber size has no direct effect on the relative growth rate and behaviour of plants from large or small seed tubers depends on the intensity of inter-plant competition to which they are subjected; if low as with widely spaced plants, the initial advantage of plants from large seed tubers may be maintained for longer (Black, 1957). Under more intense conditions of competition, the earlier onset of inter-plant competition in large seed tuber plants causes a decrease in relative growth rate compared to small seed tuber plants.

During the growth of the crop, prolonged or insufficient rains reduce vegetative growth, hence potato tuber yields (Durr and Lorenzl, 1980). Proper husbandry practices such as proper spacing, use of fertilizers and control of pests has showed direct effect on vegetative growth (Holler, 1973).

Addition of manure improves soil structure and aeration which permit free movement of water, air and roots. Manures have been known to raise elements required for plant growth (Durr and Lorenzl, 1980). The amount of chemical fertilizers to be applied to the seed bed or field depends on the type and the fertility level of the soil. Based on several experiments Wiersema (1984) reported that an optimum regime of fertilizer application is to apply the fertilizer at sowing and after plant establishment.

The yield produced by the potato is dependent upon two things: the number of tubers produced and the amount and composition of the dry matter the tubers contain. Both number of tubers and dry matter production depend upon a complex of interacting and variable factors, such as: the cultivar and the characteristics of its foliage; sunlight, photoperiod, temperature and rainfall; type of soil and manuring (Wiersema, 1984).

Photochemically combined carbon is a major and essential constituent of the compounds which provide some 95% of the dry matter of the potato tuber, and photosynthesis is the most important determinant of yield (Burton, 1989). Photosynthates are also used by the plant to provide the energy and the structural material for foliage growth. There is thus a partial conflict of interest, as it were, between foliage growth and tuber growth, because both draw upon the same raw materials. Partial, because the gross production of these raw materials is to some extent directly related to the size of the foliage producing them, and thus a high rate of tuber growth can only be achieved if the foliage is sufficiently large. Continued foliage growth after tuber initiation clearly reduces the supply of carbohydrates available for tuber growth and may thus adversely affect the yield (Iritani *et al*, 1983).

The reasons for a yield being below the optimal include, a) a less than complete interception of light, b) failure to make full use of the intercepted light, c) translocation from foliage to tubers being obstructed and hence ineffective, d) environmental and other conditions not favouring photosynthesis and e) the functional life of the foliage being not as long as possible (Hooker, 1981).

2.3 Problems in Potato Production

The demand for certified seed in Kenya per year is estimated at between 150,000 and 200,000 tonnes (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 (1982) and Haugerund and Kimani (1984), the reasons for the inadequacy of seed materials are:

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

b)Certified seed production zones (above 2400m) are far from potato growing areas. For example, Molo, a good potato seed area is 500km away from some 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 farmers can afford.

These problems are not unique to Kenya. Most tropical countries are presently relying on costly yearly importations of basic seed from developed countries as the base for potato production. Seed costs are from 50 to 70% of the total production costs under such conditions (Swaminathan and Sawyer, 1983).

2.4 Methods Used to Propagate Potatoes

The potato crop can be reproduced sexually by planting true botanical seeds, commonly referred to as true potato seeds (TPS) or asexually by using tubers (CIP, 1984b).

2.4.1 Vegetative propagation method

2.4.1.1 Whole tubers

With few exceptions (India and China) the world's potato growers plant tubers. A variety with desirable qualities can be retained in cultivation indefinitely, provided its health can be maintained (Burton, 1980). If a cultivar becomes infected with a systemic disease, such as a virus, its tubers too are infected. If these tubers are used as a means of propagation, the disease is carried on into the next and succeeding generations.

Clean healthy seed tubers may be produced from basic seed, originated from breeders material which inevitably increases the cost of healthy seed tubers. 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 (Hooker, 1981, Bokx, 1972). Yurova (1960) reported that fungus survived for several years in soil containing infected plant remains. The diseased tubers (plant remains) produce diseased sprouts, from the lesions on which the disease is spread when conditions become favourable for sporulation during the next growing season (Murphy and McKay, 1927).

2.4.1.2 Sliced tubers (the use of cut sets)

It is customary in some localities to cut tubers into two or more pieces for use as seed, thus increasing the area which can be planted with a given weight of seed tubers. Clearly such a procedure may influence yield in several ways - for example, the number of 'misses' may be increased because of excessive drying out of the cut sets, if these are stored before planting, or because of rotting due to the penetration of the cut surfaces by disease organisms (Werner, 1954). Disease organisms may also be transferred from diseased to healthy tubers by the cutting implement (Hooker, 1981, Bokx, 1972). A slightly higher multiplication rate may be achieved by planting sliced pieces of whole tuber, however the cut piece may also require treatment with fungicides before planting. This represents an appreciable increase in the cost of production of seed tubers (Cole and Wright, 1967).

Werner (1954) showed that in general the percentage emergence is inversely related to the degree of subdivision of the cut tubers, irrespective of the size of the seed-pieces over the range of 16-58g. Reduction in percentage emergence does not necessarily mean a reduction in yield under normal cultural conditions, because plants adjacent to the 'misses' have less competition and yield more heavily. In the case of cut sets, however, the effects of reduced emergence may be aggravated by a reduced number of stems per hill, with a consequent reduction in total yield (Werner, 1954). Comparing cut and uncut sets, weighing about 70 g, of cultivar Majestic, Brandreth

(1935) found that the uncut sets significantly outyielded the cut sets in both total yield (41.2 and 38.5 t/ha) and yield of ware potatoe over 45 mm (33.4 and 30.4 t/ha).

2.4.1.3 Plant cuttings

Stem cuttings may be rooted and transferred 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 (CIP, 1977). It has been shown that eight plants derived from one tuber could produce 5000 rooted cuttings in six months by cloning and recloning (Bryan *et al.*, 1981).

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 0.5kg 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 sprout growth: cut units up to 1:7600.

Techniques such as the use of tiny seedling tubers produced from leaf-bud cuttings have been used to produce upto 0.5kg of tubers per seedling tuber in field trials (Bryan, 1985). Other techniques such as the use of stolon cuttings, “making” small tubers from mother plants and variations of these methods have been subject of many studies (CIP, 1984a).

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 of infrastructural needs. For this rapid propagation, techniques are often lacking, especially in poor developing countries. Rapid propagation is therefore an extremely expensive alternative, although a large quantity of clean. healthy seed stock can be built up in a relatively short time.

2.4.2 Sexual propagation

2.4.2.1 True potato seeds (TPS)

In the past decade or so a method that had albeit been used only on a small scale by breeders has gained prominence and is increasingly becoming a promising alternative strategy in potato seed production. This is the propagation of potatoes through TPS.

There are three alternative methods by which TPS can be used to raise potatoes: namely direct field sowing, transplanting seedlings from the nursery to the field and planting seedling tubers with the latter two giving encouraging results (Bedi *et al,* 1979; CIP, 1979; 1985b; Malagamba. 1982; Wiersema, 1984).

2.4.2.1.1 Direct field sowing: This method involves the TPS being sown directly into the field. The resulting seedlings are managed to produce tubers for consumption. Direct field sowing of TPS has generally given poor germination. Bedi (1978) reported only 3-6% germination in New Zealand. He suspected that temperatures could have been the cause of poor germination. In further experiments. Bedi *et al* (1979) found that temperatures between 10-20°C were the most favourable for TPS germination. Pallais et al (1991) reported that a crucial step in high quality TPS production, when intended for sowing under high temperature (>25°C), is storing seed dry (5 to 7% moisture) at >20°C for more than 18 months before sowing. Air temperatures of upto 30°C have been found not to inhibit seed germination (Wiersema, 1984). Kunkel (1979) reported total failure to germinate seeds which had been tested and given 87% germinability. In this case the failure could have been due to unfavourable temperatures and other factors not mentioned by researcher. High tempratures and clayey soils which easily form crusts upon drying can be harmful to TPS seed germination. Hence the suitability of lower temperatures was demonstrated in a cool area at Lima, Peru in which 85% germination was obtained in the field (Accatino, 1979). Soil crusting can be minimized by the addition of manure which also improves water infiltration. However, inadequate soil moisture and small size of the seeds, particularly in the presence of weeds could contribute to the poor germination (Gray, 1979; CIP. 1979).

The poor germination experienced in direct sowing is not unique to TPS, but is a common problem with other vegetables established directly. Simply sowing the seeds dry is cumbersome given their small size. To help improve the handling and germination of the seeds in the field, pelleting, fluid sowing and the plug mix methods can be used (CIP, 1979, 1983a, 1985a). Pelleting is the addition of inert material, insecticides and fungicides to the seeds. Fluid sowing entails the pregermination of seeds in ideal conditions upto the radical emergence stage before being sown in a protective gel. The plug mix method involves the germination of seeds in moist compost and then sowing the compost containing the germinated seeds.

From literature, it is clear that sowing TPS directly in the field can be hampered by poor weather and soil conditions (Accatino, 1979). High temperatures, coupled with heavy rain, may severely limit the use of this method in some areas of East Africa. However, areas with sandy loam soils and irrigation facilities particularly, if cool with overcast skies, may find the method attractive if the potato is grown as a minor vegetable in home gardens. To get good results, seed beds should be well prepared preferably by adding manure to give a fine tilth something most of the farmers rarely do. Hand sowing is tedious and inaccurate and the use of seed drills would seem to be the ideal way. Direct sowing of TPS therefore does not seem to be an attractive alternative potato planting material.

2.4.2.1.2 Use of seedling transplants: The TPS are sown in a nursery and the seedlings are managed until they are ready for transplanting into the open field for the production of ware potatoes. This system avoids most of the unfavourable soil conditions and environmental stress factors experienced in direct sowing. Most of the trials have demonstrated that transplanting seedlings is superior to direct field sowing (CIP, 1978, 1979, Li and Shen, 1979). The production of consumer potatoes from transplanted seedlings is hampered by poor plant establishment, slow rates of ground cover and a rather long growing period (Wiersema, 1984). There are also problems associated with transplanting seedlings from seed bed such as technical know how (Sadik, 1983). These factors may limit the production of consumer potatoes in those areas where potatoes are a minor crop and where the length of the season is interfered with by other crops.

Transplanting method lends itself favourably to the farming systems in many developing countries. Use of mulches, shade by companion perennial crops such as bananas, and relay cropping with say, maize during the last month of its growth greatly enhances seedling survival and improves on tuber yields. The use of hybrid seed which has a higher seedling vigour, transplant survival, growth rate, plant and tuber uniformity than the open-pollinated seed usually gives better yields (CIP, 1980, 1982, 1983a, 1984b, 1985a; Kidane-Mariam *et al*, 1984; Wiersema, 1984).

2.4.2.1.3 Planting seedling tubers: The method involves planting of tubers derived directly from TPS. The crop produced from true seed may be used for food or alternatively it may be used for the production of seed tubers, which are either planted for a food crop or are multiplied up prior to such use (Burton, 1980). This difference from the normal propagation by seed tubers is that it is not clonal propagation of a cultivar, but the propagation of a mixed population regularly renewed from true seed, and this is not subjected to the build up of tuber borne diseases.

Seedling tubers can be produced in a small field area when soil and climatic conditions are suitable for transplanting. A nursery may also be required to produce the transplants since, in most cases, field conditions do not allow direct TPS sowing (CIP, 1982). In order to reduce the storage period, production of first generation seedling tubers during off-season periods may have advantages. Seedling tuber production in a small field area needs an area where water supply, disease, and pest control can be effectively managed. Inorder to maximize the number of tubers produced per unit area, planting should be done at close spacing (CIP, 1982).

Tubers produced from TPS are smaller (5-10 g) than normal size of conventional seed tubers (20-30 g) and hence are excellent for use as seed tubers. A well documented case of the use of seedling tubers was done by Li and Shen (1979) in China. TPS was used to produce seed potatoes mainly through mass or clonal selection. They reported an increase in the market tuber yield of 35-155% higher than the use of the conventional seed tubers. The method is used in a number of provinces of China, the total area planted with seed tubers produced by this means being 21660 ha in 1979 (Li and Shen 1979). Wiersema (1984) cited similar use of seedling tubers in Russia and Ethiopia with reasonable yields.

The use of seedling tubers will ensure that a planting material which can still withstand most of the environmental conditions is availed. Healthier planting material is also envisaged (Burton, 1980) but this can only be ensured if the production is handled by experienced seed farmers.

2.5 True Potato Seed Production

So far, one of the setbacks to the use of TPS is the unavailability of the seed (CIP, 1984a; Umaerus, 1987). The key factor to the extensive use of TPS in the future is the development of simple and low-cost techniques that permit its large scale production and availability. Open pollination is by natural pollinators. To make controlled pollination, flowers should be selected that are at the bud stage. The flower bud of the female plant is opened and emasculated. Pollen from the male plant is placed on the stigma of the emasculated flowers (Accatino and Malagamba, 1982).

The problems encountered in TPS production include few or no flowers, flower abscission, pollen sterility, self-incompatibility and few viable ovules (Howard, 1970; CIP, 1985a). The production of flowers can be improved in a number of ways. For example, potato scions can be grafted onto tomato stocks (Carson and Howard,1945). The removal of the young tubers as they are formed has long been known to stimulate flower production although it is not always successful (Abdel-Wahab and Miller, 1963). To achieve the same effect, axillary buds below the inflorescence can be pruned to reduce the competition for nutrients. This may as well improve seed quality and synchronize berry maturity (Howard, 1970; CIP, 1985a). Increasing nitrogen levels may increase flower production (CIP, 1985a).

Studies initiated by CIP have shown that improving the nutrient supply to a crop of potatoes not only improves the viability and 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, 1983).

Flower abscission has been minimized by either placing cut stems with flowers taken from field-grown plants in jars of water or spraying field plants with auxin analogues 2-3 days after pollination (Howard, 1970; CIP, 1985a).

The use of growth regulators has positive effects on pollen. For instance, at Lima, Peru, DTO 33 clone had its pollen production increased two to three fold after the application of 20 ppm kinetin and 50 ppm GA3. Pollen germination was also reported to be enhanced by the use of spemidine (CIP, 1985a). From this brief review, it is quite clear that techniques which supply adequate assimilates to the inflorescences are likely to lead to the production of more flower buds and this can benefit the growth of seeds in the berry. Such physical techniques as the grafting method require ingenuity which would limit the production of TPS in large quantities. The most practical way to ensure the production of flower buds and pollen is the use of plant growth regulators (PGRS). But studies are required under different ecological zones to determine the optimum rates and combinations of PGRS.

When cross pollinating for hybrid TPS production storability of pollen is a problem. Howard (1970) wrote that potato pollen could maintain its viability for one month when kept at 2.5°C and for 2 years at 20°C after drying. A more recent study showed that pollen retained its viability for only 2 months when kept at 10 to 20°C (CIP. 1985a), suggesting that its viability period is limited.

Gray (1979), Accatino and Malagamba (1982) and Malagamba (1982) have reported techniques of seed extraction. treatment and storage. When the potato berries are mature, they are picked and kept at about 20°C until they become soft. They are then squeezed to extract the TPS. The mucilage covering is removed from the seed by rinsing the seed several times in water. The seeds are then dried at room temperature and packaged.

2.6 TPS Seedling Tuber Production

2.6.1 Seed bed substrates and their characteristic for seedling tuber production

The most important considerations in a seed bed substrate for the raising of seedlings are the physical properties, salinity, fertility and soil-borne pests. The physical properties of a seed bed substrate are modified by the addition of organic and inorganic compounds. Media which consisted of a mix of organic compounds with soil and/or sand gave well-structured and-aerated fertile substrates that aggregated around the roots to form root blocks for transplanting (Accatino and

Malagamba, 1982; Malagamba,1982; CIP, 1983a). The same authors observed however that the use of fresh manure or undecomposed organic material was harmful to the seedlings.

Substrate salinity has been reported to affect more severely the growth rather than the emergence of TPS seedlings. Substrates with high salt contents such as cattle manure from an intensive feeding lot has been found to lower significantly seedling vigour. Low salt horse manure produced excellent results when mixed with sand (Wiersema, 1984). CIP (1982) and Wiersema (1984) noted that fertilizers supplying nitrogen and potassium tended to lower seedling weights while the phosphatic fertilizers gave encouraging results. This was partly attributed to the high salt concentrations in the nitrogen and potassium fertilizers and partly to the specific ion effects (CIP, 1982). It is therefore necessary to consult the salt index of fertilizers in order to identify suitable ones. Fortunately, the effect of high salt concentrations can be minimized by frequent irrigation and the addition of some soil to the substrates which increases the water holding capacity of substrates (CIP, 1982). The effect of high salt content is however, more pronounced in the trays than the nursery beds, because the limited depth in trays exposed the seedlings to continue high salt concentrations.

Inspite of the physical and chemical attributes of a substrate, the presence of soil borne pathogens, nematodes and insect pests can badly affect seedling vigour (Wiersema, 1984).

Studies on the substrates for seedling production have shown that the addition of organic compounds such as peat moss, horse manure and cattle manure tended to improve mainly the physical properties of the media (CIP, 1982). The use of organic and inorganic materials retains sufficient moisture, permits good drainage and aeration of the media. The current recommendation is that the media should be able to retain sufficient moisture and provide adequate drainage and aeration for the plant roots (CIP, 1982). It appears that due to the small size of the seedlings from TPS their nutrient requirements are low. So depending on the type of organic compound, the use of inorganic fertilizers may not be necessary. The use of formulated commercial propagation media would be ideal but their costs are prohibitive. The media however, should be free from ingredients harmful to seedlings. Charcoal for instance, has phytotoxins and coffee parchment has saturated fatty acids (Chweya. 1976).

2.6.2 Sowing and germination

TPS can be sown in trays or directly into seed beds where the soil has been improved or in a protected area in a nursery where 70-75% of the light is transmitted (Li and Shen. 1979; Sadik, 1983). The latter permits the use of fertile substrates, optimum soil moisture, reduction of soil temperature, reduced contamination by tuber - transmitted nematodes and diseases and control of insect pests and vectors (Malagamba, 1988). Seedling emergence is faster and more uniform and growth is more vigorous in shaded nurseries than when seedlings are exposed directly to sunlight in warm climates (Accatino and Malagamba, 1982).

Depth of the bed does not need to be more than 25 cm since the rooting system of seedlings is rather shallow (CIP, 1982). In this case the seedlings will be spaced at 10 x 10cm and left to finish the growth cycle in the bed. Generally, high plant population has positive effect on the number of usable tubers produced per unit area (Wiersema, 1979). Seedlings require adequate and frequent watering. In high rainfall areas raised beds with proper drainage may have to be used. Transparent roofs (e.g plastic) can also be used to avoid seedlings being damaged by heavy rains.

Emergence of seedlings usually occurs between 5-10 days after sowing (Accatino and Malagamba, 1982; Malagamba, 1982). Three to fourteen days has been also noted (CIP, 1979; Sadik, 1980). Under unfavourable temperatures and soil conditions, seedling emergence takes 3-6 weeks (Bedi *et al.*, 1979), which leads to uneven stand. Seed dormancy, one special seed characteristic of sexually propagated crops needs to be considered in the use of vigorous TPS. TPS has a dormancy period of 4 to 6 months depending on the progenies (Pallais, 1989). Dormancy can be artificially broken by immersing the seed in 1500 ppm solution of gibberellic acid for 24 hours (Chen, 1973). At room temperature and low relative humidity, seed will remain viable for several months to 2 years. Howard (1969), stored seeds at 5°C and found 68-86% germination after 15 years, and 54-96% after 20 years.

Sadik (1983) and Pallais *et al*, (1991) indicated that germination of TPS may be hampered by a number of factors ranging from the harvesting and handling of berries to the conditions prevailing during germination. Sadik (1980) working with non-dormant seed, found over 90% germination in one week at 17.5 and 20°C, about 85% at 15 and 22°C; less than 70% at 13°C; and less than 20% at 25°C. At 27 and 30°C germination was 1-2% and it did not accur at 10°C and 35°C. A few degrees difference in temperature can thus have a very marked effect and high soil temperatures can present an obstacle to the use of true seed as a means of propagation in the tropics. This implies that the seed should be well-handled and sown under suitable conditions if vigorous TPS seedlings are to be produced.

One of the systems of using TPS is direct sowing in beds to produce seed tubers either in the first tuber generation or after several cycles of multiplication. The desirability of this approach and the method of production have been extensively investigated by Wiersema (1984) and other workers (Li and Shen, 1979). This method has shown great applicability under certain conditions.

2.6.3 Seedling management

The management of the emerged seedlings is of paramount importance when raising vigorous seedlings. Certain factors may influence the rate and extent of seedling growth (Accatino 1979; Mendoza, 1979). These include day and night temperatures, pathogens, root and shoot predators, water supply, seedling spacing and hardening (Pallais *et al.*, 1991).

A study on the effect of different day/night temperature regimes on the development of seedlings revealed that the best combination for DTO-33 open-pollinated progeny was 20°C and 10°C day and night temperatures, respectively (CIP, 1983a). Shading lowers seedbed temperatures in warm tropical areas (CIP, 1983a, 1984a; Sawyer, 1984). For example at San Ramon, Peru, seedbeds shaded for more than 14 days to allow 70% light transmission at full sunshine resulted in better emergence and sturdier seedlings (CIP, 1984a). Shaded seedlings have however shown a lesser response to phosphorus when the rate of nitrogen is increased (CIP, 1983a).

In cool areas, seedling emergence and growth can be impaired by night temperatures below 10°C through reduction of seedling height, internode length, top dry weight and root dry weight (CIP, 1984a). Temperature amelioration in such cool areas has been achieved by surrounding seed beds with black-painted stones or covering beds with clear polyethylene at night.

It has been noted that during berry ripening, extraction and processing, TPS may become highly contaminated with pathogen and fungal or bacterial saprophytes which increase disease incidence in the seedbeds (CIP, 1983b). A ten minute dip of the seed in a 0.5% sodium hypochlorite was found to be the most effective control (CIP, 1984a). In the nursery the most serious pathogens to the seedlings are *Rhizoctonia solani*, *Fusarium* spp. and *Pythium* spp. (Accatino and Malagamba, 1982; CIP, 1983b, 1984a, 1985a). They can be controlled effectively by most fungicides such as Basamid, Benlate and Rizolex (CIP, 1984a, 1985a). During the growth of seedlings, they should be regularly watered. Under tropical conditions, attention should be focused on high temperatures and root cuttings and shoot eating insects. There are however, progeny differences to temperature tolerance which can be further modified by breeding (CIP, 1985a).

After emergence, when plants are still small, foliar fertilizers can be applied. In addition, nitrogen and potassium dissolved in water can be applied. The amount of nitrogen and potassium applied before sowing should be minimized to avoid high salt concentrations resulting in poor plant growth (CIP, 1983a). The response of seedling growth to phosphate is normally strong and no negative effects of high amounts of phosphate have been observed (Malagamba, 1982). Phosphorous can be applied before sowing, while nitrogen and potassium can be split in several applications according to growth requirements. A weekly application of 10 g ammonium nitrate per plant can be continued until plants show signs of physiological maturity. Application of fertilizer with irrigation water can cause leaf burning. To prevent this leaves should be splashed with clean water (CIP, 1982).

During seedling growth, off-type seedlings, as well as poorly growing seedlings, should be removed to avoid unecessary plant competition. Malagamba (1988) found that productivity reached as high as 1500 usable seed tubers/M^2 under optimal conditions with a plant population of about 100 plants/M^2 after thinning. To provide a better protection against pests (e.g. tuber moth) and to increase tuber numbers per plant, hilling can be done by adding additional substrate to the beds.

Harvesting provides another opportunity for selection of off types. To reduce progeny segregation depending on the objective of the production, tubers can be separated into different color and shape categories.

2.6.4 Yield of seed tubers from TPS

The production and utilization of seed tubers derived from true potato seed have a potential combination of rapid plant development and disease free plants at low cost (Sadik, 1983; Malagamba, 1988). With good nursery management, very high yields of 500 clean tubers per square meter of seedling tubers can be obtained (Accatino, 1979). Wiersema (1984) reported seedling tuber yields up to 12 kg/m^2. The maximum number, larger than one gramme, the size found usable for multiplication, was 1242 tubers/m^2 meaning that approximately 40 m^2 of seedbed is required to produce sufficient tubers to plant a hectare of land. Malagamba (1988) stated that with fertile seedbeds and proper nursery management, a seedbed of 10 m^2 can produce sufficient tubers to plant a hectare of land after one field multiplication (CIP, 1982). In Ethiopia, from seedlings transplanted to the field, a maximum seedling tuber - yield of 29 t/ha has been reported (Yilma, 1991).

2.7 Ware Potato Yield From Different Potato Propagation Methods

A number of reports show that TPS yields are similar to or even better than those obtained from tuber propagation (Accatino, 1979; Bedi *et al.*, 1979; Li and Shen, 1979; CIP. 1980. 1982, 1983a, 1984a; Wiersema, 1984). Of the three methods of propagating potatoes from TPS, direct sowing is the most unfavourable. Due to the limited work on direct sowing, there is not much known about the expected yields. Bedi *et al.* (1979) reported total tuber yields ranging from 15.6 to 47.2 t/ha.. Reasonable yields of 21.5 to 32.6 t/ha from open-pollinated progenies were also reported from the directly sown TPS (CIP, 1980). Alacho (1986) obtained yields ranging from 17.8 to 58.3 t/ha from a crop of TPS seedling transplants in Kenya. This was in comparison to yields of 13.8 to 32.4 t/ha obtained from clonal conventional seed tubers.

The use of TPS to produce seed potato has been practised successfully in Inner Mongolia, Yunna, Sichuan, Heilongjiang and Anhwei Provinces in China (CIP, 1979). During 1967-1979, open pollinated and intercultivar hybrid TPS were mainly used for raising seed potato. The yield of marketable potatoes derived from TPS seedling tuber seeds was 35-55% higher than controls (CIP, 1979).

In Bangladesh, seedling tubers of all the promising TPS progenies showed commendable yield and statistically out yielded a standard improved variety (Sikka *et al.*, 1990). Seedling tubers, irrespective of their progeny, produced significantly large number of tubers than the check variety.

At Collao, Peru, transplanted seedlings of a hybrid progeny was compared with the farmers local seed tubers (CIP, 1984a). Yields from seedling transplants (27.1-29.1 t/ha) almost doubled the yields of farmers' seed tubers (16.3-16.5 t/ha). Crop from transplanted seedlings had a longer (125 days) maturity period compared with the farmers' (110 days) seed tubers. In these experiments, use of seedling tubers gave intermediate yields of 20.1 - 23.5 t/ha. In contrast Wiersema (1984) found that seedling transplants gave the lowest yields of 10.9-19.1 t/ha compared to 18.1-28.1 t/ha from seedling tuber sizes of 1-60 g. It was reported that 40-60 g clonal seed tubers yielded the highest with an average of 24.7 t/ha. The yield of crops grown from seedling tubers (5-20 g) was comparable to that of crops grown from equal size clonal seed tubers (CIP, 1982). The productivity of crops grown from seedling tubers has been higher than for local cultivars in many evaluation trials carried out in China because of the poor health standard of the latter (Song, 1984).

2.8 History of the Use of True Potato Seed

The conventional method of potato propagation has been from tubers. But in the centre of origin of the potato in the Andean region, there has been a long tradition of the use of TPS by the farmers (CIP. 1982; 1983a). Potato breeding programmes have always used TPS. China and India have fairly long traditions of the use of TPS (Li and Shen, 1979; Upadhaya, 1979). This was emulated by CIP scientists where research was concentrated on the production of both consumer and seed potatoes (Accatino, 1979; Accatino and Malagamba, 1982; Malagamba, 1982; Wiersema, 1984 ; CIP, 1985b). TPS produced in Peru under disease-free conditions were distributed to a number of countries including Rwanda and Egypt in Africa, Sri Lanka and the Philippines, in Asia and Colombia in Latin America (CIP, 1984a).

The use of TPS instead of seed tubers for direct production of more potatoes has been a major objective of research at CIP and other institutes in the developing countries. In Kenya a limited amount of 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, Molo and Mau Narok areas (Alacho, 1986; CIP 1987, 1988), hence the predominance of references from Peru.

2.9 Advantages and Disadvatages of Using TPS

2.9.1 Advantages of TPS over seed tubers

Compared to seed tubers, TPS offers several advantages. Perhaps the most important and striking advantage of true potato seed is the amount of seed required to plant a hectare of land. For a hectare of land 150 g of TPS is needed while at least 2 tonnes of seed tubers is required (Burton, 1980). For subsistence farmers in developing countries, who do not have an access to good quality seed tubers, true potato seed can be a cheaper source of planting material. TPS can be easily and cheaply stored and transported. Barker and Johnston (1980) found that without stringent conditions TPS would give acceptable rates of germination after 15 years of storage. Traditionally, potatoes are grown in cool climates. Major potato production is now in the northern latitudes and in the highlands of the tropics. With the use of TPS, potatoes can be grown in warm, non-traditional potato growing areas, where there is no access to high quality planting material, true potato seed is much easier to store than seed tubers (Burton, 1980). The growth vigour is much less dependent on the physiological status of the propagule. Hence, farmers using TPS could have it for planting at any time. This would allow them to fit potatoes into the farming system where seed tubers of the optimum physiological age are not available.

Very few diseases are transmitted by TPS (Malagamba, 1983; Li, 1983; Sadik, 1983). TPS is known to transmit only a few viruses and one viroid, potato spindle tuber viroid, which may pose a potential problem. Nevertheless, virus transmission is much smaller than in the case of seed tubers and this is one of the advantages of TPS in warmer areas with high incidence of virus infection (Malagamba, 1983).

Large increases in tuber yield from TPS can be expected in areas with low yields resulting from poor seed tuber quality (Kidane-Mariam *et al*, 1985). Tuber yields and quality of some selected TPS progenies are comparable with those of conventional seed tubers under certain conditions (Li, 1983; Sikka, 1987).

TPS usually produces smaller tubers but a larger number of tubers per hill than the conventional seed tuber (CIP, 1984a, 1985a, Wiersema 1984), which is advisable to be used as seed tubers. TPS can easily be introduced into existing farming system because planting time does not depend on the physiological age of the seed tubers and there is no effect of age of the propagule on plant development (Burton, 1980).

The use of seedling tubers has its own limitations but is a promising alternative. The poor and expensive transport and storage involved in the use of clonal tubers does not limit its use. More over, the production of seedling tubers does not introduce new practices because the sowing and seedling management is similar to that of other vegetables. So farmers experienced in vegetable gardening can adapt the technology successfully.

2.9.2 Disadvantages of TPS over seed tubers

There can be considerable problems in some years in establishing a crop by direct seeding. This is particularly the case if soil temperatures are high (Accatino, 1979). There are also problems associated with transplanting seedlings from a seed bed (Sadik, 1983). In general, more horticultural expertise and a greater labour input are necessary than in the case of propagation by seed tubers, and irrigation is usually essential (Li and Shen. 1979). During the potato growing season, seedlings are much more vulnerable to adverse conditions than are plants grown from seed tubers and require a longer growing season (one month longer) to give their maximum yield (Sadik, 1983). Bare-rooted seedlings were observed to require 19 days after transplanting to recover their previous growth rate. The crop produced from true seed is not uniform. The tubers may differ in shape, colour and cooking quality. A major problem associated with the technique is poor germination and seedling establishment. Variability in the rate of loss of endodormancy and the related increases in percentage germination presents a problem in the use of true seed as a means of propagation (Howard, 1969). Propagation from short dormancy seed (i.e. high percentage germination) will lead to unconscious selection for short dormancy, and hence poor storage characteristics, in the tubers. Seeds when extracted from the berries, are normally dormant, as a result of endogenous biochemical factors. The depth of this endodormancy increases as the fruit matures and reaches a peak about six weeks after pollination (Howard, 1969). Thereafter, endodormancy is lost more or less gradually, through a specific length of time which must elapse before germination can occur depending on the cultivar, the growing condition during fruiting and the conditions under which the seed is stored (Pallais, 1989).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Site and Location

The experiment was carried out between March 1994 and January 1995 at Kabete Field Station, University of Nairobi. The station is located at latitudes 1^{o} 14' South and 36^{o} 44' East and at an altitude of 1910.7 m above sea level. The average annual rainfall is 1039 mm. Appendix 1, 2 and 3 show summary of weather conditions during the experimental period. The long rain season (April, May and June) was notably drier, with an average rainfall of 98.15 mm and irrigation had to supplement the rainfall, than the short rain season (October, November and December) with an average of 115.6 mm of rainfall.

The soil is classified as a Nitisol according to FAO/ UNESCO (1988). The parent material is the Kabete Trachyte. The top soil on the farm has a pH in the range of 5.2 to 7.7. The nutrients potassium, calcium, magnesium and phosphorus range from deficient to fairly high levels. The soil drainage is good and the water holding capacity is high. Since this experiement was not related to fertilizer rate trials soil analysis was not done.

3.2 Nursery Production of Seed Tubers

3.2.1 Source of planting material

True potato seed (TPS) and tubers of hybrids and their parental lines were supplied by CIP Regional office for Tropical Africa in Kenya, while local check varieties were obtained from the National Potato Research Centre (NPRC) Tigoni and some were bought from a local market in Nairobi.

Production of planting material for long rains (March, 1994) was done during the short rains of October, 1993 to January, 1994. Seedling tubers were produced from TPS of open-pollinated and hybrid progenies, while conventional seed tubers were produced from the parental lines of both the hybrid and open-pollinated TPS progenies, as well as the local varieties. Planting material for the short rain (October, 1994) were from the long rain season tuber yield harvest. The planting material selection was based on the availability of TPS derived from the promising advanced clones. Table 2 gives a summary of the selected planting materials.

Table 2: Source and characteristics of potato tubers used as planting materials.

Germplasm	Source	Characteristics		
		Maturity*	Yield potential	Tuber colour
Clones & Varieties				
390010.2	CIP	Medium	High	White
800946	CIP	Medium	High	White
378143.5	CIP	Medium	High	White/ purple eyes
382171.4	CIP	Medium	High	White
Annet	Tigoni	Early	Medium	White
Farmers Seed	Local market	Early	Medium	Pink
TPS Progenies				
(390010.2 x 800946)	CIP	Medium	High	Slightly Segregating
(378143.5 x 382171.4)	CIP	Medium	High	Slightly Segregating
390010.2 OP	CIP	Medium	High	Segregating
800946 OP	CIP	Medium	High	Segregating
378143.5 OP	CIP	Medium	Medium	Segregating
382171.4 OP	CIP	Medium	Medium	Segregating

*Medium = 3 - 4 months
Early = 2.5 - 3 months
TPS = True potato seed
OP = Open pollinate
CIP = International Potato Research Centre

3.2.2 Seedling seed tuber production:

Since the TPS and conventional tubers for seed tuber production were newly harvested, dormancy was broken by treating TPS with 1500 ppm of GA_3 solution for 24 hours and 1ml/kg of Rendite for the conventional seed tubers.

TPS were drilled in metal trays in a glass house. The trays had a propagation medium which was composed of 4 parts sand, 4 parts organic matter and 1 to 2 parts forest soil (Accatino and Malagamba, 1982). After 4-5 weeks, seedlings were transplanted to propagation beds and spaced 10 cm x 10 cm (CIP, 1982). Until they were well established, the seedlings were shaded to reduce soil temperature. The shade (elephant grass) was 1 m above the seedlings inorder to enable watering and other agronomic activities. Thinning to remove off-type seedlings was done during the growing season. To control aphids (*Myzus persicae*) and white flies (*Bemisia* spp) Metasystoxe at 15 ml/10 l, was used whereas to control fungal diseases Dithane M45 at 50 gm/10 l was sprayed when necessary. Using the side placement method, nitrogen at a rate of 75kg/ha C.A.N. (26%N) was applied at post-emergence stage. Harvesting of seedling seed tubers was done 4 months after transplanting.

3.2.3 Conventional seed tuber production

The production of conventional seed tubers from hybrid parental lines and local varieties was done at the same time with the production of seedling tubers inorder to have uniform tuber size (spaced 10cm x 10cm) and physiological age as seedling seed tubers from TPS. Propagation beds and other agronomic practices were as those used for the production of seedling seed tubers. However beds were not shaded and watering was done once every week. Harvesting was done 4 months after planting as in the production of the seedling tubers.

3.3.Experimental Treatments and Design:

The treatments were composed of four seed sources (hybrid and open pollinated seedling tubers, conventional seed tubers from local varieties and parental clones) (Table 2). The clones and varieties were nested within seed source such that there were 2 (390010.2 x 800946 and 378143.5 x 38217.4) types of hybrid seedling tubers, 4 (390010.2, 800946, 378143.5 and 382171.4) types of open pollinated seedling tubers, 4 conventional seed tubers from 4 (390010.2, 800946, 378143.5 and 382171.4) parental clones, and 2 (Farmers seed and Annet) conventional seed tubers from local clones. The seed sources used in the study are described in table 3.

The treatments were arranged in a split plot design with three replications. Seed source as a main plot and varieties as sub plot.

Table 3: Description of Potato Seed Tuber Sources used in the sandy

	Tuber Size and Sprouting					
	Long rain			Short rain		
Seed Tuber Source	Weight (gm)	Diameter (mm)	Sprouting	Weight (gm)	Diameter (mm)	Sprouting
Hybrid seedling tubers	20-40	20-40	Good	20-40	28-30	Good
Open Pollinated seedling tubers	10-20	18-30	Fair	20-40	28-30	Good
Conventional seed tubers (parental clones)	30-50	28-50	Fair	20-40	28-30	Good
Conventional seed tubers (local varieties)	20-50	20-30	Good	20-40	28-30	Good

The planting materials (different seed sources) were grown in two seasons, April - July 1994 (long rains) and October, 1994 - January, 1995 (short rains). In each season, the seed tubers were planted at the onset of the rains. Nitrogen and phosphorus fertilizers were thoroughly mixed with the soil 4-5 cm below the seed tubers at planting. The plants were spaced at 75 cm between rows and 30 cm within plants.

3.4 General Crop Management

All other cultural practices (fertilizes rate, weeding, ridging, disease and pest control) were carried out as recommended for commercial growing of ware potatoes in Kenya (Ballestrem and Holler, 1977).

During the growing period in both seasons late blight (caused by *Phytophthora infestans*), early blight (caused by *Alternaria solani*) and potato leaf roll virus were noted on plants. In short rains, plants from open-pollinated seedling seed tubers and conventional seed tubers of local varieties were highly affected by early blight which was not successfully controlled by weekly application of Dithane compared to the long rains. This could be attributed to the heavy rain during the season.

During the growing seasons, supplemental irrigation was used whenever there was rain shortage to avoid water stress in plants.

The crop was kept weed-free throughout the season. Early blight was controlled by using Dithane M45, at 50 g/10 litres. Aphids and white flies were controlled by the use of Metasystox at 15 ml/10 litres. Furadan, a nematicide, at a rate of 0.1g/hill was used to control nematodes at planting. At planting, 300 kg /ha diammonium phosphate (D.A.P) was applied 4-5 cm below the soil before planting while during post-emergence (45 days after planting) stage plants were top dressed with 288.5 kg/ha calcium ammoniam nitrate (C.A.N) fertilizer.

3.5 Data Collection

The effect of different seed sources on potato tuber yield was assessed through considering the following general parameters:

(a) Plant vegetative growth

(i) Plant emergence

(ii) Plant vigour

(iii) Number of main stems per hill

(b) Tuber yields, grade and characteristics.

During the growing period, plant emergence was evaluated three weeks after planting by counting the number of plants that had emerged. Vigour of plants was evaluated by visual observation 45 days after planting. Evaluation was based on a five-point score system. (1 = least vigorous, 5 = most vigorous). Counting number of main stems per hill was done 12 weeks after planting.

Tuber yield, grade and characteristics were evaluated at harvest (4 months after planting). The harvested tubers were graded into three categories:

a) Ware grade tubers whose diameter was greater than 45 mm

b) Ware grade tubers with a diameter greater than 28 mm but less than 45mm. Size grade 28-45mm can be sold as seed size I and II to growers or in the open markets for consumption or to canning factories (Gray and Hughes, 1978).

c) Unmarketable : tubers with a diameter less than 28mm. These were considered to be chatts and unsaleable.

3.6 Data Analysis

Collected data were subjected to analysis of variance using the general linear models (proc glm) procedure of the statistical analysis (SAS,1985) Programme package. Multiple comparisons among means were done using the least significant difference (LSD) at P=0.05 (Steel and Torrie,1981).

Non parametric procedure Wilcoxon's Signed Rank test and Spearman's rank correlation (non parametric) was used for variable plant vigor classified by seed source.

CHAPTER FOUR

4.0 RESULTS

4.1 Effects of Seed Tuber Source on Vegetative Growth of Potato Plants

4.1.1 Plant emergence and vigour

In the long rains plant emergence was uneven hence a few plants had emerged by the third week after planting. In contrast, plants in the short rains emerged uniformly by the third week after planting.

Conventional seed tubers of the local varieties showed a tendency of better emergence followed by hybrid and parental clones (Table 4). However, there was no significant difference in plant emergence due to seed tuber source. At the time when the plant emergence was determined it was observed that plants from larger seed tubers emerged later. Seed tuber source had no effect on plant vigour in both seasons (Table 5)

4.1.2 Number of main Stems per hill

In both seasons source of seed tuber had a significant effect on number of main stems per hill. The number of stems per hill was lower in the plants from open-pollinated seedling tubers than those from conventional seed and hybrid seedling tubers (Table 6). Number of stems per hill was lower during the long rains than in the short rains.

In both seasons, hybrid seedling tubers and parental clones tended to have higher number of stems per hill followed by the local varieties.

Table 4 Effect of seed tuber source on potato plant emergence three weeks after planting

Source of seed tuber	Plant emergence out of 45 plants (%)		
	Long rains	Short rains	Mean
Hybrid seedling tubers	95.01	99.73	97.37
Open pollinated seedling tubers	74.82	97.95	86.38
Conventional seed tubers parental clones	87.40	99.44	93.42
Conventional seed tubers local varieties	99.15	98.51	98.83
Mean	85.48	98.82	
LSD(P=0.05)	NS	NS	
CV%	22.32	11.57	

NS= not significant

Table 5 Effect of seed tuber source on potato plant vigor seven weeks after planting

Source of seed tuber	Plant vigor rating[a]		
	Long rains	Short rains	Mean
Hybrid seedling tubers	4.50	5.00	4.75
Open pollinated seedling tubers	3.80	4.70	4.50
Conventional seed tubers parental clones	4.00	4.80	4.40
Conventional seed tubers local varieties	4.20	4.80	4.50
P value	0.74	0.90	

a 1= Least vigorous 5= Most vigorous

Table 6 Effect of seed tuber source on the number of main stems per hill of potato plants 12 weeks after planting

Source of seed tuber	Number of stems per hill		
	Long rains	Short rains	Mean
Hybrid seedling tubers	2.95 a*	4.00 a	3.48
Open pollinated seedling tubers	2.28 c	3.50 b	2.89
Conventional seed tubers parental clones	3.33 a	3.92 ab	3.63
Conventional seed tubers local varieties	2.71bc	3.83 ab	3.27
Mean	2.71	3.78	
LSD (P=0.05)	0.59	0.44	
CV%	19.63	7.15	

* Means in a column followed by the same letter are not statistically different

4.2 Effect of Seed Tuber Source on Total Ware Potato Tuber Yield

Significant differences in tuber yield in terms of weight were observed between the different seed sources (Table 7). The total tuber yield from the hybrid seedling tubers was remarkably higher than that from the rest of the treatments in the long rain season. The total tuber yield from open pollinated seedling tubers was not different from that of conventional seed tubers of the parental clones. However, open pollinated seedling tubers outyielded conventional local varieties (Table 7). In general, the total tuber yield of the open-pollinated seedling tubers in the two seasons was lower than that from the hybrid seedling seed tubers.

In terms of seasonal changes, it seems that plants from hybrid seedling tubers were affected more in yield than those from conventional seed tubers of the parental clones in the short rains. The mean yield of all seed tuber sources was higher in the long rains than the short rains.

Table 7 Total ware potato tuber yield from seedling and conventional seed tuber sources

Source of seed tuber	Yield (t/ha)		
	Long rains	Short rains	Mean
Hybrid seedling tubers	66.24a*	50.13	58.19
Open pollinated seedling tubers	53.75b	51.06	52.40
Conventional seed tubers parental clones	50.00bc	51.59	50.75
Conventional seed tubers local varieties	45.00c	38.76	41.40
Mean	53.13	49.03	
LSD (P=0.05)	6.65	NS	
CV%	9.80	18.75	

* Means in a column followed by the same letter(s) are not statistically different

NS Not significant

4.3 Effect of Seed Tuber Source on Tuber Characteristics and Tuber Size Categories

4.3.1 Tuber characteristics of ware potatoes of different seed tuber sources

In most cases, the uniformity (shape and skin colour) of the tubers from conventional seed tubers was superior to that from seedling tubers (Table 8).

Tubers from the hybrid seedling tubers were superior in uniformity to those from open pollinated seedling tubers. Tubers from conventional varieties, inspite of their uniformity in shape and colour, were in the same tuber size category as those from the open pollinated seedling tubers.

4.3.2 Marketable ware potato tuber yield of seedling and conventional seed tubers

Marketable ware potato tuber yield from conventional seed tubers of the parental clones tended to be high in the long rains while in the short rains, conventional seed tubers of local varieties yielded significantly lower marketable yield than the other sources (Table 9). On the average, parental clones seed tubers, and hybrid seedling tubers gave more marketable ware potatoes than open pollinated seedling tubers and local varieties seed tubers.

Table 8 Effect of seed tuber source on ware potato tuber characteristics

Source of seed tuber	Tuber size[a]	Tuber shape	Tuber skin colour
Hybrid seedling tubers	5-3	SS	SS
Open pollinated seedling tubers	4-1	S	S
Conventional seed tubers parental clones	5-3	Uniform	Uniform
Conventional seed tubers local varieties	4-1	Uniform	Uniform

[a] 1= Small 5=Large
SS = Slightly Segregated
S = Segregated

Table 9 Marketable ware potato tuber yield of seedling and conventional seed tuber sources

Source of seed tuber	Marketable tuber yield (t/ha)			
	Long rain		Short rain	
	M	U%	M	U%
Hybrid seedling tubers	48.37	9	41.20a*	19b
Open pollinated seedling tubers	46.50	10	40.74a	20b
Conventional seed tubers parental clones	59.19	7	44.77a	16b
Conventional seed tubers local varieties	39.15	13	23.55b	39a
Mean	48.30	9.75	39.38	23.50
LSD (P=0.05)	NS	NS	7.99	7.99
CV%	5.8	6.38	19.58	12.72

* Means in a column followed by the same letter are not statistically different

M = Marketable

U = Unmarketable

4.3.3 Tuber size categories of ware potato from different seed sources

Conventional seed tubers of local varieties gave the highest percent potato tubers in size category less than 28 mm and the least in the category more than 45 mm. This was followed by seedling tubers of open-pollinated progenies. Hybrid seedling tubers and the conventional seed tuber of the parental clones had the largest tuber yield in the size category more than 45 mm and the least in the size category less than 28 mm.

Generally .conventional seed tubers of the local varieties and open-pollinated seedling tubers gave high medium sized ware potato tubers. All the seed sources gave higher medium (28-45 mm) sized tubers during the long rains than in the short rains. The ware potatoes grown during the short rains had many unmarketable tubers.s.

Table 10 Size categories of ware potato tuber yields from seedling and conventional seed tubers

Source of seed tuber	Size categories %					
	<28mm		28-45mm		>45mm	
	Long rain	Short rain	Long rain	Short rain	Long rain	Short rain
Hybrid seedling tubers	9	19	66	56	25	25
Open pollinated seedling tubers	10	20	70	60	20	20
Conventional seed tubers parental clones	7	16	53	46	40	38
Conventional seed tubers local varieties	13	39	82	56	5	5

CHAPTER FIVE

5.0 DISCUSSION

5.1 Effect of Seed Tuber Source on Vegetative Growth of Potato Plants

In this study, results showed that during long rains, plant emergence was uneven probably because they were from different seed sources thus tuber size and sprouting were not uniform. In the short rain, however, emergence was uniform because seed tuber sprouting was uniform and tuber size of seedling tubers had been increased as they were second generation tubers (CIP. 1984a; 1985a). Wiersema (1984) observed that seedling tubers increased in size as the generation increased. Toosey (1963) and Wakankar (1944) working in India, used seed pieces of Darjeeling - red potatoes weighing 10, 20 and 40g and found that the number of sprouts increased with increasing seed tuber size.

According to Morris (1966) sprouting of potato seed tubers is important in advancing the growth cycle of the plant. If seed tubers are well sprouted and planting is done timely in the season, then each phase of the growth cycle (that is emergence, growth and senescence of foliage, initiation of bulking and maturity of tubers) occurs earlier.

In general, emergence of plants from conventional seed tubers tended to be better than that of plants from seedling tubers in the long rain. This could be because the size of conventional seed tubers exceeded that of open pollinated seedling seed tubers. Morris (1966) working on the effect of seed tuber size on emergence of potato plants concluded that the rapidity of plant emergence was affected by the number and size of sprouts on the mother seed tuber at the time of planting. Wurr (1978) reported that total sprout length increased with the initial tuber weight increase. However, the results of this study showed slight difference in plant emergence due to difference in seed source and seasonal differences.

Plants from hybrid seedling tubers and conventional seed tubers tended to be vigorous in the study. This shows that these plants could have a higher radiation interception and canopy photosynthetic efficiency. Allen (1978) reported that plant vigour is important because it affects the amount of radiation intercepted for photosynthesis which provides assimilates for tuber growth. Watson (1952) noted that when leaf area index was less than one, crops evince low efficiency in light utilization. Low light utilization results in low rates of photosynthesis, hence less assimilation and relatively little tuber growth. Growing well sprouted large seed tubers shortens the period of complete ground cover, therefore, utilizing optimum light.

The hybrid seedling tubers resulted in plants that were more vigorous than those produced from open-pollinated seedling tubers mainly due to hybrid vigour. Macaso-Khwaja *et al*, (1983) observed similar results and found that hybrid seedling transplants were more superior in vegetative vigour to open-pollinated progenies. The lower plant vigour of the open-pollinated progenies could be attributed to the high rate of selfing. The difference in plant vigour gave an advantage to the plants from hybrid seedling tubers to consequently give higher ware potato tuber yields.

The number of sprouts and main stems that develop per seed tuber is dependent on the seed tuber size. The number of main stems is used as a unit of plant density (Reestman & Dewit, 1959; Bleasdale, 1965). Stems can arise directly from the mother seed tuber. Moorby (1967) considered each stem above the ground to be a separate individual which is potentially capable of separate existence and relies on its own leaves and roots for supplies of carbohydrates, mineral nutrients and water. In this study and in both seasons the number of main stems per hill were slightly higher in the plants derived from conventional and hybrid seedling tubers than in those from open-pollinated seedling tubers. The number of main stems per hill increased with increasing seed tuber size. This finding is in accord with those of other workers (Birecki and Roztropowicz, 1963; Bremmer and Taha, 1966; Mundy and Bowles, 1973; Wurr and Allen, 1974; Wurr and Morris, 1979). In the long rains, however, the number of stems per hill was lower than in the short rains. This was probably due to poor sprouting of seed tubers used in the long rains.

Since small seed tubers give rise to a smaller number of stems per hill than large seed tubers inter and intra-plant competition is expected. The higher the number of stems per hill, the greater the photosynthetic apparatus. Plants from hybrid seedling tubers had a higher number of stems than the others did, thus resulting in relatively higher yield than the others. However, overcrowding of leaves leads to mutual shading, resulting in reduced net assimulation rate and early senescence of lower leaves. The extent to which this postulate works depends on spacing used and other environmental factors, e.g., moisture, nutrient availability and temperature. Generally, increasing stem density usually increases total ware potato tuber yield up to a maximum when further increase results in a reduced proportion of large tubers. The determination of optimum stem densities is important as only the light falling onto green leaves and stems is used by the plant for photosynthesis. But of greater significance is the arrangement of the plants. Potato production from TPS has the disadvantage that the resulting crop may be less uniform in vegetative growth which affects tuber uniformity (Monares *et al*, 1983). In the present study, plants derived from TPS seedling tubers were found to be less uniform compared to those from conventional seed tubers of the parental clones and local standard varieties, possibly due to the heterozygous nature of TPS. This could partly be attributed to the lower marketable tuber proportion of seedling tubers. This observation is similar to that of Monares *et al.* (1983).

An important observation in this study was that plants derived from seedling tubers looked healthier than those from convetional seed tubers of local varieties, which could be due to the fact that seedling tubers are freer from diseases than the seed tubers are.

One of the advantages of using TPS is that very few diseases are transmitted by the sexual seeds, thus first generation seedling tubers can be free of most diseases. It is therefore important to produce first generation tubers in an area protected from diseases (Accatino and Malagamba, 1983; Li, 1983; Monares *et al.*; 1983; Sadik, 1983).

5.2 Effect of Seed Tuber Source on Ware Potato Tuber Yield and Tuber Characteristics

There were seasonal differences in total and marketable ware potato tuber yields. The long rainy season was usually dry. Dry seasons are usually associated with high tuber dry matter yields (Burton, 1980). Due to that fact, total and marketable tuber yields of the long rainy season seemed to be higher than those of the short rainy season which received adequate rainfall. During the short rainy season, which received more rainfall (115.6 mm compared to 98.15mm for the long rains) and average monthly minimum temperature of 13.6^{o}C, there was a high incidence of early blight that may have contributed to the lower tuber yields.

Generally, the average yields from hybrid seedling tubers were higher than those from any of the others, namely, the open-pollinated seedling tubers, conventional seed tubers of the parental clones and local varieties. The reasons for the high yields of the hybrids could be due to hybrid vigor and the fact that the planting materials (being TPS) were clean and free of diseases normally found in seed tubers; the uniformity of tubers is another advantage compared to open-pollinated lines.

Seedling tubers from hybrid and open-pollinated TPS progenies significantly outyielded conventional seed tubers of the local varieties in the long rainy season. However, during the short rains yield of hybrid seedling tubers was very low possibly due to high late blight infestation. The out yielding ability of seedling tubers in the long rains is supported by the research findings of Kidane-Mariam *et al* (1985), Li (1983) and Sikka (1987). However, this study indicated that the tuber yields of seedling tubers tended to be small and therefore the overall percentage of marketable yield was rather low compared to conventional parental clones.

When the yield of plants from seedling tubers was compared with conventional seed tubers of the local checks the former gave higher total yields than the latter in both seasons. Similarly, work done in Bangladesh, showed that seedling tubers out yielded conventional seed tubers (Sikka *et al*, 1990). The productivity of plants grown from seedling tubers have constantly been higher than that from local cultivars in many evaluation trials carried out in China and India (Song, 1984).

In general, the total and marketable tuber yields of open-pollinated progenies were low with predominantly small tubers. However, it is important to note that the average tuber yield of open-pollinated progenies was close to that of the hybrid progenies. This result suggests that even among open-pollinated progenies, there is a possibility of selecting high yielding progenies. Though the tuber yields of the open-pollinated progenies were substantially lower than those of the hybrid ones, their economic yield could be significantly higher because of the higher costs associated with the production of hybrid seeds. The use of open-pollinated seedling tubers which may give acceptable level of yield and uniform tubers may be more appropriate in low input farming systems than using hybrid seedling tubers. Such TPS seed from open-pollinated of the cultivar Kuannae has been acceptable for farmers in China (Li and Shen, 1979). Li and Shen described the seedling tubers produced from TPS of Kuannae as fairly uniform in terms of shape and colour with an average yield of 23-38 t/ha depending on the region where it is grown. Previous research results show that use of hybrid seed which has a higher seedling vigour, transplanting survival, growth rate and plant and tuber uniformity usually gives better yields than open-pollinated seeds (CIP, 1980, 1982, 1983a, 1984b, 1985a; Kidane Mariam *et al*, 1984; Wiersema, 1984). Therefore since TPS hybrid seeds are generally superior to open pollinated progenies in plant vigour and tuber yield (Accatino, and Malagamba, 1982; Sadik, 1983) yield of hybrid seedling tubers was remarkebly higher during the long rain.

In this study the tuber yield from parental clones and hybrid seedling tubers in the short rain was 51.59 and 50.13 t/ha, respectively. However, in the long rains tuber yield of the hybrid progenies (66.25 t/ha) was higher than that of the parental lines (50.00 t/ha), possibly due to hybrid vigor. On average, the hybrids gave better yield than parental lines.

Yield from seedling tubers of open-pollinated TPS progenies and conventional seed tubers of the parental lines showed no significant differences in both seasons. Though the tuber yield of the open-pollinated TPS progenies was similar to that of the parental clones, their economic yield could be significantly higher. The advantage of open-pollinated progenies is that the TPS seed production does not require hand pollination and the amount of seed required is very low and, therefore, the cost of producing open-pollinated seeds is significantly lower than that of seed tubers. CIP (1982) reported results of many yield trials of crops grown from small seedling tubers (5-20 g) which had comparable yields with that of crops grown from 5-20 g seed tubers. Tuber yields and quality of some selected TPS progenies are comparable with those of convetional seed tubers under certain conditions (Li. 1983, Sikka. 1987).

5.3 Effect of Seed Tuber Sources on Marketable Tuber Yield:

Variation in seed tuber source affects both total and marketable tuber yield and is due to several factors including plant density, number of stems per hill, size of stems, date of plant emergence, seed tuber sizes at planting.

The lower percent marketable tuber yield of plants derived from TPS compared to those from conventional parental seed tubers in this study is in line with findings reported by CIP (1984a; 1985a) and Wiersema (1984). This could partly be attributed to the seed size differences at planting since seed tubers from TPS were less uniform in shape, colour, and size than conventional seed tubers from clones.

Conventional seed tubers of local varieties gave the lowest rank in percent marketable tuber yield in both seasons. Despite tuber uniformity in shape and colour, which are important attributes in market acceptability, the proportion of size category less than 28 mm was much higher than size category more than 45 mm. The low marketable yield can be attributed to differences in bulking rate and bulking duration. Local clones those used in the study are of early maturity.

In terms of tuber size, the hybrid progenies produced a higher proportion of large sizes (>45 mm) than the open-pollinated progenies. The higher proportion of smaller size seedling tubers from open-pollinated progenies could be useful source of seed tubers for subsequent seasons. The experience of several countries is that TPS cannot be used directly for ware potato production (Song, 1984). However, in places where there is no seed potato production scheme, but a tradition of growing vegetables exists, the relatively higher yielding open-pollinated progenies may be used directly as ware potatoes. In Srilanka, for example, ware potatoes are produced on small farms using open-pollinated seed from the most popular local variety (Bryan, 1985).

The result of this study showed that there were no significant differences between seedling tubers from hybrid progenies and their parental clones in marketable tuber yield in both seasons. However, parental clones tended to show better marketable tubers. This result supports the observation by Wiersema (1984) that the use of seedling tubers as an alternative planting material could result in external quality and the yield potential similar to those of selected tuber clones which usually represent superior genotypes. Tuber yields and quality of some selected TPS progenies have been comparable with those of conventional seed tubers under certain conditions in Ethiopia and elsewhere (Li, 1983; Sikka, 1987).

Even though there was no significant difference in marketable yield between hybrid and open-pollinated seedling tubers, hybrid progenies were generally superior to open-pollinated progenies in seedling vigour and tuber yield. As a general observation during the harvesting time potatoes from hybrid progenies showed more uniformity in tuber characteristics than the open-pollinated progenies.

The result indicated that the higher the uniformity the higher the percentage marketable tuber yield . This agrees with findings reported by CIP (1980, 1982, 1983a, 1984b, 1985a) Kidane-Mariam *et al*, (1984) and Wiersema (1984) where use of hybrid seed gave better marketable tuber yield and uniformity.

As the tubers produced from TPS are less uniform in shape, colour and size than tubers produced from standard clones, it is possible that parental clones marketable yield were superior to seedling tuber yields. During short rains, there was no significant marketable yield differences between sources of seed tubers although the average marketable tuber yield of conventional seed tubers was higher than that from seedling tubers. In general, marketable tuber yield was highly affected by seasonal changes. Short rains marketable yields were 9-26% less than those during long rains due to remarkable early blight and stem rot infestation. Spraying with chemical was not effective because of heavy rain.

There was no significant difference in marketable tuber yield between TPS derived progenies and the parental clones. However, parental clones had trend of increasing yield.

Lack of tuber uniformity is believed to be one of the problems in using TPS for ware potato production. The results indicated that tuber yields from seedling tubers were not uniform compared to conventional seed tubers. Work done by Muller (1923) with white skinned tubers, showed that on selfing, nearly 25% of plants gave coloured tubers. Although this finding is unusual, most varieties with white skinned tubers breed true for this character. Variability in the crop from seedlings tubers need not be as great as suggested by Huber (1930) that tubers of selfed progenies have high variability in tuber characterstics. It is possible to achieve a high degree of uniformity by selection of parents, as in the study of Li and Shen (1979) in China. If both parents, or the selfed variety, have round tubers, the progeny usually have round tubers. Similarly, if the parents have white - skinned tubers or yellow fleshed tubers, these characteristics are usually passed on to the progeny (Swaminathan and Sawyer, 1983). Mendoza (1979) studied the variability of a number of progenies with respect to yield, tuber number per plant, tuber colour and shape and found six families as having outstanding uniformity in tuber characterstics without sacrificing yield.

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

These results confirmed previous investigations that at the mid altitude conditions such as at Kabete, it is possible to produce reasonable ware potato tuber yields from seedling tubers of hybrid and open-pollinated TPS progenies.

From the results obtained in this study, the following broad conclusions were reached.

1) Plants from conventional seed tubers and hybrid seedling tubers produced higher number of main stems per hill than the open-pollinated seedling tubers.

2) It was possible to detect potato yield differences among the different seed sources.

3) Tuber yields of plants from seedling tubers were higher than those from the conventional seed tubers from local varieties.

4) Tuber yields of plants from hybrid seedling tubers were better than the yields of plants from conventional seed tubers of the parental lines.

5) Tuber yields from plants of open-pollinated seedling tubers and parental clones were more or less similar in the short rain.

6) Marketable tuber yields of plants from clones of the conventional seed tubers from the parental lines were higher followed by hybrid and open-pollinated seedling tubers.

7) Marketable tuber yield of plants from seedling tubers was significantly higher than the yield of conventional local varieties.

The above results demonstrate the viability of the use of seedling tubers for ware potato production. This leads to the conclusion that it may be advantageous for farmers to use seedling tubers rather than clonal seed tubers.

There is a possibility, that if this method of potato production is improved, acceptable yields would be achievable. Thus the manipulation of breeding on TPS characteristics such as tuber size and shape uniformity may partly improve the marketable yield proportion, hence, the technology could easily be adopted by farmers for production of clean seed potatoes or ware potatoes in home gardens.

6.2 Recommendations for Further Research Work:

1. To be valid over a wide range, the results of this trial need to be confirmed using more hybrid and open-pollinated TPS progenies from both advanced promising varieties and other local varieties.

2. Since yield was found to be dependent on seed source, work combining seed size and type of progenies need to be carried out so as to find out the best progeny and seed size that would give best yields.

3. More work with locally adapted varieties may need to be carried out to identify the varieties whose TPS could be used for propagation. This can help farmers to plant varieties of their own choice depending on their production objectives.

4. There is a tendency for TPS derived seedling tubers to produce many smaller tubers and to have lack of tuber uniformity than conventional seed tubers. Breeding best TPS progenies would ease these constraints. The use of hybrid lines would ensure uniformity.

5. Results of this study need to be supported with economic analysis (cost of production) since seedling tuber production needs extra work and time compared to the production of conventional seed tubers.

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APPENDICES

Appendix 1: Weather Conditions at the University of Nairobi Meteoro-logical Station, Kabete Field Station from March 1994 to January 1995

	Temperature			Rainfall	
Period	Mean (max) (°C	Mean (min) (°C)	Mean of 24hr	Amt. (mm)	Rainy days
March	25.9	14.4	20.1	56.3	11
April	23.8	14.6	19.2	237.2	14
May	22.2	13.8	18.0	92.2	16
June	21.7	11.9	16.8	44.4	7
July	20.5	11.8	16.2	18.8	6
August	20.5	12.2	16.2	33.9	5
September	23.1	12.1	17.7	1.3	1
October	24.1	13.8	19.0	87.8	9
November	22.3	14.0	18.1	301.4	12
December	-	13.3	-	64.7	9
January	-	13.2	-	8.6	2

Apendix 2: Summary of weather conditions in the long rains

	Temperature (^{o}C)			Rainfall	
Month	Minimum	Maximum	Average	Amount (mm)	Days
April	14.6	23.8	19.2	237.2	14
May	13.8	22.2	18.0	92.2	16
June	11.9	21.7	16.8	44.4	7
July	11.8	20.5	14.4	18.8	6
Average	13.025	22.05	17.1	98.15	10.75

The weather data covers the period between crop emergence to the end of crop harvest.

Appendix 3: Summary of weather conditions in the short rain

	Temperature (oC)			Rainfall	
Month	.Minimum	Maximum	Average	Amount (mm)	Days
October	13.8	24.1	18.0	87.8	9
November	14.0	22.3	18.2	301.4	12
December	13.3	-	-	64.7	9
January	13.2	-	-	8.6	2
Average	13.6	-	-	115.6	8

Appendix 4: Analysis of variance table using general linear model procedure for plant emergence in the long rain

Source	D.F.	S.S	MS	F Value	Pr >F
Block	2	44.33	22.17	0.30	0.74
SRCE	3	453.47	151.6	4.18	0.07
Var (SRCE)	8	1740.17	217.52	2.95	0.03
Block* SRCE	6	217.11	35.19	0.45	0.81
Error	16				
Total Error	35	2455.64			

Coefficient of variation: 22.32

Appendix 5: Analysis of variance table using general linear model procedure for plant emergence in the short rain

Source	D.F.	S.S	MS	F Value	Pr >F
Block	2	0.58	0.29	0.60	0.56
SRCE	3	3.64	1.21	1.77	0.25
Var (SRCE)	8	6.67	0.83	1.7	0.17
Block* SRCE	6	4.11	0.69	1.4	0.27
Error	16				
Total	35	15.00			

Coefficient of variation: 1.57

Appendix 6: Non parametric procedure table for plant vigour scores in the long rain

NPARIWAY PROCEDURE

Wilcoxon Scores (Ranksums) and spearman's rank correlation for variable PVIGOR Classified by variable source

	SRCE	VAR	VIGOR
SRCE	1.00	0.96	-0.06
*Prob=0.0	0.001	0.74	
VAR	0.96	1.00	-0.28
Prob=0.0001	0.0	0.099	
VIGOR	-0.06	-0.28	1.000
	Prob=0.74	0.097	0.0

* Spearman correlation coefficients /Prob>/R/under HO: Rho-0/N-36

Appendix 7 Non parametric procedure table for plant vigour scores in the short rain

NPARIWAY PROCEDURE

Wilcoxon Scores (Ranksums) and spearman's rank correlation for variable PVIGOR Classified by variable source

	SRCE	VAR	VIGOR
SRCE	1.00	0.96	-0.021
*Prob=0.0	0.001	0.902	
VAR	0.96	1.00	-0.091
Prob=0.001	0.0	0.596	
VIGOR	-0.0211	-0.09149	1.000
	Prob=0.9025	0.596	0.0

* Spearman correlation coefficients /Prob>/R/under HO: Rho-0/N-36

Appendix 8 **Analysis of variance table using general linear model procedure for plant main stem count in the long rain**

Source	DF	SS	MS	F.value	Prop
Block	2	0.23	0.16	0.41	0.67
SRCE	3	4.95	1.65	7.18	0.02
VAR (SRCE)	8	5.79	0.72	2.56	0.05
Block *SRCE	6	1.38	0.23	0.81	0.58
Error	16				
Total	35	12.75			
Coefficient of variation:		19.63			

Appendix 9 **Analysis of variance table using general linear model procedure for plant main stem count in the short rain**

Source	DF	SS	MS	F.value	Prop
Block	2	0.58	0.29	4.00	0.039
SRCE	3	1.47	0.49	3.79	0.08
VAR (SRCE)	8	6.83	0.85	10.43	0.0001
Block *SRCE	6	0.78	0.13	1.78	0.17
Error	16				
Total	35	9.66			

Coefficient of variation: 7.15

Appendix 10 **Analysis of variance table using general linear model procedure for total yield in long rain**

Source	DF	SS	MS	F.value	Pr>p
Block	2	102.27	51.14	1.89	0.18
SRCE	3	1551.56	517.19	17.51	0.0023
VAR (SRCE)	8	7003.13	875.49	32.40	0.0001
Block *SRCE	6	177.25	29.54	1.09	0.4077
Error	16				
Total	35	8855.44			

Coefficient of variation: 9.78

Appendix 11 **Analysis of variance table using general linear model procedure for total yield in short rain**

Source	DF	SS	MS	F.value	Pr>p
Block	2	408.57	204.29	2.42	0.12
SRCE	3	768.51	256.17	3.96	0.07
VAR (SRCE)	8	7070.74	883.84	10.46	0.0001
Block *SRCE	6	387.84	64.64	0.77	0.61
Error	16				
Total	35	8635.66			

Coefficient of variation: 18.75

Appendix 12: Analysis of variance table using general linear model procedure for MKTYLD in long rain

Source	DF	SS	MS	F.value	Pr>p
Block	2	112.33	56.17	2.03	0.164
SRCE	3	152.00	50.66	1.63	0.28
VAR (SRCE)	8	294.00	36.75	1.33	0.29
Block *SRCE	6	186.83	31.14	1.12	0.39
Error	16				
Total	35	745.16			

Coefficient of variation: 5.80

Appendix 13: Analysis of variance table using general linear model procedure for MKTYLD in short rain

Source	DF	SS	MS	F.value	Pr>p
Block	2	396.64	198.32	3.34	0.0615
SRCE	3	1903.42	634.40	14.89	0.0004
VAR (SRCE)	8	6367.03	795.88	13.39	0.0001
Block *SRCE	6	255.73	42.62	0.72	0.6415
Error	16				
Total	35	8022.82			

Coefficient of variation: 19.58