THE EFFECT OF SEEDLING AGE AND PRICKING-OUT OF TRUE POTATO (*Solanum tuberosum* L.) SEED SEEDLINGS ON PLANT SURVIVAL AND TUBER YIELD

BY

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DECLARATION

I, Teresia Stephen Mrema hereby declare that this is my original work and has not been presented in any other University.

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DEDICATION

This thesis is dedicated to my father the late Mr. Stephen Mrema, my mother Felistas Mrema, my husband Joram and my children Joe, Janet and Steve

ABSTRACT

The effect of transplanting true potato (*Solanum tuberosum*) seedlings of hybrid and open pollinated progenies, either pricked-out or not at various ages (28, 35 and 42 days after sowing - DAS) on plant survival and tuber yield was investigated under field conditions at Kabete Field Station, University of Nairobi, during the short and long rains of 1994/95 cropping seasons. A factorial experiment arranged in Randomized Complete Block Design with three replications was used. Data collected included number of true leaves of seedlings, seedling height and seedling vigour at transplanting, plant survival at establishment and at maturity, plant vigour in the field, top fresh and dry weights per hill, total and marketable tuber yield, mean tuber yield per plant and tuber size distribution.

The general performance of seedling age treatment indicated a significant effect during the long rains. The oldest seedlings (42 days) had more plants surviving (80.9 and 72.9% at establishment and maturity, respectively) and more total (18.5 t/ha) and marketable (15.6 t/ha) tuber yields than the young ones.

Pricking out increased plant survival rate at maturity from 74.7 to 80.2 % (short rains), 53.8 to 63.1% (long rains), total tuber yield from 28.2 to 34.4 and 13.2 to 15.7 t/ha (short and long rains, respectively) and marketable tuber yield from 25.1 to 30.6 t/ha during the short rains.

Hybrid progeny was significantly superior to open-pollinated progeny in plant survival (66.2%) at maturity during the long rains, total (34.3 and 18.0 t/ha) and marketable (31.2 and 14.5 t/ha) tuber yields in short and long rains, respectively.

The interaction between seedling age and pricking-out was not significant for most of variables except for seedling vigour and height at transplanting. Pricking-out effect increased with an increase in seedling age for seedling height and decreased with an increase in seedling age for seedling vigour .

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1.0 INTRODUCTION

1.1 The role of Potato (*Solanum tuberosum* L.) in Food Production

Some parts of Kenya are endowed with suitable climatic and edaphic conditions for production of various kinds of agricultural crops. The majority of Kenyan population depend mainly on cereals and beans food crops (Anon, 1981). Potato (*S. tuberosum* L.) is now gaining popularity almost all-over the country. Central Province, however, remains to be the major producer and consumer of potatoes . In this Province, the land under potato is estimated to be over 100,000 ha an area that has a potential of producing approximately 900,000 tonnes of potatoes annually (Provincial annual reports, 1991, 1992).

The potato (*S. tuberosum* L.) has a high nutritive value (Hawkes, 1990). It is a highly nutritious food with high quality protein. It contains a substantial amount of essential vitamins, minerals and trace elements (International Potato Centre,CIP, 1984). The potato ranks first in protein production per hectare per day in a group of most important food crops. The ratio of protein to carbohydrates is higher in potato than in cereals and other root and tuber crops. Potato can be boiled, roasted or fried, put into soups, stews, made into chips and crisp, ground into flour and/or used as livestock feed (Personal experience). Generally, potato has a shorter growing cycle than most other food crops especially in the tropics.

1.2 Potato (*S. tuberosum* L.) Production in Kenya.

The potato which was introduced in Kenya over 80 years ago has over time become a very important food and cash crop (Ngugi, 1983). The crop has expanded in cultivated areas, total production and usage as an important item of diet for a large cross - section of the Kenya population. It is grown in the highlands and mid-altitude areas almost in all provinces except Coastal area due to high temperatures (Ngugi, 1983).

A survey conducted by Durr (1980) in Nakuru, Nyandarua, Kiambu, Nyeri, Murang'a and Meru revealed that about one-third of the farmers grew the crop. Between one-third and one half of the Kenyan population is estimated to consume potatoes (Ngugi, 1983). It was also estimated that the annual total hectarage some of which accommodate two crops per year to be 75,000-100,000 ha grown by 450,000 farmers (owning between 1.2-2.0 ha of land) with probable production between 400,000-500,000 tonnes annually.

In Kenya, many farmers use their own seed tubers usually of small size planted at 2 - 2.5 tonnes per hectare. Very few farmers plant certified seed tubers because of high costs and unavailability (Ngugi, 1983). In Kenya, potato industry is based on about ten varieties, namely, Anett, Kenya Baraka, Kerr's pink, Roslin Eburu (B53), Roslin Gucha, Roslin Tana, Roslin Ruaka, Roslin Karura and Roslin Athi. Many of these varieties were introduced from Scotland (U.K), the Netherlands and West Germany. Most varieties are mature and ready for harvesting within 3-31/2 months. Potato yields in Kenya vary considerably between areas. Average yield is very low compared with potential yields. National average yield is estimated at 5 tonnes per hectare (Horton, 1978; Durr, 1980; Ngugi, 1983). In high potential areas, where good husbandry is practised, yields of 30-40 t/ha have been obtained (Holler,1973).

1.3 Constraints of Potato (*S. tuberosum* L.) Production in Kenya

Diseases are a major limiting factor to potato production in Kenya. The most devastating disease is the late blight (caused by *Phytophthora infestans*). Although most recommended varieties possess some resistance none are completely resistant. Kerr's pink, the most popular variety, is extremely susceptible yet farmers persist in growing it.

The other constraint is the poor transport and marketing infrastructure. Consequently, prices fluctuate considerably making potato growing and marketing a highly risky business. Also in most of the production areas, suitable storage facilities do not exist both for ware and "seed" potatoes. This, therefore, contributes to higher post-harvest losses. This results in farmers selling their potatoes immediately after harvest in order to avoid such losses. Thus, they are not able to take advantage of higher prices later.

The major limiting factor contributing to the low yield of potato production in Kenya has been identified to be lack of good quality potato "seed". In Kenya, farmers use their own "seed" or may buy from their neighbours or local markets. There is no adequate supply of certified "seed" at planting time. Normally farmers make selection from the current crop and these selections may involve small and unhealthy tubers that cannot otherwise be sold as ware potatoes in the market. The selections are used in the subsequent seasons. Ware potatoes have almost always been higher priced than "seed" tubers thus healthier "seed" tubers are consequently sold as ware.

In order to minimize the constraints associated with the use of potato "seed" tubers, potato crop can be propagated sexually by planting tiny true potato seeds (TPS). The spread of soil-borne and many other seed borne diseases is avoided by the use of TPS (Accatino and Malagamba 1982; Sadik, 1983; CIP, 1983a). Only 100-150 g of TPS give sufficient seedlings to plant a hectare of land (Sadik, 1983; Burton, 1989; Accatino and Malagamba, 1982). TPS can be stored much longer and more easily than "seed" tubers (Burton, 1989). Also by using TPS there is the possibility of expanding cultivation into regions that previously were unable to produce potatoes due to the lack of storage facilities for seed tubers (CIP, 1983; Sadik 1983). Furthermore, planting of TPS eliminates the sprouting stage necessary in "seed" tubers (CIP, 1983a).

Despite the apparent advantages in using TPS, there are several disadvantages. Sometimes the establishment of the crop in some bad years such as in drought conditions can be a problem especially with direct seeding in the field (Accatino, 1979). A great labour input and horticultural expertise are required when transplanting seedling from a seed bed (Sadik, 1983). The seedlings established from TPS are much more vulnerable to adverse conditions than plants grown from seed tubers and seedlings require a month longer to give their maximum yields (Burton, 1989). The crop produced from TPS is not as uniform as crop produced from seed tubers.

However, the problems associated with the use of "seed" tubers seem to weigh heavily against their use in some areas in the tropics. Most of problems of TPS are surmountable with further research. The problems can be solved with time as more knowledge and experience with TPS are gained and as superior progenies are bred.

Evaluation of agronomic and breeding aspects in TPS is among the important areas to be dealt with. In both aspects, potato production from TPS has been approached in three ways, namely, direct sowing in the field, transplanting seedlings in the field and by using seedling tubers derived from TPS (CIP, 1983; Sadik, 1983; Wiersema, 1984). So far the use of seedlings and seedling tubers has been found to be the most viable alternative in areas where this technology of TPS has been adopted (Wiersema, 1984).

The use of TPS seedlings entails among other practices, the raising of vigorous seedlings in nurseries and then transplanting them into the field. Under Kenyan conditions, very little is known about the effect of age of transplanting and pricking-out of TPS seedlings on transplant survival and tuber yields. Hence the objectives of this study were:

1. To determine the effect of seedling age of hybrid and open-pollinated TPS progenies on plant survival and total and marketable tuber yields.

2. To show the effect of pricking-out of True Potato (TP) seedlings of hybrid and open-pollinated progenies on plant survival and total and marketable tuber yields.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Origin of Potato

The potato (*Solanum tuberosum* L.) was first domesticated in South America over 8,000 years ago (Hawkes, 1978). Later it was introduced to Europe in the sixteenth century (Salaman, 1970; Hawkes, 1990) and in eighteenth century became an acceptable food stuff throughout Europe (Burton, 1989). Today potato crop ranks fourth in world production following wheat, maize and rice (Hawkes, 1990). Its cultivation in Kenya was started by the British East Africa Trading Company and settlers mainly from South Africa (Ballestrem and Holler, 1977; Durr, 1980).

2.2 Botanical Aspects of Potato Plant.

The potato plant is one of 2,000 species in the family Solanaceae which comprises such plants as tobacco, tomato, eggplant and peppers (Horton, 1987, Hawkes, 1990). It is classified as a dicotyledonous annual though it can persist in the field vegetatively as tubers from one season to the next (Horton,1987, Burton 1989).

It has shallow roots that seldom extend deeper than 40-50 cm. The tuber is an enlarged portion of an underground stem (stolon) adapted to storage of photosynthates and reproduction of the plant. About 2-4 weeks after the first stem emergence from the soil, young tubers begin to grow at the tips of the stolons as a results of cell division and elongation. There are early, medium and late maturing varieties. The length of a potato cycle can be influenced by environmental conditions, so that a variety that is late under one set of growing conditions can be early under another. Three periods can be distinguished in potato cycle: pre-emergence/emergence, foliage growth and tuber growth (Horton, 1987). Tuberization is not dependent upon flowering, although the two are sometimes associated as it has been reported by Horton (1987). Thus, conditions that favour flowering usually favour tuberization. Most common tuber skin colour as described by Burton (1989) are Whitish, yellowish, pinkish and reddish and flower colours are white, pinkish and purplish.

2.3 Propagation Methods of Potato

Potato can be propagated vegetatively from seed tubers or sexually from true potato seed (TPS). True potato seed refers to the botanical seed extracted from mature potato berries resulting from sexual reproduction. When pollination occurs naturally the resulting TPS is termed as open-pollinated progeny. In this progeny only the female parent is known. When pollination occurs under controlled conditions where both parents are known the resulting TPS is known as hybrid progeny (Accatino and Malagamba, 1982). Traditionally commercial production of potatoes has been based on the use of seed tubers for planting while the use of TPS was limited to breeding and selection (Sadik, 1983). However, from various TPS research findings it has been observed that both methods can be used in potato production of ware potatoes (CIP, 1982, 1983; Accatino, 1979; Sadik, 1983, Malagamba, 1982). Both methods have several advantages and disadvantages as reported by various authors (CIP, 1983; Sadik, 1983; Accatino and Malagamba, 1983; Burton, 1989).

2.4 Constraints of Using Seed Tubers in Potato Production

The propagation method experienced by majority of farmers in developing countries is the use of seed tubers. This system has been observed to be a major limiting factor because seed tubers represent 30-70% of potato production costs (Accatino and Malagamba, 1982; Sadik, 1983). This limitation has been experienced in North Africa and Asia were most tubers are imported (CIP, 1983). It has been estimated that 2-2.5 tonnes of seed tubers are needed to plant one hectare and this can be replaced by only 100-150 grams of TPS (Accatino and Malagamba, 1982; Burton, 1989). Seed tubers are expensive to store from harvesting to planting thus require costly refrigerated storage facilities and energy to transport them from field to storage and to producing areas (Sadik, 1983). Moreover lack of good quality low-cost seed tubers has been observed as a major limiting factor to the expansion of potato production in the tropics (Accatino and Malagamba, 1982). Other problems include bulkiness of the seed tubers and ease of introducing diseases and pests (CIP, 1982, 1983; Accatino and Malagamba, 1982). Seed tubers are often the main carrier of diseases and pests which can reduce yield considerably (CIP, 1982, 1983).

2.5 History of the Use of TPS

Because of the problems associated with seed tubers, CIP through research at its headquarters in Lima, Peru, and its regional facilities throughout the world started to develop alternative methods for potato production that are applicable to conditions in developing countries and research on ways to improve the quality of locally produced seed tubers. Among the cheap and most promising alternative is the use of TPS(White and Sadik, 1983). The idea of using TPS at this time is not new. Potato researchers, particularly breeders, were always using TPS in breeding research and selection to develop new varieties (Sadik, 1983).

Research on TPS at CIP started in 1976 while effective technology transfer began in 1987 (Pallais, 1994). The first effort consisted of studying the genetic nature of variability for several traits relevant to TPS and then techniques adapted to the environmental conditions and cultural practices in potato producing areas within the tropical region (Malagamba, 1982, 1988; Mendoza, 1984). The research has extended rapidly to a great number of the cooperating institutions throughout the world and at present is being carried out in more than 40 countries within the tropics. During the initial phase, breeding and agronomy received special attention while in recent years emphasis has been given to physiological aspects related to production, seed quality and techniques for producing vigorous seedlings (Malagamba, 1988).

2.6 Transfer of TPS Technology

Research on TPS technology started in the People's Republic of China during the late 1950's in the Inner Mongolia region (Malagamba and Monares, 1988). This initiation was due to the high incidence of virus diseases which had reduced potato yield. Farmers in that country adopted this technology since 1972 and areas of potatoes raised from TPS has increased significantly (Accatino and Malagamba, 1982). Selected farmers produce big quantities of TPS from open-pollinated progenies which are high yielding and late blight resistant potato varieties. In China about 15,000 hectare of potatoes have been cultivated using TPS (Bo Fu, 1984). Normally the seedlings are raised in seed beds and transplanted into the field for ware potato production and smaller seedling tubers are kept by farmers as a seed source for the following seasons. These seedling tubers are used as planting materials for about 5-6 growing seasons then replaced with new ones (Malagamba and Monares, 1988).

In Egypt the seed potato system are based on locally produced seed tubers and imported seed potatoes from Europe for planting in winter and spring seasons (Crissman et al., 1991). The seed potatoes locally produced by farmers are most likely to have a low yield potential due to build-up of virus and other pathogens and pests. Currently there is a high adoption potential of TPS due to the rapid progress made in the development of improved progenies and agronomic practices (CIP, 1992). The major emphasis in research is the production of seedling tubers as an alternative planting material. Private companies and many cooperations have been involved in the commercial seedling tuber production (Crissman et al., 1991). Farmers get their seedling tubers from research centers (Sabaa et al., 1991).

In Kenya development of progenies adapted to the local conditions is going on in more than three locations. In Burundi, Ethiopia, Rwanda and Tunisia TPS is currently being tested at the experimental stations and on-farm (Pallais, 1994).

In Indonesia it has been observed that the quantity of seedling tuber sales and their prices indicate how TPS is an acceptable source of both seed and ware potatoes. From initial farmer evaluation on TPS in that country in terms of production costs, it appeared that TPS was highly favourable when compared with imported seed tubers (Chilver, 1994).

As it was concluded by Monares et al., (1983) it appeared that the adoption of TPS technology can occur first in areas where environmental conditions are suitable for potato production, where good seed tubers are expensive or not available and labour is cheap. Also adoption is likely to be greatest where the costs of seed tubers represent a high proportion of total cost and where seed storage and transportation are problematic but skilled labour is available while consumer do not have strong preferences for specific tuber characteristic. Adoption can also be realized in areas with extremely low yield caused by very poor seed tuber quality, therefore introduction of TPS may result in marked increases in yields and farm returns thus encouraging rapid adoption.

2.7 True Potato Seed Production

True potato seed production can follow steps similar to those used to produce many other vegetable crop seeds. Pollination leading to sexual reproduction can occur naturally or under controlled conditions. Under appropriate conditions, a potato plant produces flowers and later produce fruits known as berries. When pollination occur naturally the resulting TPS is termed "open-pollinated seed" (OP) and only the female parent is known. Much of these seeds result from self pollination. When pollination is done under controlled conditions (e.g. hybridization of known parents) the resulting TPS is termed "hybrid progeny" (HP). This can be done manually in field or in the greenhouse under controlled conditions (CIP, 1983a). Few days after pollination, berries will start to develop on the plants and in about 40 days the berries will be ready for harvesting. The harvested berries are kept under room temperature until they are soft enough to easily extract the seeds by squeezing them to remove the mucilage and washing them with running water. The number of TPS per berry can range from 50-

500, though the average usually is about 200 (CIP, 1983a). The extracted TPS normally are dried at room temperature in low relative humidity. TPS can remain viable under room temperature for several months up to approximately 2 years (Accatino and Malagamba, 1982). At 4° and low humidity, TPS can be stored for several years (> 10 years) without loosing viability.

Dormancy in TPS is a major factor affecting uniformity and speed of germination (Malagamba, 1988). If TPS are used soon after extraction, the seeds can be treated with 1000-1500 ppm Gibberellic acid (GA_3) (Malagamba, 1988; Tuku, 1994). Malagamba (1988) observed that if seeds are dried immediately after extraction and kept to break dormancy naturally, their germination percentage and vigour become higher than seeds treated with GA3.

2.8 Potato Production Methods from TPS

Potato production from TPS has been approached in three ways namely direct field seeding, raising seedlings in nursery beds and transplanting them and using seedling tubers derived from the seed (Accatino and Malagamba, 1982; Sadik, 1983; CIP, 1983a).

2.8.1 Direct field seeding

This method has been advantageous in areas with mild temperatures and where rainfall is light and evenly distributed during the first 5-6 weeks (CIP, 1983a). Climatic conditions of this nature can permit good germination and seedling establishment in the field. Potato seed has been reported to germinate best at 15°C-20°C and are inhibited at temperatures above 25°C or below 10°C (Stier and Cordner, 1937; Steinbauer, 1957; Sadik, 1979).

Several experiments have shown very low plant survival when direct field sowing is done under contrasting climatic conditions. For example, Kunkel (1979) failed to obtain seed germination in a well irrigated six hectares field by direct sowing seeds that had 87% germination in the laboratory. The higher temperatures experienced after sowing were reported as the most likely factors that prevent germination. Bedi (1978) in New Zealand obtained only 6% of the total number of directly sown seed which survived until harvest. Accatino (1979) while working with direct field sowing in several environments and with soil of different composition in Peru concluded that the success of direct sowing is highly dependent on edaphic and environmental conditions during germination and seedling establishment. Martin (1983) when studying the techniques for successful field seeding using OP seeds in USA obtained a favourable results of field emergence ranging from 50-80% and tuber yield ranging from 36 58 tons per hectare when TPS was sown with precision seeds.

The poor results reported from direct field sowing seem to be largely associated with the required optimal conditions of soil structure, moisture, temperature and absence of weeds (Wiersema, 1984). Several studies as reviewed by Sadik (1983) indicate that germination, seedling emergence and establishment from directly sown seed may be satisfactory and result into good yield under certain management and growing conditions. It has been stated that the conditions required for optimal seedling emergence are moderate temperature and levelled friable soil with adequate stable soil water content (Accatino and Malagamba, 1982; Monares et al., 1983).

Several techniques are available for the direct field sowing of TPS such as the use of pelleted seeds, fluid drilling and the plug mix methods (CIP, 1983; Wiersema,1984). With plug mix, seed is pre-germinated in a prepared soil mix and sown. A plug mix formula was developed with locally available, less expensive materials and is sufficient to seed 240 hills(Accatino and Malagamba, 1982). Therefore under favourable conditions good emergence from direct sowing of TPS can be achieved and adoption of this method can be of advantageous.

2.8.2 Production from seedling tubers

In this method, seedlings are grown densely in ground beds until tuber maturity. Seedlings are established either by direct seeding or by transplanting from nurseries. The first generation of tubers produced from TPS seedlings are referred to as "seedling tubers". This method combines the attributes of potato production from TPS with those of potato production from seed tubers (CIP, 1983; Sadik, 1983; Wiersema, 1984). This system may have potential in areas where healthy seed tubers are not available or are available but expensive and growing conditions are favourable for potato production. When properly managed a nursery bed can yield as many as 800 clean seedling tubers per square metre (CIP, 1983). Wiersema, (1984) reported yield of up to 12 kg/m^2 which is sufficient to plant an area of 60 m^2

By using this methods seedling tubers can be used to increase seed tuber supply. Furthermore seedling tubers can be multiplied to produce additional potatoes for consumption and growers can avoid problems associated with seedling survival and establishment from transplants.

2.8.3 Production through transplanting to the field

Frequently poor emergence and stands are obtained in direct TPS seeding, if optimal germination and seedling growth conditions are not maintained (Casimir et al., 1988). Characteristics of the seed and normally the low early vigour of seedling restrict the use of this method to small areas that can be managed more intensively (Malagamba, 1984). Transplanting is a common practice to many vegetable grown on small farms and has shown great application with potato production (Malagamba, 1982; Sadik, 1983).

In this method, TPS can be sown in trays or ground beds in nursery containing soil of proper physical structure, fertility and moisture as practised for seedling production of other vegetable crops (Sadik, 1983). In warm climates use of shade in nurseries for 15-20 days after sowing has been reported to help in achieving more uniform emergence and vigorous seedling growth (Sadik, 1983). From different observation it has been reported that germination and emergence can occur between 7-10 days after sowing and vigorous seedlings can be ready for transplanting into the field 4-5 weeks after sowing (Accatino and Malagamba, 1982; CIP, 1983a). It has been found that when adequate management practices are followed, adapted progenies can yield more than 30 tons per hectare of marketable potatoes (CIP, 1983a).

This method avoids a number of problems associated with direct sowing in the field because seedlings are established under careful management in small protected areas where pests, edaphic and environmental stresses can be easily controlled. Therefore, this system has promising application especially in areas where vegetable production by transplanting is a common practice and where potato is a high value crop.

2.9 Potential Use of Hybrid and Open-pollinated Progenies in Potato Production.

An extensive list of hybrid and OP progenies have been evaluated at the International Potato Center in Peru, the Templelon plant breeders in New Zealand and in CIP's regional centers throughout the world. Initially, the objective of CIP in evaluating TPS progenies was to identify hybrids and OP families that had seedling vigour, good yield and acceptable tuber uniformity (Accatino and Malagamba, 1982). Currently, breeding efforts are directed towards producing superior TPS genetic materials in which satisfactory uniformity of tubers and growth are combined with good yields, adaptation to tropical conditions, earliness and resistance to pest and diseases (White and Sadik, 1983). The reason of evaluating HP and OP was based on the advantages that the two types of progenies offer. The obvious reason of using HP progenies is because they provide the means to continue improving desirable characters through breeding of selected parental materials. The use of OP is because seed production is simple, less expensive and can be done by farmers on their own land (Accatino and Malagamba, 1982). Based on the evaluation, several progenies have been selected on the basis that they meet satisfactorily uniformity standards in terms of growth, high yielding ability and high degree of tuber uniformity in respect to size, colour and shape.

Results from several evaluation studies confirmed that OP are generally inferior to HP in many characters. Kidane-Mariam et al., (1984a; 1985) found greater TPS weight, germination percentage and seedling vigour in HP from 4x X 2x crosses than in OP. Germination percent was 90.9 in HP and 74.8 in OP while seedling vigour (rating 1 for least vigorous and 4 for highly vigorous) was 4 for HP and 2.3 for OP.

Several other comparisons have been made between the two progenies on yield and other horticultural traits. Macaso-Khwaja and Peloquin (1983) found that hybrid progenies have high potential of producing more vigorous plants and higher seedling tuber yield than the HP progenies. When using different families from each type, Kidane-Mariam et al.,(1984b,1985) found higher tuber yield in HP families of about 28% higher than that of the highest yielding OP group and about 48% higher than the combined mean yield of three groups of OP families. Also better plant uniformity was found in HP than in OP's.

In a trial to compare the yield potential of different F1 HP seedling, OP seedlings and tuber families from HP and OP seedlings, Li (1983) found that the yield of HP groups was the highest and significant with relatively uniform tubers. Based on this trial, he then concluded that the use of HP in production hybrid progenies in both seasons. He noted that genetic diversity is very important for increasing yield assuming that OP results mostly in selfed seeds. In this experiment both number of marketable tubers and average weight of marketable tubers provided highly significant correlation coefficients with marketable yield in both seasons. Also a highly significant correlation coefficients were obtained between the two seasons except for the average weight of marketable tubers.

From recent research findings in Ethiopia, Tuku (1994) in dry season observed a significant differences in seedling tuber yield in terms of weight and number between the OP progenies and hybrid progenies. In this study mean seedling tuber yield of the hybrids (46 t/ha) was remarkably higher than that of the op progenies (31 t/ha).

Sadik (1983) commented that the use of hybrid seeds will probably be the choice for large farming operations because of better plant vigour, yield and tuber uniformity. He also added that due to high skill required and costly management of hybrid seed production, op seeds can probably be relevant to backyard home gardeners who grow potatoes for family consumption as the production of these seeds is easy.

2.10 Seedling Production Method and Management

2.10.1 Seedbed characteristics

Most vegetable seedlings for transplanting are produced in the seedbed in a field nursery, in trays flats or pots (Malagamba, 1982; CIP, 1983a). In Peru potato seedlings have been grown satisfactorily in different types of seed beds (Malagamba, 1982), however, they require higher nutrients and good soil structure than seedlings of other vegetables (Accatino, 1979; Malagamba, 1982). In vegetable growing areas, different seed beds can be found. The most common and cheap one is prepared on well-prepared and levelled piece of land usually rectangular where the organic matter content of soil is higher than the rest of the field. Normally this is accomplished by the application of farm yard manure, compost or other organic materials, then the seeds are drilled in a shallow furrows. According to Malagamba (1982) potato seedlings require more or less similar seedbeds having characteristic similar as those described above.

Climatic conditions are among the factors that are of paramount importance during the production of seedling for transplanting. The most important one is temperature. It is generally accepted that the minimum temperature for potato seed germination range from 11-20°C when the maximum temperature does not exceed 30°C (Malagamba, 1982). Temperatures above 25°C and below 10°C are generally inhibitory to germination (Sadik, 1979; CIP, 1981). Lack of uniformity and loss of seedling vigour have been found when the temperatures were out of the above range (Malagamba, 1982).

Exposure of seedlings to direct sunlight can result into more vigorous seedlings that will survive transplanting in better conditions. In areas of high temperatures shade can be provided using the cheap available materials such as branches or leaves or they can be placed under the shade of a tree (Malagamba, 1982). Shading reduces temperatures at the seedbed but it is advised not to reduce sunlight more than 20-30% thus removal of shade during the first 3-4 weeks after sowing has been observed to be important (Malagamba, 1982; Sadik, 1983).

Seedbed substrate is another area where adaptive research is highly recommended. Possible materials to use as seed bed substrate are extremely variable. The most important consideration is the structure of the seed bed substrate, its physical properties, salinity, fertility and soil-borne pests.

Seedbed substrate containing 2:1:1:1:1 mixture of forest soil, sand, gravel, well decomposed farm yard manure and well decomposed coffee husks, respectively, is commonly used at the University of Nairobi, Kabete, Field station, to raise potato seedlings in glasshouse for transplanting. A ratio of 15% sand, 70% soil and 15% well decomposed horse manure has been found to give vigorous potato seedlings when raised in a glasshouse at Field Station, Kabete (Alacho, 1986).

Seedbed substrate must be free from soil-borne pathogens, parasitic nematodes, insect-pests and weed seeds. These factors when present can adversely affect the seedling vigour. These can be minimized by steam sterilization or use of chemical with both nematicidal and insecticidal action such as carbofuran (Malagamba, 1982; CIP, 1983a; Wiersema, 1984).

2.10.2 Seed sowing and seedling establishment

Higher efficiency in potato seedling management and safer transplanting is dependent on how the sowing is done. Sowing is recommended to be done in shallow furrows that are 0.5-1.0 cm deep spaced 5.0 cm apart (Malagamba, 1982). Seeds are distributed 1.5 cm apart in each furrow and watering is done immediately after sowing and frequently during the seedling production period. Results from studies of germination and emergence of potato seedling have shown these processes to occur 5-10 days after sowing (Malagamba, 1982; Accatino and Malagamba, 1982) or even after more than 10 days (Sadik, 1979; Accatino, 1979; CIP, 1979). It has been observed that seedling emergence is influenced mainly by the progeny itself and the soil temperature. In hot climates, seedling emergence takes longer because the temperatures are above the optimum (15-20°C) one for TPS germination.

Seedling growth progresses slowly during the first 20 days after sowing (Malagamba, 1982). This period coincides with the development of the first pair of true leaves, then the growth increases very fast and reaches a stage of transplanting.

2.11 Factors Affecting Seedling Survival in the Field.

Seedling survival has been found to be greatly affected by weather condition, capacity of root regeneration, stage of transplanting, genetic potential of the seed and method of transplanting. Transplanting during proper weather conditions has been found to enhance transplant survival (CIP, 1983b; Alacho, 1986). Temperature has been found to have a large influence on seedling establishment (Malagamba, 1982; Accatino and Malagamba, 1982; Sadik, 1983; Alacho, 1986). High day temperature and lack of water considerably reduce the number of transplant surviving. For successful field establishment after transplanting especially in warm tropical areas, potato seedlings should overcome limitations related to high temperature stress and sub-optimal management practices under low input agricultural conditions. Weather condition has been found to contribute to wide variation in the survival rates between seasons (Alacho, 1986).

Therefore it is advised that in hot climates transplanting should be done late in the afternoon to facilitate seedling recovery and to prevent wilting. Temperatures can be reduced by using straw mulch to cover the ridges or any other materials during the first 10 days after transplanting to improve seedling survival (Malagamba, 1982). On the other hand the author explained that in the cool climates plastic sheets or plastic mulch have been used to cover the ridges so as to increase the soil temperatures.

It has been observed that, seedling survival can be improved by reducing the excessive heat from direct solar radiation, but identification of TPS lines with the capacity of withstanding the transplanting shock is the best solution (Malagamba, 1982). However, while CIP is working on such lines, production of potato from the current available TPS lines continues.

Studies in tomato plants have reported that the capacity of seedlings for immediate regeneration of adventitious root system is a most highly responsible factor for transplant survival (Arteca, 1982; Aung, 1982). In agronomic research in potato, the regeneration of roots after transplanting has been identified as a major factor conveying increased field survival of transplants (CIP, 1985). New root formation in the period immediately after transplanting has been found to account for 87% of the response in recovery after transplanting (Malagamba, 1984). High soil temperatures have been related to reduced root development which in turn reduces growth of the tops because of limited capacity for nutrient uptake (Malagamba, 1988).

Genetic of the seed can also affect seedling survival. Hybrid progenies have shown a higher recovery rate from transplanting shock than the op progenies (CIP, 1980; 1985; Kidane-Mariam et al., 1984).

2.12 Age of Seedlings at Transplanting.

In many vegetable crop raised through production of seedlings in seedbed, age of seedling at transplanting is very important because it can affects transplant survival and thus final yield. Different stages of transplanting TPS seedlings have been individually reported in various studies under different climatical conditions. For example Accatino (1980) and Li and Shem (1980) considered height of seedling as transplanting index. Seedlings were transplanted when they were 6-12 cm high (Accatino, 1980) and when 15-20 cm high (Li and Shem, 1980). Accatino (1979) found that seedlings 9-12 cm high yielded significantly more than the shorter ones of the same progeny. Generally it has been observed that taller seedlings have the tendency of giving higher tuber yields (CIP, 1979, 1980). Another transplanting index which has been used by several researchers is the time in terms of number of days or weeks after sowing. Upadhya (1980) in India transplanted seedlings 4-5 weeks after sowing. After this age the number of true leaves of seedlings were ranging between 4 and 5. It has been observed that when seedlings are produced under good conditions, they are normally be read after 35 days after sowing and at this stage the seedlings have developed their fifth leaf while the height is between 8-10 cm high (Malagamba, 1982).

Accatino and Malagamba (1982) considered climatic conditions as a determining factor of stage when TPS seedlings can be transplanted. They tried to elaborate that, transplanting is done when the seedlings are about 10 cm high, when they are at the fourth to fifth leaf stage. Further they explained that this stage is reached in about 4 weeks in warm climate and up to 6 weeks in cooler environments.

Good results have been obtained in San Ramon, a hot-humid mid-elevation tropical location and in Lima when seedlings were transplanted 35-40 days after sowing (Malagamba, 1983). In these hot area's experiments, row of maize planted 70 days before transplanting were used as shade to reduce the high temperature stress.

In Kenya, seedlings have been transplanted at the age of 4 and 6 weeks with good results (Kidane-mariam, unpublished results). Alacho (1986) in Kenya transplanted seedlings from both glasshouse and field nursery at the age of 5 and 6 weeks, respectively. In this study the seedlings at the age of 5 weeks after sowing gave better results than the seedlings transplanted at the age of 6 weeks after sowing. In Ethiopia, Mussa (1993) evaluated the effect of age of seedling on yield components and tuber yield and found that seedlings transplanted at the age of 35 days after sowing had a significantly higher values of percent plant survival and total fresh and dry tuber yield. Also seedlings have been found to be ready for transplanting after 6 weeks of germination for both dry and rain seasons (Tuku, 1994).

From different studies in other vegetables, stage of transplanting has been found to have an influence on the final yield. Observations made in onions and pepper showed that the yield increases with seedling age up to a certain point (Vachnani and Patel, 1989; Choe and Lee, 1990). In leek it has been observed that early planting in the season give better yield if 80 day old seedlings are used and when using much older seedlings for later planting the yield was reduced by 40% (Moneka, 1990). In Bangladesh, Islam et al., (1989) when working with cabbage obtained the highest yield from seedlings transplanted at the age of 28 days and lowest yield from 42 days old seedlings.

However, it has been observed that if potato seedlings stay longer in the seed bed before transplanting a considerable number of tubers start to develop (Malagamba, 1983). When large number of tubers are initiated before transplanting yield reduction usually occur (Accatino and Malagamba, 1982). Work done at the CIP, (1980) indicated that seedlings transplanted before tuber initiation can yield more than those with small tubers. Therefore it will be wise if potato seedlings are ready for transplanting before a considerable number of tubers start to develop. Thus studies on ages for transplanting TPS seedlings remain important.

2.13 Pricking-out of Seedlings

Pricking-out is a management operation whereby seedlings are transplanted from the original seedbed or trays and transplanted to another seedbed or tray at a predetermined spacing few weeks after emergence. The main aim of this exercise especially in TPS research is to give the seedlings enough space for establishment so that they can be transplanted with enough substrate adhered to the roots (root block). In this practice wastage of seedlings is minimized as compared to the non-pricked seedlings.

Pricking out practice is commonly done by CIP researchers at Kabete Field Station to produce seedlings for transplanting. Results obtained from non-pricked seedlings (28 DAS) established on trays at Kabete field Station revealed that higher tuber yield can be obtained without pricking-out the seedlings (Kidane-Mariam, 1994 Unpublished data). The main requirement in the practice is that the seedlings should be protected from heavy rains for the first few weeks until the seedlings get established in the field.

2.13.1 The effect of transplanting TPS with or without a ball of soil on their roots on plant survival, total and marketable tuber yield.

Method of transplanting has been reported to have a great effect on seedling survival and establishment. It has been observed that in order to reduce shock at transplanting due to adverse conditions, TPS seedlings can be transplanted with a ball of soil adhered on their roots (CIP, 1983a). From research findings however, TPS seedlings can be transplanted with or without a ball of soil on their roots. Upadhya (1980) reported 70-75% transplant survival when the seedlings were transplanted without root blocks (bare roots) compared with 90% survival when transplanted with root blocks. Root block of proper structure promotes growth of adventitious roots at the expense of the tops, a favourable characteristics for transplanting. Under farmers' level when the two methods (with or without root blocks) were compared both total and marketable tuber yield were higher from those seedlings that were transplanted with root blocks than that were transplanted with bare rooted (Malagamba, 1984).

A conflicting evidence was found by Accatino (1979) as to the effect of bare or covered roots on survival rates and tuber yields. He obtained higher survival and tuber yield in covered roots whereas CIP (1979, 1983b) found no differences in plant survival when transplanting seedlings with or without a soil plug around the roots under adequate moisture conditions of Lima, Peru. However, under heat stress conditions, covered roots reduced the transplant shock hence higher survival rates and tuber yields. It has been observed that 80% of the total root length is lost with bare-rooted seedlings even under careful transplanting (Sattelmacher and Minzeman, 1984; CIP, 1985). Alacho

(1986) at Kabete Field Station found that seedlings whose roots were covered with enough substrate had a higher survival rate than the bare-rooted ones.

Depth of transplanting can affect the survival of seedling depending on weather condition. When transplanting is done with all leaves above the ground more seedling survival were obtained (Accatino, 1979). However, Accatino and Malagamba (1982) reported that in cool areas in seasons, such as winter season in Lima, Peru seedling survival was still adequate when the seedlings were transplanted either with all the leave above the ground or with basal leaves buried or with only the top leaves above the ground. They observed that at San Ramon, Peru, where temperatures were higher (42°C) there was a poor survival for seedlings transplanted with only top leaves above the ground.

2.14 Field Management of Potato Transplants

Poor performance of potato transplant in the field can be attributed to a number of factors such as condition of the field at transplanting, poor agronomical practices, climatic or environmental stress factors such as high temperatures and heavy rainfall.

Before transplanting the field should be well prepared, properly fertilized and adequately watered. Accatino and Malagamba (1982) recommended that the field should be well prepared to avoid presence of huge clods and to facilitate the construction of ridges. It is well known that potato seedlings are sensitive to the trauma of transplanting (Sadik, 1983; Malagamba, 1982; CIP, 1983a). Malagamba (1982) advised that the difference in moisture content from the seedbed to field should be kept to a minimum to avoid the shock of transplanting and also the time between lifting the seedlings from the seed bed and placing them in the soil must be as short as possible. It has been observed that if the seedlings are raised vigorously and be well hardened few days before transplanting by withholding the rate of watering and by exposure to full sunlight, the severity of transplanting shock can be reduced (CIP, 1981, 1983a; Accatino and Malagamba, 1982; Sadik, 1983).

Seedling survival and growth have been found to be increased by shading them with companion crops, straws or other objects (CIP, 1981). Although it has been observed that transplanting shock can be reduced by transplanting seedlings with soil covered roots by using compost cubes, banana leaf cups or thin plastic trays (CIP, 1983a; Malagamba,1982) the practicability of this method to small farmers is questionable.

Seedling density is one of the agronomical factors to be considered during transplanting. Different seedling densities have been studied and there are several conclusions. However the adoption as to how many seedlings to be planted per hill rely on the economic potential contributed to the final results. Accatino (1979) noted that the number of seedling per hill determined the yield per hill thus yield per hectare. Upadhya (1980) observed that it was necessary to have more seedlings per hill from nursery as compared to those raised in fabricated blocks or plastic cups whose survival was superior. CIP (1979) reported that three seedlings per hill appeared to be the optimal for tuber yield. Higher yields have been obtained when 4 or 5 seedlings were transplanted per hill (CIP, 1980; Accatino and Malagamba, 1982).

In Ethiopia higher yields have been obtained from hybrid and op progenies when single seedling was planted per hill in the dry season (Tuku, 1994). International potato center researchers, in Kenya have adopted single seedling transplanting per hill in the TPS experiments. Generally the recommended spacing for single potato plant per hill is 30 X 75 cm in Kenya Alacho (1986) when studying the effect of density on seedling survival found that seedlings transplanted singly per hill had a significantly higher survival rate than those clamped per hill at 30 cm apart within the row.

Hilling operation is one of the cultural practice done to ensure good growth and performance of the crop in terms of tuber yield. For potato seedling it is recommended to have a first small hilling 10 to 15 days after transplanting so as to provide better condition for the rooting zone. The subsequent hilling after the first one are meant to support seedling transplants and cover the stolon exposed to sunlight. Final hilling is recommended to be done when the transplant are 20-25 cm high (Accatino and Malagamba, 1982). Alacho (1986) observed that hand weeding during hilling satisfactorily control weeds.

Insect-pests and diseases can cause considerable damage during crop establishment. Potato grown from TPS are attacked by the same insect-pest and diseases similar to those found on potato from seed tubers (CIP, 1981). Cutworms are the most damaging to young seedlings in the field. Carbamate when applied as side dressing in the soil have been found to offer good protection in desert areas while in the tropical area with high rainfall cutworms, aphids, leaf hoppers, leaf minors, flies, potato tuber moth and leaf beetles can be controlled effectively by the use of foliar sprays (CIP, 1981). Benomyl and Pentachloronitrobenzene (PCNB) sprays have given good control to fungal diseases when applied to the seedling immediately after transplanting.

2.15 Potential Tuber Yield From TPS

Potential yields from TPS can be very high when growing conditions are optimal for potato production. Li and Shem (1979) reported a total yield of up to 38 tons per hectare in the Southwest mountain region of China where ideal temperatures and rainfall are present. Bedi (1979) obtained yields ranging from 20.2 to 47.2 tons per hectare from direct sown seeds. In another experiment they compared yield from transplants and direct sown seeds and found that the mean total yield of 10 seed progenies ranged from 15.6- 39.6 tons per hectare by direct seeding and 9.1-35.8 tons per hectare by transplanting. Malagamba as quoted by Sadik (1983) compared the total and marketable tuber yield of 75 hybrid seed and op progenies by transplanting. From the best progenies obtained marketable tuber yields ranging from 26.8 to 40.0 tons per hectare for hybrid progenies and 16.6 to 25.5 tons per hectare from op progenies. The total tuber yield ranged from 30.9 to 44.8 and 21.2 to 30.9 tons per hectare for the hybrids and op progenies, respectively. Wiersema (1984) found that seedling transplants gave the lowest yields of 10.9 - 19.1 tons per hectare compared to 18.1 - 28.1 tons per hectare from seedling tubers.

2.17 Tuber Size Distribution

In some research results, different categories are used to differentiate the marketable and unmarketable tuber yields as one of the criteria considered in tuber quality. Gray and Hughes (1978) suggested that while dealing with tuber quality, size grade 28-45 mm in diameter can be sold as seed size II to growers or canning factories while the tubers of grade >45 mm can be sold as seed size I or in the open market for consumption. Alacho (1986), when dealing with TPS and tuber clones, obtained the largest TPS tuber yield in the size category 28-45 mm and the least in the category >45 mm as compared to tuber clones which had the largest tuber yield in the size category >45 mm and least in size category <28 mm.

Generally yields reported in literature show a progression with time as a result of the development of better plant management practices and the availability of better seed progenies. These research show that reasonable tuber yields can be realized with the use of seedling transplants. Therefore, there is a possibility that when this method is improved particularly with the use of hybrids acceptable yields would be achievable.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Site and Location

The experiment was carried out in two phases at Kabete. Field Station, Faculty of Agriculture. University of Nairobi which is located at 1°14'South and 36°44'East. The site elevation is about 1900 metres above sea level.

3.2 Weather Condition and Site Soil Characteristics

The site has a bimodal rainfall distribution with long and short rains occurring from March to June and October to December, respectively. The mean annual rainfall is approximately 1000 mm and average monthly maximum temperature is approximately 23 °C (Siderius and Muchena, 1977).

The weather condition during the experimental seasons is presented in Appendix 1. During the short rains total rainfall was 768.4 mm and average temperature was 18.9 °C. The highest amount of rainfall was obtained in November, 1994 (301.4 mm) and the lowest was obtained in January, 1995 (8.6 mm). During the long rains total rainfall was 673.5 mm most of which concentrated in the first three months. The highest amount of rainfall was obtained in April, 1995 (259.7 mm) while the lowest was obtained in July, 1995 (18.2 mm). Average temperature in this season was 17.5 °C.

Soils of Kabete farm are dark reddish brown clay, derived from Kabete and Limuru Trychytes which are volcanic in nature, with Kaolin being a dominant clay mineral

(Nyandat and Michieka, 1970; Siderius and Muchena, 1977). The soil are deep and well drained and allow good root development. Available nutrients range from deficiencies to fairly high levels (Nyandat and Michieka, 1970).

The soil characteristics of the sites are presented in Appendix 2. The site used during the short rains had more fertile soils than the site used during the long rain season. Total nitrogen was twice as much in the short rains (0.25%) when compared to the long rains (0.12%). The organic matter was 4.02 and 1.99% in the short and long rains, respectively.

3.3 Planting Materials (Progenies)

True potato seeds (TPS) were used as propagating material. These included one hybrid progeny (HP) designated as KP 94865 and one open-pollinated (OP) progeny designated as KP 94954 (CIP 720084). Seeds were obtained from CIP Regional office for Tropical Africa based at Nairobi, Kenya. The hybrid progeny was obtained from the cross of CIP 800946 X 800945. It is an early maturing progeny that takes about 90 - 100 days to maturity after transplanting when using seedlings. The open-pollinated progeny mature within 100 days after transplanting when using seedlings.

Both TPS were produced by CIP during the long rains of 1994 (between the months of February and July, 1994). TPS seeds used during the long rains were stored in a CIP's cold room at a temperature below 4°C for a period of five months.

3.4 Experimental Seasons

The experiment was conducted in two seasons. The first one was during the short rains of 1994/1995 (October to March 1995). The second one was during the main cropping season of 1995 in the months of April to August.

3.5 Treatments and Experimental Design.

In this experiment three factors were studied. The first one was Progeny with two levels (Hybrid and Open-pollinated progenies). The second factor was Pricking-out of seedlings with two levels (Pricked-out or not). Seedlings were transplanted either directly from their original trays to the field or first sown in a tray, transplanted to another after three weeks of sowing and then transplanted to the field. The third factor was Age of seedling - 28, 35 and 42 days after sowing. The three factors and their levels were combined factorially (2 x 2 x 3) to give a 12 treatment combinations.

A completely randomized design was used to produce the seedlings in a glasshouse for transplanting into the field. This was replicated twice thus giving a total number of 24 trays. Single tray measuring 45 x 60 cm was regarded as an experimental unit.

In the field a randomized complete block design experiment with three replications was used.

Each plot contained 4 rows of 12 plants each. The length of the plot was 3.6 m and the width was 3.0 m making the total plot area to be 10.8 m^2

3.6 Seedling Production

3.6.1 Dormancy breaking

The dormancy of the seed had not yet been broken naturally when the seeds were acquired. Gibberellic Acid-3 (GA_3) at 1500 ppm was used to break the dormancy. Seeds were soaked in GA_3 solution for 24 hours then dried and sown immediately.

3.6.2 Preparation of substrate.

In this study, substrate consisting 2:1:1:1:1 mixture of forest soil, gravels, farm yard manure, sand and coffee husks, respectively, was used to produce the seedlings in the glasshouse. The components were mixed thoroughly using a hand spade. It is well documented that substrate depending on its origin, may contain high population of parasitic nematodes, insects, weed seeds and soil-borne pathogens (Accatino and Malagamba, 1982; Malagamba, 1982; CIP, 1985). Therefore, the substrate used was sterilized by steaming and left to cool before use.

3.6.3 Sowing procedure

Substrate was put in trays to a depth of about 10 cm. Before sowing the substrate was watered with little amount of water. Seeds were sown in shallow furrows of about 1.0 cm deep and were spaced at about 5.0 cm. The seeds were drilled in the furrows, covered with a thin layer of substrate and then watered immediately. Watering was done regularly, once everyday, using a watering can in order to maintain adequate moisture content.

3.6.4 Sowing dates.

In both season three sowings were done according to the proposed ages of transplanting. The first sowing was for the seedlings to be transplanted after 6 weeks of sowing, second and third sowings were done at one week interval after the first one for transplanting at 5 and 4 weeks age, respectively.

In both seasons, seedling emergence commenced 7 days after sowing and was completed after 14 days.

3.6.5 Pricking-out

In the pricking-out treatments pricking out into new tray was done three weeks after emergence at a spacing of 10 x 10 cm in one half of the trays. In the second half of trays the seedlings were maintained for a further 7 - 21 days depending on age at transplanting. Seven days before transplanting seedlings were subjected to direct sunlight and less moisture in order to harden them.

3.7 Transplanting and Field Management

3.7.1 Field operation.

Different fields were used in both seasons. The fields were previously under common beans and were prepared by first ploughing by a tractor drawn disc-plough and then harrowing and levelling manually. Field layout was done one day before transplanting.

3.7.2 Transplanting procedure

When necessary, plots were irrigated two days before transplanting. This was to obtain similar moisture content similar to that of the transplant substrate in the seed-bed.

Di ammonium Phosphate (DAP) fertilizer was applied at transplanting at the rate of 500 kg/ha. In order to reduce the transplanting shock, trays containing the transplants were carried to the field where the transplant were lifted and planted immediately. One seedling was planted per hill in both seasons. Transplanting was done by hand at a spacing of 75cm between rows and 30 cm within rows. Thorough watering was done after transplanting a plot.

3.7.3 Field management

During the short rains there were no rains at the time of transplanting. Transplanted seedlings were therefore watered using watering cans for ten days. During the long rains there were heavy rains at the time of transplanting thus there was no need of watering the seedlings.

Weeds were regularly controlled manually using hand hoe, forked hoe and/or hand pulling. First hilling was done 3 weeks after transplanting while the second one was done 2 weeks later. Hilling in later stages was done so as to cover the stolon from being exposed to direct sunlight. No hilling was done after complete ground cover by the crop.

Crop protection against insect pests and diseases was done regularly. After transplanting, the transplants were sprayed with a mixture of fungicide (Dithane M45) and insecticide (Decis 25EC) at a rate of 2 kg/ha and 1000 ml/ha, respectively, in order to control the plants from being attacked by fungal diseases, especially late blight caused by *Phytophthora infestans* and insect pests such as cutworms.

3.8 Data Collection and Sampling Procedures

3.8.1 Greenhouse data

In the greenhouse where seedlings were raised, number of days to seedling emergence were recorded. One day before transplanting, seedling vigour, height and number of true leaves per plant were determined. Seedling vigour was determined by visual scoring using scores 1-5, (1 =least vigorous, 3= average and 5= most vigorous), while seedling height and number of true leaves were determined from an average of 10 plants per tray.

3.8.2 Field data

3.8.2.1 Seedling survival

Seedling survival was determined by counting surviving plants at establishment (14 days after transplanting) and at maturity (104 days after transplanting). The data were recorded as a percentage of seedling transplanted per plot.

3.8.2.2 Growth vigour.

This was determined from both visual observation and destructive sampling at 30 and 60 days after transplanting. In visual observation, scores 1-5 (as in the greenhouse) were used to rate the vigour. Vigour in the destructive sampling was determined on the basis of fresh and dry weights of the tops. Three plants per plot sampled randomly were used to estimate the mean value of these parameters per plant. Samples for dry matter determination were dried in an oven at 100°C for 30 hours or until a constant weight of each sample had been obtained.

3.8.2.3 Data at harvest.

Harvesting was done 104 days after transplanting. Number of tubers per plant were determined by obtaining a mean from 5 plants selected randomly within the harvesting area.

Tuber sizes were categorized into 3 parts: Sizes <25 mm in diameter were considered unmarketable (chats); 25-45 mm in diameter were considered marketable as seed potatoes; and >45 mm in diameter were considered marketable as ware potatoes. Total marketable tuber yield was determined by weighing all the tubers with sizes greater than 25 mm while the rest were considered as unmarketable tubers. Total tuber yield was determined by adding the weights of marketable and unmarketable tuber yields. Yield in all categories was converted on hectare basis.

3.9 Data Analysis

Data collected were subjected to statistical analysis using a micro-soft computer. MSTAT-C program. Analyses included Analysis of Variance (ANOVA) and mean separation by Duncan's Multiple Range Test (DMRT) using 5% level of significance. Data for plant survival percentage were not transformed because they did not fall within the ranges (0 - 25 or 80 - 100) for transformation according to Steel and Torrie (1980)

CHAPTER FOUR

RESULTS

4.1 The Effect of Potato Progeny, Age and Pricking-out of True Potato Seedlings on Growth Parameters.

4.1.1 Seedling growth characteristics at transplanting.

Table 1 presents number of true leaves, seedling height and vigour of potato progenies at different ages at the time of transplanting during the short and long rains. The table shows that hybrid progeny had produced more leaves than open-pollinated progeny but the difference was significant only during the short rains. The table further shows that hybrid progeny produced seedlings that were significantly taller in both seasons and seedlings that were significantly more vigorous only during short rains. Number of true leaves, seedling height and seedling vigour significantly increased with increase in seedling age in both seasons. In general, older seedlings (42 days) in both progenies were more vigorous and had more number of true leaves than the younger ones (28 and 35 days).

The interaction between pricking-out and seedling age for seedling height at transplanting was significant (Figure 1 & 2). Pricking-out effect increased with an increase in seedling age for seedling height and decreased with an increase in seedling age for seedling vigour .

Table 1. Effect of true potato progeny and seedling age on number of true leaves, height and vigour at transplanting during the short and long rains 1994/95 cropping season.

Treatment	Number of true leaves/plant		Seedling height (cm)		Seedling vigour[1]	
	Short rains	Long rains	Short rains	Long rains	Short rains	Long rains
Progeny						
KP 94954(OP)	3.5a	2.6b	6.7b	5.6b	3.2b	3.2a
KP 94865(HP)	3.8a	3.4a	9.3a	6.1a	4.0a	3.8a
Seedling age (days)						
28	2.7c	2.2c	4.2c	2.8c	2.8c	2.8b
35	3.5b	3.1b	7.1b	6.1b	3.4b	3.1b
42	4.9a	3.8a	12.7a	8.7a	4.6a	4.5a
C.V (%)	10.9	15.8	2.7	5.5	12.8	20.4

[1] 1 = Least vigorous 3 = Average 5 = Most vigorous

Means (seedling age effect) followed by same letter within same column do not differ significantly (P=0.05) according to Duncan Multiple Range Test.

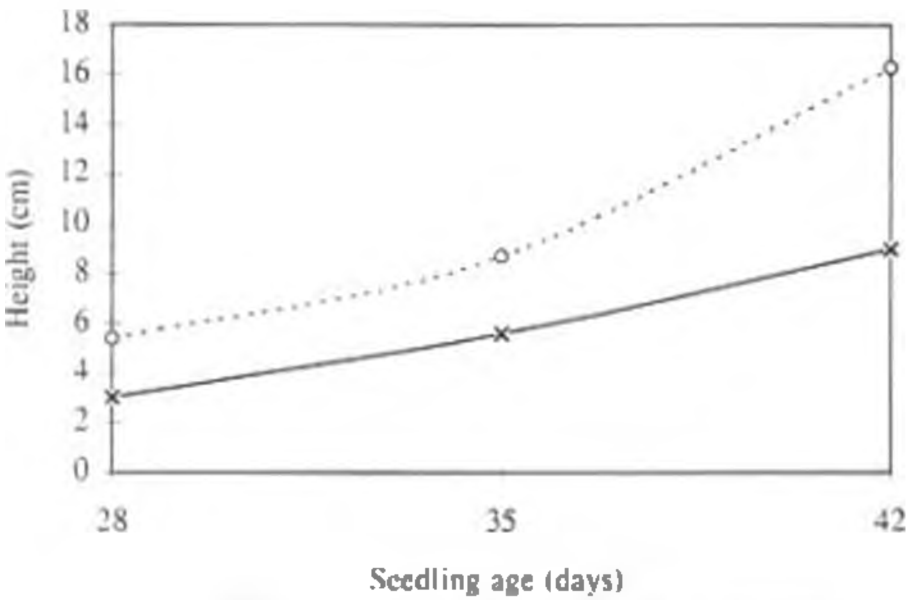

Figure 1. Interaction between pricking-out and age for seedling height during the short rains 1994/95 cropping season

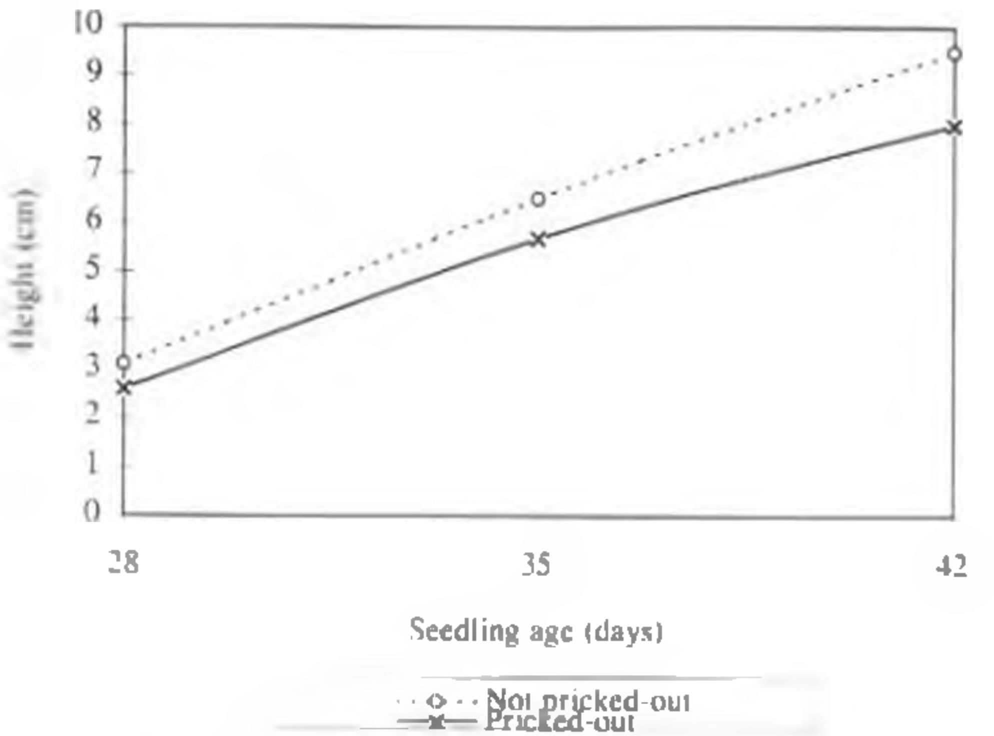

Figure 2. Interaction between pricking-out and age for seedling height during the long rains 1994/95 cropping season

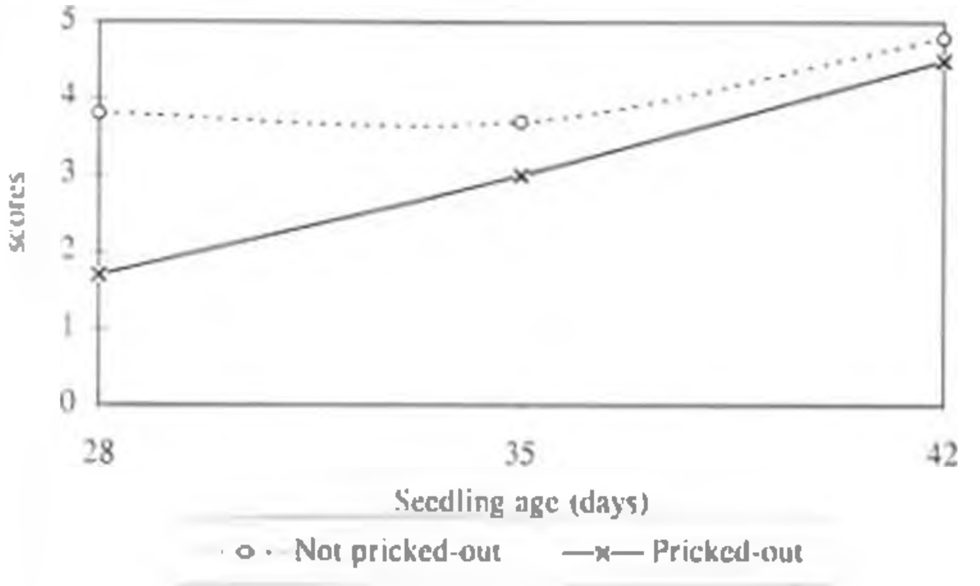

Figure 3. Interaction between pricking-out and age for seedling vigour during the short rains 1994/95 cropping season

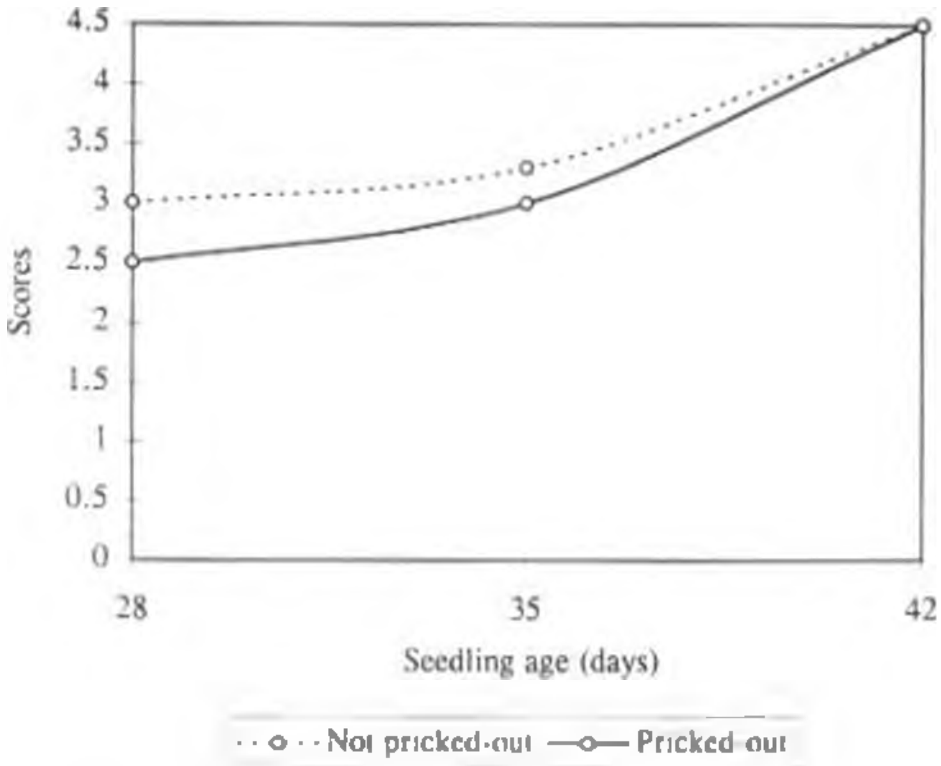

Figure 4. Interaction between pricking-out and age for seedling vigour during the long rains 1994/95 cropping season

4.1.2 Plant survival.

The evaluation on plant survival was made at seedling establishment (14 days after transplanting - DAT) and at maturity (104 DAT) during the short and long rains (Table 2). During establishment short rains had greater survival rates (over 90%) compared to long rains (less than 80%). This trend was maintained at maturity although the values were respectively lower. At maturity 42 days old gave significantly higher plant survival rate than both 28 and 35 days old which had similar rates.

Pricking-out significantly increased plant survival to 86.1 from 78.0% at plant establishment (Table 3). However, the effect was significant during the short rains only. At maturity stage pricking-out significantly increased plant survival rate to 71.7 from 64.3%.

Table 2. The effect of age of true potato seedlings on plant survival at plant establishment and maturity during the short and long rains 1994/95 cropping seasons

Seedling age (days)	Plant survival (%)			
	At plant establishment (14 DAT)		At maturity stage (104 DAT)	
	Short rains	Long rains	Short rains	Long rains
28	93.8a	65.1b	78.7a	49.8b
35	93.2a	67.0b	77.6a	52.6b
42	92.2a	80.9a	76.1a	72.9a
C.V (%)	5.9	22.6	10.1	19.7

Means followed by same letter within the same column do not differ significantly (P=0.05) according to Duncan Multiple Range Test.

Table 3. The effects of pricking-out of true potato seed seedlings on plant survival at plant establishment and at maturity during the short and long rains 1994/95 cropping season.

Pricking-out	Plant survival (%)			
	At plant establishment		At plant maturity	
	Short rains	Long rains	Short rains	Long rains
Non-pricked	89.6b	66.4	74.7b	53.8b
Pricked-out	96.5a	75.6	80.2a	63.1a
	*	N.S	*	*
C.V(%)	5.9	22.6	10.1	19.7

* = F-test significant at P=0.05. N.S = Not significant.
Means followed by same letter within the same column do not differ significantly (P=0.05) according to Duncan Multiple Range Test.

4.1.3 Plant vigour.

Plant vigour in the field 60 DAT was not affected by the main effects of seedling age and pricking-out of seedlings. The interactions between seedling age and pricking-out, seedling age and progeny, pricking-out and progeny and seedling age x pricking-out x progeny were not significant. However, the effect of progeny was significant. Hybrid progeny gave higher scores (4.2 and 4.4) than open-pollinated ones (3.2 and 3.5) during the short and long rains, respectively.

Seedling age significantly affected foliage fresh and dry weight production 60 DAT, but only during the long rains (Table 4). Seedlings transplanted at the age of 35 and 42 days gave significantly higher foliage fresh weight than those seedlings transplanted at the age of 28 days. Foliage dry weight had a tendency of increasing with an increase in seedling age during the long rains.

Pricking-out significantly increased both foliage fresh and dry weight (Table 5). Progenies were also significantly different. Hybrid progeny produced significantly more fresh (678.5 g/plant) and dry (54.5 g/plant) than the open-pollinated progeny.

Interactions between progeny and pricking-out, progeny and seedling age, pricking-out and seedling age and between progeny x pricking-out x seedling age were not significant for foliage fresh and dry weights

Table 4. Effect of age of true potato seedlings on foliage fresh weight at 60 days after transplanting during the short and long rain rains (1994/95 cropping season).

Age of seedling (days)	Foliage fresh weight per plant (g)		Top foliage dry weight per plant (g)	
	Short rains	Long rains	Short rains	Long rains
28	440.4a	369.0b	40.3a	29.3c
35	617.1a	602.9a	55.0a	42.4b
42	623.6a	703.6a	54.4a	55.3a
C.V(%)	36.2	38.9	33.0	27.7

Means followed by same letters within same column do not differ significantly (P=0.05) according to Duncan Multiple Range Test.

Table 5. Effects of pricking-out of true potato seedlings on foliage fresh and dry weight 60 days after transplanting during the short and long rains (1994/95 cropping season).

Pricking-out	Foliage fresh wt/plant (g)		Foliage dry weight/plant (g)	
	Short rains	Long rains	Short rains	Long rains
Non-pricked	466.8b	504.4b	41.1b	34.9b
Pricked	653.9a	612.6a	58.6a	49.7a
C.V(%)	36.2	38.9	33.0	27.7

Means followed by same letter within the same column do not differ significantly (P=0.05) according to Duncan Multiple Range Test.

4.2 The Effect of Age and Pricking-out of True Potato Seedlings on Tuber Characteristics.

4.2.1 Mean Tuber Yield Per Plant.

The main effects of seedling age and pricking-out were not significant for mean tuber yield per plant. Mean tuber yield per plant however was significantly affected by progeny type but only during the short rains. Hybrid progeny gave more overall mean tuber yield per plant (1.0 kg/plant) than the OP (0.8 kg/plant).

No significant interactions were obtained between progeny and seedling age, progeny and pricking-out and progeny x seedling age x pricking-out.

Number of tubers per plant was not affected by the various factors in both seasons.

4.2.2 Tuber size grading.

Table 6 presents tuber size grading at different seedling ages. Seedling age did not significantly affect all tuber size categories in the short rains whereas categories of tubers with diameter <25 and between 25 - 45 mm were not affected during the long rains. More tubers with diameters between 25 - 45 mm were obtained followed by tubers with diameters >45 and <25 mm in that order. A significant seedling age effect was observed in category of tuber sizes with diameters >45 mm during the long rains only. In this season, younger seedlings (28 days old) gave significantly lower proportion (21.5%) of ware tubers than the older seedlings (35 and 42 days old) which gave 26.9 and 29.1%, respectively.

The effects of pricking seedlings did not significantly affect tuber size grading in all categories in both seasons.

When comparing the two progenies at different seedling age group, hybrid progeny had significantly higher percentage of tubers with diameter >45 mm (31.5%) than OP (26.4%). Open pollinated progeny gave higher percentage (15.1 and 58.6%) for tubers with diameters <25 mm and between 25 - 45 mm, respectively, than hybrid progeny which gave 13.7 and 54.9%. All interactions between the factors studied were not significant for tuber size grading in all categories in both seasons.

Table 6. Effect of age of seedlings on tuber size grading of potatoes during the short and long rains 1994/95 cropping season.

Seedling age (days)	Diameter					
	Short rains			Long rains		
	< 25 mm (%)	25 - 45 mm (%)	>45 mm (%)	< 25 mm (%)	25 - 45 mm (%)	> 45 mm (%)
28	10.6a	56.2a	33.2a	19.7a	58.7a	21.5b
35	12.0a	56.7a	31.2a	16.2a	56.8a	26.9a
42	11.5a	57.1a	31.4a	16.1a	54.8a	29.1a
C.V (%)	25.c	5.7	8.0	37.1	13.6	23.1

Means followed by same letters within the same column do not differ significantly (0.05) according to Duncan Multiple Range Test.

4.3 The Effect of Seedling Age, Pricking-out and Progeny of True Potato Seedling on Tuber Yield

4.3.1 Total Tuber Yield.

Seedlings transplanted at the age of 42 days significantly out-yielded the rest in total tuber yield during the long rains but not during the short rains (Table 7). During the long rains using older seedlings (42 days old) gave significantly higher total tuber yield (18.5 t/ha) than using younger ones at the ages of 28 and 35 days which produced 11.3 and 13.6 t/ha, respectively.

Pricking-out generally increased the total tuber yield from 28.2 to 34.4 t/ha and 13.2 to 15.7 t/ha during the short and long rains, respectively (Table 8).

Table 7. **Effect of age of true potato seedlings on total tuber yield during the short and long rains of 1994/95 cropping season.**

Seedling age (days)	**Total tuber yield (t/ha)**	
	Short rains	Long rains
28	31.6a	11.3b
35	29.7a	13.6b
42	32.5a	18.5a
C.V (%)	15.7	18.9

Mean followed by same letter within the same column do not differ significantly (P=0.05) according to Duncan Multiple Range Test.

Table 8. **Effects of pricking-out of true potato seedlings on total tuber yield during the short and long rains of 1994/95 cropping season.**

Pricking-out	Total tuber yield (t/ha)	
	Short rains	Long rains
Non-pricked	28.2b	13.2b
Pricked	34.4a	15.7a
C.V (%)	15.7	18.9

Mean followed by same letter within the same column do not differ significantly (P=0.05) according to Duncan Multiple Range Test.

4.3.2 Marketable tuber yield

The seedling age effect , however, was observed only in the long rains (Table 9) when seedlings at the age of 42 days produced significantly more marketable tuber yield (15.7 t/ha) than the other ages. Seedlings transplanted at the age of 35 days significantly out-yielded younger seedlings (28 days) with 11.2 versus 8.6 t/ha. However, the proportional of marketable yield was unaffected by seedling age in both seasons.

During the short rains pricking-out significantly increased marketable tuber yield to 30.6 from 25.1 t/ha (Table 10). The effect was not significant during the long rains.

Table 9. Effect of seedling age on marketable tuber yield of potato during the short and long rains of 1994/95 cropping season.

Seedling age (days)	Marketable tuber yield (t/ha)		Marketable tuber yield (%)	
	Short rains	Long rains	Short rains	Long rains
28	28.4a	8.6c	89.4a	82.5a
35	26.3a	11.2b	88.0a	83.8a
42	28.9a	15.6a	88.5a	84.0a
C.V (%)	17.3	19.5	4.1	6.0

Means followed by same letter within the same column do not differ significantly (P=0.05) according to Duncan Multiple Range Test.

Table 10. Effect of pricking-out of true potato seedlings on marketable tuber yield during the short and long rains (1994/95 cropping season)

Pricking out	Marketable tuber yield (t/ha)		Marketable tuber yield (%)	
	Short rains	Long rains	Short rains	Long rains
Non-pricked	25.1b	11.3a	89.0a	84.2a
Pricked	30.6a	12.4a	87.9a	82.7a
C.V(%)	17.3	22.3	4.1	6.0

Mean followed by same letter within the same column do not differ significantly (P=0.05) according to Duncan Multiple Range Test.

CHAPTER FIVE

5.0 DISCUSSION

5.1 The Effect of Progeny, Age and Pricking-out of True Potato Seedlings on Plant Survival.

There were more plants surviving at establishment (14 days after transplanting) than at maturity (104 days after transplanting) at all seedling ages. Some of the plants died after seedling establishment probably due to poor root regeneration which could have led to poor recovery rate from transplanting shock and thus realizing less plants surviving at maturity. Results show that the seedling age effect on plant survival was not significant during the short rains signifying that all seedlings had probably more or less similar rates of recovering from transplanting shock because of good root regeneration which is important in water absorption and nutrients uptake from the soil and therefore resulting into healthier plants. New root formation in the period immediately after transplanting have been found by other researchers to contribute positively into plant survival (Malagamba, 1984; CIP, 1985)

During the long rains older seedlings (42 days) had better survival rate than those of younger ages probably because these seedlings at the time of transplanting were more vigorous with more number of true leaves than the others. By having more true leaves which are more vigorous, more light could have been intercepted and thus increasing the photosynthesis rate at early stages of plant development hence more plant surviving. Major environmental factor which might have contributed to poor plant survival in young seedlings was the heavy rains experienced at the time of transplanting. Although this was an isolated case it interfered with the establishment process of the young seedlings which were shorter than the older ones at transplanting due to observation that they were submerged for at least two days. By being shorter and submerged, physiological processes such as photosynthesis might have been affected because the foliage part which is important in intercepting the light could not function in a normal way and thus resulting into poor root regeneration and poor plant anchorage.Since at early stages there was no good root regeneration and good root anchorage some plants could not recover from transplanting trauma due to inefficient water absorption and nutrient uptake. Poor root regeneration has bee found to greatly affect the transplant survival in tomato (Arteca, 1982; Aung, 1982) and in potato (CIP, 1985). Different findings were obtained by Wiersema (1984) who found that TPS seedlings survive the transplanting shock much better when they are younger than when they are older but in this study the older seedlings (42 days) survived better than the younger ones (28 and 35 days). Also more plant survival have been obtained from seedlings at the age of 35 days than at 28, 42 and 49 days (Mussa, 1993) at both plant establishment and maturity.

At all seedling ages seedlings from hybrid survived better than that from open-pollinated progeny. Generally hybrid seedlings were more vigorous with more true leaves than those of OP, therefore, there was a possibility of faster new root regeneration and recovery rate. Similar results were obtained by several researchers (CIP, 1980, 1982, 1985; Kidane-mariam *et al.*, 1984b). The two progenies behaved differently at different seedling ages whereby open-pollinated seedlings at the age of 42 days had higher survival rate than at 28 and 35 days while hybrid seedlings survived better when transplanted at the age of 35 and 42 days. The possible reason for better survival rates could be attributed to the fact that older seedlings were more vigorous and had more number of true leaves which probably enhanced better and faster new roots regeneration than younger seedlings at the age of 28 and 35 days for OP and 28 days for hybrid. The results suggested that when transplanting true potato seedlings at different ages, the two progenies should be considered separately because seedlings from hybrid progeny will probably take less time to be ready for transplanting than from open pollinated due to their ability of growing more vigorous as it has been reported in various research (Sadik, 1983; Kim et al., 1983, Kidane Mariam et al., 1984, 1985; Tuku, 1994)

In both seasons, pricked out seedlings had higher plant survival rates than the non-pricked ones at both plant establishment and maturity. The possible reason for better survival rate in pricked out seedlings might be due to the fact that the spacing between seedlings was wider (10 cm apart) thus it was possible that when seedlings were being uplifted from the trays for transplanting there was probably less disturbance of root system than in non-pricked seedling where the seedlings were crowded. It is possible that some roots were lost when separating the crowded non pricked-out seedlings at transplanting. Sattelmacher and Minzenmay (1984) observed similar root loss which reduced the plant survival rate. Little disturbance of root system for pricked-out seedlings might have resulted to faster regeneration of new adventitious roots which might have given good plant anchorage, water absorption and nutrient uptake and finally better plant survival. Most of the seedlings that were not pricked-out were transplanted bare-rooted while those that were pricked-out were transplanted with a ball of soil adhered to the roots. Although TPS seedlings can be transplanted with or without a ball of soil on the roots, the former has a tendency of promoting faster growth of new adventitious roots than bare-rooted and this characteristics is important for transplanting as was observed by Malagamba (1984). Similar observations were made by Alacho (1986). However, under different weather conditions the findings vary greatly as ~~it was later~~ reported by CIP (1983).

5.2 The Effect of Progeny, Age and Pricking-out of True Potato Seedlings on Total Tuber Yield.

There was no significant seedling age effect observed on total tuber yield during the short rains. However, during the long rains seedlings transplanted at the age of 42 days significantly out-yielded the ones transplanted at the ages of 28 and 35 days. This was because the older seedlings (42 days) were more vigorous with more foliage fresh and dry weight which may have led to quick establishment than in the younger ones (28 and 35 days). Due to quick establishment most of physiological processes such as photosynthesis were also more efficient in plants from 42 days' old seedlings and consequently resulted in more photosynthates being concentrated to the storage organs such as tubers (source to sink relationship) and finally higher total tuber yield. These results conform to other research findings such as by Accatino (1979) and CIP (1979, 1980) who obtained higher tuber yield from the more vigorous seedlings. The factor which might have contributed to poor yields from the younger seedlings was the lower survival rate. There could have been slow and poor recovery rate from transplanting shock due to harsh weather condition caused by heavy rains at the time of transplanting. Younger seedlings (28 and 35 days)were less vigorous and shorter than the older ones resulting into their foliage being submerged after heavy rainfall. This condition caused stunted growth impairing most of physiological processes which led to poor foliage development which finally resulted into poor photosynthetic yield. Due to slow growth and development it is possible that tuber initiation was reduced and this finally resulted into poor tuber yield. However, although weather condition affect tuber yield (Burton, 1989), this condition of heavy rains is not enough for making an inference because weather conditions are unpredictable.

Pricking out significantly produced mora total tuber yield in both season. In this effect seedlings that were pricked out established [illegible] during the first four weeks after transplanting than the non- pricked out ones. This indicates that the pricked out seedlings had recovered from the transplanting shock much faster than the non -

pricked ones and it is possible that they started tuberization much earlier resulting into more total tuber yield at maturity. Since the pricked-out seedlings were transplanted with a ball of soil adhered to the roots it means that they were less affected by transplanting than the non-pricked ones which were transplanted bare-rooted in addition to loss of some roots. Malagamba (1984) obtained higher total tuber yield from seedlings transplanted with a ball of soil adhered to the roots as compared to that obtained from bare-rooted seedlings. the latter might have taken more time to recover their normal growth rate and thus affecting the total tuber yield. The same effect had been observed by Sadik (1983) who stated that bare-rooted seedlings required 19 days after transplanting to recover their previous growth rate while with soil-covered roots the time was significantly reduced. Another possible reason for higher total tuber yield from the pricked-out seedlings could be due to the fact that these seedlings had already been subjected to first transplanting shock when pricked out from their original flat to a second one. In the field it could be possible that the transplanting shock was much less in pricked out seedlings because they had already hardened up from the first transplanting trauma as compared to the non pricked out ones and thus established faster resulting into more efficient physiological processes right from the initial stages and finally a positive effect in total tuber yield. It is possible that due to faster establishment tuberization might have also started early. Early tuber initiation has been reported to contribute to good tuber yield as it provides a sink for any carbohydrates available for translocation, surplus to the demands of the foliage (Burton, 1989).

5.3 The Effect of Potato Progeny, Age and Pricking-out of True Potato Seedlings on Marketable Tuber Yield

Seedling age did not have a significant effect on marketable tuber yield during the short rains. In this season tuber sizes which contributed to marketable tuber yield (tubers with diameters >25mm) were also not significantly affected by seedling age. However, there was a significant effect of seedling age on marketable tuber yield during the long rains. The trend was that the older the seedling the larger the tubers produced in consistent with the vigour and survival ability among older seedlings from establishment to maturity. The older seedlings produced more foliage which in turn resulted into increased carbohydrate. Vigorous plants gave more tubers with higher proportion of marketable tubers in agreement with other workers (Accatino, 1979; CIP, 1979, 1980). With translocation of carbohydrates from the foliage to the tubers, good yield of tubers will be realized (Burton, 1989). Seedlings at the age of 35 days have been reported to result to higher marketable tuber yield than at the age of 28, 42 and 49 days (Mussa, 1993). From the overall mean of progeny effect, hybrid progeny significantly had higher yields in marketable tuber yield than OP in both season. This was probably due to the ability of hybrid progeny growing more vigorously and producing more foliage which in turn produced enough carbohydrates translocated into the tubers that was manifested by higher marketable tuber yield in comparison to open-pollinated. Similar results were obtained by Kim et al., (1983) and Li et al., (1983) when comparing total and marketable tuber yield of both hybrid and open pollinated progenies.

Pricking-out of seedlings resulted to significantly more marketable tuber yield during the short rains. This was probably due to good establishment of the crop from seedlings that were pricked-out because they were transplanted with a ball of soil covering the root and this could have probably reduce the transplanting shock due to early new good root regeneration, thus resulting into more vigorous plant with more effective physiological processes such as photosynthesis. With effective photosynthesis more carbohydrates could have been produced and translocated to the storage organs and resulted into bigger sizes of tubers that can be marketable (Burton, 1989). Transplanting TPS with a ball of soil covering their roots (root-block) has been reported to give more marketable tuber yield (Accatino, 1979; Malagamba, 1984).

CHAPTER SIX

6.0 CONCLUSION

6.1 Conclusion and Recommendation.

From the results of this study it can be concluded that:

Seedlings at the age of 42 days were more vigorous with more number of true leaves had better plant survival rates and gave more total and marketable tuber than younger ones. This indicates that transplanting seedlings at this age (42 days) will be more advantageous because since they will be more vigorous with more number of true leaves there will be a good establishment in the field and finally will yield more.

Hybrid progeny had more survival rates and more total and marketable tuber yield than the open-pollinated ones. This implies that it is more advantageous to use hybrid seeds since they have a tendency of producing more vigorous seedlings which will recover faster from the transplanting shock and grow vigorously in the field and finally yielding more than open-pollinated progeny. However, since the production of hybrid is more expensive, using open-pollinated seeds can be promising because are much easier and cheaper to produce than hybrid seeds.

Pricking-out resulted to less vigorous seedlings but had more plant survival rates at maturity stage and resulted in more total and marketable tuber yield than not pricking-out. This implies that although by pricking-out seedlings there is a possibility of increasing transplanting shock at transplanting, the seedlings are transplanted with a ball of soil adhered to their roots and hence transplanting shock is minimized. This results into more plant survival at maturity and thus realizing more total and marketable tuber yield.

6.2 Future Research

A research should be done to find out weather much younger or older seedlings than the one used in this study can have an effect on plant survival and marketable tuber yield.

A research could be done to find out the proper time of pricking-out the seedlings and how long the seedlings can stay in the nursery/trays after pricking before transplanting into the field and the subsequent effect on plant survival and tuber yield.

More hybrid and open-pollinated progenies can be studied at different seedling ages to find out weather they will behave differently in plant survival and tuber yield.

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8.0 APPENDICES

Appendix 1. Climatic conditions at the University of Nairobi Meteorological Station, Kabete, Field Station from October 1994 - October 1995

Month	Temperature °C		Mean Relative humidity(%)		Total Rainfall(mm)	Rainy days
	Mean max.	Mean min.	9.00 am	3.00 pm		
SHORT RAIN SEASON 1994/95						
Oct.	24.1	13.8	81.5	48.8	87.8	12
Nov.	22.3	14.0	89.0	64.0	301.4	20
Dec.	22.8	13.3	81.2	59.2	64.7	11
Jan.	25.7	13.2	70.5	46.8	8.6	3
Feb	26.2	13.3	75.2	42.0	139.7	6
Mar.	24.6	14.0	84.9	58.0	166.2	14
LONG RAIN SEASON 1995						
Apr	24.2	14.9	89.8	60.9	259.7	29
May	22.0	14.2	88.0	67.8	244.5	22
Jun.	23.1	12.2	89.3	60.1	120.3	9
Jul.	20.2	11.3	88.7	65.4	18.2	9
Aug.	21.3	11.5	86.4	56.4	30.8	8

Source: Meteorological Station, Kabete, Field Station

Appendix 2. Soil analysis of the sites used during the short and long rain seasons 1994/95 cropping seasons*.

	Mechanical Analysis(%)	
	Short rain season	Long rain season
Sand	23.3	19.3
Silt	32.0	32.0
Clay	44.7	48.7
Texture	Clay	Clay
	Chemical analysis	
PH in water	6.02	6.30
PH in 0.01M $CaCl_2$	5.15	5.31
Total N%	0.25	0.12
Carbon %	2.33	1.15
Organic matter %	4.03	1.99
K m.e%	1.54	2.05
Na m.e%	0.65	0.67
Ca m.e%	4.05	4.05
Mg m.e%	3.79	3.38
CEC	24.00	24.00
P ppm	17.80	11.40
Cu ppm	13.50	11.00
Fe ppm	32.00	32.00
Zn ppm	54.00	47.00
Mn ppm	114.00	106.00

*Analysis done by Soil department, Kabete Campus, University of Nairobi.

Appendix 3. Mean squares for number of true leaves, height and vigour of true potato seedlings at transplanting during the short and long rains 1994/95 cropping season

Source of variation	Df	Mean squares					
		No. of true leaves		Seedling height (cm)		Seedling vigour (scores)	
		Short rains	Long rains	Short rains	Long rains	Short rains	Long rains
Block	2	0.082	0.202	0.135	1.450	0.667	0.042
Progeny (A)	1	0.375	4.335	41.082	1.654	4.167	2.042
Pricking-out (B)	1	0.202	0.027*	109.227*	5.510*	6.000*	0.375
A X B	1	1.042	0.060	42.135	0.260	0.000	1.042
Seedling age (C)	2	9.447*	5.202*	146.555*	69.252*	7.292*	6.792*
A X C	2	0.020	0.485	6.927	0.585	0.042	0.292
B X C	2	0.407	0.052	14.047*	0.527*	1.625*	0.125*
A X B X C	2	0.327	0.285	7.715	0.247	0.375	0.292
Error	22	0.165	0.224	0.047	0.103	0.212	0.496
Total	35						

* = F - Test significant at P=0.05, N.S = Non significant.

Appendix 4. Mean squares for potato plant survival during the short and long rains 1994/95 cropping season

Source of Variation	Degrees of Freedom	Mean Squares			
		Short rains (October'94-March'95)		Long rains (April'95 - August'95)	
		14 DAS	104 DAS	14 DAS	104 DAS
Block	2	108.840	455.912	424.036	382.155
Progeny (A)	1	0.444	4.340	161.71N.S	2163.80**
Pricking-out (B)	1	434.03**	278.334*	759.002	771.914*
A X B	1	0.490	17.223	342.867	1.914
Seedling age (C)	2	7.544	20.704	893.751	1908.25**
A X C	2	13.132	171.347	235.879	784.591**
B X C	2	15.594	72.370	123.521	194 441
A X B X C	2	8.208	183 186	315.805	259.058
Error	22	30.055	61.348	257.036	132.685
Total	35				

* = F - Test significant at P=0.05, ** = F - Test significant at P = 0.01,
N.S = Non significant.

Appendix 5. Mean squares for plant vigour, fresh and dry weight of true potato at 60 DAT during the short and long rains 1994/95 cropping season

Source of variation	Df	Mean squares					
		Plant vigour		Fresh weight (g)		Dry weight (g)	
		Short rains	Long rains	Short rains	Long rains	Short rains	Long rains
Block	2	2.10	1.08	6520.24	53588.81	28.27	214.75
Progeny (A)	1	9.00*	8.03*	580915.82	444755.62	3207.33	1903.87
Pricking-out (B)	1	1.00	0.25	315183.06*	105235.36*	2745.76*	1956.59*
A X B	1	0.11	0.25	105437.67	373.77	729.00	36.80
Seedling age (C)	2	0.03	4.75	129752.97	353710.87*	826.68	2034.53*
A X C	2	0.08	1.36	56908.25	108467.41	217.10	197.43
B X C	2	0.08	0.08	55059.02	636.53	403.87	20.10
A X B X C	2	0.36	0.25	36590.52	181201.09	187.57	603.90
Error	22	0.72	0.59	41260.72	47196.67	270.89	137.47
Total	35						

* = F Test significant at P=0.05, N.S = Non-significant.

Appendix 6. Mean squares for proportion of potato tuber size during the short and long rains 1994/95 cropping season

Source of variation	Df	Mean squares					
		Diameter					
		< 25 mm (%)		25 - 45 mm (%)		> 45mm (%)	
		Short rains	Long rains	Short rains	Long rains	Short rains	Long rains
Block	2	93.56	71.35	28.51	16.43	145.92	70.61
Progeny (A)	1	255.13	225.09	10.74	370.25	161.17	17.96
Pricking-out (B)	1	7.74	23.13	22.72	174.93	3.94	70.84
A X B	1	2.72	17.37	29.38	3.95	49.99	37.87
Seedling age (C)	2	14.72	180.63	2.54	45.90	6.00	51.08*
A X C	2	16.38	12.36	3.35	101.00	11.24	46.45*
B X C	2	9.15	15.04	17.00	13.47	10.41	17.80
A X B X C	2	13.43	45.34	19.20	12.12	30.44	46.35
Error	22	6.51	35.74	10.36	59.67	10.22	41.51
Total	35						

* = F Test significant at P=0.05, N.S = Non-significant.

Appendix 7. Mean squares for Total and Marketable potato tuber yield during the short and long rains 1994/95 cropping season.

Source of Variation	Degrees of Freedom	Mean Squares			
		Short rains (October'94-March'95)		Long rains (April'95-August'95)	
		Total tuber yield	Mktable tuber yield	Total tuber yield	Mktable tuber yield
Block	2	123.287	139.809	48.437	56.281
Progeny (A)	1	339.174**	408.714**	451.279**	267.868**
Pricking-out (B)	1	346.580**	267.322**	55.403*	12.250
A X B	1	18.063	32.680	35.036*	9.818
Seedling age (C)	2	24.485	22.741	162.640**	156.60**
A X C	2	51.672	52.528	42.187*	30.426*
B X C	2	39.127	37.123	0.791	0.451
A X B X C	2	0.426	1.914	4.381	6.984
Error	22	24.051	23.150	7.441	6.972
Total	35				

* = F - Test significant at P = 0.05, ** = F Test significant at P = 0.01
N.S = Non-significant