DISSERTATION

FACTORS INFLUENCING CONSUMER POTATO STORABILITY IN THE WARM TROPICS

Submitted by

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WE HEREBY RECOMMEND THAT THE DISSERTATION PREPARED UNDER OUR SUPERVISION BY ALBERTO L.TUPAC YUPANQUI ENTITLED FACTORS INFLUENCING CONSUMER POTATO STORABILITY IN THE WARM TROPICS BE ACCEPTED AS FULFILLING IN PART REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY.

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ABSTRACT OF DISSERTATION

FACTORS INFLUENCING CONSUMER POTATO STORABILITY IN THE WARM TROPICS

This study was done to determine the feasibility of and explore ways to store consumer potatoes in the warm tropics and reduce storage losses to acceptable levels.

The research was done during 2 years, 1988 and 1989,at the mid-elevation jungle research station of the International Potato Center located at San Ramon (800 m elevation), Peru.

Pathogen induced rotting is the major cause of loss during storage in the warm tropics. Studies were done to evaluate the storage potential of clones adapted to the warm tropics and determine if any significant relationship existed between storage potential and rotting response to Erwinia and Fusarium spp. when inoculated separately and simultaneously. Finding a suitable relationship would simplify screening in breeding programs to identify progeny with good storage potential. Some of the more suitable clones that were identified for storage in the warm tropics were Desiree,Kufri Jyoti,Serrana,LT-5 and B71 240.2. A significant relationship between storage potential and rotting induced by inoculation was only obtained when the Erwinia and Fusarium spp. were inoculated simultaneously.

Since rapid wound healing is essential to reduce pathogen invasion and rotting, the rapidity of wound healing was evaluated. Thirteen of 15 test clones showed over a 90% reduction in F.solani induced dry rot after only 6 days at 25 C. Thus,this evaluation is probably not sufficiently sensitive to differentiate clones in their storage potential.

Delaying harvest for 8 days after vine senescence to allow skin setting was slightly beneficial during the dry season but was detrimental during the wet season. A hazard of delaying harvest is the possibility of increased potato tuber moth (PTM) infestation.

Removing visibly diseased,insect infested and damaged tubers before storage was very effective in reducing storage losses due to rotting and PTM infestation.

Dipping potatoes in solutions of sodium hypochlorite and thiabendazole was very detrimental. However,dusting with thiabendazole just after harvest and dusting with chloro-isopropyl-phenyl-carbamate (CIPC) after 4 weeks was beneficial. CIPC did not reduced sprouting but completely controlled PTM infestation.

This research has shown that it is possible to store potatoes in the warm tropics using the proper clones and procedures.

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To my wife,Viviana

and my sons,Alberto and Luis

To my parents,Luis and Daria

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1. GENERAL INTRODUCTION

1.1 INTRODUCTION

On a world basis one of mankind's most valuable foods is the potato,with an annual production of about 258 million tons (Horton et al, 1984). As a major food crop in the Third World, potato ranks fourth behind rice, wheat and maize in cash value, although it is second only to cassava among root and tuber crops in terms of crop area and quantities produced (Horton et al,1984).

The potato has been traditionally considered as a temperate climate crop, but increasing consumption trends in developing warm countries suggest a wide geographical acceptability. Even if production costs are reduced and potato production expands, limited storage capacity, together with high post-harvest losses and high storage costs still limit year around availability and consumption (Horton and Sawyer,1985).

Observation trials in the warm tropics from 1980-1983 at San Ramon, Peru (800 m elevation) showed average total yields of 20 MT/Ha in the rainy season with cultivars Desiree and Rosita (adapted to the warm tropics) and Revolucion (non-adapted cultivar). Mean losses in storage were 25%,35% and 59% after 1, 3 and 5 months storage,respectively. Factors affecting storability were sprouting, mechanical damage, poor periderm development,lack of curing and disease incidence. In the dry

season total yields were 12 to 15 MT/Ha. Irrigation was inadequate and there was a higher proportion of secondary growth and potato tuber moth (PTM) infestation than in the wet season. PTM damage occured on almost 50% of the tubers. Total losses in storage were 10%,40% and 81% after one, three and five months,respectively (Personal observations).

The objectives of the present research were:

1. To evaluate the storage potential of clones with different genetic backgrounds.

2. To evaluate the relationship between laboratory assessments of clone reaction to soft rot and dry rot and losses that occur in rustic storage.

3. To study pre- and post-harvest factors and treatments that affect storability of potatoes in the warm tropics.

1.2 LITERATURE REVIEW

1.2.1 Potato storability in the warm tropics

When a new clone is released,its post-harvest characteristics are usually not completely known. Some characteristics that should be known are weight loss, susceptibility to major diseases,sprouting,and bruise susceptibility (Leach,1978).

Mendoza,1987 stated that the development of new potato populations for the warm tropics has relied on:1.Breeding for earliness and heat tolerance and for combined resistance to bacterial wilt and root knot nematode. 2. Utilizing germ plasm from general breeding programs that focus on: a) adaptation and utilization of potato populations b)breeding for resistance to Alternaria and Erwinia. c)Breeding for resistance to late blight,d)breeding for resistance to PLRV and PVY,d)Ploidy level manipulations using haploids and 2n gametes and e) breeding for insect resistance.

Storage evaluation is often the least emphasized area in potato breeding programs for the warm tropics.

Factors that affect the storability of potatoes in the warm tropics are:susceptibility to nematodes and tuber moth and tuber diseases, cracking and secondary growth,susceptibility to damage during harvesting and handling,the rate of wound healing, dormancy period and physiological shrinkage.

1.2.2 Tuber susceptibility to major storage diseases

Many potato tuber diseases occur in the tropics. Those causing economic losses are:brown rot caused by Pseudomonas solanacearum; soft rot caused by a complex of bacterial organisms including Erwinia spp.,Bacillus spp.,Pseudomonas marginalis and other pectolytic strains of Pseudomonas,Clostridium spp. and Flavobacterium spp.; leak caused by Pythium spp.; pink rot by Phytophthora erythroseptica;stem rot by Sclerotium rolfsii; black rot by Rosellinia spp.;charcoal rot by Macrophomina phaseoli and dry rot caused by several Fusarium spp. The most important storage diseases in the warm tropics are bacterial soft rot caused by Erwinia spp.and dry rot caused by Fusarium spp.(International Potato Center,1987a).

1.2.2.1 Tuber susceptibility to soft rot caused by Erwinia spp.

Storage soft rot is a serious problem in the warm tropics due to the high temperature and relative humidity. E.chrysanthemi (Echy) and E.carotovora subsp carotovora (Ecc) are most frequently associated with soft rot in storage in the warm tropics (De Lindo et al.,1978; International Potato Center,1987a).

Improved storage of tubers and resistant cultivars hold the most promise for reducing losses from tuber rot in the warm tropics (Hidalgo and Echandi,1983). Considerable research to assess tuber susceptibility of potato cultivars and clones to bacterial soft rot has been reported (Bourne et al.,1981; McGuire and Kelman,1983,Lapwood et al.,1984; Ciampi-Panno et al.,1984; Workman and Holm,1984;Bain and Perombelon,1988; Wastie et al.,1988) but most of this research has been done in temperate zones where E.carotovora subsp. atroseptica (Eca) and to a lesser extent Ecc are the main causal agents. The potato cultivars used were adapted to temperate climates where S.tuberosum subsp. tuberosum is the main component of the genetic background.

Tuber susceptibility to soft rot caused by Erwinia spp. is influenced by many factors. Some of these are: a. The method of inoculation used with the Erwinia spp. has resulted in different clone rankings. Some methods used are:puncture wounding (Lapwood et al.,1984;Bourne et al., 1981; Bain and Perombelon,1988); tuber slices (Lapwood et al.,1984; Wastie et al., 1988); vacuum infiltration(Bain and Perombelon,1988) and microinjection (Ciampi-Panno et al.,1984; De Boer and Kelman,1978;International Potato Center,1981;Hidalgo and Echandi,1982;Hidalgo and Echandi,1983;Bain and Perombelon,1988). b.Erwinia species or subsp.Hidalgo and Echandi,1982 working with selected S. tuberosum subsp. andigena clones, inoculated suspensions of Echy,Ecc and Eca into tubers using the microinjection method and found that Ecc induced more rot than Echy or Eca. Ciampi-Panno et al.,reported in 1984 that ten of his 15 clones rotted more extensively when inoculated with Ecc than with Eca and five clones showed more rotting when inoculated with Eca than with Ecc. c.Influence of storage time on susceptibility. De Boer and Kelman reported in 1978 that fusarex-treated

tubers were slightly more susceptible to Ecc when tested 1 week after harvest than after 4 weeks storage at 3 C, but by the 7th week their susceptibility had increased again to the original level. Untreated tubers also decreased in susceptibility between the first and fourth weeks, but remained constant thereafter. Hidalgo and Echandi (1983) reported that tuber soft rot caused by Echy increased significantly in S.tuberosum subsp.andigena stored from 6 to 16 weeks at 4 C but not at 23 C and that the tuber soft rot increased significantly in S.tuberosum subsp.tuberosum stored at both 4 and 23 C from 6 and 16 weeks. d.Physiological status of the tuber. McGuiree and Kelman (1986) reported that tuber dry matter,reducing sugars and calcium content influenced soft rot susceptibility. Biehn et al.,(1972) found that Katahdin tubers with high dry matter were less susceptible to soft rot caused by Ecc than tubers with a lower dry matter. Workman et al.,(1976) found a significant correlation between the rate of Erwinia decay,membrane permeability and sucrose content of the tubers. Otazu and Secor (1980) obtained a highly significant correlation between reducing sugar content and soft rot severity in Norgold Russet potato tubers. Hidalgo and Echandi (1983) inoculated tubers with Echy using the microinjection method and found that tuber soft rot was highly correlated with electrolyte leakage,total sugars and reducing sugars in clones of S.tuberosum subsp.andigena and subsp.tuberosum stored at 4 C and 23 C and with non reducing sugars only in subsp.andigena at 23 C. Water status of the tuber is also a factor in soft rot development (Bartz and Eckert, 1987). Most pathogenic bacteria require a substrate with high water potential for rapid growth. Bacteria,in particular,and some fungi such as Pythium spp. are generally prevented from growing if the water potential in vitro drops below -30 to -40 bars (Cook,1978).

The lower susceptibility of non-turgid (-6bar) than turgid (-2 bar) discs suggested that low water potential increased tissue resistance. However, growth of Ecc was not detectably affected by osmotic potentials of up to -12 bar in vitro (Perombelon and Lowe,1975). Cother and Cullis (1987) found no correlation between moisture content and soft rot.

e.Clonal variation. Sources of resistance to Echy were found in the World Germplasm Collection of the International Potato Center when using the microinjection method with different inoculum concentrations (International Potato Center,1981). A wide variation in tuber susceptibility to Echy was observed when 287 advanced clones (True potato seed progenitors) were tested by the vacuum infiltration method. Preliminary results suggested that among the 287 advanced clones,6.0% were relatively resistant (<5% rotting per tuber by weight) whereas 6.3% were very susceptible (>30% rotting per tuber by weight. The cultivar Kufri Jyoti and the clone DTO-33 were reported to be resistant and the cultivar Desiree to be susceptible (International Potato Center,1988a).

1.2.2.2 Tuber susceptibility to dry rot caused by Fusarium spp.

Tuber dry rot caused by several Fusarium spp. results in large storage losses throughout the world. In Europe F.solani 'Coeruleum' is mostly responsible, although F.avenaceum,F.arthrosporioides,F.sporotrichiodes and F.oxysporum are also involved (Boyd,1972). F.sulphureum is also considered a major cause of dry rot in Europe and sometimes it has appeared to be the dominant species (Tivoli & Jouan,1981). In North America,dry rot is mostly associated with F.roseum 'Avenaceum',F.roseum 'Sambucinum',and F.solani 'Coeruleum' of which F.roseum'Sambucinum' and F.solani 'Coeruleum'are the most destructive (Leach and Webb,1980).

Potato cultivars differ in their resistance to Fusarium spp. (Boyd, 1952;Ayers,1956;Jellis,1975;Wiersema,1977;Leach and Webb,1980; Bjor,1987). Cultivars react differently to different Fusarium spp.even if methods of inoculation and incubation are similar (Leach and Webb,1980;Seppanen, 1981; Seppanen,1983; Corsini and Pavek,1986; Tivoli et al., 1986; Wastie et al.,1989). Response to Fusarium spp. may differ with the inoculation method (Boyd,1952; Ayers,1956); incubation temperature (Boyd,1952; Seppanen,1983), type of wounding (Jellis and Starling,1983;Tivoli et al., 1986); and the length of storage period prior to inoculation (Wiersema, 1977; Leach and Webb,1980; Tivoli et al.,1986).

Sources of resistance and clones resistant to Fusarium dry rot have been identified (Leach and Webb,1980;Davis et al.,1983). De Lindo and French (1984) screened 957 clones of S.tuberosum subsp. andigena for resistance to F.solani and found no rotting at the inoculation site in 13 clones. By screening for resistance to tuber dry rot in S.tuberosum subsp.andigena it was found that clone 379597.1 was resistant to both F.solani and F.oxysporum (International Potato Center,1988a). Huaman et al.,(1989) working with tubers from open pollinated progenies of 15 cultivars of S.tuberosum subsp.andigena inoculated with F.oxysporum (Fo) found a range of 8 to 29% (mean=18.6%) of genotypes with no rotting symptoms;those inoculated with F.solani (Fs) had a range from 6 to 41% (mean=24.3%) of genotypes with no rotting symptoms.

Even though cultivars adapted to the warm tropics have been released,little is known about their relative susceptibility to Fusarium spp. during storage.

Fo and Fs are the principal organisms causing dry rots in rustic storages at San Ramon (International Potato Center,1987a).

1.2.2.3 Synergistic responses resulting from simultaneous Erwinia and Fusarium inoculations

Most research on the relationship between fungi and bacteria has focused on seed piece decay. Bacterial soft rot of seed pieces was induced when inoculated with Fs (Stanghellini and Russell,1971). Zinc and Secor (1982) reported higher yield reduction when seed tubers were inoculated with Eca plus F.sulphureum than when seed tubers were inoculated with Eca or F.solani 'Coeruleum' alone. Interactions of Ecc or Eca with Pythium butleri in development of blackleg have also been reported (Abo-el-Dahab, 1978). Interactions of Eca with Phoma exigua to cause reduced plant emergence have also been reported (Logan and Copeland,1979).

Davis et al.,(1983) working with the Russet Burbank cultivar in laboratory and field studies provided evidence for synergism between Eca and F.roseum'Sambucinum'. When the two pathogens were inoculated together the severity of tuber rot was significantly greater that when either pathogen was inoculated separately. Huaman et al.,(1989),working with open pollinated progenies of 15 cultivars of S.tuberosum subsp.andigena, identified 115 of 512 genotypes with combined resistance to Echy and Fusarium spp. Seven of these were resistant to Fo and Echy, 25 to Fs and Echy and more importantly 27 genotypes were resistant to Fo,Fs and Echy.

Corsini and Pavek stated in 1986, that bacterial interaction with Fusarium spp. is an important consideration in determining storage rot resistance.

Frequent association of Ecc with both Fs and Fo was found in rotted tubers in rustic storages at San Ramon (International Potato Center, 1987). No information was found as to the effect of combining Erwinia and Fusarium spp. on tuber rotting of clones adapted to the warm tropics.

The incorporation of subsp.andigena resistance into populations with adaptation for the tropics could reduce tuber decay caused by the interaction of these pathogens in hot environments (Huaman et al, 1989).

1.2.3 Tuber condition before storage

In addition to appropriate storage technologies,an important factor in minimizing storage losses,is the quality of potato tubers being placed into storage (Booth,1987).

Many factors determine tuber storability. Some of these are: infestation of tubers by potato tuber moth,infection with bacterial wilt,the tuber soft rot complex,tuber maturity and the amount of mechanical damage (Booth,1988). It is known that to reduce lenticel infection,excessive soil moisture before harvest should be avoided. To further reduce soft rot infection,harvesting and handling damage should be minimized and harvested tubers must be protected from solar radiation and desiccation (Harrison and Nielsen,1981).

It is known that tubers grown in the highlands are more suitable for storage than tubers grown in the lowlands. In the same storage conditions tuber weight loss was much higher by potatoes produced at San Ramon (800 m elevation) than those brought from Huancayo (3,200 m elevation) (International Potato Center,1987b).

1.2.4 Tuber selection for storing

As mentioned above the quality of tubers placed in the storage is very important (Booth and Shaw,1981). Pre-storage selection is always important but is **critical** where less control over the storage environment is possible. In the more technically developed countries, great emphasis

has been placed on reducing storage losses by sophisticated and expensive control of the storage environment. In less technically developed countries,it is usually impossible to build or manage sophisticated systems (Booth and Shaw,1981). Therefore, emphasis must be placed on tuber selection prior to storage and also re-selection during the storage period itself. The degree of selection which must be applied before storage will vary with tuber quality at harvest time.

1.2.5 Storage conditions

Temperature control is very important for succesful storage. Temperature influences water loss,sprouting,metabolism,quality changes and microbial activity. Other factors that affect the storage life of the tubers are relative humidity, degree of ventilation to provide oxygen and remove carbon dioxide, presence of light,etc.

In technically developed countries the use of sophisticated potato storages is a necessity. In less technically developed countries their high cost and the lower scale of production and storage prohibits their use, thus the use of rustic storages is more appropriate.(Booth and Shaw,1981).

Rustic storages should be built with local low cost materials, provide adequate ventilation and cooling and be easily adopted by developing countries (Booth and Shaw,1981). Rustic storages for consumer potatoes in San Ramon have walls made with a 25 cm. layer of charcoal or white stone kept in place by chicken wire. A pipe with holes every 2-3 cm allows water to trickle down the wall,resulting in a large moist surface for evaporative cooling (International Potato Center,1987b). Under the humid conditions of San Ramon, storage temperatures in the hottest period

of the day were reduced by up to 10 C by using this method of cooling (Tables A.4,A.5 and A.6). At an average ambient relative humidity of 68% during the storage period,wetting the charcoal walls of storages increased the relative humidity to 84%,reduced the temperature from 26.3 to 23.7 C and reduced total tuber weight loss over a three month storage period from 19.1% to 14.6% (International Potato Center,1988b).

1.2.6 Tuber treatments to control storage losses

1.2.6.1 Control of diseases

a. Soft rots

Soft rot in the warm tropics usually results from infection by the coliform bacteria Ecc and Echy (Perombelon and Kelman,1980). Bacterial soft rot is the most prevalent of all storage diseases.Erwinia spp. are tuber borne and anaerobic conditions hasten development of infection in naturally inoculated lenticels (Nielsen,1978). Factors which predispose tubers to infection are immaturity at harvest,tuber damage,frosted or wet potatoes,excessive soil mixed with the tubers in storage and inadequate ventilation (Nash, 1985). Temperatures above the minimum required for growth of the pathogen (Perombelon and Kelman,1980) and physiological factors such as high water potential also favor infection (Cromarty and Easton,1973). Perhaps the major factor leading to soft rot development is the presence of surface water on tubers and consequent depletion of oxygen within the tubers (Lund and Nicholls,1970). In storage,rotting in tubers initially begins in small pockets but after initiation the rot proceeds very rapidly resulting in massive decay of the tubers (Perombelon and Kelman,1980).

Control of Erwinia soft rot requires careful growth of the crop, harvesting in reasonably dry conditions,avoidance of mechanical damage and cooling tubers to 10 C or lower as soon as possible after harvest. To avoid the formation of water films on the tubers avoid washing if possible (Harrison and Nielsen,1981). Drying of well cured tubers before storage in well ventilated dry condition may be an effective control method (Bartz & Kelman,1985). The efficacy of chlorine solutions in reducing losses due to bacterial potato pathogens has been demonstrated (Letal,1977). Erwinia soft rots may be reduced by disinfecting with chlorine solutions (Leach, 1978). Hypochlorite solutions are used as a disinfestant in wash water in potato packing plants,especially in the northern hemisphere (Grigg and Chase,1967). The use of chlorine solutions to control rotting in the warm tropics at San Ramon was not successful. Pre-storage dipping in sodium hypochlorite increased rotting to 35% by weight while only 12.8% of the tubers rotted in untreated samples (International Potato Center,1988b).

b. Dry rots

Fs and Fo are the principal organisms causing dry rots at San Ramon (International Potato Center,1986). Both are wound parasites, so dry rot is not usually observed before lifting unless it develops in growth cracks or through insect damage (Boyd,1972). Tuber infection occurs through wounds incurred during harvesting lifting,transport and grading or through broken-off sprouts (Meijers,1981). Favorable conditions for growth of both fungi are high humidity and high temperature (15-20 C) (Meijers,1981). Effective control of Fusarium dry rot using thiabendazole has been reported (Henriksen,1975; Leach,1978; Cayley et al.,1979; Logan,1982, Cayley et al.,1983). Control of Fusarium dry rot with thiabendazole was unsuccessful with San Ramon grown potatoes (International Potato

Center,1989). However,other studies showed successful control of Fusarium when potato tuber moth was not present (Elphinstone and Wiersema,1988).

1.2.6.2 Control of sprouting

Sprout inhibition in consumer potatoes is very important. Sprouting occurs in warm temperatures leading to higher weight losses, reduced consumer appeal and lower prices to the producer. The tubers are also more susceptible to damage (Rastovski and Van es,1981).

Large differences in sprouting patterns do occur among clones adapted to the warm tropics. I have observed that DTO-33,CFK 69.1,LT-2 and LT-8 sprouted more than Serrana,Desiree,B71 240-2 an Kufri Jyoti.

The following chemicals are used as sprout inhibitors:tetrachloro-nitrobenzene (TCNB),isopropyl n-phenyl carbamate (IPC),isopropyl N-(3-chlorophenyl) carbamate (CIPC),maleic hydrazide (MH) and also many alcohols (Sawyer and Thorne,1962).

In San Ramon,in one study,tubers treated with the sprout inhibitor CIPC had a 46.4 % weight loss compared to 10.4 % in untreated tubers (International Potato Center,1988). Possibly this could have resulted from the application of the chemical to inadequately suberized tubers (Cunninghan,1953). It is said that weight loss of tubers tends to be higher in CIPC treated tubers than in untreated tubers, probably due to the inhibition in the rate of wound healing (Leach,1978a). Audia et al.,1962 showed that CIPC prevented periderm formation and therefore would allow extra moisture loss.

1.2.6.3 Control of water loss

The rate of water loss is determined mostly by the physical condition of the tuber surface. Water loss occurs through lenticels,tuber skin, sprouts, cuts and abrasions and disease lesions (Nash, 1985).

Stage of maturity at harvest is important since the nature and structure of the periderm layer change progressively during development. Immature potatoes lose water rapidly but after wound healing the rate of loss will decrease 5 to 10 times (Burton,1982).

In San Ramon,I have observed that clones such as Serrana,Desiree, B71 240.2 and Kufri Jyoti lost weight less rapidly than clones such as LT-2 and CFK 69.1. The difference was independent of rotting and sprouting.

1.2.6.4 Control of Potato Tuber Moth (PTM)

Potato tuber moth (PTM) is a major pest of stored seed and consumer potatoes in warm climates (Booth, 1984). Under lowland humid tropical conditions with temperatures of about 24-26 C, PTM develops rapidly and causes extensive tuber damage (Raman et al,1987). PTM damage has been reduced with light/pheromone traps, insecticides, specific viruses and also repellent weed species (Raman and Booth, 1984). Covering the stored seed tubers with dried and crushed leaves of the weed Lantana sp. reduced sprout damage below 20%. Over 70% damage occurred in control treatments. Sprout damage was reduced to 40 % with woodash or lime (Raman and Booth,1984).

PTM damage occurred on 17 % of the tubers when stored in rustic storages at San Ramon with a 5-cm cover of crushed dried leaves of Mynthostachys and Eucalyptus compared to 76% damage in unprotected tubers (International Potato Center,1988b).

2. GENERAL MATERIALS AND METHODS

2.1 LOCATION

This research was done primarily at the Mid-elevation Tropical Research Station of the International Potato Center located in the city of San Ramon,provincia of Chanchamayo,Departamento of Junin, Peru. San Ramon is located in the jungle on the eastern slope of the Peruvian Andes at 11.08 degrees latitude in the southern hemisphere and 800 m elevation. There are two potato crop seasons:the rainy season from November to April has average maximum and minimum temperature of 29.5 C and 18.2 C, respectively and average total rainfall of 1132 mm and the dry season from May to October has average maximum and minimum temperature of 28.2 C and 15.8 C,respectively and average total rainfall of 386 mm. Relative humidity averages 75% in the wet season and 65% in the dry season. Principal crops in the San Ramon area are corn,coffee,oranges, pineapple, cocoa and sugar cane. Potatoes are not grown commercially.

2.2 BACTERIAL CULTURES

Evaluation of tuber soft rot susceptibility was done using Erwinia chrysanthemi Burkholder,Mc Fadden & Dimock strain CIP 367 and Erwinia carotovora subsp. carotovora (Jones) Dye strain CIP 360. Both strains were isolated from rotting tubers at San Ramon and used in this research because they were the most virulent among various strains. Cultures of

both strains were maintained in sterile distilled water at 25 C. Pathogenecity of both strains was checked periodicaly during the two years (1988 and 1989) by inoculating tuber slices in petri dishes in the laboratory.

2.3 FUNGUS CULTURES

Evaluation of tuber dry rot susceptibility was done using Fusarium solani Snyder & Hansen and Fusarium oxysporum Snyder & Hansen isolated from rotting tubers and identified by Dr. J. Tivoli at San Ramon. Pathogencity tests of both Fusarium spp. were made before using by inoculating potato tuber slices in the laboratory.

2.4 POTATO TUBERS

Potato tubers of all cultivars and clones for disease susceptibility and physiological studies were produced at the Cool Andean Highland Research Station of the International Potato Center near the city of Huancayo, provincia of Huancayo,Departamento of Junin,Peru. Huancayo is located in the Mantaro Valley in the central part of Peru at 12.07 degrees south latitude and 3280 m.elevation. The major potato crop season is from November to April during which the average maximum and the minimum temperatures are 20.6 C and 6.4 C,respectively and average total rainfall is 645 mm. There is a minor season from August to January during which limited potato production occurs which is entirely dependent on irrigation. Main crops in the Huancayo area are corn,potatoes,peas,wheat,barley and some vegetables. Tubers used in susceptibility tests were produced in the main crop season of 1987-88, minor crop season of 1988 and also in the main crop season of 1988-89. Vines of each clone were removed when 90% dead and tubers left in soil for 15 days to allow good skin setting.

After harvest,tubers were selected and placed in 30 Kg-wood boxes and sent to San Ramon for tuber disease susceptibility tests.

Potato tubers for storage trials were produced at San Ramon and also in Huancayo for some experiments. Seed tubers for all experiments were grown at the Huancayo station and were green sprouted before planting to enhance rapid and uniform emergence. Following harvest,tubers were treated and stored as described in each experiment.

Both named cultivars and numbered clones were used in these studies. Subsequently,both cultivars and clones will be referred to simply as clones.

2.5 STORAGES

2.5.1 Charcoal Walled Rustic Storage

Experimental Rustic Storages for consumer potatoes in San Ramon have walls made with a 25 cm. layer of charcoal or white stone kept in place by chicken wire (Figure 1a). A pipe with holes every 2-3 cm allows water to trickle down the wall,resulting in a large moist surface for evaporative cooling (Figure 3 Left). The wood floor had 1-inch separations between boards to allow air movement. Tubers were stored in 20 wood constructed bins (1 m x 0.5 m x 1 m) to hold 250 Kg of tubers in each bin. Arrangement of the bins inside of the rustic storage is shown in Figures 1b and 2.

2.5.2 Farmer's Storage

The simulated Farmer's Storage at San Ramon was constructed with dry tree trunks with killou leaves in the walls and ceiling (Figure 3.Right). Dry tree trunks also served as a floor to protect tubers from getting wet. Tubers were placed in bags on the floor.

2.5.3 Adobe Rustic Storage

The Adobe Rustic Storage at Huancayo was built with adobe bricks (40 x 25 x 15 cm). Ventilation occurrs through underfloor ducts and ceiling vents. A water reservoir was placed in the ducts to improve humidity. The wood floor had 1-inch separations between boards to allow air movement. The storage was 6 x 6 x 3 m with a capacity of 35 M.T. Tubers are stored in bulk in fixed bins. Metal screen supported wheat straw in the ceiling. The roof was made with tiles to protect from rain and was painted white to reflect radiation (Figure 4).

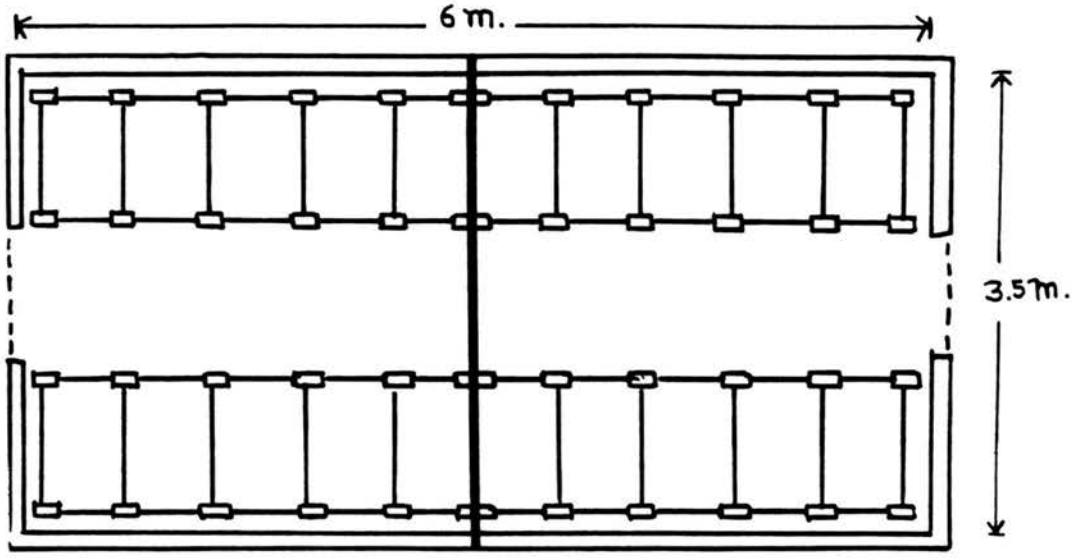
a.

b.

Figure 1.a:Charcoal Walled Rustic Storage at San Ramon

b:Bins with leaves of Lantana spp. over the tubers in the Charcoal Walled Rustic Storage at San Ramon.

a.



b.

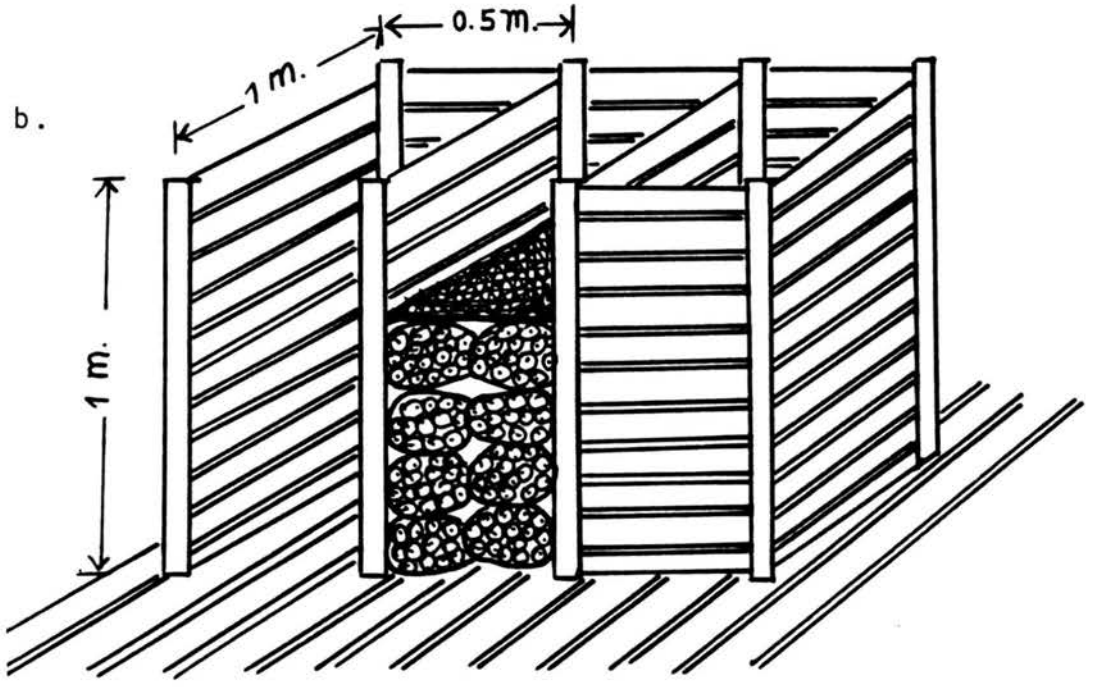


Figure 2 a.Arrangement of bins in Charcoal Walled Rustic Storage

b.Bins with and without potatoes

Figure 3. Left:Pipe with holes (left one) allows water to trickle down the charcoal wall.

Right:Farrmer's Storage at San Ramon.

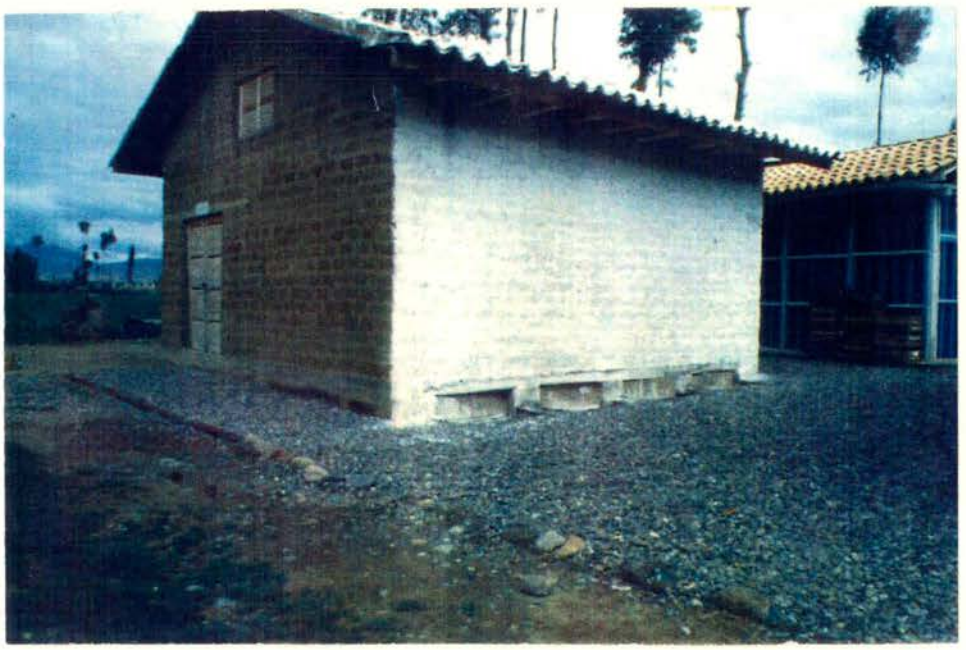


Figure 4 : Adobe Rustic Storage at Huancayo

3. COMPARISON OF STORABILITY OF CLONES ADAPTED TO THE WARM TROPICS

3.1 Introduction

The genetic background of a clone will determine its potential storage life under optimum conditions. Clones having a high metabolic rate, a short rest period, poor wound healing ability, high disease susceptibility and sensitivity to damage will have a short storage life irrespective of pre-storage treatments and methods of storage.

A large number of clones were used in these and subsequent studies. Their origin, the required growing period to reach maturity and the length of the tuber rest period are shown in Table A.1. Large differences existed in both, the required growing periods and in the rest periods suggesting considerable genetic diversity. Yield observations taken on these clones grown at San Ramon are shown in Table A.2 and A.3.

Three experiments were conducted to compare the storability of several clones adapted to the warm tropics with and without various treatments.

3.2 Materials and Methods

Experiment 1:March-June,1988

Seed tubers of DTO-33,LT-1,LT-2,B71 240.2,Desiree,CFK 69.1,Atzimba, I-139,CGN 69.1,Kufri Jyoti and Rosita were planted in San Ramon during the rainy season (November,1987). Vines of each clone were removed when 90% dead and tubers were left in the soil for 8 days to allow skin setting. Tubers were harvested by hand and selection was done to avoid tubers with cuts,diseases,Potato tuber moth (PTM) infestation and skin peeling. Four replicates of 10 kg each per clone, were stored in mesh bags in the charcoal walled rustic storage at San Ramon without tuber treatments; another 4 replicates were treated as follows and placed in the same storage. The tubers were soaked 10 minutes in sodium hypochlorite solution (0.5% active chlorine) followed by 10 minutes in a thiabendazole solution (0.2% active ingredient) and air drying for 2 days and then dusted with Chloro-isopropyl-phenyl carbamate (CIPC) (1.5 gr commercial product per kg of tubers) after 2 weeks of storage. During storage,the treated tubers were covered with a 15 cm layer of dried and crushed leaves of Lantana spp. to reduce PTM infestation. An additional 4 replicates of each clone were stored under refrigeration (4 C). Tubers were stored for 4 months and the Weight Loss was obtained by subtracting the weight of each replicate after 4 months in storage from the initial weight and calculating the percentage loss. Weight loss included rotting,sprout removal and shrinkage. Temperature and Relative Humidity inside and outside of the charcoal walled rustic storage during the storage period were recorded with hygrothermographs (Table A.4).

Experiment 2:August-November,1988

Seed tubers of DTO-33,B71 240.2,LT-2,LT-1,LT-5,Desiree, Kufri Jyoti, LT-7, Atzimba, I-139, CFK 69.1, Serrana, CGN 69.1 and Rosita were planted in San Ramon during the dry season (May 1988). Vines of each clone were removed when 90% dead and tubers were left in the soil for 8 days to enhance skin setting. At harvest,selection was done to avoid tubers with cuts,diseases,PTM infestation and skin peeling. Four replicates of 10 kg each per clone were stored in mesh bags in the charcoal walled rustic storage at San Ramon without tuber treatments, another 4 replicates were treated as follows and placed in the same storage. The tubers were dusted with thiabendazole (1.5 g Tecto 60 per kg of tubers) immediately after harvest and with CIPC (1.5 g commercial product per kg of tuber) after one month storage. During storage the treated tubers were covered with two layers of hessian sack and a layer of plastic screen to prevent PTM infestation. An additional four replicates of each clone were stored under refrigeration (4 C). After 4 months storage, the Total Percentage Weight Loss and Sprout Growth was determined. Sprout Growth is expressed as percentage of the initial tuber weight. Total percentage weight loss included rotting,sprout removal and shrinkage. Temperature and relative humidity inside and outside the charcoal walled rustic storage during the storage period were recorded with hygrothermographs (Table A.5).

Experiment 3:September-December,1989

Seed tubers of the following 19 clones were planted in San Ramon in the dry season (June,1989):DTO-33,B71 240.2,LT-2,LT-1,LT-5,Desiree,Kufri Jyoti,LT-7,LT-8,LT-9,C84 580.1,Atzimba,I-139,CFK 69.1,Serrana,CGN 69.1, Rosita, Mariva and Yungay. Vines of each clone were removed when 90% dead and tubers were left in the soil for 8 days to enhance skin setting.

At harvest,tubers were carefully selected to eliminate those with cuts,diseases,PTM infestation and skin peeling. Selected tubers were dusted with thiabendazole (1.5 gr of Tecto-60 per kg of tubers) immediately after harvest and placed in 30 kg-wood boxes in the charcoal walled rustic storage for curing. After 10 days, tubers of each clone were re-selected and healthy tubers were placed in 8 replicates of 10 kg each in mesh bags and stored in the charcoal walled rustic storage. After one month storage all replicates were dusted with CIPC (Nobrotan 1.5 gr per kg of tubers) and divided in two lots. Four replicates of each clone were placed in bins and covered with two layers of hessian sack and a layer of plastic screen. To possibly improve the effect of the sprout inhibitor (CIPC) the other four replicates of each clone were covered with 4 layers of hessian sack and a layer of plastic screen with a single layer of hessian sack lining the bin walls. After four months storage (3 months following CIPC application),Total Percentage Weight Loss and Sprout Growth expressed as percentage of initial weight were determined. Total Percentage Weight Loss included rotting,sprout removal and shrinkage. Temperatures and relative humidity inside and outside the charcoal walled rustic storage were registered with hygrothermographs (Table A.7).

3.3 Results

Experiment 1:March-June,1988

The analysis of variance for this experiment is shown in Tables A.11 and A.12 and the data in Table 3.1.

The mean weight loss of the treated tubers greatly and significantly exceeded the weight loss of the control tubers. This increase in weight loss was consistent for all clones and was due to increased rot. Wetting

Table 3.1 Total Percentage Weight Loss of 10 clones during 4 months under refrigeration and in rustic storage (March-June, 1988). 1/

	Total Percentage Weight Loss 2/			
	Refrigeration	Rustic storage		
Clones	4 C	Control	Treated 3/	Mean
Kufri Jyoti	4.7 cde	8.7 d	18.0 e	13.3 g
DTO-33	3.8 ef	16.0 bcd	53.5 d	34.8 f
Rosita	8.8 b	12.4 cd	76.8 c	44.6 e
Desiree	2.6 f	8.8 d	86.9 b	47.9 de
CGN 69.1	7.9 b	9.4 d	94.0 ab	51.7 cd
LT-1	5.8 cd	8.9 d	96.0 ab	52.4 cd
B71 240.2	5.9 cd	13.7 bcd	100.0 a	56.8 bc
Atzimba	12.2 a	23.2 b	93.1 ab	58.1 abc
LT-2	6.2 c	20.8 bc	100.0 a	60.4 ab
I-931	4.4 de	33.4 a	95.8 ab	64.6 a
Mean	6.2 C	15.5 B	81.4 A	

1/Potatoes grown during the rainy season in San Ramon. Vines of each clone were removed when 90% dead,tubers harvested after 8 days;cut, diseased,tuber moth damaged and skinned tubers eliminated.

2/Data for rustic storage and refrigeration were analyzed separately. Column values followed by the same lower case letter and row values followed by the same upper case letter do not differ at the 5% probability level (Duncan's Multiple range test).

3/Tubers treated as follows: a) soaked 10 minutes in sodium hypochlorite and 10 minutes in thiabendazole immediately after harvest, b)dusted with CIPC after 2 weeks in rustic storage and c)covered with a 15 cm layer of dried and crushed leaves of Lantana spp. during storage.

the tubers in solutions of sodium hypochlorite and thiabendazole was most likely the primary causal factor. A secondary factor may have been the lack of air circulation caused by the 15 cm layer of crushed leaves of Lantana spp.

There were significant differences among the 10 test clones in Weight Loss of the control tubers. Losses ranged from 8.7% (Kufri Jyoti) to 33.4% (I-931). Six other clones did not differ significantly from Kufri Jyoti. I-931 lost significantly more weight than all other clones.

Weight loss of tubers stored at 4 C was significantly less than the control tubers stored in rustic storage. Shrinkage was the primary weight loss factor of most clones at 4 C.Significant differences in weight loss at 4 C occurred among clones. Atzimba lost significantly more weight than the other 9 clones due to rotting.

There was no significant correlation between weight loss of tubers stored at 4 C and control tubers stored in the rustic storage.

Experiment 2:August-November,1988

The analyses of variance for this experiment are shown in Tables A.13 and A.14 (Weight loss) and A.15 (Sprouting). The mean weight loss of the treated tubers of the 14 clones was significantly less than that of the controls (Table 3.2). However,a comparison of the weight loss of the control and treated tubers of each clone indicates that treating the tubers was of little or no benefit for most clones. Only clones CFK 69.1 and LT-7 benefited substantially from the tuber treatments.

Weight loss of the control and treated tubers was significantly correlated (r=0.91). When the weight loss from control and treated tubers was averaged, CFK 69.1 lost significantly more weight (due to excessive rot) than the other 13 clones. There were significant differences in

Table 3.2 Total Percentage Weight Loss of 14 clones during 4 months under refrigeration and in rustic storage (August-November, 1988) 1/

Clones	Total Percentage Weight Loss 2/							
	Refrigeration 4 C		Rustic Storage					
			Control		Treated 3/		Mean	
Desiree	3.6	d	6.1	f	6.6	f	6.3	g
Kufri Jyoti	3.6	d	7.4	ef	6.1	f	6.7	g
LT-5	4.7	cd	10.8	de	6.8	ef	7.2	g
CGN 69.1	7.0	b	7.2	ef	8.3	ef	7.8	g
Serrana	4.2	cd	7.9	ef	8.0	ef	7.9	g
Rosita	6.1	bc	8.1	ef	8.5	ef	8.3	fg
B71 240.2	5.0	cd	8.9	ef	8.4	ef	8.7	fg
LT-1	3.9	d	10.8	de	10.4	cde	10.6	ef
LT-7	3.4	d	16.4	c	9.0	def	12.7	de
LT-2	6.0	bc	13.7	c	12.3	cd	13.0	d
DTO-33	7.2	b	15.9	c	13.7	c	14.8	d
I-931	4.9	cd	22.9	b	18.2	b	20.5	c
Atzimba	4.9	cd	25.5	b	21.1	ab	23.3	b
CFK 69.1	11.9	a	43.1	a	21.8	a	33.5	a
Mean	5.5	C	14.4	A	11.4	B		

1/Potatoes grown during the dry season in San Ramon. Vines of each clone were removed when 90% dead,tubers harvested after 8 days;cut,diseased, insect damaged and skinned tubers discarded.

2/Data for rustic storage and refrigeration were analyzed separately. Column values followed by the same lower case letter and row values followed by the same upper case letter do not differ at the 5% probability level (Duncan's Multiple range test).

3/Tubers treated as follow: a)thiabendazole dusting immediately after harvest, b)CIPC dusting one month after harvest and c)covered during storage with 2 layers of hessian sack and single layer of plastic screen.

Table 3.3 Effect of tuber treatments on Sprout Growth of 14 clones expressed as Percentage of Initial Weight during 4 months in rustic storage (Aug-Nov,1988). 1/

Clones	Sprout Growth-% Initial Weight Rustic Storage					
	Control		Treated		Mean	
B71 240.2	0.59	f	0.84	f	0.71	g
Desiree	0.87	ef	0.87	f	0.87	fg
Serrana	0.91	ef	0.91	ef	0.91	fg
CGN 69.1	0.97	ef	0.88	f	0.92	ef
Kufri Jyoti	1.06	ef	1.19	cdef	1.12	ef
LT-7	1.15	de	1.12	def	1.14	ef
Rosita	0.82	ef	1.50	cd	1.15	ef
LT-5	0.89	ef	1.43	cd	1.16	ef
I-931	1.49	cd	1.35	cde	1.42	de
Atzimba	1.78	bc	1.31	cdef	1.55	d
LT-1	2.05	b	2.00	b	2.02	c
CFK 69.1	3.75	a	1.62	bc	2.68	b
LT-2	3.83	a	1.61	bc	2.72	b
DTO-33	3.84	a	4.10	a	3.96	a
Mean	1.72	A	1.48	B		

1/ See footnotes Table 3.2

weight loss among the remaining clones, although 7 clones showing the lowest weight loss did not differ significantly from each other.

The mean weight loss at 4 C was significantly less than the loss in rustic storage. However,certain clones,eg. CGN 69.1,lost about the same amount at 4 C as in rustic storage. Five other clones lost only from 2 to 4% more weight in rustic storage than at 4 C. Other clones,such as CFK 69.1,Atzimba and I-931 lost much more weight in rustic storage than at 4 C due to rotting. For most clones,loss at 4 C was primarily shrinkage.

A significant correlation was found between weight loss at 4 C and weight loss by control tubers in rustic storage (r=0.69).

To control sprouting,CIPC was applied to treated tubers in addition to thiabendazole. Treated tubers of all clones sprouted (Table 3.3). Based on the average of 14 clones,treated tubers had significantly less sprout growth (1.48%) than control tubers (1.72%). However,treated tubers of 7 of 14 clones had the same or more sprout growth than the controls. Thus a strong interaction occurred between CIPC treatments and clones.

When control and treated values for each clone were averaged the sprout growth ranged from 0.71% (B71 240.2) to 3.96% (DTO-33) of the initial tuber weight.

Experiment 3:September-December,1989

The analyses of variance for experiment 3 are shown in Tables A.16 (Weight loss) and A.17 (Sprout growth). The weight loss data are shown in Table 3.4. Increasing the number of layers of hessian sack from 2 to 4 significantly increased the mean weight loss of 19 clones from 10.7% to 18.9%. For 13 of 19 clones this increase was small ranging from 2 to 4%. However,the increase for the remaining 6 clones ranged from 10 to over 40%. A significant correlation in weight loss (r=0.87) occurred between 2 and 4 layers of hessian sack covering. Clones varied greatly and significantly in weight loss,ranging from a low of 4.1% to a high of 20.9% with two layers of covering and a low of 6.9% to a high of 62.7% with 4 layers of covering.

Sprouting data are shown in Table 3.5. Rather than decreasing sprouting as postulated,increasing the covering from 2 to 4 layers of hessian sack significantly increased sprouting based on the mean of 19 clones.

Table 3.4 Effect of layers of hessian sack covering on the Total Percentage Weight Loss of 19 clones during 4 months in rustic storage (September-December,1989). 1/

Clones	Total Percentage Weight Loss 2/ Layers of Covering two 3/		four 4/		Mean	
Serrana	4.1	f	6.9	h	5.5	g
Desiree	5.5	ef	6.4	h	5.9	g
Kufri Jyoti	6.1	def	6.5	h	6.3	g
Yungay	6.5	def	6.9	h	6.7	g
LT-7	6.6	cdef	7.0	h	6.8	g
LT-5	6.5	def	7.5	h	7.0	g
B71 240.2	7.0	cdef	8.9	gh	7.9	fg
LT-1	7.5	cdef	8.6	gh	8.1	fg
CGN 69.1	9.2	cdef	10.9	fgh	10.0	fg
Rosita	8.7	cdef	11.6	fgh	10.2	fg
LT-8	12.5	abcdef	12.7	fgh	12.6	ef
LT-9	15.1	abcd	16.4	efg	15.7	de
C84.580.1	10.5	bcdef	22.3	de	16.4	de
DTO-33	15.2	abcd	19.0	ef	17.1	de
Mariva	12.5	abcdef	27.7	cd	20.1	cd
LT-2	13.9	abcde	30.5	c	22.2	c
Atzimba	15.6	abc	42.7	b	29.2	b
I-931	19.0	ab	44.5	b	31.8	b
CFK 69.1	20.9	a	62.7	a	41.8	a
Mean	10.7	B	18.9	A		

1/Potatoes grown during the dry season in San Ramon. Vines of each clone removed when 90% dead,tubers harvested after 8 days;cut, diseased,insect damaged and skinned tubers discarded;remaining tubers dusted with thiabendazole immediately after harvest,then cured 10 days in rustic storage and again sorted.Healthy tubers returned to rustic storage and dusted with CIPC after one month storage and divided in 2 lots.

2/Column values followed by the same lower case letter and row values followed by the same upper case letter do not differ at the 5% probability level (Duncan's Multiple range test).

3/Covered with 2 layers of hessian sack and a layer of plastic screen

4/Bin lined with hessian sack and covered with 4 layers of hessian sack and a layer of plastic screen.

Table 3.5 Effect of layers of hessian sack covering on Sprout Growth of 19 clones expressed as Percentage of Initial Weight during four months in rustic storage (September-December, 1989). 1/

Clones	Sprout Growth - % Initial Weight Layers of covering two		four		Mean	
CGN 69.1	0.62	de	0.62	f	0.63	g
Rosita	0.62	de	0.62	f	0.63	g
B71 240.2	0.52	e	0.77	f	0.65	g
Serrana	0.68	de	0.63	f	0.65	g
Desiree	0.71	de	0.62	f	0.66	g
Kufri Jyoti	0.65	de	0.77	f	0.71	g
LT-9	0.72	de	0.72	f	0.72	g
Yungay	0.75	cde	0.90	ef	0.82	fg
C84.580.1	1.00	bcde	0.83	ef	0.91	efg
Mariva	1.09	bcd	0.93	ef	1.01	ef
LT-5	1.00	bcde	1.28	de	1.14	de
LT-7	1.09	bcd	1.67	bcd	1.38	cd
I-931	1.21	bc	1.68	bcd	1.45	c
Atzimba	1.31	b	1.83	bc	1.57	c
LT-8	2.18	a	1.57	cd	1.88	b
LT-1	1.87	a	2.08	b	1.98	b
CFK 69.1	2.09	a	2.13	b	2.11	b
DTO-33	1.96	a	2.81	a	2.38	a
LT-2	2.00	a	2.85	a	2.42	a
Mean	1.16	B	1.34	A		

1/ See footnotes Table 3.4

Fourteen of 19 clones showed equal or more sprouting with 4 layers compared to 2 layers while 5 clones showed less sprouting. Thus, an interaction occurred between coverings and clones. Significant differences in sprouting occurred among clones both under 2 and 4 layers of covering. Sprout growth as percentage of initial weight ranged from a low of 0.62% to a high of 2.18% with 2 layers of covering and from a low of 0.62% to a high of 2.85% with 4 layers of covering.

3.4 Discussion

Storage losses for most clones in rustic storage were not reduced by the pre-storage or storage treatments tested in the experiments.

In experiment 1,soaking tubers in sodium hypochlorite and in thiabendazole increased weight loss due to rotting in all clones from 2 to 10 fold. This was probably due mainly to wetting the tubers prior to storage but part of it may also have resulted from restricted air movement due to the 15 cm layer of dried and crushed leaves of Lantana spp.

In experiment 2,dusting with thiabendazole and CIPC resulted in a small (3%) but significant decrease in the mean loss of 14 clones. However,12 of 14 clones either did not benefit or had slightly increased loss. Only the poorest storing clone,CFK 69.1,showed a marked decrease in loss due to pre-storage treatments. CIPC was not effective in preventing sprouting.

In experiment 3, the covering of tubers in storage was increased from 2 to 4 layers of hessian sack to possibly improve the retention of CIPC and decrease sprouting. This was not successful. Fourteen of 19 clones actually had equal or more sprouting when covered with 4 layers. In addition, loss due to rotting was markedly increased by increasing the layers of covering in the poorer storing clones,eg. CFK 69.1. On the other hand,losses in the better storing clones;Serrana,Desiree,Kufri Jyoti,Yungay,etc. were only slightly increased by the 4 layer covering of hessian sack.

Table 3.6 Summary of 5 observations showing mean Total Percentage Weight Loss of 14 clones during 4 months in rustic storage. 1/

Clones	Total Percentage Weight Loss 2/						
	Mar-Jun 1988	Aug-Nov 1988		Sept-Dec 1989			
	Control	Control	Treated	Two	Four	Mean	
Desiree	8.8	6.1	6.6	5.5	6.4	6.7	e
Serrana	7.3 3/	7.9	8.0	4.1	6.9	6.8	e
Kufri Jyoti	8.7	6.4	6.1	6.1	6.5	6.8	e
LT-5	7.9 3/	7.5	6.8	6.6	7.5	7.3	e
CGN 69.1	9.4	7.2	8.3	9.2	10.9	9.0	de
B71 240.2	13.7	8.5	8.4	7.0	8.9	9.3	de
LT-1	8.9	10.7	10.4	7.5	8.6	9.7	de
Rosita	12.4	8.0	8.5	8.7	11.6	9.8	de
LT-7	9.0 3/	16.4	9.0	6.6	7.0	9.9	de
DTO-33	16.0	15.9	13.7	15.2	19.0	15.9	cd
LT-2	20.8	13.7	12.3	13.9	30.5	18.2	bc
Atzimba	23.2	25.4	21.1	15.6	42.7	25.6	b
I-931	33.4	22.8	18.2	19.0	44.5	27.6	b
CFK 69.1	38.3 3/	43.1	21.8	20.9	62.7	37.4	a

1/Values taken from Tables 3.1,3.2 and 3.4.

2/Means followed by the same letter do not differ at the 5% probability level (Duncan's Multiple range test).

3/Calculated values using the formula of Yates for estimation of missing values (LeClerg et al,1962).

Table 3.6 summarizes the 3 experiments showing losses for clones that were common to all experiments (Analysis of variance is shown in Table A.18). Data from treated tubers in experiment 1 were not included due to the fact that treatments induced unusually high losses. Based on the mean of the 3 experiments,9 of 14 clones did not differ significantly and showed low losses ranging from 6.7% to 9.9%. Losses of the remaining clones ranged from 15.9 to 37.4%. Clone CFK 69.1 showed significantly higher losses than all other clones.

4. TUBER SUSCEPTIBILITY TO SOFT ROT CAUSED BY ERWINIA spp.

4.1 Introduction

Soft rot of potatoes may be the most serious storage disease in the warm tropics. The lack of refrigeration in the tropics make the use of inexpensive rustic storages necessary even though less control of temperature and humidity is possible.

In rustic storages, bacterial soft rot occurs frequently. Erwinia chrysanthemi (Echy) and Erwinia carotovora subsp. carotovora (Ecc) are the main causal organisms (International Potato Center,1987a). Since refrigeration is not readily available in the warm tropics,the identification of clones having resistance to soft rot caused by Erwinia spp. is very important.

The objectives of these studies were:

1. Assess tuber susceptibility of clones adapted to the warm tropics to soft rot caused by Echy and Ecc,using different methods of inoculation.
2.Study the relationships of dry matter and tuber water potential to severity of soft rot caused by Erwinia spp.

4.2 ASSESSMENT OF TUBER SUSCEPTIBILITY TO SOFT ROT CAUSED BY ERWINIA spp. IN CLONES ADAPTED TO THE WARM TROPICS

4.2.1 Materials and Methods

4.2.1.1 Source and Preparation of tubers

All test clones were grown under cool climatic conditions at Huancayo to obtain tubers with less disease. Vines of each clone were removed when 90% dead and the tubers were harvested 15 days later and transported to San Ramon.

Upon arrival from Huancayo, the tubers were sorted and washed with well water and surface disinfected by soaking for 10 minutes in a sodium hypochlorite solution containing 0.5% active chlorine and then rinsed twice with well water and allowed to air dry for 2 days. Tests were performed one week after harvest (0 months of storage) and again after 2 and 4 months storage. Tubers were stored in plastic mesh bags in the charcoal walled rustic storage at San Ramon,protected against Potato tuber moth (PTM) with a plastic screen.

4.2.1.2 Preparation of inoculum

Cultures of Echy and Ecc were maintained in sterile distilled water at 25 C and then streaked on casamino acido-peptone-glucose (CPG) agar medium (Cuppels and Kelman,1974). Cultures were incubated at 27 C for 24-48 hr and then rinsed from the CPG plates to 30 ml of CPG-broth in 250 ml flasks and incubated for 16 hr at 27 C in a shaking water bath. Inoculum was then prepared by diluting the CPG-broth liquid culture in sterile distilled water to obtain the required concentrations.

Bacterial populations were obtained from a standard curve by measuring optical density of the suspension with a Bausch & Lomb'Spectronic-20' spectrophotometer at 450 nm.

4.2.1.3 Inoculation methods

Two methods of inoculation,immersion and vacuum infiltration of tubers in a bacterial suspension,were used the first year and these 2 methods plus a microinjection method were also used in the second year.

a.Immersion method:For each evaluation,3 replicates of 5 tubers each per clone contained in 3 separate mesh bags,were immersed for 30 minutes in 10 l of bacterial suspension containing 1×10^6 c.f.u. of Erwinia per ml.

b.Vacuum infiltration method:Three replicates of 5 tubers each per clone contained in 3 separate mesh bags were placed in a water suspension containing 1×10^6 cfu of Erwinia spp. in a vacuum chamber and a vacuum of -86 KPa was maintained for 5 minutes. The vacuum was released slowly to allow the suspension to replace air in the tubers which escaped from the lenticels. Following vacuum release the samples were left 5 minutes inside the chamber.

c.Microinjection method:Three replicates of 5 tubers each per clone were inoculated at each evaluation.Three sites per tuber were inoculated separately using a microsyringe to inject 0.01 ml of inoculum containing $1x\ 10^4$,1×10^5 and 1×10^6 c.f.u. per ml to a depth of 5 mm into the cortex. The sites were sealed with vaseline after inoculation. Lenticels were avoided as inoculation sites.

4.2.1.4. Incubation and rot evaluation

Inoculated tubers were placed on metal screen shelves in a mist chamber and arranged in a predetermined randomized pattern. Tubers were

misted to maintain a constant film of water on the tuber surface and incubated 4 days at 25 C. Tubers inoculated by immersion and vacuum infiltration were evaluated as follows:the amount of rot per tuber was determined by weighing tubers before and after washing away the rotted tissue. The percentage rot based on the initial tuber weight was then calculated.

Tubers inoculated by the microinjection method were cut through the inoculation site and the maximum diameter of rotting tissue was measured.

4.2.1.5 Specific experimental procedures

March-June,1988-Vacuum and Immersion inoculation

Two inoculation methods,immersion and vacuum infiltration and two bacterial pathogens Echy and Ecc were used. One hundred and eighty tubers of each clone each weighing 80-120 grs were used. Cut,diseased and excessively skinned tubers were discarded. Tubers were cleaned and disinfected as described. Sixty tubers from each clone were evaluated one week after harvest (0 months in storage). The remaining 120 tubers of each clone were stored at San Ramon in the charcoal walled rustic storage. Sixty tubers of each clone were removed from storage after either 2 or 4 months and then inoculated and evaluated using methods identical to tubers not stored. Temperature and Relative humidity during storage are shown in Table A.4.

March-June,1989-Vacuum,immersion and microinjection inoculation methods.

Both bacterial pathogens (Ecc and Echy) and all three methods of inoculation,immersion,vacuum infiltration and microinjection were used. Two hundred and seventy tubers of each clone each weighing 80-120 grs

were carefully selected to avoid those that were cut,diseased or excessive skinned. After surface disinfectation and drying as described before, ninety tubers were evaluated one week after harvest (0 months in storage) and the remaining 180 tubers were stored at San Ramon in the charcoal walled rustic storage for evaluation after 2 and 4 months storage. Temperature and Relative humidity during storage are shown in Table A.6.

4.2.2 Results

March-June,1988-Vacuum and immersion infiltration

Analysis of variance is presented in Table A.19.

Susceptibility to soft rot caused by Erwinia spp. decreased significantly with time in storage (Table 4.1). When averaged over 11 clones, 2 inoculation methods and 2 pathogens, susceptibility decreased markedly from 42.7% rot before storage to 11.4% and 2.9% after 2 and 4 months in rustic storage,respectively.

Echy was significantly more virulent than Ecc (Table 4.1). Based on the mean of 11 clones and 2 inoculation methods,Echy inoculation resulted in 49.7% rotting while Ecc caused 35.6% rotting when evaluation was before storage. After 2 months storage,tubers inoculated with Echy also rotted significantly more than those inoculated with Ecc. After 4 months storage,however,no significant difference between pathogens was found. A significant correlation (r=0.68) occurred between Echy and Ecc in respect to rotting of the 11 clones when measured before storage. However, after 2 and 4 months storage significant correlations were not found.

Table 4.1 Effect of Erwinia ssp.and time in rustic storage on tuber soft rot of 11 clones (March-June,1988) 1/

Erwinia spp.	Percentage Rot by Weight 2/ Months of storage 0	2	4
E.carotovora subsp. carotovora	35.6 b	5.6 b	2.6 a
E.chrysanthemi	49.7 a	17.2 a	3.4 a
Mean	42.7 A	11.4 B	2.9 C

1/Each value is the mean of 2 inoculation methods;immersion and vacuum infiltration and the mean response of 11 clones. Tubers incubated 4 days at 25 C in a mist chamber following inoculation before evaluation.

2/Column values followed by the same lower case letter and row values followed by the same upper case letter do not differ at the 5% probability level(Duncan's multiple range test).

The influence of method of inoculation,immersion or vacuum, time in storage, and clonal rotting response are shown in Table 4.2. Tubers of all clones inoculated by vacuum infiltration consistently showed more decay in each of the 3 evaluations (0,2,4 months) than tubers inoculated by immersion. A significant correlation in clonal rotting occurred between immersion and vacuum when measured before storage (r=0.71) and after 4 months (r=0.67) but not after 2 months. The significant correlation at 4 months is probably not meaningful since little rotting resulted from immersion.

Significant differences in rotting occurred among clones with both methods of inoculation after 0 and 2 months storage but only following vacuum infiltration after 4 months. The greatest difference in rotting among clones occurred following both methods of inoculation when

Table 4.2 Influence of method of inoculation and time in rustic storage on tuber soft rot susceptibility of 11 clones (March-June,1988). 1/

Clones		Percentage Rot by Weight 2/ Months of storage 0		2		4	
IMMERSION							
1	Desiree	20.9	e	5.1	ab	0.1	a
2	DTO-33	22.2	e	2.1	b	0.5	a
3	LT-1	24.2	de	3.4	b	0.1	a
4	Kufri Jyoti	28.3	d	3.1	b	0.1	a
5	CFK 69.1	29.2	d	7.4	ab	0.3	a
6	CGN 69.1	35.5	d	2.6	b	1.1	a
7	B71 240.2	38.2	bc	6.9	ab	0.1	a
8	Rosita	39.2	bc	1.7	b	0.8	a
9	Atzimba	43.5	b	1.9	b	1.4	a
10	LT-2	48.8	a	9.9	a	0.5	a
11	I-931	49.2	a	2.7	b	1.9	a
	Mean	34.4 A		4.3 B		0.6 C	
VACUUM INFILTRATION							
1	LT-1	38.8	e	22.9	b	2.6	ab
2	Rosita	41.8	de	11.9	e	5.2	ab
3	Kufri Jyoti	42.9	de	20.3	bc	3.2	ab
4	CFK 69.1	44.0	cde	20.5	bc	4.1	ab
5	Desiree	44.4	cde	28.2	a	1.9	b
6	CGN 69.1	46.9	cd	13.4	de	5.8	ab
7	B71 240.2	49.4	c	17.0	cde	8.0	a
8	DTO-33	55.4	b	20.3	bc	5.9	ab
9	Atzimba	64.0	a	17.0	cde	8.1	a
10	I-931	65.4	a	18.7	bcd	8.1	a
11	LT-2	66.5	a	21.2	bc	5.3	ab
	Mean	50.1 A		18.6 B		5.3 C	

1/Each value is the mean response to Ecc and Echy inoculated separately using immersion and vacuum infiltration.Following inoculation,tubers were incubated at 25 C in a mist chamber for 4 days before evaluation.

2/Column values followed by the same lower case letter and row values followed by the same upper case letter do not differ at the 5% probability level (Duncan's multiple range test).

measurements were made before storage. The differences among clones became progressively less after 2 and 4 months storage. No significant correlations were found among the three times of observation (0,2,4 months) using either immersion or vacuum infiltration. The most meaningful comparison among clones is probably when the measurements are made before storage. Clones such as LT-2 and I-931 rotted significantly more than the other 9 clones following both immersion and vacuum infiltration. Atzimba also was quite susceptible to soft rot but did not differ significantly from Rosita and B71 240.2 when inoculated by immersion. Soft rotting in LT-1 was consistently low following both types of inoculation. Certain clones reversed position in susceptibility according the method of inoculation,eg. Rosita,Desiree and DTO-33. Rosita was among the more susceptible clones when inoculated by immersion and among the most resistant when vacuum inoculated. In contrast,DTO-33, was among the more resistant following immersion but was among the more susceptible clones following vacuum infiltration.

March-June,1989-Vacuum and immersion infiltration

This experiment was essentially a repeat of the previous experiment with the addition of 5 more clones: Serrana,Yungay,Mariva,LT-7 and LT-5. The analysis of variance for this experiment is shown in Table A.20 and the data are shown in Tables 4.3 and 4.4. The results confirmed those of the first Erwinia study,specifically all clones decreased in susceptibility with time in storage,differences among clones in soft rot response became progressively less with time in storage;Echy was more virulent than Ecc;vacuum infiltration caused more rotting than immersion and no significant correlations were found among the three times of observations (0,2,4 months) either following vacuum or immersion infiltration.

Table 4.3 Effect of Erwinia spp. and time in rustic storage on tuber soft rot of 16 clones (March-June,1989) 1/

Erwinia spp.	Percentage Rot by Weight 2/ Months of storage 0		2		4	
E.carotovora subsp. carotovora	28.6	b	6.2	b	2.5	b
E.chrysanthemi	36.8	a	15.4	a	6.8	a
Mean	32.7	A	10.8	B	4.7	C

1/Each value is the mean of 2 inoculation methods,immersion and vacuum infiltration and the response of 16 clones.Tubers incubated 4 days at 25 C in a mist chamber following inoculation before evaluation.

2/Column values followed by the same lower case letter and row values followed by the same upper case letter do not differ at the 5% probability level(Duncan's multiple range test).

Vacuum and immersion methods of inoculation were significantly correlated for the 16 clones when measurements were made before storage (r=0.68) and after 2 months storage (r=0.82) but not after 4 months storage.

In this experiment,when evaluated before storage,Yungay,Serrana, Desiree,LT-1 and Kufri Jyoti were among the more resistant clones following immersion inoculation and Yungay,Desiree,Serrana and Kufri Jyoti were also most resistant following vacuum infiltration (Table 4.4). However,DTO-33 was one of the more susceptible clones when vacuum infiltrated.

Table 4.4 Influence of method of inoculation and time in rustic storage on tuber soft rot susceptibility of 16 clones (March-June,1989) 1/

Inoculat. Method		Clones	Percentage Rot by Weight 2/ Months of storage 0		2		4	
I	1	Serrana	17.1	f	4.9	bcd	1.9	a
M	2	Desiree	18.4	ef	3.8	bcd	4.4	a
M	3	Yungay	18.5	ef	4.3	bcd	0.9	a
R	4	LT-1	18.5	ef	8.0	b	0.9	a
S	5	K.Jyoti	18.7	ef	7.7	bc	2.7	a
S	6	DTO-33	21.9	de	7.9	b	4.8	a
I	7	CFK 69.1	25.5	cd	2.7	cd	1.9	a
O	8	Atzimba	25.6	cd	4.9	bcd	0.3	a
N	9	CGN 69.1	25.7	cd	3.4	bcd	1.4	a
	10	Mariva	26.1	cd	4.9	bcd	1.3	a
	11	Rosita	26.8	c	5.7	bcd	2.4	a
	12	LT-7	27.8	c	16.9	a	2.1	a
	13	LT-5	29.9	bc	5.4	bcd	3.5	a
	14	I-931	33.1	ab	1.9	d	0.9	a
	15	B71 240.2	33.5	ab	3.9	bcd	2.3	a
	16	LT-2	35.5	a	4.8	bcd	1.8	a
		Mean	25.2	A	5.7	B	2.1	C
V	I	1 Yungay	27.1	i	12.9	cd	1.7	f
A	N	2 Desiree	30.7	hi	15.2	bcd	10.2	ab
C	F	3 Serrana	34.3	gh	14.7	bcd	4.7	cdef
U	I	4 K.Jyoti	34.9	fgh	16.1	bcd	10.6	ab
U	L	5 CGN 69.1	37.0	efg	12.3	d	2.5	f
M	T	6 Rosita	38.1	efg	16.2	bcd	4.4	def
	R	7 LT-1	39.1	def	17.3	bcd	9.6	abc
	A	8 Mariva	40.6	cde	15.5	bcd	3.6	ef
	T	9 B71 240.2	41.5	cde	13.1	cd	7.8	abcde
	I	10 CFK 69.1	43.6	bcd	14.6	bcd	9.4	abc
	O	11 LT-5	43.5	bcd	18.8	b	8.6	abcd
	N	12 Atzimba	43.6	bcd	17.7	bc	8.6	abcd
		13 I-931	44.2	bc	15.2	bcd	5.8	bcdef
		14 DTO-33	44.2	bc	15.8	bcd	8.6	abcd
		15 LT-2	47.5	b	14.3	bcd	7.7	abcde
		16 LT-7	53.4	a	23.7	a	12.2	a
		Mean	40.2	A	15.8	B	7.2	C

1/Each value is the mean response to Ecc and Echy inoculated separately using either immersion or vacuum infiltration. Following inoculation tubers were incubated at 25 C in a mist chamber for 4 days before evaluation.

2/Column values followed by the same lower case letter and row values by the same upper case letter do not differ at the 5% probability level (Duncan's multiple range test).

March-June,1989-Microinjection Method

Analysis of variance of rot data is shown in Table A.21. The extent of rotting was directly related to the log of the bacterial concentration used in the inoculation (Table 4.5). The correlation coefficient was 0.99.

As in the previous studies there also was a significant correlation between Ecc and Echy. Therefore the rotting response of each of the 16 clones is shown as the mean rotting response to two pathogens at 3 concentrations (Table 4.6).

There was no significant correlation between inoculation by infiltration (vacuum or immersion) used in the previous studies and microinjection. Some clones,eg.DTO-33,B71 240.2 and LT-2 that were quite susceptible (relative to other clones) when vacuum infiltrated proved to be quite resistant when injected (compare Tables 4.2 or 4.4 with Table 4.6). Desiree on the other hand was quite resistant regardless of the method of inoculation. Other clones, eg. Yungay and Serrana were more resistant than most other clones when infiltrated but were intermediate in susceptibility when injected. Mariva,LT-5 and Atzimba were among the most susceptible whether infiltrated or injected.

Similar to infiltration inoculation,no correlation was found among the 3 times of evaluation (0,2 and 4 months storage) when tubers were inoculated by microinjection. All clones became less susceptible with time in storage but the difference in rotting among observations was less pronounced than when tubers were inoculated by infiltration.

Table 4.5 The effect of inoculum concentration on Tuber Soft Rot susceptibility using the microinjection method of inoculation (March-June,1989). 1/

Inoculum concentration c.f.u. per ml.	Rot diameter 2/ mm	
1×10^4 3/	14.7	c
1×10^5	17.5	b
1×10^6	22.5	a

1/Each value is the mean of 3 evaluations,before storage and after 2 and 4 months storage; 16 clones and 2 pathogens E.carotovora subsp.carotovora and E.chrysanthemi inoculated separately using microinjection. Tubers incubated 4 days at 25 C in a mist chamber before evaluation.

2/Means with the same letters do not differ at the 5% probability level (Duncan's multiple range test).

3/Correlation coefficient,Log Conc. vs Rot Diameter=0.99

Table 4.6 Influence of time in rustic storage on tuber soft rot rot susceptibility of 16 clones using the microinjection method of inoculation (March-June,1989). 1/

Clones	Rot Diameter (mm) 2/ Months of storage 0	2	4
DTO-33	19.8 i	13.5 ghi	8.4 d
B71-240-2	21.6 hi	15.5 fgh	11.2 cd
CGN-69-1	22.8 gh	13.9 ghi	11.5 cd
Desiree	23.2 gh	18.8 de	12.9 bc
Kufri Jyoti	23.8 fgh	20.3 cd	14.3 abc
LT-2	25.4 efg	16.4 efg	11.1 cd
LT-7	25.9 def	27.6 a	13.4 abc
Serrana	26.1 cdef	17.7 def	3.6 e
Yungay	26.1 cdef	12.7 hi	8.6 d
LT-1	26.6 cde	18.8 de	15.9 a
Rosita	27.5 bcde	14.0 ghi	12.1 bc
CFK-69-1	28.2 bcd	17.9 def	11.1 cd
I-931	28.8 bc	12.6 hi	8.7 d
Atzimba	29.6 b	11.4 i	8.5 d
Mariva	32.1 a	17.7 def	11.5 cd
LT-5	33.9 a	23.4 b	15.2 ab
Mean	26.3 A	17.2 B	11.1 C

1/Each value is the mean of 3 levels of inoculum; $1x10^4$, $1x10^5$ and $1x10^6$ c.f.u. per ml and 2 pathogens; *E.carotovora* subsp.*carotovora* and *E.chrysanthemi* inoculated separately using microinjection. Tubers incubated at 25 C in a mist chamber for 4 days before evaluation.

2/Column values followed by the same lower case letter and row values followed by the same upper case letter do not differ at the 5% probability level (Duncan's multiple range test).

4.3 RELATIONSHIP OF DRY MATTER AND WATER POTENTIAL TO SOFT ROT SUSCEPTIBILITY CAUSED BY ERWINIA spp. IN TUBERS OF CLONES ADAPTED TO THE WARM TROPICS

4.3.1 Materials and Methods

4.3.1.1 Soft rot evaluation

Seed tubers of the following seventeen clones were planted in Huancayo in late November,1988:DTO-33,B71 240.2,LT-2,LT-1,LT-5,Desiree, Kufri Jyoti,LT-7,LT-8,Atzimba,I-931,CFK 69.1,Serrana,CGN 69.1,Rosita,Mariva and Yungay. Tubers were harvested during the period from March to May,1989 and then taken to San Ramon. Tubers were carefully selected,to avoid those with cuts,rots or excessive skinning. Tubers were washed with well water and soaked in sodium hypochlorite solution (0.5% active chlorine) for 10 minutes. They were then washed twice with well water and allowed to dry for 2 days. Tubers were evaluated before storage and again after storing 2 and 4 months at a temperature of about 24 C in a charcoal walled rustic storage at San Ramon. For each evaluation, tubers were inoculated with Erwinia spp. by vacuum infiltration using a bacterial suspension containing 1×10^6 cfu per ml. For each evaluation 30 tubers from each clone were placed in 6 plastic mesh bags,five tubers per bag. Three replicates of five tubers each were inoculated with Echy and the other three with Eccc.

Inoculated tubers were placed randomly in a mist chamber at about 25 C to maintain a constant film of water on the tuber surface.After four days incubation tubers were removed from the chamber and the amount of rotted tissue in each tuber was determined by weighing tubers before and after washing away the rotted tissue with running well water.

4.3.1.2 Dry matter content

Three samples of five tubers each per clone were washed,dried and weighed. Tubers were then sliced and placed in paper bags and dried 4 days at 70 C. Percentage Dry matter was calculated by dividing the dry weight by the initial weight and multiplying by 100.

4.3.1.3 Water potential

The water potential of the potato tubers was estimated using the Weight Change Method described by Ross (1974). This method is based on the principle that tubers placed in a solution with the same water potential neither gain nor lose water. This is determined by changes in tissue weight following immersion in solutions having a range of water potentials.

A 1 M sucrose solution was prepared and diluted appropriately to make solutions of 0.15 M, 0.20 M, 0.25 M, 0.30 M and 0.35 M sucrose. For each evaluation,45 cylinders of tissue were cut from tubers of each clone using a 8-mm cork borer. Each cylinder was cut with care to 40 mm length removing any suberized tissue. For each clone 3 replicates of 3 cylinders each were weighed and placed into a petri dish containing one of the sucrose solutions. The cylinders were soaked for two hours, then removed and blotted lightly on a paper towel and weighed again. The % weight change was plotted on a graph with % weight decrease or increase plotted on the ordinate and molarity of the sucrose solution plotted on the abscissa. A straight line that best fit the data was then drawn. The water potential of the sucrose solution where the line crossed the zero change line was considered equivalent to the water potential of the potato tissue.

4.3.2 Results

Analysis of variance of Tuber Rot susceptibility to Ecc and Echy,Tuber Dry Matter and Tuber Water potential are shown in Tables A.22,A.23,A.24 and A.25,respectively. The data obtained after 0,2 and 4 months in rustic storage are shown in Tables 4.7,4.8 and 4.9,respectively. As shown previously, susceptibility of all clones to both Ecc and Echy decreased with time in storage. Also,Ecc was less virulent than Echy on each observation. Rotting in all clones decreased with time in storage, % dry matter increased and water potential decreased.

The coefficients of linear correlation relating each factor for the three observations are shown in Table 4.10. A highly significant correlation occurred between Ecc and Echy in causing soft rot in the 17 clones. This confirmed observations in previous studies. No significant correlations were found between either Ecc or Echy rotting and percentage dry matter or tuber water potential.

The means of the 17 clones in rotting,dry matter and water potential for each observation are shown in Table 4.11. Using these means, a highly significant correlation also occurred between Ecc and Echy in the extent of rotting. The linear correlation coefficient obtained for all comparisons among Ecc,Echy,dry matter and water potential although high numerically were not significant even at the 0.1% level (see footnote Table 4.11).

Table 4.7 Relationship of Soft Rot Susceptibility to Dry Matter and Water Potential of tubers of 17 clones before storage (May,1989). 1/

Clones	Percentage Rot by Weight 2/		Dry Matter 2/	Water Potential 2/
	E.carotovora subsp.carotovora	E.chrysanthemi	%	bars
Serrana	18.0 f	18.6 h	17.5 bcd	-7.4 ab
Yungay	14.9 f	25.2 gh	18.9 abc	-6.6 bc
DTO-33	16.6 f	28.8 g	19.5 ab	-7.1 ab
I-931	20.7 ef	28.7 fg	18.7 abc	-3.7 fg
Kufri Jyoti	16.4 f	36.8 ef	16.3 d	-4.7 d
CFK 69.1	27.7 d	38.8 e	17.4 bcd	-2.9 gh
LT-8	16.8 f	41.7 de	18.6 abc	-7.4 ab
B71 240.1	34.1 c	42.1 de	18.7 abc	-1.9 i
CGN 69.1	40.8 b	43.2 de	18.9 abc	-6.2 c
Atzimba	20.0 f	44.4 cde	19.9 a	-4.1 def
Rosita	44.3 b	48.4 cd	16.9 cd	-4.6 de
LT-5	25.6 de	50.7 cd	19.1 ab	-4.4 def
LT-1	29.6 cd	50.0 cd	19.4 ab	-7.6 a
LT-7	33.4 c	50.2 cd	19.4 ab	-3.2 gh
Mariva	43.7 b	53.0 c	19.5 ab	-3.7 fg
LT-2	57.4 a	62.0 b	18.1 abcd	-2.7 hi
Desiree	40.2 b	72.6 a	18.6 abc	-6.8 abc

1/Following inoculation by vacuum infiltration, tubers were incubated at 25 C in a mist chamber for 4 days before evaluation.

2/Means with the same letter in each column do not differ at the 5% probability level (Duncan's multiple range test).

Table 4.8 Relationship of Soft Rot Susceptibility to Dry Matter and Water Potential of tubers of 17 clones after 2 months in rustic storage (May-June,1989). 1/

Clones	Percentage Rot by Weight 2/		Dry Matter 2/		Water Potential 2/	
	E.carotovora subsp.carotovora		E.chrysanthemi		%	bars
Rosita	2.5	e	7.6	f	20.8 ab	-9.5 ab
Yungay	2.9	cde	9.8	ef	19.6 abcd	-10.0 a
B71 240.1	7.2	bcde	11.3	ef	18.9 bcd	-9.2 abc
LT-8	8.0	bcd	14.9	def	19.7 abcd	-8.2 d
LT-1	4.8	bcde	16.6	cde	21.5 a	-9.8 ab
Serrana	8.0	bcd	16.6	cde	18.2 de	-9.5 ab
LT-2	7.9	bcd	16.7	bcde	19.8 abcd	-9.1 abc
CGN 69.1	2.7	de	16.8	bcde	19.8 abcd	-9.1 abc
Atzimba	7.3	bcde	22.3	abcd	20.4 abcd	-5.5 f
CFK 69.1	6.8	bcde	22.4	abcd	18.3 cd	-8.5 cd
DTO-33	5.3	bcde	22.8	abcd	20.4 abcd	-9.6 ab
Kufri Jyoti	11.1	b	23.5	abcd	16.3 e	-8.4 cd
Desiree	8.9	bc	24.9	abc	18.9 bcd	-6.8 e
LT-5	10.9	b	25.9	ab	19.5 abcd	-5.6 f
I-931	6.7	bcde	27.1	a	18.4 cd	-7.0 e
Mariva	7.4	bcde	28.7	a	20.8 ab	-9.3 abc
LT-7	17.9	a	30.5	a	20.5 abc	-5.9 f

1/Following inoculation by vacuum infiltration,tubers were incubated at 25 C in a mist chamber for 4 days before evaluation.

2/Means with the same letter in each column do not differ at the 5% probability level (Duncan's multiple range test).

Table 4.9 Relationship of Soft Rot Susceptibility to Dry Matter and Water Potential of tubers of 17 clones after 4 months in rustic storage (May-August,1989). 1/

Clones	Percentage Rot by Weight 2/				Dry Matter 2/ %		Water Potential 2/ bars	
	E.carotovora subsp.carotovora		E.chrysanthemi					
Serrana	2.3	bc	3.6	g	18.4	ef	-11.7	defg
Yungay	0.4	c	5.7	fg	20.2	bcde	-13.7	b
LT-1	1.8	bc	5.3	fg	20.8	abcd	-12.7	c
B71 240.1	3.9	abc	7.2	efg	18.9	def	-12.7	c
LT-5	0.9	c	7.7	efg	21.8	ab	-11.4	efg
Desiree	0.8	c	8.4	defg	19.3	cde	-10.4	h
Kufri Jyoti	2.4	bc	8.9	cdefg	17.2	f	-11.4	efg
DTO-33	3.6	abc	12.2	bcdefg	21.1	abcd	-12.4	cd
LT-8	2.0	bc	14.4	bcdef	20.5	abcde	-14.6	a
Rosita	2.2	abc	15.4	bcde	18.5	ef	-11.9	cdef
CFK 69.1	7.2	ab	16.8	bcd	19.2	cdef	-11.7	defg
LT-2	6.0	abc	17.2	bcd	19.6	bcde	-11.2	fgh
Mariva	2.1	bc	17.3	bcd	21.3	abc	-10.9	gh
CGN 69.1	2.0	bc	17.8	abc	21.1	abcd	-12.3	cde
I-931	3.1	abc	18.6	ab	19.5	cde	-12.6	c
LT-7	8.9	a	20.1	a	22.4	a	-12.4	cd
Atzimba	5.8	abc	26.1	a	20.1	bcde	-11.9	cdef

1/Following inoculation by vacuum infiltration,tubers were incubated at 25 C in a mist chamber for 4 days before evaluation.

2/Means with the same letters in each column do not differ at the 5% probability level (Duncan's multiple range test).

Table 4.10 Coefficients of linear correlation showing the relationship between Ecc and Echy induced rot,tuber Dry Matter content and tuber Water Potential using data obtained on 17 clones after 3 periods of storage.

Time in storage Months	Ecc/Echy	Ecc/Dry Matter	Ecc/Water Potential	Echy/Dry Matter	Echy/Water Potential
0	0.71 **	0.02	-0.41	-0.23	-0.23
2	0.66 **	-0.22	-0.64	-0.11	-0.63
4	0.61 **	0.13	-0.07	0.27	0.05

** Significant at the 1% probability level

Table 4.11 Summary of Tables 4.7,4.8 and 4.9 showing the effect of time in rustic storage on Soft Rot susceptibility,Dry Matter and Water Potential of tubers of 17 clones (May-August,1989). 1/

Storage period Months	Percentage Rot by Weight 2/ Ecc	Echy	Dry Matter 2/ %	Water Potential 2/ bars
0	29.4 a 3/	43.3 a	18.6 c	-4.99 a
2	7.3 b	19.9 b	19.4 b	-8.30 b
4	3.3 c	13.1 c	19.9 a	-12.11 c

1/Each value is the mean of 17 clones.Following inoculation by vacuum infiltration,tubers were incubated at 25 C in a mist chamber for 4 days before evaluation.

3/Means with the same letter in each column do not differ at the 5% probability level (Duncan's multiple range test).

2/Correlation coefficients:
Ecc vs Echy 1.00 **
Ecc vs Dry Matter -0.97 ns
Ecc vs Water Potential 0.91 ns
Echy vs Dry Matter -0.98 ns
Echy vs Water Potential 0.94 ns

4.4 DISCUSSION

For the 11 clones common to both years a highly significant correlation in rotting response was found between 1988 and 1989 when measurements were made before storage. This was true for either vacuum or immersion infiltration of the bacteria. Due to the excellent correlations in rotting response of the 11 clones for the two years the data for 1988 and 1989 were combined. The results are shown in Table 4.12. The 4 observations;immersion or vacuum infiltration after 0,2 and 4 months storage in 1988 and 1989 were used as replications in the Analysis of variance (Table A.26). Before storage,Desiree was the least susceptible to soft rot, but did not differ significantly from 6 other clones. LT-2, I-931, and Atzimba were the most susceptible and did not differ significantly from each other. No significant correlations were found in the percentage rot in the 11 clones between 0 and 2 months storage nor between 2 and 4 months. After 2 months storage some statistical differences occurred among clones but the numerical differences among clones in percentage rot was small. No significant differences occurred among clones after 4 months storage and the differences did not exceed 2 %.

If the CIP scale for rating soft rot susceptibility (International Potato Center,1988a) were to be applied to these data, all clones would be rated either susceptible (10-30% rot) or very susceptible (>30%) when measurements were made before storage. After 2 months storage,however, most clones were either medium resistant or approaching medium resistant (5-10% rot). After 4 months storage all were "resistant" (<5% rot). From these observations it is very clear that any soft rot susceptibility evaluations should be done before storage-at least when stored in rustic storage at 25 C.

Table 4.12 Summary of tuber soft rot susceptibility of 11 clones studied in 1988 and 1989. 1/

Clones	Percentage Rot by Weight 2/ Months of storage 0	2	4
Desiree	28.6 d	13.1 a	4.1 a
LT-1	30.2 d	12.9 a	3.3 a
Kufri Jyoti	31.2 d	11.8 ab	4.2 a
CFK 69.1	34.6 cd	11.3 ab	3.9 a
DTO-33	35.9 cd	11.5 ab	4.9 a
CGN 69.1	36.3 cd	7.7 b	2.7 a
Rosita	36.5 cd	8.9 b	3.2 a
B71 240.2	40.7 bc	10.2 ab	4.6 a
Atzimba	44.2 ab	10.4 ab	4.6 a
I-931	47.9 ab	9.6 ab	4.2 a
LT-2	49.6 a	12.6 a	3.9 a
Mean	37.8 A	10.9 B	3.9 C

1/Each value is the mean of 4 observations;immersion and vacuum infiltration for 1988 and 1989 tests;data from Tables 4.2 and 4.4.

2/Column values followed by the same lower case letter and row values followed by the same upper case letter do not differ at the 5% probability level(Duncan's multiple range test).

Changes that occur in storage at 25 C would be many. The most important changes contributing to this apparent increase in "resistance" to soft rot could be a decrease in water potential, increase in periderm resistance to penetration due to suberization and lignification and a complete loss of sugar or changes in other substrates.

Irrespective of the CIP rating scale Table 4.12 shows that there were clonal differences in soft rot susceptibility. Before storage,Desiree showed the least rot with a mean of 28.6% soft rot but did not differ significantly from 6 other clones while LT-2 on the other extreme averaged 49.6%. Other clones fell in between and there was considerable statistical overlap.

The higher percentage rot resulting from vacuum infiltration compared to immersion most likely reflects the more effective penetration of the periderm and consequent higher concentration of bacteria in the tubers. Differences among clones in soft rot susceptibility may reflect a difference in mechanical periderm resistance rather than a physiological resistance present within the tuber. As mentioned above, some of the apparent increased resistance with time in storage may also be due to increased periderm resistance.

There was no significant correlation between infiltration of the bacteria by either vacuum or immersion and microinjection. With some clones,eg. DTO-33 susceptibility relative to other clones was low when injected and high when immersed. Perhaps this may be explained by the following. The amount of rotting was proportional to the inoculum concentration in the microinjection study. The number of bacteria that may enter the tuber when infiltrated would depend on the resistance offered by the periderm and therefore could vary among clones. On the other hand with microinjection, the concentration of bacteria in all clones would be equal. Possibly then a clone like DTO-33 could posses a degree of resistance within the tuber but having a weak thin periderm would have received a higher concentration of bacteria than some other clones. The opposite seemed to be the case with Yungay and Serrana that were both more resistant when infiltrated but were more susceptible relative to other clones when injected.

Another difference between infiltration and injection is that different tissues within the tuber may carry the bacteria. With infiltration most bacteria may be in the cortical tissue while with injection most bacteria may be in the pith.

No significant correlations were found between Ecc or Echy rotting and dry matter or water potential. Other work has indicated that certain bacterial pathogens cannot rot tissue if water potential is below -49 bars (Anonymous,1960). The water potential among the test clones before storage was only from -1.9 bars to -7.4 bars which most likely is insufficient to override inherent clonal differences in soft rot susceptibility. After 2 months storage,water potential ranged only from -5.6 to -10 bars and after 4 months from -10.4 to -14.6 bars. Again the differences in water potential were most likely insufficient to override clonal differences in soft rot susceptibility.

The mean change in water potential among the 3 observation dates (-4.99,-8.30 and -12.1) likewise was probably not a significant factor in the large decrease in rotting that occurred with time in storage (Table 4.11). As mentioned above many other internal biochemical and physiological changes could occur in tubers stored at 25 C that could alter their soft rot susceptibility. Future research with fewer clones would permit a more detailed analysis of tuber stored at 25 C and possibly identify factors that are responsible for the apparent decrease in soft rot susceptibility.

5. TUBER SUSCEPTIBILITY TO DRY ROT CAUSED BY FUSARIUM Spp.

5.1 INTRODUCTION

Tuber dry rot of the potato is caused by many Fusarium spp. and is a serious disease of stored potatoes worldwide (Rich,1983). In North America,Fusarium tuber rot and seed piece decay are major causes of loss to the potato industry (Leach,1981). In San Ramon,Peru,F.solani (Fs) and F.oxysporum (Fo) were responsible for 23.7% and 45.3% of tuber rot in seed tubers held in diffuse light seed storage,respectively (International Potato Center,1987a).

Two experiments with Fusarium spp. were designed and carried out with the following objectives:

1.Assess tuber susceptibility to dry rot caused by F.solani and F.oxysporum in clones adapted to the warm tropics.

2. Determine the wound healing ability of clones to reduce rotting due to F.solani.

5.2 ASSESSMENT OF TUBER SUSCEPTIBILITY TO DRY ROT CAUSED BY FUSARIUM spp. IN CLONES ADAPTED TO THE WARM TROPICS

5.2.1 Materials and Methods

The following 16 clones were evaluated:DTO-33,B71 240.2,LT-2, LT-1, LT-5,Desiree, Kufri Jyoti,LT-7,Atzimba,I-931,CFK 69.1,Serrana,CGN 69.1, Rosita, Mariva and Yungay. The clones were all grown at Huancayo (3200 m elevation). Vines were removed from each clone when 90% dead and tubers were harvested after 15 days and transported to San Ramon. Only tubers free of cuts,diseases and excessive skinning were used. Tubers were washed with well water, soaked in sodium hypochlorite solution (0.5% active chlorine) for 10 minutes,rinsed twice in well water and air dried for 2 days.

Stock cultures of F.solani Snyder & Hansen (Fs) and F.oxysporium Snyder & Hansen (Fo) isolated from rotting tubers in San Ramon were maintained at 4 C on Potato Dextrose Agar (PDA-Difco Ltd.) slants. Bits of growth from stock cultures were transferred to PDA plates and incubated for 10 days at 25 C to increase inoculum for inoculation.

Thirty tubers each weighing 80-120 grs of each clone were evaluated before storage. Another sixty tubers of each clone were stored in a charcoal walled rustic storage at San Ramon for evaluation after 2 and 4 months storage. For each evaluation, three replicates of five tubers were inoculated with Fs and another three replicates were inoculated with Fo. The inoculation method of Tivoli and Jouan (1981) was used. A core of tuber cortex tissue 0.5 cm diameter and 0.5 cm deep was removed midway

between the bud end and stolon end of each tuber with a # 2 cork borer. Each injury site was inoculated by placing a 0.5 cm diameter disc of growth from the outer edge of a Fusarium culture into each wound. The core of potato tissue was replaced on top of the inoculum disc. The inoculated tubers were placed on metal wire racks inside non-sealed plastic chambers (45 x 25 cm) humidifed by lining with wet paper towels. The chambers were placed on wooden shelves in the charcoal walled rustic storage which averaged 24 C and 85% relative humidity. After 20 days incubation,the degree of visible external rotting was determined by measuring the maximum radius of the dry rot lesion on the surface of each tuber.

5.2.2 Results

The Analysis of variance for this study is shown in Table A.27. The amount of tuber dry rot caused by Fs was significantly greater than that caused by Fo (Compare Tables 5.1 and 5.2). A weak correlation (r=0.50) was found between the two pathogens in causing tuber dry rot in the 16 clones when tubers were evaluated before storage.No correlations were found between the two pathogens in causing tuber dry rot when evaluations were done after 2 and 4 months in rustic storage.

Certain clones eg. Serrana and LT-1 were very susceptible to Fs and quite resistant to Fo. To a lesser extent,the reverse was true for clones such as I-931 and Atzimba (Tables 5.1 and 5.2).

Tuber susceptibility of all clones to both Fs and Fo increased significantly with time in storage. The mean maximun radius of the lesions of 16 clones inoculated with Fs increased from 11.4 mm before storage to 16.8

Table 5.1 Influence of time in rustic storage on susceptibility of 16 clones to tuber dry rot caused by F.solani (March-June,1989). 1/

Clones	Maximum Radius of Dry Rot Lesions (mm) 2/ Months of storage 0		2		4		Mean	
LT-7	1.5	g	1.9	d	3.6	i	2.3	g
LT-5	7.7	g	8.8	d	17.1	fgh	11.2	f
Mariva	7.6	g	12.9	c	14.2	h	11.6	f
Kufri Jyoti	8.9	efg	13.8	bc	15.8	gh	12.8	f
I-931	8.5	fg	13.9	bc	22.0	bcde	14.8	e
Desiree	11.2	defg	16.9	ab	17.1	fgh	15.1	e
Atzimba	10.9	defg	13.8	bc	20.6	cdef	15.1	e
B71 240.2	8.9	efg	17.0	ab	23.8	abc	16.5	cde
CGN 69.1	15.6	bc	16.8	ab	19.5	def	17.3	bcd
Rosita	11.9	def	19.2	a	22.2	bcde	17.8	bcd
DTO-33	11.1	defg	18.1	a	25.3	ab	18.2	abc
LT-2	14.0	cd	18.8	a	23.6	abc	18.8	ab
CFK 69.1	12.5	cde	17.5	a	26.7	a	18.9	ab
LT-1	14.2	cd	19.9	a	23.1	bcd	19.0	ab
Serrana	18.2	ab	19.3	a	20.5	cdef	19.3	ab
Yungay	19.4	a	19.5	a	21.2	cde	20.0	a
Mean	11.4	C	16.8	B	19.9	A		

1/Following inoculation,tubers were incubated in rustic storage for 20 days before evaluation.

2/Column values followed by the same lower case letter and row values followed by the same upper case letter do not differ at the 5% probability level (Duncan's Multiple range test).

Table 5.2 Influence of time in rustic storage on susceptibility of 16 clones to tuber dry rot caused by F.oxysporum (March-June,1989). 1/

Clones	Maximum Radius of Dry Rot Lesions (mm) 2/ Months of storage 0	2	4	Mean
LT-7	0.0 d	0.0 e	0.9 g	0.3 i
Serrana	0.3 cd	0.8 de	0.9 g	0.3 i
Mariva	0.5 bcd	1.0 de	1.2 g	0.9 i
LT-1	0.0 d	1.9 cde	2.3 g	1.4 hi
Kufri Jyoti	2.1 bcd	3.3 bcde	4.2 efg	3.2 fgh
Rosita	0.3 cd	3.6 bcde	6.8 def	3.3 fgh
LT-5	0.9 bcd	1.3 cde	3.7 fg	3.5 efg
Desiree	1.1 bcd	2.3 cde	7.1 def	3.5 efg
DTO-33	1.7 bcd	3.7 bcde	7.5 cde	4.3 def
CFK 69.1	2.0 bcd	4.0 bcde	8.6 bcd	4.9 cdef
CGN 69.1	3.2 bcd	3.6 bcde	9.6 bcd	5.5 bcde
LT-2	4.2 b	4.6 bc	7.7 cde	5.5 bcde
Atzimba	3.9 bc	4.3 bcd	9.6 bcd	5.9 bcd
I-931	1.8 bcd	7.1 ab	11.0 abc	6.6 bc
B71 240.2	2.8 bcd	5.0 bc	13.5 a	7.1 b
Yungay	8.9 a	9.4 a	11.6 ab	9.9 a
Mean	2.1 C	3.4 B	6.6 A	

1/Following inoculation,tubers were incubated in rustic storage for 20 days before evaluation.

2/Column values followed by the same lower case letter and row values followed by the same upper case letter do not differ at the 5% probability level (Duncan's Multiple range test).

and 19.9 mm after 2 and 4 months in rustic storage,respectively (Table 5.1). Similarly,when tubers were inoculated with Fo,mean lesion size increased from a maximum radius of 2.1 mm before storage to 3.4 mm and 6.6 mm after 2 and 4 months storage,respectively (Table 5.2).

Significant correlations were found between the amount of dry rot caused by Fs before storage and after 2 months in rustic storage (r=0.79) and between 2 and 4 months in rustic storage(r=0.86). Therefore,clonal comparisons can be made on the mean of the 3 evaluations (0,2 and 4 months). LT-7 was significantly more resistant to Fs than the other 15 clones (Table 5.1). Below LT-7,clones appeared to fall into roughly 4 groups but some statistical overlapping occurred. The more susceptible clone were Yungay,Serrana,LT-1,CFK 69.1,LT-2 and DTO-33.

Significant correlations were also found between the amounts of dry rot caused by Fo before storage and after 2 months in rustic storage (r=0.84) and between 2 and 4 months in rustic storage (r=0.84). Thus,clonal comparisons for reaction to Fo can also be made based on the mean of 3 observations (0,2 and 4 months). LT-7,Serrana and Mariva were significantly more resistant than the other 13 clones.Yungay was the most susceptible clone to Fo. Between the most resistant and susceptible,the clones fell into about 3 groups although considerable statistical overlapping occurred.

5.3 EFFECT OF WOUND HEALING PERIODS ON THE EXTENT OF DRY ROT CAUSED BY F.solani

5.3.1 Materials and Methods

The following 15 clones were used in this study: DTO-33,B71 240.2, LT-2, LT-1, LT-5, Desiree, Kufri Jyoti, LT-7, Atzimba, I-931,CFK 69.1, Serrana, CGN 69.1, Rosita and Mariva. All clones were grown at Huancayo and each was harvested following 90% vine death and removal. The tubers were transported to San Ramon for evaluation. Tubers,each weighing from 80 to 120 grs were carefully selected to avoid those with cuts, diseases and excessive skinning. Tubers were washed with well water and soaked in sodium hypochlorite solution (0.5% active chlorine) for 10 minutes,washed twice in well water and allowed to dry for 2 days. Tubers were stored for one month in a charcoal walled rustic storage before evaluation. This study was done during May-June,1989. The temperatures in the storage at this time averaged 24 C with 85 % relative humidity. Tubers were protected from Potato Tuber Moth (PTM) by covering them with a layer of plastic screen.

A stock culture of F.solani Snyder & Hansen (Fs) was maintained at 4 C on Potato Dextrose Agar (PDA-Difco Ltd.) slants. Small portions of fungus growth from the colony were transferred to PDA in petri dishes and incubated 10 days at 25 C to produce inoculum for inoculation.

One fourth of the apical end of each tuber was cut off with a sterile knife and discarded 10,8,4,2 or 0 days before inoculation and discarded. The remaining portion of each tuber was placed in non-sealed plastic chambers to enhance healing of cut surfaces. The chambers were placed in the charcoal walled rustic storage until inoculation.

On the day of inoculation a disk of PDA 0.5 cm in diameter containing the fungus was cut from the outer edge of the F.solani culture and placed in the center of the cut surface of each tuber. Three replicates of five tubers each for each wound healing period and for each clone were inoculated. Inoculated tubers were placed on wire mesh inside the non-sealed plastic chambers (45 x 25 cm) containing wet paper towels. Chambers were returned to the charcoal walled rustic storage for incubation.

After 20 days incubation,the maximum radius of the dry rot lesion on the cut tuber surface was measured. The radius of the lesion on tubers without wound healing (0 days) was used as the reference to calculate the percentage reduction after 2,4 and 6 days healing.

5.3.2 Results

Analysis of variance for this study is shown in Table A.28. A significant reduction in the mean lesion size for 15 clones occurred with each healing period through 8 days (Table 5.3). No significant change in the mean lesion size occurred between 8 and 10 days. Significant differences in lesion size were observed among clones before healing and after each of the 5 wound healing periods. The magnitude of differences among clones diminished with successive wound healing periods. After 6,8 and 10 days of wound healing, only clone CFK 69.1 differred significantly from the other 14 clones. With the exception of this clone,all clones had developed a barrier completely resistant to F.solani with 8 days of healing.

In order to determine the rate at which barrier formation occurred in each clone, the percentage reduction in lesion size was calculated using the lesion size before healing as a reference (Table 5.4).

Table 5.3 Influence of the Wound Healing of the cut surface on tuber susceptibility of 15 clones to F.solani (April,1989). 1/

Clones	Maximum Radius of Dry Rot Lesions 2/ Days of Wound Healing											
	0		2		4		6		8		10	
LT-7	8.1	g	4.6	e	1.1	c	0.0	b	0.0	b	0.0	b
LT-5	10.4	fg	4.8	e	2.3	c	0.0	b	0.0	b	0.0	b
B71 240.2	10.5	fg	5.0	e	2.4	c	0.4	b	0.0	b	0.0	b
Kufri Jyoti	11.4	f	4.8	e	0.5	c	0.0	b	0.0	b	0.0	b
I-931	15.3	e	10.1	d	7.5	b	2.8	b	0.9	b	0.0	b
DTO-33	15.7	e	5.7	e	2.1	c	0.7	b	0.0	b	0.0	b
Atzimba	16.3	de	11.1	bcd	7.1	b	2.6	b	0.8	b	0.0	b
Serrana	17.4	de	10.9	cd	2.4	c	0.0	b	0.0	b	0.0	b
LT-2	19.1	d	7.1	e	2.0	c	0.9	b	0.0	b	0.0	b
CGN 69.1	22.0	c	13.4	abc	9.1	ab	1.3	b	0.0	b	0.0	b
LT-1	22.5	bc	14.1	ab	3.4	c	1.2	b	0.0	b	0.0	b
Mariva	23.2	bc	11.4	bcd	7.2	b	0.8	b	0.0	b	0.0	b
Rosita	24.7	abc	13.4	abc	8.5	ab	1.3	b	0.0	b	0.0	b
CFK 69.1	25.3	ab	16.2	a	11.1	a	7.4	a	6.5	a	4.5	a
Desiree	27.0	a	15.3	a	0.9	c	0.0	b	0.0	b	0.0	b
Mean	17.9	A	9.8	B	4.9	C	1.3	D	0.5	E	0.3	E

1/Following inoculation,tubers were incubated in rustic storage for 20 days before evaluation.

2/Column values followed by the same lower case letter and row values followed by the same upper case letter do not differ at the 5% probability level (Duncan's Multiple range test).

Table 5.4. Influence of Wound Healing of the cut surface on the Percentage Reduction of tuber susceptibility of 15 clones to F.solani (April,1989). 1/

Clones	Percentage of Reduction of Dry Rot Lessions 2/ Days of Wound Healing 2		4		6		Mean	
Kufri Jyoti	57.5	ab	96.1	a	100.0	a	84.5	a
LT-2	62.8	a	89.6	ab	94.7	ab	82.4	ab
DTO-33	63.9	a	86.9	ab	95.2	ab	82.0	ab
Desiree	42.8	bcde	96.7	a	100.0	a	77.1	abcd
LT-5	53.1	abc	78.2	bc	100.0	a	77.1	abcd
LT-7	43.0	bcde	85.6	ab	100.0	a	76.2	abcd
B71 240.2	52.4	abc	76.7	bc	96.5	ab	75.2	abcd
Serrana	37.1	cde	85.4	ab	100.0	a	74.2	bcd
Mariva	50.3	abcd	68.7	cd	96.5	ab	71.9	cde
LT-1	34.0	de	78.1	bc	96.4	ab	69.8	de
Rosita	45.4	bcde	64.4	cde	94.8	ab	68.2	de
CGN 69.1	38.6	cde	58.7	de	91.3	ab	62.9	ef
Atzimba	30.9	e	56.7	de	83.9	abc	57.2	f
I-931	33.8	de	50.8	e	81.6	bc	55.4	f
CFK 69.1	36.2	cde	56.3	de	71.0	c	54.5	f
Mean	45.5	C	75.3	B	93.5	A		

1/Following inoculation,tubers were incubated in rustic storage for 20 days before evaluation.

2/Column values followed by the same lower case letter and row values followed by the same upper case letter do not differ at the 5 % probability level (Duncan's Multiple range test).

Calculations were made only for 2,4 and 6 days healing since in most clones healing was complete on the eighth day. Analysis of variance is shown in Table A.29.

Significant differences among clones in the percentage reduction in lesion size occurred at each of the 3 healing periods (Table 5.4). After 2 days,the mean value was 45.5%. DTO-33 reached 63.9% but did not differ significantly from 5 other clones. Atzimba reached only 30.9% but did not differ significantly from 9 other clones. After 4 days,the mean value was 75.3%. Six clones exceeded 85% healing with Kufri Jyoti reaching 96.1%. The differences among these 6 clones were not significant. After 6 days healing the mean value had reached 93.5%. Thirteen of 15 clones exceeded 83.9% and the differences among them were not significant. The mean percentage reduction over the three healing periods ranged from 54.5% (CFK69.1) to 84.5% (Kufri Jyoti). Six other clones did not differ significantly from Kufri Jyoti and 3 others did not differ significantly from CFK 69.1.

5.4 Discussion

In this study susceptibility to tuber dry rot caused by either F.solani or F.oxysporum increased significantly with storage time. This agrees with prior studies (Tivoli and Jouan,1986). However,in this study the rate of increase in susceptibility varied among the clones. From this,it appears that the best time to test clonal susceptibility to dry rot is before storage.

No correlation was observed between the two Fusarium spp. in causing dry rot in tubers of the clones tested. Possibly the mechanism of resistance to each species is independent. This finding agrees with those of others who worked with different species of Fusarium (Corsini and Pavek,1986;Wastie et al,1989).

Some clones such as Desiree,Serrana and Yungay were moderate to highly susceptible when inoculated with F.solani but in previous studies they had low storage losses when exposed to natural inoculum and stored 4 months in rustic storage at San Ramon (Chapter 3). Other clones such as Atzimba and I-931 had low amounts of dry rot when inoculated with F.solani but had high losses in rustic storage. Still other clones such as LT-2 and CFK 69.1 showed high dry rot susceptibility following inoculation and poor storability. These observations suggest that inoculation studies with Fusarium alone are not adequate to define the storability of clones. Interaction studies with other pathogens and evaluations of damage susceptibility and wound healing characteristics are necessary. This must be followed by testing under grower production practices and storage under warm tropical conditions.

Results of the wound healing studies showed that the critical period for wound healing for the majority of the test clones is between 4 and 6 days. CFK 69.1 had significantly more dry rot development then the other 14 clones when inoculated after 6 days of wound healing. CFK 69.1 is known to store poorly (Chapter 3). In this study even after 8 and 10 days healing CFK 69.1 still showed some dry rot.

6. SYNERGISTIC EFFECTS OF ERWINIA AND FUSARIUM SPECIES ON THE ROT SUSCEPTIBILITY OF 18 CLONES

6.1 Introduction

It is probable that under most conditions potato tuber wounds that result from harvesting and other practices harbor more than one type of pathogen. In Chapter 4 and 5, clonal susceptibility to single pathogens was reported. In this study, the synergistic effects of combining Erwinia and Fusarium species on clonal rot susceptibility was examined.

6.2 Materials and Methods

In order to obtain tubers with a lower level of natural infection the 18 test clones were grown in Huancayo. Immediately following harvest, the tubers were moved to San Ramon for evaluation. Tubers weighing from 80 to 120 grs were carefully selected avoiding those with cuts, diseases and skin peeling. The selected tubers were washed with well water and surface disinfected for 10 minutes in sodium hypochlorite solution (0.5 % active chlorine) followed by two rinses in well water and air drying for 2 days. Tubers of each clone were evaluated before storage and again after storing 2 and 4 months in rustic storage. During storage the tubers were protected from Potato Tuber Moth with a layer of plastic screen.

For each evaluation three replicates of five tubers per clone were inoculated with the following pathogen(s) 1.No inoculation, 2.E.carotovora subsp.carotovora (Ecc) 3.E.chrysanthemi (Echy), 4.F.oxysporum (Fo), 5.F.solani (Fs) 6.Ecc + Fo, 7.Echy + Fo, 8.Ecc + Fs, and 9.Echy + Fs.

Tubers were inoculated with Fo or Fs using the Tivoli method (Tivoli and Jouan,1981). Tubers were inoculated with either Ecc or Echy using vacuum infiltration of a bacterial suspension containing 10^6 c.f.u per ml with a vacuum of -86 KPa. After bacterial inoculation,the tubers were placed in a greenhouse to dry for two days. After drying,tubers in treatments 6,7,8 and 9 were also inoculated with either Fs or Fo.

For incubation,control and inoculated tubers were placed on wire shelves inside non-sealed plastic chambers (45 x 25 cm) humidified by lining with wet paper towels. The chambers were placed on wooden shelves in the charcoal walled rustic storage for incubation. After 20 days the tubers were removed for evaluation. The Percentage Rot was determined by weighing tubers before and after removal of rotted tissue and performing the necessary calculations. The rot resulting from simultaneous inoculation with Erwinia and Fusarium spp. more closely resembled soft rot than dry rot.

6.3 Results

Analysis of variance is shown in Table A.30. Table 6.1 shows the clonal response when tubers were inoculated before storage. Due to the lack of free moisture on the tubers the amount of rotting due to the two Erwinia species was less than observed previously when inoculated tubers were incubated in the mist chamber. However,significant differences were

Table 6.1 Clonal rotting response of 18 clones to Erwinia and Fusarium species when inoculated separately and in paired combinations before storage (May,1989) 1/

Clone	Percentage Rot by Weight 2/																	
	Ecc		Echy		Fo		Fs		Ecc Fo		Ecc Fs		Echy Fo		Echy Fs			
Desiree	0.0	b	7.9	de	5.6	a	10.3	bc	5.6	b	25.9	def	30.7	def	23.2	f		
LT-8	7.3	ab	11.0	cde	0.0	a	11.3	bc	0.0	b	12.7	f	10.3	gh	16.3	f		
Serrana	0.0	b	0.0	e	0.0	a	12.5	bc	0.0	b	15.7	f	16.9	fgh	20.9	f		
Yungay	0.0	b	0.0	e	7.8	a	15.7	bc	13.5	b	19.3	ef	16.2	fgh	25.5	ef		
B71.240.2	0.0	b	7.1	de	4.9	a	7.9	bc	4.4	b	30.5	def	5.3	h	29.7	def		
K.Jyoti	0.0	b	0.0	e	6.1	a	10.7	bc	12.4	b	14.9	f	17.2	fgh	31.3	def		
LT-7	7.9	ab	22.7	abcd	0.0	a	2.9	c	2.7	b	20.0	ef	19.1	efgh	42.0	cde		
LT-2	23.5	a	30.2	abc	5.7	a	34.4	a	20.1	b	57.6	b	14.6	efgh	42.8	cde		
LT-1	0.0	b	7.2	de	2.3	a	11.1	bc	2.5	b	30.9	def	19.1	efgh	47.9	bcd		
LT-5	7.2	ab	16.9	bcde	4.0	a	7.5	bc	12.8	b	26.4	def	30.0	defg	51.9	bc		
DTO-33	0.0	b	0.0	e	0.0	a	8.9	bc	0.0	b	50.6	bc	7.1	h	52.2	bc		
C84-580.1	9.6	ab	7.3	de	5.6	a	11.9	bc	10.5	b	28.9	def	25.1	defgh	56.7	bc		
Mariva	7.0	ab	14.6	cde	15.3	a	9.9	bc	0.0	b	15.5	f	37.2	de	51.6	bc		
I-931	22.0	a	37.5	a	15.3	a	15.3	bc	58.3	a	37.3	cde	58.1	c	57.3	bc		
Atzimba	14.3	ab	29.7	abcd	13.3	a	14.9	bc	45.5	a	37.8	cde	63.7	bc	64.0	b		
CGN 69.1	4.9	b	20.2	abcde	5.3	a	8.4	bc	40.3	a	42.3	bcd	76.9	b	84.0	a		
Rosita	14.7	ab	14.3	cde	6.7	a	15.4	bc	19.3	b	92.5	a	38.9	d	100.0	a		
CFK 69.1	21.3	a	35.7	ab	11.1	a	27.7	ab	55.3	a	95.0	a	100.0	a	100.0	a		

1/Following inoculation,tubers were incubated 20 days in rustic storage before rot measurements.

2/Means with same letters in each column do not differ at the 5% probability level (Duncan's Multiple range test).

observed among clones in their rotting response to the two Erwinia spp. Echy produced more rotting than Ecc in nearly all clones where soft rotting occurred.

Some significant differences were observed among clones in rotting response to Fs. However,16 of 18 clones did not differ significantly. No significant differences in rotting response to Fo occurred among clones.

I-931,Atzimba,CGN 69.1 and CFK 69.1 showed significantly greater rotting than the remaining 14 clones when inoculated with both Ecc and Fo. CFK 69.1 also showed significantly more rotting than the other 17 clones when inoculated with both Echy and Fo. Rosita and CFK 69.1 showed significantly more rotting than the other 16 clones when inoculated with both Ecc and Fs. CGN 691.1,Rosita and CFK 69.1 showed significantly more rotting when inoculated with both Echy and Fs than the other 16 clones. Inoculation with both Erwinia and Fusarium species resulted in greater rotting than when either pathogen was inoculated alone in 136 of 144 comparisons (18 clones x 8 paired comparisons). In some clones the increase was nearly 10 fold (CFK 69.1 inoculated with Echy + Fo Vs. Fo alone).

Table 6.2 shows the clonal rotting response when tubers were inoculated after storing 2 months in rustic storage. No significant differences among clones were observed in rotting response due to either Ecc or Echy. Most clones did not rot following inoculation with either pathogen. Significant differences among clones in rotting response to Fs and Fo did occur. Percentage rotting caused by Fs ranged from a low of 6.8% (LT-7) to a high of 32.2% (LT-2). Percentage rotting caused by Fo ranged from a low of 0% (LT-7) to a high of 22.5% (LT-2). Only these two clones differed significantly from each other.

Table 6.2 Clonal rotting response of 18 clones to Erwinia and Fusarium species when inoculated separately and in paired combinations after 2 months in rustic storage (May-June,1989). 1/

Clone	Percentage Rot by Weight 2/							
	Ecc	Echy	Fo	Fs	Ecc Fo	Ecc Fs	Echy Fo	Echy Fs
Serrana	0.0 a	0.0 a	6.3 ab	13.3 ab	7.2 d	14.7 d	7.0 d	17.3 e
LT-7	0.0 a	0.0 a	0.0 b	6.8 b	11.5 d	13.2 d	6.9 d	18.7 e
DTO-33	0.0 a	0.0 a	5.2 ab	11.6 ab	18.9 cd	26.4 cd	6.9 d	22.5 e
Yungay	0.0 a	0.0 a	8.7 ab	17.3 ab	9.7 d	18.3 cd	9.3 d	23.0 e
Mariva	0.0 a	0.0 a	6.0 ab	8.7 b	5.3 d	18.3 cd	4.9 d	24.0 de
Desiree	0.0 a	0.0 a	5.3 ab	13.0 ab	7.6 d	26.7 cd	17.0 cd	26.3 cde
Kufri Jyoti	0.0 a	0.0 a	7.2 ab	14.3 ab	13.3 d	19.3 cd	16.2 cd	37.3 cde
LT-8	0.0 a	0.0 a	4.7 ab	12.0 ab	5.7 d	17.7 cd	6.3 d	28.7 cde
B71 240.2	0.0 a	0.0 a	5.7 ab	14.7 ab	11.3 d	31.7 cd	17.9 cd	30.9 cde
Atzimba	0.0 a	7.0 a	9.0 ab	13.0 ab	32.3 bc	38.0 c	24.0 cd	33.7 cde
CGN 69.1	0.0 a	0.3 a	6.3 ab	14.9 ab	15.9 cd	14.8 d	43.3 b	34.0 cde
I-931	7.0 a	8.7 a	13.7 ab	15.0 ab	41.7 b	58.3 b	29.3 bc	36.7 cde
Rosita	0.0 a	16.0 a	6.0 ab	12.7 ab	15.3 cd	27.0 cd	20.7 cd	43.3 cd
LT-1	0.0 a	0.0 a	4.3 ab	13.0 ab	5.6 d	30.0 cd	23.3 cd	43.7 cd
LT-5	0.0 a	0.0 a	6.0 ab	11.3 b	12.3 d	26.9 cd	31.3 bc	45.7 c
C84-580.1	0.0 a	0.0 a	6.7 ab	12.7 ab	11.7 d	29.7 cd	16.8 cd	45.3 c
CFK 69.1	15.0 a	7.0 a	12.7 ab	15.7 ab	24.3 bcd	60.7 b	74.0 a	79.7 b
LT-2	0.0 a	0.0 a	22.5 a	32.2 a	100.0 a	100.0 a	70.7 a	100.0 a

1/Following inoculation,tubers were incubated for 20 days in rustic storage before evaluation.

2/Means followed by the same letter in each column do not differ at the 5% probability level (Duncan's Multiple range test).

Significant differences occurred among clones in the percentage rot when inoculated with each of the following pathogen combination:Ecc + Fo, Ecc + Fs, Echy + Fo and Echy + Fo. Clones showing the lowest and highest percentage rot following inoculation with each pair of pathogens were as follows: Ecc + Fo,Mariva (5.3%) and LT-2 (100.0%);Ecc + Fs, LT-7 (13.2%) and LT-2 (100%); Echy +Fo,Mariva (4.9%) and CFK 69.1 (74.0%); Echy + Fs, Serrana (17.3%) and LT-2 (100%).

Combining Erwinia and Fusarium species produced more rotting than when either pathogen was used singly in 142 of 144 comparisons. Although,most clones did not rot when inoculated with either of the Erwinia species, combining the erwinias and fusaria produced more rotting than when the fusaria were used alone.

Table 6.3 shows the clonal rotting response when tubers were inoculated after storing 4 months in rustic storage. None of the clones rotted following inoculation with either Ecc or Echy.

Significant differences in rotting occurred among clones when inoculated with either Fs or Fo. When inoculated with Fs the percentage rot varied from 7.1% (LT-7) to 48.7% (Atzimba) and when inoculated with Fo the percentage rot varied from 6.0% (DTO-33) to 33% (Atzimba).

Significant differences in percentage rot occurred among clones when inoculated with each Erwinia + Fusarium combination. Very large differences in the percentage rot occurred among the clones most resistant and most susceptible to each pathogen combination. Combining the erwinias with the fusaria increased the percentage rot that resulted from the inoculation with the fusaria alone. However,the magnitude of the increase varied among clones e.g. Desiree showed little or no increase in rotting in response to the dual inoculation whereas LT-7 showed a 9 to 15 fold increase.

Table 6.3 Clonal rotting response of 18 clones to Erwinia and Fusarium species when inoculated separately and in paired combinations after 4 months in rustic storage (May-August,1989). 1/

Clones	Percentage Rot by Weight 2/															
	Ecc		Echy		Fo		Fs		Ecc Fo		Ecc Fs		Echr Fo		Echy Fs	
Desiree	0.0	a	0.0	a	8.8	cd	23.0	cdefg	18.3	g	16.9	e	9.6	e	22.7	d
C84-580.1	0.0	a	0.0	a	9.6	bcd	14.0	fg	19.3	g	39.3	cd	12.7	de	25.3	d
K.Jyoti	0.0	a	0.0	a	7.7	cd	19.7	defg	41.0	ef	34.4	de	25.3	de	30.7	cd
Serrana	0.0	a	0.0	a	7.9	cd	16.3	efg	15.4	g	31.3	de	12.6	de	32.3	cd
DTO-33	0.0	a	0.0	a	6.0	cd	13.3	fg	26.3	fg	38.9	cd	13.9	de	40.3	cd
Yungay	0.0	a	0.0	a	25.3	abcd	32.3	abcdef	21.6	g	53.7	c	21.7	de	48.9	c
B71 240.2	0.0	a	0.0	a	10.6	bcd	17.7	efg	17.7	g	26.7	de	27.9	de	71.2	b
Mariva	0.0	a	0.0	a	7.0	cd	17.6	efg	17.3	g	73.3	b	30.3	d	66.3	b
LT-1	0.0	a	0.0	a	7.6	cd	24.6	cdefg	8.4	g	79.7	b	53.7	c	100.0	a
LT-8	0.0	a	0.0	a	7.8	cd	13.8	fg	59.0	de	73.3	b	51.7	c	100.0	a
LT-7	0.0	a	0.0	a	5.6	d	7.1	g	50.7	e	80.7	ab	85.3	a	100.0	a
Atzimba	0.0	a	0.0	a	33.0	a	48.7	a	74.7	cd	92.0	ab	66.7	bc	100.0	a
CGN 69.1	0.0	a	0.0	a	25.7	abcd	28.0	bcdef	100.0	a	80.7	ab	100.0	a	100.0	a
Rosita	0.0	a	0.0	a	17.7	abcd	35.5	abcde	94.0	ab	91.3	ab	100.0	a	100.0	a
CFK 69.1	0.0	a	0.0	a	26.7	abc	45.3	ab	88.3	ab	88.3	ab	100.0	a	100.0	a
LT-5	0.0	a	0.0	a	6.7	cd	19.0	defg	48.3	bc	100.0	a	84.7	a	100.0	a
I-931	0.0	a	0.0	a	29.0	ab	38.3	abcd	78.0	bc	100.0	a	80.8	ab	100.0	a
LT-2	0.0	a	0.0	a	22.0	abcd	40.3	abc	81.0	bc	95.7	a	100.0	a	100.0	a

1/Following inoculation,tubers were incubated in the rustic storage for 20 dats before evaluation.

2/Means with same letters in each column do not differ at the 5% probability level (Duncan's Multiple range test).

Table 6.4 Mean Percentage Rot of 18 clones showing the effect of time in storage and Erwinia and Fusarium species inoculated separately and in paired combinations (May-August,1989). 1/

Treatments	Percentage Rot by Weight 2/ Months of storage 0	2	4
None	0.0 e	0.0 f	0.0 g
Ecc	7.8 d	1.2 f	0.0 g
Echy	14.6 c	2.2 f	0.0 g
Fo	5.2 d	7.5 e	14.7 f
Fs	13.2 c	14.0 d	25.2 e
Ecc + Fo	16.9 c	16.8 d	47.2 d
Echy + Fo	32.6 b	23.7 c	53.9 c
Ecc + Fs	36.3 b	31.8 b	66.7 b
Echy + Fs	49.8 a	38.4 a	74.3 a

1/Each value is the mean of 18 clones.Following inoculation tubers were incubated in the rustic storage at San Ramon for 20 days before evaluation.

2/Means followed by the same letter do no differ at the 5% probability level (Duncan's Multiple range test).

The mean percentage rot for the 18 clones for each evaluation (0,2,4 months in storage) and pathogen or pathogen combination is shown in Table 6.4. The data show the following: 1. Tubers decreased in susceptibility to Erwinia spp. with storage time, 2. Tubers increased in susceptibility to Fusarium spp. with storage time, 3. When the organisms were inoculated together, the tubers decreased slightly in susceptibility after 2 months storage and then increased in susceptibility after 4 months storage,4.Echy and Fs were more pathogenic than Ecc and Fo,respectively when used singly and the Echy + Fs combination was more pathogenic than Ecc+Fo combination.

Of particular interest in this study was the synergism that occurred when the erwinias and the fusaria were inoculated together. Table 6.5 shows the mean synergistic values of 18 clones for the 4 pathogen pairs

Table 6.5 Synergistic effect of simultaneous inoculation with two pathogens compared to the effect of the same two pathogens inoculated separately (May-August,1989)

Combinations	Ratios of Synergistic Effect of Pathogens 1/ Months of storage 0	2	4	Mean
Ecc x Fs 2/ / Ecc + Fs 3/	2.1 ± 1.2	2.1 ± 0.6	3.2 ± 2.4	2.5 ± 1.4
Ecc x Fo / Ecc + Fo	1.4 ± 0.9	2.1 ± 0.9	3.4 ± 1.9	2.3 ± 1.2
Echy x Fs / Echy + Fs	2.1 ± 1.2	2.8 ± 1.8	3.6 ± 3.1	2.8 ± 2.0
Echy x Fo / Echy + Fo	1.7 ± 0.8	2.5 ± 1.8	4.4 ± 3.6	2.9 ± 2.1
Mean	1.8 ± 1.0	2.4 ± 1.5	3.7 ± 2.8	

1/Ratio of the mean weight loss of 18 clones and the standard deviation

2/Pathogens inoculated simultaneously

3/Pathogens inoculated separately

and the 3 evaluations (0,2,4 months storage). Before storage,combining the pathogens increased tuber rotting between 1.4 to 2.1 times compared to inoculating with the pathogens separately;after 2 months storage this increased to between 2.1 to 2.8 times and after 4 months storage the increase was between 3.2 to 4.4 times. As shown by the magnitude of the standard deviation, the clones varied least in the synergistic response before storage. Somewhat more variability occurred among clones after 2 months storage and still more after 4 months storage. The standard deviation expressed as a percentage of the mean was 55%,62% and 75% for 0,2 and 4 months,respectively.

6.4 Discussion

In this study the importance of simultaneous inoculation of two pathogens in clonal evaluations was demonstrated. All clones showed a synergistic response when two pathogens were inoculated together, i.e. rotting was usually greater with simultaneous inoculations than the sum of the rot when pathogens were inoculated separately. However,the degree of synergism varied among the clones, combination of pathogens and time in storage.

Before storage,the degree of synergistic response of the different clones ranged from about one to nearly six. Similar or greater differences among clones were observed after 2 and 4 months storage depending on the pathogen combination. Therefore,a clone may show low susceptibility to pathogens inoculated separately but fairly high susceptibility when pathogens are inoculated together. Possibly, clonal evaluations would be more realistic if the major pathogens were combined rather than tested separately. However,this may not be practical.

The mean rotting response of the 18 clones to the 4 pathogen combinations is shown in Table 6.6. The analysis of variance is shown in Table A.31 and was run using the clonal response to each pathogen combination as a replication. Before storage,the mean percentage rot ranged from 9.8% (LT-8) to 87.6% (CFK 69.1). LT-8 did not differ significantly from 11 other clones but CFK 69.1 did differ significantly from the 17 other clones. After 2 months,storage, the mean percentage rot ranged from 11.6% (Serrana) to 92.7% (LT-2). Serrana did not differ significantly from 12 other clones but LT-2 differed significantly from the other 17 clones.

Table 6.6 The mean rotting response of 18 clones to 4 pathogen combinations:Ecc-Fo, Ecc-Fs,Echy-Fo and Echy-Fs.

Clones	Mean Percentage Rot by Weight 1/ Months in rustic storage							
	0		2		4		Mean	
Serrana	13.4	de	11.6	f	22.9	f	15.9	f
Desiree	21.3	de	19.4	def	16.9	f	19.2	ef
Yungay	18.6	de	15.1	ef	36.5	ef	23.4	ef
Kufri Jyoti	18.9	de	21.5	def	32.9	ef	24.4	ef
B71 240.2	17.5	de	22.9	def	35.9	ef	25.4	ef
DTO-33	27.5	de	18.7	def	29.9	ef	25.4	ef
C84 580.5	30.3	de	25.9	def	24.2	f	26.8	ef
Mariva	26.1	de	13.1	f	46.8	de	28.7	def
LT-8	9.8	e	14.6	ef	71.0	bc	31.8	cdef
LT-1	25.1	de	25.7	def	60.5	cd	37.1	cdef
LT-7	20.9	de	12.6	f	79.2	abc	37.6	cdef
LT-5	30.3	de	29.1	cde	83.3	ab	47.6	bcde
CGN 69.1	60.9	b	27.0	def	83.4	ab	57.3	abcd
Atzimba	52.8	bc	32.0	cd	89.7	ab	58.2	abcd
Rosita	62.7	b	26.6	def	96.3	a	61.9	abc
I-931	52.8	bc	41.5	c	89.7	ab	61.3	abc
LT-2	33.8	cd	92.7	a	94.2	a	73.6	ab
CFK 69.1	87.6	a	59.7	b	94.2	a	80.5	a

1/Means followed by the same letter in each column do not differ at the 5% probability level (Duncan's Multiple range test).

After 4 months storage,Desiree showed the least (16.9%) and Rosita the the greatest rot (96.3%). Six other clones did not differ significantly from Desiree while Rosita did not differ significantly from other seven clones.

An important finding in this study was the large difference among clones in their change in susceptibility with time in storage. From 0 to 2 months storage, all clones except LT-2 either remained about the same in susceptibility or decreased. LT-2 increased from 33.8% to 92.7%. Between 0 and 4 months,rot susceptibility of most clones to the 4 pathogen combinations increased. Certain clones increased greatly in susceptibility eg. LT-8 (9.8 to 71%),LT-7 (20.9 to 79.2%),LT-1 (25.1 to 60.5%), LT-5 (30.3 to 83.3%) and LT-2 (33.8 to 94.2%). These LT clones were selected for use in the lowland tropics. Other clones either did not change in susceptibility or changed only slightly eg.Serrana (13.4 to 22.9%),Desiree (21.3 to 16.9%) DTO-33 (27.5 to 29.9%) and C84.580.1 (30.3 to 24.2%).

Simultaneous inoculation with Fusarium and Erwinia spp. before storage and after periods of 2 and 4 months in rustic storage may be a reasonable approach to determine the suitability of clones for storage in the warm tropics. Clones such as Serrana,Desiree,Yungay,Kufri Jyoti and B71 240.2 had relatively low storage losses in the storage tests (Chapter 3) and were among the less susceptible clones when inoculated simultaneously with the Erwinia and Fusarium spp. combinations. Other clones showed extensive rotting in storage tests and in the simultaneous inoculation experiments,eg. CFK 69.1,Atzimba,I931 and LT-2.

In this study rotting by the erwinias was less than observed in studies shown in Chapter 4. This was most likely due to the fact that tuber respiration was aerobic and dryer conditions existed in the rustic storage compared to the mist chamber,where tuber respiration was probably partially anaerobic due to the water film on the tubers. Oxygen moves slowly through water and at 25 C oxygen could be limiting within the tuber. Thus,the normal tuber defense mechanisms may not be functioning at their optimum level and a false evaluation of resistance or susceptibility may result.

7. EFFECT OF TUBER SELECTION ON STORAGE LOSSES

7.1 Introduction

The most important factor determining success or failure of storing potatoes is the quality of tubers placed in storage (Booth and Shaw,1981). Pre-storage selection is always important but is most **critical** in situations where little control over the storage environment is possible. In the technically developed countries, storage losses are minimized by careful control of the storage environment. In less technically developed countries it is usually impossible to build sophisticated systems (Booth and Shaw,1981). Therefore, major emphasis must be placed on tuber selection prior to storage.

The objective of this study was to evaluate the difference in storability among potatoes with various levels of biological and mechanical defects and to determine if good storability could be identified at harvest.

7.2 EFFECT OF THE SELECTION BEFORE STORAGE ON TOTAL STORAGE LOSSES.

7.2.1 Materials and Methods

Experiment 1:1988

Desiree seed tubers were planted during the rainy season (November, 1987) in San Ramon. Vines were removed when 90% dead and tubers were left in the soil for 8 days to allow skin setting.Tubers were harvested by hand and sorted into the following categories: 1.All diseased,insect infested,cut and mechanically damaged tubers were removed; 2.Diseased tuber removed but some skinned and insect damage (Diabrotica spp) tubers included and 3.Diseased tubers were removed but cut,damaged and insect infested tubers were left in the samples.

Eight replicates of 10 Kg of each of the three categories were stored in the charcoal walled rustic storage at San Ramon. Four replicates were stored without tuber treatments and the other four were treated as follows: soaked in both a sodium hypochlorite solution (0.5 % active chlorine) for 10 minutes and a thiabendazole solution (0.2 % active ingredient)for 10 minutes; dusted with CIPC after 2 weeks storage and covered with 15 cm of dried and crushed leaves of Lantana spp. during storage to protect from Potato Tuber Moth (PTM). An additional 4 replicates of each category were stored under refrigeration (4 C).

After 4 months storage Total Percentage Weight Loss,which included rotting,sprout removal and shrinkage,was determined. Data on Total Percentage Weight Loss of tubers stored in rustic storage and those stored under refrigeration were analyzed separately. Analyses of variance for this experiment are shown in Tables A.32 and A.33. Temperature and relative humidity during storage is shown in Table A.4.

Experiment 2:1989

Desiree and LT-5 seed tubers were planted during the dry season (June,1989) at San Ramon. Harvesting and sorting were done as described for Experiment 1 except all visible PTM infested tubers were removed from all categories.Treated tubers were dusted immediately after harvest with thiabendazole (1.5 gr Tecto 60 per kg of tubers) and with CIPC after one month storage. During storage the treated tubers were covered with two layers of hessian sack and a layer of plastic screen. After 4 months storage,Total Percentage Weight Loss was determined. Analyses of variance are shown in Tables A.34 and A.35. Due to the similarity in response of Desiree and LT-5,the data were combined. Temperature and relative humidity during storage are shown in Table A.7.

7.2.2 Results

Experiment 1:1988

After 4 months storage significant differences in Total Percentage Weight Loss occurred among the 3 categories of tuber selection (Table 7.1). Similar results were obtained at 4 C and in both control and treated tubers stored in rustic storage. The losses increased from Categories 1 through 2 and 3 paralleling the increase in defective tubers allowed to remain in the samples.

Treating tubers by soaking in sodium hypochlorite and thiabendazole was detrimental. Possibly covering with a 15 cm of Lantana leaves reduced air circulation and also contributed to the increased loss from treated tubers.

Table 7.1 Effect of tuber selection on Total Percentage Weight Loss of Desiree during 4 months storage (March-June,1988) 1/

Category of selection 3/	Total Percentage Weight Loss 2/			
	Refrigeration	Rustic storage		
	4 C	Control	Treated 4/	Mean
1	3.0 b	5.8 b	19.4 c	12.6 c
2	3.5 b	8.4 ab	24.8 b	16.6 b
3	4.5 a	11.2 a	28.8 a	20.0 a
Mean	3.7 C	8.5 B	24.3 A	

1/Grown at San Ramon from Nov.1987 to March 1988. Vines removed when 90% dead and tubers left in soil for 8 days.

2/Data for rustic storage and refrigeration were analyzed separately. Column values followed by the same lower case letter and row values followed by the same upper case letter do not differ at the 5% probability level (Duncan's Multiple range test).

3/Category 1:All diseased and defective tubers removed; Category 2: Diseased tubers removed,some skinned and slight insect damaged included; Category 3:Diseased tubers removed,cut,skinned and insect damaged included.

4/Tubers soaked 10 minutes in sodium hypochlorite and 10 minutes in thiabendazole solution and dusted with CIPC after 2 weeks in rustic storage. In storage,tubers covered with 15 cm. layer of dried and crushed leaves of Lantana spp.

Losses by tubers stored at 4 C were significantly less than losses by tubers stored in rustic storage. Control tubers lost about twice the weight of those stored at 4 C and treated tubers lost about 6 times more weight than those stored at 4C. The increased loss was primarily due to rotting.

Experiment 2:1989

Losses in 1989 were higher than those observed in 1988 (cp.Tables 7.1 and 7.2). This occurred in both refrigerated storage and to a greater extent in control tubers stored in rustic storage. The increased losses may have resulted from a higher incidence of potato tuber moth both in the field and during storage in 1989.

Increasing the number of defective tubers in the samples resulted in progressive and significant increases in loss. Losses increased progressively from categories 1 to 2 and 3 (Table 7.2). Category 3 control tubers lost 75.4 % of their initial weight primary due to rotting.

Dusting tubers with thiabendazole and CIPC and covering with 2 layers of hessian sack and a layer of plastic screen significantly decreased losses in each category of selection. The mean percentage weight loss was reduced from 40.8% to 24.1% by tuber treatment.

Mean losses in rustic storage exceeded those in refrigeration by a factor of 5 for the controls and 3 for treated tubers.

Table 7.2 Effect of tuber selection on mean Total Percentage Weight Loss of Desiree and LT-5 during 4 months storage (August-November, 1989). 1/

Category of selection 3/	Total Percentage Weight loss 2/			
	Refrigeration	Rustic storage		
	4 C	Control	Treated 4/	Mean
1	5.2 b	14.6 c	6.9 c	10.8 c
2	7.4 b	32.6 b	21.8 b	27.2 b
3	11.5 a	75.4 a	43.7 a	59.5 a
Mean	8.0 C	40.8 A	24.1 B	

1/Grown at San Ramon from May to July,1989. Vines were removed when 90% dead and tubers left in soil for 8 days.

2/Data for rustic storage and refrigeration were analyzed separately. Column values followed by the same lower case letter and row values followed by the same upper case letter do not differ at the 5% probability level (Duncan's Multiple range test).

3/Same categories of selection described in Table 7.1.

4/Tubers dusted with thiabendazole immediately after harvest and with CIPC after one month in rustic storage. In storage tubers covered with 2 layers of hessian sack and a layer of plastic screen.

7.3 EFFECT OF POTATO TUBER MOTH INFESTATION BEFORE STORAGE ON STORAGE LOSSES

7.3.1 Materials and Methods

Desiree and LT-5 seed tubers were planted in San Ramon during the dry season (June,1989). Vines were removed when 90% dead and tubers were left in the soil for 8 days to allow skin setting. Tubers were then harvested carefully and selected to eliminate those with diseases,cuts and excessive skinning.One half of the tubers of each clone was dusted with thiabendazole (1.5 gr of Tecto 60 per kg of tubers) immediately after harvest. All tubers with and without this treatment were placed in 30 kg wood boxes in the charcoal walled rustic storage for 2 weeks and then reselected to remove diseased and PTM infested tubers. PTM infested tubers were easily identified by the presence of PTM excrement on the surface. Sixteen samples of 100 tubers visibly free of diseases and insects were collected from each clone and from both thiabendazole treated and non treated tubers. Samples from each clone were then prepared with 4 levels of infestation of PTM. This was done by replacing 0,5,15 and 25 healthy tubers with PTM infested tubers to adjust the samples to 0,5,15 and 25% initial PTM infestation. Tubers which had been dusted with thiabendazole were also dusted with CIPC (1.5 No-brotan per kg of tubers) two weeks after harvest. All samples were stored in the charcoal walled rustic storage.

Each PTM infestation level in control and treated tubers were isolated from each other in the storage bins with a plastic screen to avoid cross infestation.

Two layers of hessian sack were placed over the treated tubers to retain CIPC. After 4 months storage,Total Percentage Weight Loss was determined by substracting the weight of edible tubers from the initial weight and also by counting the number of tubers with visible external signs of PTM infestation. Analyses of Variance are shown in Tables A.36 and A.37. The two clones reacted similarly so the data were combined for analysis. Temperature and relative humidity during storage is shown in Table A.7.

7.3.2 Results

Total Percentage Weight Loss in the control tubers increased significantly with increasing levels of PTM infestation (Table 7.3). The linear coefficient of correlation between the initial PTM levels and weight loss was 0.99 and was significant at the 5% probability level. A similar but less dramatic response occurred with the treated tubers, however,there were no significant differences among levels of PTM infestation.

Tubers treated with thiabendazole and CIPC and covered in storage with hessian sack and plastic screen did not show any visible PTM infestation after 4 months storage (Table 7.4). Control tubers showed significantly increased levels of PTM infestation after storage with increasing levels of initial PTM infestation. With 25 % initial infestation,84.8% of the control tubers became infested with PTM during 4 months storage. The linear coefficient of correlation between the initial PTM infestation and percentage of tubers infested after 4 months storage was 0.94. This was significant at the 0.1% probability level.

Table 7.3 Effect of Potato Tuber Month infestation before storage on the mean Total Percentage Weight Loss of Desiree and LT-5 during 4 months in rustic storage (September-December,1989). 1/

Initial PTM levels % 3/	Total Percentage Weight Loss 2/ Control	Treated 4/	Mean
0	11.1 c	6.4 a	8.7 c
5	15.8 c	7.2 a	11.5 c
15	31.9 b	8.7 a	20.3 b
25	38.9 a	10.8 a	24.9 a
Mean	20.9 A	8.3 B	

1/Grown at San Ramon from June to August,1989. Vines removed when 90% dead and tubers left in soil for 8 days.

2/Column values followed by the same lower case letter and row values followed by the same upper case letter do not differ at the 5% probability level (Duncan's Multiple range test).

3/Diseased tubers removed after harvest and again after 2 weeks and all visible PTM infested tubers also removed after 2 weeks. PTM tubers then added back to give the indicated infestation levels. Each level of infestation was separated from the others.

4/Dusted with thiabendazole immediately after harvest and dusted with CIPC after 2 weeks of harvest. In storage,covered with 2 layers of hessian sack and a layer of plastic screen.

Table 7.4 Effect of Potato Tuber Moth infestation before storage on the mean Percentage of Tubers Infested with PTM in Desiree and LT-5 during 4 months in rustic storage (September-December,1989). 1/

Initial PTM levels %	Percentage of Tubers Infested with PTM		
	Control	Treated 2/	Mean
0	16.8 d	0.0 a	8.4 d
5	51.5 c	0.0 a	25.8 c
15	70.9 b	0.0 a	35.5 b
25	84.8 a	0.0 a	48.4 a
Mean	55.9 A	0.0 B	

1/ See footnotes in Table 7.3

2/ No visible external signs of PTM infestation.

7.4 Discussion

Tuber condition at harvest will determine the degree of selection to be done before storage. In these experiments when all damaged,diseased and skinned tubers were removed before storage,losses in untreated control tubers stored in rustic storage did not greatly exceed those at 4 C (Table 7.1). Similar results were obtained in a second experiment conducted at a different time (Table 7.2). In the second experiment tuber treatment with dry thiabendazole and CIPC was beneficial and reduced losses to within 2% of those occurring at 4 C.

Soaking tubers in hypochlorite and thiabendazole solutions was detrimental probably due to the water film on the tubers. Also,the heavy covering with dried Lantana spp. leaves may have restricted ventilation and contributed to the increased rotting of tubers treated with liquid chemical application.

Storage losses increased in proportion to the initial levels of PTM infestation. PTM is very serious in potatoes grown during dry seasons since this favors development of the pest and infestation in the field.It is extremely difficult to recognize infested tubers at harvest,but if sorting is delayed 2 weeks infested tubers are easily recognized and removed.

Dusting tubers with CIPC completely eliminated PTM and significantly decreased rotting and weight loss. Although thiabendazole was also applied to tubers treated with CIPC,the control of PTM was probably due to CIPC alone. This conclusion is supported by the fact that just after harvest one half of the tubers were treated with thiabendazole and one half were not treated. Both treated and non-treated tubers were then stored 2 weeks in rustic storage prior to removal of all visibly infested PTM tubers. After the two weeks storage,there was no visible difference between the control and thiabendazole treated tubers regarding the number of PTM infested tubers. Unfortunately, in these studies CIPC was not tested alone. However,in an earlier study perfect control of PTM was achieved with CIPC alone while non-treated had 54.% PTM infestation and thiabendazole treated tubers had 52% infestation (International Potato Center,1989b).

8. EFFECT OF LEAVING TUBERS IN THE SOIL FOLLOWING VINE SENESCENCE AND REMOVAL ON STORAGE LOSSES

8.1 Introduction

In traditional potato production,tubers usually are left in the soil for a period of time following senescence to improve their storability. In temperate climates, the tubers may remain in the soil for 15 to 20 days. In the warm tropics,this practice may not be beneficial due to high moisture and temperature,diseases,nematodes and tuber moth. Harvesting the tubers as soon as the plant matures could help to avoid diseases and tuber moth infestation,however,storability of these tubers may decrease because of inadequate skin setting. On the contrary leaving the tubers in the soil for a period of time could enhance skin setting but may also increase disease and insect damage.

The following studies were done in San Ramon and were designed to examine the effect of time in the soil following vine senescence and removal in combination with postharvest treatments and storage in different conditions on storage losses.

8.2 Materials and methods

Experiment 1:May-August,1988

There were 5 variables in this experiment:2 clones,2 growing locations, 2 harvest dates, 2 postharvest treatments and 3 storage conditions. A factorial design with 6 replications and 10 kg of tubers per replication was used.

Desiree and LT-1 were planted at San Ramon and Huancayo in November,1987 during the rainy season. Vines were cut and removed when 90% were dead. Tubers were either harvested immediately or after 8 (San Ramon) and 15 days (Huancayo). After each harvest,visibly diseased and insect infested tubers were discarded. One half of the tubers from each harvest were not treated and the other half were soaked 10 minutes in sodium hypochlorite solution (0.5% active chlorine) and 10 minutes in thiabendazole (0.2% active ingredient). Treated tubers were allowed to dry 4 days before being randomly distributed into the 10 Kg replicates. Control tubers were also randomly distributed into replications at this time. Each replicate sample was placed into a plastic mesh bag. Three storage conditions were tested as follows:(1) refrigeration at 4 C, (2) Adobe rustic storage at Huancayo and (3) charcoal walled rustic storage at San Ramon. After 8 days in storage at San Ramon and 30 days in Huancayo, tubers previously treated with sodium hypochlorite and thiabendazole were also dusted with CIPC. During storage the treated tubers were covered with a 15 cm layer of dried and crushed leaves of Lantana spp. at San Ramon and 1 layer of hessian sack at Huancayo. After 4 months storage, the total weight loss in each replicate sample was determined by subtracting the weight of sound tubers from the initial weight. Temperature and relative humidity within and outside the storages are shown in Table A.4

Experiment 2: August-November,1988

There were 4 variables in this experiment:2 clones,2 harvest dates, 2 postharvest treatments and 4 storage conditions. The experimental design was a factorial with 5 replications and 10 Kg of tubers per replication.

Desiree and LT-1 seed tubers were planted in San Ramon in May,1988 during the dry season. Vines were removed when 90% dead. Tubers were either harvested immediately after vine removal or 8 days later. After each harvest diseased and insect infested tubers were discarded. One half of the healthy tubers were dusted with thiabendazole (1.5 gr of Tecto 60 per Kg of tubers) immediately after harvest. The other half was untreated. Both control and treated tubers were cured 10 days in the rustic storage before being distributed randomly into 10 Kg replicates. Each replicate was placed in a plastic mesh bag. The four storage conditions studied were: (1) refrigeration at 4 C,(2)Adobe rustic storage at Huancayo, (3)Charcoal walled rustic storage and (4)simulated farmer's storage at San Ramon. After one month,tubers previously treated with thiabendazole were also dusted with CIPC. Treated tubers were covered with 2 layers of hessian sack and a layer of plastic screen when stored in the charcoal walled rustic storage and farmer's storage at San Ramon and with 1 layer of hessian sack at Huancayo. After 4 months storage, the total weight loss in each replicate was determined by subtracting the weight of sound tubers from the initial weight. Temperature and relative humidity within and outside the storages are shown in Table A.5.

Experiment 3:September-December,1989

Desiree and LT-1 seed tubers were planted in San Ramon during June,1989 during the dry season. This experiment was essentially a duplication of experiment 2 but was conducted one year later. Procedures

were the same as in experiment 2. Temperature and relative humidity within the storages and outside is presented in the Table A.7.

8.3 Results

Experiment 1:May-August,1988

The two clones responded similarly and therefore the data for both were combined for analysis. Weight loss data for Huancayo and San Ramon grown potatoes were analyzed separately (Tables A.38 and A.39). This was done to permit the use of a 3 way analysis of variance for Huancayo and also San Ramon grown potatoes.

Huancayo grown tubers consistently lost less weight than San Ramon grown potatoes (Table 8.1). Delaying harvest of San Ramon grown potatoes for 8 days increased weight loss under each storage condition and with both control and treated potatoes. When potatoes were grown at Huancayo no significant differences in weight loss occurred between potatoes harvested immediately and those harvested 15 days after vine removal.

Dipping potatoes in sodium hypochlorite and thiabendazole solutions and dusting with CIPC significantly increased weight loss of San Ramon grown potatoes stored in the rustic storage at San Ramon but did not effect weight loss of San Ramon potatoes stored at Huancayo or at 4 C. The same treatments applied to Huancayo grown potatoes harvested at vine senescence significantly decreased losses when stored at San Ramon. The treated tubers stored in the rustic storage at San Ramon were covered with 15 cm of dried Lantana leaves. This may have contributed to the high losses of the San Ramon grown potatoes. However,the Huancayo grown

Table 8.1 The effect of delay in harvest following 90% vine senescence and removal and post-harvest treatments on Total Percentage Weight Loss during 4 months in 3 storage environments (March-June,1988). 1/

Harvest	Storage	Total Percentage Weight Loss 2/ Grown in: San Ramon (SR) Control	San Ramon (SR) Treated 3/	San Ramon (SR) Mean	Huancayo (Hyo) Control	Huancayo (Hyo) Treated 3/	Huancayo (Hyo) Mean
At vine senescence	Refrig.4 C	6.5 c	7.9 c		2.7 d	3.2 cd	
	Huancayo	9.8 bc	8.9 c		6.7 c	4.5 cd	
	SR rustic	17.4 b	31.3 a		15.2 a	10.6 b	
	Mean	11.2 B	16.0 A	13.6 b	8.2 A	6.1 A	7.2 a
After 8 (SR) 15 (HYO) days	Refrig.4 C	7.1 c	8.6 c		1.8 c	2.4 c	
	Huancayo	12.6 c	11.4 c		6.4 b	3.3 bc	
	SR rustic	21.0 b	63.6 a		15.6 a	13.8 a	
	Mean	13.5 B	27.8 A	20.7 a	7.9 A	6.5 A	7.2 a
	Overall mean	12.4 B	21.9 A		8.0 A	6.3 B	

1/Potatoes grown from early November,1987 to early Februery,1988 in San Ramon and to late February, 1988 in Huancayo.Each value is a mean of Desiree and LT-1.

2/San Ramon and Huancayo data each analyzed separately as a 3 way analysis of variance.Within each group (8 values) and column values followed by the same lower case letter and row values followed by the same upper case letter do not differ significantly at the 5% probability level (Duncan's Multiple range test).

3/Soaked 10 minutes in both sodium hypochlorite and thiabendazole immediately after harvest and dusted with CIPC after 2 weeks storage.Tubers stored at San Ramon were covered with 15 cm layer of dried and crushed leaves of Lantana spp. and in Huancayo were covered with only a layer of hessian sack.

potatoes stored in the same manner were not adversely affected. Perhaps this was due to the lower level of field infestation by pathogens and PTM.

Although some statistically significant differences in weight loss occurred between potatoes stored at Huancayo and 4 C the actual differences ranged only from about 1 to 6%.

Experiment 2:August-November,1988

The two clones again reacted similarly and therefore the weight loss data were combined for statistical analysis. The analysis of variance is shown in Table A.40.

In contrast to experiment 1, over all storage conditions and treatments a small but significant decrease of about 3% in the mean weight loss resulted from delaying harvest 8 days after vine senescence (Table 8.2).

Dusting tubers with thiabendazole at harvest and with CIPC after one month storage significantly decreased weight loss between 2 and 8 % in the 3 non-refrigerated conditions. There was no significant benefit of treatments when the potatoes were stored at 4 C.

Significant differences in weight loss occurred among the 4 storage conditions. The least loss occurred at 4 C followed by Huancayo adobe storage, then San Ramon rustic and the highest loss occurred in the San Ramon farmer storage.

Experiment 3:September-December,1989

Desiree and LT-1 reacted similarly in weight loss and PTM infestation so the data were combined for analysis. The analyses of variance are shown in Table A.41 (Weight loss) and A.42 (Percentage of PTM infested tubers).

Table 8.2 The effect of delay in harvest following 90% vine senescence and removal and post-harvest treatments on Total Percentage Weight Loss during 4 months in 4 storage environments (August-November,1988). 1/

Harvested	Storage	Total Percentage Weight Loss 2/ Control		Treated 3/		Mean	
At vine senescence	Refrig. 4 C	4.2	e	4.7	e		
	Huancayo	14.1	bc	9.1	d		
	San Ramon rustic	16.4	b	13.3	c		
	San Ramon farmer's	23.3	a	15.5	bc		
	Mean	14.5	A	10.6	B	12.6	A
After 8 days	Refrig. 4 C	4.5	de	2.8	e		
	Huancayo	10.4	bc	6.4	d		
	San Ramon rustic	12.5	b	9.2	c		
	San Ramon farmer's	16.4	a	11.6	bc		
	Mean	10.9	A	7.5	B	9.2	B
	Overall mean	12.7	A	9.1	B		

1/Potatoes grown in San Ramon from May to July,1988.After harvest tubers were cured 10 days in rustic storage at San Ramon.Each value is a mean of Desiree and LT-1.

2/Within each group (8 values) and column values followed by the same lower case letter and row values followed by the same upper case letter do not differ at the 5% probability level (Duncan's Multiple range test).

3/Dusted with thiabendazole immediately after harvest and with CIPC after one month storage.Tubers were covered with 2 layers of hessian sack and a layer of plastic screen in the rustic and farmer's storage at San Ramon and only with a layer of hessian sack in the adobe storage at Huancayo.

Delaying harvest 8 days after vine senescence did not significantly decrease the mean percentage weight loss (Table 8.3). Also, delaying harvest did not significantly change the mean percentage of tubers infested with PTM.

Dusting tubers with thiabendazole at harvest and with CIPC after one month storage significantly decreased weight loss of potatoes stored in the farmer's storage. This decrease in weight loss was 66% for potatoes harvested immediately after vine senescence and 65% for potatoes harvested 8 days after vine senescence. The treatment also decreased weight loss of potatoes stored in the charcoal walled rustic storage but this was not statistically significant. There was no effect of treatment when potatoes were stored at 4 C and at Huancayo.

Dusting tubers with thiabendazole and CIPC completely prevented PTM tuber infestation in the charcoal walled rustic storage. Only slight infestation occurred in tubers stored in the farmer's storage. No PTM infestation occurred in either the control or treated tubers stored at 4 C or in the adobe storage at Huancayo.

No significant differences in percentage weight loss occurred between tubers stored at 4 C and at Huancayo,although loss at Huancayo exceeded those at 4 C by 3 to 5%.

Table 8.3 The effect of delay in harvest following 90% vine senescence and removal and post-harvest treatments on Total Percentage Weight Loss and on the Percentage of Tubers infested with PTM during 4 months in 4 storage environments (September-December,1989). 1/

Harvest	Storage	Total Percentage Weight Loss 2/			Percentage of Tubrs with PTM 2/		
		Control	Treated 3/	Mean	Control	Treated 3/	Mean
At vine senes-cence	Refrig.4 C	3.8 c	4.3 c		0.0 c	0.0 c	
	Huancayo	9.2 c	8.1 c		0.0 c	0.0 c	
	San Ramon rustic	18.5 b	11.1 bc		34.8 b	0.0 c	
	San Ramon farmer's	54.2 a	18.3 b		60.8 a	2.5 c	
	Mean	21.4 A	10.5 B	15.9 a	23.9 A	0.6 B	12.2 a
After 8 days	Refrig.4 C	4.3 d	3.8 d		0.0 c	0.0 c	
	Huancayo	7.5 d	6.4 d		0.0 c	0.0 c	
	San Ramon rustic	15.7 bc	9.3 cd		30.6 b	0.0 c	
	San Ramon farmer's	52.3 a	18.4 b		57.6 a	1.8 c	
	Mean	19.8 A	9.5 B	14.6 a	22.1 A	0.5 B	11.3 a
	Overall mean	20.6 A	9.9 B		22.9 A	0.6 B	

1/Potatoes grown at San Ramon during the dry season from June to August,1989.After harvest tubers were cured 10 days in rustic storage.Each value is a mean of Desiree and LT-1.

2/Within each group (8 values) and column values followed by the same lower case letter and row values followed by the same upper case letter do not differ significantly at the 5% probability level (Duncan's Multiple range test).

3/Dusted with thiabendazole immediately after harvest and with CIPC after one month storage and covered with 2 layers of hessian sack and a layer of plastic screen in rustic and farmer's storage at San Ramon and only with a layer of hessian sack at Huancayo.

8.4 Discussion

The two fold objective of this study was to determine if delaying harvest after vine senescence of potatoes grown in the warm tropics and postharvest treatments would reduce losses during storage. In one experiment,potatoes were also grown at the same time in Huancayo. Huancayo is located at 3200 meters and is cooler than San Ramon and more suitable for growing potatoes. When the same clones were grown at San Ramon and Huancayo and treated the same way,the Huancayo grown potatoes always had less weight loss than San Ramon grown potatoes.

The remainder of this discussion will focus on the results with San Ramon grown potatoes. To aid in the discussion data were taken from Tables 8.1,8.2 and 8.3 to show the mean response of San Ramon grown potatoes to time of harvest,postharvest treatments and storage conditions (Table 8.4).

Part '1' of Table 8.4 shows the results when potatoes were grown and stored at San Ramon. Potatoes grown during the wet season (planted Nov, 1987) had more loss if tubers remained in the soil 8 days after vine senescence. On the other hand when grown during the dry season (planted May,1988 or June,1989) there was a slight benefit from delaying harvest. Based on the means of 3 experiments there were no significant differences in losses between tubers harvested at vine senescence and delaying 8 days. Losses were increased when tubers were soaked in solutions of sodium hypochlorite and thiabendazole (March-June,1988) but decreased if dusted with thiabendazole (Aug-Nov,1988 and Sept-Dec,1989). Based on the means of 3 experiments tuber treatments did not reduce losses.

Part '2' of Table 8.4 shows the results of 3 experiments when San Ramon grown potatoes were stored at Huancayo. Losses were considerably

Table 8.4 Data taken from Tables 8.1,8.2 and 8.3 showing Total Percentage Weight Loss of potatoes grown in San Ramon and stored in different conditions.

1) Potatoes grown and stored in rustic storage at San Ramon.

Planted (p) and stored (s)	Total Percentage Weight Loss 1/ Harvested					
	At senescence			After 8 days		
	Control	Treated	Mean	Control	Treated	Mean
(p)Nov,1987 (s)Mar-June,1988	17.4	31.3	24.3	21.0	63.2	42.3
(p)May,1988 (s)Aug-Nov,1988	16.4	13.3	14.9	12.5	9.2	10.9
(p)Jun,1989 (s)Sep-Dec,1989	18.5	11.1	14.8	15.7	9.3	12.5
Mean	17.4 A	18.6 A		16.4 A	27.2 A	

Overall mean:
Harvest: At senescence 18.0 A After 8 days 21.9 A
Tuber treatments: Control 16.9 A Treated 22.9 A

2) Potatoes grown at San Ramon and stored in Huancayo

Planted (p) and stored (s)	Total Percentage Weight Loss 1/ Harvested					
	At senescence			After 8 days		
	Control	Treated	Mean	Control	Treated	Mean
(p)Nov,1987 (s)Mar-June,1988	9.8	8.9	9.4	12.6	11.5	12.5
(p)May,1988 (s)Aug-Nov,1988	14.1	9.1	11.6	10.4	6.4	8.4
(p)Jun,1989 (s)Sep-Dec,1989	9.1	8.1	8.6	7.5	6.4	6.9
Mean	11.0 A	8.7 A		10.2 A	8.1 A	

Overall mean:
Harvest: At senescence 9.9 A After 8 days 9.1 A
Tuber treatments :Control 10.6 A Treated 8.4 A

Table 8.4 Continuation....
3) Potatoes grown at San Ramon and stored in 4 C

Planted (p) and stored (s)	Total Percentage Weight Loss 1/ Harvested At senescence			After 8 days		
	Control	Treated	Mean	Control	Treated	Mean
(p)Nov,1987 (s)Mar-June,1988	6.5	7.9	7.2	7.0	8.6	7.8
(p)May,1988 (s)Aug-Nov,1988	4.2	4.7	4.5	4.5	2.8	3.7
(p)Jun,1989 (s)Sep-Dec,1989	3.8	4.3	4.1	3.8	3.8	3.8
Mean	4.8 A	5.6 A		5.1 A	5.1 A	

Overall mean:
Harvest: At senescence 5.2 A After 8 days 5.1 A
Tuber treatments: Control 5.0 A Treated 5.3 A

1/Row values followed by the same letter do not differ at the 5% probability level (Duncan's Multiple range test).

less than losses from similar tubers stored at San Ramon. Based on the mean of 3 experiments,no significant benefit resulted from delay of harvest or tuber treatments.

Part '3' of Table 8.4 shows the results of 3 experiments when San Ramon grown potatoes were stored at 4 C. Based on the mean of 3 experiments,no significant benefit resulted from delay of harvest or tuber treatments.

Overall mean losses of San Ramon grown potatoes stored at San Ramon was 19.9%; when stored at Huancayo, 9.5% and 5.1% at 4 C. Thus,potatoes grown in the warm tropics can be stored with minimal loss if temperature control is possible. The temperature coefficient (Q 10) for the mean weight loss of potatoes stored at San Ramon (T=25 C) and Huancayo (T=12.5 C) was 1.81. The Q10 between Huancayo and 4 C was 2.1 and between San

Table 8.5 Data taken from Tables 8.2 and 8.3 showing Total Percentage Weight Loss of potatoes grown at San Ramon and stored 4 months in rustic and farmer's storage at San Ramon.

	Total Percentage Weight Loss 1/ Harvested						
	At senescence			After 8 days			Overall
Storage	Control	Treated	Mean	Control	Treated	Mean	Mean
Rustic	17.5	12.2	14.8	14.1	9.3	11.7	13.3 b
Farmer's	38.8	16.9	27.8	34.4	14.9	24.7	26.3 a
Mean	28.1 A	14.6 A		24.2 A	12.1 A		

Overall means: Harvest: Senescence 21.3 A 8 days 18.2 A
Tuber treat: Control 26.2 A Treated 13.3 B

1/Column values followed by the same lower case letter and row values followed by the same upper case letter do not differ at the 5% probability level (Duncan's Multiple range test).

Ramon and 4 C it was 1.9. These Q10 values are characteristic of most biological processes in response to temperature. The regression coefficient between Log of the mean loss and mean temperature of the 3 storage condition was 0.998. This was significant at the 5 % probability level.

Storage losses of San Ramon grown potatoes were significantly less when stored in the charcoal walled rustic storage compared to losses in the farmer's storage (Table 8.5). Greater PTM infestation was mainly responsible for the increased loss in the farmer's storage. Average temperature in the charcoal walled storage was about 25 C and 33 C in the farmer'storage. Thus,there was a major PTM infestation and increasing losses. No significant mean differences occurred between times of harvest but tuber treatments significantly decreased loss. The greatest benefit from tuber treatments occurred when tubers were stored in the farmer's storage. The treatments were only applied as a dust in the 2 experiments.

9. SUMMARY AND CONCLUSIONS

9.1 Clone storage potential and relationship to clone susceptibility to Erwinia and Fusarium species

One objective of this study was to evaluate the storage potential of clones adapted to the warm tropics and determine if any significant relationships existed between storage potential and response to Erwinia and Fusarium species inoculated separately.

Table 9.1 shows the relative comparison of 14 clones in their loss and rotting response to Erwinia spp, F.solani and to simultaneous inoculation with Erwinia and Fusarium species. For these comparisons,only the results from tuber inoculations made before storage were used. This table was prepared by summarizing data from several experiments over 2 years and using the Duncan's multiple range test in each separate experiment to rank the clones. A relative rating scale from 1.0,lowest loss or susceptibility to 5.0, highest loss or susceptibility was used to compare clones.

Nine of the 14 clones had a ratings of 1 in storage losses (Table 9.1). One clone had a rating of 2 and three had ratings of 4 to 5. The mean losses in storage for the 9 best clones ranged from 6.7 to 9.9% while the poorest clones showed mean losses from 25.6% to 37.4% (Table 3.6).

When Erwinia spp. were inoculated by infiltration,only 2 clones had a mean rating below 2,ten clones rated from 2 to 3, one clone rated above 3 and one rated above 4. Thus most clones were similar in their rotting response to Erwinia spp. (Data was summarized from Tables 4.7 and 4.12).

Table 9.1 Relative comparison of 14 clones in storage losses and in rotting response to Erwinia spp.,F.solani and to simultaneous inoculation with Erwinia and Fusarium spp.

Clones	Storage Loss	Evaluation 1/ Erwinia spp. Infilt.2/	Mic.3/	F.solani	Erwinia and Fusarium 4/
Kufri Jyoti	1	1.3	2	1.3	1.0
Serrana	1	2.5	3	2.3	1.0
Desiree	1	3.3	2	2.3	1.3
B71 240.2	1	3.0	1	1.0	1.0
LT-5	1	2.3	5	1.0	1.8
CGN 69.1	1	3.0	2	1.7	3.3
LT-1	1	2.0	3	2.3	2.0
LT-7	1	3.0	3	1.0	1.3
Rosita	1	3.0	3	2.0	3.5
DTO-33	2	1.7	1	1.3	2.0
LT-2	3	4.7	2	3.0	2.0
I-931	4	2.3	4	1.3	2.8
Atzimba	4	2.7	5	1.0	3.0
CFK 69.1	5	2.3	4	2.7	4.3

1/Values shown are means of several experiments conducted during two years. The numerical scale used to compare clones ranges from 1.0,low loss or susceptibility to 5.0,highest loss or susceptibility. The ratings are based on the rankings provided by the Duncan's multiple range test in each experiment.

2/Infiltration includes inoculation by both immersion and vacuum infiltration.Tubers inoculated before storage.

3/Mic.:inoculation by microinjection.Tubers inoculated before storage.

4/Simultaneous inoculation

Only one experiment was run using the microinjection method to inoculate tubers with the Erwinia spp. The rotting response did not correlate significantly with results from either immersion or vacuum infiltration.

Nine of 14 clones had a dry rot rating in response to F.solani of 2 or below while the remaining 4 clones had ratings between 2 and 3 (Table 9.1). Thus,most clones were also similar in their rotting response to F.solani.

The relative rotting response to the simultaneous inoculation of Erwinia and Fusarium spp. ranged from a low of one to a high of 4.3. Nine clones had ratings of 2 or below, one clone had a rating between 2 and 3 and 4 clones had ratings of 3 or higher. CFK 69.1 was the most susceptible with a relative rating of 4.3.

The linear coefficients of correlation between storage losses and the rotting response to Erwinia spp.,response to F.solani and response to the simultaneous inoculation of Erwinia and Fusarium spp. are shown in Table 9.2. The correlation coefficients between storage losses and Erwinia spp. either by infiltration or microinjection methods and F.solani were non significant. A significant correlation occurred between storage losses and rotting following simultaneous inoculation of Erwinia and Fusarium spp.

From the above,it appears that simultaneous inoculation with Erwinia and Fusarium spp. is a better predictor of storage rotting potential than separate inoculations with the same pathogens. Storage losses in this study also included loss due to sprout removal and shrinkage in addition to rotting. However,rotting was the main factor.

Table 9.2 Linear Correlation Coefficients between storage losses and factors shown in Table 9.1

Factor	Coefficient
Erwinia spp. (Infiltration)	0.06 ns
Erwinia spp. (Microinjection)	0.45 ns
F.solani	0.19 ns
Erwinia spp. + Fusarium spp.	0.63 sig.

Other observations that were made from the inoculation studies are the following: Tuber susceptibility to soft rot caused by Erwinia spp. during both 1988 and 1988 decreased with time in rustic storage. E.chrysanthemi was more virulent than E.carotovora subsp.carotovora but they were significantly correlated. Vacuum infiltration of the bacteria caused more rotting than immersion and no significant correlations were found among the three times of observation (0,2 and 4 months storage) either following vacuum or immersion infiltration. These two methods were significantly correlated when measurements were done before storage but not after 2 and 4 months storage.

9.2 Clone variation in synergistic response to Erwinia and Fusarium spp.

It is well known that the combining of Erwinia and Fusarium spp. in inoculation studies increases rotting beyond the sum of the rotting resulting from separate inoculations (Davis et al,1983). This synergistic

response was also observed in these studies. However,of particular interest was the variation in the synergistic response in rotting among clones. Before storage,the synergistic response ranged from 1 to nearly 6. Similar or greater differences among clones were observed after 2 months storage depending on the pathogen combination. Therefore, a clone may show low susceptibility to two pathogens inoculated separately and may or may not show an increase in susceptibility when pathogens are inoculated simultaneously (Table 6.1,6.2 and 6.3). Under field conditions wounds most likely carry more than one pathogen. Thus, simultaneous inoculations may more closely simulate natural infections.

9.3 Value of delaying harvest after vine senescence and chemical treatments.

Studies were conducted to evaluate the benefit of delaying harvest after vine senescence and combining this with various postharvest treatments. Potatoes grown during the wet season at San Ramon had more loss in storage if tubers remained in the soil for 8 days beyond vine senescence. On the other hand, when grown during the dry season a slight benefit resulted from the 8 day delay. The differences were not statistically significant (Table 8.4). Delaying harvest did not change the percentage of tubers infested with tuber moth provided a good selection was done before storage (Table 8.3).

Storage losses were increased when tubers were soaked in solutions of sodium hypochlorite and thiabendazole but were decreased if dusted with thiabendazole. Treating tubers with CIPC from 2 weeks to 4 weeks after storage did not reduce sprouting but completely prevented PTM infestation. Increasing the amount of hessian sack covering over treated potatoes

did not improve the effectiveness of CIPC to prevent sprouting but did increase storage losses.

9.4 Value of tuber selection before storage

Clones grown in the warm tropics at San Ramon were more diseased and had less storage potential than the same clones grown at the higher elevation research station at Huancayo. However,with careful selection and elimination of visibly diseased,damaged and PTM infested tubers prior to storage,losses during storage were greatly reduced. Repeating the selection again after a 2 week holding period in rustic storage further reduced losses and in particular PTM tuber infestation. After 2 weeks,PTM infested tubers could be easily identified due to the excrement on the tuber surface. With proper selection, losses in rustic storage at temperatures of about 25 C could be reduced to within 2 % of the storage losses at 4 C. Tubers that are eliminated before storage may also be used immediately and thus be salvaged.

In another study the relationship between initial levels of PTM infestation and storage losses was evaluated. Four levels of PTM tuber infestation were prepared by adding the appropriate number of PTM infested tubers to non-infested tubers. After 4 months in rustic storage, storage losses and PTM infested tubers were directly correlated with the initial infestation.

9.5 Clone wound healing ability

The value of wound healing of the cut surface to reduce susceptibility to F.solani was evaluated in 15 clones. The critical period for wound healing of the majority of the test clones was between 4 and 6 days

in the rustic storage (Table 5.4). After 6 days of wound healing 13 of 15 clones showed over a 90% reduction in dry rot.

9.6 Relationship between soft rot susceptibility,water potential and dry matter

It has been reported that susceptibility of tubers to Erwinia spp. decreases with decreasing water potential and dry matter content (Perombelon and Lowe,1975;Biehn et al,1972). These relationships were evaluated in 17 clones. No significant correlations were found between rotting induced by either Ecc or Echy and water potential and dry matter. The range in water potential among the test clones before storage was from -1.9 to -7.4 bars,this increased to -5.6 to -10 bars after 2 months storage and to -10.4 to -14.6 bars after 4 months storage. These differences were possibly insufficient to override inherent clonal differences in susceptibility. Possibly the same explanation would apply to dry matter.

9.7 Storage structures and supplemental storage practices

An evaluation of storage structures was not an objective of these studies. However, 4 different storage environments were used in some experiments. Potatoes were stored at Huancayo in an adobe structure, at San Ramon in both in a charcoal walled rustic storage cooled by evaporative cooling and also in a simulated farmer's rustic storage and finally in 4 C. The least loss occurred at 4 C followed by the adobe storage, charcoal walled rustic storage and farmer's rustic storage (Table 8.3). The mean temperature in the adobe storage was 12.5 C, in the charcoal walled rustic storage it was 26.6 C and in the farmer's storage about

33 C (Table A.4). The evaporative cooling in the charcoal walled rustic storage reduced temperature nearly 10 C from ambient. Over all experiments the Q10 of storage losses was about 2 which is characteristic of most biological reactions.

The greatest benefit from dusting tubers with thiabendazole and CIPC was observed in the farmer's storage (Table 8.3).

There was no benefit in using heavy covering with hessian sacks or Lantana leaves in storing tubers in the charcoal walled rustic storage. Simply using a plastic screen and 2 layers of hessian sack effectively reduced PTM infestation.

9.8 General comments

This research has shown that it is possible to store potatoes up to 4 months in the warm tropics if the following procedures are used:

1. Use properly evaluated clones such as Serrana,Kufri Jyoti,Desiree and also LT-5 and B71 240.2. These clones had low losses in rustic storage,low levels of rotting when simultaneously inoculated with Erwinia and Fusarium spp.,low sprout growth,high yield and a high proportion of commercial size tubers and good tuber shape.
2. Follow good agronomic practices in growing the potatoes,control diseases and harvest at proper maturity.
3. Use tuber selection at harvest and repeat after 2 weeks to eliminate diseased, insect infested and damaged tubers.
4. Dust tubers with thiabendazole after harvest and with CIPC after a holding period of 2 to 4 weeks to allow wound healing.
5. Use good storage management to provide ventilation and evaporative cooling.

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11. APPENDICES

Table A.1 Origin, susceptibility to frost, maturity, rest period and adaptation characteristics of potato clones used in different experiments.

Clone	Origin 1/	Frost 2/	Maturity 3/	days 4/	Rest per. at 25 C days 5/	Adaptation to Cool tropics	Warm tropics	Hot 6/
DTO-33	USA	S	E	70	20	Y	Y	Y
B71 240-2	ARG	-	M	85	50	Y	Y	-
LT-2	CIP	S	E	75	35	-	Y	Y
LT-1	CIP	S	E	75	35	-	Y	Y
LT-5	CIP	S	M	85	35	Y	Y	Y
Desiree	HOL	S	E	80	45	Y	Y	Y
Kufri Jyoti	IND	-	M	95	45	Y	Y	N
LT-7	CIP	S	L	115	40	Y	Y	Y
LT-8	CIP	S	M	100	40	Y	Y	Y
Serrana	ARG	-	M	90	45	Y	Y	-
Atzimba	MEX	S	M	95	40	Y	Y	-
I-931	IND	-	M	95	40	Y	Y	-
CFK 69-1	MEX	-	M	95	40	Y	Y	-
CGN 69-1	MEX	-	M	100	45	Y	Y	-
Rosita	MEX	S	M	105	45	Y	Y	-
Mariva	PER	S	M	115	45	Y	N	N
Yungay	PER	-	L	>120	45	Y	N	N

1/USA=United States of America, ARG=Argentina, CIP=International Potato Center, HOL=Holand, IND=India, MEX=Mexico, PER=Peru.
2/S=susceptible to frost
3/E=early, M=medium, L=late
4/Vines 90% dead at San Ramon
5/Period from harvest to appearance of first sprout (2mm)
6/Cool tropics, Warm tropics, Hot tropics. Y=adapted N=Non adapted

Table A.2 Yield of clones in San Ramon (Metric Tons/Ha.)1/

Wet season 1987-88 Clones	MT/Ha	Dry season 1988 Clones	MT/Ha	Dry season 1989 Clones	MT/Ha
I-931	21.9 a	CGN 69.1	24.6 a	LT-7	26.9 a
DTO-33	18.4 ab	Serrana	24.4 ab	B71240.2	26.3 a
Desiree	18.3 ab	LT-7	24.2 ab	K.Jyoti	25.2 ab
Atzimba	18.2 abc	I-931	23.9 abc	Serrana	24.4 abc
CGN 69.1	16.8 abc	Rosita	22.9 abcd	Desiree	23.5 abcd
K.Jyoti	16.2 abcd	Atzimba	22.5 abcd	CFK 69.1	22.8 abcde
Rosita	14.0 bcd	B71240.2	21.5 abcd	LT-8	22.6 abcde
LT-2	13.8 bcd	K.Jyoti	21.1 abcde	DTO-33	22.2 abcde
B71240.2	12.5 cd	DTO-33	20.9 bcde	Rosita	20.2 bcde
LT-1	11.1 d	CFK 69.1	20.6 cdef	Atzimba	19.7 cde
		Desiree	19.5 def	I-931	19.6 cde
		LT-5	17.9 ef	LT-5	19.2 de
		LT-2	17.2 f	LT-1	18.8 de
		LT-1	12.2 f	CGN 69.1	18.8 de
				Yungay	18.7 de
				Mariva	18.3 de
				LT-2	17.9 e

Table A.3 Summary of 3 seasons showing the yield in San Ramon of 14 clones adapted to the warm tropics

	Yield:Metric Tons/Ha			
Clones	Wet season 1987-1988	Dry season 1988	Dry season 1989	Mean 1/
LT-7	21.6 2/	24.2	26.9	24.2 a
Serrana	20.7 2/	24.4	24.4	23.2 ab
I-931	21.9	23.9	19.6	21.8 ab
Kufri Jyoti	16.2	21.1	25.2	20.8 abc
DTO-33	18.4	20.9	22.2	20.5 abc
Desiree	18.3	19.5	23.5	20.4 abc
CFK 69.1	17.4 2/	20.6	22.8	20.3 abc
Atzimba	18.2	22.5	19.7	20.1 abc
B71 240.2	12.5	21.5	26.3	20.1 abc
CGN 69.1	16.8	24.6	18.8	20.1 abc
Rosita	14.0	22.9	20.2	18.6 bc
LT-5	13.9 2/	17.9	19.2	17.0 cd
LT-2	13.8	17.2	17.9	16.3 cd
LT-1	11.1	12.2	18.8	14.0 d

1/Means followed by the same letter do not differ at the 5% probability level (Duncan's Multiple range test).

2/Calculated values using the formula of Yates to estimate missing values (Le Clerg et al,1962).

Table A.4 Average Temperature and Relative Humidity inside and outside storages at Huancayo and San Ramon from March to June,1988.

	Temperature (C) and Relative Humidity(%)				
	March	April	May	June	Mean
Inside Adobe storage-Huancayo					
Maximum Temperature (C)	14.4	14.7	14.4	12.7	13.5
Minimum Temperature (C)	13.5	13.4	12.3	6.6	11.4
Relative Humidity (%)	-	-	-	-	-
Outside-Huancayo					
Maximum Temperature (C)	20.3	20.5	20.4	18.2	19.6
Minimum Temperature (C)	11.5	10.3	8.4	3.7	8.4
Relative Humidity (%)	-	-	-	-	-
Inside Rustic storage-San Ramon					
Maximum Temperature (C)	24.7	24.2	23.8	22.7	23.8
Minimum Temperature (C)	22.4	22.3	22.3	20.2	21.8
Relative Humidity (%)	86.0	86.0	85.0	85.0	85.5
Outside-San Ramon					
Maximum Temperature (C)	31.4	32.8	34.6	34.1	33.2
Minimum Temperature (C)	22.6	22.8	22.4	20.0	21.9
Relative Humidity (%)	73.2	72.1	73.8	69.9	72.2

Table A.5 Average Temperature and Relative Humidity inside and outside storages in Huancayo and San Ramon from August to November,1988.

Storages	Temperature (C) and Relative Humidity (%) Aug.	Sept.	Oct.	Nov.	Mean
Inside Adobe storage-Huancayo					
Maximum Temperature (C)	15.3	15.2	15.8	16.4	15.6
Minimum Temperature (C)	8.7	11.8	11.1	11.8	10.9
Relative Humidity (%)	-	-	-	-	-
Outside-Huancayo					
Maximum Temperature (C)	21.6	23.0	22.6	23.8	22.3
Minimum Temperature (C)	5.4	9.1	9.3	9.0	8.4
Relative Humidity (%)	-	-	-	-	-
Inside Rustic storage-San Ramon					
Maximum Temperature (C)	25.8	25.1	25.8	26.0	25.7
Minimum Temperature (C)	23.2	21.3	21.9	21.5	21.9
Relative Humidity (%)	84.0	85.0	85.0	85.0	84.7
Inside farmer's storage-San Ramon					
Maximum Temperature (C)	35.0	33.2	31.2	31.4	32.7
Minimum Temperature (C)	28.3	27.0	26.1	26.9	27.1
Relative Humidity (%)	-	-	-	-	-
Outside-San Ramon					
Maximum Temperature (C)	37.8	34.8	35.1	35.0	35.4
Minimum Temperature (C)	23.5	22.9	23.6	23.6	23.4
Relative Humidity (%)	42.1	66.3	68.3	67.8	61.1

Table A.6 Average Temperature and Relative Humidity inside and outside storage at San Ramon from March to June,1989.

Storage	Months of storage March	April	May	June	Mean
Inside Rustic storage-San Ramon					
Maximum Temperature (C	26.9	27.0	26.4	26.2	26.6
Minimum Temperature (C)	22.8	22.8	21.6	21.7	22.2
Relative Humidity (%)	85.0	85.0	83.0	83.0	84.0
Outside-San Ramon					
Maximum Temperature (C)	37.5	40.6	37.7	35.6	37.4
Minimum Temperature (C)	24.7	24.5	24.3	24.4	24.5
Relative Humidity (%)	63.0	61.3	57.0	56.6	59.5

Table A.7 Average Temperature and Relative Humidity inside and outside storage at Huancayo and San Ramon from September to December,1989.

Storages	Months of storage 2/ Sept.	Oct.	Nov.	Dec.	Mean
Inside Adobe storage-Huancayo					
Maximum Temperature (C)	15.2	14.9	15.4	15.5	15.3
Minimum Temperature (C)	12.1	12.4	11.8	11.0	12.3
Relative Humidity (%)	-	-	-	-	-
Outside-Huancayo					
Maximum Temperature (C)	23.9	23.6	22.7	21.8	23.0
Minimum Temperature (C)	9.1	10.0	5.0	3.7	7.2
Relative Humidity (%)	-	-	-	-	-
Inside Rustic storage-San Ramon					
Maximum Temperature (C	27.3	26.5	26.5	25.6	26.4
Minimum Temperature (C)	23.4	23.3	23.0	23.8	23.6
Relative Humidity (%)	85.0	85.0	85.0	85.0	85.0
Inside Farmer'storage-San Ramon					
Maximum Temperature (C)	29.4	27.6	28.7	28.5	28.6
Minimum Temperature (C)	22.2	21.8	23.4	23.0	22.6
Relative Humidity (%)	-	-	-	-	-
Outside-San Ramon					
Maximum Temperature (C)	36.9	38.2	39.5	38.9	38.3
Minimum Temperature (C)	23.6	21.9	23.5	24.9	23.5
Relative Humidity (%)	66.2	68.0	67.5	66.2	66.9

Table A.8 Analysis of variance of the yield of 10 clones grown during the wet season of 1987-88 at San Ramon.(Table A.2)

Source of Variance	Degrees of freedom	Sum of squares	Mean square	F value	Prob
Replication	3	259.39	86.46	6.99	0.0012
Clones	9	387.31	43.03	3.48	0.0057
Error	27	333.60	12.35		
Total	39	980.31			

Coefficient of Variation:21.78%

Table A.9 Analysis of variance of the yield of 14 clones grown during the dry season,1988 at San Ramon.(Table A.2)

Source of Variance	Degrees of freedom	Sum of squares	Mean square	F value	Prob
Replication	3	41.05	13.68	2.86	0.0487
Clones	13	614.27	47.25	9.90	0.0000
Error	39	186.00	3.76		
Total	55	841.33			

Coefficient of Variation: 10.42%

Table A.10 Analysis of variance of the yield of 17 clones grown during the dry season,1989 at San Ramon (Table A.2).

Source of Variance	Degrees of freedom	Sum of squares	Mean square	F value	Prob
Replication	3	49.14	16.38	1.71	0.1763
Clones	16	558.85	34.92	3.65	0.0002
Error	48	458.85	9.54		
Total	67	1066.34			

Coefficient of Variation: 14.39%

Table A.11 Analysis of variance of Storage Losses by 10 clones during 4 months storage at 4 C (Mar.-Jun,1988;Table 3.1).

Source of Variance	Degrees of freedom	Sum of squares	Mean square	F value	Prob
Clones	9	279.85	31.09	31.40	0.0000
Error	30	29.70	0.99		
Total	39	309.55			

Coefficient of Variation: 15.92%

Table A.12 Analysis of variance of Storage Losses by 10 clones as influenced by tuber treatments during 4 months in rustic storage (Mar.-June,1988;Table 3.1).

Source of Variance	Degrees of freedom	Sum of squares	Mean square	F value	Prob
Clones	9	16238.93	1804.32	46.77	0.0000
Tuber Treatm.	1	86806.12	86806.12	2250.34	0.0000
Cl x TT	9	11216.33	1246.33	32.30	0.0000
Error	60	2314.47	38.57		
Total	79	116575.86			

Coefficient of Variation: 12.81%

Table A.13 Analysis of variance of Storage Losses by 10 clones during 4 months storage at 4 C (Aug.-Nov.1988; Table 3.2).

Source of Variance	Degrees of freedom	Sum of squares	Mean square	F value	Prob
Clones	13	260.72	20.05	12.52	0.0000
Error	42	67.25	1.60		
Total	55	327.25			

Coefficient of Variation: 23.19%

Table A.14 Analysis of variance of Storage Losses by 14 clones as influenced by tuber treatments during 4 months in rustic storage (Aug.-Nov.,1988;Table 3.2).

Source of Variance	Degrees of freedom	Sum of squares	Mean square	F value	Prob
Clones	13	6101.41	469.33	88.34	0.0000
Tuber Treatm.	1	253.29	253.29	47.67	0.0000
Cl x TT	13	866.01	66.61	12.53	0.0000
Error	84	446.27	5.31		
Total	111	7666.99			

Coefficient of Variation: 17.90%

Table A.15 Analysis of variance of Tuber Sprout Growth of 14 clones as influenced by tuber treatment during 4 months in rustic storage (Aug.-Nov.,1988;Table 3.3).

Source of Variance	Degrees of freedom	Sum of squares	Mean square	F value	Prob
Clones	13	90.41	6.95	80.78	0.0000
Tuber Treatm.	1	1.54	1.54	17.98	0.0001
Cl x TT	13	19.73	1.51	17.63	0.0000
Error	84	7.23	0.08		
Total	111	118.93			

Coefficient of Variation: 18.36%

Table A.16 Analysis of variance of Storage Losses by 19 clones as influenced by layers of hessian sack covering during during 4 months in rustic storage (Sept.-Dec.,1989;Table 3.4).

Source of Variance	Degrees of freedom	Sum of squares	Mean square	F value	Prob
Clones	18	2584.39	2584.39	88.70	0.0000
Layers	1	15081.40	837.85	28.75	0.0000
Cl x L	18	5031.78	279.54	9.59	0.0000
Error	114	3321.48	29.13		
Total	151	26019.48			

Coefficient of Variation: 36.45%

Table A.17 Analysis of variance of Tuber Sprout Growth of 19 clones as influenced by layers of hessian sack covering during 4 months in rustic storage (Sept.-Dec.,1989;Table 3.5).

Source of Variance	Degrees of freedom	Sum of squares	Mean square	F value	Prob
Clones	18	2584.39	2584.39	88.70	0.0000
Layers	1	15081.40	837.85	28.75	0.0001
Cl x L	18	5031.78	279.54	9.59	0.0000
Error	114	3321.48	29.13		
Total	151	26019.07			

Coefficient of Variation: 36.45%

Table A.18 Analysis of variance of Storage Losses by 14 clones during 4 months in rustic storage using data from 5 separate experiments as replications (Table 3.6).

Source of Variance	Degrees of freedom	Sum of squares	Mean square	F value	Prob
Replication	4	741.69	185.42	5.48	0.0009
Clones	13	5962.29	458.63	13.56	0.0000
Error	52	1758.68	33.82		
Total	69	8462.66			

Coefficient of Variation: 40.81%

Table A.19 Analysis of variance of Tuber Soft Rot susceptibility of 11 clones to two erwinias species when inoculated by immersion and vacuum infiltration and stored 0,2 and 4 months in rustic storage (Mar.-June,1988,Tables 4.1 and 4.2).

Source of Variance	Degrees of freedom	Sum of squares	Mean square	F value	Prob
Evaluations	2	115434.61	57717.30	2846.12	0.0000
Clones	10	4638.76	463.87	22.87	0.0000
E x Cl	20	7565.68	378.28	18.65	0.0000
Erwinia spp.	1	7723.95	7723.95	380.87	0.0000
E x Er	2	3280.82	1640.41	80.89	0.0376
Cl x Er	10	397.98	39.79	1.96	0.0000
E x Cl x Er	20	2036.74	101.83	5.02	0.0000
Methods	1	13816.75	13816.75	681.32	0.0000
E x M	2	2567.87	1283.93	63.31	0.0000
Cl x M	10	1205.86	120.58	5.94	0.0000
E x Cl x M	20	1299.59	64.98	3.20	0.0000
Er x M	1	862.40	862.40	42.52	0.0000
E x Er x M	2	837.44	418.72	20.64	0.0000
Cl x Er x M	10	945.84	94.58	4.66	0.0000
E x Cl x Er x M	20	1622.29	81.11	3.99	0.0000
Error	264	5353.71	20.27		
Total	395	169590.34			

Coefficient of Variation: 23.68%

Table A.20 Analysis of variance of Tuber Soft Rot susceptibility of 16 clones to two erwinias species when inoculated by immersion and vacuum infiltration and stored 0,2 and 4 months in rustic storage (Marc.-June,1989;Tables 4.3 and 4.4).

Source of Variance	Degrees of freedom	Sum of squares	Mean square	F value	Prob
Evaluations	2	83478.58	41739.29	3148.02	0.0000
Clones	15	3687.99	245.86	18.54	0.0000
E x Cl	30	4280.93	142.69	10.76	0.0000
Erwinia spp.	1	7515.77	7515.77	566.84	0.0000
E x Er	2	636.43	318.21	24.00	0.0000
Cl x Er	15	722.39	48.16	3.63	0.0000
E x Cl x Er	30	806.59	26.88	2.02	0.0014
Methods	1	14499.38	14499.38	1093.55	0.0000
E x M	2	2371.82	1185.91	89.44	0.0000
Cl x M	15	667.82	44.52	3.35	0.0000
E x Cl x M	30	905.54	30.18	2.27	0.0002
Er x M	1	1098.11	1098.11	82.82	0.0000
E x Er x M	2	290.46	145.23	10.95	0.0000
Cl X Er x M	15	519.66	34.64	2.61	0.0009
E x Cl x Er x M	30	969.92	32.33	2.43	0.0001
Error	384	5091.41	13.23		
Total	575	127542.88			

Coefficient of Variation: 22.71%

Table 21. Analysis of variance of Tuber Soft Rot susceptibility of 16 clones to erwinias species when inoculated by microinjection and stored 0,2, and 4 months in rustic storage (Mar.-June,1989; Tables 4.6 and 4.7)

Source of Variance	Degrees of freedom	Sum of square	Mean square	F Value	Prob
Evaluations	2	33796.42	16898.21	1330.76	0.0000
Clones	15	6279.95	418.66	32.97	0.0000
E x Cl	30	5412.99	180.43	14.21	0.0000
Concentration	2	8876.36	4438.18	349.51	0.0000
E x Conc.	4	651.83	162.95	12.83	0.0000
Cl x Conc.	30	496.07	16.53	1.30	0.1324
E x Cl x Conc.	60	364.41	6.07	0.48	
Erwinias	1	3951.55	3951.55	311.19	0.0000
E x Er	2	331.09	165.54	13.04	0.0000
Cl x Er	15	611.43	40.76	3.21	0.0000
E x Cl x Er	30	1237.38	41.24	3.25	0.0000
Conc. x Er	2	164.41	82.20	6.47	0.0017
E x Conc. x E	4	106.84	26.71	2.10	0.0790
Cl x Conc. x E	30	156.09	5.20	0.41	
E xClxConcxEr	60	415.97	6.93	0.55	
Error	576	7314.13	12.69		
Total	863	70166.93			

Coefficient of Variation:22.91%

Table A.22 Analysis of Variance of Tuber Rot susceptibility of 17 clones to Ecc when stored 0,2 and 4 months in rustic storage (May-Aug.,1989;Tables 4.7,4.8,4.9 and 4.11).

Source of Variance	Degrees of freedom	Sum of squares	Mean square	F value	Prob
Eveluations	2	20101.65	10050.82	100.21	0.0000
Clones	16	2974.00	185.87	18.50	0.0000
E x Cl	32	5492.58	171.64	17.08	0.0000
Error	102	1024.97	10.04		
Total	152	29293.20			

Coefficient of Variation:23.69%

Table A.23 Analysis of Variance of Tuber Rot susceptibility of 17 clones to Echy when stored 0,2 and 4 months in rustic storage (May-Aug.,1989;Tables 4.7,4.8,4.9 and 4.11).

Source of Variance	Degrees of freedom	Sum of squares	Mean square	F value	Prob
Evaluations	2	252508.03	12754.01	545.19	0.0000
Clones	16	5145.18	321.57	13.75	0.0000
E x Cl	32	7656.89	239.27	10.23	0.0000
Error	102	2386.15	23.39		
Total	152	49696.24			

Coefficient of Variation: 19.02%

Table A.24 Analysis of variance of Tuber Dry Matter content of 17 clones stored 0,2 and 4 months in rustic storage (May-Aug.,1989;Tables 4.7,4.8,4.9 and 4.11).

Source of Variance	Degrees of freedom	Sum of squares	Mean square	F value	Prob
Evaluations	2	52.71	26.357	20.82	0.0000
Clones	16	184.64	11.540	9.12	0.0000
E x Cl	32	24.10	0.753	0.59	
Error	102	129.10	1.266		
Total	152	390.55			

Coefficient of Variation: 5.83%

Table A.25 Analysis of variance of Tuber Water Potential of 17 clones stored 0,2 and 4 months in rustic storage (May-Aug.,1989;Tables 4.7,4.8,4.9 and 4.11).

Source of Variance	Degrees of freedom	Sum of squares	Mean square	F value	Prob
Evaluations	2	1295.45	647.726	681.33	0.0000
Clones	16	166.99	10.437	43.20	0.0000
E x Cl	32	165.58	5.174	21.42	0.2845
Residual	102	24.64	0.242		
Total	152	1652.66			

Coefficient of Variation: 5.80%

Table A.26 Analysis of variance of Tuber Rot susceptibility to erwinias species of 11 clones using observations made in 1988 and 1989 as replications.

a.Evaluation before storage

Source of Variance	Degrees of freedom	Sum of squares	Mean square	F value	Prob
Replication	3	3719.30	1239.77	52.78	0.0000
Clones	10	1981.37	198.13	8.43	0.0000
Error	30	704.66	23.48		
Total	43	6405.34			

Coefficient of Variation: 12.83 %

b.Evaluation after 2 months storage

Source of Variance	Degrees of freedom	Sum of squares	Mean square	F value	Prob
Replication	3	1846.97	615.65	79.47	0.0000
Clones	10	119.81	11.98	1.54	0.1716
Error	30	234.39	7.74		
Total	43	2199.18			

Coefficient of Variation: 25.55 %

b.Evaluation after 4 months storage

Source of Variance	Degrees of freedom	Sum of squares	Mean square	F value	Prob
Replication	3	336.13	112.04	28.36	0.0000
Clones	10	17.83	1.78	0.45	
Error	30	118.49	3.96		
Total	43	472.45			

Coefficient of Variation: 50.08 %

Table A.27 Analysis of variance of Tuber Dry Rot susceptibility of 16 clones to F.solani and F.oxysporum when stored 0,2 and 4 months in rustic storage (Mar.-June,1989;Tables 5.1 and 5.2).

Source of Variance	Degrees of freedom	Sum of squares	Mean square	F value	Prob.
Evaluations	2	2052.74	1026.37	254.41	0.0000
Clones	15	2629.79	176.31	43.46	0.0000
E x Cl	30	612.70	20.42	5.06	0.0000
Fusarium spp.	1	9498.32	9498.32	2354.34	0.0000
E x F	2	198.09	99.04	24.55	0.0000
Cl x F	15	1001.73	66.78	16.55	0.0000
E x Cl x F	30	173.71	5.79	1.44	0.7700
Error	192	774.60	4.03		
Total	287	16941.68			

Coefficient of Variation:20.48%

Table A.28 Analysis of variance of of the influence of Wound Healing on tuber dry rot susceptibility of 15 clones to F.solani (May,1989;Table 5.3).

Source of Variance	Degrees of freedom	Sum of squares	Mean square	F value	Prob.
Clones	14	1651.14	117.93	40.68	0.0000
WH periods	5	10940.32	2188.06	754.88	0.0000
Cl x W.H.periods	70	5891.95	21.04	7.25	0.0000
Error	180	521.73	2.89		
Total	269	14586.19			

Coefficient of Variation:29.63%

Table A.29 Analysis of variance of the Percentage of Reduction in tuber dry rot susceptibility of 15 clones to F.solani due to wound healing (May,1989;Table 5.4).

Source of Variance	Degrees of freedom	Sum of squares	Mean square	F value	Prob.
Clones	14	12457.44	889.81	11.30	0.0000
WH periods	2	52855.20	26427.60	335.84	0.0000
Cl x W.H.periods	28	4950.25	176.79	2.24	0.0022
Error	90	7082.02	78.68		
Total	134	77344.92			

Coefficient of Variation:12.42%

Table A.30 Analysis of variance of Tuber Rot susceptibility of 18 clones resulting from separate and simultaneous inoculations with Erwinia and Fusarium spp.(May-Aug.,1989.Tables 6.1,6.2,6.3,6.4)

Source of Variance	Degrees of freedom	Sum of squares	Mean square	F value	Prob
Evaluations	2	68683.99	34341.99	308.48	0.0000
Clones	17	158389.21	9317.01	83.69	0.0000
E x Cl	34	46148.50	1357.30	12.19	0.0000
Erwinia spp.	2	138313.54	69156.77	621.21	0.0000
E x Er	4	15328.95	3832.24	34.42	0.0000
Cl x Er	34	50273.50	1478.63	13.28	0.0000
E x Cl x Er	68	27006.52	397.15	3.56	0.0000
Fusarium spp.	2	318715.99	159358.00	1431.46	0.0000
E x F	4	55607.94	13901.98	124.87	0.0000
Cl x F	34	57221.59	1682.98	15.11	0.0000
E x Cl x F	68	47419.72	697.34	6.26	0.0000
Er x F	4	45809.47	11452.36	102.87	0.0000
E x Er x F	8	11148.00	1393.50	12.51	0.0000
Cl x Er x F	68	20996.14	308.76	2.77	0.0000
Ex Clx Erx F	136	30523.85	224.44	2.01	0.0000
Error	972	108207.75	111.32		
Total	1457	1199794.73			

Coefficient of Variation: 47.9%

Table A.31 Analysis of variance of Tuber Rot susceptibility of 18 clones to 4 pathogen combinations (Ecc-Fo,Ecc-Fs,Echy-Fo and Echy-Fs). Combinations were used as replications (Table 6.6)

a.Evaluation before storage

Source of Variance	Degrees of freedom	Sum of squares	Mean square	F value	Prob
Replication	3	9952.86	3317.62	18.49	0.0000
Clones	17	29629.65	1742.92	9.71	0.0000
Error	51	9146.30	179.33		
Total	71	48728.82			

Coefficient of Variation: 39.50 %

b.Evaluation after 2 months storage

Source of Variance	Degrees of freedom	Sum of squares	Mean square	F value	Prob
Replication	3	3850.40	1283.46	15.36	0.0000
Clones	17	26806.00	1576.82	18.87	0.0000
Error	51	4261.40	83.55		
Total	71	34917.40			

Coefficient of Variation: 32.29 %

b.Evaluation after 4 months storage

Source of Variance	Degrees of freedom	Sum of squares	Mean square	F value	Prob
Replication	3	8801.74	2933.91	17.51	0.0000
Clones	17	57867.88	3403.99	20.31	0.0000
Error	51	8544.41	167.53		
Total	71	75214.41			

Coefficient of Variation: 21.43 %

Table A.32 Analysis of variance of the influence of tuber selection before storage on Storage Losses of Desiree during 4 months at 4 C (Mar.-June,1988; Table 7.1).

Source of Variance	Degrees of freedom	Sum of squares	Mean square	F value	Prob
Categories	2	3.68	1.84	23.42	0.0003
Error	9	0.70	0.07		
Total	11	4.39			

Coefficient of Variation: 7.52%

Table A.33 Analysis of variance of the influence of tuber selection and treatments before storage on Storage Loss of Desiree during 4 months in rustic storage (Mar.-June,1988;Table 7.1).

Source of Variance	Degrees of freedom	Sum of squares	Mean square	F value	Prob
Categories	2	222.03	111.01	11.60	0.0006
Tuber Treat.	1	1502.74	1502.74	157.11	0.0000
C x TT	2	17.50	8.75	0.91	
Error	18	172.16	9.56		
Total	23	1914.43			

Coefficient of Variation: 18.85%

Table A.34 Analysis of variance of the influence of tuber selection before storage on Storage Losses of tubers during 4 months storage at 4 C (Sept.-Dec.,1989;Table 7.2).

Source of Variance	Degrees of freedom	Sum of squares	Mean square	F value	Prob
Categories	2	162.31	81.15	15.44	0.0001
Error	21	110.34	5.25		
Total	23	272.65			

Coefficient of Variation: 28.45%

Table A.35 Analysis of variance of the influence of tuber selection and tuber treatments before storage on Storage Losses of tubers during 4 months in rustic storage (Sept.-Dec.,1989;Table 7.2).

Source of Variance	Degrees of freedom	Sum of squares	Mean square	F value	Prob
Categories	2	19705.23	9852.61	150.90	0.0006
Tuber Treat.	1	3375.13	3375.13	25.75	0.0000
C x TT	2	1363.72	681.86	5.20	0.0096
Error	42	5503.32	131.03		
Total	47	29947.41			

Coefficient of Variation: 35.23%

Table A.36 Analysis of variance of the influence of levels of initial PTM infestation on Storage Losses of tubers during 4 months in rustic storage (September-December,1989;Table 7.3).

Source of Variance	Degrees of freedom	Sum of squares	Mean square	F Value	Prob
Tuber treat.	1	4185.44	4185.44	134.21	0.0000
PTM levels	3	2720.74	906.91	29.08	0.0000
TT x PTM lev	3	1534.26	511.42	16.40	0.0000
Error	56	1346.28	31.18		
Total	63	10186.73			

Coefficient of Variation: 34.15%

Table A.37 Analysis of variance of the influence of levels of initial PTM infestation and tuber treatments on PTM Infestation of tubers during 4 months in rustic storage (Sept.-Dec.,1989;Table 7.4).

Source of Variance	Degrees of freedom	Sum of squares	Mean square	F Value	Prob
Tuber Treat.	1	50120.01	50120.01	1633.51	0.0000
PTM levels	3	10434.54	3478.18	112.59	0.0000
TT x PTM lev	3	10434.54	3478.18	112.59	0.0000
Error	56	1729.87	30.89		
Total	63	72718.98			

Coefficient of Variation: 19.86%

Table A.38 Analysis of variance of the influence of time of harvest and tuber treatments on Storage Losses of tubers grown in Huancayo and stored 4 months in 3 different storages (Mar.-Jun.1988, Table 8.1)

Source of variance	Degrees of freedom	Sum of squares	Mean square	F Value	Prob
Harvest	1	0.09	0.09	0.02	
Tuber treat.	1	115.95	115.95	6.48	0.0121
H x TT	1	3.44	3.44	0.19	
Stores	2	3306.67	1653.33	92.40	0.0000
H x St	2	53.66	26.83	1.49	0.2270
S x St	2	96.80	48.40	2.70	0.0706
H x TT x St	2	22.11	11.05	0.61	
Error	132	2361.79	17.89		
Total	143	5960.55			

Coefficient of Variation:58.89%

Table A.39 Analysis of variance of the influence of time of harvest and tuber treatments on Storage Losses of tubers grown in San Ramon and stored 4 months in 4 different storages (Mar.-June,1988 Table 8.1).

Source of variance	Degrees of freedom	Sum of squares	Mean square	F Value	Prob
Harvest	1	1800.80	1800.80	19.68	0.0000
Tuber treat.	1	3292.11	3292.17	35.99	0.0000
H x TT	1	818.10	828.10	8.94	0.0033
Stores	2	18984.85	9492.42	103.78	0.0000
H x St	2	2176.80	1088.40	11.90	0.0000
S x St	2	6327.67	3163.83	34.59	0.0000
H x TT x St	2	1656.06	828.04	9.05	0.0002
Error	132	12072.76	91.46		
Total	143	47129.25			

Coefficient of Variation: 55.67%

Table A.40 Analysis of variance of the influence of time of harvest and tuber treatments on Storage Losses of tubers grown in San Ramon and stored 4 months in 4 different storages (Aug.-Nov.,1988; Table 8.2).

Source of Variance	Degrees of freedom	Sum of squares	Mean square	F Value	Prob
Harvest	1	452.94	452.94	62.03	
Tuber treat.	1	532.76	532.76	72.96	0.0000
H x TT	1	1.78	1.78	0.24	
Stores	2	3399.31	1133.10	155.18	0.0000
H x St	2	112.00	37.33	5.11	0.0000
S x St	2	174.77	58.25	7.97	0.0001
H x TT x St	2	33.65	11.21	1.53	0.2076
Error	132	1051.41	7.30		
Total	143	5758.65			

Coefficient of Variation: 24.79%

Table A.41 Analysis of variance of the influence of time of harvest and tuber treatments on Storage Losses of tubers grown in San Ramon and stored 4 months in 4 different storages (Sept.-Dec.,1988; Table 8.3).

Source of variance	Degrees of freedom	Sum of squares	Mean square	F value	Prob
Harvest	1	56.47	56.47	0.86	
Tuber treat.	1	3610.80	3610.80	55.07	0.0000
H x TT	1	2.46	2.46	0.03	
Stores	2	19513.40	6504.46	99.20	0.0000
H x St	2	20.25	6.75	0.10	
S x St	2	6514.62	2171.54	33.12	0.0000
H x TT x St	2	7.44	2.48	0.03	
Error	132	7343.06	65.56		
Total	143	37068.53			

Coefficient of Variation: 52.90%

Table A.42 Analysis of variance of the influence of harvest time and tuber treatments on tuber PTM Infestation of tubers grown in San Ramon and stored 4 months in 4 different storages (Sept.-Dec., 1989;Table 8.3).

Source of Variance	Degrees of freedom	Sum of squares	Mean square	F value	Prob
Harvest	1	31.00	31.00	0.59	
Tuber treat.	1	16087.69	16087.69	308.76	0.0000
H x TT	1	21.94	21.94	0.42	
Stores	2	20987.39	6995.79	134.26	0.0000
H x St	2	31.14	10.38	0.19	
S x St	2	18452.08	6150.69	118.04	0.0000
H x TT x St	2	24.58	8.19	0.15	
Error	132	5835.62	52.10		
Total	143	61471.49			

Coefficient of Variation: 61.39%