EVALUATION OF ADVANCED R - GENE FREE POTATO GENOTYPES FOR LATE BLIGHT RESISTANCE, YIELD, COOKING AND PROCESSING QUALITIES

KIPLAGAT WILLY KIBET

A THESIS SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER OF SCIENCE DEGREE IN HORTICULTURE

DEPARTMENT OF PLANT SCIENCE AND CROP PROTECTION
UNIVERSITY OF NAIROBI

DECLARATION

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

Kiplagat Kibet Willy

Signature ..... Date 05/08/2008

This thesis is submitted with our approval as University supervisors

1. Dr.Richard O. Nyankanga

   Department of Plant Science and Crop Protection

   University of Nairobi

Signature ..... Date 5/8/2008

2. Dr. Rama D. Narla

   Department of Plant Science and Crop Protection

   University of Nairobi

Signature R.D. Narla Date 5.8.2008

3. Dr. Juan Landeo

   International Potato Centre (CIP)

   Sub- Saharan Africa, Nairobi

Signature ..... Date 05/08/2008

DEDICATION

This thesis is dedicated to my late grand parents, Mr. Kwambai Lotia and Mrs. Kimoi Kwambai; my parents, Mr. Joseph Kiplagat Kwambai and Mrs. Susan Jeruto Kiplagat for their commitment to my education. Not forgetting my brothers and sisters for their encouragement all through and friends who contributed in one way or another to the success of this work.

ACKNOWLEDGEMENT

I wish to express my sincere appreciations to the collective efforts of a number of individuals and institutions that made this work successful. Special thanks to the University of Nairobi for awarding me a scholarship, without which I could not have completed the course and the International Potato Centre (CIP) and Kenya Agricultural Research Institute (KARI) for availing funds to conduct the research activities.

Deep appreciation and sincere gratitude are due to my supervisors, Dr. R. O. Nyankanga, Dr. R. D. Narla, Dr. J. N. Kabira, Dr. J. Landeo and Prof S. I. Shibairo for diligent guidance, invaluable supervision, encouragement and constructive criticisms when undertaking the research and during the preparation of the thesis.

Thanks are also due to the staff of Kenya Agricultural Research Institute (KARI), National Potato Research Centre, Tigoni and the International Potato Centre (CIP) for their unreserved cooperation in executing field experiments.

Last but not the least; my very special thanks go to my parents, brothers and sisters for their support, love, encouragement and patience while I was away from home. Above all, praise, glory and honour are to the Heavenly Father, through whom all things are possible.

ABSTRACT

Late blight (*Phytophthora infestans*) is a major constraint to potato production in the tropical highlands of Kenya causing significant yield losses of 30 - 75% in highland tropics of Kenya. Farmers rely on fungicide application to manage the disease. However, control is often inadequate due to limited fungicide applications and use of cultivars with low to moderate resistance to late blight. Use of resistant cultivars is viewed to be more sustainable both economically and environmentally. However, resistance alone does not guarantee adoption by farmers of any cultivar as farmers have other preferences like earliness, good storability and/or good cooking characteristics. Moreover, resistance breaks down owing to changes in pathogen population necessitating the need for evaluation of new germplasm to replace old varieties whose resistance has broken down. The objectives of the study were to assess early and late harvest performance; stability of R free late blight resistant genotypes; and to determine the effect of harvesting date on the storage, cooking and processing qualities of R free late blight resistant potato tubers in Kenya. Ten advanced late blight resistant potato genotypes free of R genes from population B3 and two checks Tigoni, moderately resistant to late blight and Kerr's Pink, susceptible to late blight were used. Field experiments were conducted at two sites; Tigoni, Limuru and Marimba, Meru. Field and storage experiments were laid out in a randomised complete block design (RCBD) with three replications while the cooking and processing quality experiments was laid out in a completely randomized design replicated eight times. Field experiments were harvested at 90 (early) and 120 (late harvests) days after emergence (DAE). Significant differences ($P \leq 0.05$) were observed for tuber yields, AUDPC, foliage maturity, specific gravity, tuber weight loss (%), sprouting (%) and tuber rots (%) among the potato genotypes at early and

late harvests. The AUDPC ranged from 35 to 3803 and was significantly higher for Kerr's Pink than all population B3 genotypes and Tigoni. Population B3 genotypes performed better at late than early harvests but the increase in tuber yields due to delayed harvest varied with genotype and was greater at Tigoni, Limuru than at Marimba, Meru. Significant negative correlations between AUDPC and tuber yield were observed on the local checks but no correlations were observed on population B3 genotypes. Rankings of genotypes with respect to reactions to disease severity and tuber yield for early and late harvests varied across seasons and locations. AMMI analysis showed that the proportion of genotypic variance was larger than that due to the environmental variance and the G X E interaction. Genotypes (G), environments (E) and the G X E interactions accounted for 43.0% and 53.4%, 39.6% and 29.7%, 17.5% and 16.9% for tuber yield while for AUDPC it accounted for 80.2% and 82.3%, 5.0% and 4.6%, 14.8% and 13.1% of the treatment sum of squares at early and late harvests respectively. Five genotypes at early harvests and all population B3 genotypes except two genotypes at late harvests were stable while for late blight resistance, four and six genotypes at early harvests and late harvests were stable respectively. Except for genotype 393280.57, population B3 genotypes had acceptable specific gravity (above 1.07), high acceptability scores (scores of over 5) for use as boiled potatoes, chips and crisps of good quality and acceptable low weight losses (below 10%) at early and late harvests. Population B3 genotypes commenced sprouting by the 4^{th} week except four genotypes that sprouted by 6^{th} week at early harvest while sprouting was reduced to the 2^{nd} week and 4^{th} week at late harvest respectively. Most of population B3 genotypes from early and late harvests can be kept for 10-12 and 6-8 weeks except four genotypes that can store well for over 12 and 10-12 weeks respectively. Kerr's Pink and Tigoni sprouted by the second week of

storage with Kerr's Pink having its % sprouting levelling off regardless of the harvesting date. Levels of resistance in population B3 potato genotypes varied from moderate resistance to high resistance and population B3 entries 385524.9, 389746.2, 392617.54, 393371.58, 393385.39 and 393385.47 were better performers and could be considered for on farm trials. Most of the population B3 genotypes were suitable and acceptable for storage, cooking and processing qualities.

TABLE OF CONTENTS

CHAPTER THREE: ASSESSMENT OF EARLY AND LATE HARVEST PERFORMANCE AND STABILITY OF R-FREE LATE BLIGHT RESISTANT POTATO GENOTYPES IN KENYA

LIST OF TABLES

Table **Page**

LIST OF FIGURES

Figure **Page**

LISTS OF ACRONYMS

a.s.l = above sea level

AUDPC= Area under disease progress curve

AMMI= Additive Main Effect and Multiplicative Interaction

CV= Coefficient of variation

CIP= International Potato Centre

DAE= Days after emergence

E= Environment

G= Genotype

L= Location

S= Season

G X S = Genotype X Season

Rep= Replication

G X E= Genotype X Environment Interaction

Kg^2= (Area 3m*3m)

MOA= Ministry of Agriculture

ns= Not significant at 5% level of significance

SSA= Sub Sahara Africa

* = Significant at 5% level of significance

PTM = Potato tuber moth

LIST OF APPENDIXES

Appendix **Page**

CHAPTER ONE

INTRODUCTION

The cultivated potato (*Solanum tuberosum* L.) is thought to have originated from the Andean highlands of South America (Horton, 1987) and is one of the world's most important crops, exceeded only by wheat, maize and rice in total production (Burton, 1989). Currently the world's production stands at 320 million tonnes and the developing world's potato production of 165 million tonnes has exceeded 155 million tonnes of the developed world (FAO, 2008). Thus production is high in most of the developing countries and over the past both the hectarage and production of potato has increased much faster than any other crop in the in Sub Saharan Africa [SSA] (Scott, 1990).

Potato production is hampered by many factors, which are responsible for low productivity in SSA. These are continuous cultivation, declining soil fertility, prevalence of pests and diseases, lack of certified seed, poor storage and marketing, high cost of inputs like fertilizers and pesticides (Nyankanga *et al.*, 2004). In Kenya, the current on farm yield of 6.6t/ha is far below the world's average of 16.64t/ha, Africa's average of 10.84t/ha (FAO, 2008) and the 40t/ha attainable under research station conditions (Lungaho *et al.*, 1997). This yield gap has been attributed to among other factors; late blight, lack of late blight resistant varieties and favourable environment for potato production that is also conducive to disease development.

1.1 Problem statement and justification

Late blight caused by the fungus *Phytophthora infestans* Mont. de Bary is the most important and destructive disease of potato worldwide (Hardy *et al.*, 1995; Fry and Goodwin, 1997; Fry *et al.*, 2001). It is a devastating disease in the major potato growing tropical highlands of SSA (CIP, 2004) and it is estimated that the production of potatoes lost to late blight is 15% with a loss of $3 billion annually in developing countries alone (CIP, 1997). The magnitude of yield losses ranges from 30-75% on susceptible varieties (Olanya *et al.*, 2001b) and the disease is more prevalent in highland tropical locations because of year round potato and tomato production, which results in a continuous presence of inoculums (Hijmans *et al.*, 2000). Therefore the infections that occur at the initial or during various stages of crop growth present an enormous economic threat because of the rapid development of the disease due to favourable conditions. Heavy attacks can destroy potato crop almost completely (Fry, 1978; Kankwatsa *et al.*, 2002) thus its management remains a major threat among small-scale farmers in the tropical highlands of Kenya who produce most of the crop (Nyankanga *et al.*, 2004). Moreover, many of the varieties available locally like Kerr's Pink, Ngure, Kimande and Arka are highly susceptible (Nyankanga *et al.*, 2004). Thus, there is inadequate control of the disease for most of the poor farmers due to preference of susceptible cultivars (Nyankanga *et al.*, 2004). The threat on potato production is increasing, as it is even more difficult to manage the disease (CIP, 2002) due to the development of more aggressive and fungicide resistant genotypes of the fungus.

The optimum management of late blight is often accomplished by a combination of measures that include the use of resistant varieties, sanitation, cultural measures and judicious use of appropriate fungicides (Umaerus *et al.*, 1983; Fry *et al.*,

1993; 2001). Fungicides are available to control the disease but they are not only expensive and environmentally unfriendly but also pose health hazards for small holders (Schuster and Schroeder, 1990). In addition, fungicide effectiveness is constrained by knowledge input to apply the fungicides (Nyankanga *et al.*, 2004).

The use of resistant cultivars is viewed to be the most promising strategy for a more reliable way of managing late blight hence its use is the cheapest and environmentally friendliest means of controlling plant disease. Studies have shown that the use of more resistant cultivars and better deployment of host resistance could reduce losses and dependence on chemical control. Grunwald *et al.*, 2000 illustrated that at 40 days after emergence, disease severity was 100% and 4% in Alpha (susceptible) and Nortena (resistant) cultivars respectively. Nonetheless, resistance alone do not guarantee full adoption of a variety by farmers (CIP, 2002). This is because farmers have other preferences like good taste, high dry matter, early maturity and high yielding varieties (CIP, 2002; Nyankanga *et al.*, 2004). Resistant genotypes however, tend to be late maturing (Devaux and Haverkort, 1987; Umaerus *et al.*, 1983), which is a disadvantage where the growing seasons are short and where two crops a year are needed.

1.2 Research objectives

The major objective of the study was to evaluate advanced R gene free potato genotypes from population B3 for late blight resistance, yield, cooking and processing qualities. Specific objectives were to:

(i) Assess the performance of early and late yields and stability of R-free late blight resistant potato genotypes in Kenya

(ii) Determine the effect of harvesting date on the storage, cooking and processing quality of R-free late blight resistant potato tubers.

CHAPTER TWO

LITERATURE REVIEW

2.1 Potato production in Kenya

Potato was introduced in Kenya in the second half of the century by European settlers. The crop is an important cash and food crop (Lung'aho *et al.*, 2005; MOA, 2005). It is ranked as the second most important food crop after maize (Guyton *et al*, 1994). The crop requires annual rainfall of between 1050 and 1900 mm and the temperature range of 8°C to 23°C (MOA, 2005). Cultivation of the crop is concentrated in the high altitude areas ranging from 1500 to 3000m above sea level (MOA, 2005). The areas form the high potential tea and coffee zones found on the slopes of Mount Kenya (Meru, Embu and Kirinyaga), parts of Laikipia, and both sides of the Aberdare range covering parts of Nyeri, Muranga, Kiambu and Nyandarua districts. Others are the highlands of the Mau escarpment (Mau Narok, Bomet, Timboroa and Molo; Tinderet, Nandi escarpment and the Cherangani hills) and small acreages cultivated in Kericho and Kisii highlands and isolated patches near the coast in the Taita hills (MOA, 2005).

During the 1997-2000 periods, productions fluctuated between 670,000 and 1,050,000 tonnes per year (MOA, 2005). Currently, production is estimated at 800 000 tonnes per year in two growing seasons from an estimated total acreage of 120,000 ha per year (FAO, 2008). Central province accounts for 40-60% of the national potato production hence led in area and production averaging 57,650 ha per year and 412,700 tonnes per year respectively (MOA, 2005). Rift Valley province is second with an annual average production of 228,230 tonnes from 27,138 ha and

Eastern province is third with an annual average production of 160,725 tonnes from 22,315 ha (MOA, 2005).

The most common varieties in Kenya include - Kenya Baraka, Roslin Tana, Roslin Gucah, Kerr's Pink, Roslin Eburu, Anett and Desiree. Others are Asante, Tigoni, Dutch Robjyn, Romano, Kenya Dhamana and Cruza 148 (CIP, 1998) and Kenya Faulu, Kenya Karibu, Kenya Mavuno and Kenya Sifa that were released in 2002 (Lung'aho *et al.*, 2005). All these varieties differ in susceptibility to late blight, skin and flesh colour, palatability and processing qualities, days to maturity and storability. However, all the 14 varieties that were released prior to 1996 and the more than 60 informally released varieties are susceptible to late blight (Maingi *et al.*, 1991; Kinyae *et al.*, 1994) thus the need to adopt new germplasm with at least some tolerance.

2.2 Nutritional and economic importance of potato

Potato is a vital source of vitamins, potassium, calories, protein and fibre (Horton, 1987; Harris, 1992). The protein to carbohydrates ratio is higher in potato than in many cereals and any other roots or tubers (Horton, 1987; Harris, 1992) hence its popularity as a food is due to its palatability; ease of cooking and convenience therefore used for the fresh market as well as for local and multinational snacks and fast food industries (CIP, 1996). Based on the biological value, the nutritive value of potato is higher than that of maize, beans, soybeans, peas and wheat thus it is superior to most crops in food production per hectare (Horton, 1987; Harris, 1992). Moreover, it is twice as good as dry beans and slightly better than wheat in terms of protein production per hectare per day (Horton, 1987; Harris, 1992). The ability to grow in the high altitude areas where maize does not do well and its high nutritive value

makes the potato an important crop (Horton, 1987; Harris, 1992). Carbohydrates, which constitute about 75% of total dry matter, are the main source of calories. 100g of edible portion contain 80% water; 2.1g protein; 76kcal. 0.1g fats; 0.95g ash; 7mg calcium; 53mg phosphorus; 0.6mg iron; 3mg sodium; 407mg potassium; 0.09mg thiamine; 0.04mg riboflavin; 1.5mg niacin and 16mg ascorbic acid.

Potato as a cash crop contributes significantly to the growth of the economy and the value of the crop at consumer prices are more than Kenya Shillings 10 billion per year (MOA, 2005). Potato farming is labour intensive offering employment opportunities in production, marketing and processing sectors (MOA, 2005). Currently there are approximately 500,000 potato growers and the annual production of the crop is worth Kenya Shillings 5 billion at farm gate prices (MOA, 2005). It is produced mainly by small-scale farmers mostly women and therefore helps narrow down the rural urban income gap. Potatoes are commonly intercropped with maize, beans and other crops (Nyankanga *et al.*, 2004). Urbanization has created demand for fast cooking foods, as urban dwellers prefer potatoes and vegetables with low demand for cooking energy and the proliferation of French fries or potato chips, which are popular among urban workers (MOA, 2005).

2.3 Late blight

2.3.1 Origin, spread and distribution of *Phytophthora infestans*

Phytophthora infestans (Mont.) de Barry, an oomycete causes late blight of foliage and tubers in field and in storage. The pathogen originated from the Central highlands of Mexico (Wastie, 1991; Fry *et al.*, 1993) where the pathogen's greatest genetic variability is (Niederhauser, 1991) and has evolved on wild relatives of the cultivated potato like *Solanum demissum* and *Solanum stoloniferum*.

It probably migrated into South America in ancient times and subsequently into North America and Europe in the early 1840s (Fry and Goodwin, 1997), where potato crops were practically wiped out in 1843 and 1845/1846 respectively. The pathogen was transported into the rest of the world with infected European seed tubers (Fry *et al.*, 1993). The disease was first reported in East Africa in 1941, in the East African Rift valley, and it quickly spread over to most potato growing areas in Kenya.

2.3.2 Importance and damage caused by late blight

Potato and tomato production is constrained by late blight worldwide (Fry and Goodwin, 1997), and plants are defoliated rapidly and tubers are infected when spores are washed into the soil causing tuber decay during growth, development and storage. The most affected plant parts are leaves, stems, tubers, flowers, fruits and stolons except the roots (Erwin and Ribeiro, 1996). The damage causes destruction of the foliage and rot of the tubers.

Foliar lesions begin as small light green to dark green irregularly shaped water soaked spots that rapidly expand. As lesions age the centres become necrotic turning brown to black. Expanding lesions on some potato cultivars are bordered by a green halo. Under moist moisture conditions, profuse sporulation occurs especially on the underside of the leaf. Presence of white specks on a lesion is often a useful characteristic of the disease. Lesions also occur on petioles and stems often killing the entire leaves and branches of the plant. It also affects tubers while in the soil by rain borne spores from blighted foliage. Tuber lesions are irregular in shape, brown to purplish in colour and slightly depressed (Erwin and Ribeiro, 1996).

2.3.3 Disease development and epidemiology

Late blight epidemics are severe when weather conditions are suitable, i.e. heavy rains, cool temperatures (<20° C), high relative humidity (>90 %) and presence of moisture on the potato leaves for an extended period (>8-10 hours for several consecutive days) (Harrison, 1992; Low, 1997). Its severity depends on cultivar susceptibility and weather conditions for sporulation and spread of the pathogen (Kankwatsa *et al.*, 2002). Subsequent yield loss depends on how early and quickly the disease destroys the foliage and haulms (Harrison, 1992). The primary and secondary inoculums are spread by wind blown rain, fog and mists or by splashing rain. The distance that the inoculia can be blown and remain viable depend on the humidity, temperature and wind velocity.

The disease is favoured by cool wet weather. The optimum temperature is probably near 20°C (Harrison, 1992), though disease can occur over a range of 5 to 30°C. The time required for sporulation is dependent on temperature of the host and pathogen with sporulation occurring later on resistant hosts. Moreover, more sporangia are formed at temperatures ranging from 18 - 22°C (Harrison, 1992) but sporulation occurs in reduced amounts between 5 – 15°C and 20 – 25°C. Germination and the activity of zoospores occur at very low temperatures, near 0°C, though at a very slow rate. Above 30°C, sporangia do not germinate (Crossier, 1933; Harrison, 1992). Temperature affects survival mainly by reducing viability of both sporangia and oospores (Drenth *et al.*, 1995). Sporangia germinate either directly forming a germ tube or indirectly via zoospores (Crossier, 1933), at temperatures of 15 –24 °C and below 15 °C respectively.

Water, as either vapour or liquid, or relative humidity above 90% affects germination, sporulation, inoculum survival and spread (Harrison, 1992). After

infection, the mycelium is relatively protected from low humidity, but high ambient humidity near saturation is needed for sporangia formation (Harrison, 1992).

Year round potato production (Hijmans *et al.*, 2000; Kankwatsa *et al.*, 2002), cull piles next to fields or volunteer plants (Nyankanga *et al.*, 2004; Kamoun and Smart, 2005), oospores in the soil or plant (Kamoun and Smart, 2005) has resulted in continuous presence of inoculums. Tubers infected before harvesting, at harvesting or during storage may be disposed in waste piles or may end up as latently infected seed tubers planted into the field hence a source of inoculums that enable hibernation of the pathogen (Fry *et al.*, 2001).

2.4 Strategies of late blight management

2.4.1 Chemical Control

Continuous production of potatoes and the favourable conditions suitable to the development of late blight enables build up of the pathogen population in the highland tropics (Olanya *et al.*, 2001a). To reduce the rate of disease development and lower the final disease levels, fungicides are used especially when environmental conditions are favourable. The efficiency of the fungicide in the control of late blight is governed by the time of application in relation to stage of *P. infestans* development.

Protectant fungicides are applied before infection occurs for it to be effective in late blight control especially if applied on a scheduled basis (Olanya *et al*, 2001a). The effect of this is to reduce sporulation and infection efficiency of the spores. However protectant fungicides cannot penetrate the foliar tissue that makes them ineffective once the infection has occurred.

Systemic fungicides are very effective in controlling disease damage and when sprayed become distributed locally within plant tissues and protect foliage from

infection by spores. They have little or no effect on germination of sporangium or zoospore and mobility of zoospore. However, fungal isolates that are resistant to metalaxyl have been reported (Davidse *et al.*, 1981; Dowley and O'Sullivan, 1981).

On-farm research has indicated that three timely applications of a protectant or a protectant alternated with a systemic give effective late blight control (Olanya *et al*, 2001a). However, management of late blight is difficult because acquisition of the fungicides by most of the small scale farmers who are the major producers is a problem as they lack sufficient knowledge of applying the fungicides properly (Nyankanga *et al*., 2004) and the development of resistance to the fungicide metalaxyl impeding the desired expansion of potato cultivation. To address this, new strategies of chemical control rely on reducing fungicide inputs combined with use of potato cultivars possessing acceptable levels of non-race specific resistance to late blight. Moreover, schedules of spraying have been modified according to the favourability of the environmental conditions and to the host resistance level hence resistant varieties are often used in conjunction with fungicide control (Olanya *et al*., 2001a).

2.4.2 Cultural measures

Disease severity is related to the amount of initial inoculum. Initial inoculum for late blight is from infected tubers, culls piles, volunteer plants and infected seed. Cultural control involves the use of clean and healthy disease free seed pieces, removal of volunteer potato plants, hilling with adequate amount of soil, management of soil nutrition and using crop rotation (Garrett and Dendy, 2001). Also shifting the growing period out of the wet season (Devaux and Haverkort, 1987), utilization of resistant varieties and field sanitation are other measures that reduce pathogen population by reducing its survival, dispersal and reproduction of (Garrett and Dendy,

2001). High population densities tend to make conditions favourable for late blight. Hence use of the correct spacing could reduce late blight. Hilling, ridging, crop rotation are also important cultural practices in reducing late blight. Haulm killing is also important in reducing tuber infection. Use of a combination of these cultural practices has been shown to delay or reduce late blight infection (Garrett and Dendy, 2001).

2.4.3 Host resistance

Breeding for resistance is regarded as desirable means of managing late blight (Colon *et al.*, 1995; Inglis *et al.*, 1996). It is more important in developing countries than in the developed countries (Forbes and Jarvis, 1994) because it is considered as a major source of disease control especially among resource constrained farmers thereby reduces crop damage regardless of environmental conditions and also is a potential source of new variety releases (Landeo *et al.*, 2001). Resistance against *P. infestans* was found in the hexaploid Mexican species *Solanum demissum* and was introduced into the potato breeding programme in the beginning of the twentieth century (Ross, 1986). *Solanum demissum* was the source of at least 11 race-specific resistance (R) genes most of which provided complete resistance to late blight (Ross, 1986; Turkensteen, 1989). The dominant nature, monogenic inheritance of the R genes facilitated the introgression into the tetraploid potato crop. Two forms of resistance are distinguished in the potato. The first is specific resistance conferred by major genes (R-gene mediated) which is race specific and provokes a hypersensitive reaction to incompatible but not compatible races of the pathogen. However, potato cultivars containing R-genes proved ineffective in the field as new virulent races of the pathogen quickly evolved (Wastie, 1991; Fry and Goodwin, 1997) and their use is

no longer advocated (Ross, 1986). The second type is horizontal resistance that is partial, polygenic, non race specific. It is thought to be effective against all variants of the pathogen thus more stable and durable (Black, 1970; Turkensteen, 1993; Colon *et al.*, 1995; Inglis *et al.*, 1996; Forbes *et al.*, 1998; Haynes *et al.*, 1998; Landeo *et al.*, 2000) but not sufficient to confer absolute resistance to *Phytophthora infestans* (Thurston, 1971; Forbes *et al.*, 2005). It has the disadvantage of being associated with late maturity (Umaerus *et al.*, 1983)

Horizontal resistance has been the focus by plant breeders at the International Potato Centre (CIP) for improvement and utilization in the development of varieties. Two approaches were followed in upgrading gene frequencies for horizontal resistance to late blight. The first in presence of R genes (population A) and the second in absence of R genes (Landeo *et al.*, 1997). Population A required the use of a single most complex race of the pathogen to overcome R genes (Landeo *et al.*, 1997). However, upgrading quantitative resistance was cumbersome due to masking effects, simulation of horizontal resistance by R genes and differential spore loads in the field despite inoculation of single isolates (Landeo and Turkensteen, 1989; Turkensteen, 1993; Landeo *et al.*, 2001).

A four way hybrid cross between *Solanum acaule*, *Solanum bulbocastanum*, *Solanum phureja*, and *Solanum tuberosum* led to the development of genotypes with horizontal resistance free of R genes (population B) (Landeo *et al.*, 1997). Two groups were developed as separate populations. First from primitive cultivars of Solanum *tuberosum* ssp *andigena* (B1), known to be free of R genes and a second (B3) derived from population A after eliminating the R genes (Landeo *et al.*, 1995) and the absence of the genes have been tested and confirmed (Landeo *et al.*, 1995; 1997; 2000; 2001). The population to date has shown a steady increase of gene

frequencies and levels of resistance, absence of R genes and stability to a wide range of environments and pathogen populations (Landeo *et al.*, 2001). The role of environment in expression of the horizontal resistance has been reported (Kulkarni and Chopra, 1982). It is only recently that some cultivars with higher field resistance have been produced in appreciable quantities.

2.4.4 Integrated disease management

This includes integrating the use of resistant cultivars, fungicides, cultural measures, and forecasting systems for controlling late blight (Kankwatsa *et al.*, 2002). This will reduce the risk of losing the efficacy of a single method (Mundt *et al.*, 2002). Host resistance to late blight plays a big role in integrated disease management because the population structure of the pathogen is evolving and fungicide resistance is increasing yet most of the farmers cannot afford the high cost of fungicides. Kirk *et al.*, 1999 reported that horizontal resistance to late blight might be prolonged in production systems that use managed fungicide applications. Kankwatsa *et al.*, 2002 reported that integration of host resistance and fungicide application reduce late blight severity by over 50% and resulted in yield gains of more than 30%. This indicates that high yield is due to late blight control and the genetic constitution of cultivars. Integrated disease strategy contributes to resistance durability by allowing use of resistance (Mundt *et al.*, 2002) and is obtained by combining practices, each providing less than adequate disease reduction when used alone (Mundt *et al.*, 2002). It has also been reported that improvement of late blight control could be achieved by enhancing farmers' knowledge, development and deployment of integrated disease management practices (Nyankanga *et al.*, 2004).

2.5 Foliage maturity in potato and its relation with late blight resistance

Breeding for horizontal resistance to late blight is difficult because it is characterized by a continuous variation in phenotypic appearance and a complex polygenic inheritance. In addition, the number of genes involved is unknown (Simko, 2002) and it is hard to prove race-non-specificity. The association of race-non-specific resistance with late foliage maturity (Toxopeus, 1958) caused the non-existence of early maturing potato varieties with satisfactory levels of resistance to late blight (Swiezynski, 1990).

The association may be either genetic or physiological (Toxopeus, 1958). Physiological linkage is supported by photoperiod where short photoperiod reduces late blight resistance and cause early foliage maturity (Pohjakallio *et al.*, 1957). The presence of two separate loci for the two traits seems improbable, as potato breeders have tried fruitlessly to combine resistance to late blight with early foliage maturity for decades (Muskens and Allefs, 2002). All loci for foliage maturity type coincide with loci for late blight resistance (Collins *et al.*, 1999; Bormann *et al.*, 2004; Bradshaw *et al.*, 2004), therefore the association has been confirmed especially on chromosome 5 (Visker *et al.*, 2005). Thus there is a positive correlation between relative AUDPC and foliage maturity type where low relative AUDPC values coincided with low values of foliage maturity type and vice versa (Visker *et al.*, 2004; Visker *et al.*, 2005).

Genetically, race non specific resistance against *P. infestans* is found only in late maturing potato genotypes (Toxopeus, 1958; Swiezynski, 1990; Visker *et al.*, 2004) thus there is no existence of early maturing potato varieties with satisfactory levels of late blight resistance (Swiezynski, 1990). The negative relationship between maturation time and late blight resistance makes combining early maturity and late

blight resistance difficult (Umaerus and Umaerus, 1994). Breeding for early maturing potato cultivars with durable resistance to late blight would be important in managing and reducing crop losses from late blight.

2.6 Genotype x Environment effect on agronomic performance of genotypes

Genotype by Environment interaction (G X E) is the change in cultivars relative performance over environments resulting from differential response of the genotypes to various edaphic, climactic and biotic factors (Dixon *et al.*, 1991). The presence of G x E interactions effects complicates selection of superior potato genotypes making prediction of the performance across environments difficult (Mulema *et al.*, 2008). Also it reduces the efficiency of genetic progress through selection and leads to unreliable recommendation as farmers demand more than just a genotype with satisfactory yield (Ngeve, 1993). Therefore the recommendation of cultivars to specific regions, where they express their superior genetic potential is restricted by the differential response of genotypes to the different environments (Kang and Magari, 1996).

Phenotypic expression of a plant is determined by its genetic composition and the environment. Crop performance therefore is a function of its genotype and nature of the production. However the quantitative characters are under the influence of many genes and their contribution differs among environment. Multilocational trials over a number of seasons are conducted to evaluate and measure the interaction effect of G × E hence the measure of stability in performance of the genotypes either spatially, temporally and/or a combination of the two. Stability measurements indicate the adaptability of genotypes to general or specific conditions and form the cornerstone for recommending the type of varieties that should be grown under

particular production environments as well as the yield expected from the varieties (Getinet, 1988).

One approach to evaluate the G X E interaction is the Additive Main Effects and Multiplicative Interaction (AMMI) model proposed by Zobel *et al.*, 1988 that is used to partition genotype, environments and the G X E interaction and obtain better yield estimates of genotypes. The model uses ANOVA to separate the additive variance from the multiplicative (G × E) variance and a principal component analysis (PCA) to describe the G × E effect and identify patterns in the data (Gauch and Zobel, 1988; Shaffii and Price, 1998). The G × E interaction patterns are diagnosed graphically by the AMMI biplot analysis.

Research has shown that some potato genotypes maintain their relative rankings through time (Colon *et al.*, 1995; Inglis *et al.*, 1996). This is supported by the maintenance of high levels of resistance in some genotypes that have been planted for many seasons (Forbes & Jarvis, 1994). Haynes *et al.*, 1998; 2002 in their evaluation reported that the most resistant materials were stable and some of the intermediate clones were less stable.

2.7 Processing and cooking quality

Raw product plays an important role in processing, fry yield and finished quality (Kabira and Lemaga, 2003). Appearance of the tuber (size, shape, and eye depth), absence of diseases or defects, proper starch and sugar content, flavor, and cooked texture all contribute to potato quality as it influences the wastage that occurs during peeling (Kabira and Lemaga, 2003). The shape of the tuber is significantly important to the processors of crisps and chips whereby long/long oval tubers are good for preparation of chips while round oval tubers are ideal for crisps. In addition,

the absence of defects (diseased tubers with rots and sprouts) reduces the loss during peeling resulting in uniform processed products. Varieties with shallow eyes are most preferred for processing since deep eyes results in higher peel losses. Eye depth and shape of the tubers are greatly influenced by the variety while tuber size is determined by the cultural practices. Low starch that corresponds to low specific gravity can lead to poor texture and excess oiliness, and tuber greening as a result of exposure of tubers to light leads to high levels of glycoalkaloids (solanine) which are toxic at high concentrations or when consumed at lager amounts (Kabira and Lemaga, 2003).

The genetic component of the cultivar influences the initial reducing sugar levels in a mature tuber (Stevenson *et al.*, 1964) as well as during storage. The amounts of reducing sugars in a tuber affect the quality of potatoes especially the colour of the finished product (Roe *et al.*, 1990). The presence of high amounts of reducing sugars cause undesirably dark fry colour and is a result of the Maillard reaction between the sugars and the free amino acids present in the tuber at high temperature and low moisture (Schallenberger *et al.*, 1959). The reaction affects the colour, flavours (Kumar et al., 2004), and is related to acrylamide formation in fried products (Mottram *et al.*, 2002). The reducing sugars (fructose and glucose) are responsible for the development of brown colour in fried chips and crisps (Roe and Faulks, 1991) while the bitter tasting is attributed to high contents of acrylamide (Tareke *et al.*, 2002) and such products are not acceptable as they contain potentially toxic compounds.

Dry matter content of potato tubers is influenced by the harvest date. It has been reported that delayed harvest of potatoes result in higher dry matter content (Jewell and Stanley, 1989; DeBuchananne and Lawson, 1991) and palest fry colour (Hope *et al.*, 1960). It has also been shown that later dates of defoliation gave the

lowest reducing sugar levels (Jewell and Stanley, 1989). Nelson and Shaw, 1976 reported that tubers from late planting had higher glucose and sucrose than tubers from plants seeded early.

CHAPTER THREE

ASSESSMENT OF EARLY AND LATE HARVEST PERFORMANCE AND STABILITY OF R FREE LATE BLIGHT RESISTANT POTATO GENOTYPES IN KENYA

3.1 Abstract

Late blight (*Phytophthora infestans*) is a major constraint to potato production in the tropical highlands of Kenya causing significant yield losses of 30 - 75%. Farmers rely on fungicide application to manage the disease. However, control is often inadequate due to limited fungicide applications and use of cultivars with low to moderate resistance to late blight. Use of resistant cultivars is viewed to be more sustainable both economically and environmentally. Resistance alone, however, does not guarantee adoption by farmers of any cultivar as farmers have other preferences like earliness or good cooking characteristics. Moreover, resistance breaks down owing to changes in pathogen population necessitating the need for evaluation of new germplasm to replace old varieties whose resistance has broken down. The objective of the study therefore were to assess early and late harvest performance and stability of R free late blight resistant genotypes in Kenya. Ten advanced late blight resistant potato genotypes free of R genes from population B3 and two checks Tigoni, moderately resistant to late blight and Kerr's Pink, susceptible to late blight were used. Field experiments were conducted at two sites; Tigoni in Limuru and Marimba in Meru over a period of two years and laid out in a randomised complete block design (RCBD) with three replications. Field experiments were harvested at 90 (early) and 120 (late harvests) days after emergence (DAE). Significant differences ($P \leq 0.05$) were observed for tuber yields, AUDPC, and foliage maturity among the potato genotypes at early and late harvests. The AUDPC ranged from 35 to 3803 and was

significantly higher for Kerr's Pink than all population B3 genotypes and Tigoni. Population B3 genotypes performed better at late than early harvests but the increase in tuber yields due to delayed harvest varied with genotype and was greater at Tigoni, Limuru than at Marimba, Meru. Significant negative correlations between AUDPC and tuber yield were observed on the local checks but no correlations were observed on population B3 genotypes. Rankings of genotypes with respect to reactions to disease severity and tuber yield for early and late harvests varied across seasons and locations. AMMI analysis showed that the proportion of genotypic variance was larger than that due to the environmental variance and the G X E interaction. Genotypes (G), environments (E) and the G X E interactions accounted for 43.0% and 53.4%, 39.6% and 29.7%, 17.5% and 16.9% for tuber yield while for AUDPC it accounted for 80.2% and 82.3%, 5.0% and 4.6%, 14.8% and 13.1% of the treatment sum of squares at early and late harvests respectively. From the biplot, five genotypes at early harvests and all population B3 genotypes except two genotypes at late harvests were stable while for late blight resistance, four and six genotypes at early harvests and late harvests were stable respectively. The levels of resistance in population B3 potato genotypes varied from moderate resistance to high resistance. Population B3 entries 385524.9, 389746.2, 392617.54, 393371.58, 393385.39 and 393385.47 were better performers and could be considered for on farm trials.

3.2 Introduction

The most important constraint to potato production and productivity worldwide is the late blight disease caused by *Phytophthora infestans* (Mont. De Bary) and the lack of high yielding cultivars with resistance to the disease (CIP, 2002). The disease is a major threat to potato growing in the tropical highlands

causing significant yield losses ranging from 35% to 75% (Olanya *et al.*, 2001b) depending on varietal susceptibility and environmental conditions. Although late blight could be controlled by use of fungicides, costs are prohibitive to most of the small scale farmers, detrimental to the environment and fungicide effectiveness is constrained by lack of sufficient knowledge of managing the disease well (Nyankanga *et al.*, 2004).

Use of host plant resistance is the most effective, environmentally friendly and economically viable disease management option especially for resource-constrained small-scale farmers (Umaerus *et al.*, 1983). Use of late blight resistant cultivars is viewed to be more sustainable as a major source of disease control and a potential source for new variety releases (Landeo *et al.*, 2001). Genotypes without major genes have high levels of partial resistance to *P. infestans* and are more stable and durable (Landeo *et al.*, 1997). Resistance if not stable and durable breaks down shortly owing to changes in pathogen population particularly in its racial spectrum and long favourable environmental conditions therefore necessitating the need for evaluation of new sources of germplasm with more stable and durable resistance to replace old varieties whose resistance has broken down.

In countries like Kenya where potatoes are grown twice a year, farmers prefer early maturing genotypes since there is less chance of yields being suppressed by unfavourable conditions and infection by pests and diseases. In addition, early harvests achieve better prices (Turkensteen and Zimnoch- Gucowska, 2002). However, horizontal resistance against *P. infestans* has been found only in late maturing potato genotypes (Toxopeus, 1958; Swiezynski, 1990; Visker *et al.*, 2004). Thus selection for fast-bulking genotypes among late blight resistant genotypes might overcome the problems of late maturity. This study was conducted with the aim to (i)

evaluate early and late harvest performance and (ii) quantify the stability of advanced R-free clones from population B3 under Kenyan conditions.

3.3 Materials and methods

3.3.1 Study sites, experimental design and agronomic practices

Experiments were established at two locations; Tigoni in Limuru, 2100m a.s.l, and Marimba in Meru, 1844m a.s.l, during the 2005 and 2006 cropping seasons. The average annual rainfall at Tigoni is 800 mm, with mean temperature of 18°C and average annual precipitation at Marimba is 1299 mm, with mean temperature of 18.5 °C. The soil types for Tigoni, according to FAO classification are humic nitisols and ustic palehumults according to USDA classification while for Marimba, the major soil types are humic nitisols (Jaetzold and Schmidt, 1983).

At Tigoni, Limuru, experiments were conducted during the long rain season (April – August) and the short rain season (October – March) in 2006 while at Marimba, Meru, experiments were conducted during the long rain seasons (October – March) of 2005 and 2006 representing Season 1 and 2 respectively. The experimental materials consisted of ten advanced late blight resistant clones from breeding population B3 developed by CIP's breeding program and introduced to Kenya by CIP's Sub Sahara Africa regional office in 2002. The clones are 385524.9, 389746.2, 391696.96, 392617.54, 392637.10, 392657.8, 393280.57, 393371.58, 393385.39, and 393385.47 and two local checks, Tigoni (moderately resistant to late blight) and Kerr's Pink (highly susceptible to late blight) were used.

Experimental plots at each location were ploughed, harrowed to achieve a moderate soil texture and ridged. Tuber seed for the 12 genotypes were planted on furrows in a randomised complete block design replicated three times. Each experimental plot consisted of four rows, each containing ten plants/hill with plant

spacing of 30 by 75cm within and between rows respectively. In all the experimental plots, normal agronomic practices for potato production were carried out. N: P: K (17:17:17) compound fertilizer was applied at planting at a rate of 500kg/ha that was mixed thoroughly with the soil to avoid direct contact with the tubers. Weeding was done immediately the potato plants emerged and the field was kept weed free throughout the growing period. Earthing up was done twice during the growing period. No fungicides were applied to the experimental plots. However, insecticide (Duduthrin) was administered during the growth period for the control of aphids.

3.3.2 Late blight disease assessment

Late blight disease was initiated from natural infections from the surrounding fields. Late blight occurs naturally in the two locations throughout the year under favourable conditions hence there was no need for artificial inoculation. Plants in experimental plots were assessed for late blight development by visual rating of foliage for percent of leaf area blighted beginning from the time when 5% leaf area damage was noticed on the most susceptible cultivar. Subsequent readings of disease severity were recorded weekly based on visual assessments on a scale of 0% to 100% where, 0% = no disease and 100% = total leaf area affected by blight (Henfling, 1987), until the severity on the most susceptible cultivar approached 100%.

The weekly disease data were used to calculate AUDPC (Shaner & Finney, 1977) for each genotype following the midpoint rule (Campbell & Madden, 1990).

The formula used was:

$$AUDPC = \Sigma \{[(yi + yi+ 1)/2] (ti+1-ti)\}$$

Where:

yi= percentage of foliage damaged by blight at the i th observation; t= time in days after planting at the i th observation; and n= the number of readings.

3.3.3 Foliage maturity assessment

Foliage maturity was assessed at 86 (early harvest) and 106 (late harvest) DAE using 1-9 scale where 1= immature (green foliage and flowering); 3= Initiating maturity (less green and almost no flowering); 5= intermediate (vines turning dark green and plants start lodging); 7= approaching maturity (vines get yellow and plants lodge); 9= completely mature (vines completely senesced) (Landeo, 2004).

3.3.4 Yield determination

This was determined from four rows in each plot (10 hills per row). The number of hills harvested per plot was counted and recorded. The harvested tubers per plot were separated using a sieve with holes of different diameters and were assessed at 90 (early harvest) and 120 (late harvest) DAE. Depending on the holes, the tubers were categorized as marketable (size above 25 mm), unmarketable [chats] size below 25 mm tubers, and their numbers and fresh weights were recorded. The total number of tubers per plot was obtained by adding the marketable and unmarketable tubers. Tubers per hill were calculated by dividing the total number of tubers per plot by the number of hills harvested per plot. The weights of the marketable and unmarketable (chats) tubers per plot separated previously were recorded. These were used to calculate the total tuber weight per area for comparison among the genotypes.

3.3.5 Determination of the incidence of potato tuber moth and tuber rot

The incidence of the potato tuber moth in the field was assessed at harvest by recording the number of tubers damaged by tuber moth or with the typical symptoms of tuber moth. This is the tunnelling on the surface of the tuber, with or without the presence of the moth itself for each genotype and plot and was expressed as a percentage of total number of tubers.

The incidence of tuber rots in the field was assessed at harvest by recording the number of tubers with rots in each plot and for each of the genotypes and was expressed as a percentage of the total number of tubers.

3.4 Data analysis

The data collected was subjected to the analysis of variance (ANOVA) using the Genstat statistical package (Genstat, 2006). Where the 'F' statistic showed significance, the means were separated by Least Significant Difference (LSD).

G x E interaction effects on yield and AUDPC were analysed using the additive main effects and multiplicative interaction (AMMI) model as described by Gauch, 1992 as:

$$Y_{ger} = \mu + \alpha_g + \beta_e + \sum_n \lambda_n \gamma_{gn} \delta_{en} + \rho_{en} + \varepsilon_{ger}$$

where:

Y_{ger} = the yield of genotype g in the environment e for r replications; μ = the grand mean; α_g = the deviation of the mean of the genotype g; β_e = the deviation of the mean of the environment e; $\sum_n \lambda_n \gamma_{gn} \delta_{en}$ = the multiplicative fraction, with multiplicative parameters λ_n, the characteristic value of IPCA axis n; γ_{gn} = the

genotype eigenvector for axis n; δ_{en} = the environment eigenvector for axis n; ρ_{en} = the residue of the interaction; ε_{ger} = the error associated to Y_{ger}.

3.5. RESULTS

3.5.1 Late blight severity and disease progress

Disease severity was significantly ($P \leq 0.05$) different among the genotypes during all seasons at both locations at early and late harvests (Table 1 and 2). Generally, the weather was very favourable for development of late blight epidemic (Appendix 5). The epidemic started earlier in Kerr's Pink compared to the population B3 genotypes and the moderately resistant check variety, Tigoni.

Table 1: Analysis of variance for AUDPC, tuber yield, foliage maturity, tuber moth and rot for field experiments carried out at Marimba, Meru and Tigoni, Limuru during 2005 and 2006 growing seasons

Source of variation	df	F value		P>F	
		90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]
AUDPC					
Rep	2	2.95	0.45	0.0557	0.6379
Genotype (G)	11	45.21	53.99	0.0001	0.0001
Location (L)	1	4.52	5.00	0.0354	0.0271
Season (S)	1	22.40	26.87	0.0001	0.0001
G * L	11	7.34	7.73	0.001	0.001
G * S	11	10.23	11.01	0.001	0.001
G * Rep	22	0.00	0.00	0.00	0.00
G * L * S	11	6.64	6.29	0.001	0.001
Tuber yield					
Rep	2	0.98	0.01	0.3799	0.9926
Genotype (G)	11	16.93	19.05	0.0001	0.0001
Location (L)	1	138.73	61.95	0.0001	0.0001
Season (S)	1	0.21	10.15	0.6468	0.0018
G * L	11	14.62	12.48	0.001	0.001
G * S	11	9.24	11.55	0.001	0.001
G * Rep	22	0.00	0.00	0.00	0.00
G * L * S	11	8.80	9.23	0.001	0.001
Tuber Moth					
Rep	2	0.08	2.42	0.9257	0.0934
Genotype (G)	11	1.73	5.66	0.0746	0.0001
Location (L)	1	0.07	6.04	0.7916	0.0153
Season (S)	1	13.09	2.55	0.00004	0.1126
G * L	11	1.31	1.40	0.23	0.185
G * S	11	2.32	1.51	0.015	0.140
G * Rep	22	0.00	0.00	0.00	0.00
G * L * S	11	1.66	1.22	0.095	0.282
Tuber Rot					
Rep	2	4.76	1.17	0.0101	0.3139
Genotype (G)	11	1.89	1.51	0.0457	0.1342
Location (L)	1	0.29	3.18	0.5889	0.1046
Season (S)	1	36.16	0.06	0.0001	0.5394
G * L	11	2.47	1.19	0.009	0.306
G * S	11	2.56	0.89	0.007	0.558
G * Rep	22	0.00	0.00	0.00	0.00
G * L * S	11	2.47	1.50	0.009	0.146
Foliage maturity					
Rep	2	0.43	1.65	0.00	0.00
Genotype (G)	11	80.42	56.20	0.001	0.001
Location (L)	1	142.30	245.26	0.001	0.001
Season (S)	1	41.75	50.67	0.001	0.001
G * L	11	9.57	19.72	0.001	0.001
G * S	11	18.71	21.93	0.001	0.001
G * Rep	22	0.00	0.00	0.00	0.00
G * L * S	11	1.93	32.43	0.045	0.001

DAE[a] =Days after emergence (Harvest Date)

Significantly, higher AUDPC values were obtained for Kerr's Pink than the population B3 genotypes irrespective of the location, the season (Table 2). However with respect to performance of the moderately resistant variety Tigoni, some of the population B3 genotypes had lower performance, some as equal as and some showing superiority. Mean AUDPC values were higher at Tigoni, Limuru and Marimba, Meru, during season 2 and lower during season 1 (Table 2). The disease progress curves on the genotypes had similar trends with observable differences between seasons (Figures 1 – 4). Final disease values were highest during the second season than in the first season at Tigoni, Limuru and Marimba, Meru. Kerr's Pink had also the highest final disease values regardless of season and location (Figures 1 – 4).

Table 2: Mean Area under Disease Progress Curve (AUDPC) for twelve potato genotypes harvested at different dates at Tigoni, Limuru and Marimba, Meru during Season 1 and 2

Genotype	NPRC, Tigoni				Marimba, Meru			
	Season 1		Season 2		Season 1		Season 2	
	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]
392617.54	58	117	367	263	210	274	940	880
393385.39	87	82	671	624	157.5	134	640	693
392637.10	122	88	531	496	169.2	204	453	500
393280.57	122	58	636	554	35	88	353	253
392657.8	128	140	1003	718	99.2	70	613	493
393385.47	187	53	204	158	87.5	193	600	353
393371.58	327	111	157	566	274.2	262	360	213
385524.9	449	589	385	478	291.7	344	700	707
389746.2	519	490	939	928	396.7	332	667	820
391696.96	811	630	1108	1295	175	233	633	620
K. Pink	3803	3599	2176	2158	2135	2257	2333	2267
Tigoni	402	560	677	811	256.7	163	460	500
Mean	585	543	738	754	357.3	380	729	692
LSD (5%)	249.9 *	265 *	312.8 *	266.8 *	80.37 *	188.6 *	492 *	382.4 *
% CV	25.2	28.8	25.0	20.9	13.3	29.3	39.8	32.6

* Significant at 5% level of significance; DAE[a] =Days after emergence (Harvest Date)

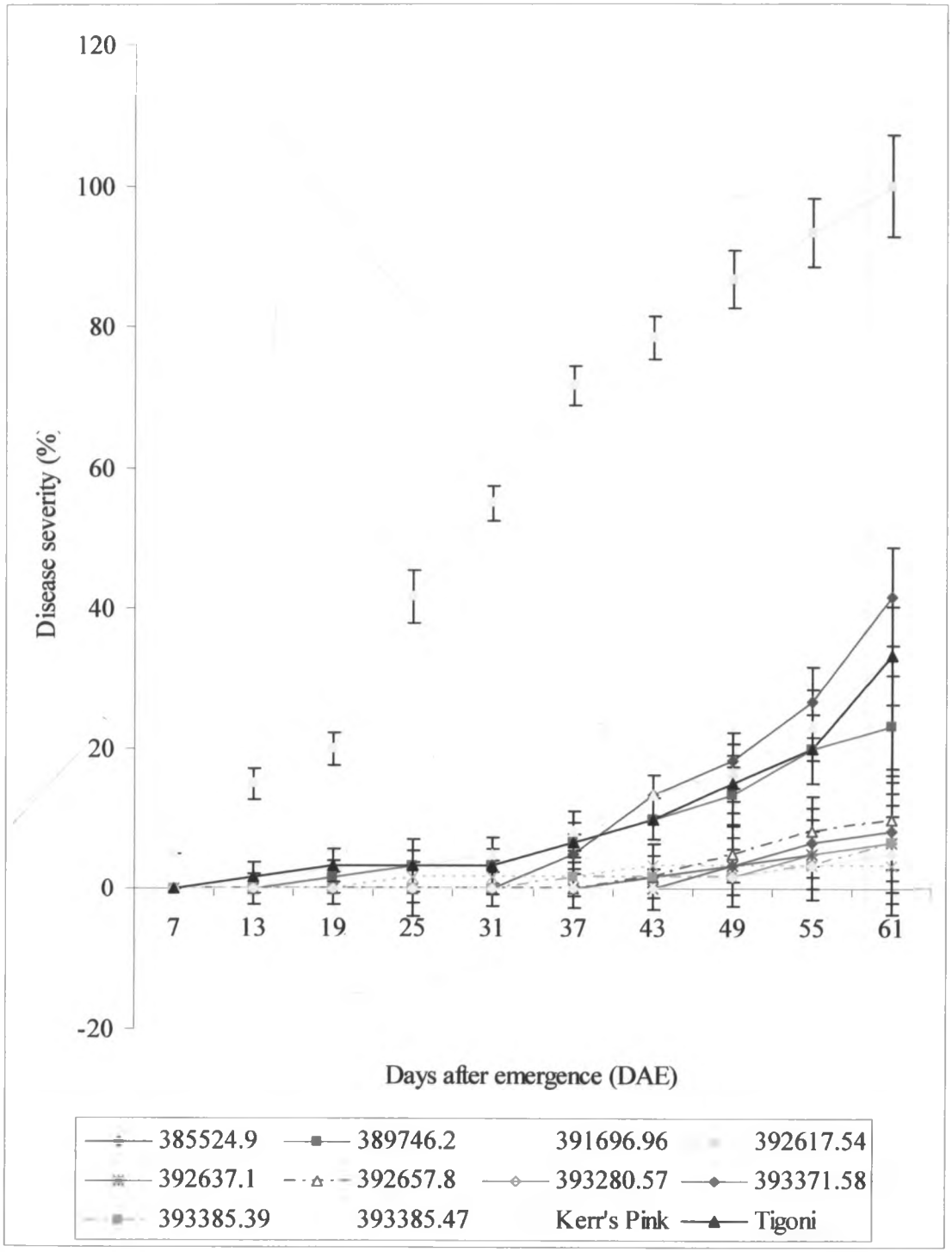


Fig. 1: Disease progress curves on different potato genotypes at Tigoni, Limuru during the 2006 long rains. The bars indicate standard error (SE) of the mean.

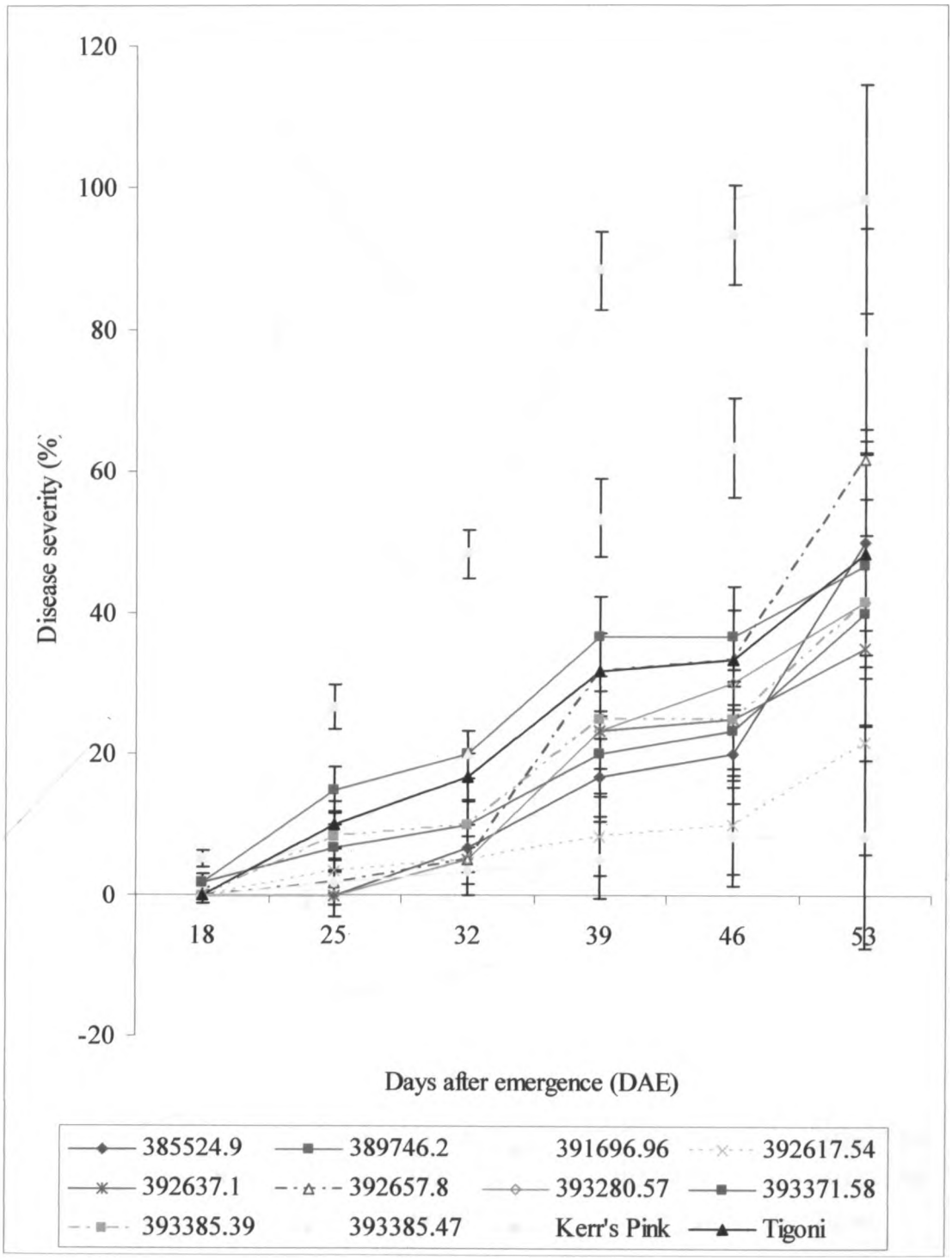


Fig 2: Disease progress curves on different potato genotypes at Tigoni, Limuru during 2006 short rains. The bars indicate standard error (SE) of the mean.

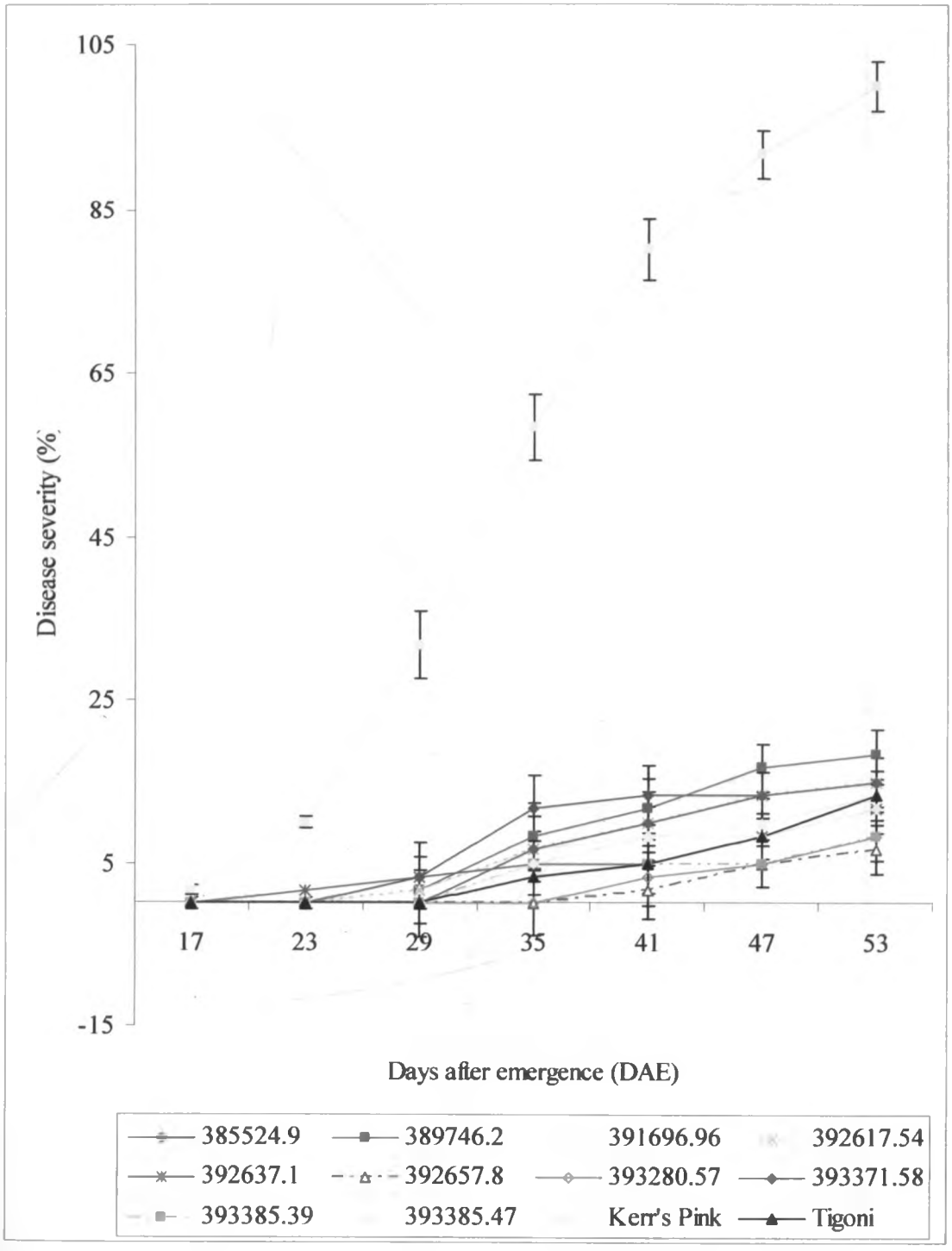


Fig 3: Disease progress curves on different potato genotypes at Marimba, Meru during 2005 long rains. The bars indicate standard error (SE) of the mean.

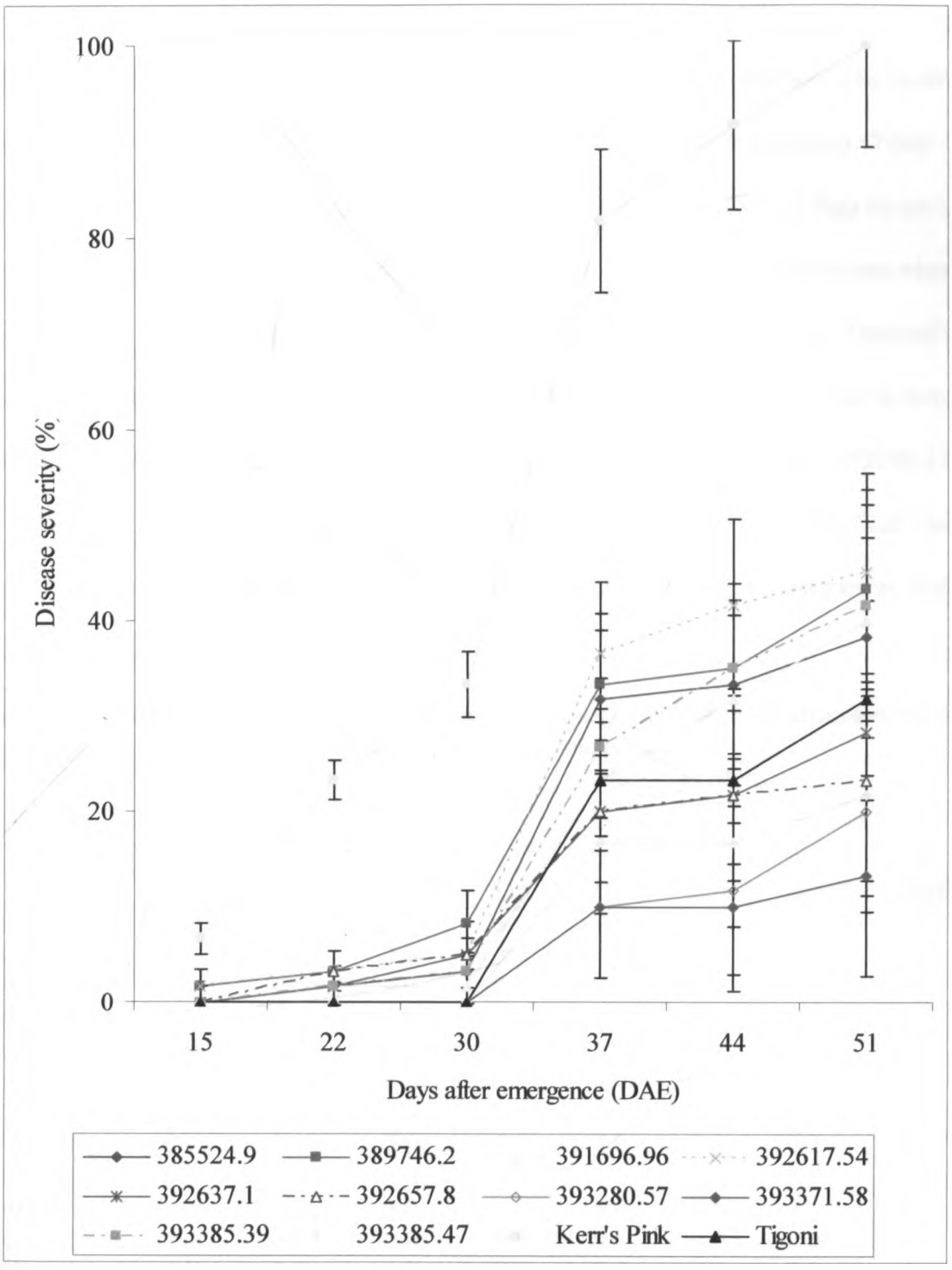


Fig 4: Disease progress curves on different potato genotypes at Marimba, Meru during 2006 long rains. The bars indicate standard error (SE) of the mean.

3.5.2 Foliage maturity

Significant differences ($P \leq 0.05$) in foliage maturity were observed among the genotypes during all the seasons at early and late harvests at both locations (Table 1 and 3). Higher scores of foliage maturity were observed in late harvest than in early harvest (Table 3). For early yield, Kerr's Pink showed higher scores of earliness when compared to all Population B3 and the moderately resistant Tigoni variety. Generally population B3 genotypes 385524.9, 389746.2, 391696.96, 393371.58 and Tigoni were medium early and early while 392617.54, 392637.10, 392657.8, 393280.57, 393385.39 and 393385.47 were medium late and medium early at early and late harvests respectively. Kerr's Pink was found to be early during all seasons at both locations.

Table 3: Foliage maturity of twelve potato genotypes harvested at different dates at Tigoni, Limuru and Marimba, Meru during season 1 and 2

Genotype	NPRC, Tigoni				Marimba, Meru			
	Season 1		Season 2		Season 1		Season 2	
	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]
385524.9	7.0	9.0	7.7	9.0	7.0	9.0	5.0	9.0
389746.2	7.0	9.0	7.0	9.0	7.0	9.0	5.0	7.7
391696.96	7.0	9.0	9.0	9.0	7.0	9.0	7.0	9.0
392617.54	3.7	5.0	5.0	9.0	5.0	7.0	3.7	6.3
392637.10	3.0	7.0	7.0	9.0	1.0	5.0	3.7	7.0
392657.8	3.0	7.0	8.3	9.0	3.0	5.0	3.7	7.7
393280.57	3.0	7.0	6.3	9.0	1.0	3.0	1.7	5.0
393371.58	6.3	9.0	7.0	9.0	7.0	9.0	5.7	7.0
393385.39	5.0	7.7	9.0	9.0	3.0	5.0	5.0	7.7
393385.47	4.3	8.3	5.0	9.0	5.0	7.0	3.0	5.7
Kerr's Pink	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0
Tigoni	6.3	9.0	6.3	9.0	7.0	9.0	5.0	7.0
Mean	5.4	8.0	7.2	9.0	5.2	7.2	4.8	7.3
LSD (5%)	1.17 *	0.78 *	1.09 *	*	*	0.56 *	1.66 *	1.29 *
% CV	12.8	5.8	8.9	0.0	0.0	4.6	20.5	10.3

* Significant at 5% level of significance, DAE[a] =Days after emergence (Harvest Date), 1= immature (green foliage and flowering); 5= intermediate (vines turning dark green and plants start lodging); 9= completely mature (vines completely senesced).

3.5.3 Yield and yield components

3.5.3.1 Total tuber yields

Total yields per plot differed significant differences ($P \leq 0.05$) among the genotypes at early and late harvests (Table 1 and 4). All genotypes significantly outperformed Kerr's Pink in total tuber yields. In regard to the yield performance of variety Tigoni, some of the population B3 genotypes (391696.96 and 393280.57) had significantly lower, some (392637.10, 392657.8) as equal as and some (385524.9, 389746.2, 392617.54, 393371.58, 393385.39 and 393385.47) higher total tuber yields for early and late yields (Table 4 and 5). Generally higher total tuber yield per plot were observed from late than in early harvest (Table 4 and 5) and also there were higher mean tuber yields during all the seasons at Tigoni, Limuru than at Marimba, Meru for early and late harvests (Table 4 and 5).

3.5.3.2 Marketable tuber yields

There were significant ($P \leq 0.05$) differences among the genotypes at early and late harvests at both locations (Table 4 and 5). All genotypes significantly outperformed Kerr's Pink in marketable tuber yields. Comparing the performance of variety Tigoni and the population B3 genotypes, some (391696.96 and 393280.57) significantly had lower, some (392637.10, 392657.8) as equal as and some (385524.9, 389746.2, 392617.54, 393371.58, 393385.39 and 393385.47) had higher marketable tuber yields (Table 4 and 5). Overall higher marketable tuber yield per plot was observed at late than early harvests (Table 4 and 5).

Table 4: Mean tuber yield per plot, Kg[a] for twelve potato genotypes harvested at different dates at Marimba, Meru during season 1 and 2

Season 1

Genotype	Unmarketable		Marketable		Total	
	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]
385524.9	1.7	2.3	15.6	19.6	17.3	21.9
389746.2	1.8	1.1	16.9	23.7	18.7	24.8
391696.96	1.5	2.1	8.5	12.4	10.0	14.5
692617.54	1.9	2.7	13.2	23.5	15.1	26.2
392637.10	1.7	1.0	8.1	14.3	9.8	15.3
392657.8	1.6	1.0	8.3	15.7	9.9	16.7
393280.57	2.7	2.1	8.9	15.9	11.6	18.0
393371.58	0.9	0.8	16.6	29.7	17.5	30.5
393385.39	2.4	1.7	13.4	25.0	15.8	26.7
393385.47	0.9	0.7	10.0	12.8	10.9	13.5
Kerr's Pink	4.0	3.6	0.3	2.1	4.3	5.7
Tigoni	1.4	1.4	10.4	16.9	11.8	18.3
Mean	1.8	1.7	10.9	17.6	12.7	19.3
LSD (5%)	1.76	1.53 *	3.51 *	4.22 *	3.24 *	3.55 *
% CV	55.7	52.5	19.1	14.1	15.0	10.8

Season 2

Genotype	Unmarketable		Marketable		Total	
	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]
385524.9	2.0	2.3	9.5	10.7	11.5	13.0
389746.2	0.4	1.3	13.0	16.5	13.4	17.8
391696.96	0.6	0.8	2.3	4.7	2.9	5.5
692617.54	0.7	0.4	9.1	11.2	9.8	11.6
392637.10	0.9	0.7	8.8	10.3	9.7	11.1
392657.8	0.7	1.5	7.6	9.0	8.3	10.5
393280.57	0.8	1.0	5.3	9.0	6.1	10.0
393371.58	0.6	0.5	8.3	12.0	8.9	12.5
393385.39	1.4	2.0	10.5	15.0	11.9	17.0
393385.47	1.3	1.1	7.6	9.7	8.9	10.8
Kerr's Pink	1.1	1.5	0.0	0.0	1.1	1.5
Tigoni	0.7	0.8	10.8	12.4	11.5	13.2
Mean	1.0	1.2	7.7	10.0	8.7	11.2
LSD (5%)	0.69 *	0.76 *	3.30 *	4.18 *	3.19 *	4.15 *
% CV	42.9	37.9	25.2	24.6	21.7	21.9

* Significant at 5% level of significance; Kg[a] is weight from 3M x 3M plot area; DAE[a] =Days after emergence (Harvest Date).

Table 5: Mean tuber yields per plot, Kg[a] for twelve potato genotypes harvested at different dates at Tigoni, Limuru during season 1 and 2

Season 1

Genotype	Unmarketable		Marketable		Total	
	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]
385524.9	0.7	0.7	19.9	23.6	20.6	24.3
389746.2	0.4	0.2	21.4	24.2	21.8	24.4
391696.96	0.7	0.7	12.3	12.5	13.0	13.2
392617.54	0.6	0.5	24.0	30.3	24.6	30.8
392637.10	0.5	0.5	11.8	15.4	12.2	15.9
392657.8	0.6	0.1	7.4	13.5	8.0	13.6
393280.57	0.5	0.3	9.4	14.2	9.9	14.5
393371.58	0.5	0.2	25.3	26.1	25.8	26.3
393385.39	0.6	0.5	23.5	25.0	24.1	25.5
393385.47	0.5	0.2	15.0	21.4	15.5	21.6
Kerr's Pink	4.9	4.9	0.0	0.0	4.9	4.9
Tigoni	0.7	0.4	27.9	28.5	28.6	28.9
Mean	0.9	0.8	16.5	19.7	17.4	20.5
LSD (5%)	0.31 *	0.30 *	2.27 *	2.73 *	2.29 *	2.71 *
% CV	19.9	22.7	8.1	8.2	7.8	7.9

Season 2

Genotype	Unmarketable		Marketable		Total	
	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]
385524.9	0.9	1.7	29.6	29.0	30.5	30.7
389746.2	0.2	0.5	26.2	26.5	26.4	27.0
391696.96	1.3	1.3	11.1	11.7	12.4	13.0
392617.54	0.4	0.4	23.2	24.3	23.6	24.7
392637.10	1.0	1.7	23.5	23.8	24.5	25.5
392657.8	0.7	0.8	19.4	21.0	20.1	21.8
393280.57	0.6	1.0	10.6	11.5	11.2	12.5
393371.58	0.9	1.2	35.5	35.0	36.4	36.2
393385.39	2.7	2.0	23.0	24.2	25.7	26.2
393385.47	0.6	1.5	28.4	31.5	29.0	33.0
Kerr's Pink	5.7	2.7	0.0	4.8	5.7	7.5
Tigoni	0.7	0.8	19.6	19.7	20.3	20.5
Mean	1.3	1.3	20.8	21.9	22.1	23.2
LSD (5%)	0.67 *	1.16 *	5.03 *	3.46 *	5.24 *	3.74 *
% CV	30.1	52.8	14.3	9.3	14.0	9.5

* Significant at 5% level of significance; Kg[a] is weight from 3M x 3M plot area; DAE[a] =Days after emergence (Harvest Date).

3.5.3.3 Unmarketable tuber yields

There were significant ($P \leq 0.05$) differences among the genotypes on the unmarketable tuber yield per plot at early and late harvests during all the seasons at both locations except at Marimba, Meru during the first season where it was not significant for early harvest (Table 4 and 5). Kerr's Pink significantly had higher unmarketable tuber yields than Tigoni and all the population B3 genotypes. With respect to the variety Tigoni, there were not much significant differences in unmarketable tuber yields with some of the late blight resistant genotypes from population B3 significantly showing superiority, some as equal as and some had lower performance for early and late harvest (Table 4 and 5). However, higher unmarketable tuber yields were observed at early than in late harvests for some varieties (Table 4 and 5).

3.5.4 Number of tubers per hill

Total number of tubers per hill differed significantly ($P \leq 0.05$) among the genotypes (Table 6 and 7). However, there were no significant differences in the number of tubers per hill between the early and late harvests at both locations except at Tigoni, Limuru for unmarketable tubers per hill during the second season and at Marimba, Meru for marketable tubers per hill during the first season (Table 6 and 7). Generally Kerr's Pink had higher number of tubers per hill followed by population B3 genotypes 393385.39 and 385524.9 compared to the remaining population B 3 genotypes and the resistant check, Tigoni.

Table 6: Mean tubers per hill for twelve potato genotypes harvested at different dates at Tigoni, Limuru during season 1 and 2

Season 1

Genotype	Unmarketable		Marketable		Total	
	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]
385524.9	1.4	1.5	9.0	8.3	10.4	9.8
389746.2	0.6	0.5	5.2	5.8	5.8	6.3
391696.96	1.4	1.4	5.9	5.1	7.3	6.5
392617.54	1.3	1.3	7.9	7.8	9.2	9.1
392637.10	0.8	1.3	5.1	5.9	5.9	7.2
392657.8	1.1	0.9	3.4	4.4	4.5	5.3
393280.57	1.3	0.8	5.0	4.7	6.3	5.5
393371.58	0.8	0.6	7.6	6.9	8.4	7.5
393385.39	1.8	1.1	7.6	7.2	9.4	8.3
393385.47	1.0	0.7	6.1	6.0	7.1	6.7
Kerr's Pink	7.7	11.6	4.5	1.6	12.2	13.2
Tigoni	1.3	1.0	8.0	8.5	9.3	9.5
Mean	1.7	1.9	6.3	6.0	8.0	7.9
LSD (5%)	1.32 *	2.01 *	1.34 *	1.64 *	1.78 *	1.97 *
% CV	45.5	62.8	12.6	16.1	13.1	14.7

Season 2

Genotype	Unmarketable		Marketable		Total	
	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]
385524.9	2.8	2.5	13.7	12.9	16.5	15.4
389746.2	0.7	1.2	9.5	8.2	10.2	9.4
391696.96	2.8	2.7	9.4	5.8	12.2	8.5
392617.54	1.5	0.9	9.1	7.6	10.6	8.5
392637.10	3.0	2.9	9.4	10.2	12.4	13.1
392657.8	2.0	1.5	8.6	8.8	10.6	10.3
393280.57	2.5	2.1	7.3	7.9	9.8	10.0
393371.58	2.0	1.6	11.3	8.2	13.3	9.8
393385.39	6.3	4.7	12.9	11.0	19.2	15.8
393385.47	1.5	2.1	9.2	13.1	10.7	15.2
Kerr's Pink	15.0	10.7	0.0	5.7	15.0	16.4
Tigoni	1.9	1.7	8.2	7.5	10.1	9.2
Mean	3.5	2.9	9.1	8.9	12.6	11.8
LSD (5%)	1.97 *	2.02 *	3.17 *	2.54 *	4.36 *	3.01*
% CV	33.4	41.3	20.6	16.8	20.5	15.1

* Significant at 5% level of significance; DAE[a] =Days after emergence (Harvest Date).

Table 7: Mean tubers per hill for twelve potato genotypes harvested at different dates at Marimba, Meru during the season 1 and 2

Season 1

Genotype	Unmarketable		Marketable		Total	
	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]
385524.9	4.4	3.9	8.9	8.7	13.3	12.6
389746.2	2.4	2.5	6.8	8.3	9.2	10.8
391696.96	7.3	6.2	4.5	5.8	11.8	12.0
692617.54	4.1	4.0	6.0	6.8	10.1	10.8
392637.10	2.9	2.8	6.5	5.0	9.4	7.8
392657.8	2.9	2.2	4.5	4.5	7.4	6.7
393280.57	3.9	3.8	5.8	5.6	9.7	9.4
393371.58	3.1	2.5	6.0	7.5	9.1	10.0
393385.39	4.2	3.8	7.8	10.0	12.0	13.8
393385.47	3.1	2.3	3.7	4.7	6.8	7.0
Kerr's Pink	9.3	8.9	0.8	2.1	10.1	11.0
Tigoni	3.4	2.9	7.1	6.8	10.5	9.7
Mean	4.3	3.8	5.7	6.3	10.0	10.1
LSD (5%)	1.80 *	2.20 *	1.98 *	2.04 *	2.35 *	2.67 *
% CV	25.0	34.0	20.6	19.1	14.0	15.6

Season 2

Genotype	Unmarketable		Marketable		Total	
	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]
385524.9	4.8	4.6	6.1	5.9	10.9	10.5
389746.2	1.0	3.3	5.9	4.8	6.9	8.1
391696.96	1.8	1.8	2.3	2.9	4.1	4.7
692617.54	1.4	1.0	5.1	5.0	6.5	6.0
392637.10	1.8	1.2	5.3	3.8	7.1	5.0
392657.8	1.8	2.2	5.2	4.8	7.0	7.0
393280.57	2.9	2.3	3.3	4.1	6.2	6.4
393371.58	1.3	1.5	3.1	4.1	4.4	5.6
393385.39	4.4	4.5	6.7	7.0	11.1	11.5
393385.47	2.4	1.8	4.1	3.4	6.5	5.2
Kerr's Pink	9.1	7.8	0.0	0.0	9.1	7.8
Tigoni	1.3	1.0	5.4	5.0	6.7	6.0
Mean	2.8	2.7	4.4	4.2	7.2	6.9
LSD (5%)	1.74 *	2.38 *	1.65 *	1.45 *	2.10 *	2.76 *
% CV	36.6	51.2	22.3	20.3	17.3	23.3

* Significant at 5% level of significance; DAE[a] =Days after emergence (Harvest Date).

3.5.5 Incidences of potato tuber moth and tuber rots

Significant differences in potato tuber moth were observed among the genotypes at early and late harvest during all seasons at both locations except at Tigoni, Limuru during the second season for early and late harvest and Marimba, Meru during the first season for early harvest (Table 8). Infestation of the genotypes by potato tuber moth was minimal and it was significantly higher in tubers from late than those of early harvests except at Tigoni, Limuru during the second season.

Table 8: Percent number of tubers infested with potato tuber moth of 12 potato genotypes harvested at different dates at Tigoni, Limuru and Marimba, Meru during season 1 and 2

Genotype	NPRC, Tigoni				Marimba, Meru			
	Season 1		Season 2		Season 1		Season 2	
	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]
385524.9	0.2	2.6	1.0	0.5	0.2	1.2	0.3	0.5
389746.2	0.2	2.1	0.9	0.0	0.3	0.5	0.1	0.0
391696.96	0.1	0.0	1.8	0.0	0.0	0.2	0.2	0.6
692617.54	0.0	2.6	3.2	0.3	0.2	0.4	0.3	0.0
392637.10	0.0	0.0	0.3	0.4	0.2	0.5	0.0	0.0
392657.8	0.0	3.6	0.9	0.5	0.0	0.0	0.0	0.0
393280.57	0.0	7.7	0.0	0.1	0.0	0.1	0.0	0.0
393371.58	0.1	0.0	0.0	1.3	0.3	0.7	0.7	1.7
393385.39	0.0	0.9	0.8	0.1	0.0	0.2	0.1	0.1
393385.47	0.7	0.0	0.9	0.3	1.1	2.2	0.8	1.7
Kerr's Pink	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tigoni	0.8	2.0	0.8	3.2	1.1	2.2	0.9	1.9
Mean	0.2	1.8	0.9	0.6	0.3	0.7	0.3	0.5
LSD (5%)	0.49 *	1.29 *	1.92	1.91	0.96	1.36 *	0.54 *	1.01*
% CV	163.3	17.9	130.3	204.7	203.2	118.9	114.3	110.0

* Significant at 5% level of significance; DAE[a] =Days after emergence (Harvest Date).

No significant differences in rotting were observed among the genotypes for early and late harvests except at Tigoni, Limuru during the first season. Few incidences of rotting were observed during the second season and were slightly and significantly higher in tubers from early than those of late harvest (Table 9). No incidences of rots were observed in tubers from early harvest during the first season at both locations (Table 9).

Table 9: Percent numbers of tubers with tuber rot of 12 potato genotypes harvested at different dates at Tigoni, Limuru and Marimba, Meru during season 1 and 2

Genotype	NPRC, Tigoni				Marimba, Meru			
	Season 1		Season 2		Season 1		Season 2	
	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]
385524.9	0.0	0.0	0.2	0.0	0.0	0.0	0.6	0.2
389746.2	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0
391696.96	0.0	0.8	1.0	0.2	0.0	0.0	0.0	0.0
692617.54	0.0	0.0	0.3	0.1	0.0	0.0	1.4	0.0
392637.10	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0
392657.8	0.0	0.0	0.3	0.0	0.0	0.0	0.4	0.0
393280.57	0.0	0.0	0.1	0.0	0.0	0.0	0.7	0.0
393371.58	0.0	0.0	0.4	0.8	0.0	0.0	0.0	0.0
393385.39	0.0	0.0	1.1	0.1	0.0	0.0	4.0	0.0
393385.47	0.0	0.7	0.4	0.1	0.0	0.0	0.3	0.3
Kerr's Pink	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tigoni	0.0	0.0	0.1	0.0	0.0	0.0	0.4	0.0
Mean	0.0	0.1	0.3	0.1	0.0	0.0	0.9	0.1
LSD (5%)	0 00	0.59	0.63 *	0.65	0.00	0.00	2.25	0.33
% CV	0.00	288.1	110.9	395.0	0.00	0.00	196.6	410.9

* Significant at 5% level of significance; DAE[a] =Days after emergence (Harvest Date).

3.5.6 Relationships between unmarketable, marketable, tuber yields and the late blight disease levels

There was a negative correlation between AUDPC and the unmarketable, marketable and total tuber yields at 90 and 120 DAE during all seasons at both locations except at Marimba, Meru during the first season and at Tigoni, Limuru during the second season at 120 DAE (Table 10). However, non-significant negative correlations with unmarketable tuber yields were detected on population B3 genotypes at 90 and 120 DAE during all seasons and locations except at 120 DAE during the first season 2 at Tigoni, Limuru (Table 10). For marketable and total tuber yields, AUDPC was negatively correlated at 90 and 120 DAE except at Tigoni, Limuru during the second season and at Marimba, Meru during the second season at 90 DAE (Table 10).

Table 10: Correlation coefficients of AUDPC and the unmarketable, marketable and the total tuber yield for 12 potato genotypes harvested at different dates at Tigoni, Limuru and Marimba, Meru during season 1 and 2

Site	Season 1		Season 2	
	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]
Tigoni, Limuru				
Unmarketable tuber yield				
Checks	-0.79 *	-0.77 *	-0.79 *	-0.82 ns
Population B3	-0.96 ns	-0.84 *	-0.79 ns	-0.86 ns
Marketable tuber yield				
Checks	-0.71 *	-0.71 *	-0.86 *	-0.91 *
Population B3	-0.94 ns	-0.96 ns	-0.95 *	-0.96 *
Total tuber yield				
Checks	-0.82 *	-0.81 *	-0.70 *	-0.85 *
Population B3	-0.94 ns	-0.96 ns	-0.95 *	-0.96 *
Marimba, Meru				
Unmarketable tuber yield				
Checks	-0.87 *	-0.84 ns	-0.96 ns	-0.95 *
Population B3	-0.87 ns	-0.84 ns	-0.84 ns	-0.83 ns
Marketable tuber yield				
Checks	-0.73 *	-0.79 *	-0.70 *	-0.68 *
Population B3	-0.95 *	-0.95 ns	-0.93 ns	-0.95 ns
Total tuber yield				
Checks	-0.91 *	-0.88 *	-0.77 *	-0.76 *
Population B3	-0.96 *	-0.96 ns	-0.94 ns	-0.95 ns

* and ns are significant and not significant respectively at 5%; DAE[a] =Days after emergence (Harvest Date).

3.6 Genotype by Environment (G x E) interaction

3.6.1 G x E interaction effect on stability of late blight resistance

The AMMI analysis of genotype means AUDPC across environments and environments mean AUDPC across genotypes are presented in Table 11. The main effect treatment was partitioned into genotypes (G), environment (E), and G x E interaction with significant ($P \leq 0.05$) differences. G, E and G x E accounted for 80.2% and 82.3%, 5.0% and 4.6%, 14.8% and 13.1% of the treatment sums of squares at 90 and 120 DAE respectively (Appendixes 1 - 2). G X E interaction was partitioned into principal component axes (IPCA) with significant ($P \leq 0.05$) differences (Appendixes 1 - 2). The sum of squares for G, E and IPCA 1 and 2 provided 99% of treatment sum of squares thus the treatment sum of squares contains 99% pattern related to treatment design and 1% noise related to experimental design.

Table 11: AMMI analysis of AUDPC and the proportion of the two first principal components of 12 potato genotypes mean scores for genotypes and environment harvested at different dates at Tigoni, Limuru and Marimba, Meru

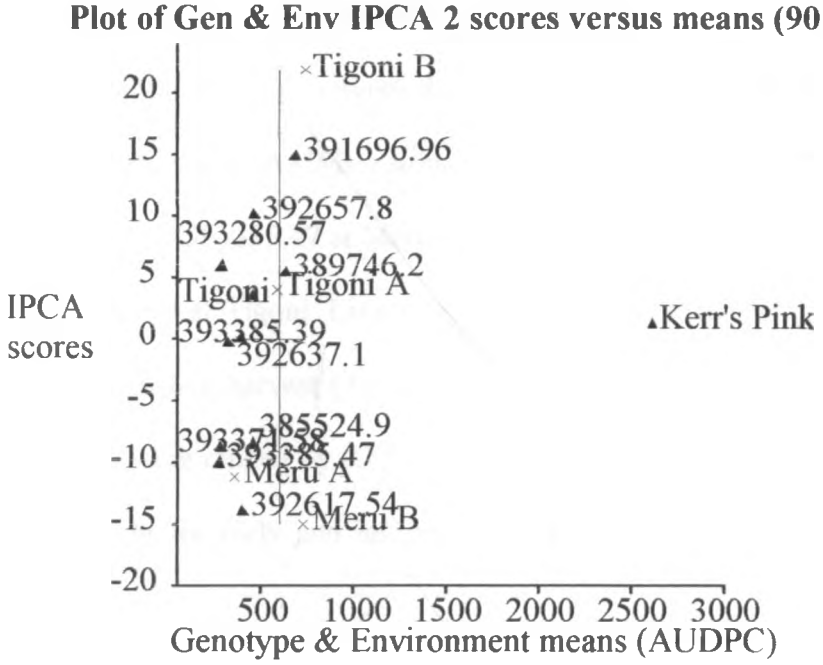
Environment/ Genotype	Mean		IPCA1		IPCA2	
	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]
Marimba, Meru A	357.3	379.7	4.8	2.4	-11.2	-11.0
Marimba, Meru B	729.4	691.7	12.0	11.9	-14.9	-15.6
Tigoni, Limuru A	584.8	543.0	-33.8	-31.3	4.1	4.9
Tigoni, Limuru B	737.9	754.0	16.9	17.0	21.9	21.6
385524.9	456.5	529.6	-1.3	-4.3	-8.4	-6.5
389746.2	630.4	642.5	3.2	4.3	5.5	2.4
391696.96	681.9	694.6	-2.1	3.7	14.8	17.4
692617.54	394.0	383.3	8.4	5.0	-14.0	-17.0
392637.10	319.0	321.9	4.9	5.1	-0.3	-3.4
392657.8	461.0	355.2	10.8	6.3	10.1	4.4
393280.57	286.7	238.3	4.9	4.1	6.0	3.9
393371.58	279.6	288.1	-3.7	3.1	-8.7	3.0
393385.39	389.0	383.3	8.5	8.3	0.1	-2.8
393385.47	269.6	189.0	1.0	0.5	-10.0	-9.4
Kerr's Pink	2611.9	2570.4	-35.4	-34.3	1.3	0.4
Tigoni	449.0	508.5	0.9	-1.7	3.6	7.8

PCA1 & 2 = Interactive Principal Component Axis 1 & 2; Marimba, Meru A and Tigoni, Limuru A = Season 1; Marimba, Meru B and Tigoni, Limuru B = Season 2; DAE[a] =Days after emergence (Harvest Date).

3.6.1.1 Relative AUDPC AMMI plot

The biplot graph accounted for 96.31% and 95.95% of the sum of squares total at 90 and 120 DAE respectively. From Figure 5, it was observed that at both 90 and 120 DAE genotypes 391696.96, 389746.2 and Kerr's Pink had high AUDPC values and thus low resistance to late blight and all were positively interactive with the environments. Population B3 genotype 391696.96 had the highest AUDPC and positive IPCA scores and thus was more susceptible to late blight infection interacted positively with the environment. On the other hand, all the other genotypes had low AUDPC values implying that these genotypes have high levels of resistance. Population B3 genotypes (389746.2, 392637.10, 393385.39) and Tigoni at 90 DAE while 389746.2, 392637.10, 392657.8, 393280.57, 393371.58 and 393385.39 at 120 DAE were stable. 391696.96, 392617.54 and 393385.47 were unstable.

For the environments, the second seasons of Tigoni, Limuru and Marimba, Meru had high AUDPC values and were more conducive to late blight with high positive and negative first principal component analysis (IPCA) values respectively at 90 and 120 DAE hence highly interactive with the genotypes compared to the first seasons of Marimba, Meru and Tigoni, Limuru with negative and positive IPCA values respectively at 90 and 120 DAE. Only one environment (the first season of Tigoni, Limuru) was stable.



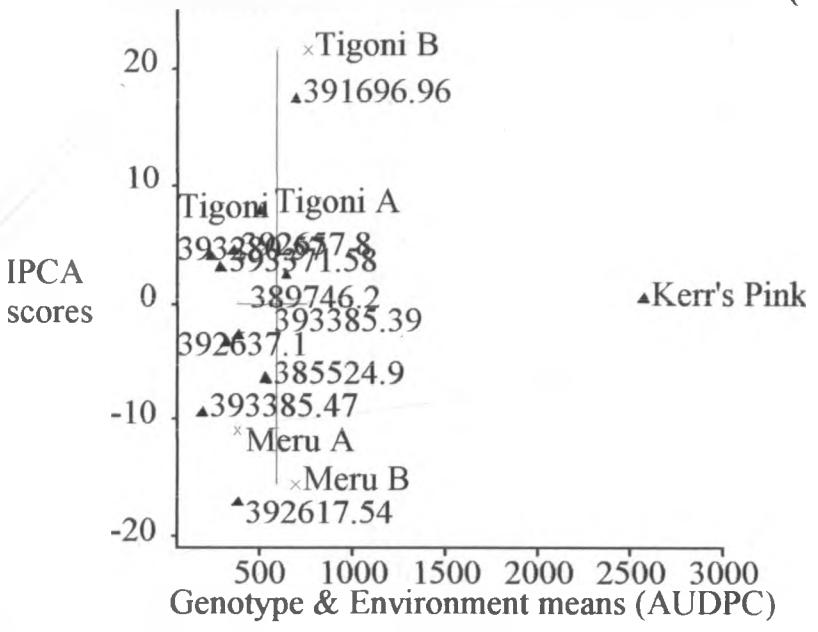


Figure 5: Biplot of AMMI model of the main effects on the abscica and the first IPCA axis on the ordinate for AUDPC of 12 potato genotypes harvested at different dates in Tigoni, Limuru and Marimba, Meru during 2005 – 2007 cropping seasons. Meru A and Tigoni A= Season 1; Meru B and Tigoni B= Season 2

3.6.1.2 Ranking of potato genotypes for AUDPC

AMMI ranked genotypes differently in all the environments for early and late harvest (Table 12). AMMI estimation selected genotypes 392637.10, 393280.57, 393371.58 and 393385.47 at Marimba, Meru while 392617.54, 393385.47, 392637.10 and 393385.39 at Tigoni, Limuru as having higher levels of resistance to late blight for early and late harvest (Table 12). Generally, genotypes 385524.9, 389746.2 and 391696.96 were ranked by AMMI estimation as having moderate levels of resistance to late blight for early and late harvest. The most susceptible genotype was Kerr's Pink.

Table 12: Ranking by AMMI estimates for AUDPC of 12 potato genotypes harvested at different dates grown in 2 environments

Genotype/Site	Season 1		Season 2	
	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]
Tigoni, Limuru				
385524.9	448.0 (4)	581.6 (3)	384.8 (9)	478.3 (10)
389746.2	528.3 (3)	471.9 (5)	940.3 (4)	927.3 (3)
391696.96	797.2 (2)	615.2 (2)	1106.6 (2)	1294.9 (2)
692617.54	36.9 (12)	95.7 (9)	364.8 (10)	262.3 (11)
392637.10	133.3 (8)	97.5 (8)	532.2 (8)	495.9 (9)
392657.8	119.4 (10)	131.1 (7)	1002.2 (3)	717.4 (5)
393280.57	128.3 (9)	79.2 (10)	636.6 (7)	554.4 (8)
393371.58	352.1 (6)	157.6 (6)	160.7 (12)	566.3 (7)
393385.39	83.2 (11)	62.3 (12)	670.3 (6)	624.0 (6)
393385.47	178.3 (7)	77.3 (11)	203.1 (11)	157.7 (12)
Kerr's Pink	3796.0 (1)	3596.0 (1)	2174.9 (1)	2158.3 (1)
Tigoni	416.6 (5)	550.5 (4)	678.4 (5)	810.7 (4)
Marimba, Meru				
385524.9	299.3 (4)	378.5 (3)	693.8 (4)	680.0 (4)
389746.2	339.4 (3)	414.5 (2)	713.7 (3)	756.3 (3)
391696.96	261.2 (5)	300.5 (5)	562.5 (7)	567.8 (6)
692617.54	344.9 (2)	369.0 (4)	829.2 (2)	806.3 (2)
392637.10	100.9 (11)	159.1 (8)	509.4 (10)	535.1 (7)
392657.8	155.4 (8)	110.2 (9)	567.2 (6)	462.1 9)
393280.57	-1.5 (12)	-6.8 (12)	383.3 (12)	326.7 (12)
393371.58	113.7 (10)	50.5 (11)	491.8 (11)	378.1 (11)
393385.39	184.6 (6)	221.7 (6)	617.7 (5)	625.3 (5)
393385.47	140.2 (9)	80.4 (10)	556.7 (8)	440.5 (10)
Kerr's Pink	2181.5 (1)	2271.9 (1)	2295.1 (1)	2255.5 (1)
Tigoni	167.9 (7)	206.4 7)	532.9 (9)	466.5 (8)

DAE[a] =Days after emergence (Harvest Date).

3.6.2 G x E interaction effect on yield stability

The AMMI analysis of genotype mean yields across environments and environments mean yields across genotypes are presented in Table 13. Genotypes (G), environment (E) and G × E interaction were significantly ($P \leq 0.05$) different and accounted for 43.0% and 53.4%, 39.6% and 29.8%, 17.5% and 16.9% of the treatment sums of squares at 90 and 120 DAE respectively (Appendixes 3 - 4). The sum of squares for G, E and IPCA 1 and 2 provided 98% and 96% of treatment sum of squares thus the treatment sum of squares contains 98% and 96% pattern related to treatment design and 2% and 4% noise related to experimental design at 90 and 120 DAE respectively.

Table 13: AMMI analysis of tuber yield and the proportion of the 2 first principal components of 12 potato genotypes mean scores for genotypes and environment harvested at different dates at Tigoni, Limuru and Marimba, Meru

Environment/genotype	Mean		IPCA1		IPCA2	
	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]
Marimba, Meru A	12.7	19.4	1.2	1.5	1.2	0.3
Marimba, Meru B	8.7	11.2	1.4	1.2	1.7	2.2
Tigoni, Limuru A	17.4	20.3	1.0	0.9	-3.2	-2.7
Tigoni, Limuru B	22.2	23.2	-3.6	-3.6	0.2	0.2
385524.9	20.0	22.5	-1.0	-1.0	0.2	-0.4
389746.2	20.1	23.5	0.2	0.4	0.2	0.5
391696.96	9.6	11.5	1.1	0.9	-0.1	0.3
692617.54	18.3	23.4	0.4	0.9	-1.2	-2.1
392637.10	14.0	16.9	-0.9	-1.1	1.0	0.9
392657.8	11.6	15.6	-0.3	-0.3	1.8	1.3
393280.57	9.7	13.8	1.6	1.7	1.1	0.9
393371.58	22.2	26.4	-2.2	-1.3	-1.2	-0.6
393385.39	19.4	23.9	0.1	0.7	-0.8	0.1
393385.47	16.1	19.7	-1.7	-2.5	0.4	-0.4
Kerr's Pink	4.0	4.9	1.5	0.6	0.9	1.1
Tigoni	18.1	20.2	1.2	1.1	-2.2	-1.6

PCA1 & 2 = Interactive Principal Component Axis 1 & 2; Marimba, Meru A and Tigoni, Limuru A = Season 1; Marimba, Meru B and Tigoni, Limuru B = Season 2; DAE[a] =Days after emergence (Harvest Date).

3.6.2.1 Relative tuber yield AMMI biplot

The bi plot graph for tuber yield accounted for 91.9% and 92.2% of the sum of squares total at 90 and 120 DAE respectively (Appendixes 3 - 4). Genotypes 393385.47, 385524.9, 393385.39 and 389746.2 at 90 and 120 DAE except 393385.39 at 90 DAE and 385524.9 at 120 DAE were high yielding and interactive as they had positive IPCA values. The first and second seasons of Tigoni, Limuru were high yielding environments with higher negative hence highly interactive and positive IPCA values thus interactive respectively at 90 and 120 DAE (Figure 6).

Genotypes 393371.58, 392617.54 and Tigoni at 90 DAE were high yielding but with negative interactions while 391696.96, 392657.8, 392637.10, 393280.57 and Kerr's Pink had low yields with positive interactions at 90 and 120 DAE except 391696.96 at 90 DAE that had a negative interaction. The environment Marimba, Meru first and second seasons were identified as low yielding with positive IPCA values at 90 and 120 DAE except the first season of Marimba, Meru at 120 DAE (Figure 6).

Population B3 genotypes 385524.9, 389746.2, 391696.96, 393385.39 and 393385.47 at 90 DAE while all population B3 genotypes except 392617.54 and 392657.8 at 120 DAE were stable. The second season of Tigoni, Limuru at 90 and 120 DAE while only the first season of Marimba, Meru at 120 DAE was stable.

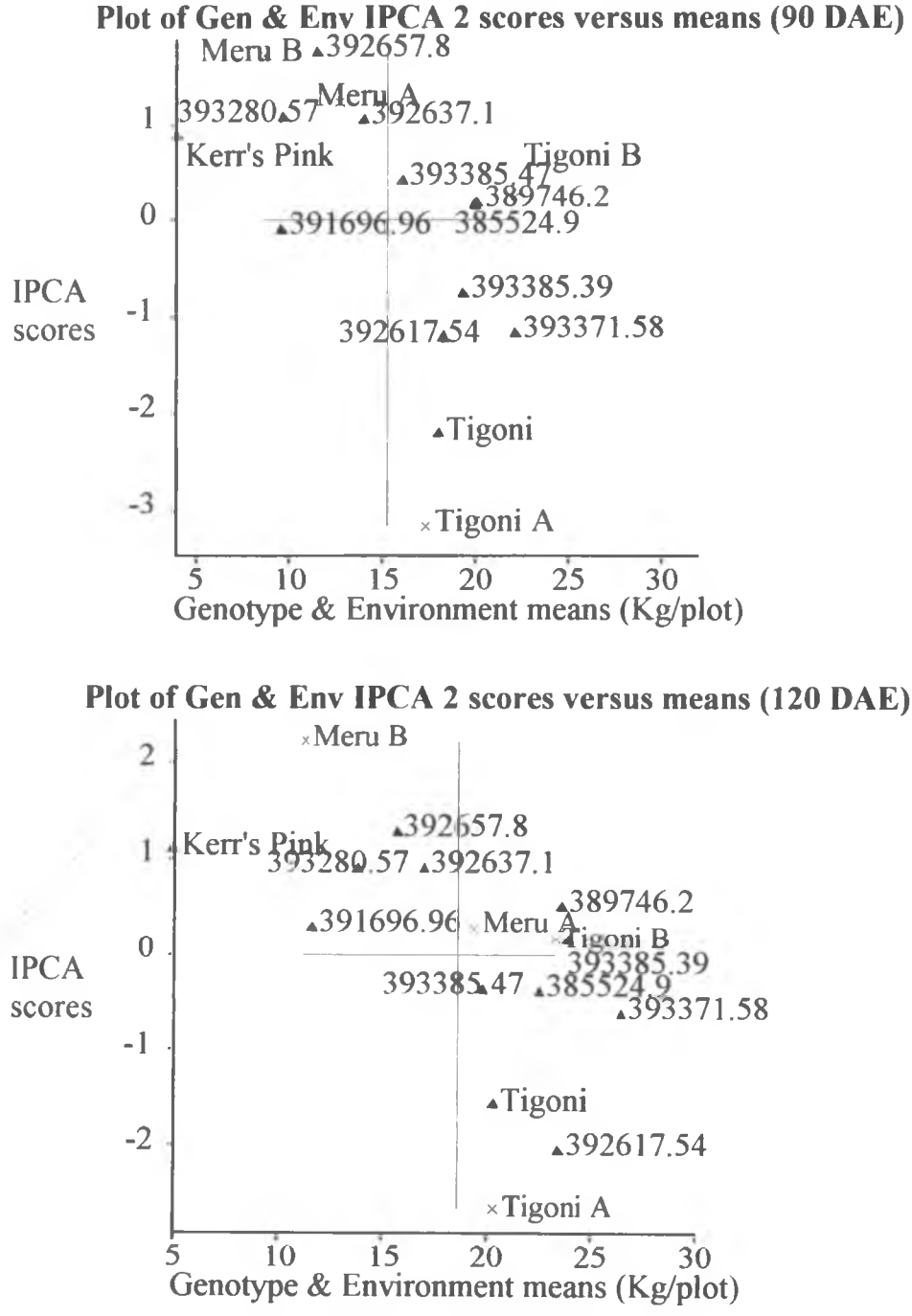


Figure 6: Biplot of AMMI models of the main effects on the abscica and the first IPCA axis on the ordinate for tuber yields of 12 potato genotypes harvested at different dates grown in Tigoni, Limuru and Marimba, Meru during 2005 and 2007. Meru A and Tigoni A= Season 1; Meru B and Tigoni B= Season 2

3.6.2.2 Ranking of potato genotypes for total tuber yield

The relative ranking of the genotypes for total tuber yield as selected by AMMI differed from season to season and location to location. Generally genotypes 385524.9, 389746.2, 392617.54, 393371.58, 393385.39 and 393385.47 were ranked highly in terms of total tuber yields while Kerr's Pink was ranked as the least yielder with population B3 genotypes 383280.57 and 391696.96 for early and late harvest (Table 14).

Table 14: Ranking by AMMI estimates for tuber yield of 12 potato genotypes harvested at different dates grown in 2 environments

Genotype/Site	Season 1		Season 2	
	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]
Tigoni, Limuru				
385524.9	20.65 (6)	24.44 (5)	30.56 (2)	30.65 (3)
389746.2	21.87 (5)	24.33 (6)	26.39 (4)	27.01 (4)
391696.96	13.15 (8)	13.48 (11)	12.45 (10)	12.94 (10)
692617.54	24.64 (3)	31.42 (1)	23.61 (7)	24.61 (7)
392637.10	12.06 (9)	15.38 (8)	24.41 (6)	25.61 (6)
392657.8	7.85 (11)	13.77 (10)	20.07 (9)	21.73 (8)
393280.57	10.04 (10)	14.77 (9)	11.20 (11)	12.44 (11)
393371.58	25.97 (2)	28.68 (2)	36.46 (1)	35.67 (1)
393385.39	24.04 (4)	25.93 (4)	25.69 (5)	26.07 (5)
393385.47	15.37 (7)	20.21 (7)	29.03 (3)	33.30 (2)
Kerr's Pink	4.86 (12)	4.32 (12)	5.66 (12)	7.62 (12)
Tigoni	28.35 (1)	27.18 (3)	20.29 (8)	20.88 (9)
Marimba, Meru				
385524.9	16.38 (2)	21.70 (6)	12.22 (2)	13.11 (4)
389746.2	18.00 (1)	25.02 (3)	14.08 (1)	17.73 (1)
391696.96	8.31 (11)	13.84 (11)	4.43 (11)	5.91 (11)
692617.54	14.71 (5)	24.94 (4)	10.14 (5)	12.47 (5)
392637.10	11.70 (8)	16.37 (9)	7.99 (7)	10.35 (9)
392657.8	10.78 (9)	16.29 (10)	7.53 (9)	10.75 (6)
393280.57	10.40 (10)	17.39 (7)	7.16 (10)	10.40 (8)
393371.58	15.59 (4)	25.07 (2)	10.58 (4)	16.15 (3)
393385.39	16.04 (3)	25.76 (1)	11.65 (3)	17.64 (2)
393385.47	12.04 (7)	16.69 (8)	7.89 (8)	8.70 (10)
Kerr's Pink	4.40 (12)	6.90 (12)	1.07 (12)	0.70 (12)
Tigoni	14.24 (6)	22.23 (5)	9.35 (6)	10.64 7)

DAE[a] =Days after emergence (Harvest Date).

3.7 DISCUSSION

Genotypes from population B3 had low AUDPC values and lower rates of disease progress in relation to the disease on the highly susceptible check, Kerr's Pink. Differences in late blight severities were detected among the population B3 genotypes and there were differential rankings in performance of the genotypes from location to location and season to season. The variation in disease reaction between locations and seasons is probably attributed to the differences in weather and climactic conditions during the different cropping seasons. During the second season, late blight epidemics increased in the presence of the heaviest rainfall that occurred, favouring rapid late blight development and spread (Appendix 5). Severe epidemics of late blight have been known to occur during periods of high rainfall, high relative humidity, temperatures below 20 °C (Olanya *et al.*, 2001a) and prolonged leaf wetness (Harris, 1992). The results agree with previous studies where differences in foliar reactions to late blight (Olanya *et al.*, 1999) and variability in late blight disease pressure among locations and over seasons have been reported (Lunga'ho *et al.*, 1997).

The variations in the yields due to delayed harvesting varied across genotype, location and season were probably due to variation in climatic conditions. All genotypes responded positively to delayed harvesting and this could be attributed to the ample amount of rainfall that ensured adequate amount of water for tuberization and tuber bulking and the prolonged longevity of individual potato leaves hence the capacity to photosynthesize leading to an increase in the dry matter. According to Mehta and Kaul, 2003 and Pandey *et al.*, 2005, total and marketable tuber yield of potatoes increased with delayed harvesting. In addition, Burke & O'Donovan, 1998

found that delaying the desiccation date increased yields of potato tubers of over 45mm.

Total tuber yield is related to the amount of dry matter produced that is closely influenced by the light intercepted by plant canopy (Ebwongu *et al.*, 2001) and the performance of different genotypes depends on their growth and development rates. Population B3 genotypes generally were more or less green for early and late harvest respectively suggesting that they could be medium to late maturing varieties. Therefore coupled with a high leaf area index and thus light interception the genotypes produced larger amounts of dry matter thus a higher tuber yield obtained due to delayed harvest. However, lower yields were recorded from Marimba, Meru during the second season despite the favourable environmental conditions and this maybe due to the higher levels of disease that reduced the green foliage and the cold temperatures reducing the growth and bulking of tubers (Van Oijen, 1991; Olanya *et al.*, 2001b; Nyankanga *et al.*, 2004; Olanya *et al.*, 2006). Van Oijen, 1991 working with potato cultivars of different maturity classes and levels of resistance concluded that the maintenance of the green leaf area is very important for optimal performance of potatoes in the presence of late blight.

Few incidences of tuber rotting and potato tuber moth (PTM), *Phthorimaea operculella* (Zeller) infested the genotypes and the damage was slightly higher with delay in harvest and may reduce yields. This may imply that infestation by potato tuber moth is time dependent especially with delayed harvesting and could cause yield instability.

The significant negative correlation between the AUDPC and tuber yield observed on the local checks indicates that higher late blight epidemics could significantly affect tuber yields. A quantitative relationship between late blight of

potato and loss in tuber yield has been attributed to effects of disease on foliage loss and cultivar effects (James *et al.*, 1972). Therefore high levels of late blight may have resulted in reduced tuber yields by decreasing the cumulative light interception by the leaves (Van Oijen, 1991; Olanya *et al.*, 2001b; Nyankanga *et al.*, 2007; Olanya *et al.*, 2006). The non-significant correlation between the AUDPC and the tuber yield on population B3 genotypes imply that the genotypes may be able to tolerate late blight disease with little effect on tuber yield as has been previously reported (El Bedewy *et al.*, 2001; Nakitandwe *et al.*, 2005; Olanya *et al.*, 2006). This is because population B3 genotypes were selected for early tuberization and bulking with a large area of foliage remaining green to resist late blight.

The differences in rainfall, physical and chemical properties of the soil associated with the different locations may have influenced the performance of all the genotypes. The difference in the performance in some of the genotypes across locations and over seasons is an indication of genotype X environment interactions (Haynes *et al.*, 1998; Abalo *et al.*, 2001; Lunga'ho *et al.*, 1998). Large additive genetic variances for horizontal resistance to late blight in population B3 have been noted (Landeo *et al.*, 2001). In this study, the proportion of the variation of treatment sum of squares due to genotypes was much larger than the proportion of treatment sum of squares due to environment and G X E interaction thus contributed more to the total variability of late blight resistance and tuber yield. This concurred with recent studies of G X E (Ntawuruhunga *et al.*, 2001) on cassava for tuber yield while for late blight resistance (Wulff *et al.*, 2007; Forbes *et al.*, 2005). However, the same results did not agree with earlier G X E studies (Nakitandwe *et al.*, 2005; Abalo *et al.*, 2003) where the proportion of sum of squares due to G X E interaction variation for tuber yield was usually larger than genotype main effects.

The AMMI bi plot allowed visualisation of the relationships between the means of the genotypes and the environments (main effects) and the eigen values for the first interaction principal component axis (IPCA1). Zobel *et al.*, 1988 elucidated that displacement along the abscissa reflect differences in main effects while the displacement along the ordinate exhibited the differences in interaction effects. Genotypes or environments on the same parallel line relative to the ordinate have similar yields and resistance and a genotype or environment on the right side of the midpoint of the axis has higher yields and highly susceptible for tuber yields and late blight resistance respectively than those on the left side. Based on this the levels of resistance in population B3 genotypes varied from moderate resistance to high resistance. This was expected as such genotypes were developed for horizontal resistance to late blight (Landeo *et al.*, 1995). The results collaborate with similar studies reported for population B genotypes tested in Uganda (Mulema *et al.*, 2004; Nakitandwe *et al.*, 2005) and Peru (Wulff *et al.*, 2007). For tuber yield, all population B3 genotypes except 391696.96, 392637.10, 392657.8, and 393280.57 were high yielding.

When the PCA 1 values of genotypes and environments are close to zero, the entries have small interaction effects and its general response pattern across the environments parallels the mean of all the genotypes in the trial and is considered stable (Crosa *et al.*, 1991; Cooper *et al.*, 1996; Fox *et al.*, 1997). Based on this, five genotypes (385524.9, 389746.2, 391696.96, 393385.39 and 393385.47) for early harvest and all population B3 genotypes except 392617.54 and 392657.8 for late harvest were stable. This agrees with reports from Uganda (Mulema *et al.*, 2008; Nakitandwe *et al.*, 2005, Abalo *et al.*, 2003). In their studies, Mulema *et al.*, 2008 found that high (392618.250 and 392127.270) and low (392618.256, 391049.255 and

392127.256) yielding potato clones were stable. However, other high yielding clones (381471.18, 387121.4 and the variety Victoria) were found to be unstable as they had high principal component score (IPCA1) values. Nakitandwe *et al.*, 2005 found that only three (389746.2, Robjyn and 381381.13) genotypes were stable than all genotypes except Torridon that was very unstable. Also out of 12 high yielding potato genotypes with good levels of late blight resistance only two genotypes (391558.11 and 391557.1) were stable as reported by Abalo *et al.*, 2003. Stability of late blight resistance in tropical environments has been shown for population B3 genotypes (Landeo *et al.*, 2002). However, the stability differs across environments as they show different rankings in all the environments but within the levels of moderately resistant to resistant.

In conclusion, population B3 genotypes responded by performing differently at the two environments according to their genetic differences, but their physical interaction with the physical factors of the environment were important and the study is of great significance in development of genotypes and useful for future regional multilocational trial sites. Population B3 genotypes were found to be resistant to late blight as indicated by the low AUDPC values and six genotypes (385524.9, 389746.2, 392617.54, 393371.58, 393385.39 and 393385.47 were identified to be high yielding therefore it is recommended to be tested on farm under farmer's own practices. This could perhaps act as a benchmark in adoption of the genotypes that would satisfy their expectations through assessing the performance of the genotypes in comparison with the locally grown varieties. In addition it is suggested that early harvesting of the genotypes should be adopted though this would depend on the genotype. The AMMI model was successfully used to diagnose the G X E interaction pattern of AUDPC and tuber yields of potato genotypes in population B3. The study showed that the

proportion of genotypic variance was larger than that due to the environmental variance and the G X E interaction contributing more to the total variation. The biplot identified some of the population B3 genotypes for tuber yield and late blight resistance as stable while others were not stable for early and late harvests. The study was conducted in only two environments thus it is further recommended that the population B3 genotypes needs to be investigated and tested over many diverse environments to see whether their stability holds.

CHAPTER FOUR

THE EFFECT OF HARVESTING DATE ON THE STORAGE, COOKING AND PROCESSING QUALITIES OF R-FREE LATE BLIGHT RESISTANT POTATO WARE TUBERS

4.1 Abstract

Experiments were conducted to assess the effect of harvesting date on the storage, cooking and processing qualities of population B3 potato genotypes at Tigoni, Limuru, Kenya. Storage experiment was laid out in a randomised complete block design replicated three times while the cooking and processing quality experiment was laid out in a completely randomized design replicated eight times. Ten advanced late blight resistant potato genotypes free of R genes from population B3 and two checks (Tigoni- moderately resistant to late blight and Kerr's Pink- susceptible to late blight) harvested at 90 (early) and 120 (late harvests) days after emergence (DAE) were used. Genotypes were significantly different in specific gravity, tuber weight loss (%), sprouting (%) and tuber rots (%) at early and late harvest. Except for genotype 393280.57, most of the population B3 genotypes had acceptable specific gravity (above 1.07), high acceptability scores (scores of over 5) for use as boiled potatoes, chips and crisps of good quality and acceptable low weight losses (below 10%) at early and late harvests. All population B3 genotypes commenced sprouting by the 4th week except four genotypes that sprouted by 6th week at early harvest while sprouting was reduced to the 2nd week and 4th week at late harvest respectively. Most of population B3 genotypes from early and late harvests can be kept for 10-12 and 6-8 weeks except for four genotypes that can store well for over 12 and 10-12 weeks respectively. Kerr's Pink and Tigoni sprouted by the second week of storage with Kerr's Pink having its % sprouting levelling off regardless of the

harvesting date. Most of the population B3 genotypes were suitable and acceptable for storage, cooking and processing qualities. Potato quality tended to improve with delay in harvest.

4.2 Introduction

Potato is generally used as a vegetable and it is consumed in different forms such as cooked, roasted, French-fried, and chipped. Most potato producers require higher yielding varieties with resistance to disease, good eating/processing qualities and the desired physical tuber characteristics like skin colour, flesh colour, tuber shape, tuber size, eye depth and storage potentiality (Horton, 1987). However, resistance alone will not guarantee adoption by farmers of any cultivar as farmers have other preferences like earliness, good cooking characteristics and good storability. This is because most of the potato consumers need potato tubers that would fetch higher premium prices and some would want tubers that have high dry matter as it will hold its shape on cooking while others would prefer those with low dry matter so that it would disintegrate (Horton, 1987).

Potato consumption in processed form is rapidly increasing in Kenya as evidenced by increase in restaurants that sell chips and number of crisp processors. All these use approximately 5-6 bags of around 130 Kg per day. Thus, there is great opportunity in the rapidly expanding domestic market because of the higher population growth, urbanization and tourism sectors. The price potatoes fetches in the ware market depend on tuber physical characteristics (skin and flesh colour, dry matter content, taste, texture and damage due to pests and diseases); how they would be used; local tastes and preferences and the local market conditions (Horton, 1987). Moreover, many small-scale farmers do not store potatoes and harvest their potato

tubers only on demand. This leads to oversupply at harvesting time that would eventually lead to depression of prices. Potato storage not only aims at maintaining tubers in their most edible and marketable condition but also provide a uniform flow of high quality ware tubers to market and processing plants (Eltawil *et al.*, 2006) so as to support the rapidly expanding chipping businesses in urban areas (Kabira, 2000).

Low cost potato stores in highland areas constructed using locally available materials could hold processing potatoes for up to 10 weeks (Kabira and Lemaga, 2003). Therefore there is need to improve storage to bridge the supply gap between the harvests, steady prices and ensure food security (Kabira and Lemaga, 2003). This would lead to higher market prices being obtained by the small-scale farmer after 2-3 months of storage. There is lack of information concerning the storability of population B3 genotypes in Kenya especially concerning early and late harvest. This is because early maturing varieties enables a small scale producer a multiple number of crops to be grown in addition to less chance of the yields being suppressed by unfavourable weather conditions and infestation by pests and diseases. In addition, farmer could sacrifices yields by harvesting early to achieve better prices (Turkensteen and Zimno – Gucowska, 2002). The objective of this study was to assess storage potential, cooking and processing quality for early and late yield of population B3 genotypes.

4.3 Materials and Methods

4.3.1 Study site and experimental design

The study was established at Tigoni, Limuru. Ten advanced late blight resistant genotypes (385524.9, 389746.2, 391696.96, 392617.54, 392637.10, 392657.8, 393280.57, 393371.58, 393385.39, and 393385.47) and two local checks;

Tigoni (moderately resistant to late blight) and Kerr's Pink (highly susceptible to late blight) were planted at Tigoni, Limuru during the long rainy season (April – August) and the short rainy season (October – March) in 2006 and at Marimba, Meru during the long rainy seasons (October – March) of 2005 and 2006 representing Season 1 and 2 respectively. Tigoni, Limuru lies 2100m a.s.l, with an annual rainfall of 800 mm, mean temperature of 18°C while Marimba, Meru lies 1844m a.s.l, with an annual precipitation of 1299 mm, mean temperature of 18.5 °C (Jaetzold and Schmidt, 1983). Potato tubers were planted in furrows at the recommended spacing of 30 by 75cm in 3m X 3m plots and covered with soil. N: P: K (17:17:17) compound fertilizer was applied at planting at a rate of 500kg/ha. Weeding, earthing up and pest control was done according to the recommended practices. No fungicide was administered.

The potatoes were harvested at 90 (early harvest) and 120 days after emergence (late harvest). Good ware size potato tubers of between 50 - 60 mm, free of diseases and dirt, undamaged were placed in nylon woven mesh bags and transported to a store where they were left to cure for two weeks under dark storage condition to stabilize at ambient room conditions.

4.3.2 Determination of cooking and processing qualities

After two weeks, the tubers were removed and data on eye depth, tuber shape and tuber flesh colour and specific gravity were determined. The depth of the eyes was recorded as S= Superficial; I= Intermediate; D= Deep. The predominant shape of the mature tubers was also recorded (Rd= Round; Ob= Oblong; El= Elongated; Ov= Oval) and secondary shapes was indicated if present i.e. Ob/Rd (Oblong to round), Skin colour was recorded as Wh= White; Cr= Cream; Rd= Red; Pi= Pink; Pr=

purple), Flesh colour was recorded after cutting one tuber across the length using the scale (Wh = White, Cr = Cream and Ye = Yellow) (Landeo, 2004).

Specific gravity was used to measure the dry matter content of the tubers and it was done using a balance with a capacity of 5 kilogram's and an accuracy of 1 gram. Duplicate samples of good ware sized potatoes were placed in a metal basket, weighed in air (5 Kg) and again in cold tap water (x g).

$$\text{Specific gravity} = \frac{\text{Weight in air}}{\text{Weight in air-Weight in water}}$$

Boiled potatoes

Two to three mid size tubers for each clone including the controls were obtained from previously stored tubers and boiled after writing the clone number twice on the surface of each tuber with permanent ink marker. Tubers were boiled in water and they were ready when a fork penetrated the tuber. A code was assigned to each sample and the relation recorded. The cooked tubers were presented to the panellists on plates and assessed. An untrained panel of more than eight members were used to carry out tests following a scale where 1 = unacceptable; 3 = barely acceptable; 6 = acceptable and 9 = extremely acceptable (Appendix 6).

Chips:

Samples of at least 40 tubers of each clone were selected and peeled by hand. They were then cut longitudinally into halves. The sticks were washed for 1-2 minutes in running tap water and superficially dried using a cloth towel. About 200 g samples

were pre-fried in fat of 150 ± 5°C for 4 minutes after which they were removed from the fat shaking off adhering fat and allowing the product to cool to room temperature. Then the samples were finish fried in fat at 180°C for 2 minutes. The fried chips were presented to the untrained panellists on plates for assessment following the suggested scale where 1 = unacceptable; 3 = barely acceptable; 6 = acceptable and 9 = extremely acceptable (Appendix 6). In addition the colour of the samples was assessed using a Munsell colour card scoring system of 1 (very light) to 5 (very dark).

Crisps:

Samples of at least 40 tubers of each clone were selected, peeled and trimmed. They were then sliced into uniform slices, 1.2 – 1.3 mm thick and washed for 1 – 2 minutes under running tap water to remove adhering starch and were dried superficially using a cloth towel. About 100 g samples were fried in vegetable oil set at 175 ± 5°C for about 5 minutes, constantly stirring the oil bath to ensure a uniform frying of all the slices. The crisps were removed from the oil and drained by shaking the frying basket. The fried crisps were presented to the untrained panellists on plates for assessment following the scale where 1 = unacceptable; 3 = barely acceptable; 6 = acceptable and 9 = extremely acceptable (Appendix 6). In addition the colour of the finished product was assessed using Potato Chips / Snack Food Association (PC/SFA) colour card system of 1 (light cream – denoting low sugar levels) [acceptable] to 5 (very dark brown – denoting very high sugar levels) [highly unacceptable].

4.3.3 Determination of storage qualities

Potato tubers between 50 - 60 mm for all the clones except Kerr's Pink 30 mm to 35 mm were left to cure for two weeks under dark storage condition after each

harvest to stabilize at ambient room conditions. Thirty tubers for each genotypes harvested at 90 and 120 days after emergence were put in gunny bags and placed in raised well-ventilated dark store. The design used was a randomised complete block design replicated three times and the tubers were evaluated for tuber weight loss, tuber sprouting and incidences of potato tuber moth and rotting every two weeks for a period of 12 weeks under the same storage conditions.

The weight of each sample was determined by use of a balance. This was used to determine the percentage tuber weight loss. The number of tubers sprouted was counted and recorded. This was used to determine the percentage number of tubers sprouted. The incidence of the potato tuber moth in the store was assessed by recording the number of tubers damaged by tuber moth or with the typical symptoms of tuber moth which is tunnelling on the surface of the tuber with or without the presence of the moth itself for each genotype and was expressed as a percentage of total number of tubers while the incidence of tuber rots in the store was assessed by recording the number of tubers with rots for each of the genotypes and was expressed as a percentage of the total number of tubers.

4.4 Data analysis

The data collected was subjected to the analysis of variance (ANOVA) using the Genstat statistical package (Genstat, 2006). Where the 'F' statistic showed significance, the means were separated by Least Significant Difference (LSD) and standard error differences of means (SED).

4.5 RESULTS

4.5.1 Tuber characteristics

Population B3 genotypes have good tuber characteristics. Skin colour varied from cream pink to red and white except for genotype 391696.96 that had deep purple colour (Table 15). Population B3 entries 393371.58, 389746.2, 391696.96, 392637.10 and 393385.47 have oblong/round tubers and could be considered for preparing chips while 393385.39, 385524.9, 392617.54 and 393280.57 were round oval and are ideal for crisps. The flesh colour for most genotypes was white and the eye depth was intermediate (Table 15).

Table 15: Descriptions of physical tuber characteristics of potato genotypes in population B3 and cultivars evaluated in this study

Genotype	Eye Depth	Tuber Shape	Flesh Colour	Skin Colour
385524.9	Shallow	Round	White	White
389746.2	Intermediate	Oblong round	White	Cream with Pink splashes
391696.96	Shallow	Oblong round	White	Deep purple
392617.54	Intermediate	Round	White	Cream pink/less pink eyes
392637.10	Intermediate	Round oblong	Cream	Cream pink/pinkish eyes
392657.8	Intermediate	Round	Yellow	Cream pink/pink splashes
393280.57	Intermediate/deep	Oblong round	Yellow	Deep red
393371.58	Intermediate	Round oval	White	White
393385.39	Intermediate/deep	Round	Yellow	Light red
393385.47	Shallow	Ob/ elongated	Yellow	White
Kerr's Pink	Intermediate	Oblong/round	White	Light red
Tigoni	Shallow	Round	Cream	White

4.5.2 Effect of genotype and harvest date on tuber specific gravity

There were significant differences ($P \leq 0.05$) among the genotypes at early and late harvest during all seasons at both locations. Most of the genotypes had acceptable mean tuber specific gravity for domestic consumption i.e. above 1.070 (Table 16). Generally, it was observed that specific gravity of early harvest was more or less equal to late harvested crop. Also it was observed that the specific gravity varied from genotype to genotype and from location to location (Table 16).

Table 16: Specific gravity of eleven potato genotypes harvested at 90 and 120 days after emergence (DAE) at Tigoni, Limuru and Marimba, Meru during season 1 and 2

Genotype	Season 1				Season 2			
	Tigoni, Limuru		Marimba, Meru		Tigoni, Limuru		Marimba, Meru	
	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]
385524.9	1.07	1.08	1.07	1.07	1.08	1.08	1.07	1.07
389746.2	1.07	1.08	1.08	1.08	1.08	1.07	1.07	1.07
391696.96	1.08	1.09	1.07	1.07	1.08	1.07	1.07	1.07
392617.54	1.08	1.09	1.07	1.07	1.08	1.08	1.07	1.08
392637.10	1.07	1.08	1.07	1.08	1.09	1.08	1.08	1.08
392657.8	1.07	1.07	1.07	1.07	1.08	1.08	1.07	1.08
393280.57	1.06	1.07	1.06	1.06	1.08	1.07	1.06	1.07
393371.58	1.08	1.08	1.08	1.09	1.09	1.08	1.08	1.08
393385.39	1.07	1.07	1.07	1.08	1.08	1.07	1.07	1.07
393385.47	1.08	1.09	1.08	1.08	1.09	1.08	1.08	1.08
Tigoni	1.08	1.08	1.07	1.08	1.08	1.07	1.07	1.07
Mean	1.07	1.08	1.07	1.08	1.08	1.08	1.07	1.08
LSD (5%)	0.016 *	0.00005 *	0.0024 *	0.0038 *	0.0028 *	0.0029 *	0.0040 *	0.0024 *
% CV	0.1	0.0	0.1	0.2	0.2	0.2	0.2	0.1

* Significant at 5% level of significance; DAE[a] =Days after emergence (Harvest Date)

Table 17: Combined analysis of variance on the effect of harvesting date on the cooking and processing qualities of population B3 genotypes at Tigoni, Limuru and Marimba, Meru during season 1 and 2

90 DAE[a]

Source of variation	df	Colour		Texture		Flavour		Oiliness		Overall Acceptability	
		F value	P>F	F value	P>F	F value	P>F	F value	P>F	F value	P>F
Boiling											
Genotype(G)	10	2.21	0.02	1.95	0.04	0.84	0.59	0.00	0.00	1.46	0.15
Location (L)	1	0.10	0.75	0.00	1.00	0.74	0.39	0.00	0.00	0.12	0.73
Season (S)	1	0.10	0.75	0.53	0.47	0.86	0.35	0.00	0.00	0.60	0.44
G x L	10	0.97	0.47	0.88	0.55	1.05	0.40	0.00	0.00	1.31	0.23
G x S	10	1.16	0.32	0.53	0.87	0.70	0.73	0.00	0.00	1.03	0.42
G x L x S	10	1.21	0.28	1.15	0.32	1.17	0.31	0.00	0.00	1.21	0.28
Chips											
G	10	6.81	0.001	4.11	0.001	3.75	0.001	2.39	0.01	4.84	0.001
L	1	2.98	0.09	3.90	0.05	0.00	0.97	0.66	0.42	2.98	0.09
S	1	9.55	0.002	7.29	0.01	8.86	0.003	10.53	0.001	5.36	0.02
G x L	10	1.99	0.03	0.82	0.61	0.71	0.72	0.64	0.78	0.63	0.79
G x S	10	2.79	0.003	1.31	0.22	1.77	0.06	1.02	0.42	1.18	0.30
G x L x S	10	1.45	0.16	0.76	0.67	1.24	0.26	0.50	0.89	1.33	0.22
Crisps											
G	10	2.12	0.02	2.48	0.01	2.05	0.03	1.30	0.23	3.25	0.001
L	1	1.15	0.28	1.23	0.27	2.74	0.10	3.42	0.07	0.01	0.93
S	1	0.73	0.40	7.46	0.01	0.89	0.35	3.42	0.07	2.05	0.15
G x L	10	0.36	0.96	0.39	0.95	0.38	0.95	0.52	0.87	0.41	0.94
G x S	10	0.99	0.45	0.40	0.95	0.93	0.50	0.55	0.86	0.90	0.53
G x L x S	10	1.07	0.38	0.48	0.90	1.21	0.28	0.73	0.70	1.03	0.42

120 DAE[a]

Source of variation	df	Colour		Texture		Flavour		Oiliness		Overall Acceptability	
		F value	P>F	F value	P>F	F value	P>F	F value	P>F	F value	P>F
Boiling											
Genotype(G)	10	3.97	0.001	2.29	0.01	2.60	0.01	0.00	0.00	3.10	0.001
Location (L)	1	5.31	0.02	3.23	0.07	4.33	0.04	0.00	0.00	9.30	0.002
Season (S)	1	1.42	0.23	0.05	0.83	0.05	0.82	0.00	0.00	1.85	0.18
G x L	10	1.02	0.43	0.98	0.46	0.48	0.90	0.00	0.00	1.28	0.24
G x S	10	0.98	0.47	0.63	0.79	0.86	0.57	0.00	0.00	0.84	0.59
G x L x S	10	1.53	0.13	1.85	0.05	1.25	0.26	0.00	0.00	2.65	0.004
Chips											
G	10	11.08	0.001	6.04	0.001	4.68	0.001	3.82	0.001	8.47	0.001
L	1	5.65	0.02	5.47	0.02	5.78	0.02	0.01	0.93	4.84	0.03
S	1	0.23	0.64	1.93	0.17	0.18	0.67	2.59	0.11	0.80	0.37
G x L	10	0.51	0.88	0.71	0.71	0.75	0.67	0.93	0.51	1.22	0.28
G x S	10	2.30	0.01	1.46	0.15	1.83	0.06	1.63	0.10	2.60	0.01
G x L x S	10	4.20	0.001	0.97	0.47	0.62	0.80	1.30	0.23	2.23	0.02
Crisps											
G	10	3.05	0.001	1.82	0.06	1.51	0.14	1.62	0.10	2.50	0.01
L	1	6.46	0.01	5.04	0.03	1.26	0.26	14.25	0.001	2.02	0.16
S	1	5.72	0.02	24.25	0.001	6.09	0.01	15.54	0.001	8.06	0.01
G x L	10	1.86	0.05	1.83	0.06	2.17	0.02	0.69	0.74	1.58	0.11
G x S	10	2.48	0.01	1.00	0.45	1.13	0.34	0.62	0.80	1.59	0.11
G x L x S	10	1.43	0.17	0.86	0.57	1.13	0.34	2.81	0.99	0.95	0.49

DAE[a] =Days after emergence (Harvest Date).

4.5.3 Effect of genotype and harvest date on cooking quality

Population B3 genotypes displayed high acceptability scores for use as boiled potatoes with an average mean of over 5.0 for early and late harvest (Table 18 and 19). However, the scores were slightly higher in the late than the early harvests.

Table 18: Mean sensory scores of boiled potatoes of 11 test genotypes harvested at 90 and 120 days after emergence (DAE) during season 1 at Tigoni, Limuru and Marimba, Meru

Tigoni, Limuru

Genotype	Colour		Texture		Flavour		Overall acceptability	
	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]
385524.9	4.8	5.5	5.1	4.9	5.4	5.4	5.1	5.8
389746.2	4.8	5.1	5.5	5.3	5.9	5.1	5.8	5.8
391696.96	5.4	5.3	5.8	5.5	5.5	6.1	5.6	5.8
392617.54	5.3	5.1	5.5	4.6	5.5	4.9	5.6	5.0
392637.10	5.5	5.5	5.6	5.4	5.8	5.3	5.8	5.4
392657.8	5.1	5.5	5.5	4.6	5.4	4.1	5.5	4.3
393280.57	6.3	6.1	6.1	5.5	5.9	5.5	6.3	5.6
393371.58	6.0	5.4	6.1	6.0	5.8	5.8	6.5	5.9
393385.39	5.4	5.5	5.1	4.9	6.1	5.0	6.0	5.1
393385.47	5.9	6.6	5.5	6.0	5.6	5.8	5.8	6.0
Tigoni	6.3	7.0	5.6	6.4	4.5	6.5	5.0	6.5
Mean	5.5	5.7	5.6	5.4	5.6	5.4	5.7	5.6
SE	0.70	0.65	0.65	0.81	0.70	0.65	0.60	0.77
% CV	25.5	22.8	23.3	30.3	25.0	31.7	21.0	27.7

Marimba, Meru

Genotype	Colour		Texture		Flavour		Overall acceptability	
	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]
385524.9	4.1	5.5	4.4	5.1	4.9	5.3	4.6	6.0
389746.2	4.6	6.1	4.5	5.9	4.8	5.0	5.3	6.1
391696.96	4.1	4.8	4.6	5.1	5.5	6.0	5.5	6.1
392617.54	5.1	5.8	4.5	4.9	3.9	5.3	4.4	5.6
392637.10	4.3	5.3	4.3	5.0	4.5	4.8	4.3	5.3
392657.8	4.9	6.0	5.0	5.0	4.5	3.9	4.9	4.8
393280.57	4.6	6.0	4.5	5.3	4.9	5.5	5.1	6.0
393371.58	5.3	5.5	5.9	5.5	5.0	4.9	5.1	5.1
393385.39	5.3	6.3	4.0	5.6	2.9	5.3	2.4	6.0
393385.47	6.6	6.8	4.6	6.1	4.8	6.1	4.9	6.4
Tigoni	6.3	6.3	6.0	5.3	4.8	5.5	5.4	5.9
Mean	5.0	5.8	4.8	5.3	4.6	5.2	4.7	5.8
SE	0.85	0.76	0.77	0.72	0.86	0.86	0.83	0.71
% CV	33.8	26.2	32.5	26.9	37.8	32.9	35.3	24.6

Scores (1 = extremely poor; 2= very poor; 3= poor; 4= below fair/above poor; 5 = fair; 6= below good/above fair; 7=good; 8= very good; 9 = extremely good). Scores of 5 and above are acceptable for colour, texture, flavour and overall acceptability; DAE[a] =Days after emergence (Harvest Date).

Table 19: Mean sensory scores of boiled potatoes of 11 test genotypes harvested at 90 and 120 days after emergence (DAE) during season 2 at Tigoni, Limuru and Marimba, Meru

Tigoni, Limuru

Genotype	Colour		Texture		Flavour		Overall Acceptability	
	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]
385524.9	5.9	4.5	5.6	4.6	5.5	4.9	5.3	4.9
389746.2	4.4	6.4	4.4	5.6	4.0	5.3	4.5	5.6
391696.96	4.9	5.1	4.5	5.0	4.8	5.3	4.5	5.5
392617.54	4.5	4.8	4.4	4.5	4.3	4.9	4.1	5.0
392637.10	3.8	5.4	4.0	4.3	3.9	3.6	3.9	3.4
392657.8	5.0	4.6	5.1	4.4	4.6	3.9	5.0	3.9
393280.57	4.4	5.9	4.4	5.3	4.4	5.1	4.5	5.4
393371.58	5.9	4.9	5.3	4.4	5.1	4.3	5.4	4.5
393385.39	5.0	5.8	4.5	5.9	4.5	5.8	4.6	6.1
393385.47	4.9	6.9	3.5	6.8	3.8	6.3	5.0	6.9
Tigoni	5.5	4.5	5.4	4.6	5.4	4.8	5.3	4.6
Mean	4.9	5.3	4.6	5.0	4.6	4.9	4.6	5.1
SE	0.69	0.64	0.71	0.70	0.78	0.76	0.75	0.69
% CV	28.1	24.0	30.5	27.7	34.1	30.9	32.5	27.3

Marimba, Meru

Genotype	Colour		Texture		Flavour		Overall Acceptability	
	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]
385524.9	5.5	5.1	5.0	5.1	5.3	5.4	5.8	5.0
389746.2	5.8	5.6	5.9	5.8	5.6	6.3	5.5	6.4
391696.96	5.5	4.6	5.4	4.5	5.4	5.6	5.4	5.3
392617.54	5.4	6.6	4.8	6.4	4.1	6.5	4.5	6.9
392637.10	5.9	6.1	5.8	5.8	5.4	5.5	5.9	6.1
392657.8	4.6	5.6	5.1	5.9	5.4	6.0	5.4	5.8
393280.57	5.5	6.0	4.8	4.6	5.4	5.4	5.3	5.4
393371.58	5.1	5.9	5.9	5.9	4.9	5.6	5.8	5.9
393385.39	5.4	5.9	5.4	5.1	5.0	4.8	5.3	4.6
393385.47	6.0	6.4	6.1	6.0	5.8	6.3	6.1	6.0
Tigoni	5.9	6.5	6.3	6.6	5.8	6.5	6.1	6.6
Mean	5.5	5.9	5.5	5.6	5.3	5.8	5.5	5.8
SE	0.74	0.62	0.78	0.74	0.86	0.75	0.83	0.73
% CV	26.8	21.2	28.6	26.3	32.8	25.9	29.9	25.2

Scores (1 = extremely poor; 2= very poor; 3= poor; 4= below fair/above poor; 5 = fair; 6= below good/above fair; 7=good; 8= very good; 9 = extremely good). Scores of 5 and above are acceptable for colour, texture, flavour and overall acceptability; DAE[a] =Days after emergence (Harvest Date).

4.5.4 Effect of genotype and harvest date on processing quality

4.5.4.1 Effect of genotype and harvest date on chipping quality

Most of the genotypes produced chips of good quality (score of over 5) except for genotype 393280.57 that was generally low. In addition, most of the genotypes displayed higher acceptable values for chipping quality from genotypes harvested at 120 DAE than those of 90 DAE. Among population B3, genotypes 391696.96, 389746.2, 393371.58 and 393385.47 were highly acceptable for chips.

At Tigoni, Limuru during the first season, there were non-significant and significant ($P \leq 0.05$) difference among the genotypes for colour, texture, oiliness, flavour and the overall acceptability at 90 and 120 DAE respectively (Table 20). At Marimba, Meru during the first season, there were significant ($P \leq 0.05$) difference among the genotypes for colour, texture, flavour, oiliness and the overall acceptability at both 90 and 120 DAE (Table 20) except for the colour, texture and oiliness at 120 DAE.

During the second season at Tigoni, Limuru, there were significant differences ($P \leq 0.05$) among the genotypes for colour and the overall acceptability at both 90 and 120 DAE while for texture, oiliness and flavour it was not significant ($P \leq 0.05$) at 90 and 120 DAE except for texture at 90 DAE (Table 21). At Marimba, Meru, only the colour at 90 and 120 DAE and the overall acceptability at 120 DAE were significantly ($P \leq 0.05$) influenced by the genotypic difference while the other variables were non significant ($P \leq 0.05$) (Table 21).

Table 20: Mean sensory scores of potato chips prepared from 11 test genotypes harvested at 90 and 120 days after emergence (DAE) during season 1 at Tigoni, Limuru and Marimba, Meru

Tigoni, Limuru

Genotype	Colour		Texture		Oiliness		Flavour		Overall Acceptability	
	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]
385524.9	4.8	5.8	5.3	6.6	4.9	5.4	4.8	5.8	5.4	6.0
389746.2	5.3	6.6	5.6	6.3	5.0	6.1	5.1	6.6	5.5	6.6
391696.96	5.1	6.6	5.8	6.6	5.3	6.3	5.0	6.6	5.8	6.8
392617.54	5.9	6.5	5.6	6.0	5.5	5.3	5.9	5.6	5.8	6.0
392637.10	5.0	4.9	4.6	4.9	4.6	4.8	4.9	4.8	5.3	4.8
392657.8	4.4	5.9	4.4	5.9	4.3	5.9	4.8	6.0	5.3	5.8
393280.57	4.4	2.5	5.1	3.9	4.5	3.4	4.8	3.8	5.1	3.6
393371.58	5.3	6.4	5.3	6.5	5.1	6.0	5.0	6.5	5.3	6.6
393385.39	5.1	5.3	5.1	5.4	5.1	5.0	4.9	5.4	5.4	5.0
393385.47	5.0	7.1	4.0	6.6	5.0	6.3	4.6	6.8	4.6	7.0
Tigoni	6.1	7.1	5.6	6.6	5.0	6.5	5.9	6.9	6.0	7.3
Mean	5.1	5.9	5.1	5.9	4.9	5.5	5.1	5.9	5.4	5.9
SE	0.63	0.55	0.66	0.65	0.69	0.52	0.64	0.69	0.57	0.61
% CV	24.6	18.8	25.9	22.0	28.1	18.9	25.4	23.8	21.2	20.6

Marimba, Meru

Genotype	Colour		Texture		Oiliness		Flavour		Overall Acceptability	
	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]
385524.9	4.1	4.8	4.8	4.4	5.0	5.1	5.3	5.0	4.9	5.3
389746.2	6.0	6.0	6.0	5.4	5.6	5.5	6.3	5.9	5.9	6.1
391696.96	5.1	6.1	6.1	6.4	5.5	5.9	6.5	6.1	6.4	6.3
392617.54	4.9	5.4	5.4	5.4	5.4	5.4	5.6	5.1	5.6	5.3
392637.10	6.0	5.6	5.6	5.4	5.3	5.6	6.0	5.4	5.5	5.5
392657.8	5.0	4.3	4.3	5.0	4.5	5.1	4.1	4.3	4.6	4.8
393280.57	2.4	4.1	4.1	3.3	3.6	4.6	4.1	3.6	3.8	4.5
393371.58	5.4	5.3	5.3	5.9	5.4	5.9	5.9	5.6	5.9	6.5
393385.39	4.6	4.3	4.3	4.4	5.9	4.1	5.0	4.3	5.5	4.5
393385.47	5.6	5.5	5.5	6.0	5.5	6.1	5.4	5.9	5.9	6.3
Tigoni	6.0	6.1	6.1	6.4	5.9	5.9	6.4	5.9	6.0	6.5
Mean	5.0	5.2	5.2	5.3	5.2	5.4	5.5	5.2	5.4	5.6
SE	0.71	0.74	0.67	0.74	0.64	0.62	0.65	0.87	0.67	0.72
% CV	28.2	28.4	25.7	28.3	24.6	23.0	23.6	33.4	24.5	25.7

Scores (1 = extremely poor; 2= very poor; 3= poor; 4= below fair/above poor; 5 = fair; 6= below good/above fair; 7=good; 8= very good; 9 = extremely good). Scores of 5 and above are acceptable for colour, texture, flavour and overall acceptability. For oiliness, acceptable scores are those below 6; DAE[a] =Days after emergence (Harvest Date).

Table 21: Mean sensory scores of potato chips prepared from 11 test genotypes harvested at 90 and 120 days after emergence (DAE) during season 2 at Tigoni, Limuru and Marimba, Meru

Tigoni, Limuru

Genotype	Colour		Texture		Oiliness		Flavour		Overall Acceptability	
	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]
385524.9	4.8	5.8	5.9	5.1	5.4	5.4	5.1	5.9	5.1	6.1
389746.2	5.5	6.5	5.6	5.6	6.0	5.3	6.0	6.0	6.4	6.3
391696.96	7.3	5.5	6.9	5.6	6.3	5.0	7.0	5.3	7.5	5.5
392617.54	4.1	5.3	5.0	5.4	5.6	4.5	5.3	5.1	4.9	4.8
392637.10	5.6	6.9	6.3	5.9	5.5	5.3	6.0	5.8	5.9	6.3
392657.8	6.4	5.0	5.6	4.5	6.0	5.1	5.4	5.3	6.1	5.5
393280.57	5.3	5.1	5.3	4.6	5.4	5.4	5.5	5.3	5.0	5.4
393371.58	5.6	5.0	5.6	5.8	6.0	5.3	6.0	5.3	5.8	5.5
393385.39	5.9	4.6	6.3	5.3	5.8	4.8	6.1	5.9	6.6	5.9
393385.47	5.5	5.0	5.6	4.6	5.8	5.0	6.5	5.3	5.9	4.9
Tigoni	6.8	6.8	6.6	6.8	6.1	5.9	6.3	7.1	6.7	7.4
Mean	5.7	5.6	5.9	5.4	5.8	5.2	5.9	5.6	6.0	5.8
SE	0.66	0.65	0.55	0.75	0.58	0.65	0.66	0.66	0.67	0.55
% CV	23.1	23.3	18.8	27.8	20.1	25.3	22.2	23.4	22.3	19.1

Marimba, Meru

Genotype	Colour		Texture		Oiliness		Flavour		Overall Acceptability	
	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]
385524.9	5.3	5.9	5.1	5.3	5.4	5.3	5.6	6.0	5.6	5.6
389746.2	5.5	7.0	5.8	5.5	5.8	5.6	5.6	6.1	6.0	6.3
391696.96	6.8	6.6	6.1	5.9	6.5	5.8	6.5	5.8	6.1	6.1
392617.54	4.8	5.6	4.4	6.3	4.3	5.9	4.5	5.5	4.6	6.1
392637.10	5.4	6.4	5.1	5.5	5.3	5.8	4.6	6.1	5.1	6.4
392657.8	5.0	5.1	4.6	5.4	4.8	5.4	5.1	5.8	5.0	5.5
393280.57	3.6	2.8	4.6	4.5	5.0	4.5	5.1	4.4	5.0	3.4
393371.58	4.8	6.1	5.1	5.1	5.1	4.9	5.5	5.4	5.5	5.5
393385.39	6.0	5.0	5.6	4.3	5.5	5.0	6.3	5.0	6.0	4.6
393385.47	6.1	5.1	5.3	5.5	5.0	5.5	5.1	5.4	5.3	5.5
Tigoni	5.3	6.0	5.8	5.8	5.5	5.4	6.0	5.8	5.9	5.6
Mean	5.3	5.6	5.2	5.4	5.3	5.3	5.5	5.6	5.5	5.5
SE	0.66	0.74	0.75	0.77	0.70	0.71	0.67	0.77	0.62	0.72
% CV	24.9	26.3	28.6	28.7	26.7	26.7	24.5	27.8	22.8	26.2

Scores (1 = extremely poor; 2= very poor; 3= poor; 4= below fair/above poor; 5 = fair; 6= below good/above fair; 7=good; 8= very good; 9 = extremely good). Scores of 5 and above are acceptable for colour, texture, flavour and overall acceptability. For oiliness, acceptable scores are those below 6; DAE[a] =Days after emergence (Harvest Date).

Except for genotype 393280.57, most of the genotypes displayed good scores for colour at 90 and 120 DAE (Table 22). However, the scores were slightly better for 120 DAE than 90 DAE.

Table 22: Colour scores of half-cooked chips of 11 genotypes harvested at 90 and 120 days after emergence (DAE) at Tigoni, Limuru and Marimba, Meru during season 1 and 2

Genotype	Season 1				Season 2			
	Tigoni, Limuru		Marimba, Meru		Tigoni, Limuru		Marimba, Meru	
	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]
385524.9	1.0	2.0	2.0	1.0	3.0	2.0	1.0	2.5
389746.2	1.0	1.0	1.0	1.0	2.0	1.0	1.0	1.0
391696.96	1.0	1.0	1.0	1.0	1.0	1.0	1.0	2.0
392617.54	1.0	1.0	2.0	1.0	4.0	2.0	2.5	2.0
392637.10	1.0	1.5	5.0	2.0	1.0	1.0	2.5	2.0
392657.8	1.0	3.0	5.0	2.0	1.0	2.5	1.0	2.5
393280.57	4.0	4.0	5.0	4.0	3.5	3.0	4.0	4.0
393371.58	3.0	2.0	2.5	2.0	2.5	2.0	2.0	2.5
393385.39	3.0	2.5	2.5	3.0	1.5	2.0	1.0	1.5
393385.47	1.0	2.0	3.0	2.0	2.0	2.0	2.0	1.0
Tigoni	2.0	1.0	1.5	1.0	1.0	1.0	2.0	2.0

Based on a scale of 1 – 5 (1 = excellent; 5 = very poor), scores of 3.0 and below are acceptable; DAE[a] =Days after emergence (Harvest Date).

4.5.4.2 Effect of genotypes and harvest dates on crisping quality

Most of the genotypes displayed higher acceptability scores for use as crisps of good quality (score of over 5) except for genotype 393280.57 that was generally low. In general, most of the genotypes displayed higher acceptable values for crisping quality from genotypes harvested at 90 DAE than those of 120 DAE.

At Tigoni, Limuru in the first and the second season, there were no significant ($P \leq 0.05$) difference among the genotypes for colour, texture, oiliness, flavour and the overall acceptability at both 90 and 120 DAE except for flavour at 120 DAE during the second season (Tables 23). At Marimba, Meru during the first season, there were no significant difference among the genotypes for colour, texture, oiliness, flavour and the overall acceptability at 90 and 120 DAE except for the flavour and overall acceptability at 90 DAE (Table 23).

Table 23: Mean sensory scores of potato crisps prepared from 11 test genotypes harvested at 90 and 120 days after emergence (DAE) during season 1 at Tigoni, Limuru and Marimba, Meru

Tigoni, Limuru

Genotype	Colour		Texture		Oiliness		Flavour		Overall Acceptability	
	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]
385524.9	6.3	5.4	6.4	5.3	5.9	5.3	6.1	5.0	6.4	5.1
389746.2	5.5	5.4	5.9	5.3	5.9	5.6	5.8	5.5	6.3	5.5
391696.96	6.3	5.6	5.8	5.9	5.5	5.6	6.5	6.3	6.1	6.4
392617.54	6.1	5.8	5.8	5.8	5.9	5.8	6.4	5.9	6.8	5.9
392637.10	6.1	4.8	7.0	5.6	6.4	5.9	5.9	6.1	6.4	5.4
392657.8	5.6	5.1	5.1	5.5	6.4	5.0	5.5	5.3	5.9	5.4
393280.57	4.1	5.3	5.5	5.3	5.0	5.3	5.0	5.5	5.3	5.3
393371.58	5.0	5.9	5.8	6.3	5.6	5.8	5.4	6.0	5.5	6.3
393385.39	5.0	5.0	6.1	5.9	5.6	5.8	5.5	5.9	5.8	5.8
393385.47	5.4	5.9	6.1	6.4	5.9	6.0	5.9	6.4	6.0	6.4
Tigoni	5.9	5.9	5.6	6.0	5.9	6.0	5.9	5.9	6.1	5.9
Mean	5.6	5.4	5.9	5.7	5.8	5.6	5.8	5.8	6.0	5.7
SE	0.77	0.70	0.67	0.63	0.64	0.66	0.69	0.61	0.70	0.56
% CV	25.1	28.4	21.3	23.4	22.7	22.6	21.1	24.0	18.5	24.4

Marimba, Meru

Genotype	Colour		Texture		Oiliness		Flavour		Overall Acceptability	
	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]
385524.9	6.1	6.1	6.0	5.9	6.4	5.8	6.6	5.4	6.8	5.6
389746.2	5.8	6.0	6.3	6.0	6.8	5.8	6.3	5.6	6.9	5.8
391696.96	6.3	5.9	6.3	6.4	6.0	6.5	6.8	6.1	6.8	6.3
392617.54	6.9	6.3	6.8	5.8	5.8	5.6	5.8	5.4	6.5	5.8
392637.10	6.6	5.6	6.9	6.1	6.5	6.1	6.4	5.4	6.6	5.6
392657.8	5.6	6.5	5.5	5.8	6.1	5.9	6.1	5.3	6.3	6.0
393280.57	5.6	4.8	6.1	5.1	6.0	5.4	6.4	4.4	6.3	4.5
393371.58	5.9	6.4	5.9	6.3	5.8	5.6	5.6	5.9	5.9	6.4
393385.39	6.1	6.4	6.3	6.0	5.9	6.0	4.9	5.0	5.6	5.5
393385.47	6.8	6.6	6.8	6.4	6.9	6.3	7.3	6.4	7.4	6.5
Tigoni	5.4	6.4	5.5	6.3	5.8	6.1	6.1	6.0	6.3	6.3
Mean	6.1	6.1	6.2	6.0	6.2	5.9	6.2	5.5	6.5	5.8
SE	0.61	0.74	0.65	0.66	0.58	0.66	0.56	0.84	0.49	0.68
% CV	20.1	24.3	21.1	21.9	18.6	22.4	18.0	34.8	15.3	23.3

Scores (1 = extremely poor; 2= very poor; 3= poor; 4= below fair/above poor; 5 = fair; 6= below good/above fair; 7=good; 8= very good; 9 = extremely good). Scores of 5 and above are acceptable for colour, texture, flavour and overall acceptability. For oiliness, acceptable scores are those below 6; DAE[a] =Days after emergence (Harvest Date).

At Tigoni, Limuru in the second season, there were no significant ($P \leq 0.05$) difference among the genotypes for colour, texture, oiliness, flavour and the overall acceptability at both 90 and 120 DAE except for flavour at 120 DAE (Tables 24).

During the second season, there were non-significant and significant difference among the genotypes for colour, texture, flavour, oiliness and the overall acceptability at 90 and 120 DAE (Table 24).

Table 24: Mean sensory scores of potato crisps prepared from 11 test genotypes harvested at 90 and 120 days after emergence (DAE) during season 2 at Tigoni, Limuru and Marimba, Meru

Tigoni, Limuru

Genotype	Colour		Texture		Oiliness		Flavour		Overall Acceptability	
	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]
385524.9	5.5	5.0	6.1	4.8	6.3	4.8	6.5	4.1	6.3	4.8
389746.2	5.8	4.9	6.1	4.5	6.1	4.9	6.0	4.4	6.4	4.6
391696.96	5.1	5.6	5.6	5.3	6.0	5.0	6.5	4.8	5.9	5.4
392617.54	6.1	3.8	6.0	4.3	6.3	4.3	6.1	3.5	6.4	4.1
392637.10	6.5	5.8	6.3	5.4	6.6	5.1	6.5	5.0	6.4	5.3
392657.8	5.5	6.0	5.4	5.1	6.3	5.0	6.3	5.5	6.3	5.8
393280.57	5.9	5.1	5.9	5.1	5.6	4.6	6.3	5.5	6.0	5.1
393371.58	5.9	5.6	6.1	4.5	5.9	4.9	6.1	5.5	6.0	5.9
393385.39	5.8	5.8	6.1	5.8	6.0	5.0	6.1	5.5	6.3	5.6
393385.47	6.6	5.9	6.4	5.4	6.6	4.9	7.0	6.0	7.4	5.5
Tigoni	5.1	5.3	5.5	5.5	6.1	5.1	5.9	5.0	5.8	5.8
Mean	5.8	5.3	6.0	5.1	6.2	4.9	6.3	5.0	6.3	5.3
SE	0.71	0.69	0.48	0.61	0.501	0.65	0.571	0.69	0.59	0.59
% CV	24.5	26.0	16.2	24.3	6.2	26.8	8.1	27.7	18.8	22.4

Marimba, Meru

Genotype	Colour		Texture		Oiliness		Flavour		Overall Acceptability	
	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]
385524.9	5.3	6.4	5.4	6.0	5.0	6.0	5.0	6.5	5.6	6.5
389746.2	6.5	6.4	5.9	6.0	5.5	6.1	5.5	6.1	6.3	6.5
391696.96	6.0	7.1	5.9	6.0	5.9	6.6	6.1	6.0	6.4	6.3
392617.54	5.5	4.5	5.1	5.5	5.3	5.0	5.4	5.1	6.1	4.8
392637.10	6.1	6.4	5.6	5.9	5.9	6.3	6.0	6.1	6.5	5.9
392657.8	5.0	6.0	5.0	5.8	4.8	5.6	4.6	6.0	5.5	5.8
393280.57	5.1	3.0	5.1	3.8	4.6	4.5	5.1	4.4	4.5	4.5
393371.58	5.3	5.9	4.8	5.3	5.4	5.4	4.8	5.4	5.1	5.5
393385.39	5.8	4.6	5.9	4.9	5.9	5.5	6.4	5.3	6.6	5.4
393385.47	6.0	4.9	5.6	4.5	4.7	5.4	5.9	4.6	6.6	4.5
Tigoni	5.1	5.0	5.1	5.6	5.5	5.3	4.9	5.9	5.1	5.5
Mean	5.6	5.5	5.4	5.4	5.3	5.6	5.4	5.6	5.9	5.6
SE	0.84	0.64	0.71	0.52	0.77	0.59	0.913	0.61	0.84	0.58
% CV	30.0	23.4	26.4	19.4	28.9	21.9	3.6	21.9	28.6	20.9

Scores (1 = extremely poor; 2= very poor; 3= poor; 4= below fair/above poor; 5 = fair; 6= below good/above fair; 7=good; 8= very good; 9 = extremely good). Scores of 5 and above are acceptable for colour, texture, flavour and overall acceptability. For oiliness, acceptable scores are those below 6; DAE[a] =Days after emergence (Harvest Date).

Except for genotype 393280.57, most of the genotypes displayed good scores for colour at both 90 and 120 DAE (Table 25). However, the scores were slightly better for 120 DAE than 90 DAE.

Table 25: Colour scores of crisps of 11 genotypes harvested at 90 and 120 days after emergence (DAE) at Tigoni, Limuru and Marimba, Meru during season 1 and 2

Genotype	Season 1				Season 2			
	Tigoni, Limuru		Marimba, Meru		Tigoni, Limuru		Marimba, Meru	
	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]
385524.9	3.0	1.0	2.0	1.0	1.5	1.0	2.0	1.0
389746.2	2.0	2.0	1.0	2.0	2.5	2.0	1.0	1.0
391696.96	2.0	1.0	1.0	1.0	1.0	1.0	2.0	1.0
392617.54	1.0	1.0	2.0	2.0	3.0	2.0	3.0	1.0
392637.10	1.0	2.0	3.0	3.0	3.0	2.5	1.0	2.0
392657.8	3.0	2.0	1.5	2.5	1.0	1.5	1.0	2.0
393280.57	4.0	3.0	3.0	4.0	3.0	3.0	3.0	4.0
393371.58	3.0	1.5	3.0	1.0	3.0	2.5	2.0	1.0
393385.39	2.0	1.0	2.0	1.0	2.0	2.0	1.0	2.0
393385.47	2.5	2.0	2.0	1.0	2.0	1.0	1.5	2.5
Tigoni	2.0	2.0	1.0	1.0	1.5	1.0	2.5	2.0

Based on a scale of 1 – 5 (1 = excellent; 5 = very poor), scores of 3.0 and below are acceptable; DAE[a] =Days after emergence (Harvest Date).

4.5.5 Effect of genotype and harvest date on sprouting (%)

Tuber sprouting differed significantly ($P \leq 0.05$) among the genotypes during all the seasons at both 90 and 120 DAE at Tigoni, Limuru and Marimba, Meru (Table 26). Most of the population B3 genotypes commenced sprouting by the 4th week except 393385.39, 392657.8, 392637.10 and 393280.57 that sprouted by 6th week for early harvest while it was reduced to the 2nd week and 4th week respectively for late harvest. Kerr's Pink and Tigoni sprouted by the second week of storage with Kerr's Pink having its % sprouting levelling off regardless of the harvesting date (Figures 7-10).

In all genotypes, potato tubers harvested at 120 DAE showed higher levels of sprouting compared to those harvested at 90 DAE during all seasons at both locations (Figure 7-10). Furthermore, it was observed that most of the genotypes harvested at 90 DAE can be kept for 10-12 weeks except for 393385.39, 392657.8, 392637.10 and 393280.57 that can store well for over 12 weeks. Those harvested at 120 DAE can be kept for a maximum of 6-8 weeks except for genotypes 393385.39, 392657.8, 392637.10 and 393280.57 that can be kept for 10-12 weeks before sprouting losses become excessive (Figure 7-10).

Table 26: Combined analysis of variance on the effect of harvesting date on the storage of population B3 genotypes at Tigoni, Limuru and Marimba, Meru during season 1 and 2

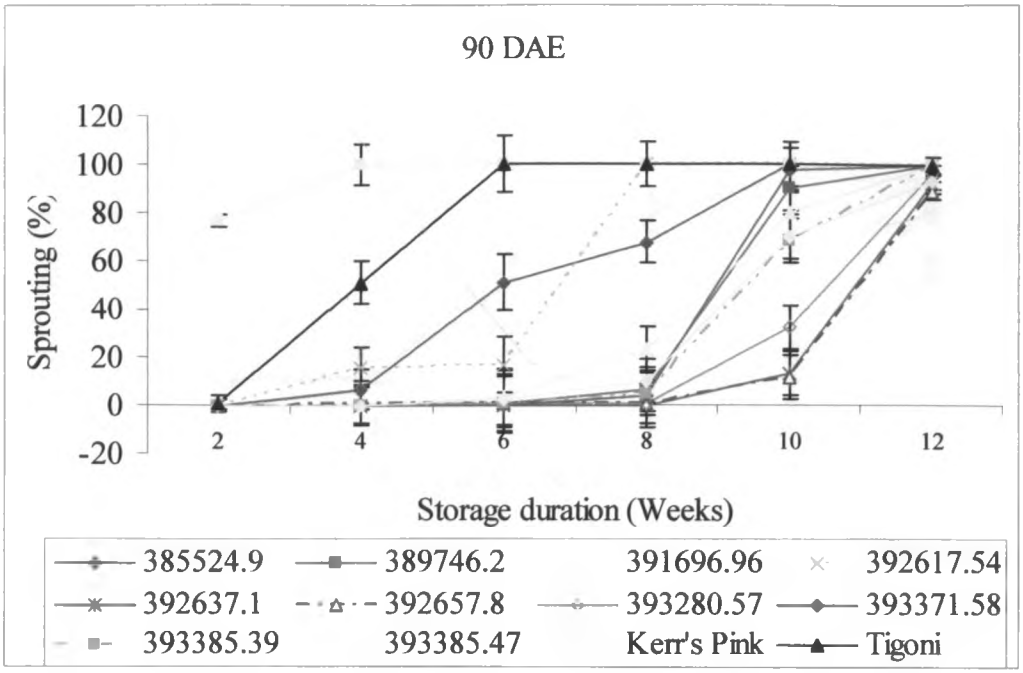
90 DAE[a]

Source of variation	df	Storage duration (Weeks)											
		2		4		6		8		10		12	
		F value	P>F	F value	P>F	F value	P>F	F value	P>F	F value	P>F	F value	P>F
PTM (%)													
Rep	2	1.24	0.00	1.15	0.00	0.18	0.31	0.08	0.00	0.25	0.00	1.31	0.00
Genotype(G)	11	0.33	0.98	0.88	0.56	1.19	0.01	1.61	0.11	1.27	0.25	1.58	0.12
Location (L)	1	7.75	0.01	5.27	0.02	7.12	0.30	3.84	0.05	1.38	0.24	0.91	0.34
Season (S)	1	1.53	0.22	4.10	0.05	1.09	0.19	0.08	0.78	0.42	0.52	3.83	0.05
G x L	11	1.02	0.44	1.69	0.09	1.39	0.02	1.99	0.04	1.62	0.11	1.56	0.12
G x S	11	1.06	0.40	1.64	0.10	2.24	0.42	1.88	0.05	1.15	0.34	1.42	0.18
G x Rep	22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
G x L x S	11	0.60	0.82	0.46	0.93	1.16	0.33	0.77	0.67	1.58	0.12	1.77	0.07
Sprouting													
Rep	2	0.48	0.00	1.37	0.00	0.42	0.001	0.76	0.00	4.22	0.00	2.00	0.00
G	11	741.97	0.001	251.01	0.001	54.07	0.001	64.41	0.001	77.12	0.001	10.93	0.001
L	1	2.07	0.15	3.58	0.06	31.21	0.05	22.83	0.001	37.63	0.001	6.17	0.02
S	1	0.18	0.67	17.95	0.001	3.96	0.001	0.43	0.51	0.02	0.89	1.10	0.30
G x L	11	2.98	0.002	3.95	0.001	5.17	0.001	5.20	0.001	5.05	0.001	2.75	0.004
G x S	11	0.15	0.99	5.97	0.001	11.69	0.001	7.23	0.001	5.18	0.001	1.53	0.13
G x Rep	22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
G x L x S	11	3.48	0.001	3.34	0.001	4.84	0.001	7.61	0.001	4.21	0.001	0.35	0.97
Rots (%)													
Rep	2	0.16	0.00	2.45	0.00	0.73	0.00	0.58	0.00	0.54	0.00	0.98	0.00
G	11	4.75	0.001	2.99	0.002	1.43	0.17	3.04	0.002	3.19	0.001	1.68	0.09
L	1	5.07	0.03	0.43	0.51	0.20	0.66	19.30	0.001	51.11	0.001	16.65	0.001
S	1	16.86	0.001	15.78	0.001	43.17	0.001	48.35	0.001	54.97	0.001	21.06	0.001
G x L	11	0.32	0.98	1.33	0.22	1.64	0.09	1.80	0.06	2.62	0.01	1.49	0.15
G x S	11	5.91	0.001	2.27	0.02	1.75	0.07	2.53	0.01	3.49	0.001	1.86	0.06
G x Rep	22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
G x L x S	11	0.52	0.89	1.62	0.11	1.29	0.24	1.64	0.10	3.13	0.001	1.79	0.07

120 DAE[a]

Source of variation	df	Storage duration (Weeks)											
		2		4		6		8		10		12	
		F value	P>F	F value	P>F	F value	P>F	F value	P>F	F value	P>F	F value	P>F
PTM (%)													
Rep	2	0.41	0.00	0.40	0.00	1.45	0.00	0.56	0.00	0.17	0.00	0.01	0.00
Genotype(G)	11	1.69	0.09	0.93	0.51	1.01	0.45	1.11	0.36	1.20	0.30	1.62	0.11
Location (L)	1	5.81	0.02	3.10	0.08	4.49	0.04	0.53	0.47	1.38	0.24	0.17	0.68
Season (S)	1	0.93	0.34	0.00	0.99	15.19	0.001	29.63	0.001	32.44	0.001	42.53	0.001
G x L	11	0.74	0.70	1.34	0.22	1.10	0.37	0.78	0.66	0.81	0.63	0.73	0.71
G x S	11	0.42	0.94	0.81	0.63	1.27	0.26	1.30	0.24	1.56	0.12	0.78	0.66
G x Rep	22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
G x L x S	11	1.25	0.27	1.44	0.17	0.93	0.52	0.61	0.81	1.57	0.12	1.41	0.18
Sprouting													
Rep	2	2.86	0.00	0.02	0.00	0.54	0.00	1.61	0.00	0.56	0.00	1.00	0.00
G	11	53.85	0.001	40.25	0.001	50.69	0.001	24.63	0.001	0.96	0.49	2.58	0.01
L	1	18.24	0.001	1.12	0.29	0.03	0.87	0.30	0.59	1.16	0.28	2.58	0.11
S	1	25.13	0.001	58.00	0.001	1.62	0.21	0.40	0.53	10.22	0.002	2.58	0.11
G x L	11	2.24	0.02	2.54	0.01	6.43	0.001	2.19	0.02	1.60	0.11	2.58	0.01
G x S	11	2.48	0.01	7.02	0.001	4.38	0.001	1.16	0.32	1.45	0.16	2.58	0.01
G x Rep	22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
G x L x S	11	3.36	0.001	5.11	0.001	9.11	0.03	1.16	0.33	1.59	0.12	2.58	0.01
Rots (%)													
Rep	2	2.51	0.00	0.17	0.00	0.48	0.00	0.37	0.00	0.01	0.00	1.70	0.00
G	11	0.98	0.47	1.38	0.20	0.91	0.54	0.89	0.55	4.76	0.001	1.85	0.06
L	1	1.03	0.31	9.55	0.003	3.98	0.05	2.28	0.13	5.59	0.02	13.42	0.001
S	1	1.03	0.31	21.50	0.001	1.41	0.24	2.28	0.13	2.77	0.10	11.19	0.001
G x L	11	0.89	0.55	0.86	0.59	1.02	0.43	0.68	0.75	3.74	0.001	3.18	0.001
G x S	11	1.17	0.32	2.07	0.03	0.91	0.53	1.42	0.18	2.09	0.03	2.94	0.002
G x Rep	22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
G x L x S	11	0.42	0.94	1.09	0.38	1.03	0.43	0.38	0.96	1.31	1.31	2.13	0.03

DAE[a] =Days after emergence (Harvest Date).



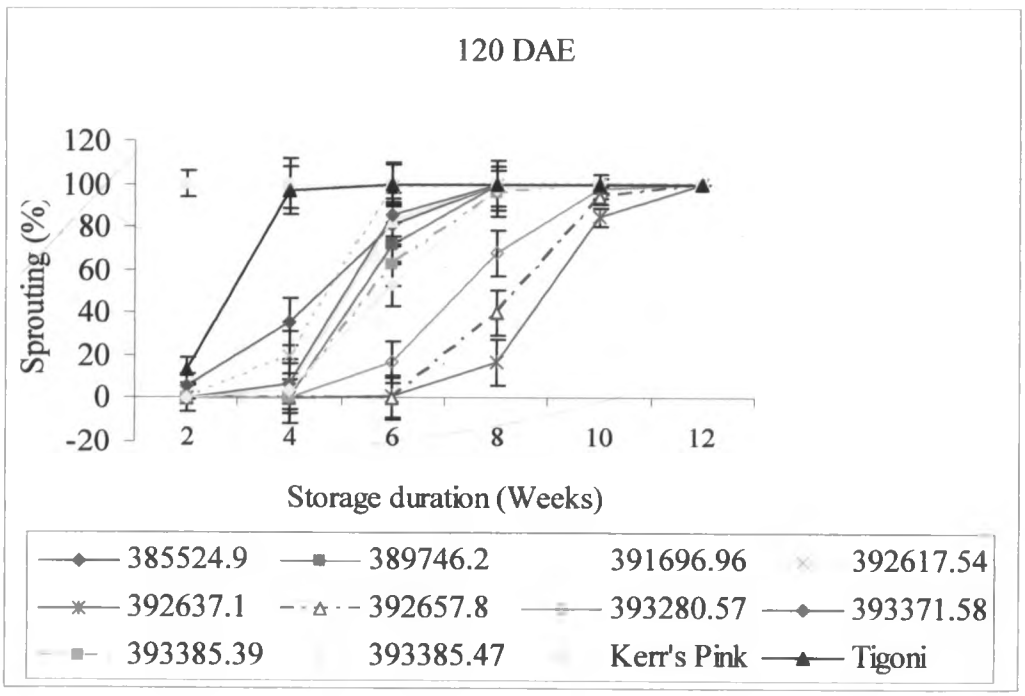


Figure 7: Percentage spouting on different genotypes of potato ware tubers harvested at different dates at Tigoni, Limuru in season 1 during 12 weeks of dark storage conditions. The bars indicate the standard error (SE) of mean.

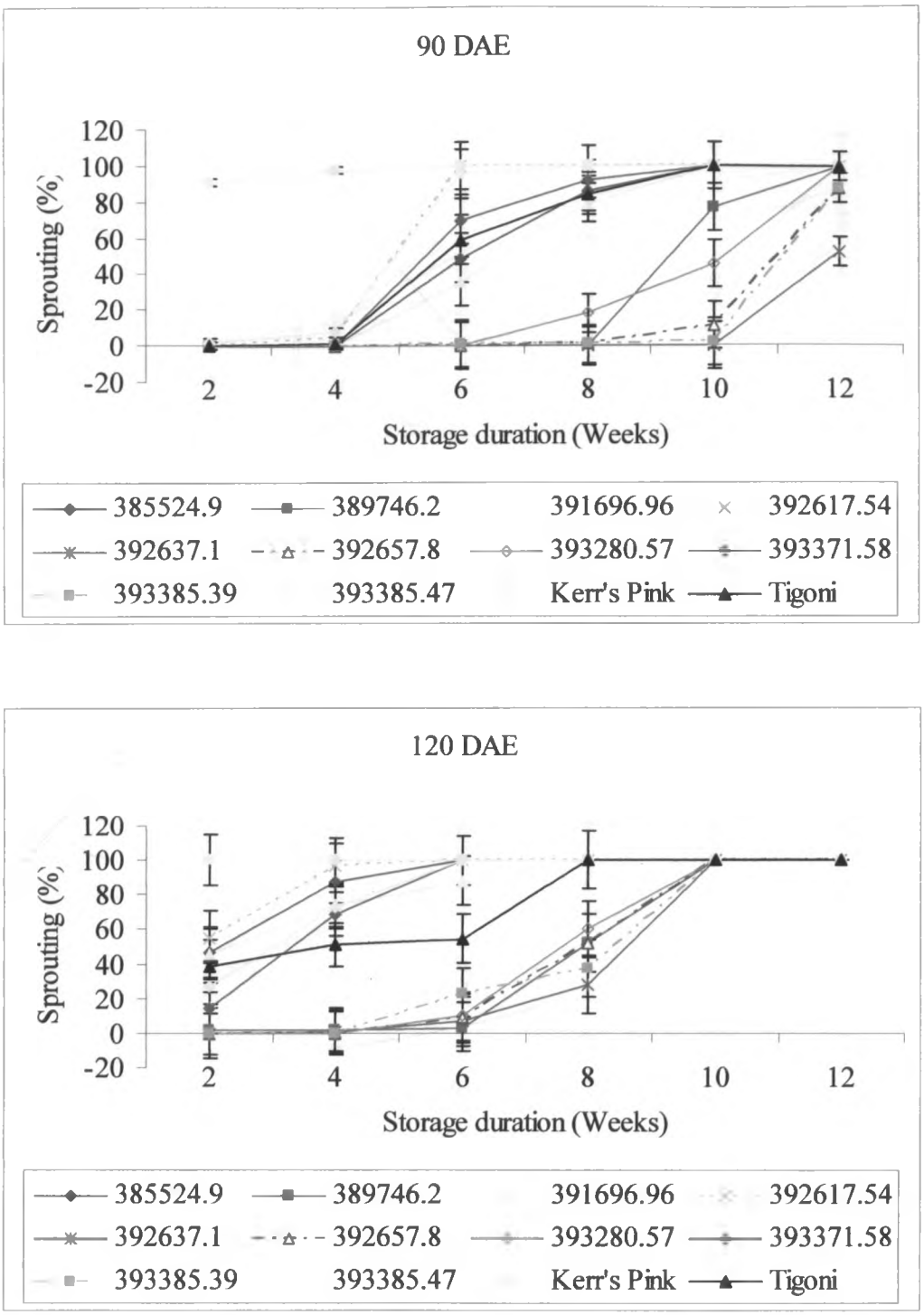
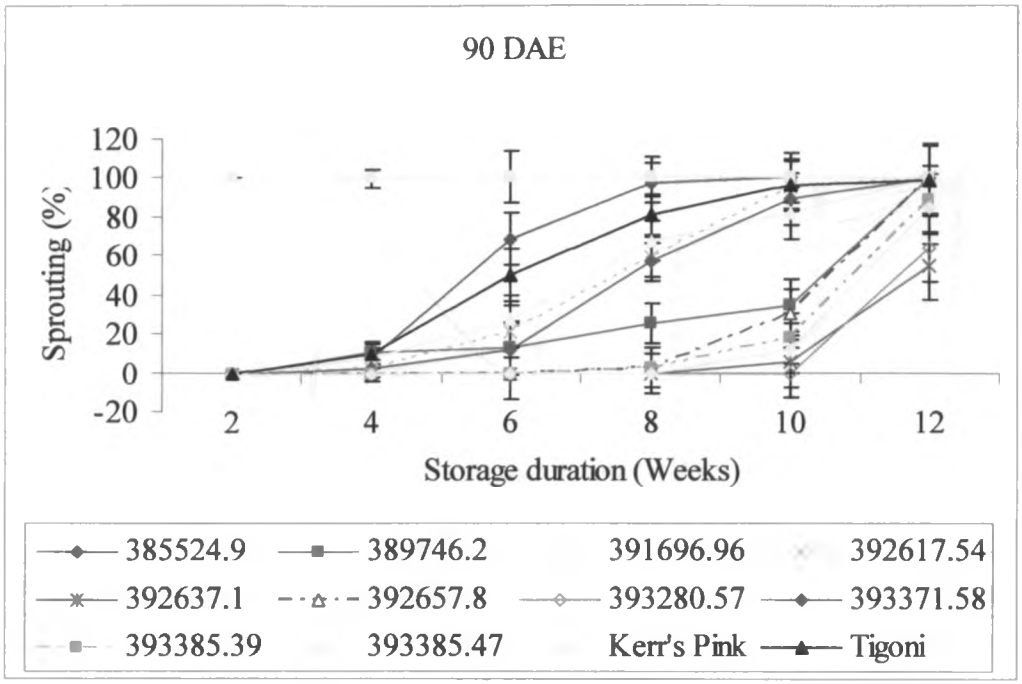


Figure 8: Percentage spouting on different genotypes of potato ware tubers harvested at different dates at Tigoni, Limuru in season 2 during 12 weeks of dark storage conditions. The bars indicate the standard error (SE) of mean.



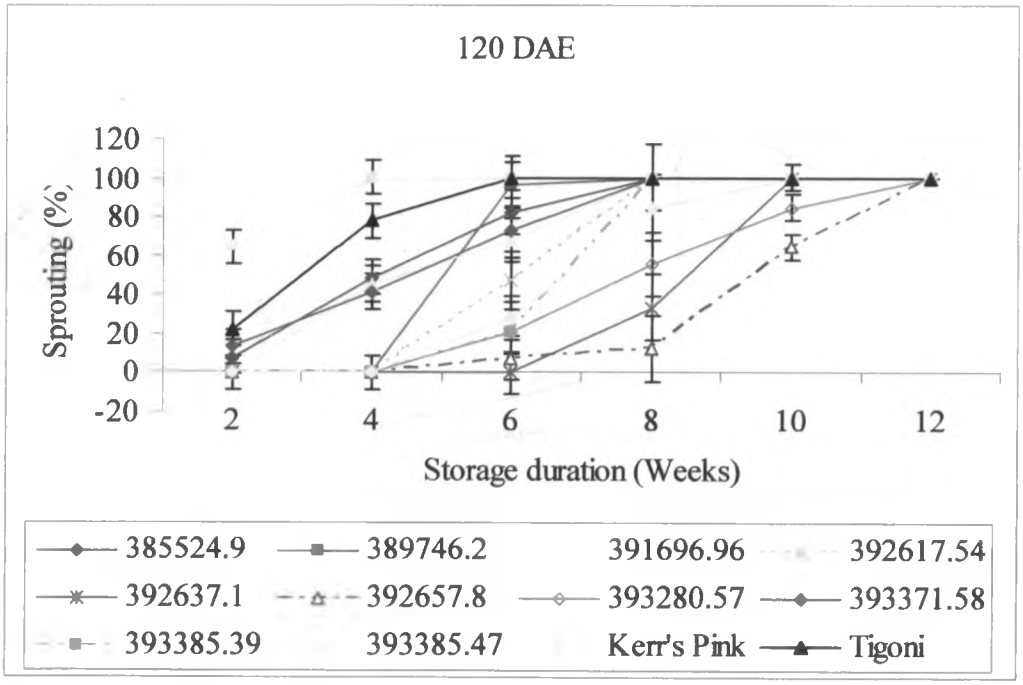


Figure 9: Percentage spouting on different genotypes of potato ware tubers harvested at different dates at Marimba, Meru in season 1 during 12 weeks of dark storage conditions. The bars indicate the standard error (SE) of mean.

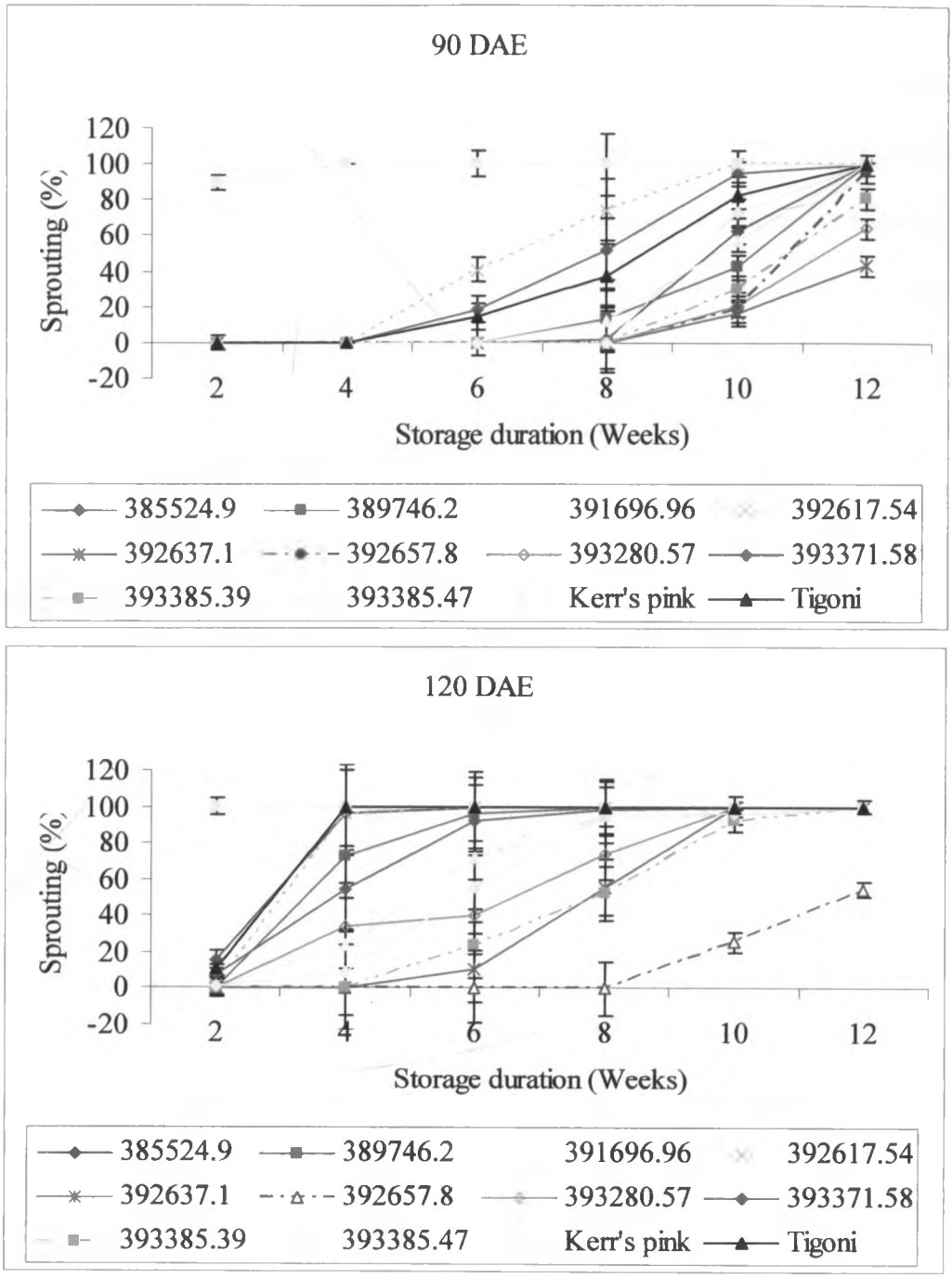


Figure 10: Percentage spouting on different genotypes of potato ware tubers harvested at different dates at Marimba, Meru in season 2 during 12 weeks of dark storage conditions. The bars indicate the standard error (SE) of mean.

4.5.6 Effect of genotypes and harvest date on weight loss (%)

There were significant differences among the genotypes at both locations at 90 and 120 DAE except at Tigoni, Limuru during the first season at 90 DAE and during the second season at Marimba, Meru at 120 DAE where it was non significant (Table 27). Low weight losses were recorded from tubers harvested at 120 DAE than at 90 DAE that were mostly high (Table 27). At Tigoni, Limuru in the first season, tuber weight loss varied from 5.34 and 1.11 (393371.58) to 36.94% and 25.00 (Kerr's Pink) while at Marimba, Meru they ranged from 0.00% and 3.06% (392637.10) to 22.22% (Kerr's pink) and 11.60% (391696.96) at 90 and 120 DAE respectively.

Table 27: Mean weight loss (%) of potato ware tubers harvested at 90 and 120 days after emergence (DAE) at Tigoni, Limuru and Marimba, Meru during season 1 and 2 at 12 weeks of dark storage conditions

Genotype	Tigoni, Limuru				Marimba, Meru			
	Season 1		Season 2		Season 1		Season 2	
	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]
385524.9	8.5	4.4	8.0	7.9	10.9	6.3	5.3	7.9
389746.2	6.5	4.0	10.9	2.1	10.3	3.7	2.8	8.2
391696.96	8.5	3.6	13.9	12.0	13.2	10.5	16.4	11.6
392617.54	9.5	3.7	8.7	8.2	2.8	6.4	4.0	6.1
392637.10	7.7	4.8	8.6	6.7	24.2	3.1	0.0	7.2
392657.8	7.7	3.2	12.3	7.5	15.3	8.3	7.0	8.6
393280.57	9.5	3.5	13.3	11.6	8.1	8.9	7.1	7.3
393371.58	5.3	1.1	9.5	6.1	12.2	3.9	4.7	9.8
393385.39	7.0	5.0	11.7	8.3	6.9	4.4	7.4	5.9
393385.47	5.4	3.6	8.8	6.1	8.1	5.8	3.8	7.8
Kerr's Pink	5.7	22.5	36.9	25.0	22.2	9.8	13.9	10.5
Tigoni	7.9	3.8	5.8	2.8	8.3	8.2	8.1	6.1
Mean	8.1	5.3	12.4	8.7	11.9	6.6	6.7	8.1
LSD (5%)	5.31	5.87	8.30	8.46	9.97	3.60	7.14	5.20
% CV	42.0	65.7	39.7	57.5	49.6	32.2	62.9	38.0

* is significant at 5% level of significance; DAE[a] =Days after emergence (Harvest Date)

4.5.7 Incidence of potato tuber moth (%)

In the first season, all genotypes showed some levels of infestation by potato tuber moth. Higher incidences of potato tuber moth were observed at both locations during this season though it was slightly higher in tubers from Marimba, Meru than those from Tigoni, Limuru. It was also higher in genotypes harvested 120 DAE than at 90 DAE (Tables 28 and 29). However, this depended on the genotype and was higher on genotypes that varied from 2.22-25.56% (Tables 28 and 29). In the second season, low incidences of potato tuber moth (upto 7.78 %) were observed at both 90 and 120 DAE at both locations (Tables 28 and 29).

Table 28: Incidence of potato tuber moth on potato ware tubers harvested at 90 and 120 days after emergence (DAE) in season 1 during 12 weeks of dark storage conditions at Tigoni, Limuru and Marimba, Meru

Tigoni, Limuru

Genotype	Storage duration (Weeks)											
	2		4		6		8		10		12	
	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]
385524.9	2.2	0.0	2.2	0.0	2.2	4.4	2.2	4.4	2.2	4.4	2.2	6.7
389746.2	1.1	0.0	1.1	0.0	1.1	2.2	1.1	3.3	1.1	3.3	2.2	4.4
391696.96	0.0	0.0	0.0	0.0	0.0	2.2	0.0	3.3	2.2	3.3	2.2	6.8
392617.54	2.2	0.0	3.3	1.1	3.3	4.4	3.3	5.6	3.3	5.6	7.8	5.6
392637.10	1.1	0.0	1.1	0.0	2.2	0.0	2.3	3.3	3.4	3.3	5.6	3.3
392657.8	0.0	1.1	0.0	2.2	0.0	4.4	0.0	4.4	4.7	4.4	5.9	6.7
393280.57	2.2	0.0	3.3	0.0	3.3	4.4	4.4	5.6	5.6	6.7	6.7	6.7
393371.58	2.2	0.0	3.3	0.0	5.6	1.1	5.6	3.3	5.6	3.3	6.7	3.3
393385.39	1.1	1.1	1.1	1.1	1.1	3.3	1.1	3.3	1.1	1.1	1.1	2.2
393385.47	0.0	0.0	0.0	0.0	0.0	3.3	0.0	3.3	0.0	5.6	0.0	6.7
Kerr's Pink	3.3	0.0	5.6	1.1	5.6	1.1	6.7	1.1	6.7	1.1	6.7	1.1
Tigoni	4.4	1.1	5.6	1.1	5.6	2.2	5.6	3.3	5.6	3.3	6.7	4.4
LSD (5%)	4.71	1.63	4.14	2.46	3.90	6.00	3.60	7.31	5.13	5.68	5.26	5.26

Marimba, Meru

Genotype	Storage duration (Weeks)											
	2		4		6		8		10		12	
	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]
385524.9	0.0	1.1	1.1	3.3	1.1	8.9	2.2	10.0	4.4	10.0	6.0	10.0
389746.2	0.0	0.0	0.0	0.0	1.1	0.0	1.1	5.6	4.4	6.7	4.4	8.9
391696.96	0.0	1.1	0.0	1.1	1.1	2.2	1.1	2.2	2.2	5.6	3.8	6.7
392617.54	0.0	0.0	1.1	0.0	1.1	2.2	3.3	3.3	3.3	5.6	5.8	5.6
392637.10	0.0	0.0	1.1	3.3	1.1	5.6	2.2	5.6	3.3	7.8	4.3	10.0
392657.8	0.0	0.0	1.1	0.0	2.2	1.1	3.3	1.1	3.3	3.3	5.1	5.6
393280.57	0.0	0.0	0.0	1.1	1.1	5.6	1.1	6.7	4.4	7.8	4.4	8.9
393371.58	0.0	0.0	1.1	0.0	3.3	1.1	3.3	2.2	4.4	2.2	4.4	3.3
393385.39	0.0	0.0	1.1	0.0	1.1	0.0	1.1	0.0	2.2	7.8	5.5	7.9
393385.47	0.0	0.0	1.1	1.1	2.2	1.1	3.3	2.2	4.4	2.2	6.2	3.3
Kerr's Pink	0.0	0.0	0.0	1.1	1.1	1.1	2.2	3.3	2.2	3.3	2.2	4.4
Tigoni	0.0	1.1	2.2	1.1	4.4	2.2	6.7	5.6	6.7	6.7	8.9	8.9
LSD (5%)	4.70	1.63	2.74	3.17	3.06	3.06	3.92	3.92	4.13	7.61	3.99	7.25

* is significant at 5% level of significance; DAE[a] =Days after emergence (Harvest Date).

Table 29: Incidence of potato tuber moth on potato ware tubers harvested at 90 and 120 days after emergence (DAE) in season 2 during 12 weeks of dark storage conditions at Tigoni, Limuru and Marimba, Meru

Tigoni, Limuru

Genotype	Storage duration (Weeks)											
	2		4		6		8		10		12	
	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]
385524.9	0.0	1.1	0.0	2.2	5.6	2.2	5.6	2.2	5.6	2.2	7.8	4.5
389746.2	0.0	1.1	0.0	1.1	0.0	1.1	1.1	1.1	1.1	4.5	1.1	4.5
391696.96	1.1	3.3	2.2	4.4	3.3	4.4	3.3	4.4	3.3	4.5	3.3	5.6
392617.54	0.0	0.0	1.1	1.1	2.2	1.1	2.2	1.1	2.2	1.1	2.2	2.2
392637.10	0.0	1.1	0.0	1.1	0.0	1.1	0.0	1.1	0.0	4.5	1.1	4.5
392657.8	0.0	0.0	0.0	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	3.3
393280.57	0.0	0.0	0.0	0.0	0.0	0.0	7.8	0.0	8.9	1.1	8.9	2.2
393371.58	1.1	0.0	1.1	0.0	1.1	0.0	3.3	0.0	4.4	0.0	4.4	0.0
393385.39	1.1	2.2	1.1	2.2	4.4	2.2	4.4	2.2	5.6	2.2	5.6	3.3
393385.47	1.1	0.0	2.2	1.1	4.4	1.1	6.7	1.1	6.7	1.1	6.7	2.2
Kerr's Pink	1.1	0.0	2.2	0.0	2.2	0.0	2.2	0.0	2.2	0.0	2.2	0.0
Tigoni	0.0	2.2	1.1	2.3	3.3	3.4	5.6	3.4	6.7	3.7	6.7	3.7
LSD (5%)	2.07	3.02	3.02	3.26	4.81	3.50	5.76	3.50	5.28	5.28	4.70 *	5.68

Marimba, Meru

Genotype	Storage duration (Weeks)											
	2		4		6		8		10		12	
	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]
385524.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
389746.2	0.0	0.0	0.0	1.1	0.0	1.1	2.2	1.1	2.2	1.1	2.2	1.1
391696.96	0.0	0.0	1.1	0.0	1.1	0.0	1.1	2.2	2.2	2.2	3.3	5.6
392617.54	0.0	0.0	1.1	0.0	1.1	0.0	1.1	0.0	4.4	0.0	4.4	0.0
392637.10	1.1	0.0	1.1	0.0	2.2	0.0	2.2	0.0	4.4	0.0	4.4	0.0
392657.8	0.0	0.0	3.3	0.0	4.4	0.0	5.6	0.0	5.6	0.0	5.6	0.0
393280.57	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.0	1.1	0.0
393371.58	0.0	0.0	0.0	0.0	1.1	1.2	2.2	1.2	2.2	4.5	2.2	5.6
393385.39	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.0
393385.47	0.0	0.0	2.2	0.0	2.2	0.0	6.7	0.0	6.7	0.0	7.8	0.0
Kerr's Pink	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tigoni	0.0	0.0	0.0	0.0	0.0	1.1	1.1	2.2	1.1	2.2	2.2	3.3
LSD (5%)	2.58*	0	3.89 *	0.94	3.76	1.65	5.05	1.92	4.71	1.89 *	5.15	2.35 *

* is significant at 5% level of significance; DAE[a] =Days after emergence (Harvest Date).

4.5.8 Effect of genotype and harvest date on tuber rotting (%)

In the first season, higher incidences of tuber rotting were observed at both locations. However, it was higher in genotypes harvested 90 DAE than at 120 DAE (Tables 30 and 31). Also it was higher in genotypes harvested from Marimba, Meru than at Tigoni, Limuru especially 391696.96, 392637.10, 392657.8, 393385.47 and 393371.58, which varied from 2.22-12.22% (Tables 30 and 31). In the second season, few incidences of rotting (upto 4.44 %) were observed for both 90 and 120 DAE at both locations (Tables 30 and 31). The fungi *Phytophthora infestans* was observed from tuber areas with wet rots and tissue browning while the fungi of *Fusarium* spp was observed from tuber areas that were dry.

Table 30: Incidence of tuber rotting on potato ware tubers harvested at 90 and 120 days after emergence (DAE) in season 1 during 12 weeks of dark storage conditions at Tigoni, Limuru and Marimba, Meru

Tigoni, Limuru

Genotype	Storage duration (Weeks)											
	2		4		6		8		10		12	
	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]
385524.9	0.0	1.1	3.3	3.3	5.6	0.0	0.0	0.0	0.0	1.1	0.0	1.1
389746.2	0.0	0.0	1.1	4.4	2.2	0.0	2.2	0.0	0.0	3.3	0.0	0.0
391696.96	0.0	0.0	0.0	2.2	0.0	1.1	1.1	1.1	0.0	1.1	0.0	0.0
392617.54	0.0	2.2	0.0	4.4	0.0	0.0	0.0	0.0	0.0	2.2	2.2	1.1
392637.10	1.1	0.0	5.6	0.0	1.1	0.0	2.3	0.0	0.0	1.1	0.0	0.0
392657.8	10.	0.0	5.6	6.7	4.4	0.0	1.1	0.0	0.0	2.2	0.0	0.0
393280.57	0.0	0.0	0.0	2.2	2.2	0.0	2.2	0.0	2.2	0.0	1.2	0.0
393371.58	0.0	0.0	0.0	1.1	5.6	0.0	1.1	0.0	0.0	3.3	0.0	0.0
393385.39	1.1	0.0	4.4	3.3	5.6	0.0	1.1	0.0	0.0	3.3	0.0	1.1
393385.47	1.1	2.2	3.3	2.2	2.2	0.0	2.2	0.0	0.0	3.3	0.0	1.1
Kerr's Pink	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tigoni	0.0	0.0	0.0	1.1	4.4	0.0	0.0	0.0	0.0	1.1	0.0	0.0
LSD (5%)	3.37 *	2.81	5.92	5.42	6.75	0.94	4.05	0.94	1.88	4.10	1.88	1.88

Marimba, Meru

Genotype	Storage duration (Weeks)											
	2		4		6		8		10		12	
	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]
385524.9	1.1	0.0	0.0	0.0	4.4	3.3	1.1	2.2	1.1	0.0	2.3	2.2
389746.2	0.0	1.1	0.0	2.2	0.0	2.2	0.0	2.2	0.0	0.0	0.0	1.1
391696.96	2.2	1.1	6.7	0.0	7.9	0.0	9.0	4.4	9.0	5.6	5.1	5.6
392617.54	0.0	1.1	0.0	0.0	0.0	1.1	1.1	1.1	2.2	1.1	5.7	6.7
392637.10	3.3	0.0	5.6	0.0	4.4	0.0	12.2	2.2	11.1	1.1	7.2	1.1
392657.8	10.0	0.0	7.8	1.1	4.4	3.3	6.7	2.2	10.0	7.8	5.2	7.8
393280.57	4.4	0.0	3.3	3.3	5.6	1.1	5.6	1.1	8.9	2.2	6.7	3.3
393371.58	1.1	0.0	3.3	0.0	6.7	0.0	8.9	0.0	8.9	0.0	9.6	0.0
393385.39	3.3	0.0	1.1	1.1	2.2	1.1	4.4	2.2	4.4	1.1	1.1	2.2
393385.47	2.2	0.0	7.8	0.0	3.3	0.0	6.7	0.0	6.7	0.0	5.7	0.0
Kerr's Pink	1.1	0.0	2.2	0.0	2.2	0.0	1.1	0.0	0.0	0.0	1.1	0.0
Tigoni	0.0	0.0	1.1	0.0	0.0	0.0	1.1	0.0	2.2	2.2	0.0	3.3
LSD (5%)	5.17 *	1.47	3.98 *	2.12 *	5.00 *	4.16	6.97 *	4.39	6.83 *	5.93 *	6.77	4.50 *

* is significant at 5% level of significance; DAE[a] =Days after emergence (Harvest Date).

Table 31: Incidence of tuber rotting on potato ware tubers harvested at 90 and 120 days after emergence (DAE) in season 2 during 12 weeks of dark storage conditions at Tigoni, Limuru and Marimba, Meru

Tigoni, Limuru

Genotype	Storage duration (Weeks)											
	2		4		6		8		10		12	
	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]
385524.9	0.0	0.0	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
389746.2	1.1	0.0	2.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
391696.96	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.0	1.1	0.0	1.1
392617.54	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
392637.10	0.0	1.1	1.1	1.1	1.1	1.1	0.0	1.1	0.0	4.5	0.0	4.5
392657.8	0.0	0.0	1.1	0.0	0.0	1.1	0.0	0.0	0.0	0.0	0.0	0.0
393280.57	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	0.0
393371.58	0.0	1.1	1.1	0.0	0.0	0.0	0.0	1.1	0.0	1.1	1.1	1.1
393385.39	0.0	0.0	2.2	0.0	2.2	0.0	1.1	0.0	1.1	0.0	2.2	0.0
393385.47	1.1	1.1	4.4	1.1	2.2	1.1	2.2	3.3	2.2	2.2	1.1	2.2
Kerr's Pink	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tigoni	0.0	0.0	2.2	0.0	0.0	0.0	0.0	1.1	2.3	2.3	0.0	0.0
LSD (5%)	1.27	1.63	2.71	1.36	1.53 *	1.63	1.30 *	3.46	1.30 *	3.35	1.82	2.93

Marimba, Meru

Genotype	Storage duration (Weeks)											
	2		4		6		8		10		12	
	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]	90 DAE[a]	120 DAE[a]
385524.9	0.0	0.0	3.3	0.0	0.0	0.0	0.0	0.0	0.0	2.2	0.0	3.3
389746.2	2.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
391696.96	0.0	0.0	0.0	2.3	0.0	0.0	1.1	0.0	0.0	0.0	0.0	0.0
392617.54	2.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
392637.10	1.1	1.1	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
392657.8	0.0	0.0	0.0	0.0	0.0	1.1	0.0	0.0	0.0	0.0	0.0	1.1
393280.57	0.0	0.0	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
393371.58	0.0	0.0	1.1	0.0	0.0	2.3	0.0	0.0	0.0	0.0	0.0	1.1
393385.39	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
393385.47	0.0	0.0	0.0	1.1	0.0	0.0	0.0	1.1	0.0	0.0	0.0	0.0
Kerr's Pink	0.0	0.0	0.0	0.0	2.2	0.0	0.0	0.0	1.1	0.0	1.1	0.0
Tigoni	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LSD (5%)	2.58	0.94	3.26	1.40	1.88	1.31 *	0.94	0.94	0.94	0.94 *	0.94	1.94 *

* is significant at 5% level of significance; DAE[a] =Days after emergence (Harvest Date).

4.5 DISCUSSION

The impression of a food product is given by its appearance (tuber colour, size of the tuber and tuber defects) and determines the visual attractiveness of finished product (Kabira and Lemaga, 2003). Population B3 genotypes have good tuber characteristics. Skin colour has an acceptability attribute is variable among consumers in Kenya with some preferring pink or red skinned varieties while others prefer white skinned varieties (McArthur Crissman, 1989).

Specific gravity of population B3 genotypes except for 393280.57 was above 1.07. This is considered suitable for processing into chips, crisps and cooking quality. Specific gravity that is related to dry matter was equal or slightly increased with delayed harvesting. According to Sabba *et al.*, 2007 physiologically mature tubers have maximum dry matter content resulting in high specific gravities. Burke and O'Donovan, 1998 found that tuber dry matter increased with a delay in desiccation date. Asghar *et al.*, 2003 and Mehta and Kaul, 2003 found that dry matter content increased up to the last stage of harvest (60-90 days after planting). Specific gravity varied from genotype to genotype and partly explains the differences observed among the genotypes. Other than the genotype, tuber maturity, temperature during the growth and cultural factors (irrigation, pests and diseases, fertilization, ridging, weeding, mechanical stresses inflicted on the tubers and handling during storage) has been reported to affect specific gravity (Kumar *et al.*, 2004).

Most of population B3 genotypes could be acceptable for cooking and processing of potatoes into chips and crisps (scores of over 5.0) and the colour scores was generally pale for both chips and crisps except for 393280.57 especially with delayed harvesting indicating the desired low levels of sugars. The level of sugar content present in a tuber at harvest determines the quality of potatoes for processing

(Roe *et al.*, 1990; Sabba *et al.*, 2007). Some of the genotypes (393280.57, 392657.8, 392637.10 and 393385.39) at early harvest were slightly more or less brownish in colour. This could be attributed to the high amounts of sugars that resulted in unacceptably brown colour and bitter taste after frying. The browning occurred as a result of the Maillard reaction (non enzymatic browning) between the sugars and the free amino acids present in the tuber (Schallenberger *et al.*, 1959) and affected the colour and flavours of the genotypes (Kumar *et al.*, 2004) and is also related to acrylamide formation in fried potato products (Mottram *et al.*, 2002). The reducing sugars (fructose and glucose) are responsible for the development of brown colour in fried chips and crisps (Roe and Faulks, 1991) while the bitter tasting is attributed to high contents of acrylamide (Tareke *et al.*, 2002) and such products are not acceptable as they contain potentially toxic compounds.

The storage potential of potatoes is governed by tuber maturity at harvest (Nelson and Shaw, 1976) with different cultivars having different maturity periods (Kumar *et al.*, 2003), the temperature and relative humidity during storage (Sun MaoLin *et al.*, 2004). The average temperature and relative humidity over the storage duration was 17.85±1.46 °C, 18.57±0.79 °C and 90.71%, 91% in season 1 while 16.85±1.57 °C, 16.71±1.25 °C and 90.29±0.49%, 90.14% in season 2 for early and late harvested tubers in Tigoni, Limuru while 19.29±0.76 °C, 18.43±1.27 °C and 91%, 90.71±0.49% in season 1 while 16.57±1.51 °C, 16.00±1.00 °C and 90.29±0.49%, 90.14±0.38% in season 2 for early and late harvested tubers from Marimba, Meru respectively (Appendix 7). These were within the optimum temperature of between 15-18°C and relative humidity 85-90% (FAO, 1998) reported in the highland tropics that allow potatoes to be stored in low cost structures as ware tubers for extended periods of time without serious losses (Hunt, 1985). The

temperature of the storage environment determines the length of storage, the quality and quantity of stored potatoes. It also influences the onset of disease incidence, chemical changes and physiological changes such as sprouting (Burton, 1989) and affects the rate of respiration and the growth rate of the sprouts and the development of rotting organisms and infestation by insects. This explains partly the differences observed among the genotypes.

Tubers from early harvest lost most weight than late harvested tubers suggesting that weight loss is affected by harvest date (Mehta and Kaul, 2003; Sabba *et al.*, 2007). This is because tubers under storage are not static but are living entities, which produces heat through respiration and loses moisture through respiration and evaporation. During the process of respiration, the starch present in the tuber is broken down into sugars with the liberation of carbon dioxide and water. Therefore it is highly likely that early harvested tubers were not well suberized permitting greater levels of respiration to occur (FAO, 1998) and prone to skinning and mechanical injury due to poor skin set and may lead to tubers deteriorating in storage (Sabba *et al.*, 2007). However the losses for most off the genotypes were below 10% of the original fresh weight and were considered acceptable (Ezekiel *et al.*, 2004; KARI, 2001). Ezekiel *et al.*, 2004 comparing the storage behaviour of potato tubers in heap and pit in India found that weight loss varied from 3.1 to 4.8%.

Sprouting or the breaking of dormancy is associated with the increase in reducing sugars (Dimalla & Stadan, 1977; Burton *et al.*, 1992) when the apical eyes open. It seems that late harvested potato tubers were physically mature while early harvested tubers were physiologically mature (Iritani, 1981) hence the lower levels of sprouting as evidenced by the longer duration of time to sprout.

Pests and diseases may cause serious losses and affect the quality of the ware potatoes in storage. Though losses of upto 90% due to potato tuber moth have been reported in Kenya (KARI, 1998), few incidences of potato tuber moth of upto 10% were recorded in the ware potato tubers by the 12 weeks of storage. The damage caused by the potato tuber moth is through tunnelling (CIP, 1988) leaving its excreta on the tunnels and as such the tubers may become exposed to fungal and bacterial infections that may lead to reduced quality of tubers. Rotting incidences were slightly higher in early than late harvested tubers (Mehta and Kaul, 2003; Sabba *et al.*, 2007) and it was slightly higher in tubers from Meru probably due to damage impacted on the tubers while being transported. Further analysis revealed that the fungi *Phytophthora infestans, Fusarium sp.* and soft rots infected the tubers under storage. This was observed on genotypes 393385.47 (*Phytophthora infestans*), 392637.10 and 392657.8 (Soft rot) and 393385.39 (*Fusarium* spp). Thus significant reduction to tuber quality may occur because of tuber injuries caused by pests that can significantly reduce the storage period and the quality of the tubers.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

The thrust of potato breeding is to develop varieties that meet the various needs of the potato industry. Varieties that are weak in certain characteristics have often been accepted due to their possessing certain superior traits compared to those in existing varieties. Resistance to late blight (*Phytophthora infestans*) and high tuber yields are not the only considerations that are looked for but also good table and processing qualities besides superior storability are equally important.

In the present study, population B3 genotypes were found to be resistant to late blight as indicated by the low AUDPC values and performed better and highly from late than early harvest. The AMMI model was successfully used to diagnose the G X E interaction pattern of AUDPC and tuber yields of potato genotypes in population B3. The study showed that the proportion of genotypic variance was larger than that due to the environmental variance and the G X E interaction contributing more to the total variation and the biplot identified some of the population B3 genotypes as stable while others were not stable. Most of the population B3 genotypes were found to be suitable and acceptable for storage, cooking and processing qualities. The quality of population B3 genotypes tended to improve with delay in harvest.

5.1 Future research recommendations

(i) Population B3 genotypes responded by performing differently at the two environments according to their genetic differences, but their physical interaction with the physical factors of the environment were important and the study is of great significance in development of genotypes and useful for future regional multilocational trial sites. The study was done in only two high altitude areas of Kenya and it is recommended that further studies be done on the promising genotypes in the different agro ecologies to determine their late blight resistance, yield and stability in the country.

(ii) Six genotypes (385524.9, 389746.2, 392617.54, 393371.58, 393385.39 and 393385.47) were identified as better yield performers therefore, it is recommended for on farm trials. This can act as a benchmark in adoption of the genotypes to be recommended by the National Potato Research Program that would satisfy farmer's expectations through assessing the performance of the genotypes in comparison with the locally grown varieties.

(iii) The need to initiate breeding work where commercially grown varieties that are weak in certain characteristics but possessing superior traits are crossed with other varieties possessing equally important characteristics and the resultant crosses be evaluated over a wide geographical area before being adopted and accepted in Kenya.

(iv) Farmer education through extension on the relevance and the benefits of using resistant cultivars in management of late blight is recommended.

(v) It is suggested that for evaluation of potato genotypes in potato growing areas of Kenya, proper insect control and ridging should be done adequately to improve potato

tuber quality. This is because infestation by potato tuber moth is time dependent especially with delayed harvesting and may cause yield instability.

(vi) There is a need to look into the extent to which the respiratory gases accumulated in the storage environment and initiated sprouting of the genotypes as this was not determined in the study.

(vii) There is a need to explore the effect of storage period on the processing quality of population B3 genotypes. This would give an insight on which genotypes are suitable and good for processing into crisps and chips.

(viii) The need to determine the nutritive and quality levels (Ascorbic acid content, levels of reducing sugars [glucose and fructose], sucrose content, minerals, amino acids and vitamins content) of population B3 genotypes is further recommended as this was not looked into.

CHAPTER SIX

REFERENCES

Abalo, G., Hakiza, J. J., Kakuhenzire, M. R., El Bedewy, R., and Adipala, E. 2001. Agronomic performance of twelve elite potato genotypes in south western Uganda. African Crop Science Journal 9:17-24.

Abalo, G., Hakiza, J. J., El- Bedewy, R. and Adipala, E. 2003. Genotype x environment interaction studies on yields of selected potato genotypes in Uganda. African Crop Science Journal 11:9-15.

Asghar A., Abdur, R. and Syed, A. H. 2003. Yield and Nutrients profile of potato tubers at various stages of development. Asian Journal of Plant Sciences 2 (2): 247-250.

Black, W. 1970. The nature of inheritance of field resistance to late blight (*Phytophthora infestans*) in potatoes. American Potato Journal 47:279–228.

Bormann, C. A., Rickert, A. M., Castillo Ruiz, R. A., Paal, J., Lübeck, J., Strahwald, J., Buhr, K., Gebhardt, C. 2004. Tagging quantitative trait loci for maturity corrected late blight resistance in tetraploid potato with per-based candidate gene markers. Mol. Plant- Microbe Interact 17:1126-1138.

Bradshaw, J. E., Pande, B., Bryan, G. J., Hackett, C. A., Mclean, K., Stewart, H. E., Waugh, R. 2004. Interval mapping of quantitative trait loci for resistance to late blight (*Phytophthora infestans* [Mont] de Bary), height and maturity in a tetraploid population of potato (*Solanum tuberosum* subspecies *tuberosum*). Genetics 168: 983-995.

Burke, J. J. and O'Donovan, T. 1998. Effect of Seed-Treatment and Time of Harvesting on the Yield and Quality of Potatoes for Processing. Crops Research Centre, Oak Park, Carlow.

Burton, W. G. 1989. Factors limiting potato yields in Tropical areas and the technology available for raising yields. In Hooker, W.J (Ed) optimizing potato productivity in developing countries, report of planning conference, 1978. Up, Lima, Peru pp. 45- 67.

Burton, W. G., Es, A. van., Hartmans, K. J. 1992. The physics and physiology of storage. In The Potato Crop, p. 690. Ed. P Harris. London: Chapman & Hall.

Campbell, C. L. and Madden, L. V. 1990. Introduction to Plant Disease Epidemiology. John Wiley and Sons, New York. 532 pp.

CIP, 1988. Annual Report 1988. CIP, Lima, Peru.

CIP, 1997. CIP in 1996. The International Potato Center. Annual Report. International Potato Center, Lima, Peru. Pp59.

CIP, 1996. The International Potato Center Annual report, Lima, Peru Pp 8

CIP, 1998. Annual Report for year 1997. International Potato Center (CIP) Lima, Peru. 51pp.

CIP, 2002. Fuelling growth, health and prosperity. International Potato Center. Annual Report.

CIP, 2004. International Potato Center, Annual report, Lima, Peru. Pp 22-29.

Collins, A., Milbourne, D., Ramsay, L., Meyer, R., Chatot-Balandras, C., Oberhagemann, P., De Jong, W., Gebhardt, C., Bonnel, E., Waugh, R. 1999. Quantitative trait loci for field resistance to late blight in potato are strongly correlated with maturity and vigour. Mol. Breed 5:387-398.

Colon, L. T.; Turkensteen, L. J.; Prummel, W.; Budding, D. J. and Hoogendoorn, J. 1995. Durable resistance to late blight (*Phytophthora infestans*) in old potato cultivars. European Journal of Plant Pathology 101: 387–397.

Cooper, M., Delacy, I. H. and Basford, K. E. 1996. Relationships among analytical methods used to analyse genotype adaptation in multi-environment trials. In: Plant adaptation and crop improvement. Cooper, M. and Hammer, G. L. (Eds.), pp. 193-224. CAB International Wallingford, U.K.

Crosier, W. 1933. Studies in the biology of *Phytophthora infestans* (Mont.) De Bary. Cornell University Agricultural Experiment Station Memoir 155:1- 40pp.

Crossa, J., Fox, P. N., Pfeiffer, W. H., Rajaram, S. and Gauch, H. G. 1991. AMMI adjustment for statistical analysis of an international wheat yield trial. Theoretical and Applied Genetics 81: 27-37.

Davidse, L. C., Looijen, D., Turkesteen, L. J. and Van Der Wal, D. 1981. Occurrence of metalaxyl-resistant strains of *Phytophthora infestans* in Dutch potato fields. Netherlands Journal of Plant Pathology 87:65-68.

DeBuchananne, D. A. and Lawson, V. F. 1991. Effect of plant population and harvest timing on yield and chipping quality of Atlantic and Norchip potatoes at two Iowa locations. American Potato Journal of Potato Research. Vol. 68, No 5, pp 287-297.

Devaux, A. and Haverkort, A. J. 1987. The effects of shifting planting dates and mulching on late blight (*P. infestans*) and drought stress of potato crops grown under tropical highlands conditions. Expl. Agric. 23:325-333.

Dimalla, G. C., Stadan, J. 1977. Apical dominance and utilization of carbohydrates during storage of potato tubers. Annals of Botany 41:387-391.

Dixon, A. G. O., Asiedu, R. and Hahn, S. K. 1991. Genotypic stability: Analytical methods and implications for cassava breeding for low input agriculture. In: Tropical Root Crops 20-26 October, 1991, Accra, Ghana.

Dowley, L. J. and O'Sollivan, E. 1981. Metalaxyl resistant strains of *Phytophthora infestans* (Mont.) de Bary in Ireland. Potato Research 24:417-421.

Drenth. A., Janssen, E. M. and Govers, F. 1995. Formation and survival of oospores of *Phytophthora infestans* under natural conditions. Plant Pathology 44: 86-94.

Ebwongu, M., Adipala, E., Ssekabembe, C. K., Kyamanywa, S. and Bhagsari, A. S. 2001. Effect of intercropping maize and *Solanum* potato on the yield component crops in central Uganda. African Crop Science Journal 9:83-96.

El Bedewy, R., Olanya, O. M., Ewell, P. T., Lunga'ho, C., Ojiambo, P. S. and Karinga, J. 2001. Evaluation of potato germplasm (Populations A & B) for resistance to late blight in Kenya. African Crop Science Journal 9:215-223.

Eltawil, M., Samuel, D. and Singhal, O. 2006. Potato Storage Technology and Store Design Aspects. Agricultural Engineering International: the CIGR Ejournal. Invited Overview No. 11. Vol. VIII. April, 2006.

Erwin, D. C. and Ribeiro, O. K. 1996. Phytophthora Diseases Worldwide. APS Press, St. Paul, Minnesota, 562 pages.

Ezekiel, R. and Dahiya, P. S. 2004. Storage behaviour and processing quality of potatoes stored in heaps and pits in the Malwa Region (MP). Potato Journal 31:21-28.

FAO, 1998. Storage of roots and tubers in the tropics. Food and Agriculture Organization of the United Nations. Agro-industries and Post-Harvest Management Service. Agricultural Support Systems Division.

FAO, 2008. International year of the potato.

Flier, W. G., van den Bosch, G. B. M., and Turkensteen, L. J. 2003. Stability of partial resistance in potato cultivars exposed to aggressive strains of Phytophthora infestans. Plant Pathology 3:326-337.

Forbes, G. A., Chacón, M. G., Kirk, H. G., Huarte, M. A., Van Damme, M., Distel, S., Mackay, G. R., Stewart, H. E., Lowe, R., Duncan, J. M., Mayton, H. S., Fry, W. E., Andrivon, D., Ellissèche, D., Pellé, R., Platt, H. W., MacKenzie, G., Tarn, T. R., Colon, L. T., Budding, D. J., Lozoya-Saldaña, H., Hernandez-Vilchis, Hernandez-Vilchis and Capezio, S. 2005. Stability of resistance to *Phytophthora infestans* in potato: an international evaluation. Plant Pathology 54: 364–372.

Forbes, G. A. Hijmans, R. J. Nelson, R. J. 1998. Potato blight: a world problem. Abstracts of the 7th International Congress of Plant Pathology, 9-16 August, 1998. Edinburgh, UK: British Society for Plant Pathology. http://www.bspp.org.uk/icpp.98/abstracts/5.1/9S.html

Forbes, G. A. and Jarvis, M. C. 1994. Host resistance for management of potato late blight. In: Zehnder, G., Jansson, R. and Raman, K. V. (Eds.). Advances in potato pest biology and management. American Phytopathological Society, St. Paul, MN USA. p. 439-457.

Fox, P. N., Crossa, J. and Romagosa, I. 1997. Multi-environment testing and genotype x environment interaction. In: SStatistical methods for plant variety evaluation. Kempton, R. A. & Fox, P. N. (Eds.), pp. 117-138. Chapman and Hall, London.

Fry, W. E. 1978. Quantification of general resistance of potato cultivars and fungicide effects for integrated control of potato late blight. *Phytopathology* 68, 1650–5.

Fry, W. E. and Goodwin, S. B. 1997. Re-emergence of potato and tomato late blight in the United States. Plant Disease 81:1349-1357.

Fry, W. E., Goodwin, S. B., Dyer, A. T., Matuszak, J. M., Drent, A., Tooley. P. W., Sujiwoski, L. S., Koh, Y. J., Cohen, B. A., Spielman, L. J., Deahl, K. L., Inglis, D. A., and Sandlan, K. P. 1993. Historical and recent migrations of *Phytophthora infestans:* Chronology, pathways and implications. Plant Disease 77, 653-661.

Fry, W. E., Thurston, H. D., Stevenson, W. R. 2001. Late Blight. In: Stevenson, W.R., Loria, R., Franc, G.D., Weingartner, D.P. (eds). Compendium of potato diseases, 2nd edition. American Phytopathological Society, St. Paul, p 28-30.

Garrett, K. A. and Dendy, S. P. 2001. Cultural practices in potato late blight management. In: Fernandez-North, N. (Ed.), Complementing resistance to late blight (*Phytophthora infestans*) in the Andes. Proceedings of GILB Latin American Workshop I, 13-16 February 2001, Cochabamba, Bolivia, 107-113.

Gauch, H.G. and Zobel, R.W. 1988. Predictive and postdictive success of statistical analyses of yield trials. Theoretical and Applied Genetics 76:1–10.

Gauch, H. G. 1992. Statistical analysis of regional yield trials: AMMI analysis of factorial designs. Elsevier, Amsterdam, the Netherlands.

Genstat, 2006. Genstat Statistical Software Release 9.1. Lawes Agricultural Trust, Rothamsted Experimental Station.

Getinet, G. 1988. Grain yield stability of bread wheat cultivars in the highlands of Ethiopia. In: Fifth Regional Wheat Workshop for Eastern, Central, and Southern Africa and the Indian Ocean. Van Ginkel, M. and Tanner, D.G. (Eds.), pp. 61-65. CIMMYT, Mexico D.F.

Grunwald, N. J., Rubio-Covarrubias, O. A. and Fry, W. E. 2000. Potato late blight in the Toluca Valley: Forecasts and resistant cultivars. Plant Disease 84:410-416.

Guyton, B., Sogo, F., Mogire, J. and Njuguna, R. 1994. Kenya's Irish potato sub sector characteristics, performance and participants information needs. Market information system report. Pp 94-101 CIP, Nairobi Kenya.

Hardy, B., Trognitz, B., Forbes, G. 1995. Late blight breeding at CIP. CIP Circular 21:2-5.

Harris, P. 1992. The Potato Crop. The Scientific Basis for improvement. 2nd Edition. Chapman and Hall, London. Pp 909.

Harrison, J. G. 1992. Effects of the aerial environment on late blight of potato foliage - A review. Plant Pathology 41:384–416.

Haynes, K. G., Christ, B. J., Weingartner, D. P., Douches, D. S., Thill, C. A., Secor, G., Fry, W. E., Lambert, D. H. 2002. Foliar resistance to late blight in potato clones evaluated in national trials in 1997. American Journal of Potato Research 79, 451–457.

Haynes, K. G., Lambert, D. H., Christ, B. J., Weingartner, D. P., Douches, D. S., Backlund, J., Secor, G., Fry, W. and Stevenson, W. 1998. Phenotypic stability of resistance to late blight evaluated at eight sites in the United States. American Journal Potato Research 75: 211-217.

Henfling, J. W. 1987. Late blight of potato, *Phytophthora infestans*. Technical Information Bulletin 4. CIP, Lima, Peru. 25pp.

Hijmans, R. J., Forbes, G. A., and Walker, T. S. 2000. Estimating the global severity of potato late blight with a GIS-linked disease forecaster. Plant Pathol. 49:697-705.

Hope, G. W., MacKay, D. C., and Townsend, L. R. 1960. The effect of harvest date and rate of nitrogen fertilization on the maturity, yield and chipping quality of potatoes. American Potato Journal of Potato Research. Vol. 37, No 1, pp 28-33.

Horton, D. 1987. Potato Production, Marketing and Programs for Developing Countries, Westview Press, London. pp 47.

Hunt, G.L.T. 1985. Low cost potato storage for the tropics. Acta Horticulture (ISHS) 158:401-408 (http://www.actahort.org/books/158/158_46.htm).

Inglis, D. A., Johnson, D. A., Legard, D. E., Fry, W. E. and Hamm, P. B. 1996. Relative resistance of potato clones in response to new populations of *Phytophthora infestans*. Plant Disease, 80, 575-578.

Iritani, W. M. 1981. Growth and pre-harvest stress and processing quality of potatoes. American Potato Journal 58:71-80.

Jaetzold, R. and Schmidt, H. 1983. Farm Management Handbook of Kenya. Vol. II. Ministry of Agriculture, Nairobi, Kenya.

James, W. C.; Shih, C. S.; Hodgson, W. A. and Callbeck, L. C. 1972. The quantitative relationship between late blight of potato and loss in tuber yield. Phytopathology, 62:92-96.

Jewell, S. and Stanley, R. 1989. The influence of defoliation date and harvest interval on the quality of potatoes for french fry production. Potato Research. Vol. 32, No 4, pp 431-438.

Kabira, J. N. and Lemaga, B. 2003. Potato processing. Quality evaluation procedures for research and food industry applications in East and Central Africa. Pp.1-20.

Kabira, J. N. 2000. French fries and crisps processing characteristics of selected potato varieties in Kenya. African Crop Science Conference proceedings 5: 507-511.

Kabira, J. N. 2001. National Potato Research Centre, Tigoni- Information Bulletin.

Kamoun, S., and Smart, C. D. 2005. Late Blight of Potato and Tomato in the Genomic Era. Plant Disease 89:692-699.

Kang, M. S., Magari, R. 1996. New development in selection for phenotypic stability in crop breeding. In: Kang, MS; Gauch, H.G. (Eds). Genotype by environment interaction. Boca Raton: CRC, p.1-14.

Kankwatsa, P., Adipala, E., Hakiza, J. J., Olanya, M. and Kidanemariam, H. M. 2002. Effect of integrating planting time, fungicide application and host resistance on potato late blight development in south western Uganda. Journal of Phytopathology 150:248-257.

KARI, 1998. Annual Report.

KARI, 2001. Annual Report

Kinyae, P .M., Lung'aho, P. M., Kanguha, E. and Njenga, D. N. 1994. The status of seed potatoes in Meru, Nyandarua and Laikipia districts of Kenya. In: proceedings of the second KARI/CIP technical workshop held in Nairobi January 1994, pp5-9.

Kirk, W. W., Douches, D., Brendan, A. and Niemira, S. J. M. 1999. Combining varietal resistance with managed fungicide applications for the control of potato late blight. Pg 122. In: Late Blight: A threat to Global Food Security. Proceedings of the GILB Conference March 16-19 1999, Quito, Ecuador.

Kulkarni, R. N., and Chopra, V. L. 1982. Environment as the cause of differential interaction between host cultivars and pathogenic races. Phytopathology 72:1384-1386.

Kumar, D., Singh, S. V., Pandey, S. K. 2003. Chemical maturity in potato processing cultivars grown in western Uttar Pradesh. Journal of the Indian Potato Association 30:225-232.

Kumar, D., Singh, B. P. and Kumar, P. 2004. An overview of the factors affecting sugar content of potatoes. Annals of Applied Biology 145 (3), 247-256.

Landeo, J. A., Gastelo, M., Beltran, G. And Diaz, G. 2001. Quantifying genetic variance to horizontal resistance to late blight in potato breeding population B3C1. CIP Program Report 1999-2000. pp. 63-68.

Landeo, J. A., Gastelo, M., Forbes, G., Zapata, J. L. and Flores, F. L. 1997. Developing horizontal resistance to late blight in potato. pp 122–126 in: International Potato Center Program Report 1995–96. Lima, Peru.

Landeo, J. A. and Turkensteen, L. 1989. Assessment of partial resistance to late blight (*Phytophthora infestans*) of major genes in potato. American Potato Journal 66:530

Landeo, J. A., Gastelo, M., Roncal, E. and Mendoza, A. 2000. Phenotypic stability for horizontal resistance to potato late blight in population B. American Journal of Potato Research 77:406.

Landeo, J. A., Gastelo, M., Forbes, G. Zapata J. L. and Flores, F. J. 1996. Developing Horizontal Resistance to Late Blight in Potato. Program report 95-96. CIP (International Potato Center).

Landeo, J. A., Gastelo, M., Pinedo, H. And Flores, F. 1995. Breeding for horizontal resistance to late blight in potato free of R genes. pp 268-274 in: Dowley, L. J., Bannon, E., Cooke, L. R., Keane, T. and O'Sullivan, E. (eds), *Phytophthora infestans* 150, Proceedings of the European Association for Potato Research (EAPR)-Pathology Section Conference. Dublin, Ireland.

Landeo, J. A. 2002. Breeding for host resistance. Durable resistance: Quantitative/Qualitative resistance. In: Late Blight: Managing the global threat.

Proceedings of the Global Initiative on Late Blight Conference Hamburg, Germany March, 11-13.

Landeo, J. A. 2004. Data collection protocol in the Regional Evaluation Trials for potato variety selection in advanced late blight resistant clones. CIP/Nairobi.

Low, W. J. 1997. Sustainability of potato cropping systems in the densely populated highlands of southwest Uganda. In: Proceedings of the 4th Triennial Congress of the African Potato Association, 23–28 February (1997), Pretoria, South Africa, pp. 1–11, Agricultural Research Council, Pretoria.

Lung'aho C.L., Nganga, N. and Kidanemariam H.M. 1997. Evaluation of improved potato genetic stocks for resistance to late blight in Kenya. In: Proceedings of the 4th African Potato Association meeting, Pretoria, South Africa, 23 - 28 February, 1997. pp. 73-75.

Lung'aho, C. Ojiambo, P. S. and Kidanemariam, H. M. 1998. Yield stability analysis of promising potato clones in mid and high altitude regions of Kenya African Crop Science Journal 6:137-142.

Lung'aho, C., Nderitu, S. N., Kabira, J. N., Walingo, A., Olanya, O. M. 2005. Yield Performance and Release of Four Late Blight Tolerant Potato Varieties in Kenya. Journal of Agronomy and Crop Science. 5 (1): 57-61.

McArthur Crissman, L. 1989. Evaluation, choice and use of potato varieties in Kenya. Social Science Department Working paper 1989-1. International Potato Centre (CIP) Lima, Peru, pp35.

Maingi, D. M., Ng'anga, N. and Kidanemariam, H. M. 1991. Collection and evaluation of farmer's informally released varieties in Kenya. In: KARI/CIP Technical Workshop Collaborative Research. Nairobi, Kenya. pp. 13-18.

Mehta, A. and Kaul, H. N. 2003. Physiological losses and processing quality of potatoes under ambient temperature storage as influenced by tuber maturity. Advances in Horticultural Science 17:196-203.

Ministry of Agriculture (MOA), 2005. National Irish Potato Policy, March 2005.

Mottram, D. S., Wedzicha, B. L., Dodson, A. T. 2002. Acrylamide is formed in the Maillard reaction. Nature 419:448-449.

Mulema, J. M. K., Olanya, O. M., Adipala, E. and Wagoire, W. 2004. Stability of late blight resistance in population B potato clones. Potato Research 47: 11-24.

Mulema, J. M., Adipala, E., Olanya, O. M., Hakiza, J. J. 2008. Yield Stability analysis of Late Blight Resistant Potato Selections. Experimental Agriculture 44: 145-155.

Mundt, C. C., Cowger, C. and Garrett, K. A. 2002. Relevance of integrated disease management to resistance durability. Euphytica 124:245-252.

Muskens, M. W. M., Allefs, J. J. H. M. 2002. Breeding for late blight resistance; views from practice. In: Wenzel, G., Wulfert, I (eds) potatoes today and tomorrow. Abstracts of papers and posters of the 15th triennial conference of the EAPR. European Association for Potato Research, Bonn, pp. 85.

Nakitandwe, J., Adipala, E., El-Bedewy, R., Wagoire, W. and Berga Lemaga. 2005. Adaptability of Standard International Field Trials (SIFT) potato genotypes in different agro-ecologies of Uganda. African Crop Science Journal 13:107-116.

Nelson, D. C., Shaw, R. 1976. Effect of planting and harvest dates, location in hill and tuber size on sugar content of Kennebec potatoes. American Potato Journal 53:15-21.

Ngeve, J. M. 1993. Regression analysis of genotype x environments in sweetpotato. Euphytica 71:231-238.

Niederhauser, J. S. 1991. *Phytophthora infestans*: The Mexican connection. Pages 25-45 In: *Phytophthora*. J. A. Lucas, R. C. Shattock, D. S. Shaw, and L. R. Cooke, eds. Cambridge University Press, Cambridge.

Ntawuruhunga, P. H., Rubaihayo, P., Whyte, J. B. A., Dixon, A. G. O., and Osiru, D. S. O. 2001. Additive main effects and multiplicative interaction analysis of storage root yield of cassava genotypes evaluated in Uganda. African Crop Science Journal 9:591-598.

Nyankanga, R. O., Wien, H. C., Olanya, O. M. and Ojiambo, P. S. 2004. Farmer's cultural practices and management of potato late blight in Kenya highlands: Implications for development of Integrated Disease Management. International Journal of Pest Management 50 (2): 135- 144.

Olanya, O. M., Reeves, A. F., and Lambert, D. H. 1999. Evaluation of potato breeding lines and varieties for resistance to late blight in Maine. In: Proceedings of Global Initiative on Late Blight (GILB) meeting, March, 16-19, Quito, Ecuador.

Olanya, O. M.; Adipala, E.; Hakiza, J. J.; Ojiambo, P.; Mukalazi, J. M.; Forbes, G. and Nelson, R. 2001a. Epidemiology and population dynamics of Phytophthora Infestants in Sub-Saharan Africa: Progress and constraints. African Crop Science Journal 9:185-193.

Olanya, O. M.; El Bedewy. R. Ojiambo, P. S.; Ewell, P. T. and Hakiza, J. J. 2001b. Relationships of fungicide application to late blight development and potato growth parameters in the tropical highlands of Uganda and Kenya. In: Scientist and farmer. Partners in research for the 21st century. International Potato Center (CIP). Program Report 1999-2000. CIP, Lima, Peru. pg 76-86.

Olanya, O. M., Ojiambo, P. S. and Nyankanga, R. O. 2006. Dynamics of development of late blight (*Phytophthora infestans*) in potato, and comparative

resistance of cultivars in the highlands tropics. Canadian Journal of Plant Pathology 28: 1-11.

Pandey S. K.; Singh S. V.and Manivel, P. 2005. Yield structure, agronomic performance and stability of new potato (Solanum tuberosum) hybrids in western Uttar Pradesh. Indian Journal of Agricultural Science 75 (7):417-421.

Pohjakallio, O., Salonen, A., Antila, S. 1957. Analysis of earliness in the potato. Acta Agric Scand 7:361-388.

Roe, M. A., Faulks, R. M., Belsten, J. L. 1990. Role of reducing sugars and amino acids in fry colour of chips from potatoes grown under different nitrogen regimes. Journal of the Science of Food and Agriculture 52:207-214.

Roe, M. A. and Faulks, R. M. 1991. Colour development in a model system during frying: Role of individual amino acids and sugars. Journal of Food Science 56:1711-1713.

Ross H, 1986. Potato Breeding-Problems and Perspectives. Advances in Plant Breeding 13. Berlin and Hamburg, Germany: Paul Parey.

Sabba, R. P., Bussan, A. J., Michaelis, B. A., Hughes, R., Drilias, M. J., Glynn, M. T. 2007. Effect of Planting and Vine-kill Timing on Sugarss, Specific Gravity and Skin Set Processing Potato Cultivars. American Journal of Potato Research. 84(3):205-215.

Schallenberger, R. S., Smith, O., Treadway, R. H. 1959. Role of the sugars in the browning reaction in potato chips. Journal of Agricultural and Food Chemistry 7:274-277.

Schuster, E. and Schroeder, D. 1990. Side effects of sequentially and simultaneously applied pesticides on non-target soil microorganisms in laboratory experiments. Soil Biology and Biochemistry 22:375-384.

Scott, G. J. 1990. "Potatoes in the food systems of Sub Saharan Africa: Present patterns and future prospects. Paper presented at the second Triennial Conference of the African Potato Association, Mauritius.

Shafii, B. and Price, W. J. 1998. Analysis of genotype-by-environment interaction using the additive main effects and multiplicative interaction model and stability estimates. J Agric Biol Environ Stat 3:335–345.

Shaner, G., Finney, R. E. 1977. The effect of nitrogen fertilization on the expression of slow-mildewing resistance in Knox wheat. Phytopathology 67, 1051–1056.

Simko, I. 2002. Comparative analysis of quantitative trait loci for foliage resistance to *Phytophthora infestans* in tuber-bearing Solanum species. Am J Potato Res. 79: 125-132.

Stevenson, F. J., Akeley, R.V., Cunningham, C. F. 1964. The potato- its genetic and environmental variability. American Potato Journal 41: 46-53.

Sun MaoLin, Li XianPing, Chujoy, E., Li ShuLian. 2004. A study on the storing conditions and inhibiting sprout of ware potato. Southwest China Journal of Agricultural Sciences17:361-364.

Swiezynski, K. M. 1990. Resistance to *Phytophthora infestans* in potato cultivars and its relation to maturity. Genet Pol 31:99-106.

Tareke, E., Rydberg, P., Karlsson, P., Ericksson, S., Tornqvist, M. 2002. Analyses of acrylamide, a carcinogen formed in heated foodstuffs. Journal of Agricultural and Food Chemistry 50:4998-5006.

Thurston, H. D. 1971. Relationship of general resistance: Late blight of potato. Phytopathology 61:620-626.

Toxopeus, H. J. 1958. Some notes on the relations between field resistance to *Phytophthora infestans* in leaves and tubers and ripening time in *Solanum tuberosum* ssp *tuberosum*. Euphytica 7:123-130.

Turkensteen, L. J. 1989. Interaction of R-genes in breeding for resistance of potatoes against *Phytophthora infestans*. In: Fungal diseases of the potato. International Potato Centre, Lima, p. 85-96.

Turkensteen, L. J. 1993. Durable resistance of potatoes against *Phytophthora infestans*. In: Jacobs, T.H. and Parlevliet, J.E. (Eds) Durability of Disease Resistance (pp 115–124) Kluwer Academic Publishers, Dordrecht NL 525.

Turkensteen, L. and Zimnoch-Gucowska, E. 2002. Studies of the pathogen/breeding for host resistance wrap up. In: Late Blight: Managing the global threat. Proceedings of the Global Initiative on Late Blight Conference Hamburg, Germany March, 11-13.

Umaerus, V. and Umaerus, M. 1994. Inheritance of resistance to late blight. In: Bradshaw JE and Mackay GR (Eds) Potato Genetics (pp 365–401) CAB International, Wallingford UK.

Umaerus, V., Umaerus, M., Erjefalt, L. and Nilsson, B. A. 1983. Control of *Phytophthora infestans* by host resistance: problems and progress. Pp 315-326 in: Erwin D C, Bartnicki-Garcia S and Tsao P H (eds), *Phytophthora*, its biology, taxonomy, ecology and pathology. The American Phytopathological Society, St. Paul, MN, USA.

Van Oijen, M. 1991. Light use efficiencies of potato cultivars with late blight (*P. infestans*).Potato Research 34:123-132.

Visker, M. H. P. W. 2005. Association between late blight resistance and foliage maturity type in potato- Physiological and genetic studies. Ph.D. thesis Wageningen University, Wageningen, the Netherlands. Pp.

Visker, M. H. P. W., Heilersig, H. J. B., Kodde, L. P., Van de Weg, W. E., Voorrips, R. E., Struik, P. C., and Colon, L T. 2005. Genetic linkage of QTLs for late blight resistance and foliage maturity type in six related potato progenies. Euphytica 143: 189-199.

Visker, M. H. P. W., Van Raaij, H. M. G., Keizer, L. C. P., Struik, P. C., Colon, L. T. 2004. Correlation between late blight resistance and foliage maturity type in potato. Euphytica 137: 311-323.

Wastie, R. L. 1991. Breeding for resistance In: Ingram DS and Williams DS (eds) *Phytophthora infestans*, the cause of late blight of potato. Advances in Plant Pathology, vol. 7 (pp 193–224) Academic Press Ltd, London.

Wulff, E. G., Perez, W., Nelson, N. J., Bonierbale, M., Landeo, J. A. and Forbes, G. A. 2007. Identification of stable resistance to Phytophthora infestans in potato genotypes evaluated in field experiments in Peru. Expl Agric Vol. 43 p 353-363.

Zobel, R.W. et al., 1988. Statistical analysis of a yield trial. Agronomy Journal, Madison 80:388-393.

APPENDIXES

Appendix 1: AMMI analysis of AUDPC of 12 potato genotypes harvested at 90 DAE grown in two locations during 2005 - 2007 cropping seasons.

Source	df	SS	MS	F value	P < F	Explained
Total	143	72954172	510169	*	*	
Treatments	47	68710489	1461925	41.01	0.0000	
Genotypes	11	55127112	5011556	140.59	0.0000	80.23
Environments	3	3416155	1138718	8.23	0.0000	4.97
Interactions	33	10167222	308098	8.64	0.0000	14.80
IPCA 1	13	7633222	587171	16.47	0.0000	
IPCA 2	11	2139079	194462	5.46	0.0000	
Error	88	3136804	35645	*	*	

Appendix 2: AMMI analysis of AUDPC of 12 potato genotypes harvested at 120 DAE grown in two locations during 2005 - 2007 cropping seasons.

Source	df	SS	MS	F value	P < F	Explained
Total	143	69138267	483484	*	*	
Treatments	47	66094858	1406274	49.91	0.0000	
Genotypes	11	54408615	4946238	175.55	0.0000	82.32
Environments	3	3011675	1003892	14.24	0.0000	4.56
Interactions	33	8674568	262866	9.33	0.0000	13.12
IPCA 1	13	5996856	461297	16.37	0.0000	
IPCA 2	11	2175939	197813	7.02	0.0000	
Error	88	2479525	28176	*	*	

Appendix 3: AMMI analysis of tuber yields of 12 potato genotypes harvested at 90 DAE grown in two locations during 2005 - 2007 cropping seasons.

Source	df	SS	MS	F value	P < F	Explained
Total	143	9742	68.1	*	*	
Treatments	47	9276	197.4	42.43	0.0000	
Genotypes	11	3987	362.4	77.91	0.0000	42.98
Environments	3	3669	1223.2	173.95	0.0000	39.55
Interactions	33	1620	49.1	10.55	0.0000	17.46
IPCA 1	13	872	67.1	14.42	0.0000	
IPCA 2	11	635	57.7	12.41	0.0000	
Error	88	409	4.7	*	*	

Appendix 4: AMMI analysis of tuber yields of 12 potato genotypes harvested at 120 DAE grown in two locations during 2005 - 2007 cropping seasons.

Source	df	SS	MS	F value	P < F	Explained
Total	143	10020	70.1	*	*	
Treatments	47	9604	204.3	45.85	0.0000	
Genotypes	11	5126	466.0	104.57	0.0000	53.37
Environments	3	2857	952.5	310.07	0.0000	29.75
Interactions	33	1620	49.1	11.02	0.0000	16.87
IPCA 1	13	873	67.2	15.08	0.0000	
IPCA 2	11	440	40.0	8.98	0.0000	
Error	88	392	4.5	*	*	

Appendix 5: Weather data for Tigoni, Limuru and Marimba, Meru during 2005 - 2007 cropping seasons.

Season	Location	Total rainfall (mm)	Average Relative Humidity (%)	Average Temperature (°C)
1 (April-September 2006)	Tigoni, Limuru	935.6	79.18	14.45
2 (October 2006-February 2007)	Tigoni, Limuru	1059.4	88.73	16.21
1 (October 2005- March 2006)	Marimba, Meru	860.7	89.16	14.63
2 (October 2006- March 2007)	Marimba, Meru	1013.9	88.74	14.01

Appendix 6: Sensory evaluation score card.

Please evaluate the samples for colour, texture, flavour and overall acceptability. Do not base your scores on a personal like or dislike for the product in general. Please do not communicate with anyone while scoring. Use numerical scores under the sample number in the scoring chart below.

Acceptability	Quality description	Score
Unacceptable	Extremely poor	1
	Very poor	2
Barely acceptable	Poor	3
	Below fair/above poor	4
	Fair	5
Acceptable	Below good/above fair	6
	Good	7
	Very good	8
Highly acceptable	Extremely good	9

Sensory quality description

	Sample code											
Quality aspect	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Colour (appearance)												
Texture												
Flavour												
Overall acceptability												

Name Date Signature

Appendix 7: Average temperature and relative humidity of dark storage for potato tubers harvested from Tigoni, Limuru and Marimba, Meru during 2005 - 2007 cropping seasons.

Season	Location	Average Temperature (°C)		Average Relative Humidity (%)	
		90 DAE	120 DAE	90 DAE	120 DAE
1	Tigoni, Limuru	17.85±1.46	18.57±0.79	90.71±0.49	91
2	Tigoni, Limuru	16.85±1.57	16.71±1.25	90.29±0.49	90.14±0.38
1	Marimba, Meru	19.29±0.76	18.43±1.27	91	90.71±0.49
2	Marimba, Meru	16.57±1.51	16±1	90.29±0.49	90.14±0.38