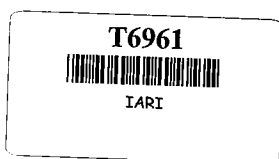


**PRE-STORAGE AND PRE-SOWING TREATMENTS
FOR ENHANCING THE SEED QUALITY OF
PARENTAL LINES OF MAIZE HYBRID**

SUNIL S. MAHAJAN



T-6961

**DIVISION OF SEED SCIENCE AND TECHNOLOGY
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NEW DELHI-110 012**

2002

**PRE-STORAGE AND PRE-SOWING TREATMENTS
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PARENTAL LINES OF MAIZE HYBRID**

By

SUNIL S. MAHAJAN

A Thesis

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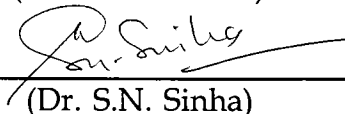
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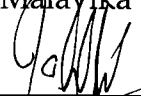
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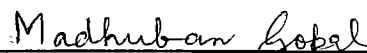
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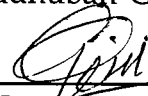
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This is to certify that the thesis entitled "**Pre-storage and pre-sowing treatments for enhancing the seed quality of parental lines of maize hybrid**", submitted to the Post-Graduate School, Indian Agricultural Research Institute, New Delhi in partial fulfilment of the requirements for the degree of **Doctor of Philosophy in Seed Science and Technology**, embodies the results of *bona fide* research work carried out by **Mr. Sunil S. Mahajan** under my guidance and supervision. No part of the thesis has been submitted for any other degree or diploma.

All the assistance and help received during the course of the investigation have been duly acknowledged by him.

Place : New Delhi

Date : May 3, 2002


(ASHOK GAUR)
Chairman
Advisory Committee

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CONTENTS

Chapter		Page No.
1.	INTRODUCTION	... 1
2.	REVIEW OF LITERATURE	... 7
3.	MATERIALS AND METHODS	... 51
4.	RESULTS	... 64
5.	DISCUSSION	... 105
6.	SUMMARY	... 153
	BIBLIOGRAPHY	... i-xxv
	APPENDIX	
	ANNEXURE	

LIST OF TABLES

Table No.	Title	Between Page
1 - 2	Moisture content (%) of <i>Rabi-1998</i> and <i>Kharif-1999</i> produce seeds after different period of storage	64-65
3 - 6	Germination (%) of <i>Rabi-1998</i> and <i>Kharif-1999</i> produce seeds after different period of storage	66-67
7 - 10	Seedling dry weight (mg) of <i>Rabi-1998</i> and <i>Kharif-1999</i> produce seeds after different period of storage	70-71
11 - 14	Seedling shoot length (cm) of <i>Rabi-1999</i> and <i>Kharif-1999</i> produce seeds after different period of storage	73-74
15 - 18	Seedling root length (cm) of <i>Rabi-1998</i> and <i>Kharif-1999</i> produce seeds after different periods of storage	76-77
19 - 22	Vigour Index of <i>Rabi-1998</i> and <i>Kharif-1999</i> produce seeds after different periods of storage	79-80
23 - 24	Germination (%) of <i>Rabi-1998</i> and <i>Kharif-1999</i> produce seeds in Accelerated ageing	82-83
25 - 26	Germination (%) of <i>Rabi-1998</i> and <i>Kharif-1999</i> produce seeds in cold test	83-84
27 - 30	Electrical conductivity (μ siemens/cm/g) of <i>Rabi-1998</i> and <i>Kharif-1999</i> produce seeds after different periods of storage	85-86
31 - 34	Per cent incidence of fungi on <i>Rabi-1998</i> and <i>Kharif-1999</i> produce seeds after different periods of storage	87-88
35	Area of inhibition zone (mm ²) of different fungicides and its combinations with insecticides at different dosage	89-90

Table No.	Title	Between Pages
36	Area of inhibition zone (mm ²) obtained in treated seeds kept under different conditions after different periods of storage	90-91
37	LT ₅₀ (days) of different seed protectants tested against <i>Rhizopertha dominica</i> after different periods of storage	94-95
38	Persistence of Deltamethrin residues (ppm/kg) on maize seeds during 18 months storage period	96-97
39-40	Seedling emergence (%) of the stored seeds (<i>Rabi</i> 1998 and <i>Kharif</i> 1999 produce) in August 2000	97-98
41-42	Seedling emergence (%) of the stored seeds (<i>Rabi</i> 1998 and <i>Kharif</i> 1999 produce) in February 2001	99-100
43-44	Seedling emergence (%) of (<i>Rabi</i> 1998 and <i>Kharif</i> 1999 produce) seeds after various pre-sowing treatments in August 2000	101-102
45-46	Seedling emergence (%) of (<i>Rabi</i> 1998 and <i>Kharif</i> 1999 produce) seeds after various pre-sowing treatments in February 2001	103-104

LIST OF FIGURES

Fig. No.	Title	Between Page
1.	Monthly temperature and relative humidities recorded during June 1999 to March 2001	64-65
2.	Inhibition zone produced by different concentrations of fungicides and its combinations with insecticide	89-90

LIST OF PLATES

Plate No.	Title	Between Page
1 and 1a.	Inhibition zone produced by maize seed treated with Captan after 6 and 12 months storage respectively	92-93
2 and 2a.	Inhibition zone produce by maize seed treated with Bavistin after 6 and 12 months storage respectively	92-93
3 and 3a.	Inhibition zone produce by maize seed treated with Captan + Deltamethrin after 6 and 12 months storage respectively	92-93
4 and 4a.	Inhibition zone produce by maize seed treated with Captan + Malathion after 6 and 12 months storage respectively	92-93
5 and 5a.	Inhibition zone produce by maize seed treated with Bavistin + Deltamethrin after 6 and 12 months storage respectively	92-93
6 and 6a.	Inhibition zone produce by maize seed treated with Bavistin + Malathion after 6 and 12 months storage respectively	92-93

ABBREVIATIONS

%	-	per cent
µg	-	microgram
cm	-	centimeter
cv	-	cultivar
EC	-	Emulsifiable concentrate
Fig	-	figure
GLC	-	Gas Liquid Chromatography
g	-	gram
HPLC	-	High Performance Liquid Chromatography
hrs	-	hours
ISTA	-	International Seed Testing Association
KCl	-	Potassium Chloride
Kg	-	Kilogram
Kpa	-	Kilopascal
lb	-	pounds
mg	-	milligram
ml	-	milliliter
mm	-	millimeter
MSCS	-	Minimum Seed Certification Standards
ng	-	nanogram
NUV	-	Near Ultra Violet
p.s.i.	-	per square inch
PDA	-	Potato dextrose agar
PEG	-	Poly Ethylene Glycol
ppm	-	parts per million
RH	-	Relative Humidity
ssp.	-	species
TO	-	Test Organism
w/w	-	weight by weight
wp	-	Wettable powder
wt	-	weight

INTRODUCTION

Maize yields have continued to increase at a fairly constant rate conditioned by a combination of improved hybrids, parental materials and better breeding techniques as well as immense use of fertilizers, chemicals etc. and disease management. It is evident from the fact that significant developments in recent past have demonstrated potential of hybrids over high yielding varieties even under stress environment. Moreover, maize hybrids particularly in *Rabi* maize growing areas in different cropping systems have paved ways for realizing enhanced production. However, changing production practices have brought with them changing problems relative to the incidence of both old and new fungal diseases especially when the seeds are under storage (Singh *et al.*, 1996). Nearly eighty per cent of the certified seed produced in India requires storage for one season and 20 per cent of the seed is carried over for subsequent sowing as a safeguard against natural hazards (Bal, 1976). However, parental lines of commercial hybrids once developed needs to be maintained for a longer period. During storage, several biotic and abiotic factors, such as moisture content, relative humidity, temperature, gaseous composition, chemical treatment, and insect and fungal infestation affects seed germination and viability causing both qualitative and quantitative losses to the stored seeds (Owen, 1956).

T-6961

Bio-deterioration of maize seeds during storage is one of the major problems, which has been attracting attention of the pathologists and seed technologists. It is well established that during storage, the activity of field fungi is arrested while that of storage fungi increases and as such they are responsible for loss in germination, vigour, discolouration, heating, mustiness, rotting, decay as well as elaboration of mycotoxins which consequently affects the yield adversely (Minocha and Christansen, 1974; Siddiqui, 1976; Varshney *et al.*, 1991 and Quenum-Florent *et al.*, 1998).

Several stored grain insect pests, considered to be destructive in maize seeds (Dang and Pant, 1965 and Singh *et al.*, 1973), which are brought into warehouses and other storage structures along with harvested grains cause heavy damage by reducing seed weight and viability (Yadav *et al.*, 1968; Bernardo, 1972; Singh and Pande, 1975; Giga *et al.*, 1991; Kossou *et al.*, 1993 and Kurdikeri *et al.*, 1993^a and 1994). Besides this, they may injure or remove a part or whole of the embryo and endosperm, form webs or cocoons around the seeds, induce fungal infestation and increase grain temperature and moisture content (Srivastava and Bhatia, 1958; Yadav *et al.*, 1968; Mookherjee *et al.*, 1969 and Taylor, 1975). Such seeds that do germinate, often fail to establish and die or become distorted. However, about 4% of the world's stored grain is lost through the activity of fungi and other organisms (Clarke, 1969). Based on experimental work and other observations, it is estimated that in India the per annum loss is of the order of 13.2 per cent which is considerably more than the global diseases loss

estimates of 9.4 per cent of the total production (Sharma and Lal, 2000). According to Payak (1985) the loss in maize grain production due to diseases is of the order of 9 lakh tonnes.

Rhyzopertha dominica (Lesser grain borer) is one of the serious pests of stored maize in India causing losses ranging from 33.2 to 52.90 per cent (Pandey and Singh, 1974 and Singh and Pandey, 1975). It not only reduces available carbohydrates (Sudesh *et al.*, 1993^a), essential and non-essential amino acids (Jood *et al.*, 1995) but also, increases the concentration of total nitrogen, total protein, non-protein nitrogen and uric acid in stored maize (Sudesh *et al.*, 1993^b). The losses to stored corn by *R. dominica* are primarily due to its preference for maize than wheat because of size of maize grain which provides ample space for oviposition (Khare and Aggarwal, 1963).

Among abiotic factors, seed moisture and temperature are the most important environmental factors influencing seed viability during storage (Bernal-Lugo and Leopold, 1998 and Jian-Fang *et al.*, 1998). Of the two factors, relative humidity, which is directly proportional to seed moisture content, is reported to exert a greater influence on seed longevity than temperature in different species (Jian-Fang *et al.*, 1998). Because of non-availability of proper storage facilities in most parts of the country, majority of the stored seed gets infected with different levels of mycoflora, which leads to deterioration of seed quality in more than one way (Christensen, 1980). However, the pattern of seed longevity and storage potential of different species has been studied by several workers both for long and medium term

under ambient and controlled storage conditions and for short term under accelerated ageing conditions.

Besides storage conditions, packaging materials as well as the kind and the amount of mycoflora associated with the seeds also play an important role in ascertaining the health status of the seeds. Nevertheless, mechanical injuries which occur during threshing, processing and handling of seeds have direct impact on the seed viability during storage as these make the seeds more vulnerable by providing a smooth passages for the entry and invasion of microorganisms in general and fungi in particular (Leist and Schmidt, 1978; Neikov, 1980; Svoboda, 1988 and Borba *et al.*, 1995).

Fungicidal seed treatment is one of the most effective and economic methods of controlling seed borne diseases. This method has a special significance in a developing country like India where efforts are on way to obtain maximum yield per unit of cultivated land since there is little prospect of increasing the total cropped area (Dharam Vir, 1983). Since storage fungi do not usually invade seed before harvest (Qasem and Christensen, 1958; Tuite, 1961), fungicides applied before storage may be useful as a seed protectant, primarily in tropical areas where the environmental conditions and lack of post harvest technology are favourable to the growth of storage fungi (Moreno-Martinez *et al.*, 1998). Over the year's seed dressing has become more and more sophisticated going from spraying powder, liquid or slurry to pelleting and film coating of seeds (Gaur and Varshney, 2001). Addition of micronutrients, trace elements incorporating draught and frost

resistance properties being additional benefits under special circumstances. Nevertheless, in order to maintain seed viability and vigour of stored seeds, several workers studied the effect of seed treatments with wide range of fungicides (Dharam Vir, 1977, 1980; Paul and Mishra, 1993, 1994), insecticides (Samson and Parker, 1989; Bhuiyah *et al.*, 1995; Pereira *et al.*, 1997) and plant products (Sharma, 1995, 1999; EL Lakwah *et al.*, 1996, 1997; Nakka, 1997). Incidentally, some fungicides simultaneously offer protection against both insect and mycoflora in treated seed as have been reported by Baldev and Amin (1974), Mummigatti and Raghunathan (1981), Babu *et al.* (1989), Savitri *et al.* (1994), Arumugam (1998) and Ramnadane *et al.* (1998).

Various seed invigouration treatments before sowing have been devised to improve the rate and uniformity of seed germination as well as vigour in a number of crops species (Mandal and Basu, 1982; Goldsworthy *et al.*, 1982; Day and Mukherjee, 1988 and Khan *et al.*, 1992; Kurdikeri *et al.*, 1993^a; Shanta Nagarajan and Pandita, 1998). Reports on seed invigouration studies on maize are scanty and standardization of cold test among seed testing laboratories has not been accomplished well (Woltz *et al.*, 1998).

Hence, seed treatment is one of the methods adopted for safe storage as it not only reduces the deleterious effects of damage to seed viability and vigour but also provides better avenues for their establishment, growth and development of seedlings. Nevertheless, very few workers have evaluated the efficacy of non-fungicidal and non-insecticidal grain protectants, such as extracts of plant products, plant antifeedants, and oil seed cakes against

stored grain pests and seed mycoflora. However, very little is known in respect of their biological effectiveness on germination, associated mycoflora as well as viability when seeds are stored for some time. It was, therefore, thought worthwhile to undertake the present study with the following objectives.

- 1) To standardize seed treatments to enhance seed vigour and to control storage pathogens.
- 2) To study the effect of anti-pathogenic substances on seed moisture, germination, vigour, seed mycoflora and insect pests and field emergence of seed stored under ambient and controlled storage conditions.
- 3) To evaluate the persistence of anti-pathogenic substances (used as pre-storage seed treatments) on seed after storage.

REVIEW OF LITERATURE

Quality seed is one of the most important inputs in agriculture for maximizing its production, so it is a prerequisite to maintain high quality parameters of the seeds from one season to next planting season. During storage, loss of quality occurs to a great extent, if the seeds are not properly stored. Although lot of work has been done on the loss of viability of different cultivars of maize, but very little information is available on the loss of viability of hybrid maize seeds specially their parental lines during storage (Justice and Bass, 1979).

2.1 Factors affecting storability of seeds

The rate at which corn deteriorates in storage is influenced greatly by a number of factors, of which the most important ones are moisture content of the seed, temperature and relative humidity of the environment, where it has been stored. Besides, the kind and the amount of microorganisms particularly fungi associated with seeds and injuries, if any, on the pericarp of kernels can't be overlooked (Qasem and Christensen, 1960).

Semeniuk and Gilman (1944) reported quick loss in viability of corn seed with high initial moisture content during storage. Lopez and Christensen (1967) enumerated that the *Aspergillus flavus* could invade the corn seed stored with moisture content of 18.5% and more, whereas at 17.5% moisture

content, it did not attack the seeds. However, Christensen (1973) reported that wheat, barley, corn and sorghum seeds with 17.0 to 19.9% moisture content stored for 24 months lost viability completely. Adesuyi and Shode (1977) noticed that in two varieties of maize stored in traditional cribs, grain moisture content increased as also the mould incidence during April to August. This happened due to heavy rainfall resulting in high relative humidity and a corresponding increase in grain moisture content during storage. Moreno-Martinez and Vidal-Gaona (1981) observed that seeds with the higher moisture content of 16.0% had a faster decrease in germination due to invasion of the seeds by storage fungi than the seeds with 9.8% initial moisture content.

Qasem and Christensen, (1958) demonstrated that a corn seed lot having 99% germination and 12-18% moisture content if inoculated with a mixture of storage fungi specially *Aspergillus* spp. and stored at 5-25⁰C for 6 to 8 months, 100% seed were infected by storage fungi at 15-25⁰C, whereas no invasion was found on seed if these were stored at 5⁰C. Further, Qasem and Christensen (1960) after inoculating the corn seed with different species of storage fungi alone and in mixture and stored for 2 yrs. at temperature 5-30⁰C and at moisture content of 12-18%, recorded heavy damage in germination of maize seeds. However, moderate to heavy germination damage occurred in grain with 17-18% moisture content when inoculated with storage fungi and kept at 10-15⁰C. Christensen (1972) noticed that the combination of a moisture

content less than 14% and temperature 10-20°C is good for preventing storage fungi on maize. Furthermore, Christensen (1973) stated that storage fungi that invade seeds at moisture contents in equilibrium with relative humidity upto 85% grow very slowly at temperature below 10°C.

Lal (1975) observed that wheat and maize with 12% and 14% moisture content respectively remained practically free from storage moulds at temperature ranging from 5°C to 25°C but at 16% moisture level, infection rises with the proportional increase in temperature. Similarly, Morace and Echandi (1976) found that the seeds of rice and maize having 9.8% to 13.5% and 9.9% to 14.1% moisture content respectively stored for 24 weeks showed decline in germination when stored at 30°C.

Likhatchev (1977) observed complete loss of germination 30 days after storage in open containers and 70 days after storage in sealed containers, when the maize cultivars and 2 hybrids were stored at 37°C and at 95 to 100% RH. Khanna and Yadav (1979) when stored the seeds of wheat, maize, barley and pearl millet at 75% or 90% RH, observed that the loss of viability was very rapid under higher RH.

Agrawal *et al.* (1981) have shown that loss of viability increased with either increased RH (from 20 to 80%) or increased temperature (from 20 to 30°C) in sorghum hybrids and their parental lines. Jorge *et al.* (1988) evaluated that the maize inbred lines stored for short period of time under improper dry (60°C) and humid (40°C and 100% RH) conditions, showed significant loss in

viability. However, Gowda and Bhole (1989) while working on various crop seeds found that the storage in the air conditioned room (20°C) with 55% RH; the germination percentage of maize was reduced to 70% from initial germination of 94% after 24 months of storage. Singh and Singh (1992) reported that maize seeds could be stored for a longer period in a cold storage than that stored under ambient conditions. Similarly, Singh and Munda (1998) revealed that dry conditions using self indicating silica gel retained the germination percentage above the certification standard (81%) upto 2 years of storage, while under ambient conditions, the germination per cent was drastically reduced in 8 months of storage in maize varieties.

Bottomley *et al.* (1950) observed that germination of corn seeds was reduced from 86% to 20.1 and 6.0% when the seeds were stored for 12 days at 25°C and 40°C , respectively. Agrawal (1974) stated that the viability of stored maize seeds was greatly influenced by the storage temperature and there was no loss in germination after 19 months of storage at 5°C as compared to 90 to 98% loss in germination, when they were stored at room temperature. Chandak (1990) while storing the maize seeds at room temperature $35 \pm 5^{\circ}\text{C}$ or at a temperature of $20 \pm 1^{\circ}\text{C}$ in an incubator recorded 50% loss in viability after 12 months of storage. Vorovenei *et al.* (1990) while taking the seeds of some maize hybrids, showed better resistance to sub-optimal conditions of germination than did the parental forms of inbred lines. Rangaswami (1994) suggested that the ear rot caused by *Cephalosporium*

accremonium and *Rhizoctonia zeae* may cause considerable damage and it may continue in the storage godown, if the ears after harvest are not properly dried before storage.

Naplava and Weingartman (1994) investigated damage to maize seeds caused by the drying process. Kernels without any external damage were tested and categorized as no, single, double and multiple stress cracks. Stress cracks analysis showed that if the initial drying temperature was higher than 45°C, the number of stress cracks was greater; the compression force decreased with the number of stress cracks; there was no difference in conductivity test between undamaged kernels and kernels with stress cracks. Drying air temperature and varietals sensitivity were recognized as the major reasons affecting stress cracks and therefore maize quality. Borba *et al.* (1995) demonstrated that the mechanical damage significantly reduced seed quality, when the seeds of single cross hybrid maize BR-201 with 4 different moisture content ranging from 10.9 to 25.0% hulled manually or mechanically and stored for 10 months.

Katta and Bullerman (1995) while studying the effect of high temperature (35°C) and high RH (85%) on stored white and yellow popcorn for 3 months, found that internal mould infection in white popcorn stored in an open container was lower (18.3%) than that stored in a closed plastic bag (75.0%) and closed plastic jar (85.3%). However, in case of yellow popcorn the internal mould infection was higher (23.3%) than the one stored in a closed plastic bag and closed plastic jar (2.6%). Quenum *et al.* (1998) found that,

among the high moisture content (16.6%) seeds of maize, *Aspergillus* spp. was the main fungi, but in seeds with medium and low moisture content (13.6% and 10.3%), *Rhizopus*, *Aspergillus*, *Fusarium* and *Penicillium* spp. were common. They also observed that the stored seed contained aflatoxin (0-7.66 ng/g), which affected seed viability, germination and vigour. Recently, Abba and Lovato (1999) while investigating the storage conditions of maize cv. Doge, untreated or treated with Carbendazim + Maneb, observed that storage condition of 30°C + 90-95% RH was lethal to maize seed viability after 40 days of storage, during which the seed equilibrium moisture rose from 10.5% to 17%. However, the 20°C + 45-50% RH storage condition was safe for at least one year of storage, during which seed equilibrium moisture remained below 11.5% and viability and vigour were practically unaffected.

Sarada *et al.* (1994) while studying the effect of stage of harvest and drying methods on the storability of maize inbred CM-201 observed that the seed harvested at 35, 40 and 45 days after flowering and dried in shade, sun or artificially at 40°C and 45°C could maintain germination above certification standard (80%) upto 12 months. The storability of the seed was markedly less when they were artificially dried at 30°C and 35°C.

Singh *et al.* (1971) while working with hybrid maize (Ganga-2, Ganga-3 and Ganga-5) and composites (Vijay, Kisan and Jawahar) sweet corn and inbred lines (CM-500, CM-200, CM-400 x CM-300 and CM-202 x CM-111) found that *Cephalosporium acremonium* as well as *Fusarium moniliforme* were in

variable percentage. However, Lal *et al.* (1976) inferred from their studies that the expression of white streaks in maize seed is not only the result of *C. acremonium* infection as reported earlier from India but it may also be due to *F. moniliforme* and some other fungi like *Helminthosporium maydis* and *Curvularia pallescens*.

Lal and Saksena (1977) encountered a total of 23 fungi associated with maize seeds and seedlings which were first determined by artificial method in wide mouth tubes under laboratory conditions and later confirmed their pathogenicity in pot culture experiments. Ahmed and Bhutta (1989) examined 57 maize seed lots and fungal pathogens recorded were *C. acremonium*, *D. maydis*, *F. moniliforme* and *F. semitectum* at the level of 14%, 6%, 98.5% and 11% respectively, while low incidence of *Fusarium equiseti*, *F. oxysporum*, *Macrophomina phaseolina* and *N. (Khuskia) oryzae*. However, maize seed samples studied by Bujari and Ershad (1993) and Kulick *et al.* (1994) exhibited the presence of 23 fungi; the predominant ones were the species of *Aspergillus*, *Fusarium* and *Penicillium*.

Rai *et al.* (1991) isolated a total of 24 fungal species belonging to 14 genera from maize grains collected from Patal Kot, Madhya Pradesh. Of these, 11 spp. were recovered from external and internal tissues of the seeds. Similarly, Paul and Mishra (1992) identified a total of 32 fungal species belonging to 16 genera from seeds of 3 maize varieties grown in north-eastern India. The most common and frequently occurring fungi were *Alternaria alternata*, *Aspergillus candidus*, *A. flavus*, *A. niger*, *A. terreus*, *Fusarium*

moniliforme, *Penicillium* spp. and *Rhizopus nigricans*. However, Vyas (1994) assessed 37 and 12 cultivars of rice and maize respectively, for the presence of seed mycoflora. Seventeen fungi were associated with rice seed and 13 with maize. The most common species of fungi observed were *Aspergillus* spp. and *Fusarium* spp. on both rice and maize. Nevertheless, Bankole (1994) encountered predominantly the different species, of which *Aspergillus* and *Penicillium*, succeeded the field fungi on stored grain as a result seed germination was decreased drastically with the storage time which was lowest after 12 months

Di *et al.* (1994) isolated *F. moniliforme* var. *intermedium* (seedling blight) from diseased maize seeds. However, Kedera *et al.* (1994) came across *F. moniliforme*, *F. graminearum*, and the species of *Helminthosporium*, *Stenocarpella* (*Diplodia*), *Penicillium* and *Rhizoctonia* from both rotted as well as asymptomatic grains obtained from 25 maize genotypes. Schumann and Zreik (1994) recorded *Fusarium culmorum* abundantly followed by *F. oxysporum*, *F. equiseti* and *F. verticillioides* on maize seeds. Nsibande (1994) indicated that mere presence of *F. moniliforme* on the seed does not reduce germination, unless the seed is heavily infested and embryo is killed.

Recently, Barney *et al.* (1995) encountered *Aspergillus flavus*, *A. glaucus*, *Fusarium* spp., *Penicillium* spp. and *Rhizopus* spp. predominantly on pioneer hybrid of maize 3378 and 3320. However, freshly harvested samples of 4 varieties of rice and two varieties of maize collected from market of Uttar Pradesh, revealed higher number of fungi (11) on rice seed than on maize

seeds (7) (Tiwari and Tiwari 1996). Similarly, Casa *et al.* (1998) identified fungi associated with maize seeds on 69 commercially treated seed samples, and on 59 untreated seed samples from the southern and south-east region of Brazil, in 1994/95 and 1995/96. *F. moniliforme*, *Penicillium* spp. and *Cephalosporium* spp. were observed at higher incidences and frequencies on untreated seed samples. Whereas, in commercially treated seeds, *G. fugikuroi* and *Fusarium/Gibberella* spp. were predominated. Recently, Varshney *et al.* (2001) reported that a total number of 18 fungal species were encountered collectively on two maize hybrid and their parental lines. The most predominant ones includes *Aspergillus* spp., *Cladosporium harbarum*, *Curoularia lunata*, *Drechslera halodes*, *Fusarium moniliforme* and *Penicillium* spp.

2.2 Efficacy of fungicide on seed quality

Seed disinfections occupy an important position in the strategy for plant disease control. It has been observed that most of the seed producing firms after procuring the seeds subjected them to fungicidal treatment before storage. Although considerable attention has been given to the studies on relative evaluation of fungicides, little information is available about the retention of fungicidal properties, when treated seeds are stored for some period.

Hoppe (1957) and Roktanen (1963) noted that Thiram and organomercurial fungicides have been reported to increase germination of maize seeds. Similarly, Laxminarayana *et al.* (1966) viewed that maize seed

treated with Agrosan GN, Captan, Coversan and Thiram are generally superior. Smith (1970) reported that there was no reduction in seed vigour during 12 months of storage, when maize seeds were treated with Ceresan, Coversan or Panogen. Singh *et al.* (1971) demonstrated that the *Cephalosporium acremonium* as well as *Fusarium moniliforme* recorded on hybrid maize seed were eradicated, when they were treated with Benlate and germination was better than the untreated control even after 133 days of storage.

Saharan *et al.* (1972) after having treated freshly harvested maize seeds with Captan, Ceresan, and Dithane Z-78 separately and in combination and stored for one year, could observe that the seed treatment with the fungicides gave higher percentage germination as compared to control. Rao *et al.* (1973) observed that the freshly harvested seeds of Deccan maize hybrids treated with Captan and stored under ambient conditions of RH and temperature in Coimbatore could maintain the germinability upto 16 months to pass through truthful labeling and certification standard. Agrawal (1974) observed that seed treatment with Thiram and D.D.T. had no influence on the storage life of maize.

Moreno-Martinez and Vidal-Gaona (1981) while working with commercial hybrid H-412 found that the seed treated with 750 ppm of active ingredient of Benomyl, Captan, Captafol, Chlorothalonil, Carbendazim plus Maneb, Dichlofluanid and Thiabendazole showed germination 82-93% after storage for 150 days as compared to 14% germination in untreated controls. Similarly, Verma and Agrawal (1981) observed that the seeds of two maize

hybrids Ganga-2 and Hi-starch when treated separately with Agrosan GN, Benomyl, Brestanol, Captan, Ceresan wet, Deuter and Dithane M-45 invariably exhibited increased germination as compared to untreated ones and maintained 85% emergence throughout the storage period.

Falloon (1982) reported that hybrid maize PX-74 treated with Captan, Etridiazole, or Thiram (1.5 g/kg seed) or combinations of Captan + Benodanil, Captan + Metalaxyl or Benomyl + Fenaminosulf (0.75 + 0.75 g/kg seed) showed increased number of emerged seedlings in a field trial by 37-50%. Similarly, Moreno-Martinez and Ramirez (1985) stored hybrid maize H-412 having a germination of 99% and 9.7% moisture content treated with 750 ppm of active material of fungicides (Benomyl, Captan, Captafol, Chlorothalonil, Carbendazim plus Maneb, Dichlofluanid and Thiabendazole) found that germination was 68% to 90%, in case of treated seeds as compared to 61% in the control after 330 days of storage. Furthermore, Moreno-Martinez *et al.* (1985) observed that the seeds of hybrid H-412 and VS-524 when treated with Benomyl, Captafol, Captan, Carbendazim + Maneb, Chlorothalonil, and Thiabendazole exhibited significant differences between treatments.

Dey *et al.* (1988) observed an improvement in seed germination of maize cv. Pratap and the seedling survival under laboratory and field conditions was maximum in case of treatment with Bavistin (0.3%) followed by Derosal (0.3%) and Agrozim (0.3%). Kapkoti and Pandey (1990) collected one year old seeds of maize, rice and wheat treated with fungicides Agrosan GN, Benlate, Blitox-50, Dithane M-45 and Dithane Z-78. Results indicated that

the percent seed germination was significantly enhanced and reduced the growth of several fungi drastically. Chakrabarthy and Rao (1992) found that there was no adverse effect on germination with 2.0% Benomyl followed by Thiabendazole on heavily infested maize seeds with *Fusarium moniliforme*. Cicero *et al.* (1992) treated corn seed cv. G-500 with fungicides Carboxin-75%, Thiram-48%, Carboxin-37.5% + Thiram-37.5%, Carboxin-20% + Thiram-20%, Carboxin-16.7% + Thiram 14.8% and Captan-50% in order to evaluate their effect on the physiological and sanitary qualities of seeds. The results in terms of the first count of the germination test, cold test, field emergence, speed of emergence, seedlings dry and fresh weight and length of seedlings root and aerial parts were generally higher for the treated seeds than that of control due to reduced incidence of seed pathogens by these fungicides.

Paul and Mishra (1994) found that, when the maize seeds are treated with Agrosan-GN, Bavistin, Benomyl, Blitox-50, Captan, Dithane M-45, Thiram and Thiram + Captan, the occurrence of fungi on the treated seeds was reduced with improved germination. Thiram + Captan were the most successful in checking seed infection by 2% as also improved seed germination (96%). Fungicides Captan, Thiram and Thiram + Captan treatments also significantly increased shoot and root length and dry weight of the seedlings.

Ribeiro *et al.* (1994) reported that maize cv. Pioneer 3069 treated with a mixture of fungicide and Zn-Biocrop, had no deleterious effects on seed quality after storage upto 8 months and the germination was 98% in contrast

to 92% in case of seed treated with Zn-Biocrop alone. However, Toman and White (1994) in an experiment concluded that usually fungicides applied after harvest may be useful as grain protectants during ambient air-drying.

Young *et al.* (1970) observed that there was neither heating nor mould growth during storage of maize with 24% moisture content having 1.5% (w/w) of Propionic acid. However, Lim and Kinsey (1973) evaluated eight fungicide treatments against seed lot of Texas male-sterile cytoplasm corn, infested with *Helminthosporium maydis* race T. Results indicated that the seedlings stands from seed treated with Carboxin + Thiram at the rate of 4 or 8 oz. per 100 wt. were significantly greater than those from other fungicides used for seed treatment and untreated control. Dhanraj *et al.* (1973) found that the Luprosil was not only effective in preventing the growth of storage moulds but also in reducing their number and eliminating them completely at higher rate of 19 gm/kg and thus preserving the stored grain even at high moisture content

According to Raju and Lal (1977) amongst the 25 systemic and non-systemic fungicides tested, Brestanol, was found effective against seedborne infection of both *Cephalosporium acremonium* and *Fusarium moniliforme*. In addition, Benomyl, Thiophanate-methyl and Carbendazim were also found equally effective against *C. acremonium* along with non-systemic fungicides, Captan, Thiram and Duter. Handoo and Aulakh (1979) having coated maize seeds with known antagonistic microorganisms for the control of seedborne fungi found that *Chaetomium globosum* could reduce seed rot and seedborne

fungi with increased percentage of healthy seedlings as compared to control and seed coated with *Trichoderma viride* proved to be pathogenic.

Russell and Berjak (1983) observed that the maize seed fungus *Fusarium verticillioides* (*F. moniliforme*) killed by dry heat treatment of γ -irradiation, which subsequently showed no decline in percentage germination and early seedlings establishment. However, Odyody and Fredericksen (1984) reported that the seed treatment of maize with Metalaxyl alone or combined with one foliar application of Metalaxyl on the 30th day of planting gave excellent disease control and increased growth yield as well as kernel weight. Cicero *et al.* (1989) observed that the seed treated with Carboxin (6.7%) +Thiram (6.7%) in the higher dosage (700 and 800 ml / 100 kg of seed), had higher vigour of the seed in the cold test and also control of seed-borne pathogens efficiently.

Drimal (1990) observed that seeds of hybrid maize TOMV-335 when treated with Vitavax-200 (Carboxin+Thiram, 1/100 kg) not only improved the health of plant but also consequently increased yield. Patricio *et al.* (1990) also reported that the product Carboxin and Thiram in combination (wetable powder) resulted in increased emergence in the field and also excelled in the control of seed-borne pathogens. However, Paul and Mishra (1993) demonstrated that Captan + Thiram was more effective than Bavistin, Captan and Dithane M-45 against *Alternaria alternata*, *Aspergillus flavus*, *Fusarium moniliforme*, *Penicillium expansum* and *Trichoderma viride* on maize. Nevertheless, White *et al.* (1993) reported that the incidence of *Penicillium*

spp., as also *Aspergillus* spp. in some cases was reduced, when the maize grains were subjected to treatment with Benomyl, Thiabendazole or A 9248 during the ambient air drying and storage in contrast to untreated ones. Similarly, Goulhart and Fialho (1998) concluded that the fungicidal treatments, in general, reduced the incidence of fungi yet Thiabendazole + Captan, Thiabendazole + Thiram and Thiabendazole alone were most effective in controlling the *Fusarium moniliforme*, *Aspergillus* spp. and *Penicillium* spp. on seeds of maize hybrid BR-201.

Casa *et al.* (1995) investigated the effect of Captan, Captan + Thiabendazole and Metalaxyl on seed lot having an infection of *F. moniliforme*, found that Metalaxyl was the best not only in the eradication of *F. moniliforme* but also equally effective against soil borne *Pythium* spp. Pinho *et al.* (1995) while working with seeds of single maize hybrid-C-1283 observed that, best control of *F. moniliforme* (*G. fujikuroi*), *Aspergillus* spp. and *Penicillium* spp. was given by Halt 50, TCMTB [2-(Thiocynomethylthio) Benzothiazole], Captan and Metalaxyl + Thiabendazole. Whereas, maize field inoculated with *Pythium* spp., Metalaxyl, Halt 50, Captan and TCMTB effectively controlled the fungus. Mukherjee and Nandi (1997) evaluated three antifungal compounds, Allyl-isothiocyanate, Propionic acid and Cinnamon oil, used individually for maize (cv. Ganga), groundnut (cv. Nizam) and soybean (cv. Bragg). In binary combinations these compounds showed synergism and better seed preservation qualities than individually treated seeds. Control sets of maize, groundnut and soybean showed fungal infection (mainly *Aspergillus*

spp.) in 100% seeds within 30 days of storage. However, Mao *et al.* (1997) observed that the seed treatments with the biocontrol agent *Gliocladium virens* isolate G1-3, as well as with Captan, significantly increased seedling stand, plant height and fresh weight, and decreased root rot severity compared with untreated seeds in pathogen in pathogen infected soil.

Goulart and Fialho (1998) evaluated the effect of fungicides using a seed health tests and sand emergence. They found that seed treatment with Tolyfluanid + Carbendazim, Tolyfluanid + Thiophanate-methyl and Thiabendazole + Captan gave the best control. The best results in relation to seedling emergence were obtained with the Tolyfluanid + Carbendazim and Tolyfluanid + Thiophanate-methyl. Similarly, Pinto (1998) observed that the seed treatment with Captan + Thiabendazole was the most efficient in controlling *Fusarium moniliforme*, *Aspergillus* spp. and *Penicillium* spp. The fungicidal treatment was not efficient to increase seedling emergence in the field. However, Captan + Thiabendazole and Thiram+Thiabendazole were the most effective in the cold test.

Berzy, Zaborszky and Feher (1999) reported a seed dressing agent containing 25 g Fludioxonil + 20 g Metalaxyl/litre increased cold tolerance in the line AMO-407 and in the hybrid maize Maxima. It also increased seedling emergence in Maxima when sown under suboptimum conditions and resulted in improved seed emergence of hybrid maize Mv. 1444 sown under optimum conditions. Seed treatment with Captan was effective with early sowing of Mv.1444 and for the line HMv. Exp.03. It was concluded that seed

dressing not only had a beneficial effect but also improved cold tolerance, leading to better seedling emergence and increased yield. Similar findings were also reported by Goulart (1993). Nevertheless, Almeida-Pinto and de Almeida Pinto (2000) studied the efficacy of Captan (120, 90, and 60 g.a.i./100 kg), Thiram (140), formulated as WP and SC, Thiabendazole (20), Thiram SC + Thiabendazole (75+10), and Carboxin + Thiram (75+75) for treatment of corn (maize) seeds of cultivar BR-106. The efficacy of the fungicides varied with evaluated characteristics: seed health, seedling emergence in the field, in sterile soils, in the field cold test, and in soils artificially infected with *Fusarium moniliforme* var. *subglutinans*, *P. aphanidermatum* and *Rhizoctonia solani*. The seed germination was not affected by the presence of fungi *F. moniliforme* var. *subglutinans*, but in cold and humid soil the fungi *P. aphanidermatum*, *F. moniliforme* var. *subglutinans* and *R. solani*, caused reduction in corn seed germination. Recently, Varshney *et al.* (2001) evaluated different fungicides and concluded that the seed treatments with Thiram + Bavistin, Thiram and Bavistin alone improved germination, increased seedling dry weight, viability, field emergence and eliminated most of the fungi encountered on maize seeds as compared to untreated control.

2.3 Efficacy of insecticides on seed quality

Several stored grain insect pests, considered to be destructive in maize seeds (Dang and Pant, 1965 and Singh *et al.*, 1973), which are brought into warehouses and other storage structures along with harvested grains cause

heavy damage by reducing seed weight and viability (Yadav *et al.*, 1968; Bernardo, 1972; Singh and Pande, 1975; Barney *et al.*, 1995; Giga *et al.*, 1991; Kossou *et al.*, 1993; Kurdikeri *et al.*, 1993^a and 1994). Besides this, they may injure or remove a part or whole of the embryo and endosperm, form webs or cocoons around the seeds, induce fungal infestation and increase grain temperature and moisture content (Srivastava and Bhatia, 1958; Yadav *et al.*, 1968; Mookherjee *et al.*, 1969 and Taylor, 1975). Such seeds that do germinate, often fail to establish and die or become distorted. Hindmarsh (1977) reported that the germination levels remained above 97% throughout the storage period when fungicides dressed seeds of maize cv. SR-52 with a pellet of Aluminium phosphide stored in a polythene-lined jute sack under commercial conditions for 3 years without loss of viability. Whereas, seed treated with admixture of Malation, Fenitrothion and Pirimiphos-methyl and stored in unlined jute sacks, did not remain viable. Samson and Parker (1989) reported that the order of potency of synthetic pyrethroides against *Rhyzopertha dominica* (F.) was Deltamethrin > Fenvalerate > Permethrin and Biovesmethrin > D-phenothrin. However, Deltamethrin (0.04 mg/kg), Fenvalerate (0.25 mg/kg) and Permethrin (0.5-1 mg/kg) gave complete protection for 9 months against *R. dominica*. Similar findings were also reported by Samson, Parker and Jones (1989).

Mutiro, Giga and Chetsanga (1992) concluded that Malathion treated and untreated maize grain samples stored over a period of 10 months in granaries exhibited damage of 81.9 and 92.6% respectively and was not

significantly effective in controlling insect pests. On the other hand Primiphos-methyl treatment significantly reduced damage by insects in storage. Santhi *et al.* (1993)^b found that the Cypermethrin and Deltamethrin suppressed adult emergence of *Callosobruchus maculatus* and *Rhyzopertha dominica* and oviposition of *C. maculatus*. At low concentration (20 and 50 ppm) for Deltamethrin and Cypermethrin, the effect persisted for up to 2 months, while at high concentration 40 and 100 ppm, respectively, the effect was evident for up to 5 months.

Bhuiyah *et al.* (1995) evaluated six insecticides [Decis (Deltamethrin), Actellic (Pirimiphos-methyl), Elsan (Phontoate), Volaton (Phoxim), Maladan (Malathion) and Sumithion (Fenitrothion)] against *Sitophilus zeamais* on stored maize seeds. All the insecticides except Actellic were found to be effective in protecting the seeds for 9 months without any adverse effects on seed viability under storage conditions.

Pereira *et al.* (1997) observed that, seed treatment with the combinations of Esfenvalerate + Fenitrothion + Piperonyl butoxide, Esfenvalerate + Fenitrothion and Fenitrothion + Deltamethrin + Piperonyl butoxide were effective against *Sitophilus oryzae* and *Rhyzopertha dominica* for 180 days. Deltamethrin + Piperonyl was effective against *R. dominica*. The use of mixtures of organophosphorus plus pyrethroides was more effective against *S. oryzae* and *R. dominica* when compared with these insecticides used alone.

Saxena, Sinha and Sinha (1999) concluded that the *R. dominica* collected from Karnal, Haryana, were resistant to Dichlorvos, Deltamethrin, Malathion and Phosphine having highest resistance against Dichlorvos and Phosphine.

Smiderle and Cicero (1999) treated maize seed with Deltamethrin and Chlorpyrifos (alone or in combinations), and Phosphine and Diatomaceous earth (Diatomite), placed in paper bags and stored for 12 months under normal environmental conditions could preserve physiological quality of maize seeds without causing any toxicity.

Sayaboc *et al.* (1999) tested three insecticides treatments, 1.) Pirimiphos methyl (4.0 mg/kg) + Permethrin (0.5 mg/kg) + Piperonyl butoxide (10 mg/kg), 2.) Pirimiphos methyl (4.0 mg/kg) + Deltamethrin (0.1 mg/kg) + Piperonyl butoxide (10 mg/kg) and 3.) Fenitrothion (6.0 mg/kg) + Fenvelerate (0.5 mg/kg) + Pieronyl butoxide (10 mg/kg) for the protection of maize seeds with 13% moisture content in the warehouse. Bioassay on samples of treated maize collected at 6-week interval revealed that all mixtures were effective against the lesser grain borer, *Rhyzopertha dominica* and the maize weevil, *S. zeamais*. All the mixtures significantly reduced dry weight loss by about 98%, protected the grain from insect infestation for 4-5 months. Recently, Srivastava *et al.* (2000) collected *R. dominica* from National Seed Programme centers, Pantnagar (Uttar Pradesh) and Karnal (Haryana) showed resistance to Malathion (X 20.8 and X 11.5). The Karnal strain showed resistance to Dichlorvos (X 8.6) and Deltamethrin (X 4.63). Whereas, the Pantnagar strain had low or nil resistance to Dichlorvos and Deltamethrin.

2.4 Efficacy of fungicide + insecticide on seed quality

Seed treatment is a biological, chemical, mechanical or physical process designed to control externally or internally seed borne or soil borne microorganisms resulting in the emergence of a healthy seedling and subsequently a healthy plant. Seeds are treated to promote good seedling establishment, to minimize yield loss or to maintain and improve seed quality and to avoid further spread of pathogens. Therefore, seeds are generally treated either with fungicides or insecticides alone to protect seed mycoflora and insect pest respectively. Few workers use combination of fungicides and insecticides as effective seed treatment to control both fungi and insect pests. Incidentally, some fungicides simultaneously offers protection against insects and mycoflora in treated seeds have been reported by Baldev and Amin, (1974); Mummigatti and Raghunathan, (1981); Babu *et al.* (1989) and Savitri *et al.* (1994).

Satyanarayana and Reddy (1994) indicated that the Deccan maize hybrid could be stored upto 15 months with minimum fungal flora when the seeds treated with Captan and its combination with Malathion WP or Malathion EC or ABC dust as compared to Thiram and its combination with ABC dust.

Klokcar *et al.* (1995) used several standard tests to determine the effect of combined fungicide-insecticides application on seed quality in hybrid maize during storage. The fungicide Thiram (300 ml) combined with the insecticide Tefluthrin at 100 and 300 g/100 kg seed in ZPTC 200 had no

adverse effect on germination. Thiram (300 ml) combined with the insecticide Carbosulfan at 4000 g/100 kg reduced vigour in the modified Hiltner-Gassner vigour test and slowed development of seedling roots immediately and after 6 and 12 months of storage. Whereas when the Combination of Carbosulfan, Flutriafol + Thiabendazole + Ethirimol used the total emergence reduced in the cold test after storage for 6 and 12 months. However, in combination with the Tefluthrin at the highest dose Flutriafol + Thiabendazole + Ethirimol reduced vigour immediately after treatments.

Oliveira *et al.* (1999) harvested seeds of maize ears at high water content which were treated with the fungicide Captan (240 g/100 kg) and the insecticides, Deltamethrin (4 g/100 kg) and Pirimiphos-methyl (6 ml/100 kg), bagged in multilayer paper bags at 12% moisture content and stored for 18 months in an open warehouse. The results showed that seed harvested mechanically as maize ears at 28% water content had the highest vigour reduction during storage compared with those at 18% water content. However, Aguilera *et al.* (2000) separated maize cv. PIONEER-32 R 21 seeds into round and oblong seeds using screens were treated with a mixture of Captan, Deltamethrin and Pirimiphos-methyl. It was observed that oblong seeds had better physiological quality and reacted significantly better to the chemical treatment than round seeds. However, chemical treatment in general increased seed germination.

2.5 Efficacy of botanical products on seed quality

The widespread use of synthetic insecticides poses hazard to both man and wildlife because of adverse effects on the environment. The detrimental effects on ecosystem are well demonstrated when beneficial insects, predators and parasites die, but often pests, themselves, survive treatments because the population has developed resistance to the chemicals used. One solution to these problems might be to replace synthetic chemicals with compounds, which occur naturally in plants.

Many insects are unable to infest certain plants because of the presence of particular noxious substances (Fraenkel, 1969). The neem tree, *Azadiracta indica*. Juss, is known to be rarely infested by insects (Bhatia and Sikka, 1957) and to have repellent or antifeedant effects (Ruscoe, 1972; Jilani and Malik, 1973; and Leuschner, 1975). Active components have been isolated from neem and these include the triterpenoids, azadiractin (Butterworth and Morgan, 1971) and melantriol (Lavie *et al.*, 1967), both of which suppress feeding.

Pareira and Wahlgemath (1982) studied the efficacy of Neem oil on maize and found that Neem seed was toxic to adults of *Rhyzopertha dominica*. Neem seed and Neem leaf extracts reduced the fecundity and productivity of all borers screened and it exerted its action by disturbing larval development. Also, Neem seed effectively protected maize seed for 3 months against *R. dominica*. On prolong storage under warm and humid conditions; the stored grain could get spoiled due to growth of Neem seed borne fungus *Aspergillus* spp.

Xu *et al.* (1993) tested 4 essential oils against the stored pests including *R. dominica*. 0.2% *Cassia* oil applied as a seed dressing, kept stored wheat free from insect damage upto 8 months. Essential oils from *Illium verum* and *Clausena dunnina* protected wheat for 4 months. Treatments of 15 ppm cassia oil, 30 ppm Malathion and 30 ppm *Cassia* oil produced 100, 89.5 and 98.5% mortality respectively. Similarly, Ekpo and Banjoko (1994) tested the efficacy of Fernasan D (FD) (25% w/w Thiram and 20% w/w Lindane) and 4 wood ashes prepared from *A. indica*, *Vernonia amygdalina*, *Gliricidia sepium* and *Cassia siamea* against seed borne fungi of maize. Seed treatment with Thiram + Lindane and various wood ash treatments gave complete control of *Cochliobolus heterostrophus*, *C. pallescens* and *C. lunatus* and a reduction in percentage incidence of *Aspergillus*, *Gibberella*, *Fusarium* and *Penicillium* spp. The wood ashes increased seed germination, improved viability of seeds and reduced incidence of pre-emergence mortality and seedling blight of maize except in *Azadiracta indica* treated seeds.

Xu-Han Hong *et al.* (1994) found that the results of bioassay of the essential oil from *Clausena dunnina* were very effective against stored-product insect pests, *Sitophilus zeamais* and other species (including *Tenebrio molitor* and *Rhyzopertha dominica*). It caused 99.33% mortality and completely inhibited the reproduction of *Triabolum castaneum* when used for fumigation at a dosage of 20 mg/litre, or mixed with wheat flour at a concentration of 0.2% by weight.

Vallador *et al.* (1994) while studying indigenous seed treatment materials found that after 7 months of storage percentage germination was 23-27% in seeds treated with *Cydista aequinoctialis*, *Ageratum conyzoides*, *Catharanthus roseus* or *Gliricidia sepium*, in comparison to 16% in control. At the same storage period, seeds treated with *G.sepium* gave the highest seedlings shoot and root length. However, Sharma (1995) studied Neem (*Azadiracta indica*) seed kernel powder (NSKP) at low dose (2% w/w) could not protect the grain from attack of *R. dominica*, *T. castaneum* and *T. granarium* for 6 weeks. A higher concentration of NSKP (10% w/w) was effective against all the test insects over longer period of time. However, even at high concentration of NSKP could not provide complete protection of maize from the attack of *T. castaneum* over a short period.

EL Lakwah *et al.* (1996) investigated the effect of acetone and petroleum ether extracts of *Lantana camara* and *Nerium oleander*, alone and in mixture with Pirimiphos-methyl (7.5-200 mg/kg) and / or Fenvalerate (0.3-10 mg/kg), on the mortality (after 2,3, 7, 14 and 21 days) and F1 progeny (after 60 days) of adults of *Rhyzopertha dominica*. They observed that the insect mortality increased with higher concentrations and longer exposure periods. Petroleum ether extracts were more effective than acetone extracts, and *N. oleander* was more toxic than *L. camara* extracts. Fenvalerate was more toxic than Pirimiphos-methyl. Similar results were obtained with *Withania somnifera* leaves and fruits extracts by EL-Lakwah *et al.* (1997).

EL-Lakwah and EL-Kashlan (1999) tested Neemazal-W (a powder of a botanical insecticide containing 10% azadirachtin) for mortality and reduction in F1 progeny of five stored product insects species at concentrations between 20-1000 ppm on wheat grain. Results revealed that average mortality of *R. dominica* adults was 32.2-100% for concentrations between 50-1000 ppm after 14 days of treatment. Inhibition of F1 progeny of *R. dominica* ranged between 79.6-95.5% at the same concentration.

2.6 Seed Vigour

It is a quality dependent on physiological potentiality, germinability and performance in the field with respect to percentage, rate and uniformity of seedling emergence, which have indirect influence on maintenance of crop stand at harvest and yield.

Krishnaveni (1984) while working on maize reported a significant reduction in germination, root length, shoot length, dry matter production and vigour index with response to period of ageing. Similarly, Tekrony *et al.* (1989) compared four seed lots of maize cv. B 73 X MO-17, having good germination (88-98%) but differing in vigour from emergence, plant growth and yield characters showed that the medium and low vigour seed lots had consistently lower emergence than high vigour seed lots, while under stress conditions also high vigour seed lots had significantly greater emergence than low vigour seed lots. However, Ravichandran (1991) reported that among the physiological manifestation of seed deterioration, the delayed and reduced

germination was evident. In maize and groundnut 25% reduction in root length coincided with 50% and 25% loss in germination respectively. He also reported a drastic reduction in the speed of germination and total emergence of aged seeds of the crops observed in the field.

Deshpande, Kulkarni and Kurdikeri (1991) studied storability of maize cv. CM-111 and CM-400 grown in the kharif (monsoon) season of 1987-1988 and harvested 70, 77, 84, 98, 105, 112 or 119 days after sowing and stored for six months. They observed that the seed germination and field emergence decreased with storage time and were higher at the later harvest dates. Vigour index increased with delay in harvest date and decreased with storage time. Singh, Kumar and Sharma (1997) observed positive correlation with speed of emergence, seedling growth rate and 100 seed weight and negative correlation with accelerated ageing (96 h). Speed of germination exhibited positive correlation with seedling growth rate and 100 seed weight with 100 seed volume. Toledo *et al.* (1999) evaluated samples of maize cv. Braskalb seeds from 10 lots were germinated on wetted paper towels or in wetted paper roll at 25°C. They concluded that the primary root emergence test in paper rolls could be of great value for evaluating the vigour of maize seeds.

2.6.1 Accelerated ageing

Accelerated ageing test was shown to be good predictor of seed performance and that as the seed age their performance in the accelerated ageing test declines (Saxena and Maheshwari, 1980). The application of the

test has however, been mainly to predict seed storage potentials. This test has been widely used to know the pattern of deterioration and to assess the seed quality in various species (Tekrony *et al.*, 1997). Likhlatchev *et al.* (1984) concluded that physiological changes in seeds subjected to accelerated ageing were largely similar to those during natural ageing with the main difference being the rate at which they occur. Similarly, Ramalal *et al.* (1995) observed that seed germination ranged from 81.9% with no accelerated aging to 40.8% with 12 days ageing treatment. Shoot and root lengths decreased from 15.8 to 8.4 from 21.9 to 11.7 cm respectively, with increase in ageing treatment from 0 to 12 days. Seedling vigour index and DM accumulation also decreased with aging treatment when maize cv. Deccan-103 seeds were kept at 42°C and 98% humidity for 0-12 days.

Gowda *et al.* (1996) while working on prediction of seed viability in storage, found that under accelerated ageing (40°C and 100% RH) seed germination was reduced to zero in 24 days. The corresponding storage period at 38°C and 75% RH was 40 days for seeds of maize cv. Ganga-5. However, Kurdikeri *et al.* (1998) subjected fresh seeds of maize cv. Deccan-103 to accelerated ageing conditions for 0, 4, 6 or 8 days to produce seeds of different vigour levels, they observed that germination percentage, vigour index and seedling dry weight decreased but electrical conductivity increased as the period of accelerated ageing increased. Field emergence, plant survival at harvest and yield/ha were highest with 4 days accelerated ageing but decreased significantly with increased ageing periods.

Padma and Reddy (1999) observed positive correlation between days of accelerated ageing with months of natural ageing. They further suggested that the accelerated ageing test at $30 \pm 1^\circ\text{C}$ and $80 \pm 2\%$ RH before storage is not only helpful in predicting the storage potentials of the maize genotype but also useful for screening the genotype for longevity.

2.6.2 Cold Test

This test is most useful to estimate seed performance from emerging ability to survival and sustenance of normal growth and development of seedling in low temperature conditions. The cold test germination indicates how a seed lot might be expected to perform under cool, moist and early spring conditions.

Cold test performance of seed may be reduced by any factor that lowers seed vigour e.g. microorganism infestation (Hoppe and Middleton, 1950), mechanical injury (Tatum and Zuber, 1943), age of seed (Hoppe and Middleton, 1950) and location and year (Odiemah, 1988).

Although, its major use is to determine emergence potential and performance weaknesses in seed lots, it is also used to determine the effectiveness of fungicides and other seed treatments, seed storability and to evaluate inbred lines of corn used in breeding for resistance to seed-rotting fungi.

Knapp (1990) while investigating relative comparability of cold test methods (Shoebox, rolled paper towel and tray) for hybrid maize seeds, they

found that there were no significant differences between methods. Nevertheless, Waes and Van (1995) while comparing the germination methods they observed that a severe cold test (18 days at 8.5°C in the dark followed by 4 days at 28.5°C in the light) provided a reliable prediction of field emergence. The highest correlation between the cold test and field emergence was attained for trials in 1991, which was a year with very unfavourable soil conditions after sowing. The correlations between the ISTA standard germination test or the cold test and the field emergence were low in general.

Zarich *et al.* (1995) tested 12 maize inbred lines for resistance to low temperatures on the basis of seed germination at 8°C using the cold test. Only the line A654-3 was resistant (with 96% germination at this temperature, vs, less than 80% in the other lines). However, when temperature was returned to 25°C, some lines had not lost their ability to germinate satisfactorily. Leist *et al.* (1997) compared the results of hybrid maize seed testing through percentage germination test and cold test (field emergence) over 10 years (1986-96) in Germany. Using the 7 days cold test, it was possible to differentiate both weak vigour and strong vigour seed lots. Similarly, Waltz *et al.* (1998) placed maize seeds in microwaved (pathogen free) and non-microwaved (raw) soil adjusted to moisture level corresponding to soil water potentials of -30, -50, -400 and -1000 KPa and tested at 10°C for seven days followed by 25°C for five days. A second experiment utilized a cold period temperature ranged from 4.5 to 13°C at a soil water potential of -40 KPa. Seed

treatments with Captan increased germination and nearly eliminated differences among soil moisture levels. The highest germination for treated and untreated seed lots in raw soil secured at 4.5°C and 13°C, while lowest germination (greater stress) occurred at 9 and 10°C. No differences in germination occurred among seed lots or among any experimental treatments (soil moisture, temperature, seed treatment) when pathogen-free soil was used.

Caseiro and Marcos (2000) while comparing different cold test procedures for evaluating maize seed vigour they found that the tray procedures (10°C for 7 days in a cold chamber, followed by germination at 25°C) exhibited a greater level of standardization than the deep-box procedures, allowing for more consistent results and a closer relationship to seedling emergence in the field.

2.6.3 Electrical conductivity

As seed age and natural deterioration proceeds, degradation and disorganization of cellular membranes may occur allowing nutrients to be leached from them in presence of water. Low leakage and therefore low conductivity is associated with seeds that emerge well, that is had high vigour, whereas low vigour seeds with poor emergence had high levels of leakage and conductivity (Matthews and Bradnock, 1967). Increased membrane permeability has been reported resulting in an increase in

electrical conductivity of seed leachates in different crop species with ageing (Ferguson *et al.*, 1990; Dadlani *et al.*, 1995 and Kalpana and Madhavrao, 1996).

The conductivity of the seed steep water is influenced both by seed moisture and soak temperature. Low seed moisture (less than 10%) increased conductivity readings for moongbean, soybean (Dadlani and Agrawal, 1983) and lotus species (Hampton *et al.*, 1994), which was ascribed to imbibition damage. Dadlani and Agrawal (1983) and later Hampton, Johnstone and Eua-Umpon (1992) studied the effect of soak temperature and found that a 25°C soak produced greater conductivity readings than a 20°C soak even though the seed lot ranking was unchanged. The electrical conductivity of seed leachate decreased with delay in harvest date and increased with storage time (Deshpande, Kulkarni and Kurdikeri, 1991).

2.7 Persistence of fungicides on maize seeds after storage

Many new systemic and non-systemic fungicides have been introduced recently, as this area is gaining importance on account of the management of plant diseases particularly those carried through the agency of seed, most of which are amenable to control by fungicidal seed treatment. It is for this reason the use of systemic fungicides has assumed a place of significance in new strategy of plant disease control because of series of advantages offered by this group of chemicals over the conventional fungicides in their capacity to become absorbed and translocated into the plant system. Though considerable information is available about the relative efficacy of various

seed dressing fungicides against different seed-borne diseases, yet very little information is available with respect to their biological effectiveness when treated seeds are stored for some time. Such information becomes necessary and inevitable because on a number of occasions left over seeds are treated and stored and then planted during the following sowing season (Dharam Vir, 1983). Hence, the persistence of systemic and non-systemic fungicides and their combination used in present study were investigated.

The first report on bioassay was described by Mead (1945) by using *Bipolaris sorokiniana* as a test fungus for detection of Ceresan M on treated seeds of wheat. He further observed that the conidia of *Helminthosporium sativum* would not germinate near the seeds treated with Ceresan in the medium and this principle was used for treating seeds for the presence of Ceresan M and more particularly for measuring coverage of the fungicidal dust. The bioassay followed for estimation of fungicides on treated seeds is being advocated and reviewed by several workers (Leben and Keitt, 1950; Army, 1952; Kulik and Crosier, 1964; Elie, 1973; Hewitt and Rennie, 1978; Patil *et al.*, 1986; Hanson, 1993 and Verma, 1998).

Singh *et al.* (1971) observed that Benlate could be absorbed and translocated into the seedlings, where its persistence could be detected in the leaves as also its antifungal activity even after 133 days of storage stressing the superiority of the compound as an ideal fungicide for the treatment of maize against *Fusarium moniliforme* and *Cephalosporium acremonium*. Dharam Vir (1977 and 1980) carried out some studies to determine the retention of

fungicidal properties when treated seeds of paddy were stored for one year. He observed that organomercurials retains their bio-efficacy for a longer period in comparison with antibiotics and Dithiocarbamates which get degraded and became biological ineffective. Similarly, Gupta and Chatrath (1983) evaluated the quantity of Thiram on the soybean seeds and found that the quantity was decreased with the increase in the storage period and fungicide degradation was maximum when the seeds were stored in cloth bags.

Saleh and Negm (1981) compared the efficacy of Carbendazim, Benomyl and Thiophonate-methyl as seed treatment (1.5 g/kg seed) and spray application (0.05% and 1.0%). It was revealed that seed treatment showed a longer persistence of Carbendazim residue than in case of spray application. Ramirez-Gongalez and Moreno (1982) reported that the fungicide residues could prevent the growth of storage fungi when treated maize seed with Benomyl and Captan stored for 120 days. Singh *et al.* (1987) demonstrated that seed treatment with Bavistin resulted in sufficiently high residues to control primary systemic infection by loose smut and bunt. After 42 days, persistence was very low. Tadiouse *et al.* (1993) reported that the initial deposits of Thiram on maize seeds of 209 ppm decreased to 203, 200, 189, 183, 180, 171, 150, 147, 144, 126, 106 and 62 ppm after 1, 2, 3, 4, 5, 7, 14, 21, 28, 35, 42 and 50 days respectively. According to Reddy *et al.* (1996) demonstrated that the seed, soil and foliar application of Metalaxyl at

different concentration could prevent and control the *Sclerospora graminicola* and the harvested seeds were free from fungicide residues.

2.8 Persistence of insecticides on maize seeds after storage

La Hue and Kadoum (1979) studied the residual efficacy of emulsified concentrates and encapsulated formulations of Malathion and Fenitrothion against stored grain pests including *Rhyzopertha dominica*. Insecticides were applied to plywood surfaces as 135, 269, 538, 807 and 1076 mg AI/m² and insects were exposed to treated surfaces for 6-72 h. They concluded that Fenitrothion was more effective than Malathion and encapsulations were also more effective than emulsion. However, residues of Fenitrothion were effective even after 12 months of ageing. Similarly, Halliday *et al.* (1992) found that Tralomethrin residues deposits on maize seeds after application were 0.47q 0.03 ppm and 1.39 q 0.19 ppm and reduced to 48.9 and 45.3% of their original values, 12 months after for the calculated rates of 0.75 ppm and 2.00 ppm, respectively, on stored wheat and maize seeds. Further they demonstrated that when the adults of *Sitophilus zeamais*, *Rhyzoprtha dominica* and *Oryziephillus surinamensis* were bioassayed on treated grains of wheat and maize with Tralomethrin (0.75 ppm) + Piperonyl butoxide (3.75 ppm) and unsynergized Tralomethrin (2.00 ppm) sampled at regular intervals during storage, they observed that mortality after 14 days exposure and suppression of the F1 generation was more than 95%. Toxicity decreased slightly at 2 months post-treatments and remained constant until 15 months. However,

Franklin *et al.* (1994) reported that the insecticide decayed quickly initially but there was no significant degradation during a storage period of 6 months when the samples of stored maize from 4 storage units in Minas Gerais, Brazil, treated with Deltamethrin at harvest, were analysed at monthly interval by gas chromatography.

Yadav and Singh (1994) evaluated the persistent toxicity of Malathion (WP) at 150 mg/m², Chlorpyrifos-methyl (EC) at 50 mg/m², Deltamethrin (WP) at 20 mg/m² and Fluvalinate (20EC) at 50 mg/m² used as jute fabric treatments. Deltamethrin protected seeds of wheat and maize for 6-9 months, and those of sorghum and chickpea for 3 months. Fluvalinate protected maize seeds for up to 5 months and chickpea seeds for 3 months. Malathion and Chlorpyrifos-methyl protected wheat and maize seeds for up to one month only. Voinescu *et al.* (1995) studied the effect of storage for one year on the maize seed hybrids, F-320, F-340, F-365 and F-420, treated with Furadon 35 st (Carbofuran), Carbodan 35 st (Carbofuran) and Terrafuran 350 FS (of unstated composition) found that the efficacy of insecticides application on seed to control *Tanymecus dilaticollis* was not affected

Gozek (1996) evaluated samples of maize, beans, wheat and barley treated with radio labelled Malathion and stored for 9 months. They found that washing the beans removed much of the insecticides residues, whereas maize, wheat and barley absorbed more Malathion than the beans. Baking barley and wheat reduced insecticide residues. Similarly, Lalah and Wandiga (1996) treated the grain samples of maize and beans with 10.36 mg/kg of

radio-labeled Malathion dust prior to storage under open basket model and the modern wooden box model and portions analyzed at regular intervals for Malathion, Malaoxon and the transformation products Isomalathion, Malathion, Alpha monocarboxylic acid and Malathion beta-monocarboxylic acid using a combination of chromatographic, radio-isotopic and mass spectrometric techniques. The findings showed a gradual penetration of Malathion into the grains in amounts, which were slightly higher in maize than in beans irrespective of the methods of storage. After 51 weeks of storage, 34-60% of the initial residues persisted in all the grains.

White *et al.* (1997) treated wheat seeds with 5 ppm Chlorpyrifos-methyl and maize seeds with 6 ppm Pirimiphos methyl stored in granary along with controls. Chlorpyrifos-methyl residues on wheat declined by 51 and 38% at the top and 1m depths, respectively. Whereas, Pirimiphos-methyl residues on maize did not decrease, however after 8 months, Pirimiphos-methyl began to appreciably lose effectiveness against *Tribolium castaneum* in 24 hrs laboratory bioassays, and after a year against *T. castaneum* and *Tarsonemus granarius* within the graneries. However, Rani (1997) carried out laboratory tests using populations of *T. castaneum*, *Sitophilus oryzae*, *Rhyzopertha dominica*, *Callosobruchus maculatus*, *Oryziephillus surinamensis* and *Corcyra cephalonica* to measure the effectiveness and stability of Deltamethrin (WP) in protecting cereals and pulses from these insect pests. Rice bran and rice husk treated with various dilutions of the toxicant were mixed with the food grains and

exposed to the insect pests resulting in 100% mortality. A single application of Deltamethrin prevented insect infestation for a period of 2 months.

Santhi *et al.* (1993^a) evaluated the efficacy of Fenvalerate, Decamethrin (Deltamethrin), Cypermethrin and Permethrin for the control of *R. dominica* on wheat grain in the laboratory. They observed that brostrichid mortality was greater (39.99%) with 40 ppm Deltamethrin followed by 100 ppm Cypermethrin (39.95%). Nevertheless, Arthur (1994) while working with wheat and maize seeds treated with 0.5, 0.75 or 1.00 ppm Deltamethrin, 0.5 ppm Deltamethrin+6.0 ppm Chlorpyrifos-methyl, 1.00 ppm Deltamethrin+6.0 ppm Chlorpyrifos-methyl or else 6.0 ppm Chlorpyrifos-methyl, and subsequently stored for 10 months, they found that the *R. dominica* and *S. oryzae* did not survive on the combination treatments applied to wheat. Survival of *R. dominica* in the 3 Deltamethrin treatments was variable but no adult progeny was found.

2.9 Seedling emergence in the field

Wilson and Mohan (1992) evaluated shrunken-2 sweet corn inbred lines treated with Captan, Captan/Imazalil, a blank (no fungicide) formulations or left untreated. Captan increased stand by 30%. Captan plus Imazalil improved stand over Captan alone up to 36%. Parera and Cantliffe (1992) compared pre-sowing seed treatments with fungicide combination (Imazalil, Captan, Apron and Thiram), Sodium hypochlorite (SH), Solid matrix priming (SMP) and SMP combined with SH during treatment

(SMPSH) to improve emergence and crop uniformity of sweet corn cv. Crisp 'N' Sweet 711 (CNS711) and How Sweet It Is (HSII). In both cultivars, SMPSH had significantly improved germination in the cold test and final emergence and ERI in the field trial for HSII compared with untreated control.

Wilson *et al.* (1993) found that, the treatment with a mixture of Captan, Thiram, Metalaxyl and Benomyl (CTMB) was most effective which significantly increased the final stand compared with an untreated control. Addition of other fungicides or insecticides to the CTMB mixture did not improve the final stand. According to Milosevic *et al.* (1994) the field emergence was most closely correlated with the results of the cold test ($r=0.94-0.95$) and the accelerated aging test ($r=0.89-9.0$). However, McGee *et al.* (1994) while investigating polymeric seed coating as alternative to fungicide seed treatment of maize, they found that the polymers in combination with Captan were as effective as Captan alone in ensuring an adequate stand of maize seedlings and reducing incidence of *Pythium* seed infection.

Lavato and Balboni (1997) studied maize seed lots of varying quality (31 in 1987 and 26 in 1988), subjected to the standard germination test, standard cold test, cold test in sand or trays and complex stressing vigour test (CSVT) and were tested in the field for emergence after sowing at early or standard dates. The standard germination test was generally not well correlated with field emergence. The other tests, particularly the cold test in sand and CSVT showed greater correlations. The cold test in sand and CSVT appeared to be the best methods for assaying seed vigour and predicting seed

performance under adverse field conditions. The decline of seed quality during storage was affected by the initial seed vigour.

Rivas, McGee and Burris (1998) investigated the effect of film coating polymers used as a seed treatment either alone or in combination with Captan on field emergence and final stand of 2 hybrids of maize. Polymers applied alone had no significant influence on emergence rate of either high or low vigour seeds in comparison with untreated controls. Whereas, in the low vigour seed lot or high vigour seed lots, the Emergence Rate Index (ERI), final emergence and seedling height was increased significantly for Captan and Captan + Certop (a polymer) as compared to untreated controls. Nevertheless, Piana *et al.* (1998) evaluated 20 seed lots of maize cv. AG 303 with different levels of vigour by sowing them in the field and exposing to water potentials of -0.1, -0.5, -15 or >-15 atm. Assessment of seedling emergence after 14 days showed that seeds of high vigour gave the best performances under conditions of water stress, with emergence highest at a soil water potential of 0.5 atm.

2.10 Effect of pre-sowing seed treatments on field emergence

Various pre-sowing physiological seed conditioning procedures have been used to improve seed performance, including pre-soaking, wetting and drying, humidifying, pre-germination and priming or osmoconditioning. More recently, solid and semi-solid systems have been used to condition the seeds.

Kurdikeri *et al.* (1993)^a while studying seed invigouration, in maize cv. Deccan, Deccan-103, Ganga-5, Ganga Safed-2, and MMH-6 reported that seeds soaked for 8 hrs in KH_2PO_4 or Bavistin + Thiram both as slurry treatments increased seed germination, vigour index, and seedling growth rate as compared to the untreated control. Further, Kurdikeri *et al.* (1993)^b studied effect of soaking with different invigourating agents to 12 or 18-months old seeds of maize hybrid cv. Deccan-103. They observed that, in 12 months old seeds germination was highest when soaked in water or Silver Thiosulphate (17.1 and 16.4% higher germination than untreated control, respectively). In 18 months old seeds germination was highest with soaking in Ammonium nitrate followed by Bavistin + Thiram (9.1 and 5.8% higher than untreated control, respectively).

Parera and Cantliffe (1994)^a reported that maize seeds var. Crisp N'Sweet 711 (CNS-711) and How Sweet It Is (HSII) were redried at 15, 20, 30 and 40°C and 25% RH after solid matrix priming (SMP). Primed seeds with a higher dehydration rate (dried at 30 or 40°C) had better seed vigour, greater field emergence and seedling vigour, lower leachate conductivity and imbibition rate and a higher respiration rate and glutamic acid decarboxylate activity than primed seeds redried at the lower temperatures or control seeds. Further, Parera and Cantliffe (1994)^b concluded that seed imbibition and leachate electrical conductivity were lower in solid matrix primed (SMP) seeds than in non-primed seeds and SMP combined with seed disinfections

using NaOCl is a promising seed-treatment substitute that improves the stand establishment and seedling vigour of sh-2 sweet corn cultivars.

Kurdikeri *et al.* (1995) found that when maize cv. Deccan-103 seeds, 12 or 18 months old, subjected to seed soaking treatments with 1% Ammonium nitrate, 2.5% KH_2PO_4 , PEG 6000, 50 ppm Mannitol, 50 ppm Ethrel (Ethephon), 50 ppm Sodium thiosulfate, 1% Sodium phosphate, 10 ppm Silver thiosulfate, 2.5 KNO_3 , 0.5% CaCl_2 , Bavistin (Carbendazim) + Thiram (1g each/ kg seed) or 100 ppm GA_3 + 50 ppm kinetin for 12 h followed by drying, increased field emergence and grain yield was obtained as compared to dry seed. Among treatments, Ethrel followed by Sodium thiosulfate gave highest field emergence and yield. However, Sinha, Mondal and Handoo (1996) reported that, seedling vigour was significantly higher in pre-treatment with 100 ppm Proline and Ascorbic acid, 1% Sodium benzoate and hydration-dehydration as compared with the untreated control in maize cv High-Starch, Ganga Safed-2 and Hemant indicating induction of low temperature ($8\pm 1^\circ\text{C}$) stress resistance.

Fan *et al.* (1997) subjected sweet corn cv. Supersweet 3 to different seed treatments before sowing in the field. Seed treatments improved seedling emergence and stand establishment in early spring. However, seed soaking in Glycerine or Acetone and seed pelleting gave good results. Gimenez *et al.* (1997) while working on osmotic preconditioning with 100 or 150 g Polyethylene glycol (PEG)/litre or 0.1 or 0.3 M potassium nitrate by imbibition from aerated solution (24 h) or from a substrate (24 or 48 h),

germination test at 15°C showed that for all treatments by substrate imbibition, the final percentage was higher than in controls. In the Hiltner's vigour test with seeds treated with 100 g PEG for 24 or 48 h or 0.1 M KNO₃ for 24 h by substrate imbibition, emergence was 35% higher than in controls. According to Bharathi *et al.* (1997) when eight months old maize seeds were subjected to hydration-dehydration treatments using 1000 ppm KH₂PO₄ or 1% KCl. They observed that germination was 87.6% with KH₂PO₄ treatments, 84.2% with KCl and 81.9% in control.

Chang and Sung (1998) investigated the emergence performance of vermiculite-primed sh-2 seeds of two maize hybrids during 12 months of dry storage. The results indicated that vermiculite priming improved seedling emergence, decreased initial seed leakage, reduced lipid peroxidation and enhanced activities of several peroxide-scavenging enzymes. However, the benefits of priming were diminished and the longevity was shortened when primed seeds were stored for 12 months, especially under 25°C storage conditions. It appears that the priming effect on sh-2 corn seeds could be maintained after storage for 6 months under 10°C. However, the primed sh-2 seeds deteriorated more rapidly than non-primed sh-2 seeds when stored at 25°C for 6 months.

Nagar, Dadlani and Sharma (1998) reported that the hydroprimed seed of maize treated with or without 0.2% Thiram or untreated seeds increased the speed of seedling emergence and improved the field stand and plant growth. Similarly, Harris *et al.* (1999) demonstrated direct benefits of hydro-

priming with water (overnight) for maize, rice and chickpea as it induced faster emergence, better stands and a lower incidence of resowing, more vigorous plants, better drought tolerance earlier flowering, earlier harvest and higher seed/ grain yield.

MATERIALS AND METHODS

3.1 Collection of seed materials

The parental lines, CM-135 (Female) and CM-136 (Male) of newly developed promising maize hybrid 'Pusa Early Makka-1' produced in *Rabi* 1998 and *Kharif* 1999 were obtained from Indian Agricultural Research Institute, Regional Station, Karnal, Haryana.

3.2 Pre-storage seed treatments

Seeds produced in *Rabi*-1998, dried to moisture content of 9.0%, and were divided into 11 parts of 3 kg each. Ten seed lots were treated with slurry of following fungicides, insecticide and/ its combinations and plant products while 11th lot was maintained as untreated control.

- 1) Captan (Captaf 50 WP) @ 3 g/kg
- 2) Bavistin (Carbendazim 50 WP) @ 3 g/kg
- 3) Deltamethrin (Decis 2.8 EC) @ 0.04 ml/kg
- 4) Malathion (Cythion 50 EC) @ 0.06 ml/kg
- 5) Econeem (3000 ppm) @ 3 ml/kg
- 6) Arappu Leaf Powder (*Albizzia amara*) @ 5 g/kg
- 7) Captan + Deltamethrin (1:1)
- 8) Captan + Malathion (1:1)
- 9) Bavistin + Deltamethrin (1:1)
- 10) Bavistin + Malathion (1:1)
- 11) Untreated Control

T-6961

Similarly, seeds produced in *Kharif*-1999 were treated with slurry of following eight seed protectant and 9th lot was maintained as untreated control.

- 1) Captan (Captaf 50 WP) @ 3 g/kg
- 2) Bavistin (carbendazim 50 WP) @ 3 g/kg
- 3) Econeem (3000 ppm) @ 3 ml/kg
- 4) Arappu Leaf Powder (*Albizzia amara*) @ 5 g/kg
- 5) Captan + Deltamethrin (1:1)
- 6) Captan + Malathion (1:1)
- 7) Bavistin + Deltamethrin (1:1)
- 8) Bavistin + Malathion (1:1)
- 9) Untreated Control

3.3 Storability of seeds

Just after seed treatments with the above fungicides, insecticides and/ its combinations and plant products, each seed lot was divided into two equal parts of 1.5 kg each. One part of each treated and untreated seeds of both the parental lines produced in *Rabi* 1998 and *Kharif* 1999 were packed in cloth bags and stored under controlled condition ($20 \pm 1^{\circ}\text{C}$ and $30 \pm 10\% \text{RH}$) at IARI, Regional Station, Karnal, Haryana, while the other part was stored under ambient conditions in the Division of Seed Science and Technology, IARI, New Delhi. The following observations were taken initially and after 90

days intervals from July 1999 to Jan.-Feb. 2001 for *Rabi* 1998 produce-seeds and from Jan. 2000 to Jan.-Feb. 2001 for *Kharif* 1999 produce-seeds.

1) Moisture contents

2) Germination Percentage

3) Seed Vigour

- Seedling dry weight
- Shoot length
- Root length
- Vigour index
- Accelerated ageing (AA)
- Cold test
- Electrical conductivity (EC)

4) Seed Health

- Seed mycoflora
- Insect pests

5) Persistence of seed protectants on seed after storage

6) Seedling Emergence in the field

- Seedling emergence of all the treated and untreated seeds kept under storage.
- Pre-sowing seed treatments to untreated stored seeds with Kalisena, Bavistin, Captan, Hydration-dehydration and Hydration-dehydration followed by seed treatment with Kalisena, Bavistin and Captan.

3.4 Determination of moisture content

The seed samples were drawn at three months interval for determination of moisture content of the seeds. The required amounts of ground seed samples in two replicates were dried at 130°C for 4 h in an oven.

The moisture content of seeds was calculated to one decimal place by the following formula:

$$\text{Percentage of moisture content (\%)} = \frac{M_2 - M_3}{M_2 - M_1} \times 100$$

Where,

M_1 = weight of empty bottle with the lid

M_2 = weight of the bottle before drying + ground material

M_3 = weight of the bottle after drying + ground material

3.5 Determination of germination

The germinability of the seeds was determined by using between paper method (ISTA, 1999). Two hundred seeds in four replications of fifty seeds each were placed between two layers of moist germination papers with the help of counting board. Then the germination papers were rolled carefully ensuring that no excess pressure is placed on the seeds. These were wrapped in a sheet of wax paper to reduce surface evaporation and placed in a germinator at 25°C temperature in an upright position. The germinated seeds were evaluated for normal, abnormal seedlings and fresh un-germinated and

dead seeds. Their counting took place on the seventh day. However, germination percentage was recorded on the basis of normal seedlings only.

3.6 Determination of seed vigour

Seed vigour is an important quality parameter, which needs to be assessed to supplement germination and viability test to gain an insight into the performance of seed lot in the field or in storage.

Seed vigour test was conducted simultaneously along with the regular germination test.

3.6.1 Seedling dry weight

Ten normal seedlings from each replicate of germinated seedlings were randomly taken after the final count of germination. Seedlings were dried overnight in an oven set at 90⁰C temperature and the final weights were taken.

3.6.2 Seedling shoot length and root length

After standard germination test, ten normal seedlings were taken at random and the shoot length and root length was recorded by linear scale.

3.6.3 Vigour index

Vigour index was calculated by using the formula suggested by Abdul Baki and Anderson, (1973).

Vigour index = Germination % × Seedling dry weight

3.6.4 Accelerated ageing

Accelerated ageing was followed by standard germination test. About 150 g of maize seed were stored in muslin cloth bags at 80% RH in sealed desiccator at $35 \pm 1^\circ\text{C}$ for 10 days in an incubator.

The 80% RH at $35 \pm 1^\circ\text{C}$ was maintained by using near saturated solution of KCl to adjust about 80% RH.

3.6.5 Cold test

It has been most commonly applied to maize. The test was conducted by planting four replications of 50 seeds in unsterilized soil, in separate boxes. A layer of field soil about 2 cm thick spread on the bottom of a box, the soil was leveled and seeds were distributed on it. The seeds were covered with approximately the same amount of soil as previously used, the soil was leveled and firmed down and water added to bring the soil to $70 \pm 5\%$ of its water holding capacity. The water adjusted to 10°C before used. The boxes were covered and put in a refrigerator at 10°C for 7 days then they were transferred in glass house at 25°C for further 4-5 days. The results of a cold test were expressed as the percentage of seedlings emerged from the soil (Agrawal and Dadlani, 1992).

3.6.6 Electrical conductivity

About 25 seeds in two replicates were soaked in 25 ml of distilled water at $25 \pm 1^\circ\text{C}$ with frequent stirrings for 3 hrs. The leachate was decanted off in a clean 50 ml beaker. The electrical conductance of the leachate was

measured at room temperature with a conductivity bridge (model CH-82T) and calculated as μ siemens/cm/g of seed.

3.7 Determination of seed mycoflora

Standard blotter method (ISTA, 1999) was followed in order to determine the per cent incidence of different fungi associated with the seeds. For each treatment four hundred seeds were used. Ten seeds per plate were placed in plastic Petri plates of 10 cm diameter containing a layer of three well-moistened blotters. These plates were then incubated at $20 \pm 2^{\circ}\text{C}$ temperature under alternating cycle of 12 h darkness and 12 lights under Near Ultra Violet (NUV) for seven days. After incubation, the seeds were examined under stereo binocular microscope for the presence of associated mycoflora. The identity of mycoflora was confirmed with the aid of compound microscope using pertinent literature.

3.8.1 Efficacy of seed protectant against *Fusarium moniliforme*

3.8.1.1 Sterilization

All the glass wares used in the present studies were thoroughly washed, dried and sterilized in a hot air oven at 180°C temperature for 6 hrs.

3.8.1.2 Medium preparation

The potato dextrose agar (PDA) medium was used for preparation of cultures. The composition of PDA used is given as under :

Peeled potatoes	- 200 g.
Agar agar	- 20 g.
Dextrose	- 20 g.
Distilled water	- 1 litre.

Two hundred gm of peeled potatoes were sliced into small pieces and boiled in about 500 ml of distilled water till they became soft. Potato extract was obtained by filtering the above said material through muslin cloth. Agar-agar (20 g) was dissolved in 500 ml of hot water to potato extract and mixed thoroughly by stirring and heating. Then 20 g of Dextrose was added to it. Finally the volume of the medium was made up to one litre by adding required quantity of distilled water. The medium was then divided into 250 ml flasks, plugged with non-absorbant cotton plugs and sterilized at 15 lb p.s.i. for 20 minutes.

3.8.1.3 Maintenance of cultures of test organism

The cultures were maintained on the PDA tubes by transferring the spores and mycelium of test organism (*Fusarium moniliforme*) and incubated at $20 \pm 1^{\circ}\text{C}$ temperature for seven days under normal conditions of 12 h light (NUV) and 12 h darkness. These were kept in refrigerator after having sufficient amount of growth.

3.8.1.4 Multiplication of test organisms

The sterilized PDA was poured in corning Petri plates of 9 cm diameter in the laminar flow bench. The medium was allowed to solidify.

Required quantity of spore suspension 10^5 spores/ml (approximately) of test organism (*F. moniliforme*) was apportioned uniformly on the medium under aseptical conditions. These plates were then incubated at $20 \pm 2^\circ\text{C}$ temperature for desired length of time in order to get the uniform growth of the test organism.

3.8.1.5 Measurement of inhibition zones

Considering the dose of fungicides and/ or their combinations with insecticides used for seed treatment, the amount of residues present on each seed is expected to be in the range of 0 μg to 800 μg . Hence an experiment was conducted by taking four concentrations (200 μg , 400 μg , 600 μg and 800 μg) of Captan, Bavistin, Captan + Deltamethrin, Captan + Malathion, Bavistin + Deltamethrin and Bavistin + Malathion solutions prepared in a sterilized water. Fungicidal activity was measured using potato dextrose agar inoculated with the spores of *Fusarium moniliforme*. Spore suspension of approximately 10^5 spores/ml was added to 1000 ml of PDA. A thin layer of 15 ml of this bioassay medium containing spores of *F. moniliforme* was poured into 9 cm diameter Petri plates.

The different solutions having concentrations 200 μg , 400 μg , 600 μg and 800 μg of fungicides and/or their combinations with insecticides were poured directly in the centre of the Petri plates containing PDA in an aseptical condition. The plates were incubated at $20 \pm 1^\circ\text{C}$ for 48 to 72 h in triplicates. The inhibition zone developed around the chemical was measured

from the centre of the hole to the widest point of the zone. Thus the area of inhibition zone was calculated with the help of formula,

$$\text{Area of inhibition zone (mm}^2\text{)} = \pi \times (\text{radius of inhibition zone})^2$$

A standard curve was prepared by taking the area of inhibition zone on Y-axis and the concentration of fungicides and/ or their combinations with insecticides on X-axis. Finally, the main experiment was conducted in three replicates in the similar manner described as above with the stored seeds already treated with fungicide and/ or their combinations with insecticides. The inhibition zones developed around the seeds were measured and thereby the quantity of fungicides and/ or their combinations with insecticides were assessed with the help of standard curve.

3.8.2 Efficacy of seed protectant against *Rhizopertha dominica*

3.8.2.1 Rearing of insects

Susceptible population of *Rhizopertha dominica* obtained from the insect Genetics Laboratory of Division of Entomology, IARI, New Delhi were used as test insect for the study. They were reared on wheat seeds. The cultures were placed in glass jar and covered with a cloth for proper ventilation, were maintained in an incubator at $25 \pm 1^\circ\text{C}$ and $70 \pm 2\%$ RH. The insects were sieved from the grain and only adults (2-3 week old) were used to assess the response.

3.8.2.2 Bioassay

The efficacy of fungicides, insecticides and/ their combinations and some botanical products were tested against the test insect by keeping 50 g treated seeds along with 10 adults of *Rhyzopertha dominica* in separate bottles in two replicates. The mortality of insects was observed at 1, 2, 3, 5 and 10 days after exposure to see the response of test insect to the pesticides used as seed treatments. The insects were classed as responding if unable to walk in a coordinated manner, this was taken as consistent criteria for comparing responses against different treatments. The observed percent mortality was transformed into corrected mortality using the Abbott's (1925) formula, which is as follows:

$$\text{Corrected mortality (\%)} = \frac{T - C}{100 - C} \times 100$$

Where,

T = Per cent mortality in treatments

C = Per cent mortality in control

The data were subjected to Probit analysis (Finney, 1971) and LT₅₀ values were calculated.

Irrespective of parental lines CM-135 and CM-136 stored under controlled and ambient conditions, LT₅₀ values were analyses by CRD factorial method against the treatments, storage periods and condition of

storage to see the relative residual effectiveness of various seed protectants against test insect after different periods of storage.

3.8.3 Determination of Deltamethrin residues on seeds by GLC

In an experiment to study the recovery of pesticides, representative maize seed samples (50 g) were spiked separately in triplicate with 2 ml (5 ppm) of analytical Deltamethrin. The seeds were shaken with 250 ml purified hexane-acetone (1:1 v/v) mixture and soaked for 20 h. The suspension was allowed to settle after vigorous shaking and filtered through a cotton plug. The filtrate was collected in a flask. The residual matter was re-extracted with hexane-acetone (1:1 v/v) mixture and filtered. The hexane-acetone mixture containing Deltamethrin residue was concentrated to 20-25 ml by rotary evaporation under reduced pressure. The concentrate was then cleaned up by diluting with 100 ml aqueous salt solution (10% v/v) and shaken thrice with hexane (3 x 25 ml) for a minute in a separatory funnel. The organic solvent was collected in a flask and the lower layer of salt solution was discarded and the organic solvent was evaporated to dryness. The concentrate was loaded on the column and then 100 ml hexane-acetone (1:1 v/v) mixture was added to the neutral alumina (5 g) column (300 mm long). The elute was collected in a bottle and its volume was measured and then it was subjected to analysis by gas chromatography containing electron capture detector. The conditions maintained in a gas chromatography for Injector, Column and Detector was 280°C, 270°C and 310°C, respectively. The recovery of Deltamethrin was calculated (75-80%) and the main experiment was conducted in a similar manner with the stored seeds already treated with Deltamethrin. The final

data obtained was processed to find out the amount of Deltamethrin residues present on the seed after storage.

3.9 Seedling emergence in the field

The seedling emergence was carried out at IARI farm, New Delhi. Four hundred stored seeds in eight replications of fifty seeds from each treatment along with the proper controls were drawn separately and were sown in the field. The distance between plant-to-plant and row-to-row was 20 cm and 60 cm respectively. The emergence of plumule was recorded from 7th day onwards to 20th days after sowing and was expressed as percentage of seedlings emergence in the field.

Similarly, Pre-sowing seed treatments were given to untreated stored seeds with Kalisena (0.3%), Bavistin (0.3%), Captan (0.3%) and Hydration-dehydration (Overnight hydration at 20°C followed by 24 h air drying) and Hydration-dehydration treatment followed by dry seed dressing with Kalisena, Bavistin and Captan and sown in similar manner as above in the field. The germination was calculated as percentage seedling emergence in the field.

3.10 Statistical Analysis

The data collected during the course of the studies were subjected to statistical analysis by adopting appropriate method of "Analysis of Variances" (Completely Randomized Design - 3 factorial) as described by Gomez and Gomez (1984).

Chapter 4

RESULTS

The seeds of parental lines, CM-135 (Female) and CM-136 (Male) of newly developed maize hybrid 'Pusa Early Makka-1', produced in *Rabi* 1998 and *Kharif* 1999, obtained from Indian Agricultural Research Institute, Regional Station Karnal, Haryana, having 9.0% moisture content were treated with slurry of fungicides, insecticides and/or their combinations and plant products. The treated seeds along with proper controls were packed in cloth bags and stored under ambient conditions of Delhi and controlled storage conditions ($20 \pm 1^{\circ}\text{C}$ and $30 \pm 10\%$ RH) at Karnal. Observations were recorded at 3 months intervals from July 1999 to Jan.-Feb., 2001 for *Rabi* 1998 produced seeds and from Jan. 2000 to Jan.-Feb., 2001 for *Kharif* 1999 produced seeds. The monthly, mean temperature and relative humidity recorded during the storage period is represented in Appendix 1.

4.1 Seed moisture content

The initial moisture content of CM-135 and CM-136 of *Rabi* 1998 produce seed was recorded to be 9.0 and 9.2 per cent, respectively. The moisture content varied from 10.1 to 12.0 per cent during ambient storage due to fluctuation in atmospheric conditions of storage environment. Significant differences between treatments, storage period and their interactions were observed. The highest moisture content (12.0%) was recorded in the months of

Table 1 : Moisture content (%) of maize CM-135 and CM-136 seeds (Rabi-1998 produce) after different periods of ambient storage

Storage period Treatments	July-Aug. '1999		Oct-Nov. '1999		Jan-Feb. '2000		Apr-May '2000		July-Aug. '2000		Oct-Nov. '2000		Jan-Feb. '2001	
	CM-135	CM-136	CM-135	CM-136	CM-135	CM-136	CM-135	CM-136	CM-135	CM-136	CM-135	CM-136	CM-135	CM-136
Captan			10.77	10.67	11.78	11.65	11.20	11.16	12.11	11.99	10.20	10.06	11.11	11.13
Bavistin			10.48	10.68	11.56	11.60	11.08	11.07	11.95	12.09	10.16	10.19	11.43	11.01
Deltamethrin			10.69	10.53	11.66	11.63	11.01	10.94	11.88	11.96	10.04	10.31	11.04	11.27
Malathion			10.77	10.38	11.70	11.54	11.27	10.89	12.00	12.22	10.08	10.02	11.31	11.29
Econeem			10.59	10.75	11.64	11.71	10.91	11.41	12.08	12.17	10.15	10.19	11.07	11.22
Arappu leaf powder			10.76	10.73	11.91	11.82	11.29	11.25	12.16	12.08	10.00	10.12	11.22	11.30
Captan + Deltamethrin			10.55	10.81	11.72	11.48	10.97	11.25	11.86	11.91	10.07	10.28	11.16	11.03
Captan + Malathion			10.95	10.87	11.84	11.86	11.55	11.30	12.20	12.24	10.13	10.41	11.30	11.37
Bavistin + Deltamethrin			10.49	10.51	11.75	11.54	11.63	11.23	12.15	12.01	10.25	10.24	11.11	11.17
Bavistin + Malathion			10.76	10.78	11.88	11.80	11.34	11.19	12.03	12.13	10.18	10.13	11.19	11.26
Control	9.03	9.23	10.51	10.60	11.71	11.76	11.38	11.16	11.97	12.01	10.09	10.18	11.20	11.19
Mean	9.03	9.23	10.67	10.66	11.74	11.67	11.24	11.15	12.04	12.03	10.12	10.19	11.19	11.20

CD (P=0.05) : For CM-135, T = 0.035 P = 0.0278 T x P = 0.09206
 For CM-136, T = 0.063 P = 0.0502 T x P = 0.16654

Where, T = Treatment ; P = Period of storage

Table 2 : Moisture content (%) of maize CM-135 and CM-136 seeds (Kharif-1999 produce) after different periods of ambient storage

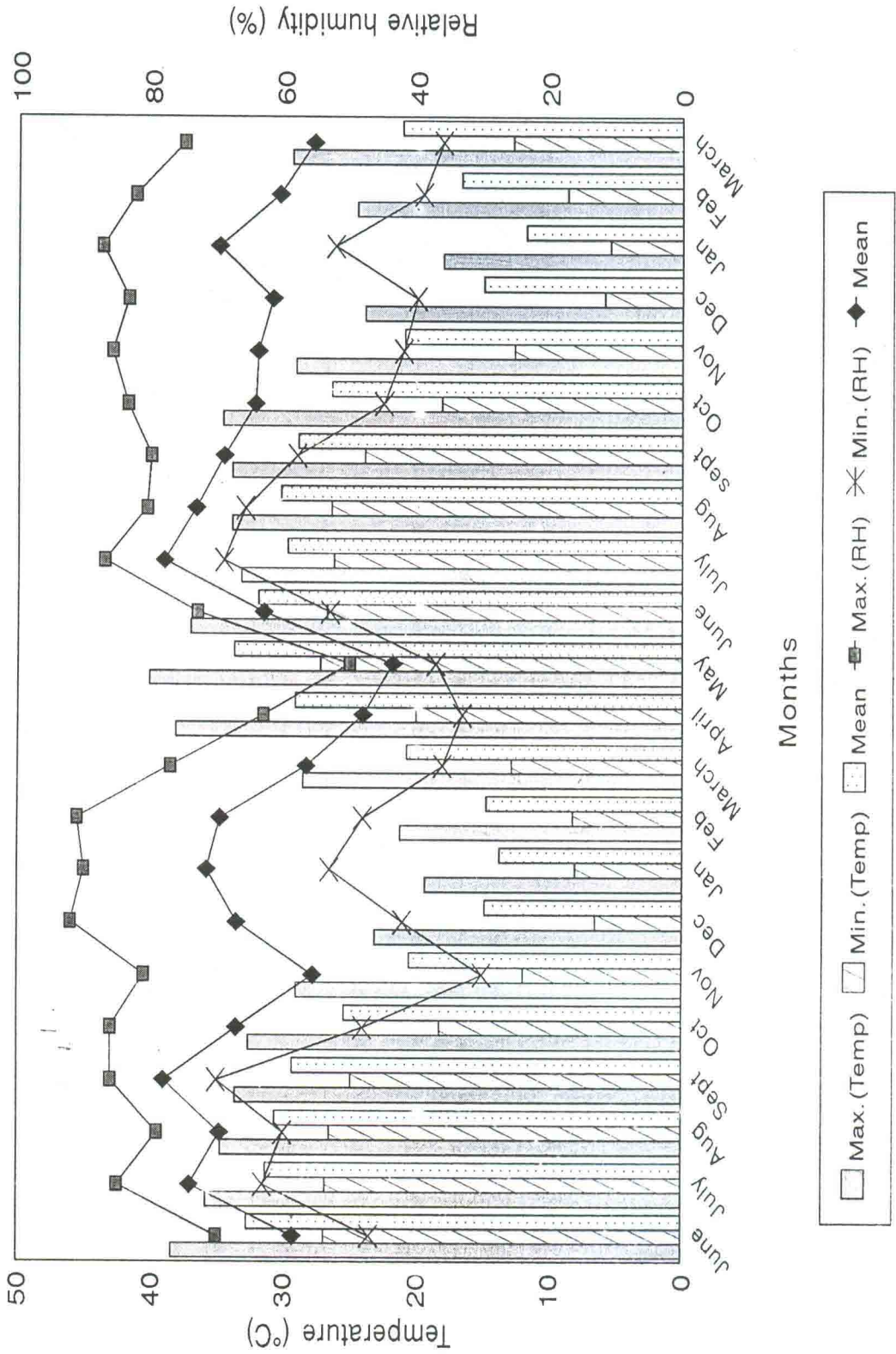
Storage period Treatments	Jan-Feb.' 2000		Apr-May' 2000		July-Aug.' 2000		Oct-Nov.' 2000		Jan-Feb.' 2001	
	CM-135	CM-136	CM-135	CM-136	CM-135	CM-136	CM-135	CM-136	CM-135	CM-136
Captan			10.38	10.30	11.80	11.68	9.85	9.93	10.67	10.80
Bavistin			10.41	10.36	11.71	11.62	9.80	9.86	10.61	10.73
Econeeem			10.33	10.28	11.62	11.69	9.92	9.83	10.78	10.72
Arappu leaf powder			10.24	10.12	11.70	11.73	9.84	9.89	10.71	10.67
Captan + Deltamethrin			10.15	10.07	11.53	11.50	9.79	9.76	10.58	10.65
Captan + Malathion			10.35	10.40	11.75	11.79	9.92	10.01	10.80	10.88
Bavistin + Deltamethrin			10.11	10.15	11.57	11.43	9.95	9.90	10.64	10.60
Bavistin + Malathion			10.30	10.23	11.68	11.56	9.97	9.94	10.76	10.68
Control	9.15	9.19	10.19	10.24	11.62	11.59	9.89	9.91	10.70	10.76
Mean	9.15	9.19	10.27	10.24	11.66	11.62	9.88	9.89	10.69	10.72

CD (P=0.05) : For CM-135, T = 0.0157 P = 0.0117 T × P = 0.0353
 For CM-136, T = 0.0088 P = 0.0066 T × P = 0.0198

Where,

T = Treatment; P = Period of storage

Fig.1 Monthly temperature and relative humidities recorded during June, 1999 to March 2001



July-Aug., 2000 as the relative humidity was higher due to rain during that period whereas, the lowest seed moisture content (10.2%) was recorded in the month of Oct.-Nov., 2000 in both the parental lines (Table 1). However, moisture content remained below 9.0% throughout the storage period when the seeds were stored under controlled storage conditions.

In *Kharif* 1999 produce seeds, the initial moisture content of CM-135 and CM-136 was recorded to be 9.2 per cent. Moisture content varied from 9.9 to 11.7 per cent in CM-135 seeds and from 9.9 to 11.6 per cent in CM-136 seeds during the period of storage from April-May, 2000 to Jan.-Feb., 2001. Significant differences between treatments, storage period and their interactions were observed. The fluctuations in seed moisture may have occurred due to changes in the atmospheric conditions of storage environment. The seed moisture content was below 9.0 per cent throughout the storage period when the seeds were stored under controlled storage conditions (Table 2).

4.2 Germination

The germination percentages along with their respective transformed values are presented in Tables 3 to 6.

4.2.1 Effect of storage period on germination

In *Rabi* 1998 produce seeds, a gradual but significant reduction in germination percentage was observed as the storage period progressed, in both the parental lines. In CM-135, the germination was 80.5 per cent after 9

months of storage whereas, in CM-136, the germination remained 81.5 per cent even after 15 months of storage irrespective of storage condition. The maximum loss (21.39%) in germination was recorded in CM-135 where the germination declined from initial 86.5 per cent to 68.0 per cent after 18 months of storage. However, the minimum loss (17.02%) in germination was observed in case of CM-136, where the germination reduced gradually from 94.0 per cent to 78.0 per cent during the same storage period. The germinability of the parental line CM-135 decreased below the Minimum Seed Certification Standard (80%) after 18 months of storage (Table 3 and 4).

In *Khariif* 1999 produce seeds; there was gradual reduction in germination percentage in both the parental lines when stored for 12 months. In CM-135, the reduction in germination was non-significant upto 3 months but after 3 months there was significant reduction upto 9 months. Similarly, in CM-136, a significant reduction in germination after 3 months and 9 months of storage was noted. Irrespective of storage conditions and treatments the germination was 88.0 and 90.5 per cent in CM-135 and CM-136 respectively even after 12 months of storage (Table 5 and 6).

4.2.2 Effect of seed treatments on germination

In *Rabi* 1998, produce seeds, Captan alone and its combination with Deltamethrin and Malathion recorded significantly higher mean germination (83.5%) followed by Bavistin + Malathion (81.5%) in CM-135. The other treatments were found least effective. Seed treatment with Captan alone and

Storage period	0 month			3 months			6 months			9 months			12 months		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean
Captan	90.0 (71.54)	87.0 (69.19)	88.0 (69.73)	85.0 (67.39)	87.0 (68.47)	86.0 (67.93)	83.0 (65.86)	83.0 (65.75)	83.0 (65.81)	80.0 (63.53)	84.0 (66.55)	83.0 (65.81)	80.0 (63.53)	84.0 (66.55)	82.0 (65.04)
Bavistin	83.0 (65.69)	83.0 (65.50)	82.5 (65.23)	80.0 (63.62)	80.0 (63.59)	80.0 (63.61)	76.0 (60.80)	79.0 (62.82)	77.5 (61.81)	71.0 (57.52)	77.0 (61.46)	77.5 (61.81)	71.0 (57.52)	77.0 (61.46)	74.0 (59.49)
Deltamethrin	85.0 (67.35)	84.0 (66.36)	84.0 (66.67)	81.0 (64.27)	82.0 (65.15)	81.5 (64.71)	78.0 (62.21)	79.0 (62.77)	78.5 (62.50)	74.0 (59.45)	80.0 (63.65)	78.5 (62.50)	74.0 (59.45)	80.0 (63.65)	77.0 (61.55)
Malathion	84.0 (66.72)	82.0 (65.18)	82.0 (65.05)	80.0 (63.66)	80.0 (63.79)	80.0 (63.72)	77.0 (61.43)	77.0 (61.45)	77.0 (61.44)	72.0 (58.10)	74.0 (59.48)	77.0 (61.44)	72.0 (58.10)	74.0 (59.48)	73.0 (58.79)
Econeem	86.0 (68.29)	85.5 (67.67)	85.0 (66.83)	83.0 (65.85)	83.0 (65.41)	83.0 (65.63)	80.0 (63.60)	80.0 (63.55)	80.0 (63.57)	75.0 (60.21)	78.0 (61.88)	80.0 (63.57)	75.0 (60.21)	78.0 (61.88)	76.5 (61.05)
Arappu leaf powder	86.5 (68.56)	84.0 (66.55)	83.0 (65.92)	82.0 (65.15)	82.0 (65.04)	82.0 (65.09)	79.0 (62.83)	81.0 (63.93)	80.0 (63.38)	74.0 (59.48)	78.0 (62.19)	80.0 (63.38)	74.0 (59.48)	78.0 (62.19)	76.0 (60.84)
Captan + Deltamethrin	90.0 (71.40)	86.0 (68.20)	87.0 (68.98)	87.0 (69.00)	88.0 (69.83)	87.5 (69.42)	84.0 (66.51)	86.0 (68.25)	85.0 (67.38)	80.0 (63.49)	84.0 (66.62)	85.0 (67.38)	80.0 (63.49)	84.0 (66.62)	82.0 (65.05)
Captan + Malathion	89.0 (70.83)	86.0 (68.08)	88.0 (70.11)	86.5 (68.49)	86.5 (68.34)	86.5 (68.41)	84.0 (66.57)	85.0 (66.94)	84.5 (66.75)	81.0 (63.87)	83.0 (65.88)	84.5 (66.75)	81.0 (63.87)	83.0 (65.88)	82.0 (64.87)
Bavistin + Deltamethrin	87.0 (69.00)	86.0 (68.29)	86.0 (68.15)	84.0 (66.77)	86.0 (68.15)	85.0 (67.46)	81.0 (64.27)	84.0 (66.62)	82.5 (65.45)	77.0 (61.43)	82.0 (65.08)	82.5 (65.45)	77.0 (61.43)	82.0 (65.08)	79.5 (63.26)
Bavistin + Malathion	85.0 (67.02)	83.0 (65.97)	83.0 (65.79)	81.0 (63.85)	80.0 (63.68)	80.5 (63.76)	77.0 (61.79)	78.0 (62.21)	77.5 (61.99)	73.5 (59.04)	76.0 (60.75)	77.5 (61.99)	73.5 (59.04)	76.0 (60.75)	74.5 (59.89)
Control	86.0 (68.18)	83.5 (66.28)	84.5 (66.86)	80.0 (63.62)	83.0 (65.87)	81.5 (64.74)	75.0 (60.28)	80.0 (63.67)	77.5 (61.97)	69.0 (56.26)	77.0 (61.46)	77.5 (61.97)	69.0 (56.26)	77.0 (61.46)	73.0 (58.87)
Mean	86.5 (68.60)	84.5 (67.02)	85.0 (67.23)	83.0 (65.61)	84.0 (66.12)	83.5 (65.86)	80.0 (63.29)	81.0 (64.36)	80.5 (63.82)	75.0 (60.22)	80.0 (63.18)	80.5 (63.82)	75.0 (60.22)	80.0 (63.18)	77.5 (61.70)

Table 3 : Germination (%) of maize CM-135 seeds (Rabi-1998 produce) after different periods of storage

Treatments	0 month			3 months			6 months			9 months			12 months		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean
Captan	90.0 (71.54)	87.0 (69.19)	88.0 (69.73)	85.0 (67.39)	87.0 (68.47)	86.0 (67.93)	83.0 (65.86)	83.0 (65.75)	83.0 (65.81)	80.0 (63.53)	84.0 (66.55)	83.0 (65.81)	80.0 (63.53)	84.0 (66.55)	82.0 (65.04)
Bavistin	83.0 (65.69)	82.0 (64.95)	82.5 (65.23)	80.0 (63.62)	80.0 (63.59)	80.0 (63.61)	76.0 (60.80)	79.0 (62.82)	77.5 (61.81)	71.0 (57.52)	77.0 (61.46)	77.5 (61.81)	71.0 (57.52)	77.0 (61.46)	74.0 (59.49)
Deltamethrin	85.0 (67.35)	84.0 (66.36)	84.0 (66.51)	81.0 (64.27)	82.0 (65.15)	81.5 (64.71)	78.0 (62.21)	79.0 (62.77)	78.5 (62.50)	74.0 (59.45)	80.0 (63.65)	78.5 (62.50)	74.0 (59.45)	80.0 (63.65)	77.0 (61.55)
Malathion	84.0 (66.72)	82.0 (65.18)	82.0 (65.12)	80.0 (63.66)	80.0 (63.79)	80.0 (63.72)	77.0 (61.43)	77.0 (61.45)	77.0 (61.44)	72.0 (58.10)	74.0 (59.48)	77.0 (61.44)	72.0 (58.10)	74.0 (59.48)	73.0 (58.79)
Econeem	86.0 (68.29)	85.5 (67.67)	85.0 (67.25)	83.0 (65.85)	83.0 (65.41)	83.0 (65.63)	80.0 (63.60)	80.0 (63.55)	80.0 (63.57)	75.0 (60.21)	78.0 (61.88)	80.0 (63.57)	75.0 (60.21)	78.0 (61.88)	76.5 (61.05)
Arappu leaf powder	86.5 (68.56)	84.0 (66.55)	83.5 (66.24)	82.0 (65.15)	82.0 (65.04)	82.0 (65.09)	79.0 (62.83)	81.0 (63.93)	80.0 (63.38)	74.0 (59.48)	78.0 (62.19)	80.0 (63.38)	74.0 (59.48)	78.0 (62.19)	76.0 (60.84)
Captan + Deltamethrin	90.0 (71.40)	86.0 (68.20)	86.5 (68.59)	87.0 (69.00)	88.0 (69.83)	87.5 (69.42)	84.0 (66.51)	86.0 (68.25)	85.0 (67.38)	80.0 (63.49)	84.0 (66.62)	85.0 (67.38)	80.0 (63.49)	84.0 (66.62)	82.0 (65.05)
Captan + Malathion	89.0 (70.83)	86.0 (68.08)	87.0 (69.09)	86.5 (68.49)	86.5 (68.34)	86.5 (68.41)	84.0 (66.57)	85.0 (66.94)	84.5 (66.75)	81.0 (63.87)	83.0 (65.88)	84.5 (66.75)	81.0 (63.87)	83.0 (65.88)	82.0 (64.87)
Bavistin + Deltamethrin	87.0 (69.00)	86.0 (68.29)	86.0 (68.21)	84.0 (66.77)	86.0 (68.15)	85.0 (67.46)	81.0 (64.27)	84.0 (66.62)	82.5 (65.45)	77.0 (61.43)	82.0 (65.08)	82.5 (65.45)	77.0 (61.43)	82.0 (65.08)	79.5 (63.26)
Bavistin + Malathion	85.0 (67.02)	83.0 (65.97)	83.0 (65.88)	81.0 (63.85)	80.0 (63.68)	80.5 (63.76)	77.0 (61.79)	78.0 (62.21)	77.5 (61.99)	73.5 (59.04)	76.0 (60.75)	77.5 (61.99)	73.5 (59.04)	76.0 (60.75)	74.5 (59.89)
Control	86.0 (68.18)	83.5 (66.28)	84.0 (66.57)	80.0 (63.62)	83.0 (65.87)	81.5 (64.74)	75.0 (60.28)	80.0 (63.67)	77.5 (61.97)	69.0 (56.26)	77.0 (61.46)	77.5 (61.97)	69.0 (56.26)	77.0 (61.46)	73.0 (58.87)
Mean	86.5 (68.60)	84.5 (67.02)	84.75 (67.13)	83.0 (65.61)	84.0 (66.12)	83.5 (65.86)	80.0 (63.29)	81.0 (64.36)	80.5 (63.82)	75.0 (60.22)	80.0 (63.18)	80.5 (63.82)	75.0 (60.22)	80.0 (63.18)	77.5 (61.70)

Table 3 : Contd.

Storage period Treatments	15 months			18 months			Mean		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean
Captan	75.0 (60.21)	82.0 (65.31)	78.5 (62.76)	69.0 (56.22)	81.0 (64.28)	75.0 (60.25)	81.0 (64.85)	85.0 (67.45)	83.0 (66.15)
Bavistin	64.0 (53.20)	74.0 (59.16)	69. (56.18)	55.0 (47.64)	72.0 (58.12)	63.5 (52.88)	74.0 (59.14)	78.0 (62.26)	76.0 (60.70)
Deltamethrin	68.0 (55.66)	78.0 (62.19)	73.0 (58.93)	61.0 (51.42)	75.0 (60.14)	68.0 (55.78)	76.0 (60.96)	81.0 (63.99)	78.5 (62.47)
Malathion	65.0 (53.80)	72.0 (58.09)	68.5 (55.94)	55.0 (47.92)	69.0 (56.21)	62.0 (52.07)	74.0 (59.54)	77.0 (61.54)	75.5 (60.54)
Econeem	68.0 (55.60)	74.0 (59.14)	71.0 (57.37)	59.0 (49.97)	71.0 (57.45)	65.0 (53.71)	77.0 (61.60)	80.0 (63.22)	78.5 (62.41)
Arappu leaf powder	69.0 (56.26)	76.0 (60.45)	72.5 (58.36)	63.0 (52.25)	73.0 (58.87)	68.0 (55.56)	77.0 (61.58)	80.0 (63.57)	78.5 (62.57)
Captan + Deltamethrin	75.0 (59.78)	82.0 (65.51)	78.5 (62.65)	67.0 (54.72)	81.0 (64.28)	74.0 (59.50)	81.5 (64.73)	85.5 (67.84)	83.5 (66.28)
Captan + Malathion	75.0 (60.09)	81.0 (64.31)	78.0 (62.20)	68.0 (55.62)	80.0 (63.76)	74.0 (59.69)	82.0 (64.79)	85.0 (67.17)	83.5 (65.98)
Bavistin + Deltamethrin	72.0 (58.10)	81.0 (64.00)	76.5 (61.05)	65.0 (53.81)	77.0 (61.49)	71.0 (57.65)	79.5 (63.09)	83.5 (66.07)	81.5 (64.58)
Bavistin + Malathion	68.0 (55.64)	75.0 (60.14)	71.5 (57.89)	60.0 (50.85)	72.0 (58.14)	66.0 (54.50)	75.5 (60.60)	78.5 (62.53)	77.0 (61.55)
Control	62.0 (51.97)	73.0 (58.84)	67.5 (55.14)	52.0 (46.25)	70.0 (56.89)	61.0 (51.57)	72.5 (58.97)	80.0 (63.11)	76.5 (61.04)
Mean	69.0 (56.39)	77.0 (61.56)	73.0 (58.98)	61.0 (51.51)	75.0 (59.97)	68.0 (55.74)	78.0 (61.81)	81.0 (64.43)	79.5 (63.12)

Note : The figures in parenthesis indicates the corresponding angular transformed values.

CD (P=0.05) : T = 1.1300 C = 0.6098 T x P = NS C x P = 1.6130 T x C x P = NS

T x C = NS

T x C x P = NS

Where, C₁ = Ambient storage ; C₂ = Controlled storage ; T = Treatment ; C = Condition of storage ; P = Period of storage

Table 4 : Germination (%) of maize CM-136 seeds (Rabi-1998 produce) after different periods of storage

Storage period Treatments	0 month			3 months			6 months			9 months			12 months		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean
Captan	97.0 (80.22)	93.0 (74.85)	94.0 (76.18)	94.0 (75.95)	96.0 (78.72)	95.0 (77.34)	92.0 (73.83)	93.0 (74.85)	92.5 (74.34)	89.0 (70.81)	92.0 (73.87)	92.5 (74.34)	89.0 (70.81)	92.0 (73.87)	90.5 (72.35)
Bavistin	92.0 (73.85)	90.0 (71.78)	90.5 (72.01)	87.0 (69.06)	89.0 (70.45)	88.0 (69.76)	84.0 (66.12)	87.0 (69.21)	85.5 (67.67)	80.0 (63.67)	87.0 (68.51)	85.5 (67.67)	80.0 (63.67)	87.0 (68.51)	83.5 (66.09)
Deltamethrin	95.0 (77.43)	95.0 (76.27)	94.5 (76.59)	91.0 (73.07)	92.0 (73.92)	91.5 (73.49)	89.0 (71.01)	92.0 (73.47)	90.5 (72.24)	85.0 (67.36)	89.0 (70.18)	90.5 (72.24)	85.0 (67.36)	89.0 (70.18)	87.0 (68.74)
Malathion	90.0 (71.82)	88.0 (69.94)	88.0 (69.89)	85.0 (67.49)	87.0 (68.47)	86.0 (67.98)	82.0 (65.21)	85.0 (66.89)	83.5 (66.07)	78.0 (62.23)	81.0 (64.39)	83.5 (66.07)	78.0 (62.23)	81.0 (64.39)	79.5 (63.31)
Econeem	96.0 (78.72)	94.0 (76.14)	94.5 (76.33)	92.0 (73.92)	93.0 (74.41)	92.5 (74.66)	91.0 (72.18)	91.0 (72.86)	91.0 (72.52)	84.0 (68.39)	88.0 (69.57)	91.0 (72.52)	84.0 (68.39)	88.0 (69.57)	86.0 (68.98)
Arappu leaf powder	93.0 (74.88)	91.5 (73.03)	91.5 (73.17)	89.0 (70.14)	88.0 (69.97)	88.5 (70.05)	85.0 (67.36)	86.0 (68.14)	85.5 (67.76)	81.0 (64.31)	87.0 (69.06)	85.5 (67.76)	81.0 (64.31)	87.0 (69.06)	84.0 (66.69)
Captan + Deltamethrin	96.0 (78.99)	94.5 (76.64)	95.0 (77.20)	93.0 (74.98)	92.0 (73.89)	92.5 (74.44)	89.0 (70.87)	94.0 (75.28)	92.5 (73.07)	85.0 (67.46)	90.0 (71.81)	91.5 (73.07)	85.0 (67.46)	90.0 (71.81)	87.5 (69.63)
Captan + Malathion	94.0 (76.32)	93.0 (74.22)	92.5 (73.95)	90.0 (71.81)	91.0 (72.93)	90.5 (72.37)	86.0 (68.29)	91.0 (72.32)	88.5 (70.31)	82.0 (65.26)	89.0 (70.39)	88.5 (70.31)	82.0 (65.26)	89.0 (70.39)	86.0 (67.83)
Bavistin + Deltamethrin	92.0 (73.92)	92.0 (73.68)	91.0 (72.65)	88.0 (69.94)	90.0 (71.05)	89.0 (70.49)	86.5 (68.63)	87.5 (69.31)	87.0 (68.97)	80.0 (63.55)	85.0 (67.52)	87.0 (68.97)	80.0 (63.55)	85.0 (67.52)	82.5 (65.54)
Bavistin + Malathion	95.0 (77.48)	94.0 (76.37)	94.0 (75.89)	93.0 (74.32)	91.0 (72.94)	92.0 (73.63)	90.0 (71.78)	89.0 (70.85)	89.5 (71.32)	86.0 (68.29)	87.0 (69.09)	89.5 (71.32)	86.0 (68.29)	87.0 (69.09)	86.5 (68.69)
Control	92.0 (73.60)	89.0 (71.03)	89.5 (71.44)	86.0 (68.50)	88.0 (69.99)	87.0 (69.24)	82.0 (65.16)	86.0 (67.96)	84.0 (66.56)	78.0 (62.23)	83.0 (65.91)	84.0 (66.56)	78.0 (62.23)	83.0 (65.91)	80.5 (64.07)
Mean	94.0 (76.11)	92.0 (74.01)	92.5 (74.12)	90.0 (71.74)	91.0 (72.67)	90.5 (72.21)	87.0 (68.95)	89.0 (71.01)	88.0 (69.98)	83.0 (65.78)	87.0 (69.11)	88.0 (69.98)	83.0 (65.78)	87.0 (69.11)	85.0 (67.45)

Table 4 : Contd.

Storage period Treatments	15 months			18 months			Mean		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean
	Captan	85.5 (67.58)	90.0 (71.85)	88.0 (69.72)	80.0 (63.61)	89.0 (70.83)	84.5 (66.32)	91.0 (72.41)	94.0 (75.74)
Bavistin	76.0 (60.73)	83.0 (65.82)	79.5 (63.28)	71.0 (57.52)	82.0 (65.12)	77.0 (61.32)	83.5 (66.11)	87.5 (69.31)	85.5 (67.71)
Deltamethrin	80.0 (63.56)	86.0 (68.22)	83.0 (65.89)	73.0 (58.79)	84.0 (66.69)	79.0 (62.74)	88.0 (69.74)	91.0 (72.30)	89.5 (71.02)
Malathion	73.0 (58.76)	82.0 (65.04)	77.5 (61.90)	67.0 (54.99)	80.0 (63.58)	73.5 (59.28)	81.0 (64.34)	85.0 (67.16)	83.0 (65.75)
Econeein	81.0 (64.24)	84.0 (66.69)	82.5 (65.46)	76.0 (60.82)	82.0 (65.00)	79.0 (62.91)	89.0 (70.63)	91.0 (72.11)	90.0 (71.37)
Arappu leaf powder	76.0 (60.75)	85.0 (67.42)	80.5 (64.08)	67.0 (54.91)	83.0 (65.57)	75.0 (60.24)	84.0 (66.77)	88.0 (69.76)	86.0 (68.27)
Captan + Deltamethrin	80.0 (63.53)	90.0 (71.16)	85.0 (67.34)	74.0 (59.52)	87.0 (69.13)	81.0 (64.32)	89.0 (70.28)	92.0 (74.01)	90.5 (72.14)
Captan + Malathion	77.0 (61.49)	87.0 (68.43)	82.0 (64.96)	72.0 (58.13)	84.0 (66.65)	78.0 (62.39)	86.0 (67.93)	90.0 (71.53)	88.0 (69.73)
Bavistin + Deltamethrin	75.0 (60.17)	83.0 (65.61)	79.0 (62.89)	70.0 (56.55)	81.0 (64.34)	75.5 (60.45)	84.0 (66.28)	87.0 (69.12)	85.5 (67.70)
Bavistin + Malathion	81.0 (63.87)	85.0 (67.38)	83.0 (65.63)	74.0 (59.46)	82.0 (64.87)	78.0 (62.17)	88.0 (70.22)	90.0 (71.29)	89.0 (70.76)
Control	72.0 (58.12)	81.0 (64.26)	76.5 (61.19)	63.0 (52.61)	80.0 (63.50)	71.5 (58.07)	81.0 (64.46)	86.0 (68.15)	83.5 (66.31)
Mean	78.0 (62.07)	85.0 (67.44)	81.5 (64.76)	72.0 (58.08)	84.0 (66.08)	78.0 (62.08)	86.0 ⁰ (68.11)	89.0 (70.95)	87.5 (69.53)

Note : The figures in parenthesis indicates the corresponding angular transformed values

CD (P=0.05) : T = 1.5403 C = 0.6569 P = 1.2288 T x C = NS
T x P = NS C x P = 1.7378 T x C x P = NS

Where, C₁ = Ambient storage ; C₂ = Controlled storage ; T = Treatment ; C = Condition of storage ; P = Period of storage

Table 5 : Germination (%) of maize CM-135 seeds (Kharif -1999 produce) after different periods of storage

Storage period Treatments	0 month			3 months			6 months			9 months			12 months			Mean	
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂
Captan	96.0 (9.82)	95.0 (9.75)	94.5 (9.72)	93.0 (9.64)	95.0 (9.75)	94.0 (9.69)	93.0 (9.64)	93.0 (9.64)	93.0 (9.64)	91.0 (9.54)	92.0 (9.59)	91.5 (9.57)	94.0 (9.68)	94.0 (9.70)	94.0 (9.69)		
Bavistin	92.0 (9.59)	93.0 (9.64)	91.5 (9.56)	89.0 (9.43)	89.0 (9.43)	89.0 (9.43)	87.0 (9.33)	91.0 (9.54)	89.0 (9.43)	85.0 (9.25)	88.0 (9.38)	86.5 (9.31)	89.0 (9.45)	90.0 (9.48)	89.5 (9.47)		
Econeem	93.0 (9.64)	91.0 (9.54)	91.5 (9.56)	89.0 (9.43)	90.0 (9.48)	89.5 (9.46)	88.0 (9.38)	88.0 (9.37)	88.0 (9.37)	85.0 (9.25)	89.0 (9.43)	87.0 (9.34)	89.0 (9.45)	90.0 (9.50)	89.5 (9.48)		
Arappu leaf powder	92.0 (9.59)	90.0 (9.49)	90.0 (9.49)	88.0 (9.38)	89.0 (9.43)	88.5 (9.41)	86.0 (9.27)	87.0 (9.33)	86.5 (9.30)	84.0 (9.16)	85.0 (9.22)	84.5 (9.19)	88.0 (9.38)	89.0 (9.41)	88.5 (9.40)		
Captan + Deltamethrin	94.0 (9.70)	93.0 (9.64)	94.0 (9.69)	91.0 (9.54)	94.0 (9.70)	92.5 (9.62)	89.0 (9.43)	91.0 (9.54)	90.0 (9.51)	90.0 (9.48)	92.0 (9.59)	91.0 (9.54)	91.0 (9.56)	93.0 (9.66)	92.0 (9.61)		
Captan + Malathion	95.0 (9.77)	94.0 (9.69)	94.5 (9.72)	92.0 (9.59)	93.0 (9.64)	92.5 (9.62)	91.0 (9.53)	92.0 (9.59)	90.5 (9.56)	89.0 (9.43)	91.0 (9.54)	90.0 (9.48)	92.0 (9.60)	93.0 (9.66)	92.5 (9.63)		
Bavistin + Deltamethrin	95.0 (9.75)	93.0 (9.64)	93.5 (9.67)	91.0 (9.54)	92.0 (9.59)	91.5 (9.56)	90.0 (9.48)	90.0 (9.48)	90.0 (9.48)	88.0 (9.38)	89.0 (9.43)	88.5 (9.41)	91.0 (9.56)	92.0 (9.59)	91.5 (9.58)		
Bavistin + Malathion	94.0 (9.70)	92.0 (9.59)	92.5 (9.62)	90.0 (9.48)	91.0 (9.53)	90.5 (9.51)	89.0 (9.43)	89.0 (9.43)	89.0 (9.43)	87.0 (9.33)	90.0 (9.48)	88.0 (9.40)	90.0 (9.51)	91.0 (9.56)	90.5 (9.53)		
Control	91.0 (9.54)	90.0 (9.49)	90.0 (9.49)	88.0 (9.38)	88.0 (9.38)	88.0 (9.38)	85.0 (9.21)	85.0 (9.22)	85.0 (9.23)	82.0 (9.08)	84.0 (9.16)	83.0 (9.12)	87.0 (9.34)	88.0 (9.36)	87.5 (9.35)		
Mean	93.5 (9.68)	92.0 (9.61)	92.0 (9.61)	90.0 (9.49)	91.0 (9.55)	90.5 (9.52)	88.5 (9.41)	89.5 (9.46)	89.0 (9.44)	87.0 (9.32)	89.0 (9.42)	88.0 (9.37)	90.0 (9.50)	91.0 (9.55)	90.5 (9.53)		

Note : The figures in parenthesis indicates the corresponding square root values.

CD (P=0.05) : T = 0.0951 C = 0.0448 P = 0.0709 T x C = NS T x P = NS
 C x P = 0.1003 T x C x P = NS

Where,

C₁ = Ambient storage ; C₂ = Controlled storage ; T = Treatment ; C = Condition of storage ; P = Period of storage

Table 6 : Germination (%) of maize CM-136 seeds (Kharif -1999 produce) after different periods of storage

Storage period	0 month			3 months			6 months			9 months			12 months			Mean
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean	
Captan	98.0 (9.90)	97.0 (9.85)	97.0 (9.85)	98.0 (9.90)	96.0 (9.80)	97.0 (9.85)	95.0 (9.75)	97.0 (9.85)	96.0 (9.80)	95.0 (9.75)	97.0 (9.85)	96.0 (9.80)	94.0 (9.69)	95.0 (9.77)	94.5 (9.73)	
Bavistin	94.5 (9.72)	94.0 (9.70)	95.0 (9.75)	93.0 (9.64)	94.0 (9.69)	93.5 (9.67)	93.0 (9.64)	93.0 (9.64)	93.0 (9.64)	93.0 (9.64)	93.0 (9.64)	93.0 (9.64)	91.0 (9.54)	92.0 (9.59)	91.5 (9.56)	
Econeem	97.0 (9.85)	95.0 (9.75)	95.0 (9.75)	95.0 (9.75)	96.0 (9.80)	95.5 (9.77)	93.0 (9.64)	95.0 (9.75)	94.0 (9.69)	95.0 (9.75)	94.0 (9.69)	94.0 (9.69)	92.0 (9.59)	94.0 (9.69)	93.0 (9.64)	
Arappu leaf powder	94.0 (9.70)	93.0 (9.64)	93.5 (9.67)	92.0 (9.59)	92.0 (9.59)	92.0 (9.59)	85.0 (9.23)	92.0 (9.59)	87.5 (9.36)	90.0 (9.48)	87.0 (9.33)	87.5 (9.35)	87.0 (9.33)	88.0 (9.38)	87.5 (9.35)	
Captan + Deltamethrin	97.0 (9.85)	95.0 (9.75)	95.0 (9.77)	96.0 (9.80)	95.0 (9.75)	95.5 (9.77)	94.0 (9.69)	95.0 (9.75)	94.5 (9.72)	95.0 (9.75)	94.5 (9.72)	94.5 (9.72)	92.0 (9.59)	93.0 (9.64)	92.5 (9.61)	
Captan + Malathion	96.0 (9.80)	94.0 (9.70)	94.5 (9.72)	93.0 (9.64)	94.0 (9.70)	93.5 (9.67)	90.0 (9.49)	93.0 (9.67)	91.5 (9.57)	93.0 (9.64)	89.5 (9.46)	90.5 (9.52)	92.0 (9.62)	92.0 (9.59)	90.5 (9.52)	
Bavistin + Deltamethrin	96.0 (9.80)	95.0 (9.75)	93.5 (9.67)	94.0 (9.70)	93.0 (9.64)	93.5 (9.67)	91.0 (9.56)	94.0 (9.69)	92.5 (9.63)	91.0 (9.54)	89.5 (9.46)	91.5 (9.55)	89.5 (9.46)	93.0 (9.64)	91.5 (9.55)	
Bavistin + Malathion	95.0 (9.75)	94.0 (9.70)	93.5 (9.67)	93.0 (9.64)	94.0 (9.69)	93.5 (9.67)	91.0 (9.54)	92.0 (9.59)	91.5 (9.56)	92.0 (9.59)	90.0 (9.49)	90.0 (9.48)	92.0 (9.62)	90.0 (9.48)	90.0 (9.48)	
Control	94.0 (9.70)	92.0 (9.60)	92.5 (9.62)	87.0 (9.35)	92.0 (9.59)	89.5 (9.47)	88.5 (9.41)	89.5 (9.47)	89.5 (9.44)	90.0 (9.48)	86.0 (9.27)	86.5 (9.30)	89.0 (9.46)	87.0 (9.33)	86.5 (9.30)	
Mean	95.5 (9.78)	94.0 (9.69)	94.5 (9.72)	93.0 (9.67)	94.0 (9.69)	93.5 (9.68)	91.0 (9.55)	93.0 (9.60)	92.0 (9.60)	93.0 (9.65)	90.0 (9.49)	90.5 (9.53)	93.0 (9.64)	91.5 (9.57)	90.5 (9.53)	

Note : The figures in parenthesis indicates the corresponding square root values.

CD (P=0.05) : T = 0.0799 C = 0.0376 T x C = NS T x P = NS
 C x P = 0.0842 T x C x P = NS

Where, C₁ = Ambient storage; C₂ = Controlled storage ; T = Treatment ; C = Condition of storage ; P = Period of storage

its combination with Deltamethrin and Malathion improved the germination and were at par in their effect. In CM-136, significantly higher mean germination (92.5%) was recorded by the seed treatment with Captan alone followed by seed treatment with Captan + Deltamethrin (90.5%), Econeem (90.0%), Deltamethrin (89.5%) alone and Bavistin + Malathion (89.0%) as compared to untreated control (83.5%). Nevertheless, seed treatment with Captan alone maintained germination above 80.0% for 18 months irrespective of storage conditions in CM-136. Similarly, in CM-135, irrespective of storage conditions, the germination was 82.0% after 12 months of storage when the seed were treated with Captan alone and its combination with Deltamethrin and Malathion. However, Malathion was found less effective in both the parental lines (Table 3 and 4).

In *Kharif* 1999 produce seeds, it was found that except Arappu leaf powder, all other treatments proved to be better as they gave significantly higher germination in both the parental lines. Amongst the treatments Captan alone and its combination with Deltamethrin and Malathion were found to be superior in CM-135. Similarly, in case of CM-136, the seed treatment with Captan and its combination with Deltamethrin and Econeem alone were found superior in improving germination percentage as compared to other treatments and untreated control. However, irrespective of treatments and storage conditions, the germination remained above Minimum Seed Certification Standard after 12 months of storage in both the parental lines (Table 5 and 6).

4.2.3 Effect of storage conditions on germination

In *Rabi* 1998 produce seeds, the reduction in germination was non-significant upto 3 months in both the parental lines but thereafter significant differences were observed. However, controlled storage condition was found to be safe as it maintained significantly higher germination (81.0%) as compared to seed stored under ambient condition where the germination was 78.0% in CM-135. Nevertheless, seed treated with Captan and its combinations with Deltamethrin and Malathion and stored under controlled condition improved germination and remained above 80.0% after 18 months of storage. The mean germination was 86.0% and 89.0% when the seeds were stored under ambient and controlled conditions respectively in CM-136. More so, irrespective of seed treatments, the germination remained above 80.0% after 18 months of storage under controlled condition. However interaction between storage period and condition of storage was statistically significant in both the parental lines (Table 3 and 4).

In *Kharif* 1999 produce seeds, irrespective of storage conditions the mean germination was above 90.0% in both the parental lines. However, the seeds stored under controlled conditions recorded significantly higher germination than that of seeds stored under ambient conditions. In CM-135, there was no significant difference in germination after 3 months of storage in both the conditions, but thereafter a significantly higher germination was noted in the seeds stored under controlled conditions. Similarly, in CM-136, a

significant difference in germination was found when the seeds were stored under controlled conditions and ambient condition except in Jul-Aug., 2000, where, the difference in germination with respect to conditions was non-significant. However, there was a significant interaction effect of storage condition and storage period on both the parental lines (Table 5 and 6).

4.3 Seed vigour

Seed vigour was evaluated in terms of seedling dry weight, shoot length, root length, vigour index, accelerated ageing, cold test and electrical conductivity. The observations were taken after 3 months interval and the results obtained during the studies are given in Tables 7 to 26.

4.3.1 Seedling dry weight

Seedling dry weight was taken after standard germination test. Ten normal seedlings were randomly taken and their dry weight was recorded after 3 months interval.

4.3.1.1 Effect of storage period on seedling dry weight

In *Rabi* 1998 produce seeds, as the storage period progressed, the seedling dry weight generally decreased significantly throughout the storage period for 18 months. In CM-135, seedling dry weight declined to 329.36 mg from the initial dry weight of 481.77 mg recording as much as 31.64% reduction in dry weight after 18 months of storage. Similarly, in CM-

136, seedling dry weight reduced to 360.41 mg from the initial 506.91 mg after 18 months with minimum loss of 28.90% (Table 7 and 8).

In *Kharif* 1999 produce seeds, there was a significant decrease in seedling dry weight as the storage period progressed. The initial dry weight 503.11 and 504.22 mg declined to 376.92 and 398.03 mg after 12 months of storage in the parental lines CM-135 and CM-136, respectively. Overall, the loss in seedling dry weight was 21.06 and 25.08 per cent in CM-136 and CM-135 respectively after 12 months of storage. After 3 months, a slightly rapid reduction in seedlings dry weight was observed in both the parental lines (Table 9 and 10).

4.3.1.2 Effect of seed treatments on seedling dry weight

In *Rabi* 1998 produce seeds, the results obtained indicate that seed treatments in general increased the seedling dry weight as compared to untreated control. In CM-135, seed treatment with Captan (427.05 mg) alone and its combination with Deltamethrin (426.14 mg) and Malathion (429.09 mg) and Bavistin + Deltamethrin (418.14 mg) increased the seedling dry weight significantly and were at par. However, seed treatment with Captan increased the dry weight from initial 478 mg to 486 and 493 mg after 3 months when the seeds were stored under ambient and controlled conditions respectively. Whereas, other treatments like Bavistin + Malathion, Arappu leaf powder, Econeem and Deltamethrin alone were at par in their effect. In case of CM-136, Captan + Deltamethrin (484.25 mg) and Captan + Malathion

Table 7 : Dry weight (mg) of 10 seedlings of maize CM-135 seeds (Rabi-1998 produce) after different periods of storage

Storage period Treatments	0 month			3 months			6 months			9 months			12 months		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean
Captan	478	486	489.5	422	460	441.0	413	436	424.5	387	417	402.0			
Bavistin	433	389	400.5	415	389	402.0	357	362	359.5	308	358	333.0			
Deltamethrin	452	449	440.0	434	448	441.0	398	423	410.5	329	382	355.5			
Malathion	487	395	420.5	402	427	414.5	342	374	358.0	317	349	333.0			
Econeem	496	472	468.5	424	406	415.0	366	413	389.5	350	380	365.0			
Arappu leaf powder	473	439	445.5	418	431	424.5	389	394	391.5	362	387	374.5			
Captan + Deltamethrin	518	465	472.5	443	412	427.5	392	431	411.5	385	424	405.5			
Captan + Malathion	530	493	500.5	467	446	456.5	403	409	406.0	358	413	385.5			
Bavistin + Deltamethrin	505	468	471.0	431	458	444.5	389	429	409.0	342	403	372.5			
Bavistin + Malathion	484	456	458.0	417	439	428.0	379	414	396.5	336	421	378.5			
Control	443	421	427.5	376	387	381.5	369	375	372.0	320	363	341.5			
Mean	481.77	448.5	454.02	422.64	427.55	425.09	381.61	405.46	393.53	344.91	390.86	367.89			

Table 7 : Contd.

Storage period Treatments	15 months			18 months			Mean		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean
	Captan	364	403	383.5	353	388	370.5	414.71	439.39
Bavistin	289	334	311.5	267	328	297.5	351.14	373.71	362.43
Deltamethrin	293	385	339.0	276	374	325.0	375.85	413.57	394.71
Malathion	274	338	306.0	249	301	275.0	352.36	388.93	370.64
Econeem	269	361	315.0	298	342	320.0	382.21	409.00	395.61
Arappu leaf powder	331	371	351.0	319	368	343.5	390.25	410.85	400.55
Captan + Deltamethrin	362	397	379.5	330	407	368.5	413.57	438.71	426.14
Captan + Malathion	341	405	373.0	324	379	351.5	416.57	441.61	429.09
Bavistin + Deltamethrin	337	413	375.0	308	392	350.0	397.14	439.14	418.14
Bavistin + Malathion	310	383	346.5	286	372	329.0	381.14	424.71	402.93
Control	254	344	299.0	274	311	292.5	351.00	379.57	365.29
Mean	311.27	375.96	343.61	298.55	360.18	329.36	384.18	414.47	399.33

CD (P=0.05) : T = 10.0735 T = 8.0359 T x C = 14.2463
 T x P = 26.6524 C x P = 11.365 T x C x P = NS

Where,

C₁ = Ambient storage ; C₂ = Controlled storage ; T = Treatment ; C = Condition of storage ; P = Period of storage

Table 8 : Seedling dry weight (mg) of 10 seedlings of maize CM-136 seeds (Rabi-1998 produce) after different periods of storage

Storage period Treatments	0 month			3 months			6 months			9 months			12 months		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean
Captan	523	491	503.5	475	516	481	478.0	451	476	463.5	427	440	433.5		
Bavistin	479	454	452.0	427	431	429.0	407	416	411.5	381	391	386.0			
Deltamethrin	487	462	467.5	448	461	454.5	413	433	423.0	382	312	347.0			
Malathion	466	430	437.0	414	431	422.5	380	418	399.0	356	383	369.5			
Econeem	506	483	490.0	437	470	453.5	409	449	429.0	418	404	411.0			
Arappu leaf powder	495	465	467.0	431	437	434.0	397	429	413.0	361	441	401.0			
Captan + Deltamethrin	553	528	533.0	489	511	500.0	467	491	479.0	438	486	462.0			
Captan + Malathion	529	506	517.0	482	510	496.0	453	470	461.5	459	461	460.0			
Bavistin + Deltamethrin	512	479	483.5	475	479	477.0	441	461	451.0	395	448	421.5			
Bavistin + Malathion	545	504	515.5	462	493	477.5	435	473	454.0	386	441	413.5			
Control	481	417	436.5	411	431	421.0	399	394	396.5	379	405	392.0			
Mean	506.91	474.46	482.05	450.32	466.64	458.48	422.86	446.32	434.59	398.39	419.27	408.84			

Table 8 : Contd.

Storage period Treatments	15 months			18 months			Mean		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean
	Captan	409	428	418.5	378	404	391.0	450.6	466.9
Bavistin	354	362	358.0	318	339	328.5	402.9	409.7	406.29
Deltamethrin	355	413	384.0	324	489	356.5	410.2	424.0	417.11
Malathion	341	358	349.5	296	323	309.5	383.3	403.3	393.29
Econeem	384	418	401.0	352	374	363.0	427.0	445.4	436.21
Arappu leaf powder	337	405	371.0	303	386	344.5	398.4	437.4	417.89
Captan + Deltamethrin	424	464	444.0	407	431	419.0	477.2	496.3	484.25
Captan + Malathion	431	443	437.0	394	417	405.5	468.4	479.7	472.29
Bavistin + Deltamethrin	362	427	394.5	344	392	368.0	429.7	458.1	443.93
Bavistin + Malathion	364	413	388.5	331	380	355.5	432.4	467.4	449.93
Control	346	354	350.0	302	345	323.5	390.7	409.4	400.11
Mean	373.14	408.00	390.57	340.82	389.09	364.95	424.31	444.79	434.55

CD (P=0.05) : $T = 10.687$ $C = 4.557$ $P = 8.5251$ $T \times C = 15.1135$ $T \times P = 28.2749$
 $C \times P = 12.056$ $T \times C \times P = NS$

Where,

C₁ = Ambient storage ; C₂ = Controlled storage ; T = Treatment ; C = Condition of storage ; P = Period of storage

Table 9 : Seedling dry weight (mg) of 10 seedlings of maize CM-135 seeds (Kharif-1999 produce) after different periods of storage

Storage period Treatments	0 month			3 months			6 months			9 months			12 months			Mean	
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂
Captan	493	519	517.0	438	488	463.0	395	453	424.0	381	432	406.5	444.4	477.0	460.70		
Bavistin	501	472	477.5	424	445	434.5	364	410	387.0	328	385	356.5	420.0	442.6	431.30		
Econeem	513	465	461.0	446	481	463.5	388	432	410.0	345	411	378.0	429.8	460.4	445.60		
Arappu leaf powder	478	431	435.0	384	368	376.0	347	387	367.0	323	371	347.0	394.2	407.0	400.60		
Captan + Deltamethrin	541	494	508.5	482	472	477.0	421	486	453.5	376	439	407.5	462.8	492.2	477.50		
Captan + Malathion	489	473	484.5	404	425	414.5	390	466	428.2	367	397	382.0	424.6	454.6	439.63		
Bavistin + Deltamethrin	528	443	466.0	453	468	460.5	351	454	402.5	350	421	385.8	434.3	462.8	448.55		
Bavistin + Malathion	502	468	489.0	416	452	434.0	373	439	406.0	352	393	372.5	422.2	459.2	440.70		
Control	483	446	462.5	378	436	407.0	359	404	381.5	338	375	356.5	400.8	435.4	418.10		
Mean	503.11	473.78	482.00	477.89	425.00	448.33	376.44	436.78	406.61	351.17	402.67	376.92	425.90	454.58	440.52		

CD (P=0.05): T = 10.766 C = 5.075
C x P = 11.355 T x C x P = 34.07

P = 8.0242 T x C = 15.2342 T x P = 24.0875

Where,

C₁ = Ambient storage ; C₂ = Controlled storage ; T = Treatment ; C = Condition of storage ; P = Period of storage

Table 10 : Seedling dry weight (mg) of 10 seedlings of maize CM-136 seeds (Kharif-1999 produce) after different periods of storage

Storage period Treatments	0 month			3 months			6 months			9 months			12 months			Mean	
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂
Captan	516	505	515.0	484	498	491.3	397	442	419.5	404	468	436.1	465.25	485.90	475.58		
Bavistin	464	470	460.5	456	478	467.0	386	437	411.5	347	399	373.0	424.60	445.80	435.20		
Econeem	520	467	480.0	447	524	485.5	374	471	422.5	369	438	403.5	440.60	484.00	462.30		
Arappu leaf powder	478	483	484.5	430	461	445.5	401	381	391.0	339	386	362.5	426.20	438.40	432.30		
Captan + Deltamethrin	548	532	517.5	490	481	485.5	437	454	445.8	408	447	427.5	477.20	492.50	484.85		
Captan + Malathion	508	488	502.5	478	502	490.0	393	426	409.5	376	430	403.3	454.40	470.90	462.65		
Bavistin + Deltamethrin	529	527	519.5	468	446	457.0	418	463	440.5	392	451	421.5	463.80	483.20	473.50		
Bavistin + Malathion	483	491	490.0	390	410	400.0	424	426	425.0	374	413	393.5	432.0	444.60	438.30		
Control	492	472	470.5	406	424	415.0	371	395	383.0	334	388	361.0	414.40	434.20	424.30		
Mean	504.22	492.78	493.89	493.34	449.89	459.64	400.11	432.89	416.50	371.47	424.58	398.03	443.92	464.77	454.34		

CD (P=0.05): T = 10.75 C = 5.067 T x C = 15.21 T x P = 24.052
C x P = 11.34 T x C x P = 34.01

Where, C₁ = Ambient storage ; C₂ = Controlled storage ; T = Treatment ; C = Condition of storage ; P = Period of storage

(472.29 mg) was found superior to all other treatments. Nevertheless, seed treatments with Captan, Bavistin + Deltamethrin, Bavistin + Malathion and Econeem were at par and found equally effective. However, seed treatment with Bavistin and Malathion alone was less effective and at par with untreated control in both the parental lines.

A significant interaction between treatments and condition of storage and/or storage period was recorded in both the parental lines (Table 7 and 8).

In *Kharif* 1999 produce seeds, seedling dry weight increased significantly with the seed treatments of Captan (460.70 mg) and its combination with Deltamethrin (477.50 mg) as compared to other treatments in CM-135. The other treatments Bavistin + Malathion and Bavistin alone were at par in recording higher seedling dry weight. Similarly, in case of CM-136, seed treatment with Captan (475.58 mg) and its combination with Deltamethrin (484.85 mg) and Malathion (462.65 mg), Bavistin + Deltamethrin (473.50 mg) and Econeem (462.30 mg) were equally effective and were at par in giving highest seedling dry weight as compared to untreated control. After 3 months storage, seed treatment with Captan increased the dry weight from 493 to 517 mg irrespective of storage conditions in CM-135. Similarly, in case of CM-136, seed treatment with Captan, Bavistin, Arappu leaf powder, Captan + Malathion and Bavistin + Malathion increased seedling dry weight after 3 months (Table 9 and 10).

4.3.1.3 Effect of storage conditions on seedling dry weight

In *Rabi* 1998 produce seeds, both parental lines showed highly significant reduction of seedling dry weight in ambient storage conditions as compared to seeds stored under controlled storage conditions. Nevertheless, storage conditions had significant differences in seedling dry weight after 3 months of storage period in both the parental lines. In general, there was a gradual decrease in seedling dry weight in both the parental lines in both the storage conditions. The highest loss in seedling dry weight 38.03% and 31.99% was noted in ambient storage as compared to 25.24% and 25.81% in controlled storage in CM-135 and CM-136 respectively after 18 months of storage.

A significant interaction between storage condition and storage period was noted in both the parental lines (Table 7 and 8).

In *Kharif* 1999 produce seeds, the results indicated that, seed stored under controlled condition had significantly higher seedling dry weight as compared to ambient storage. In CM-135, the difference in seedlings dry weight was maintained throughout the storage period of 12 months. However, in CM-136, upto 3 months there was no significant difference in condition of storage, but after 3 months, significantly higher seedlings dry weight was maintained in controlled storage upto 12 months as compared to ambient storage. Overall, the maximum loss of seedlings dry weight (30.20%) was recorded in ambient conditions as compared to controlled storage (19.96%) in CM-135. Similarly, in CM-136, the loss in seedling dry weight was

26.33% and 15.79% in ambient storage and controlled storage respectively (Table 9 and 10).

4.3.2 Seedling shoot length

Seedling shoot length was recorded after standard germination test. Ten randomly selected normal seedlings were taken and the seedling shoot length recorded at 3 months interval is summarized in Tables 11 to 14.

4.3.2.1 Effect of storage period on seedling shoot length

In *Rabi* 1998 produce seeds, seedling shoot length decreased significantly after 18 months of storage in both the parental lines. The shoot length was decreased from initial 13.94 to 8.12 cm and from 14.45 to 8.70 cm in CM-135 and CM-136 respectively, after 18 months of storage. Overall, there was a 39.83 and 41.75 per cent decrease in seedling shoot length in CM-136 and CM-135 respectively after 18 months of storage. Significant interaction between storage period and treatment and/or condition of storage was observed in CM- 135. The interaction between condition of storage and storage period was significant in CM-136 (Table 11 and 12).

In *Kharif* 1999 produce seeds, the seedling shoot length decreases significantly as the storage period progressed. The initial shoot length 9.38 and 10.04 cm was declined to 6.79 and 7.36 cm after 12 months of storage in CM-135 and CM-136 respectively. It was found that the reduction in seedling shoot length in CM-135 and CM-136 was 27.83 and 26.67 per cent respectively after 12 months of storage.

Table 11 : Shoot length (cm) of maize CM-135 seedlings (Rabi-1998 produce) after different periods of storage

Storage period Treatments	0 month			3 months			6 months			9 months			12 months		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean
Captan	14.85	13.69	14.72	14.21	12.08	13.93	13.01	11.57	12.57	12.07	11.33	12.07	10.93	11.33	11.13
Bavistin	12.79	11.87	12.83	12.35	10.76	11.50	11.13	9.96	10.85	10.41	9.63	10.41	8.74	9.63	9.19
Deltamethrin	14.93	13.19	13.18	13.19	12.71	12.09	12.40	11.24	11.26	11.25	10.78	11.25	10.33	10.78	10.56
Malathion	13.10	12.32	12.48	12.40	11.66	11.93	11.80	10.34	10.80	10.57	9.51	10.57	9.54	9.51	9.53
Econeem	15.03	13.39	13.70	13.54	12.11	12.54	12.33	10.75	11.26	11.00	10.67	11.00	9.69	10.67	10.18
Arappu leaf powder	13.70	12.26	12.88	12.57	11.84	12.50	12.17	10.37	11.47	10.92	10.03	10.92	9.37	10.03	9.70
Captan + Deltamethrin	13.83	12.72	13.59	13.16	11.31	12.25	11.78	11.00	11.68	11.34	10.76	11.34	10.21	11.31	10.76
Captan + Malathion	14.15	13.48	13.33	13.40	12.17	12.76	12.47	11.86	12.07	11.97	11.19	11.97	10.78	11.60	11.19
Bavistin + Deltamethrin	13.97	12.58	13.86	13.22	11.83	12.61	12.22	10.54	11.33	10.94	10.11	10.94	9.66	10.56	10.11
Bavistin + Malathion	13.27	12.62	13.71	13.17	11.44	12.29	11.87	10.34	11.13	10.74	9.96	10.74	9.72	10.19	9.96
Control	13.67	12.38	12.28	12.33	11.19	11.35	12.27	10.52	10.92	10.72	9.83	10.72	8.71	9.83	9.27
Mean	13.94	12.77	13.32	13.05	11.74	12.34	12.04	10.77	11.39	11.09	10.14	11.09	9.79	10.50	10.14

Storage period Treatments	15 months			18 months			Mean		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean
	Captan	9.77	10.59	10.18	8.34	9.24	8.79	11.61	12.46
Bavistin	8.04	8.67	8.36	6.63	7.78	7.21	9.83	10.58	10.20
Deltamethrin	9.43	9.34	9.39	8.13	8.67	8.40	11.42	11.46	11.44
Malathion	9.12	8.38	8.75	7.04	7.05	7.05	10.45	10.46	10.46
Econseim	8.81	8.59	8.69	6.94	7.84	7.39	10.96	11.37	11.17
Arappu leaf powder	8.43	9.72	9.08	7.25	8.52	7.88	10.46	11.26	10.86
Captan + Deltamethrin	9.74	10.87	10.31	8.65	9.63	9.14	11.07	11.88	11.47
Captan + Malathion	10.27	10.88	10.57	9.13	9.89	9.51	11.69	12.10	11.89
Bavistin + Deltamethrin	8.92	10.68	9.80	7.75	9.49	8.62	10.75	11.79	11.27
Bavistin + Malathion	8.14	9.43	8.79	7.49	8.71	8.10	10.43	11.25	10.84
Control	7.46	8.96	8.21	6.82	7.67	7.24	10.11	10.67	10.39
Mean	8.92	9.64	9.28	7.65	8.59	8.12	10.80	11.39	11.09

CD (P=0.05): T = 0.3730 C = 0.1591 P = 0.2975 T x C = 0.5277

T x P = 0.9870 C x P = 0.4209 T x C x P = NS

Where,

C₁ = Ambient storage ; C₂ = Controlled storage ; T = Treatment ; C = Condition of storage ; P = Period of storage

Table 12 : Shoot length (cm) of maize CM-136 seedlings (Rabi-1998 produce) after different periods of storage

Storage period Treatments	0 month		3 months			6 months			9 months			12 months			
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean
Captan	15.36	14.69	14.80	14.08	14.27	14.17	13.84	13.74	13.79	12.13	12.09	12.11			
Bavistin	13.74	12.43	12.53	11.17	11.35	11.26	11.64	10.96	10.80	8.81	10.18	9.50			
Deltamethrin	14.49	13.37	13.45	12.54	13.83	13.18	11.60	12.16	11.88	11.02	11.89	11.45			
Malathion	13.56	12.18	12.33	11.68	11.23	11.45	10.73	10.87	10.80	9.11	10.13	9.62			
Econeem	13.98	12.77	13.30	11.51	12.21	11.86	10.36	11.30	10.83	9.58	10.47	10.03			
Arappu leaf powder	13.37	11.94	12.19	10.88	11.35	11.12	9.57	10.76	10.17	8.32	9.54	8.93			
Captan + Deltamethrin	15.79	14.22	14.46	13.39	13.46	13.43	10.81	12.59	11.70	11.01	11.46	11.24			
Captan + Malathion	14.88	13.19	13.44	12.27	12.49	12.38	11.43	12.78	12.10	10.76	11.37	11.07			
Bavistin + Deltamethrin	14.61	13.09	13.42	12.45	12.38	12.42	11.54	11.77	11.65	10.73	11.24	10.98			
Bavistin + Malathion	15.27	14.34	14.21	13.07	13.17	13.12	12.68	12.31	12.49	11.18	11.53	11.35			
Control	13.86	12.11	12.40	11.39	11.46	11.43	10.47	10.74	10.60	9.68	10.37	10.03			
Mean	14.45	13.12	13.52	12.22	12.47	12.35	11.24	11.81	11.53	10.21	10.93	10.57			

Table 12 : Contd.

Storage period Treatments	15 months			18 months			Mean		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean
Captan	10.48	11.65	11.06	9.51	10.88	10.19	12.87	13.27	13.07
Bavistin	7.36	9.73	8.54	6.98	8.38	7.68	10.16	10.99	10.58
Deltamethrin	10.71	11.31	11.01	9.23	10.78	10.00	11.85	12.57	12.21
Malathion	8.41	9.64	9.02	7.34	8.07	7.71	10.43	10.85	10.64
Econeem	8.63	9.39	9.01	7.87	8.59	8.23	10.67	11.39	11.03
Arappu leaf powder	7.46	8.23	7.84	6.69	7.71	7.20	9.74	10.48	10.12
Captan + Deltamethrin	10.63	10.82	10.73	9.12	9.42	9.27	12.14	12.60	12.37
Captan + Malathion	9.51	10.53	10.02	8.96	9.86	9.41	11.57	12.22	11.90
Bavistin + Deltamethrin	9.37	10.83	10.10	8.06	8.91	8.48	11.41	11.92	11.67
Bavistin + Malathion	10.31	10.40	10.35	9.26	10.68	9.97	12.30	12.49	12.39
Control	8.79	9.28	9.03	6.53	8.53	7.53	10.40	10.99	10.70
Mean	9.24	10.16	9.70	8.14	9.25	8.70	11.23	11.80	11.52

CD (P=0.05): T = 0.3655 C = 0.1560 P = 0.2917 T x C = NS T x P = NS

C x P = 0.4123 T x C x P = NS

Where, C₁ = Ambient storage ; C₂ = Controlled storage ; T = Treatment ; C = Condition of storage ; P = Period of storage

Table 13 : Shoot length (cm) of maize CM-135 seedlings (Kharif -1999 produce) after different periods of storage

Storage period	0 month			3 months			6 months			9 months			12 months			Mean	
	Treatments	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₂
Captan	10.78	9.56	10.15	9.86	8.84	9.89	9.37	8.67	9.27	8.97	8.13	8.41	8.27	9.20	9.70	9.45	9.45
Bavistin	9.32	8.40	8.57	8.49	7.36	8.19	7.78	6.64	7.28	6.96	5.93	6.07	6.00	7.53	7.89	7.71	7.71
Econeem	9.32	8.74	9.51	9.13	7.47	8.63	8.05	7.25	7.59	7.42	6.44	6.53	6.49	7.84	8.32	8.08	8.08
Arappu leaf powder	8.39	8.13	8.42	8.28	7.80	7.71	7.76	6.91	7.34	7.13	5.76	6.16	5.96	7.40	7.60	7.50	7.50
Captan + Deltamethrin	8.67	9.18	8.73	8.96	8.85	7.91	8.38	7.59	8.36	7.98	6.81	7.87	7.34	8.22	8.31	8.26	8.26
Captan + Malathion	10.04	9.76	9.69	9.73	8.24	8.33	8.29	7.87	8.45	8.16	7.54	7.38	7.46	8.69	8.78	8.73	8.73
Bavistin + Deltamethrin	10.47	9.31	9.50	9.41	8.91	9.03	8.97	8.13	8.54	8.34	7.31	7.59	7.45	8.83	9.03	8.93	8.93
Bavistin + Malathion	9.27	8.34	9.48	8.91	7.42	8.29	7.86	7.09	7.52	7.31	6.15	6.21	6.18	7.65	8.15	7.90	7.90
Control	8.12	8.65	8.93	8.79	7.78	7.48	7.63	6.56	7.39	6.98	5.40	6.15	5.77	7.30	7.61	7.46	7.46
Mean	9.38	8.90	9.22	9.06	8.07	8.38	8.23	7.41	7.97	7.69	6.61	6.93	6.77	8.07	8.38	8.23	8.23

CD (P=0.05): T = 0.3508 C = 0.1654 P = 0.2615 T x C = NS T x P = 0.7849

C x P = 0.3700 T x C x P = NS

Where,

C₁ = Ambient storage ; C₂ = Controlled storage ; T = Treatment ; C = Condition of storage ; P = Period of storage

Table 14 : Shoot length (cm) of maize CM-136 seedling (Kharif -1999 produce) after different periods of storage

Storage period Treatments	0 month			3 months			6 months			9 months			12 months			
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean	
	Captan	11.13	11.46	11.08	11.26	10.81	10.92	10.87	9.57	10.49	10.03	8.86	9.03	8.95	10.37	10.53
Bavistin	10.02	9.37	9.49	9.43	8.61	8.53	8.57	7.14	7.27	7.21	6.27	6.59	6.43	8.28	8.38	8.33
Econeem	9.76	8.88	9.64	9.26	7.59	8.82	8.20	6.97	7.67	7.32	7.17	7.24	7.21	8.07	8.63	8.35
Arappu leaf powder	9.65	8.31	8.54	8.43	7.75	8.21	7.98	7.14	7.36	7.25	6.34	6.51	6.43	7.84	8.05	7.95
Captan + Deltamethrin	10.86	10.03	9.91	9.97	9.41	9.56	9.48	8.27	8.69	8.48	7.95	7.78	7.87	9.30	9.36	9.33
Captan + Malathion	10.51	9.85	10.08	9.97	9.23	9.34	9.29	8.41	8.40	8.41	8.09	8.62	8.36	9.21	9.39	9.30
Bavistin + Deltamethrin	10.33	9.52	9.78	9.65	8.67	8.93	8.80	7.83	8.51	8.17	7.60	7.44	7.52	8.79	8.99	8.89
Bavistin + Malathion	9.47	8.79	8.86	8.82	8.30	8.31	8.31	7.64	7.79	7.72	6.40	6.93	6.67	8.12	8.27	8.20
Control	8.62	8.39	8.74	8.57	7.91	7.89	7.90	7.43	7.58	7.51	6.91	6.77	6.84	7.85	7.92	7.89
Mean	10.04	9.40	9.57	9.48	8.70	8.95	8.82	7.82	8.20	8.01	7.29	7.43	7.36	8.65	8.84	8.74

CD (P=0.05): T = 0.3368 C = 0.1588 P = 0.251 T x C = NS T x P = 0.7534

C x P = NS T x C x P = NS

Where,

C₁ = Ambient storage ; C₂ = Controlled storage ; T = Treatment ; C = Condition of storage ; P = Period of storage

Significant interaction between storage period and condition of storage was observed in CM-135 whereas it was non-significant in case of CM-136 (Table 13 and 14).

4.3.2.2 Effect of seed treatment on seedling shoot length

In *Rabi* 1998 produce seeds, Captan was found to be superior as it recorded highest shoot length as compared to other treatments in both the parental lines. The effectiveness of Captan + Deltamethrin, Captan + Malathion, Deltamethrin, Bavistin + Deltamethrin and Econeem was found to be equally good next to Captan and were at par in CM-135. Seed treatment with Malathion and Bavistin alone, however, was least effective, which recorded significantly smaller shoot length in CM-135. In case of CM-136, the treatments like Bavistin + Malathion, Captan + Deltamethrin and Econeem were at par which improved the seed vigour and recorded significantly higher seedling shoot length followed by Captan + Malathion and Bavistin + Deltamethrin. However, Arappu leaf powder was found to be the least effective. Interaction effect of treatment and condition of storage and/or treatment and period of storage was significant in CM-135 whereas, it was non-significant in CM-136 (Table 11 and 12).

In *Kharif* 1999 produce seeds, the seed treatment with Captan improved shoot length significantly as compared to other treatments and untreated control in both the parental lines. The other treatments like Captan + Deltamethrin, Captan + Malathion, Bavistin + Deltamethrin and Econeem

were found significantly superior over the untreated control and Arappu leaf powder in both the parental lines. However, treatment and period of storage interaction was significant in both the parental lines (Tables 13 and 14).

4.3.2.3 Effect of storage conditions on seedling shoot length

In *Rabi* 1998 produce seeds, storage conditions had significant influence on shoot length. Seeds stored under controlled storage had recorded significantly higher shoot length than that stored under ambient conditions. A significantly higher shoot length 11.39 cm was recorded in controlled storage as compared to 10.80 cm in ambient storage in CM-135. However, in CM-136, the shoot length was 11.23 and 11.80 cm in ambient and controlled storage conditions, respectively. The interaction effect of condition of storage and period of storage was significant in both the parental lines (Table 11 and 12).

In *Kharif* 1999 produce seeds, seedling shoot length was significantly higher in controlled storage than the ambient storage and it was maintained throughout the storage period in both the parental lines. The mean seedling shoot length was higher in controlled storage conditions 8.38 cm and 8.84 cm as compared to ambient storage 8.07 and 8.65 cm in CM-135 and CM-136, respectively. The interaction effect of condition of storage and storage period was significant in CM-135 while it was non-significant in CM-136 (Table 13 and 14).

4.3.3 Seedling root length

After standard germination tests, ten randomly selected seedling were taken and their root length was recorded after 3 months intervals. The data recorded during the studies are presented in Tables 15 to 18.

4.3.3.1 Effect of storage period on seedling root length

In *Rabi* 1998 produce seeds; the seedling root length was generally decreased significantly in both the parental lines as the storage period progressed. Irrespective of the storage conditions the seedling root length was decreased rapidly from 15.68 to 12.33 cm after 18 months of storage in CM-135. Whereas, in CM-136, the seedling root length was decreased from 16.48 to 12.74 cm irrespective of storage conditions during the same storage period. The reduction in root length in terms of percentage was 21.36 and 22.69 in CM-135 and CM-136, respectively. The interaction effect of conditions of storage and period of storage was significant in both the parental lines (Table 15 and 16).

In *Kharif* 1999 produce seeds, the seedling root length decreased significantly after 12 months of storage period in both the parental lines. However, the maximum reduction in root length was 23.01% in CM-135 as compared to 21.87% in CM-136. In CM-135, the root length reduced to 11.88 cm from the initial 15.43 cm after 12 months of storage. Similarly, in CM-136, the root length was reduced to 12.36 cm from initial 15.82 cm during the same

Table 15 : Root length (cm) of maize CM-135 seedlings (Rabi-1998 produce) after different periods of storage

Storage period Treatments	0 month			3 months			6 months			9 months			12 months		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean
Captan	16.18	16.43	16.05	15.14	15.84	15.49	14.33	14.76	14.55	14.18	15.06	14.62	14.18	15.06	14.62
Bavistin	14.62	14.74	13.96	13.83	14.78	14.31	12.24	14.51	13.38	13.53	13.73	13.63	13.53	13.73	13.63
Deltamethrin	15.43	14.88	14.96	14.07	14.94	14.51	13.69	14.21	13.95	14.27	13.67	13.97	14.27	13.67	13.97
Malathion	14.83	13.71	14.34	12.49	13.62	13.06	12.38	13.43	12.91	11.57	12.53	12.05	11.57	12.53	12.05
Econeem	16.53	15.60	15.31	14.43	14.17	14.30	13.05	15.03	14.04	12.76	13.60	13.18	12.76	13.60	13.18
Arappu leaf powder	16.36	15.28	15.19	14.52	14.68	14.60	14.17	14.27	14.22	13.21	13.83	13.52	13.21	13.83	13.52
Captan + Deltamethrin	15.47	15.04	15.33	14.60	14.79	14.70	14.39	15.06	14.73	13.74	14.87	14.31	13.74	14.87	14.31
Captan + Malathion	15.74	14.73	14.59	14.21	14.67	14.44	13.86	15.19	14.53	14.54	13.63	14.09	14.54	13.63	14.09
Bavistin + Deltamethrin	15.19	15.29	15.09	14.73	14.37	14.55	14.24	13.87	14.06	13.83	14.12	13.98	13.83	14.12	13.98
Bavistin + Malathion	16.89	15.68	16.43	14.34	15.23	14.79	13.82	14.79	14.31	14.10	13.18	13.64	14.10	13.18	13.64
Control	15.27	14.48	15.59	13.63	14.41	14.02	13.37	14.16	13.77	12.18	13.67	12.93	12.18	13.67	12.93
Mean	15.68	15.08	15.07	14.18	14.68	14.43	13.60	14.48	14.04	13.45	13.81	13.63	13.45	13.81	13.63

Table 15 : Contd.

Storage period Treatments	15 months			18 months			Mean		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean
Captan	13.26	14.51	13.89	13.11	13.79	13.45	14.66	15.12	14.89
Bavistin	12.06	12.39	12.23	11.34	11.67	11.51	13.19	13.55	13.37
Deltamethrin	13.35	13.19	13.27	12.09	12.52	12.31	13.97	14.14	14.06
Malathion	11.80	11.69	11.75	10.26	11.41	10.84	12.43	13.12	12.78
Econeem	10.97	12.22	11.60	10.22	11.88	11.05	13.37	14.11	13.74
Arappu leaf powder	12.09	13.04	12.57	11.83	12.34	12.09	13.92	14.24	14.08
Captan + Deltamethrin	14.17	13.24	13.71	13.24	14.38	13.81	14.38	14.73	14.56
Captan + Malathion	13.68	14.81	14.25	13.02	14.13	13.58	14.25	14.68	14.47
Bavistin + Deltamethrin	13.14	13.96	13.55	12.61	13.41	13.01	14.14	14.29	14.22
Bavistin + Malathion	13.54	13.83	13.69	12.48	13.32	12.90	14.40	14.81	14.61
Control	11.39	12.13	11.76	11.03	11.24	11.14	13.05	13.78	13.42
Mean	12.68	13.18	12.93	11.93	12.74	12.33	13.80	14.23	14.01

CD (P=0.05): T = 0.3577 T x P = 0.9461 C = 0.1524 P = 0.2853 T x C = NS
T x P = 0.9461 C x P = 0.4034 T x C x P = NS

Where, C₁ = Ambient storage ; C₂ = Controlled storage ; T = Treatment ; C = Condition of storage ; P = Period of storage

Table 16 : Root length (cm) of maize CM-136 seedlings (Rabi-1998 produce) after different periods of storage

Storage period Treatments	0 month			3 months			6 months			9 months			12 months		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean
Captan	16.93	15.73	16.68	16.21	16.31	16.10	15.89	16.43	16.10	15.21	16.43	15.82	14.41	15.32	14.87
Bavistin	15.74	15.13	15.04	15.09	14.79	14.48	14.17	14.63	14.48	13.88	14.63	14.26	14.57	13.84	14.21
Deltamethrin	15.77	15.29	15.43	15.36	13.38	14.01	14.64	15.71	14.01	14.56	15.71	15.14	13.91	13.76	13.84
Malathion	15.43	14.84	14.51	14.68	15.18	14.74	14.29	14.36	14.74	14.08	14.36	14.22	12.62	13.91	13.27
Econeem	17.64	16.05	16.37	16.21	15.30	15.24	15.18	15.54	15.24	14.62	15.54	15.08	13.71	14.43	14.07
Arappu leaf powder	15.66	14.93	15.63	15.28	14.11	14.48	14.84	13.22	14.48	13.34	13.22	13.28	12.49	14.59	13.54
Captan + Deltamethrin	16.23	15.80	15.49	15.65	15.03	15.56	16.08	14.93	15.56	14.36	14.93	14.65	13.68	15.85	14.77
Captan + Malathion	17.08	16.35	16.14	16.25	15.44	15.89	16.33	15.65	15.89	14.74	15.65	15.20	14.57	14.05	14.31
Bavistin + Deltamethrin	17.57	16.61	17.30	16.96	16.14	16.40	16.66	15.84	16.40	15.43	15.84	15.64	14.76	15.44	15.10
Bavistin + Malathion	17.32	16.78	16.73	16.76	15.61	16.10	16.58	14.39	16.10	14.89	14.39	14.64	15.16	15.76	15.46
Control	15.87	14.71	15.63	15.17	13.34	14.07	14.79	13.46	14.07	13.66	13.46	13.56	12.53	12.93	12.73
Mean	16.48	15.66	15.91	15.78	14.97	15.19	15.41	14.92	15.19	14.43	14.92	14.68	13.86	14.54	14.20

Table 16 : Contd.

Storage period Treatments	15 months			18 months			Mean		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean
	Captan	13.85	14.86	14.36	13.07	14.71	13.89	15.07	15.83
Bavistin	12.23	12.62	12.43	11.45	11.81	11.63	13.97	13.98	13.97
Deltamethrin	13.14	14.48	13.81	12.89	13.57	13.23	14.13	14.77	14.45
Malathion	11.54	12.78	12.16	10.07	12.22	11.15	13.39	13.93	13.66
Econeem	12.43	13.56	13.00	11.75	12.31	12.03	14.50	15.00	14.75
Arappu leaf powder	11.78	13.37	12.58	11.29	12.73	12.01	13.37	14.29	13.83
Captan + Deltamethrin	13.19	15.26	14.23	12.62	14.47	13.55	14.42	15.47	14.94
Captan + Malathion	13.34	13.73	13.54	13.58	14.23	13.91	15.01	15.32	15.15
Bavistin + Deltamethrin	13.49	14.57	14.03	13.06	13.87	13.47	15.29	15.87	15.59
Bavistin + Malathion	14.27	14.12	14.20	13.65	14.51	14.08	15.38	15.63	15.51
Control	11.41	12.27	11.84	10.77	11.54	11.16	13.18	13.78	13.48
Mean	12.79	13.78	13.29	12.20	13.27	12.74	14.34	14.90	14.62

CD (P=0.05): T = 0.3523 C = 0.1504 P = 0.2817 T x C = 0.4995
T x P = 0.9344 C x P = 0.3984 T x C x P = NS

Where,

C₁ = Ambient storage ; C₂ = Controlled storage ; T = Treatment ; C = Condition of storage ; P = Period of storage

Table 17 : Root length (cm) of maize CM-135 seedlings (Kharif -1999 produce) after different periods of storage

Storage period Treatments	0 month			3 months			6 months			9 months			12 months			Mean	
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂
Captan	15.87	14.43	14.63	14.53	13.61	14.41	14.01	12.28	13.33	12.81	12.37	12.41	12.39	13.71	14.13	13.92	
Bavistin	14.78	13.51	13.82	13.67	12.54	12.89	12.72	12.08	12.24	12.16	11.35	11.39	11.37	12.85	13.02	12.94	
Econeem	15.58	14.71	14.40	14.56	13.37	13.68	13.53	11.93	12.72	12.33	11.21	11.39	11.30	13.36	13.55	13.46	
Arappu leaf powder	14.33	13.56	13.74	13.65	12.44	12.87	12.66	11.63	11.36	11.50	10.35	10.91	10.63	12.46	12.64	12.55	
Captan + Deltamethrin	15.68	14.17	14.57	14.37	13.59	14.08	13.84	12.84	13.79	13.32	12.15	12.27	12.21	13.68	14.08	13.88	
Captan + Malathion	16.24	15.37	14.89	15.13	14.42	15.17	14.80	13.67	14.64	14.16	13.16	13.13	13.15	14.57	14.81	14.69	
Bavistin + Deltamethrin	16.22	15.21	15.38	15.30	14.39	14.49	14.44	13.18	13.72	13.45	12.42	12.59	12.51	14.28	14.48	14.38	
Bavistin + Malathion	15.40	14.15	14.69	14.42	13.41	13.51	13.46	12.74	13.12	12.93	12.05	12.28	12.17	13.55	13.80	13.67	
Control	14.82	13.57	13.41	13.49	12.06	12.38	12.22	11.74	11.87	11.81	10.82	11.64	11.23	12.60	12.82	12.71	
Mean	15.43	14.30	14.39	14.35	13.31	13.72	13.52	12.45	12.98	12.72	11.76	12.00	11.88	13.45	13.70	13.58	

CD (P=0.05): T = 0.4235 C = 0.1997 P = 0.3157 T x C = NS T x P = NS
 C x P = 0.4467 T x C x P = NS

Where, C₁ = Ambient storage ; C₂ = Controlled storage ; T = Treatment ; C = Condition of storage ; P = Period of storage

Table 18 : Root length (cm) of maize CM-136 seedlings (*Khariif* -1999 produce) after different periods of storage

Storage period Treatments	0 month			3 months			6 months			9 months			12 months			Mean	
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂
Captan	15.89	14.54	15.39	14.73	14.84	14.79	13.62	13.43	13.53	12.57	12.92	12.75	14.27	14.49	14.38	14.27	14.49
Bavistin	14.48	14.83	13.63	13.59	13.34	13.47	12.27	12.56	12.42	11.45	11.04	11.25	13.32	13.01	13.17	13.32	13.01
Econeem	16.57	15.35	15.68	14.51	14.72	14.62	13.34	12.86	13.10	11.54	12.70	12.12	14.26	14.51	14.38	14.26	14.51
Arappu leaf powder	15.10	14.46	14.78	13.23	13.45	13.34	12.59	13.34	12.97	10.64	12.86	11.75	13.20	13.91	13.56	13.20	13.91
Captan + Deltamethrin	15.28	14.64	14.87	14.76	15.18	14.84	13.75	14.63	14.19	12.69	13.58	13.14	14.17	14.71	14.44	14.17	14.71
Captan + Malathion	16.09	15.54	15.67	14.13	14.86	14.50	13.41	14.13	13.77	13.06	13.81	13.44	14.45	14.91	14.68	14.45	14.91
Bavistin + Deltamethrin	17.39	15.87	16.15	14.61	15.43	15.02	13.92	14.71	14.32	12.60	12.64	12.62	14.88	15.26	15.07	14.88	15.26
Bavistin + Malathion	16.78	15.58	15.39	14.37	14.70	14.54	13.23	13.54	13.39	12.30	12.36	12.33	14.45	14.55	14.50	14.45	14.55
Control	14.81	13.68	13.78	12.44	12.52	12.48	12.35	12.47	12.42	11.78	11.93	11.86	13.01	13.10	13.06	13.01	13.10
Mean	15.82	14.94	15.04	14.99	14.34	14.17	13.17	13.52	13.34	12.07	12.65	12.36	14.00	14.27	14.14	14.00	14.27

CD (P=0.05): T = 0.4348 C = 0.2049 P = 0.3241 T x C = 0.6152 T x P = 0.9727
 C x P = 0.4586 T x C x P = NS

Where, C₁ = Ambient storage ; C₂ = Controlled storage ; T = Treatment ; C = Condition of storage ; P = Period of storage

storage period. The interaction effect of condition of storage and period of storage was significant in both the parental lines (Table 17 and 18).

4.3.3.2 Effect of seed treatments on seedling root length

In *Rabi* 1998 produce seeds, significant increase in seedling root length was observed when the seeds were treated with Captan followed by Bavistin + Malathion, Captan + Deltamethrin, Captan + Malathion, Bavistin + Deltamethrin, Arappu leaf powder and Deltamethrin which found equally effective and were at par in CM-135. The seed treatment with Econeem, Bavistin and Malathion, however found least effective. In case of CM-136, Captan, Bavistin + Malathion and Bavistin + Deltamethrin were at par in maintaining higher seedling root length as compared to other treatments and untreated control. The seed treatment with Captan + Malathion, Captan + Deltamethrin, Econeem and Deltamethrin were also found equally effective and recorded higher root length than the seed treatments with Bavistin, Arappu leaf powder, Malathion and untreated control in CM-136 (Table 15 and 16).

In *Kharif* 1999 produce seeds, the seedling root length was significantly improved with the seed treatment Captan + Malathion and Bavistin + Deltamethrin in the parental line CM-135. Similarly, seed treatment with Bavistin + Deltamethrin, Bavistin + Malathion, Captan + Malathion, Econeem, Captan alone and Captan + Deltamethrin were found equally effective and were at par in the parental line CM-136. However, seed treatment with

Arappu leaf powder and Bavistin was found least effective and were at par with untreated control (Table 17 and 18).

4.3.3.3 Effect of storage conditions on seedling root length

In *Rabi* 1998 produce seeds, storage conditions have significant influence on seedling root length. The seeds stored under controlled storage condition recorded significantly higher root length as compared to the ambient storage in both the parental lines during 18 months of storage. In CM-135, the seedling root length was 13.80 and 14.23 cm in ambient and controlled storage conditions respectively. Whereas, in CM-136, the seedling root length was 14.34 and 14.90 cm in ambient and controlled storage conditions respectively. However, the interaction effect of storage condition and storage period was significant in both the parental lines (Table 15 and 16).

In *Kharif* 1999 produce seeds, the effect of storage conditions on seedling root length was non-significant upto 3 months but thereafter a significantly higher root length was noted in controlled storage as compared to ambient storage in the parental lines CM-135. The seedling root length was significantly reduced to 11.88 cm from the initial 15.43 cm in CM-135. Similarly, in case of CM-136, the initial root length 15.82 cm was reduced to 12.36 cm after 12 months of storage. Controlled storage was found superior than ambient storage in maintaining higher root length throughout the storage period. However, CM-136, recorded higher seedlings root length as compared to CM-135 (Table 17 and 18).

4.3.4 Vigour Index

Vigour index was calculated by multiplying seedling dry weight with germination percentage after every test taken at 3 months interval. The data recorded during the storage period are summarized in Tables 19 to 22.

4.3.4.1 Effect of storage period on Vigour Index

In *Rabi* 1998 produce seeds, storage period had direct influence on vigour index. The vigour index declined rapidly over the period of 18 months storage. Nevertheless, both parental lines were found to differ significantly with respect to storage period. The initial vigour index 33080.64 and 38630.34 reduced to 18572.49 and 22758.37 after 18 months of storage in CM-135 and CM-136 respectively. The per cent loss in vigour index was 43.86 and 41.09% in CM-135 and CM-136 respectively. Significant influence of interaction between treatments and storage period was recorded in both the parental lines (Table 19 and 20).

In *Kharif* 1999 produce seeds, significant reduction in vigour index from initial 4869.5 to 3536.6 in CM-135 and from 4935.5 to 3796.1 in CM-136 after 12 months storage was observed. In CM-135, the reduction in vigour index was rapid as compared to CM-136. The overall loss in vigour index was 27.37% in CM-135 and 23.09 % in CM-136 after 12 months storage.

The reduction of vigour index could be attributed to reduction in germination and dry matter of seed during natural ageing.

Table 19 : Vigour index (Germination x Seedling dry weight) of maize CM-135 seeds (Rabi-1998 produce) after different periods of storage

Storage period	0 month			3 months			6 months			9 months			12 months		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean
Captan	34196.12	33626.34	34648.04	34137.19	28438.61	31496.22	29967.42	27200.21	28667.01	21517.11	27751.35	27933.61	21517.11	27751.35	24634.23
Bavistin	28443.77	25479.51	26759.41	26119.46	26402.31	24736.51	25569.41	21705.61	22740.84	17716.16	22002.68	22223.23	17716.16	22002.68	19859.42
Deltamethrin	30442.21	29795.64	28734.77	29265.21	27893.19	29187.22	28540.21	24759.58	26551.71	19559.05	24314.32	25655.65	19559.05	24314.32	21936.69
Malathion	32492.64	25746.11	29012.31	27379.21	25591.32	27238.33	26414.83	21009.06	22982.31	18417.71	20758.52	21995.69	18417.71	20758.52	19588.12
Econeem	33871.84	31940.23	31075.95	31508.09	27920.41	26556.46	27238.44	23277.61	26246.15	21073.51	23514.41	24761.88	21073.51	23514.41	22293.96
Arappu leaf powder	32428.88	29215.45	29795.84	29505.65	27232.71	28032.24	27632.48	24440.87	25188.42	21531.76	24067.53	24814.65	21531.76	24067.53	22799.65
Captan + Deltamethrin	36985.21	31713.01	33110.41	32411.71	30567.01	28769.96	29668.49	26071.92	29415.75	24443.65	28246.88	27743.84	24443.65	28246.88	26345.27
Captan + Malathion	37539.91	33563.44	35615.88	34589.66	31984.83	30479.64	31232.24	26827.71	27378.46	22865.46	27208.44	27103.09	22865.46	27208.44	25036.95
Bavistin + Deltamethrin	34845.01	31959.72	32303.11	32131.42	28777.87	31212.71	29995.29	25001.03	28579.98	21009.06	26227.24	26790.51	21009.06	26227.24	23618.15
Bavistin + Malathion	32437.68	30082.32	30263.41	30172.87	26625.45	27955.52	27290.49	23418.41	25754.94	19837.44	25575.75	24586.68	19837.44	25575.75	22706.64
Control	30203.74	27903.89	28939.12	28421.51	23921.12	25491.69	24706.41	22243.32	23876.25	18003.21	22309.98	23059.79	18003.21	22309.98	20156.67
Mean	33080.64	30093.24	30932.57	30512.91	27759.53	28286.95	28023.24	24177.76	26125.62	20543.10	24725.19	25151.69	20543.10	24725.19	22634.15

Table 19 : Contd.

Storage period Treatments	15 months			18 months			Mean		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean
Captan	21916.44	26319.93	24118.19	19845.66	24940.64	22393.15	26677.21	29717.04	28197.13
Bavistin	15374.81	19759.44	17567.13	12719.88	19063.36	15891.62	21120.29	23358.00	22239.15
Deltamethrin	16308.38	23943.15	20125.77	14191.92	22492.36	18342.14	23278.57	26523.68	24901.12
Malathion	14741.21	19634.42	17187.82	11932.08	16919.21	14425.65	21418.59	24148.25	22783.42
Econeem	14956.41	21349.54	18152.98	14891.06	19647.91	17269.49	23990.15	26037.47	25013.81
Arappu leaf powder	18622.06	22426.95	20524.51	16667.75	21664.16	19165.96	24305.64	26229.15	25267.39
Captan + Deltamethrin	21640.36	26007.47	23823.92	18057.61	26161.96	22109.79	27068.46	29813.95	28441.17
Captan + Malathion	20490.69	26045.55	23268.12	18020.08	24165.04	21092.56	27327.45	29776.13	28551.79
Bavistin + Deltamethrin	19579.71	26432.01	23005.86	16573.48	24104.08	20338.78	25392.27	29100.59	27246.43
Bavistin + Malathion	17248.41	23033.62	20141.02	14543.12	21628.09	18085.61	23456.12	26664.14	25060.13
Control	13200.38	20240.96	16720.67	12672.51	17692.79	15182.65	21164.02	24107.79	22635.91
Mean	17643.53	23199.37	20421.45	15465.01	21679.96	18572.49	24108.97	26861.47	25485.22

CD (P=0.05): T = 870.39 C = 371.14 P = 694.33 T x C = NS
T x P = 2302.83 C x P = 981.93 T x C x P = NS

Where,

C₁ = Ambient storage ; C₂ = Controlled storage ; T = Treatment ; C = Condition of storage ; P = Period of storage

Table 20 : Vigour index (Germination x Seedling dry weight) of maize CM-136 seeds (Rabi-1998 produce) after different periods of storage

Storage period Treatments	0 month			3 months			6 months			9 months			12 months		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean
	Captan	41955.06	36751.35	39990.01	38370.68	36075.25	37864.32	36969.79	33297.33	35628.62	34462.98	30235.87	32502.81	31369.34	
Bavistin	35374.15	32588.12	32503.52	32545.82	29488.62	30363.95	29926.29	26910.84	28791.36	27851.10	24258.27	26787.41	25522.84		
Deltamethrin	37708.41	35541.66	36075.71	35808.69	32735.36	34077.12	33406.24	29327.13	31812.51	30569.82	25731.52	21896.16	23813.84		
Malathion	33468.12	30031.21	31053.35	30542.28	27940.86	29510.57	28725.72	24779.81	27960.02	26369.92	22153.88	24661.37	23407.63		
Ecneem	39832.32	36775.64	38035.41	37405.53	32303.04	34972.74	33637.89	29521.62	32714.14	31117.88	28587.02	28106.28	28346.65		
Arappu leaf powder	37065.62	33958.95	34377.72	34168.34	30230.34	30576.89	30403.62	26741.92	29232.06	27986.99	23215.91	30455.46	26835.69		
Captan + Deltamethrin	43681.47	40465.92	41834.88	41150.40	36665.22	37757.79	37211.51	33096.29	36962.48	35029.39	29547.48	34899.66	32223.57		
Captan + Malathion	40373.28	37555.32	38903.04	38229.18	34612.42	37194.32	35903.37	30935.37	33990.41	32462.89	29954.34	32449.79	31202.07		
Bavistin + Deltamethrin	37847.04	35077.17	35170.16	35123.67	33221.52	34032.95	33627.24	30265.83	31951.91	31108.87	25102.25	30248.96	27675.61		
Bavistin + Malathion	42226.63	38490.48	39741.07	39115.78	34335.84	35959.42	35147.63	31224.31	33512.05	32368.18	26359.94	30468.69	28414.32		
Control	35401.65	29619.51	32759.04	31189.28	28153.53	30165.69	29159.61	25998.84	26776.24	26387.54	23585.17	26693.55	25139.36		
Mean	38630.34	35168.67	36403.99	35786.33	32342.00	33861.43	33101.72	29281.75	31757.44	30519.60	26248.33	29015.47	27631.90		

Table 20 : Contd.

Storage period Treatments	15 months			18 months			Mean		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean
	Captan	27640.22	30751.81	29196.02	24044.58	28615.32	26329.95	32857.09	35329.71
Bavistin	21498.42	23826.84	22662.63	18291.35	22075.68	20183.52	26915.68	28531.84	27723.76
Deltamethrin	22563.81	28174.86	25369.34	19047.96	32611.41	25829.69	28950.84	31765.17	30358.00
Malathion	20037.16	23274.32	21655.74	16277.04	20536.34	18406.69	24955.44	27209.16	26082.30
Econeem	24668.16	27876.42	26272.29	21408.64	24310.01	22859.33	30442.35	32263.90	31353.13
Arappu leaf powder	20472.75	27305.11	23888.93	16637.73	25310.02	20973.88	26903.32	30617.55	28760.44
Captan + Deltamethrin	26936.72	33018.24	29977.48	24224.64	29795.03	27009.84	33516.82	36849.94	35183.38
Captan + Malathion	26502.19	30314.49	28408.34	22903.22	27793.05	25348.14	31833.73	34431.20	33132.47
Bavistin + Deltamethrin	21718.54	28015.47	24867.01	19453.21	25221.28	22337.25	28955.08	31783.97	30369.52
Bavistin + Malathion	23248.68	27827.94	25538.31	19681.26	24650.61	22165.94	30795.31	33483.77	32139.54
Control	20109.52	22748.04	21428.78	15888.22	21907.52	18897.87	25536.63	28064.53	26800.58
Mean	23217.83	27557.59	25387.71	19805.26	25711.48	22758.37	29242.03	31848.25	30545.14

CD (P=0.05) : T = 1028.33 C = 438.48 P = 820.32 T x C = 1454.28
T x P = 2720.71 C x P = 1160.11 T x C x P = NS

Where,

C₁ = Ambient storage ; C₂ = Controlled storage ; T = Treatment ; C = Condition of storage ; P = Period of storage

Table 21 : Vigour index (Germination x Seedling dry weight) of maize CM-135 seeds (Kharif -1999 produce) after different periods of storage

Storage period	0 month			3 months			6 months			9 months			12 months			Mean	
	Treatments	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₂
Captan	4841.3	5021.3	5029.1	5025.2	4222.3	4758.0	4490.2	3807.8	4366.9	4087.4	3634.7	4142.9	3888.8	4305.5	4627.6	4466.6	4627.6
Bavistin	4804.6	4656.1	4474.6	4565.3	3998.3	4196.4	4097.3	3396.1	3911.4	3653.8	3034.0	3611.3	3322.7	3977.8	4199.6	4088.7	4199.6
Econeem	4945.3	4359.8	4459.4	4409.6	4205.8	4559.9	4382.8	3639.4	4047.8	3843.6	3191.3	3875.7	3533.5	4068.3	4377.6	4223.0	4377.6
Arappu leaf powder	4584.0	4166.1	4085.9	4126.0	3601.9	3470.2	3536.1	3216.7	3610.7	3413.7	2958.7	3420.6	3189.7	3705.5	3834.3	3769.9	3834.3
Captan + Deltamethrin	5247.7	4762.2	5099.3	4930.7	4598.3	4578.4	4588.3	3970.0	4660.7	4315.4	3564.5	4210.0	3887.2	4428.5	4759.2	4593.9	4759.2
Captan + Malathion	4777.5	4583.4	4836.0	4709.7	3874.4	4097.0	3985.7	3716.7	4468.9	4092.8	3460.8	3787.4	3624.1	4082.6	4393.4	4238.0	4393.4
Bavistin + Deltamethrin	5148.0	4714.0	4292.7	4503.3	4321.6	4488.1	4404.9	3327.5	4303.9	3815.7	3283.0	3970.0	3626.5	4158.8	4440.6	4299.7	4440.6
Bavistin + Malathion	4869.4	4488.1	4916.4	4702.3	3943.7	4307.6	4125.6	3517.4	4139.8	3828.6	3284.2	3725.6	3504.9	4020.6	4391.8	4206.2	4391.8
Control	4607.8	4232.5	4540.9	4386.7	3545.6	4089.7	3817.7	3306.4	3724.9	3515.6	3069.0	3435.0	3252.0	3752.3	4079.7	3916.0	4079.7
Mean	4869.5	4553.7	4637.1	4595.4	4034.7	4282.8	4158.7	3544.2	4137.2	3840.7	3275.6	3797.6	3536.6	4055.5	4344.9	4200.2	4344.9

CD (P=0.05): T = 113.21 C = 53.36 T x C = 160.20 T x P = 253.30
 C x P = 119.40 T x C x P = 358.21

Where, C₁ = Ambient storage ; C₂ = Controlled storage ; T = Treatment ; C = Condition of storage ; P = Period of storage

Table 22 : Vigour index (Germination x Seedling dry weight) of maize CM-136 seeds (Kharif-1999 produce) after different periods of storage

Storage period Treatments	0 month			3 months			6 months			9 months			12 months			Mean	
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂
Captan	5108.4	4974.3	5171.3	5072.8	4791.6	4880.4	4836.0	3870.8	4353.7	4112.2	3914.9	4572.4	4243.6	4532.0	4817.2	4674.6	
Bavistin	4510.1	4559.0	4419.8	4489.4	4395.8	4631.8	4513.8	3721.0	4212.7	3966.9	3310.4	3826.4	3568.4	4099.3	4320.2	4209.7	
Econorm	5122.0	4553.3	4806.8	4680.0	4358.3	5135.2	4746.7	3605.4	4592.3	4098.8	3538.7	4244.2	3891.5	4235.5	4780.1	4507.8	
Arappu leaf powder	4636.6	4656.1	4709.3	4682.7	4123.7	4421.0	4272.4	3701.2	3611.9	3656.6	3162.9	3620.7	3391.8	4056.1	4199.9	4128.0	
Captan + Deltamethrin	5397.8	5187.0	4929.4	5058.2	4802.0	4689.8	4745.9	4234.5	4426.5	4330.5	3912.7	4309.1	4110.9	4706.8	4750.5	4728.7	
Captan + Malathion	4978.4	4733.6	5035.6	4884.6	4607.9	4869.4	4738.7	3729.6	4106.6	3918.1	3557.0	4123.7	3840.3	4321.3	4622.8	4472.0	
Bavistin + Deltamethrin	5184.2	5053.9	4992.0	5023.0	4539.6	4299.4	4419.5	3996.1	4486.5	4241.3	3708.3	4347.6	4028.0	4496.4	4662.0	4579.2	
Bavistin + Malathion	4709.3	4762.7	4714.0	4738.3	3759.6	3972.9	3866.3	4045.0	4085.3	4065.2	3549.3	3915.2	3732.3	4165.2	4279.3	4222.3	
Control	4772.4	4531.2	4521.2	4526.2	3796.1	4066.2	3931.1	3491.1	3744.6	3617.9	3096.2	3620.0	3358.1	3937.4	4144.9	4041.1	
Mean	4935.5	4779.0	4811.0	4795.0	4352.8	4551.8	4452.3	3821.6	4180.0	4000.8	3527.8	4064.4	3796.1	4283.3	4508.5	4395.9	

CD (P=0.05): T = 111.92 C = 52.759 P = 83.419 T x C = 158.37 T x P = 250.41

C x P = 118.04 T x C x P = 354.13

Where, C₁ = Ambient storage ; C₂ = Controlled storage ; T = Treatment ; C = Condition of storage ; P = Period of storage

The interaction effect of storage period and condition of storage, statistically, indicated significant influence on vigour index in both the parental lines (Table 21 and 22).

4.3.4.2 Effect of seed treatments on vigour index

In *Rabi* 1998 produce seeds, results obtained indicate that seed treatments with Captan alone, Captan + Deltamethrin and Captan + Malathion were superior to other treatments in both the parental lines which increased the seedling vigour index significantly. However, Bavistin + Deltamethrin, Bavistin + Malathion, Econeem, Arappu leaf powder and Deltamethrin proved to be equally effective on both the parental lines. The seed treatments with Malathion and Bavistin alone were found least effective and were at par with untreated control. Significant influence of interaction between seed treatments and storage period was observed in both the parental lines (Table 19 and 20).

In *Kharif* 1999 produce seeds, a combination of seed treatment with Captan + Deltamethrin followed by Captan alone was found highly effective which maintained highest vigour index among all the treatments in CM-135. The other treatments like Bavistin + Deltamethrin, Econeem, Captan + Malathion and Bavistin + Malathion were found equally effective and were at par in CM-135. Similarly, in CM-136, seed treatments with Captan alone and its combination with Deltamethrin followed by Bavistin + Deltamethrin, Econeem, Captan + Malathion were found most effective. However, Arappu

leaf powder was least effective in both the parental lines which recorded lowest vigour index (Table 21 and 22).

4.3.4.3 Effect of storage condition on vigour index

In *Rabi* 1998 produce seeds, both the parental lines showed highly significant reduction in vigour index when the seed were stored in ambient conditions as compared to controlled storage conditions. The vigour index declined to 24180.97 and 26861.47 in ambient and controlled storage conditions in CM-135. However, in CM-136, it was 29242.03 and 31848.25 in ambient and controlled storage conditions after 18 months of storage from the initial 33080.64 and 38630.34 in CM-135 and CM-136, respectively. The reduction in vigour index was 27.12% as compared to 24.30% in ambient conditions and 18.80% and 17.56% in controlled storage conditions in CM-135 and CM-136, respectively, after 18 months of storage. The interaction between treatments and condition of storage was significant in CM-136, while it was non-significant in CM-135 (Table 19 and 20).

In *Kharif* 1999 produce seeds, both the parental lines recorded significant improvement in vigour index in the seeds stored under controlled storage as compared to ambient storage conditions. The initial vigour index 4869.5 and 4935.5 was reduced to 4055.5 and 4283.3 in ambient conditions and 4344.9 and 4508.5 in controlled conditions after 12 months of storage in CM-135 and CM-136, respectively. In CM-135, the loss in vigour index was 16.72% in ambient storage and 10.77% in controlled conditions after 12 months of

storage. Similarly, in CM-136, the loss in vigour index was 13.21% and 8.65% in ambient storage and controlled storage conditions respectively. The interaction effect of treatments, storage period, condition of storage and their interactions was significant in both the parental lines (Table 21 and 22).

4.3.5 Accelerated ageing

In *Rabi* 1998 produce seeds, the parental line CM-135 deteriorated fast and the germination fell rapidly from 86.0% to 67.0% to 46.5% after 0, 5 and 10 days accelerated ageing period, respectively. However, in CM-136 seed, the germination declined gradually from 92.0% to 79.0% to 59% after 0, 5 and 10 days accelerated ageing period respectively. The seeds of CM-136 withstood for 5 days under accelerated ageing. The mean germination recorded in CM-136 was higher (77.0%) as compared to CM-135, which recorded 66.0% germination after 10 days accelerated ageing (Table 23).

In *Kharif* 1999 produce seeds, the germination reduced gradually after 10 days of accelerated ageing. In CM-135, the germination was declined to 58.0% after 10 days of storage from initial 91.0%. While in case of CM-136, the initial germination of 94.0% dropped to 82.0% and 63.0% after 5 and 10 days storage respectively. Significant genotypic difference was noted in respect of storability. However, both the parental lines withstood for 5 days under accelerated ageing conditions. The deterioration of seeds started after 5 days of storage in both the parental lines. The mean germination after 10 days of

Table 23: Germination (%) of seeds (Rabi-1998 produce) in Accelerated ageing test

Parental lines Storage period	Parental lines	
	CM-135	CM-136
0 Days	86.0 (68.18)	92.0 (73.47)
5 Days	67.0 (54.99)	79.0 (62.55)
10 Days	46.5 (42.98)	59.0 (50.22)
Mean	66.0 (55.38)	77.0 (62.08)
CD (P=0.05)	P = 6.7973	P = 6.6983

Note: Figures in parenthesis indicates arcsine transformed values

Where,

P = Period of storage

Table 24: Germination (%) of seeds (Kharif -1999 produce) in Accelerated ageing test

Parental lines Storage period	Parental lines	
	CM-135	CM-136
0 Days	91.0 (72.91)	94.0 (76.37)
5 Days	78.0 (61.65)	82.0 (65.03)
10 Days	58.0 (49.33)	63.0 (52.56)
Mean	76.0 (61.29)	80.0 (64.65)
CD (P=0.05)	P = 6.258	P = 5.9199

Note: Figures in parenthesis indicates arcsine transformed values

Where,

P = Period of storage

accelerated ageing was 80.0% and 76.0% in CM-136 and CM-135, respectively (Table 24).

4.3.6 Cold test

Cold test at 10⁰C was conducted to test the tolerance of maize parental lines produced in *Rabi* 1998 to low temperature after 5 months of storage. It was found that seeds stored under controlled storage, recorded significantly higher germination as compared to ambient storage. In CM-135, seed treatments with Captan and its combinations with Deltamethrin and Malathion recorded significantly higher germination in cold test as compared to other treatments. The other treatments like Bavistin + Deltamethrin, Bavistin + Malathion, Deltamethrin and Arappu leaf powder recorded higher germination than the untreated control. In case of CM-136, the treatments like Captan, Captan + Deltamethrin and Bavistin + Malathion had recorded significantly higher emergence followed by Captan + Malathion and Bavistin + Deltamethrin and Deltamethrin alone as compared to untreated control. The mean emergence in CM-135 and CM-136 was 45.0 and 50.5 per cent, respectively. The Malathion was found to be less effective in both the parental lines (Table 25).

In *Kharif* 1999 produce seeds, the seed treatment with Captan followed by Captan + Deltamethrin, Bavistin + Malathion, Captan + Malathion, Bavistin alone and Bavistin + Deltamethrin proved equally effective in giving higher germination than Econeem, Arappu leaf powder and untreated control

Table 25: Germination (%) of seeds (*Rabi-1998* produce) in Cold Test

Parental lines Treatments	CM-135			CM-136		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean
Captan	49.0 (44.41)	57.0 (49.03)	53.0 (46.72)	60.0 (50.78)	64.0 (53.14)	62.0 (51.96)
Bavistin	40.0 (39.22)	40.0 (39.22)	40.0 (39.22)	42.0 (40.39)	45.0 (42.13)	43.5 (41.26)
Deltamethrin	44.0 (41.55)	45.0 (42.13)	44.5 (41.84)	45.0 (42.13)	52.0 (46.15)	48.5 (44.14)
Malathion	35.0 (36.26)	39.0 (38.64)	37.0 (37.45)	39.0 (38.65)	42.0 (40.39)	40.5 (39.52)
Econeem	39.0 (38.64)	40.0 (39.22)	39.5 (38.93)	49.0 (44.43)	51.0 (45.57)	50.0 (45.00)
Arappu leaf powder	42.0 (40.39)	43.0 (40.97)	42.5 (40.68)	46.0 (42.70)	48.0 (43.85)	47.0 (43.28)
Captan + Deltamethrin	52.0 (46.15)	53.0 (46.72)	52.5 (46.44)	57.0 (49.03)	61.0 (51.37)	59.0 (50.20)
Captan + Malathion	50.0 (45.00)	52.0 (46.15)	51.0 (45.57)	54.0 (47.29)	58.0 (49.61)	56.0 (48.45)
Bavistin + Deltamethrin	48.0 (43.85)	50.0 (45.00)	49.0 (44.43)	50.0 (45.00)	55.0 (47.87)	52.5 (46.44)
Bavistin + Malathion	45.0 (42.28)	47.0 (43.28)	46.0 (43.28)	58.0 (49.61)	60.0 (50.77)	59.0 (50.19)
Control	36.0 (36.86)	38.0 (38.05)	37.0 (37.46)	39.0 (38.63)	41.0 (39.81)	40.0 (39.22)
Mean	44.0 (41.42)	46.0 (42.58)	45.0 (42.00)	49.0 (44.42)	52.0 (46.42)	50.5 (45.42)

Note: Figures in parenthesis indicates arcsine transformed values.

CD (P=0.05) :

For CM - 135, T = 2.1007 C = 0.8957 T x C = 2.978

For CM - 136, T = 2.1800 C = 0.9296 T x C = NS

Where,

C₁ = Ambient storage

C₂ = Controlled storage

T = Treatment

C = Conditions of storage

Table 26: Germination (%) of seeds (*Kharif-1999* produce) in Cold Test

Parental lines Treatments	Parental lines	
	CM-135	CM-136
Captan	78.0 (62.10)	83.0 (65.75)
Bavistin	70.0 (56.87)	74.0 (59.44)
Econeem	68.0 (55.57)	78.0 (62.08)
Arappu leaf powder	64.0 (53.15)	67.0 (54.95)
Captan + Deltamethrin	74.0 (59.51)	77.0 (61.39)
Captan + Malathion	72.0 (58.09)	72.0 (58.09)
Bavistin + Deltamethrin	70.0 (56.81)	80.0 (63.51)
Bavistin + Malathion	73.0 (58.78)	75.0 (60.08)
Control	59.0 (50.21)	62.0 (51.95)
Mean	70.0 (56.79)	74.5 (59.69)
CD (P=0.05):	T = 5.6630	T = 4.7611

Note: Figures in parenthesis indicates arcsine transformed values.

Where,

T = Treatment

in CM-135. Similarly, in case of CM-136, seed treatment with Captan, Bavistin + Deltamethrin, Econeem, Captan + Deltamethrin, Bavistin + Malathion and Bavistin alone were found significantly superior over the other treatments and untreated control. It was also found that the germination was higher (74.5%) in case of CM-136 which indicates more tolerance to cold temperature than CM-135 which had the mean emergence of 70.0% (Table 26).

4.3.7 Electrical conductivity (EC)

The electrical conductivity test was conducted by taking 25 seeds in two replicates and soaked in 25 ml of distilled water at $25 \pm 1^{\circ}\text{C}$ for 3 hours. The leachate was measured at room temperature with the help of conductivity meter. The results obtained during the studies are summarized in tables 27 to 30.

4.3.7.1 Effect of storage period on electrical conductivity (EC)

In *Rabi* 1998 produce seeds; the results indicated that as the storage period progressed, the EC value also increased irrespective of storage condition and seed treatments. In CM-135, the conductivity values increased rapidly as compared to CM-136. The EC value 3.97 taken after 3 months of storage as initial value, increased to 7.14 after 18 months of storage in CM-135. Similarly, in CM-136, the initial EC value, 3.55 after 3 months of storage, increased to 6.45 after 18 months of storage, which is lower than the values obtained for CM-135. Overall, the increase in EC values after 18 months of storage was more than 75% in both the parental lines. This rapid increase in

EC values could be due to deterioration of cell membrane during storage (Table 27 and 28).

In *Kharif* 1999 produce seeds, the EC values increased as the storage period progressed. The values of EC increased gradually but significantly throughout the storage period of 12 months in both the parental lines. The initial EC values 2.81 and 2.52 were found to be increased significantly to 4.18 and 3.84 in the parental lines CM-135 and CM-136, respectively after 12 months of storage. In CM-136, the increase in EC value was slow upto 9 months as compared to CM-135. The EC values recorded for CM-135 was higher than CM-136 indicating enhanced leakage of electrolytes due to permeability of cell membrane (Table 29 and 30).

4.3.7.2 Effect of seed treatments on electrical conductivity (EC)

In *Rabi* 1998 produce seeds, significant differences in treatments, storage period and condition of storage and their interactions were observed in both the parental lines. In the parental line CM-135, seed treatment with Malathion and Arappu leaf powder recorded highest EC values i.e. 5.97 and 5.85, respectively, while the lowest EC value of 4.89 was observed in an untreated control seeds. The chemical infused with the treated seeds may be dissolved in the leachate, which contributed to increase in EC values. The seed treatment with Captan + Deltamethrin, Captan + Malthion, Bavistin + Deltamethrin, Deltamethrin and Captan alone recorded EC values in the increasing order of 5.05, 5.16, 5.18, 5.35 and 5.45 respectively in CM-135.

Table 27 : Electrical conductivity (μ siemens/cm/g) of CM-135 (Rabi-1998 produce) seed leachate after different periods of storage

Storage period Treatments	3 months			6 months			9 months			12 months		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean
Captan	4.18	3.81	3.99	4.78	4.12	4.45	5.42	4.64	5.03	5.93	5.27	5.60
Bavistin	3.94	3.79	3.86	4.58	3.98	4.28	5.92	4.59	5.25	6.67	5.03	5.85
Deltamethrin	3.83	3.89	3.86	4.42	4.08	4.25	5.31	4.53	4.92	6.48	4.85	5.67
Malathion	4.36	4.13	4.24	5.02	4.54	4.78	6.39	5.17	5.78	6.83	5.62	6.22
Econeem	4.07	3.98	4.02	4.93	4.33	4.63	5.88	4.69	5.29	6.52	5.15	5.83
Arappu leaf powder	4.06	3.95	4.01	4.81	4.69	4.60	5.78	4.98	5.38	6.79	5.74	6.26
Captan + Deltamethrin	4.27	3.54	3.90	4.69	3.82	4.26	5.16	4.27	4.72	5.82	5.45	5.18
Captan + Malathion	3.98	3.92	3.94	4.39	4.17	4.28	5.23	4.43	4.83	6.07	4.72	5.40
Bavistin + Deltamethrin	3.63	3.66	3.60	4.26	3.93	4.09	5.02	4.49	4.75	6.18	4.82	5.50
Bavistin + Malathion	4.61	4.24	4.33	5.17	4.47	4.82	5.69	4.72	5.21	6.72	5.17	5.95
Control	3.89	3.62	3.75	4.12	3.87	3.99	4.86	4.08	4.47	5.64	4.39	5.01
Mean	4.08	3.86	3.97	4.65	4.15	4.40	5.52	4.60	5.06	6.33	5.03	5.68

Table 27 : Contd.

Storage period Treatments	15 months			18 months			Mean		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean
	Captan	6.98	5.58	6.28	8.36	6.34	7.34	5.94	4.96
Bavistin	7.72	5.62	6.67	8.49	6.49	7.49	6.22	4.91	5.57
Deltamethrin	7.30	5.29	6.30	8.33	5.87	7.10	5.95	4.75	5.35
Malathion	7.84	6.09	6.96	8.90	6.79	7.85	6.56	5.39	5.97
Econeem	7.48	5.75	6.61	8.53	6.42	7.48	6.23	5.05	5.55
Arappu leaf powder	7.85	6.22	7.04	8.68	6.89	7.79	6.33	5.36	5.85
Captan + Deltamethrin	6.62	4.83	5.72	7.87	5.18	6.52	5.74	4.36	5.05
Captan + Malathion	6.84	5.09	5.97	7.62	5.45	6.54	5.69	4.63	5.16
Bavistin + Deltamethrin	7.18	5.19	6.18	8.14	5.72	6.93	5.73	4.62	5.18
Bavistin + Malathion	7.31	5.52	6.42	8.09	6.13	7.11	6.26	5.04	5.65
Control	6.79	4.74	5.76	7.52	5.24	6.38	5.47	4.32	4.89
Mean	7.26	5.44	6.35	8.23	6.05	7.14	6.01	4.85	5.43

CD (P=0.05): T = 0.0076 C = 0.0032 P = 0.0057 T x C = 0.0108
T x P = 0.0186 C x P = 0.0079 T x C x P = 0.0263

Where, C₁ = Ambient storage ; C₂ = Controlled storage ; T = Treatment ; C = Condition of storage ; P = Period of storage

Table 28 : Electrical conductivity (μ siemens/cm/g) of CM-136 (Rabi-1998 produce) seed leachate after different periods of storage

Storage period Treatments	3 months			6 months			9 months			12 months		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean
Captan	3.30	3.12	3.21	3.65	3.47	3.56	3.95	3.87	3.91	4.49	4.61	4.55
Bavistin	3.85	3.69	3.77	3.91	3.97	3.94	4.18	4.22	4.20	5.26	4.52	4.89
Deltamethrin	3.38	3.26	3.32	3.54	3.59	3.56	3.90	3.45	3.67	4.37	4.33	4.35
Malathion	3.64	3.52	3.58	3.88	3.37	3.62	4.52	4.09	4.30	5.38	4.63	5.01
Econorm	3.95	3.84	3.90	4.18	4.18	4.18	4.42	4.49	4.45	4.84	5.24	5.04
Arappu leaf powder	3.88	3.78	3.83	3.96	4.13	4.04	4.34	4.52	4.43	5.06	5.07	5.06
Captan + Deltamethrin	3.14	3.31	3.22	3.42	3.78	3.60	3.94	3.53	3.74	4.57	4.36	4.46
Captan + Malathion	3.42	3.40	3.41	3.71	3.66	3.68	4.27	3.92	4.10	5.52	4.44	4.98
Bavistin + Deltamethrin	3.72	3.71	3.72	3.87	3.92	3.89	4.21	4.37	4.28	5.32	4.75	5.03
Bavistin + Malathion	3.59	3.49	3.54	4.06	3.84	3.95	4.79	4.26	4.52	5.81	4.90	5.36
Control	3.78	3.47	3.62	3.85	3.62	3.73	4.09	3.83	3.96	4.46	4.23	4.34
Mean	3.60	3.51	3.55	3.81	3.77	3.80	4.23	4.05	4.14	5.01	4.64	4.82

Table 28 : Contd.

Storage period Treatments	15 months			18 months			Mean		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean
	Captan	5.84	4.94	5.39	6.98	5.42	6.20	4.70	4.24
Bavistin	6.38	4.89	5.63	7.46	5.93	6.69	5.17	4.53	4.85
Deltamethrin	5.48	4.82	5.15	6.92	5.28	6.10	4.60	4.12	4.36
Malathion	6.64	5.22	5.93	7.85	6.48	7.16	5.32	4.55	4.93
Econeem	5.67	5.58	5.62	6.52	6.36	6.44	4.93	4.95	4.94
Arappu leaf powder	6.24	5.44	5.84	7.31	6.29	6.80	5.13	4.87	4.99
Captan + Deltamethrin	5.72	4.73	5.22	6.83	5.04	5.94	4.60	4.12	4.36
Captan + Malathion	6.19	4.89	5.54	7.22	5.38	6.30	5.05	4.28	4.67
Bavistin + Deltamethrin	6.42	5.08	5.75	7.59	5.56	6.58	5.19	4.56	4.87
Bavistin + Malathion	6.54	5.33	5.93	7.76	6.17	6.97	5.42	4.66	5.04
Control	5.38	4.51	4.95	6.65	4.88	5.76	4.70	4.09	4.39
Mean	6.04	5.04	5.54	7.19	5.71	6.45	4.98	4.45	4.72

CD (P=0.05): T = 0.0058 C = 0.0025 P = 0.043 T x C = 0.0082

T x P = 0.0143 C x P = 0.0060 T x C x P = 0.020

Where,

C₁ = Ambient storage ; C₂ = Controlled storage ; T = Treatment ; C = Condition of storage ; P = Period of storage

Table 29 : Electrical conductivity (μ siemens/cm/g) of CM-135 (Kharif-1999 produce) seed leachate after different periods of storage

Storage period Treatments	0 month			3 months			6 months			9 months			12 months			Mean	
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂
Captan	2.87	3.10	2.93	3.01	3.31	3.23	3.27	3.69	3.56	3.62	4.39	3.88	4.13	3.47	3.29	3.38	3.38
Bavistin	2.79	2.96	2.99	2.97	3.34	3.33	3.33	3.88	3.66	3.77	4.43	4.09	4.26	3.48	3.37	3.42	3.42
Econeem	2.98	3.13	3.03	3.08	3.42	3.36	3.39	3.95	3.62	3.78	4.51	3.98	4.25	3.60	3.39	3.49	3.49
Arappu leaf powder	2.92	3.26	3.18	3.22	3.61	3.49	3.55	4.13	3.95	4.04	4.78	4.43	4.61	3.74	3.59	3.67	3.67
Captan + Deltamethrin	2.83	2.96	2.97	2.96	3.15	3.11	3.13	3.58	3.42	3.50	4.04	3.74	3.89	3.31	3.21	3.26	3.26
Captan + Malathion	2.56	2.80	2.72	2.76	3.18	2.98	3.08	3.59	3.37	3.48	4.22	3.79	4.00	3.27	3.08	3.18	3.18
Bavistin + Deltamethrin	2.73	2.97	2.88	2.92	3.23	3.07	3.15	3.62	3.44	3.53	4.29	3.82	4.06	3.36	3.19	3.27	3.27
Bavistin + Malathion	2.89	3.15	3.10	3.12	3.56	3.41	3.48	4.04	3.82	3.93	4.64	4.31	4.48	3.65	3.51	3.58	3.58
Control	2.69	2.81	2.75	2.78	3.14	2.97	3.05	3.48	3.28	3.38	4.18	3.68	3.93	3.26	3.07	3.17	3.17
Mean	2.81	3.02	2.95	2.99	3.32	3.21	3.27	3.77	3.57	3.67	4.39	3.97	4.18	3.46	3.30	3.38	3.38

CD (P=0.05): T = 0.046 C = 0.0215 P = 0.034 T x C = 0.0646

T x P = 0.102 C x P = 0.0481 T x C x P = 0.144

Where,

C₁ = Ambient storage ; C₂ = Controlled storage ; T = Treatment ; C = Condition of storage ; P = Period of storage

Table 30 : Electrical conductivity (μ siemens/cm/g) of CM-136 (Kharif-1999 produce) seed leachate after different periods of storage

Storage period Treatments	0 month			3 months			6 months			9 months			12 months			Mean	
	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂	Mean	C ₁	C ₂
Captan	2.46	2.76	2.75	2.75	3.13	3.06	3.09	3.50	3.32	3.41	4.10	3.75	3.92	3.19	3.07	3.13	3.13
Bavistin	2.52	2.72	2.68	2.64	3.07	2.98	3.03	3.44	3.26	3.35	4.05	3.67	3.86	3.16	3.01	3.09	3.09
Econeem	2.75	2.93	2.87	2.81	3.19	2.97	3.08	3.57	3.13	3.35	4.13	3.48	3.80	3.31	3.03	3.17	3.17
Arappu leaf powder	2.69	2.94	2.91	2.88	3.26	3.12	3.19	3.68	3.44	3.56	4.38	3.95	4.17	3.39	3.22	3.30	3.30
Captan + Deltamethrin	2.54	2.67	2.64	2.62	2.94	2.85	2.89	3.29	3.03	3.16	3.83	3.36	3.60	3.05	2.88	2.97	2.97
Captan + Malathion	2.34	2.59	2.58	2.67	2.95	2.81	2.88	3.31	2.98	3.14	3.98	3.42	3.70	3.03	2.82	2.93	2.93
Bavistin + Deltamethrin	2.37	2.78	2.65	2.52	3.10	2.82	2.96	3.66	3.09	3.37	4.22	3.31	3.76	3.22	2.82	3.02	3.02
Bavistin + Malathion	2.63	2.89	2.87	2.85	3.22	3.09	3.15	3.74	3.37	3.56	4.31	3.88	4.10	3.36	3.16	3.26	3.26
Control	2.43	2.62	2.60	2.58	2.92	2.74	2.83	3.35	2.91	3.13	3.89	3.39	3.64	3.04	2.81	2.92	2.92
Mean	2.52	2.76	2.73	2.69	3.08	2.94	3.01	3.50	3.17	3.33	4.10	3.58	3.84	3.19	2.98	3.09	3.09

CD (P=0.05): T = 0.0083 C = 0.0039 P = 0.0062 T x C = 0.0117 T x P = 0.0186
 C x P = 0.0087 T x C x P = 0.0262

Where, C₁ = Ambient storage ; C₂ = Controlled storage ; T = Treatment ; C = Condition of storage ; P = Period of storage

However, in the parental line CM-136, seed treatment with Malathion recorded highest EC value i.e. 5.04 followed by seed treatment with Arappu leaf powder, which recorded 4.99 EC value. Nevertheless, the lowest EC value of 4.36 was observed in the seeds treated with Captan + Deltamethrin and Deltamethrin alone and was at par followed by untreated control (4.39) in CM-136. However, the EC values 4.67, 4.85 and 4.87 recorded in the seeds treated with Captan + Malathion, Bavistin alone and Bavistin + Deltamethrin respectively (Table 27 and 28).

In *Kharif* 1999 produce seeds; the highest EC values of 3.30 and 3.67 were recorded in the seeds treated with Arappu leaf powder in the parental lines CM-136 and CM-135, respectively. In the parental line CM-135, the EC values in their increasing order 3.17, 3.18, 3.26, 3.27 and 3.38 were recorded in the seeds with no treatment, seed treatment with Captan + Malathion, Captan + Deltamethrin, Bavistin + Deltamethrin and Captan alone respectively. Similarly, in CM-136, the seed treatment with Captan + Malathion, Captan + Deltamethrin, Bavistin + Deltamethrin and Bavistin and Captan alone recorded EC values of 2.93, 2.97, 3.02, 3.09 and 3.13 respectively. However, the lowest EC value of 2.92 was observed in untreated control (Table 29 and 30).

4.3.7.3 Effect of storage condition on electrical conductivity (EC)

In *Rabi* 1998 produce seeds, the deterioration of seed was slow in case of seed stored under controlled conditions which recorded significantly lower EC values as compared to seeds stored under ambient conditions. In CM-135,

a significantly higher EC value of 6.01 was observed in the seeds stored under ambient conditions as compared to seed stored under controlled conditions, which recorded EC value 4.85 after 18 months of storage. However, in CM-136, the EC value of seed stored under ambient and controlled storage conditions was 4.98 and 4.45, respectively (Table 27 and 28).

In *Kharif* 1999 produce seeds, the results indicated that seed stored under ambient condition, had exhibited significantly higher EC values than that of seeds stored under controlled conditions. The seeds stored under ambient conditions, recorded EC values 3.46 and 3.19 whereas; the seed stored under controlled conditions recorded EC values 3.30 and 2.98 in the parental lines CM-135 and CM-136, respectively. The rate of deterioration of seed was slow in controlled storage, which indicated the lower leakage of electrolyte thereby the lower EC value than that of seeds stored under ambient conditions (Table 29 and 30).

4.4 Seed health

Seed produced in *Rabi* 1998, encountered a total number of 12 fungal species viz., *Alternaria alternata*, *Aspergillus flavus*, *A. niger*, *A. oryzae*, *Cladosporium* spp., *Curvularia lunata*, *C. pallescens*, *Drechslera hawaiiensis*, *D. tetramera*, *Epicoccum* spp., *Penicillium* spp. and *Rhizopus* spp. collectively on the seeds of both the parental lines. The occurrence of *Fusarium moniliforme* was not observed in *Rabi* 1998 produce seed but it frequently occurred in *Kharif* 1999 produce seeds. The seed treatment with different chemicals, in

Name of Fungi	Period Months		T ₁		T ₂		T ₃		T ₄		T ₅		T ₆		T ₇		T ₈		T ₉		T ₁₀		T ₁₁	
	C ₁	C ₂	C ₁	C ₂	C ₁	C ₂	C ₁	C ₂	C ₁	C ₂	C ₁	C ₂	C ₁	C ₂	C ₁	C ₂	C ₁	C ₂	C ₁	C ₂	C ₁	C ₂	C ₁	C ₂
<i>Drechslera tetramera</i>	0	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	3	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-
	6	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	9	-	-	-	-	-	1	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-
	12	-	-	-	-	-	1	-	-	-	-	2	1	-	-	-	-	-	-	-	-	-	-	-
	15	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
	18	-	-	-	-	-	-	2	1	-	-	2	1	-	-	-	-	-	-	-	-	-	-	-
	24	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Epicoccum spp.</i>	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	3	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	6	-	-	-	-	2	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
	9	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	12	-	-	1	-	-	1	1	1	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
	15	-	-	-	-	-	1	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	18	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
	24	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Penicillium spp.</i>	0	-	-	2	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	3	-	-	2	1	2	-	-	2	-	-	2	-	-	-	-	-	-	-	4	-	-	-	-
	6	2	1	1	1	3	1	2	-	4	4	3	1	1	1	1	3	2	-	-	1	2	-	-
	9	-	2	3	-	5	3	3	1	2	3	3	3	3	-	2	1	2	1	2	1	2	1	3
	12	1	3	4	3	3	2	4	3	8	5	3	2	2	2	1	-	-	-	2	2	2	15	5
	15	3	-	5	2	6	7	6	7	21	7	5	4	3	3	3	2	2	2	3	2	-	-	-
	18	2	2	10	4	9	3	15	8	13	4	12	7	4	7	2	-	-	-	4	3	13	4	10
	24	3	3	2	2	2	2	4	4	3	3	4	4	3	3	3	3	3	3	-	-	3	3	3
<i>Rhizopus spp.</i>	3	3	4	3	3	3	2	3	3	5	4	4	3	3	3	2	2	2	4	2	3	2	5	3
	6	3	2	1	3	5	3	3	2	3	4	5	3	3	4	2	3	4	4	4	2	6	2	11
	9	6	2	4	3	4	3	4	3	4	3	4	3	3	4	4	4	2	10	3	11	2	13	4
	12	3	2	5	2	8	9	5	5	4	6	4	3	4	3	4	3	4	2	5	3	9	4	17
	15	4	3	9	4	17	20	6	13	5	4	12	4	4	8	4	5	5	14	4	-	3	15	16
	18	24	9	3	7	14	8	16	8	18	14	13	10	14	4	14	6	26	9	27	5	32	23	

Where,
C₁ = Ambient conditions
C₂ = Controlled conditions
T₁ = Captan ;
T₂ = Bavistin ;
T₃ = Deltamethrin ;
T₄ = Malathion ;
T₅ = Econeem ;
T₆ = Arappu leaf powder
T₇ = Captan + Deltamethrin ;
T₈ = Captan + Malathion
T₉ = Bavistin + Deltamethrin ;
T₁₀ = Bavistin + Malathion
T₁₁ = Control

Table 32: Contd.

Name of Fungi	Period Months		T ₁		T ₂		T ₃		T ₄		T ₅		T ₆		T ₇		T ₈		T ₉		T ₁₀		T ₁₁	
	C ₁	C ₂	C ₁	C ₂	C ₁	C ₂	C ₁	C ₂	C ₁	C ₂	C ₁	C ₂	C ₁	C ₂	C ₁	C ₂	C ₁	C ₂	C ₁	C ₂	C ₁	C ₂	C ₁	C ₂
<i>Drechslera tetramera</i>	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Epicoccum</i> spp.	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Penicillium</i> spp.	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	6	2	1	2	1	2	2	2	4	2	4	2	1	4	2	2	3	1	4	2	3	2	2	4
	9	1	-	4	-	3	1	3	2	3	1	4	4	3	4	2	2	3	1	4	4	6	3	8
	12	-	1	-	4	2	3	4	5	4	3	4	3	4	3	4	3	1	4	4	4	6	3	8
	18	3	-	10	8	7	4	8	6	13	8	18	9	4	2	2	4	4	2	2	3	3	3	2
<i>Rhizopus</i> spp.	0	1	1	3	3	1	1	3	3	2	2	2	2	2	2	4	4	2	2	3	3	3	2	2
	3	3	-	2	2	2	2	3	3	1	3	4	3	2	4	5	4	5	3	3	1	5	6	8
	6	2	3	4	3	3	5	6	4	3	2	4	3	2	4	5	4	11	9	2	4	9	5	8
	9	4	6	3	5	5	4	13	7	5	7	9	7	5	4	12	7	8	6	3	11	8	10	9
	12	5	4	3	3	4	6	5	8	4	5	10	12	7	8	8	6	6	3	11	8	10	9	9
	18	6	4	7	6	9	8	12	5	8	6	18	10	8	10	10	12	16	10	15	13	19	13	13

Where,

C₁ = Ambient conditions
C₂ = Controlled conditions

T₁ = Captan ; T₂ = Bavistin ; T₃ = Deltamethrin ; T₄ = Malathion ; T₅ = Econeem ; T₆ = Arappu leaf powder
T₇ = Captan + Deltamethrin ; T₈ = Captan + Malathion ; T₉ = Bavistin + Deltamethrin ; T₁₀ = Bavistin + Malathion
T₁₁ = Control

Table 33: Contd.

Name of Fungi	Period months	T ₁		T ₂		T ₃		T ₄		T ₅		T ₆		T ₇		T ₈		T ₉	
		C ₁	C ₂	C ₁	C ₂	C ₁	C ₂	C ₁	C ₂	C ₁	C ₂	C ₁	C ₂	C ₁	C ₂	C ₁	C ₂	C ₁	C ₂
<i>Drechslera hawaiiensis</i>	0	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>D. tetramera</i>	0	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-
	3	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
	6	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-
	9	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
	12	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
<i>Epicoccum spp.</i>	0	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
	3	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-
	6	-	-	1	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-
	9	2	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-
	12	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-
<i>Fusarium moniliforme</i>	0	1	1	-	-	3	3	4	4	1	1	2	2	-	-	-	-	9	9
	3	-	-	-	-	-	2	7	5	3	-	1	1	-	-	-	-	10	6
	6	2	1	-	-	4	-	6	8	-	1	2	2	-	-	-	-	10	7
	9	1	-	1	-	2	3	8	6	1	2	1	-	-	-	2	1	11	10
	12	1	-	-	-	5	4	10	5	-	-	-	-	-	-	-	-	12	10
<i>Penicillium spp.</i>	0	1	1	1	1	2	2	3	3	-	-	2	2	2	2	3	3	8	8
	3	2	-	2	2	8	5	4	1	2	-	3	1	4	-	2	5	14	9
	6	2	3	6	4	6	4	6	4	3	1	7	5	6	5	4	2	11	5
	9	6	4	9	8	6	5	7	9	4	3	6	3	14	8	8	7	6	7
	12	3	3	18	7	16	8	23	16	-	5	4	4	22	13	26	9	16	12
<i>Rhizopus spp.</i>	0	3	3	2	2	6	6	4	4	3	3	4	4	4	9	2	2	7	7
	3	4	2	6	4	5	4	7	3	6	2	5	2	8	6	9	4	10	5
	6	6	5	10	8	6	7	4	6	4	5	4	6	5	3	6	5	7	8
	9	7	4	13	6	4	5	8	5	6	4	6	5	6	7	10	3	9	10
	12	10	7	21	13	8	6	12	9	14	7	8	6	18	10	6	5	27	18

Where,

C₁ = Ambient conditions T₁ = Captan ; T₂ = Bavistin ; T₃ = Econeem ; T₄ = Arappu leaf powder ; T₅ = Captan + Deltamethrin ;
 C₂ = Controlled conditions T₆ = Captan + Malathion ; T₇ = Bavistin + Deltamethrin ; T₈ = Bavistin + Malathion ; T₉ = Control

Name of Fungi	Period months		T ₁		T ₂		T ₃		T ₄		T ₅		T ₆		T ₇		T ₈		T ₉		
	C ₁	C ₂	C ₁	C ₂	C ₁	C ₂	C ₁	C ₂	C ₁	C ₂	C ₁	C ₂	C ₁	C ₂	C ₁	C ₂	C ₁	C ₂	C ₁	C ₂	
<i>Curvularia pallescens</i>	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Drechslera tetramera</i>	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Epicoccum spp.</i>	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
<i>Fusarium moniliforme</i>	0	1	1	-	-	-	3	3	4	4	2	2	1	1	-	-	-	-	-	9	9
	3	-	1	-	-	-	5	4	4	3	1	-	3	2	-	-	-	-	-	11	6
	6	-	1	-	-	-	9	5	5	6	-	-	-	-	-	-	-	-	-	18	13
	9	1	-	-	-	-	10	6	13	9	1	-	2	-	-	-	-	-	-	12	14
	12	-	-	-	-	-	12	8	10	7	-	-	-	-	-	-	-	-	-	15	12
<i>Penicillium spp.</i>	0	-	-	-	-	-	2	2	4	4	2	2	4	4	4	4	2	2	2	6	6
	3	4	2	3	1	4	3	5	6	7	3	5	4	6	6	3	4	4	4	24	10
	6	2	-	-	-	-	4	4	3	8	2	3	2	3	8	5	8	6	6	8	18
	9	6	3	5	6	6	8	6	17	10	2	4	12	7	15	8	12	9	16	13	13
	12	3	4	18	10	16	9	9	2	16	6	7	10	8	17	12	17	13	20	20	16
<i>Rhizopus spp.</i>	0	2	2	4	4	4	4	4	3	3	6	6	4	4	6	6	6	6	6	7	7
	3	4	3	2	3	4	5	4	5	4	4	4	6	5	8	7	11	8	10	5	5
	6	2	4	5	4	5	8	8	4	2	8	3	4	6	6	9	9	7	6	8	8
	9	6	3	3	5	6	4	4	10	10	6	7	8	4	7	4	9	9	6	13	10
	12	8	6	10	6	6	12	6	14	9	18	8	14	9	16	8	8	10	22	14	14

Where,
C₁ = Ambient conditions
C₂ = Controlled conditions
T₁ = Captan ; T₂ = Bavistin ; T₃ = Econeem ; T₄ = Arappu leaf powder ; T₅ = Captan + Deltamethrin ;
T₆ = Captan + Malathion ; T₇ = Bavistin + Deltamethrin ; T₈ = Bavistin + Malathion ; T₉ = Control

general, exhibited a significant influence as the incidence of different fungi was drastically reduced in both the parental lines. However, the per cent incidence of saprophytes like *Penicillium* spp., *Aspergillus* spp. and *Rhizopus* spp., by and large, kept on increasing with the passage of time in the untreated control. The fungi most predominant ones encountered on both the parental lines include *A. alternata*, *Aspergillus* spp., *C. lunata*, *Drechslera* spp., *Penicillium* spp. and *Rhizopus* spp.

The seed treatment with Captan, Bavistin alone and their combinations with Deltamethrin and/or Malathion proved highly effective in eliminating almost all the fungi during 18 months of storage. The other treatments like Deltamethrin, Malathion, Arappu leaf powder and Econeem were found comparatively less effective. The fungi *Aspergillus flavus* and *Aspergillus niger* were encountered on every seed of both the parental lines in untreated control. The incidence of fungi was comparatively more in the seeds stored under ambient conditions than that stored under controlled conditions (Table 31 and 32).

In Kharif 1999 produce seeds, a total number of 12 fungal species viz., *Alternaria alternata*, *Aspergillus flavus*, *A. niger*, *Cladosporium* spp., *Curvularia lunata*, *C. pallescens*, *Drechslera hawaiiensis*, *D. tetramera*, *Epicoccum* spp., *Fusarium moniliforme*, *Penicillium* spp. and *Rhizopus* spp. were encountered collectively on the seeds of two parental lines. The seed treatment with different chemicals, in general exhibited a marked influence as the incidence

of different fungi was reduced drastically as compared to untreated control. In untreated control, the fungi, by and large, were encountered frequently or increased with the increased of storage period. The seeds stored in controlled storage exhibited less number of fungi as compared to ambient storage, in general.

The seed treatment with Captan, Bavistin alone and their combinations with Deltamethrin and/or Malathion were found equally effective in checking almost all the fungi during 12 months of storage. Whereas, in case of Econeem and Arappu leaf powder treated seeds, the fungi encountered frequently remained constant to increasing during 12 months of storage (Table 33 and 34).

During the storage of *Kharif* 1999 and *Rabi* 1998 produce seeds, it was found that the infestation of insect pests was nil. It may be due to seed treatment with different fungicides, insecticides, their combinations and plant products and stored together under ambient conditions in plastic bins and controlled conditions. The overall effect of these chemicals could be responsible for checking the incidence of storage insect pests.

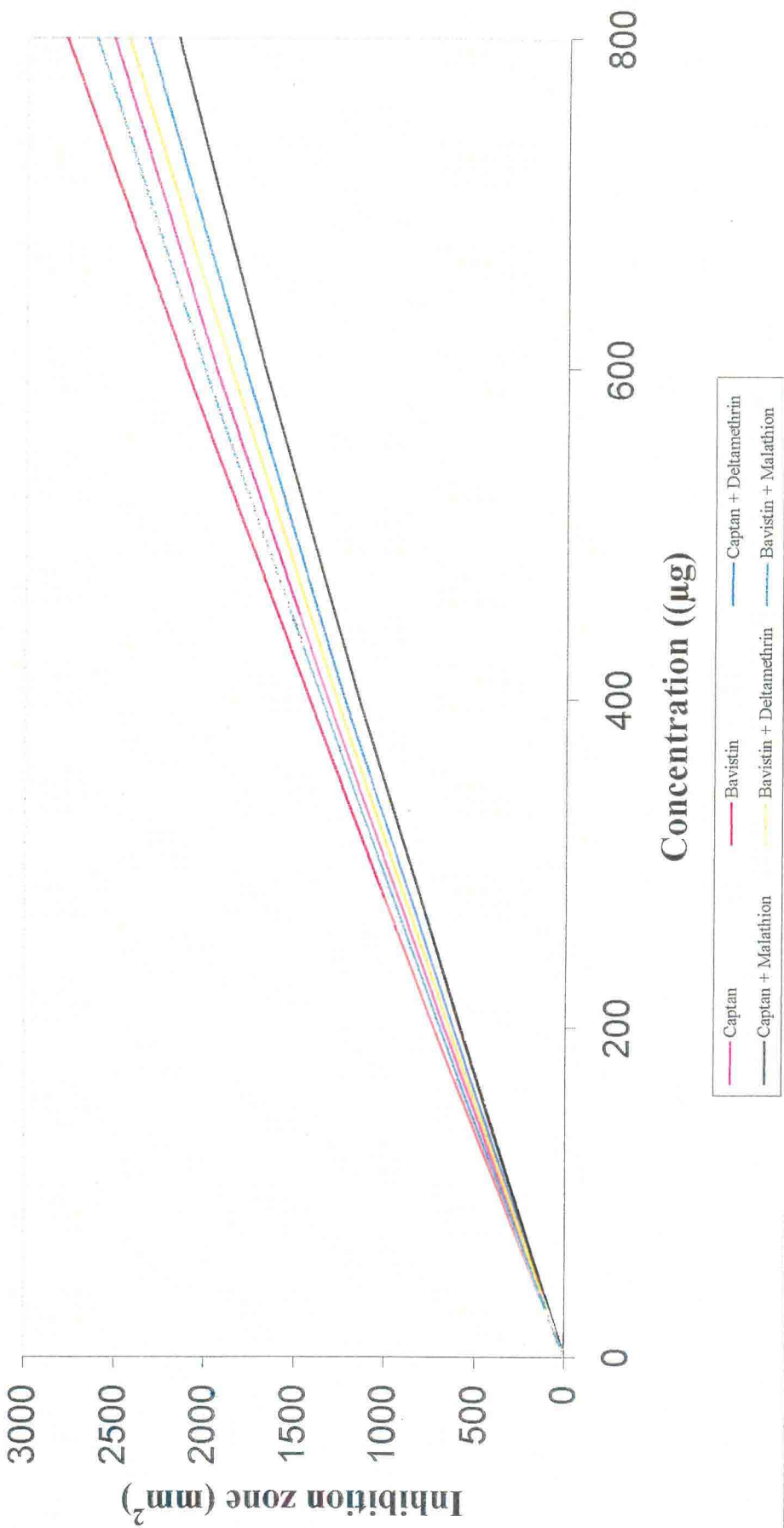
4.5 Persistence of fungicide and/or its combinations with insecticides on seed after storage

Fusarium stalk rot, ear rot and kernel rot caused by *Fusarium moniliforme* have been recognised as potentially destructive diseases of maize in India. As this pathogen is seed borne and causes seedling blight, seed treatment with fungicides would be the effective method for its control.

Table 35 : Inhibition zone (mm²) produced by different concentrations of fungicides and its combinations with insecticides

Treatments	Concentration of fungicides and/or its combinations with insecticides (µg)			
	800 µg	600 µg	400 µg	200 µg
1. Captan	2530.00	1950.00	1319.00	670.00
2. Bavistin	2790.00	2122.00	1424.00	730.00
3. Captan + Deltamethrin	2340.00	1790.00	1229.00	620.00
4. Captan + Malathion	2170.00	1680.00	1150.00	585.00
5. Bavistin + Deltamethrin	2450.00	1870.00	1270.00	645.00
6. Bavistin + Malathion	2625.00	2017.00	1355.00	697.00

Fig. 2 : Inhibition zone produced by different concentrations of fungicides and/or its combinations with insecticides



Though many fungicides were found effective in the field, their efficacy has not been studied under storage. Hence, because of its economic importance, *F. moniliforme* was taken as the test organism to study the residual effect of fungicides and/or their combinations with insecticides on seed after different periods of storage. The standard curve made with the known concentrations of fungicides and/or their combinations with insecticides is represented in Fig. 2.

In a preliminary experiment, the zones of inhibition were produced around the solution of fungicides and/or its combinations with insecticides having concentrations 200 µg, 400 µg, 600 µg and 800 µg tested (Table 35). It is evident from the table 35 that with the increase in concentration of protectants, the corresponding area of inhibition zone was also increased. Bavistin alone produced the highest inhibition zone with all the concentrations tested. Bavistin is a systemic fungicide, which restricted the growth of pathogen by diffusing in the medium, and produced highest inhibition zone. The second highest inhibition zone with all the concentrations was obtained with Bavistin + Malathion followed by Captan alone. The efficacy of fungicides and/or their combinations with insecticides, judged by the area of inhibition zone produced in the decreasing order was Bavistin > Bavistin + Malathion > Captan > Bavistin + Deltamethrin > Captan + Deltamethrin > Captan + Malathion (Table 35).

Table 36 : Inhibition zone (mm²) obtained from treated seeds kept under different conditions after different periods of storage

Treatments	0 month			6 months			12 months			18 months		
	CM-135	CM-136	Mean	CM-135	CM-136	Mean	CM-135	CM-136	Mean	CM-135	CM-136	Mean
A. Ambient Condition												
1. Captan	1923.50	1923.50	1923.50	1598.60	1580.60	1589.60	1319.60	1352.00	1335.80	1063.50	1033.50	1048.50
2. Bavistin	2041.80	2082.00	2061.90	1589.60	1625.15	1607.38	1194.00	1256.00	1225.00	934.30	961.60	947.95
3. Captan + Deltamethrin	1661.00	1625.10	1643.05	1384.75	1417.90	1401.33	1124.50	1142.50	1133.50	989.30	1017.35	1003.33
4. Captan + Malathion	1451.50	1485.40	1468.45	1256.00	1224.80	1240.40	989.30	961.60	975.45	748.40	760.40	754.40
5. Bavistin + Deltamethrin	1808.65	1771.15	1789.90	1417.90	1451.50	1434.70	1186.00	1202.00	1194.00	983.60	965.60	974.60
6. Bavistin + Malathion	1923.50	1884.80	1904.15	1474.40	1496.40	1485.40	1194.00	1224.80	1209.40	968.60	954.60	961.60
B. Controlled Condition												
1. Captan	1923.50	1923.50	1923.50	1651.00	1671.00	1661.00	1419.75	1415.40	1417.58	1158.00	1146.00	1152.00
2. Bavistin	2041.80	2082.00	2061.90	1661.00	1697.35	1679.18	1384.75	1351.95	1368.35	1045.80	1074.60	1060.20
3. Captan + Deltamethrin	1661.00	1625.10	1643.05	1463.50	1439.50	1451.50	1256.00	1224.80	1240.40	1033.50	1003.90	1018.70
4. Captan + Malathion	1451.50	1485.40	1468.45	1256.00	1319.60	1287.80	1074.60	1045.80	1060.20	854.85	854.85	854.85
5. Bavistin + Deltamethrin	1808.65	1771.15	1789.90	1519.75	1554.50	1537.13	1256.00	1256.00	1256.00	1059.50	1067.50	1063.50
6. Bavistin + Malathion	1923.50	1884.80	1904.15	1554.50	1589.60	1572.05	1319.60	1319.60	1319.60	1068.60	1080.60	1074.60

Perusal of the tables 36 with regards to biological activity of fungicides and/or their combinations with insecticides indicated that these protectants were biologically active and retained their fungicidal properties even after 18 months regardless of stored under ambient or controlled conditions. However, the seeds treated with Bavistin and Captan and their combinations with Deltamethrin and Malathion and kept under controlled conditions retained the residual effect of protectants for longer on the seed and produced higher inhibition zones as compared to seeds stored under ambient conditions. Nevertheless, irrespective of storage conditions, the area of inhibition zone produced around the seed was found reduced after 6, 12 and 18 months of storage period indicating a degradation of protectants and loss of efficacy. However, the inhibition zones produced around the seed treated with fungicides and/or their combinations with insecticides of both the parental lines were more or less equal.

The highest initial average inhibition zone of 2061.90 mm² was produced around the seed treated with Bavistin alone. Being a systemic fungicide, Bavistin effectively controlled the growth of test organism by diffusing in the media and produced highest inhibition zone. The initial inhibition zone obtained on the seed treated with Bavistin, Bavistin + Deltamethrin, Bavistin + Malathion, Captan, Captan + Deltamethrin and Captan + Malathion was 2061.90, 1789.90, 1904.15, 1923.50, 1643.05, and

1468.50 mm² respectively. The corresponding amount of these protectants initially on the seed before storage was 570, 565, 558, 585, 550 and 545 µg.

After six months, seed treated with Bavistin alone and stored under ambient conditions was highly effective as it produced biggest average inhibition zone of 1607.38 mm² with 430.00 µg of fungicide retained on the seed followed by Captan which have the second highest average inhibition zone of 1589.60 mm² with 481.25 µg of fungicide retained on the seed. Similarly, though the amount of Captan retained on the seed, stored under controlled condition, was 510.00 µg, the average inhibition zone produced by it was comparatively smaller (1661.00 mm²) which clearly showed that the Bavistin was most effective as it elaborated an average inhibition zone of 1679.18 mm² with only 443.75 µg of fungicide retained on the seed after six months (Plates 1 to 6).

After 12 months of storage, the seed treated with Captan alone produced highest average inhibition zone of 1335.80 mm² and 1417.58 mm² on the seed stored under ambient and controlled storage conditions respectively. However, the second highest zone of inhibition was obtained from the seed treated with Bavistin alone (average inhibition zone of 1225.00 and 1368.35 mm²) on the seed stored under ambient and controlled storage conditions, respectively. It indicates that the efficacy of Bavistin decreased after twelve month. However, Captan maintained the fungicidal properties and produced highest average inhibition zone as compared to Bavistin. The

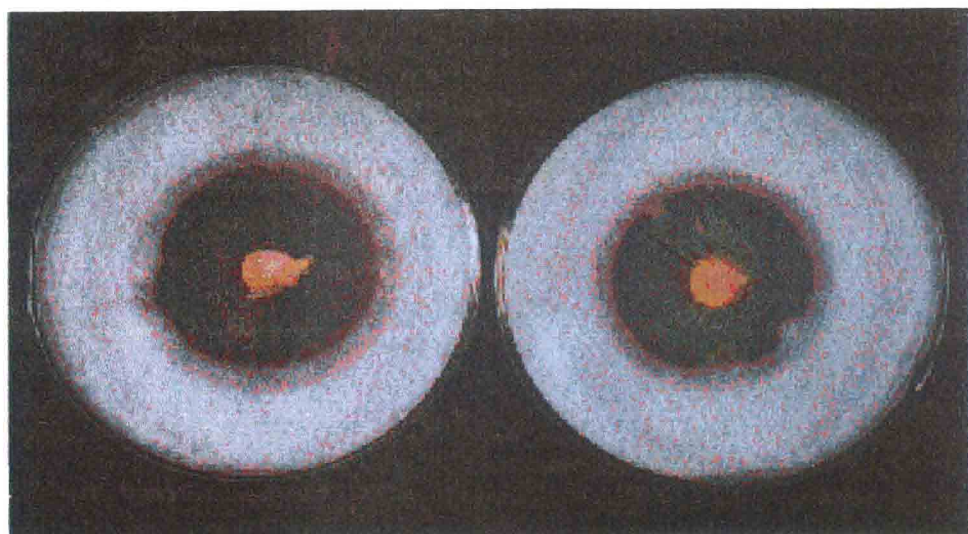


Plate. 1: Inhibition zone produced by seed treated with Captan after 6 months of storage

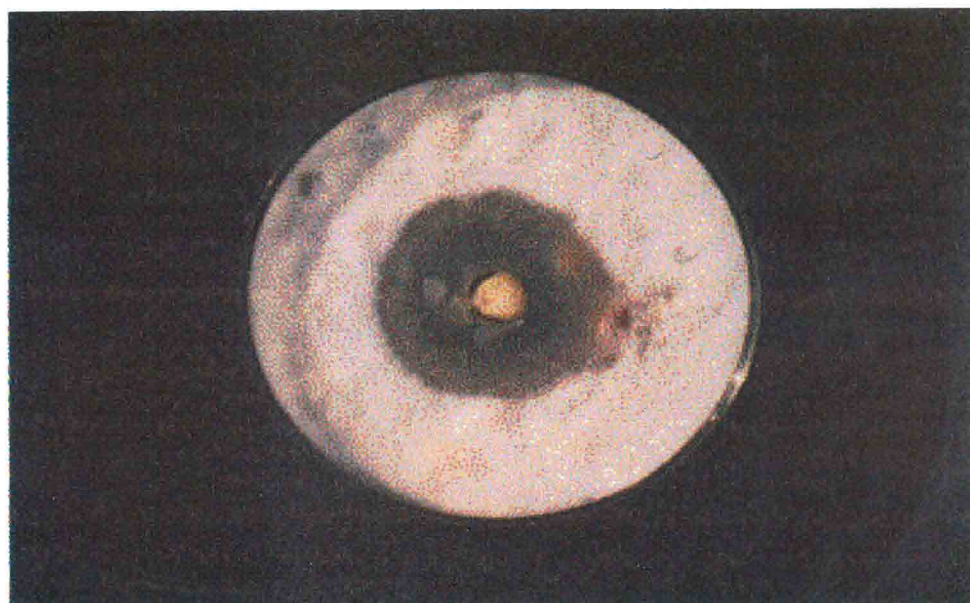


Plate. 1a: Inhibition zone produced by seed treated with Captan after 12 months of storage

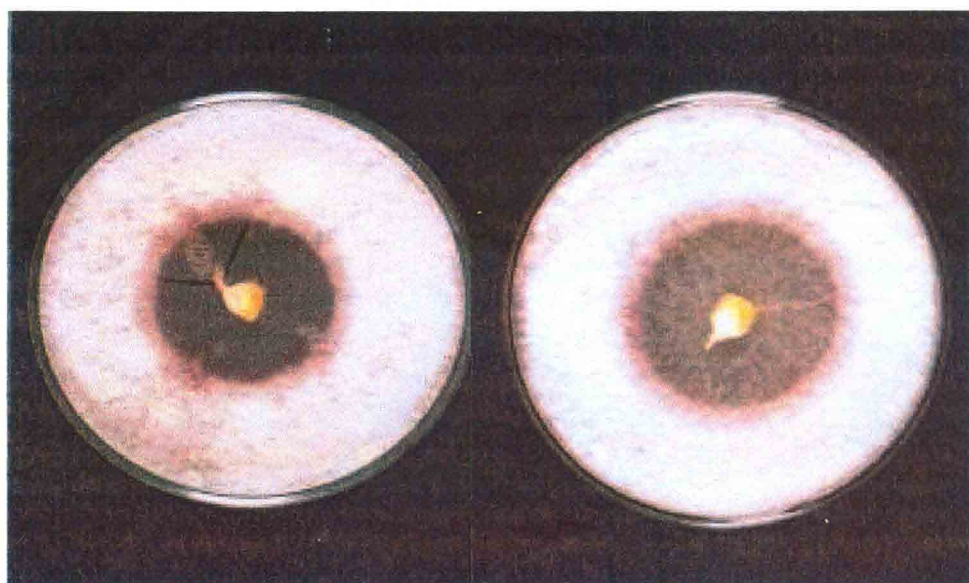


Plate. 2: Inhibition zone produced by maize seed treated with Bavistin after 6 months of storage

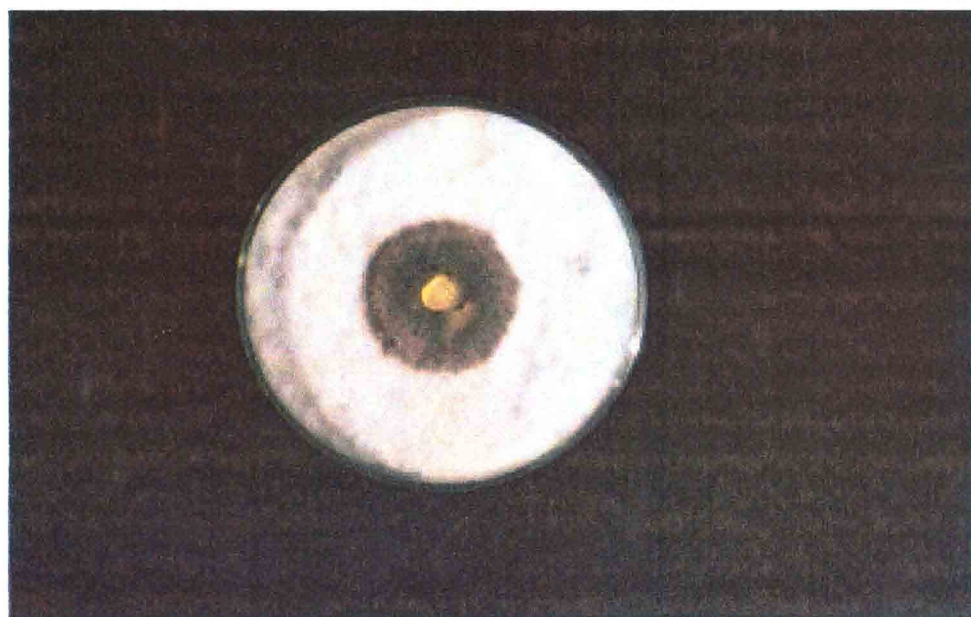


Plate. 2a: Inhibition zone produced by maize seed treated with Bavistin after 12 months of storage

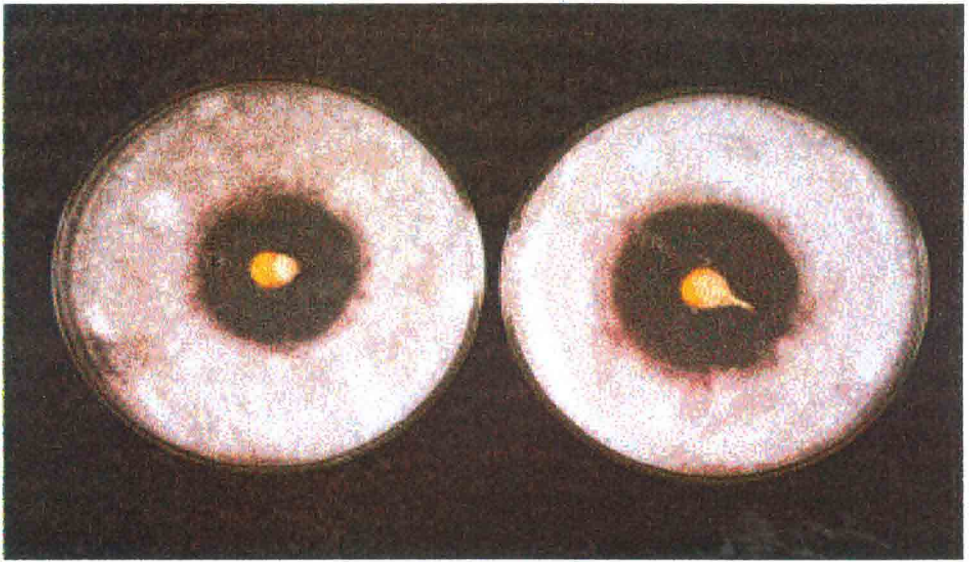


Plate. 3: Inhibition zone produced by seed treated with Captan + Deltamethrin after 6 months of storage

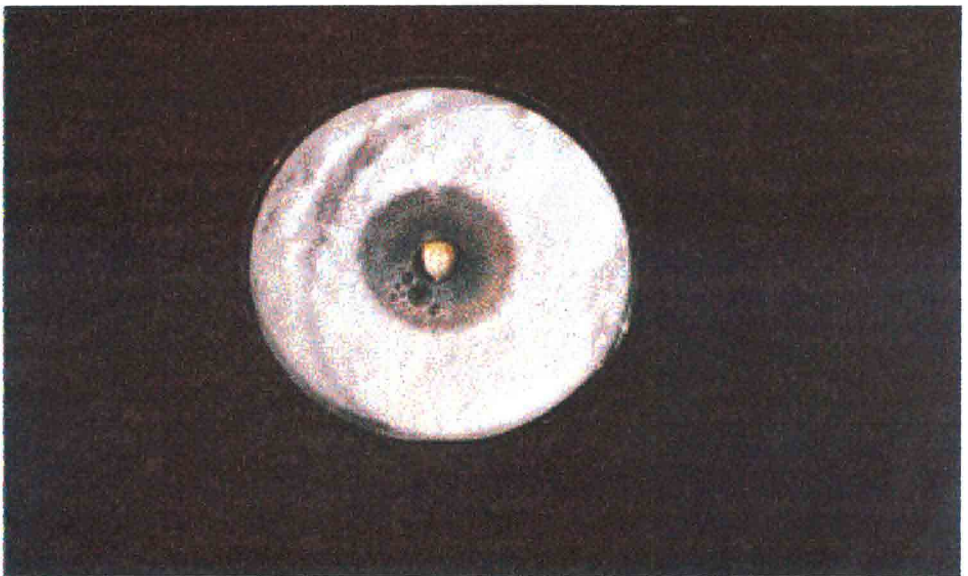


Plate. 3a: Inhibition zone produced by seed treated with Captan + Deltamethrin after 12 months of storage

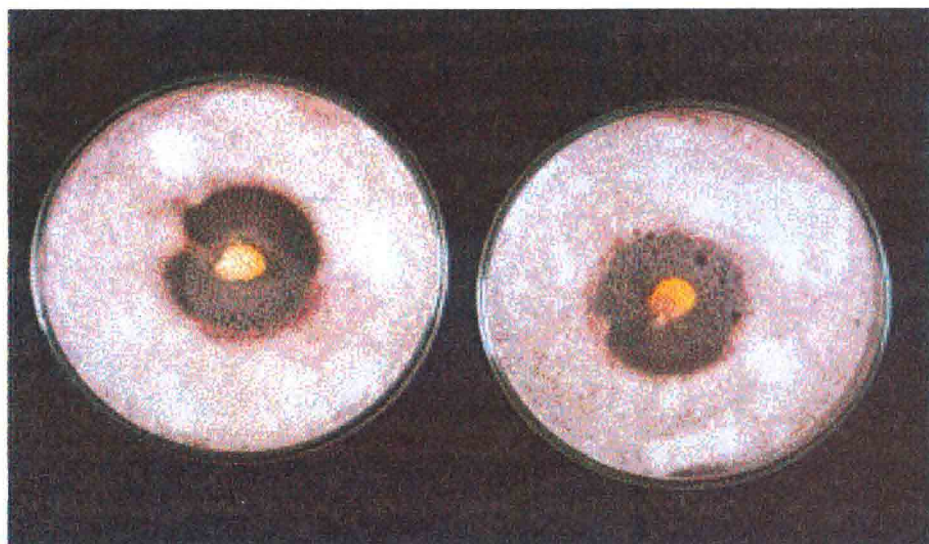


Plate. 4: Inhibition zone produced by seed treated with Captan + Malathion after 6 months of storage

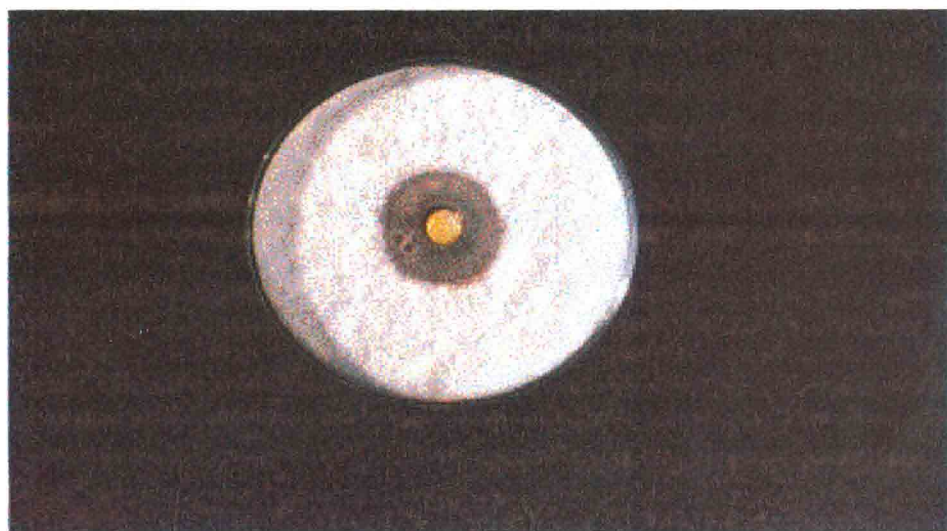


Plate. 4a: Inhibition zone produced by seed treated with Captan + Malathion after 12 months of storage

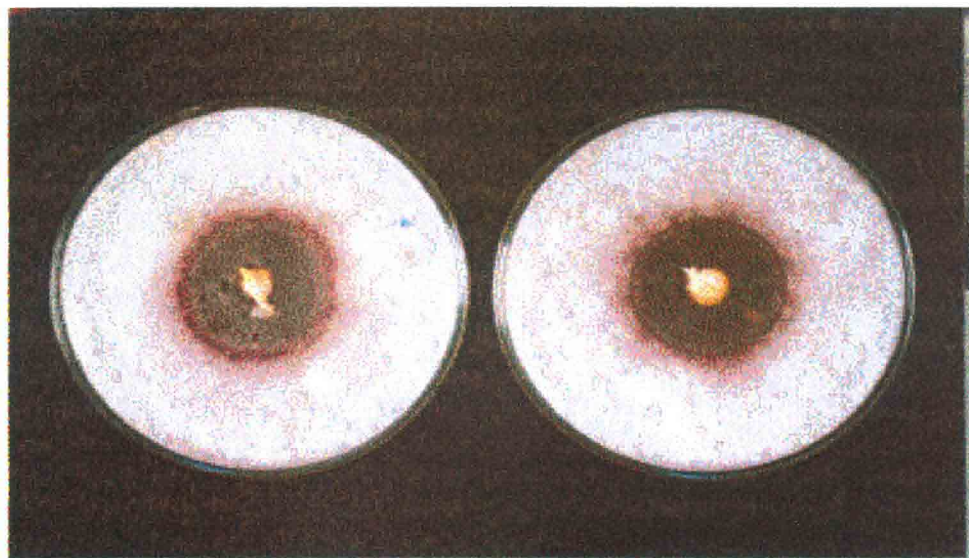


Plate. 5: Inhibition zone produced by maize seed treated with Bavistin + Deltamethrin after 6 months of storage

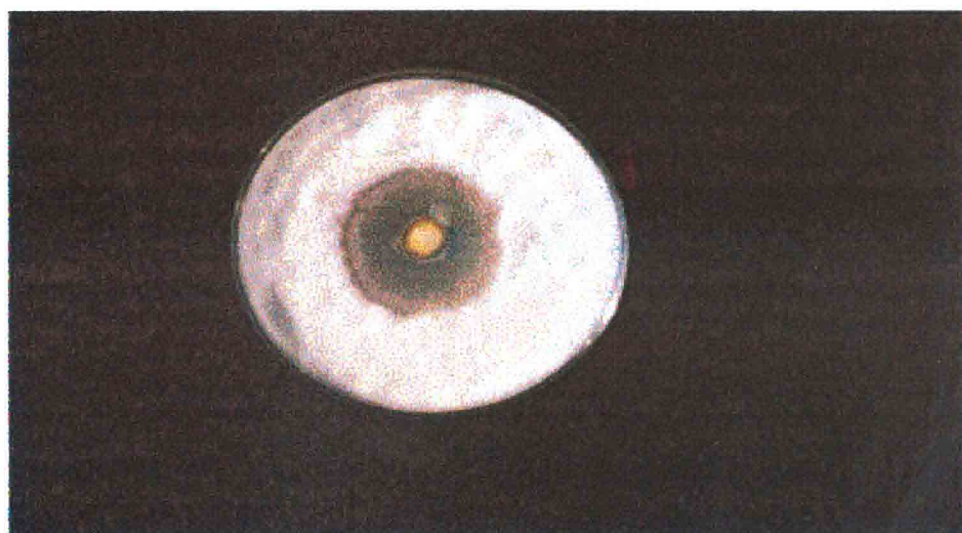


Plate. 5a: Inhibition zone produced by maize seed treated with Bavistin + Deltamethrin after 12 months of storage

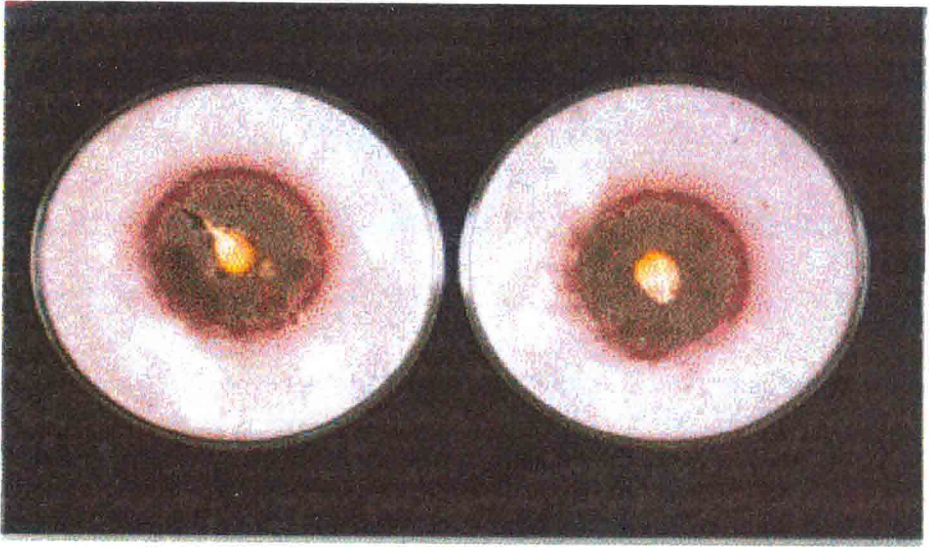


Plate. 6: Inhibition zone produced by maize seed treated with Bavistin + Malathion after 6 months of storage

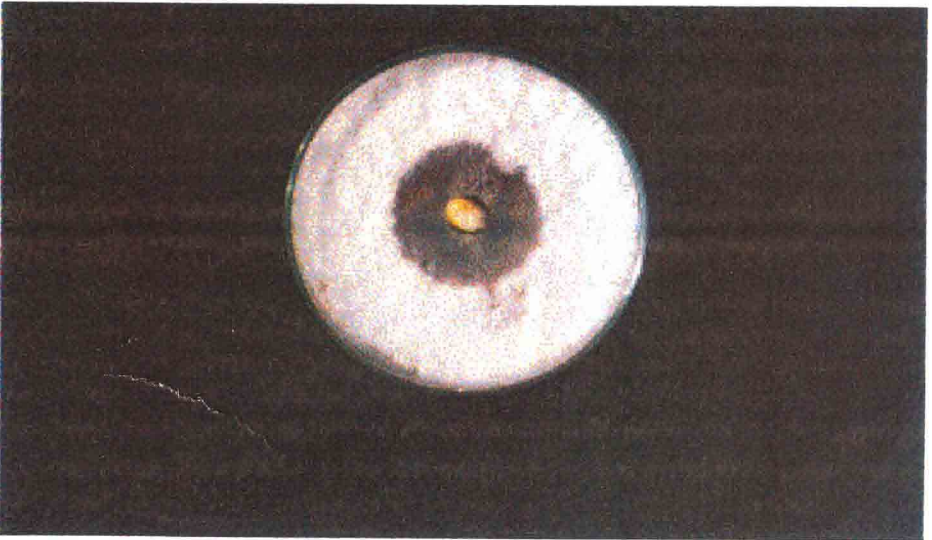


Plate. 6a: Inhibition zone produced by maize seed treated with Bavistin + Malathion after 12 months of storage

lowest average inhibition zone was produced by the seed treated with Captan + Malathion i.e. 1240.40, 975.45 and 754.40 mm² after 6, 12 and 18 months storage, respectively, when the seeds were stored under ambient conditions whereas, the inhibition zone obtained in the corresponding storage period, when the seeds were stored under controlled condition, was 1287.8, 1060.20 and 854.85 mm² (Plates 1a to 6a).

After 18 months of storage, the amount of Bavistin, Bavistin + Deltamethrin, Bavistin + Malathion, Captan, Captan + Deltamethrin and Captan + Malathion that remained on seed was 250, 300, 290, 315, 335 and 235 µg, respectively, in the seeds stored under ambient conditions. The corresponding average inhibition zones obtained from the seed treated with these protectants were 947.95, 974.60, 961.60, 1048.50, 1003.33 and 754.5 mm², respectively. Similarly, the quantity of protectants that persisted on seed after 18 months, when the seeds were stored under controlled conditions, was 295, 342, 325, 335, 340 and 270 µg of Bavistin, Bavistin + Deltamethrin, Bavistin + malathion, Captan, Captan + Deltamethrin and Captan + Malathion, respectively. The corresponding average inhibition zone obtained from the seed treated with these protectants was 1060.20, 1063.50, 1074.60, 1152.00, 1018.70 and 854.85 mm². The seed treatment with Captan alone produced highest average inhibition zone after 18 months of storage. The degradation of Bavistin and Bavistin + Malathion was observed to be more as compared to the Captan and its combinations.

4.6 Efficacy of seed protectants against *Rhyzopertha dominica*

Samples of treated maize seeds stored under ambient conditions (temperature ranging from 5.4 to 40.1⁰C and 36 to 92% of RH) and controlled storage conditions (20 ± 1⁰C and 30 ± 10% RH) were taken after 3, 6, 9, 12, 15 and 18 months after storage. Mortality of test insect, *Rhyzopertha dominica* was assayed after 1, 2, 3, 5 and 10 days after exposure to the stored treated seed. The bioassay studies were conducted as per the procedure given under para 3.8.2 and the results of Probit analysis are given in Annexure 1.

It is evident from the table 37 that the response of the test insect was positive and gave nearly 100% kill of the insect in 10 days exposure with all the seed protectants tested. As the storage period progressed, the time required to achieve the 50% mortality (LT₅₀) increased indicating the loss in efficacy of chemical during storage. Irrespective of storage conditions, all the treatments were found effective upto 12 months. However, seed stored under controlled conditions could record 100% mortality within 10 days exposure in all the treatments upto 18 months of storage. Whereas, the seed stored under ambient conditions could not kill 100% insects after 15 month of storage. It means that the 10 days exposure was not sufficient to have 100% mortality in the seeds stored under ambient conditions, which recorded LT₅₀ values as 5.06 and 6.08 after 15 months and 18 months storage, respectively. Nevertheless, differences in percentage mortality (LT₅₀) due to seed

Table 37 : LT_{50} (days) of different seed protectant tested against *Rhizopertha dominica* after different periods of storage

Storage period	3 months		6 months		9 months		12 months		15 months		18 months		Mean	
	C ₁	C ₂	C ₁	C ₂	C ₁	C ₂	C ₁	C ₂	C ₁	C ₂	C ₁	C ₂	C ₁	C ₂
Captan	2.99	2.74	3.35	3.33	4.33	3.91	5.26	4.66	5.73	5.10	6.28	5.61	4.65	4.22
Bavistin	3.28	3.19	3.59	3.48	4.56	4.42	5.80	4.90	6.35	5.65	7.32	6.68	5.15	4.72
Deltamethrin	1.77	1.25	2.03	1.60	2.54	1.71	3.42	2.31	3.80	2.90	4.60	3.66	3.03	2.24
Malathion	1.95	1.56	2.35	1.81	3.22	2.47	4.01	2.84	5.01	3.52	5.74	4.05	3.71	2.71
Econeem	2.62	2.87	3.45	2.69	3.70	3.34	4.74	3.93	5.86	4.76	6.38	5.44	4.49	3.84
Arappu leaf powder	3.45	3.09	4.02	3.33	4.85	3.82	5.91	4.36	6.52	5.78	8.34	6.61	5.43	4.50
Captan + Deltamethrin	1.96	1.33	2.05	1.75	2.51	2.19	3.64	2.66	4.36	3.23	5.28	4.03	3.30	2.53
Captan + Malathion	1.81	1.38	2.06	1.85	2.78	2.36	3.72	2.68	4.42	3.53	5.86	4.31	3.44	2.69
Bavistin + Deltamethrin	2.15	1.80	2.43	2.01	2.96	2.86	3.94	3.10	3.97	3.78	5.41	4.55	3.48	3.02
Bavistin + Malathion	2.17	1.75	2.24	2.02	2.97	2.28	3.64	2.74	4.55	3.53	5.59	4.22	3.53	2.76
Mean	2.44	2.10	2.76	2.39	3.44	2.93	4.41	3.42	5.06	4.18	6.08	4.92	4.02	3.32

CD (P = 0.05) : $T = 0.16$ $C = 0.07$ $P = 0.13$ $T \times C = 10.23$ $T \times P = 0.40$
 $C \times P = 0.18$ $T \times C \times P = 0.56$

Where,

C₁ = Ambient storage ; C₂ = Controlled storage ; T = Treatment ; C = Condition of storage ; P = Period of storage

protectants, storage conditions, period of storage and their interactions were statistically significant.

The minimum effective application rate of a protectant for any given period of protection was a function of both its inherent potency and its rate of breakdown. Therefore the order of efficacy of seed protectant depended on the period of protection desired. A combination of Captan + Deltamethrin, Captan + Malathion, Bavistin + Deltamethrin, Bavistin + Malathion and Malathion alone when tested after 3 months stored seed was of similar potency to Deltamethrin and was similarly effective (Table 37), but was less effective during long-term storage. Nevertheless, seed treatment with Deltamethrin alone and its combination with Captan and Bavistin, Malathion alone and its combination with Captan and Bavistin were found effective upto 18 months when the seeds were stored under controlled conditions which recorded 100% mortality of the test insect within 10 days of exposure. However, Malathion remained active upto 15 months when the seeds were stored under ambient conditions. The LT_{50} of the Arappu leaf powder, Bavistin, Captan and to a lesser degree, Econeem increased greatly for a longer periods of protection, whereas Deltamethrin had a greater residual effects.

The LT_{50} values for Captan and Bavistin alone were 4.33 and 4.56 after 9 months under ambient conditions whereas; it was 4.66 and 4.90 after 12 months under controlled conditions respectively. Similar effect was also

observed with Arappu leaf powder. However, the efficacy of seed treatment with neem based commercial product Econeem was found effective against *R. dominica* for 12 and 15 months in ambient conditions and controlled conditions, respectively.

Among the seed protectants tested against *R. dominica*, the order of potency (judged by LT_{50} values) was Deltamethrin > Captan + Deltamethrin > Captan + Malathion > Bavistin + Malathion > Malathion > Bavistin + Deltamethrin > Econeem > Captan > Bavistin > Arappu leaf powder.

4.7 Persistence of Deltamethrin on maize seed after storage

The quantitative analysis of Deltamethrin residues was performed by gas chromatography using electron capture detector. The recovery test was performed by blending 50 g of untreated maize seed samples with 2 ml (5 ppm) of Deltamethrin (Analytical grade) solution according to the procedure given in para 3.8.3. The recovery percentage was found to be in the range of 75-78%.

The amount of Deltamethrin residues that remained on the seed after different periods of storage is given in the table 38.

Perusal of table 38 revealed that the initial deposits of Deltamethrin retained by the seed after treatment were found to be 0.8364 and 0.8437 ppm on the seeds of CM-135 and CM -136, respectively. After 3 months of storage, the amount detected on the seeds of CM-135 and CM-136 stored under ambient conditions was 0.7530 and 0.7584 ppm, respectively. Similarly, the

Table 38: Average residues of Deltamethrin (ppm/kg) on maize seeds during 18 months of storage period

Storage period	Amount of residues (ppm/kg)							
	CM-135				CM-136			
	C ₁	% Decrease	C ₂	% Decrease	C ₁	% Decrease	C ₂	% Decrease
0 month	0.8364	-	0.8364	-	0.8437	-	0.8437	-
3 months	0.7530	9.97	0.7626	8.82	0.7584	10.11	0.7591	10.03
6 months	0.5348	36.06	0.5315	34.06	0.5435	35.58	0.5632	33.25
9 months	0.4709	43.70	0.4879	41.67	0.4654	44.84	0.4891	42.03
12 months	0.2568	69.30	0.2806	66.45	0.2583	69.38	0.2846	66.27
15 months	0.1963	76.53	0.2393	71.39	0.1984	76.48	0.2371	71.90
18 months	0.1425	82.96	0.1941	76.79	0.1469	82.59	0.1908	77.38

Where,

C₁= Ambient storage; C₂= controlled storage

seed stored under controlled conditions has retained 0.7626 and 0.7591 ppm of Deltamethrin on the seeds of CM-135 and CM-136, respectively. Thereafter, the insecticide residue was decreased progressively as the storage period progressed. But its residues on seed persisted even at low concentration after 18 months.

After 18 months, the amount of residues present on the seed stored under ambient conditions and controlled conditions was 0.1425 and 0.1469 ppm and 0.1941 and 0.1908 ppm on the seeds of CM-135 and CM-136, respectively, showing a loss of 76 to 83% irrespective of storage conditions.

4.8 Seedling emergence in the field

Field experiment was conducted in *Kharif* (August, 2000) to study the seedling emergence of *Rabi* 1998 and *Kharif* 1999 produce seeds stored for 12 and 7 months, respectively. Similarly, the seedling emergence of *Rabi* 1998 and *Kharif* 1999 produce seeds stored for 18 and 12 months, respectively, were conducted in *Winter* (February 2001). The results are summarized in Tables 39 to 42.

4.8.1 Seedling emergence in the field in August 2000

Rabi 1998 produce seeds stored under controlled storage conditions exhibited significantly higher seedling emergence than that stored under ambient storage conditions. In CM-135, the seedling emergence was 44.5 and 58.0 per cent for seeds stored under ambient and controlled storage conditions, respectively, whereas, it was 60.0 and 68.0 per cent, respectively

Table 39: Seedling emergence (%) of stored maize CM-135 and CM-136 seeds (*Rabi-1998* produce) in August-2000

Parental lines Treatments	CM-135			CM-136		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean
Captan	49.0 (44.43)	66.0 (54.38)	57.5 (49.40)	63.0 (52.56)	76.0 (60.72)	69.5 (56.64)
Bavistin	42.0 (40.37)	52.0 (46.34)	47.0 (43.36)	55.0 (47.87)	65.0 (53.74)	60.0 (50.81)
Deltamethrin	45.0 (41.94)	62.0 (51.97)	53.3 (46.95)	66.0 (54.34)	70.0 (56.82)	68.0 (55.58)
Malathion	39.0 (38.63)	50.0 (45.00)	44.5 (41.82)	50.0 (45.00)	62.0 (51.96)	56.0 (48.48)
Econeem	41.0 (39.80)	56.0 (48.49)	48.5 (44.06)	68.0 (55.58)	64.0 (53.15)	66.0 (54.37)
Arappu leaf powder	44.0 (41.54)	56.0 (48.46)	50.0 (44.99)	57.0 (49.04)	67.0 (54.98)	62.0 (52.01)
Captan + Deltamethrin	46.0 (42.71)	64.0 (53.15)	55.0 (47.93)	65.0 (53.74)	73.0 (58.71)	69.0 (56.23)
Captan + Malathion	52.0 (46.15)	67.0 (54.98)	59.5 (50.57)	62.0 (51.97)	70.0 (56.84)	66.0 (54.41)
Bavistin + Deltamethrin	49.0 (44.43)	63.0 (52.56)	56.0 (48.49)	60.0 (50.78)	65.0 (53.76)	62.5 (52.27)
Bavistin + Malathion	47.0 (43.28)	59.0 (50.22)	53.0 (46.75)	64.0 (53.15)	69.0 (56.25)	66.5 (54.70)
Control	38.0 (38.04)	47.0 (43.28)	42.5 (40.66)	49.0 (44.43)	60.0 (50.78)	54.5 (47.61)
Mean	44.5 (41.94)	58.00 (49.89)	51.5 (45.92)	60.0 (50.77)	68.0 (55.25)	64.0 (53.01)

Note : Figures in parenthesis indicates arcsine transformed values.

CD (P=0.05) :

For CM - 135, T = 4.9236 C = 2.0994 T x C = 6.9696

For CM - 136, T = 3.2265 C = 1.3427 T x C = 4.4575

Where,

C₁ = Ambient storage

C₂ = Controlled storage

T = Treatment

C = Conditions of storage

Table 40: Seedling emergence (%) of stored maize CM-135 and CM-136 seeds (Kharif-1999 produce) in August-2000

Parental lines Treatments	CM-135			CM-136		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean
Captan	78.00 (62.19)	80.00 (63.53)	79.00 (62.83)	80.00 (63.53)	83.00 (65.72)	81.50 (64.63)
Bavistin	68.00 (55.59)	75.00 (60.04)	71.50 (57.81)	67.00 (54.99)	77.00 (61.46)	72.00 (58.22)
Econeem	70.00 (56.86)	74.00 (59.38)	72.00 (58.12)	73.00 (58.75)	76.00 (60.74)	74.50 (59.74)
Arappu leaf powder	65.00 (53.76)	70.00 (56.82)	67.50 (55.29)	70.00 (56.83)	74.00 (59.40)	72.00 (58.12)
Captan + Deltamethrin	78.00 (62.15)	83.00 (65.72)	80.50 (63.94)	80.00 (63.53)	85.00 (67.31)	82.50 (65.42)
Captan + Malathion	80.00 (63.53)	81.00 (64.20)	80.50 (63.87)	82.00 (65.01)	84.00 (66.51)	83.00 (65.76)
Bavistin + Deltamethrin	74.00 (59.40)	78.00 (62.19)	76.00 (60.79)	78.00 (62.10)	79.00 (62.79)	78.50 (62.45)
Bavistin + Malathion	70.00 (56.83)	82.00 (65.23)	76.00 (60.53)	81.00 (64.20)	83.00 (65.77)	82.00 (64.99)
Control	63.00 (52.55)	67.00 (54.97)	65.00 (53.76)	71.00 (57.45)	74.00 (59.38)	72.50 (58.42)
Mean	72.00 (58.09)	77.00 (61.23)	74.50 (59.66)	76.00 (60.71)	79.00 (63.23)	77.50 (61.97)

Note : Figures in parenthesis indicates arcsine transformed values.

CD (P=0.05) :

For CM - 135, T = 3.5476 C = 1.6724 T x C = NS

For CM - 136, T = 3.4874 C = 1.6440 T x C = NS

Where,

C₁ = Ambient storage

C₂ = Controlled storage

T = Treatment

C = Conditions of storage

for CM-136. Thus CM-136 recorded higher germination (64.0%) as compared to CM-135 in which the total mean germination was 51.50% (Table 39).

The seed treatment with Captan, Captan + Malathion, Bavistin + Deltamethrin, Captan + Deltamethrin, Deltamethrin and Bavistin + Deltamethrin recorded significantly higher emergence and were at par in CM-135. While in CM-136, seed treatments with Captan, Captan + Deltamethrin, Deltamethrin, Bavistin + Malathion, Captan + Malathion and Econeem were found most effective in recording highest seedling emergence and were at par. The genotypic difference was pronounced in which CM-136 recorded higher emergence than CM-135. The interaction effect between treatment and condition of storage was statistically significant (Table 39).

In a study conducted in August 2000 in the field, the *Kharif* 1999 produce seeds with pre-storage treatments stored under ambient and controlled storage conditions, recorded good emergence as the initial seed vigour and standard germination was higher (Table 40). It was found that seed treated with Captan + Deltamethrin, Captan + Malathion, Captan alone, Bavistin + Deltamethrin and Bavistin + Malathion exhibited significantly higher emergence in CM-135. Irrespective of storage condition, seed treatment with Captan + Deltamethrin or Captan + Malathion recorded more than 80% field emergence in CM-135. Similarly, irrespective of storage conditions, seed treatment with Captan + Malathion, Captan + Deltamethrin, Bavistin + Malathion and Captan alone increased seedling emergence (more

than 80.0%) in CM-136 and were at par with each other. The mean germination was 74.5 and 77.5 per cent in the parental line CM-135 and CM-136, respectively. However, the seed stored under controlled conditions had a higher seedling emergence in the field as compared to seed stored under ambient conditions.

A non-significant interaction effect between seed treatment and storage conditions was observed in both the parental lines (Table 40).

4.8.2 Seedling emergence in the field in February 2001

In another study of field emergence conducted in February 2001, the effect of storage period was pronounced which resulted into poor emergence in *Rabi* 1998 produce seeds (Table 41). The parental line CM-135 recorded poor emergence (42.5%) in the field as compared to the parental line CM-136 that recorded 54.5% emergence giving around 22.02% higher emergence. The seed treatment with Captan + Malathion, Captan + Deltamethrin, and Captan alone recorded significantly higher emergence as compared to other treatments and untreated control in CM-135. Similarly, the seed treatment with Captan alone, Captan + Deltamethrin, Captan + Malathion and Deltamethrin exhibited significantly higher emergence and were at par in CM-136. The poor emergence (28.0%) in case of seed stored under ambient condition was noted as compared to seeds stored under controlled conditions (57.0 %) in CM-135. Whereas, significantly higher emergence (67.0%) was recorded when the seeds were stored under controlled conditions as

Table 41: Seedling emergence (%) of stored maize CM-135 and CM-136 seeds (Rabi-1998 produce) in February-2001

Parental lines Treatments	CM-135			CM-136		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean
Captan	34.0 (35.66)	65.0 (53.74)	49.5 (44.70)	48.0 (43.85)	78.0 (62.14)	63.0 (53.00)
Bavistin	20.0 (26.49)	50.0 (45.00)	35.0 (35.75)	34.0 (35.66)	68.0 (55.60)	51.0 (45.63)
Deltamethrin	28.0 (31.90)	61.0 (51.51)	44.0 (41.70)	47.0 (43.28)	72.0 (58.04)	59.5 (50.68)
Malathion	22.0 (27.92)	48.0 (43.85)	35.0 (35.89)	31.0 (33.80)	60.0 (50.79)	45.5 (42.30)
Ecneem	23.0 (28.61)	54.0 (47.45)	38.5 (38.03)	48.0 (43.85)	65.0 (53.76)	56.5 (48.81)
Arappu leaf powder	26.0 (30.63)	51.5 (45.61)	38.5 (38.12)	36.0 (36.86)	63.0 (52.48)	49.5 (44.67)
Captan + Deltamethrin	37.0 (37.45)	65.0 (53.76)	51.0 (45.61)	50.0 (45.04)	72.0 (58.09)	61.0 (51.57)
Captan + Malathion	42.0 (40.38)	67.0 (55.01)	54.5 (47.69)	53.0 (46.72)	70.0 (56.82)	61.5 (51.77)
Bavistin + Deltamethrin	32.0 (34.41)	60.0 (50.79)	46.0 (42.61)	35.0 (36.25)	67.0 (54.99)	51.0 (45.62)
Bavistin + Malathion	29.0 (32.54)	58.0 (49.62)	43.0 (41.08)	39.0 (38.83)	64.0 (52.56)	51.5 (45.69)
Control	23.0 (28.63)	45.0 (41.94)	34.0 (35.29)	40.0 (39.42)	58.0 (49.63)	49.0 (44.52)
Mean	28.0 (32.24)	57.0 (48.94)	42.5 (40.59)	42.0 (40.32)	67.0 (55.00)	54.5 (47.66)

Note : Figures in parenthesis indicates arcsine transformed values.

CD (P=0.05) :

For CM - 135, T = 3.3094 C = 1.4111 T x C = 4.6846

For CM - 136, T = 3.149 C = 1.3758 T x C = 4.5673

Where,

C₁ = Ambient storage

C₂ = Controlled storage

T = Treatment

C = Conditions of storage

Table 42: Seedling emergence (%) of stored maize CM-135 and CM-136 seeds (Kharif-1999 produce) in February-2001

Parental lines Treatments	CM-135			CM-136		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean
Captan	71.00 (57.46)	74.00 (59.42)	72.50 (58.44)	78.00 (62.09)	82.00 (64.94)	80.00 (63.52)
Bavistin	62.00 (51.97)	69.00 (56.20)	65.50 (54.09)	69.00 (56.25)	71.00 (57.45)	70.00 (56.85)
Econeem	60.00 (50.78)	65.00 (53.74)	62.50 (52.26)	67.00 (54.98)	69.00 (56.41)	68.00 (55.70)
Arappu leaf powder	55.00 (47.87)	60.00 (50.78)	57.50 (49.33)	64.00 (53.15)	63.00 (52.56)	63.50 (52.86)
Captan + Deltamethrin	73.00 (58.73)	72.00 (58.07)	72.50 (58.40)	76.00 (60.72)	79.00 (62.92)	77.50 (61.82)
Captan + Malathion	67.00 (54.78)	70.00 (56.88)	68.50 (55.93)	73.00 (58.73)	75.00 (60.06)	74.00 (59.39)
Bavistin + Deltamethrin	65.00 (53.76)	64.00 (53.15)	64.50 (53.46)	60.00 (50.79)	75.00 (60.07)	67.50 (55.43)
Bavistin + Malathion	62.00 (51.96)	66.00 (54.36)	64.00 (53.16)	70.00 (56.88)	72.00 (58.08)	71.00 (57.48)
Control	58.00 (49.64)	60.00 (50.79)	59.00 (50.22)	62.00 (51.97)	64.00 (53.13)	63.00 (52.56)
Mean	64.00 (53.02)	67.00 (54.82)	65.50 (53.92)	69.00 (56.17)	72.50 (58.40)	70.50 (57.29)

Note : Figures in parenthesis indicates arcsine transformed values.

CD (P=0.05) :

For CM - 135, T = 3.4245 C = 1.6143 T x C = NS
 For CM - 136, T = 3.632 C = 1.7122 T x C = 5.1308

Where,

C₁ = Ambient storage
 C₂ = Controlled storage
 T = Treatment
 C = Conditions of storage

compared to seed stored under ambient conditions (42.0%) giving as high as 37.31% higher emergence in CM-136. In general, the field emergence in February 2001 was low as compared to August 2000.

The interaction effect between seed treatment and storage conditions was significant in both the parental lines (Table 41).

In a study conducted in February 2001 for *Kharif* 1999 produce seed, the results showed that seedling emergence was remarkably low as compared to seedling emergence in August 2000. After 12 months of storage, the seedling emergence was improved remarkably with the seed treatment with Captan alone and Captan + Deltamethrin followed by Captan + Malathion in both the parental lines (Table 42). However, seed treatment with Arappu leaf powder and Econeem was found least effective among the treatments. It was observed that the seed treatment with Captan was most effective which recorded 80.0% emergence irrespective of storage conditions in CM-136. Genotypic differences were also noted, as the seedling emergence was 7.63% high in CM-136 than CM-135. The mean seedling emergence was 65.5% and 70.5% in CM-135 and CM-136, respectively. Nevertheless, seed stored under controlled conditions, recorded significantly high emergence as compared to seed stored under ambient conditions.

A non-significant interaction between treatments and storage conditions was noted in CM-135, whereas, it was significant in CM-136 (Table 42).

4.9 Pre-sowing seed treatment

Pre-sowing seed treatments with Captan, Bavistin, Kalisena, Hydration-dehydration (HD) and Hydration-dehydration followed by dry seed dressing with Captan, Bavistin and Kalisena to the stored untreated seeds were studied. The trial was conducted in *Kharif* (August 2000) and *Winter* (February 2001) in the field. The results are summarized in Tables 43 to 46

4.9.1 Effect of pre-sowing seed treatments on seedling emergence in August 2000

The study was conducted in the field in August 2000 and February 2001 with the seeds produced in *Rabi* 1998 and stored under ambient and controlled conditions were given pre-sowing treatments with Kalisena, Bavistin, Captan, Hydration-dehydration (HD), Hydration-dehydration followed by dry dressing with Kalisena, Bavistin and Captan. The field emergence was significantly enhanced by pre-sowing treatment over the control. The mean seedling emergence of untreated seed was 42.5 and 54.5% in CM-135 and CM-136, respectively (Table 43). The significantly highest emergence was recorded by HD + Captan (57.0%), HD (54.5%) followed by Captan (52.5%) alone in CM-135. However, in CM-136, the highest emergence was recorded with HD (71.5%) and HD + Kalisena (66.5%). However, higher emergence by 25.44% in CM-135 and 23.78% in CM-136 was noted when the

Table 43: Seedling emergence (%) of maize CM-135 and CM-136 seeds (Rabi-1998 produce) after pre-sowing seed treatments in August-2000

Parental lines Treatments	CM-135			CM-136		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean
Kalisena	43.0 (40.97)	56.0 (48.46)	49.5 (44.71)	56.0 (48.46)	68.0 (55.62)	62.0 (52.04)
Bavistin	40.0 (39.21)	52.0 (46.15)	46.0 (42.68)	47.0 (43.28)	64.0 (53.14)	55.0 (48.21)
Captan	46.0 (42.70)	59.0 (50.23)	52.5 (46.47)	54.0 (47.30)	65.0 (53.75)	59.0 (50.53)
Hydration-Dehydration (HD)	49.0 (44.42)	60.0 (50.79)	54.5 (47.61)	67.0 (54.98)	76.0 (60.72)	71.5 (57.85)
HD + Kalisena	42.0 (40.39)	50.0 (44.99)	46.0 (42.70)	61.0 (51.37)	72.0 (58.08)	66.5 (54.73)
HD + Bavistin	37.0 (37.43)	51.0 (45.87)	44.0 (42.65)	58.0 (49.63)	66.0 (54.36)	62.0 (51.99)
HD + Captan	52.0 (46.15)	62.0 (51.95)	57.0 (49.05)	55.0 (47.87)	73.0 (58.73)	64.0 (53.30)
Control	38.0 (38.04)	47.0 (43.28)	42.5 (40.66)	49.0 (44.43)	60.0 (50.78)	54.5 (47.61)
Mean	43.0 (41.16)	55.0 (47.97)	49.0 (44.57)	56.0 (48.42)	68.0 (55.65)	62.0 (52.03)

Note : Figures in parenthesis indicates arcsine transformed values.

CD (P=0.05) :

For CM - 135, T = 3.3777 C = 1.6889 T x C = NS
 For CM - 136, T = 3.3278 C = 1.6639 T x C = 4.7019

Where,

C₁ = Ambient storage
 C₂ = Controlled storage
 T = Treatment
 C = Conditions of storage

Table 44: Seedling emergence (%) of maize CM-135 and CM-136 seeds (Kharif-1999 produce) after pre-sowing seed treatments in August-2000

Parental lines Treatments	CM-135			CM-136		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean
Kalisena	69.00 (56.21)	70.00 (56.83)	69.50 (56.52)	79.00 (62.92)	78.00 (62.19)	78.50 (62.55)
Bavistin	66.00 (54.350)	75.00 (60.06)	70.50 (57.21)	76.00 (60.72)	80.00 (63.49)	78.00 (62.11)
Captan	72.00 (58.08)	74.00 (59.38)	73.00 (58.73)	84.00 (66.51)	83.00 (65.72)	83.50 (66.12)
Hydration-Dehydration (HD)	79.00 (62.92)	80.00 (63.60)	79.50 (63.26)	85.00 (67.13)	86.00 (68.13)	85.50 (67.63)
HD + Kalisena	73.00 (58.73)	74.00 (59.38)	73.50 (59.05)	75.00 (60.04)	80.00 (63.53)	77.50 (61.79)
HD + Bavistin	70.00 (56.83)	72.00 (58.07)	71.00 (57.45)	77.00 (61.42)	83.00 (65.96)	80.00 (63.19)
HD + Captan	75.00 (60.07)	77.00 (61.43)	76.00 (60.75)	80.00 (63.53)	78.00 (62.11)	79.00 (62.82)
Control	63.00 (52.55)	67.00 (54.97)	65.00 (53.76)	71.00 (57.45)	74.00 (59.38)	72.50 (58.42)
Mean	71.00 (57.47)	74.00 (59.22)	72.50 (58.34)	78.00 (62.46)	80.00 (63.69)	79.00 (63.08)

Note : Figures in parenthesis indicates arcsine transformed values.

CD (P=0.05) :

For CM - 135, T = 3.525 C = 1.7625 T x C = NS

For CM - 136, T = 3.8922 C = 1.9461 T x C = NS

Where,

C₁ = Ambient storage

C₂ = Controlled storage

T = Treatment

C = Conditions of storage

seeds were treated before sowing with HD + Captan and Hydration-dehydration respectively over the control. Nevertheless, untreated seeds stored under controlled conditions had significant influence on field emergence, which recorded 21.82% and 27.65% higher germination over the seed stored under ambient condition in CM-135 and CM-136, respectively. The parental line CM-136 recorded 20.97% higher emergence than CM-135, which indicated differences with respect to genotype (Table 43).

The field study was conducted in August 2000 with the seeds produced in *Kharif* 1999 and stored under ambient and controlled conditions. The study conducted in August 2000 revealed that, the *Kharif* 1999 produce seeds had significant influence of pre-sowing treatment on field emergence. The significantly higher emergence of 79.5% and 76.0% was observed when the pre-sowing treatment was given by Hydration-dehydration alone and followed by dry dressing with Captan respectively in CM-135. Similarly, pre-sowing treatment of Hydration-dehydration and Captan alone recorded significantly higher emergence of 85.5% and 83.5% respectively in CM-136. The lowest emergence was recorded in untreated control i.e. 65.0% and 72.5% in CM-135 and CM-136 respectively. In general, the emergence was enhanced by 18.24% and 15.20% by the pre-sowing treatment of Hydration-dehydration in CM-135 and CM-136 respectively over the untreated control. However, regardless of seed treatment, seed stored under controlled conditions recorded 80% emergence in CM-136. In general, seeds stored under ambient

condition recorded significantly low emergence as compared to seeds stored under controlled conditions. Nevertheless, parental line CM-135 had 8.23% lower field emergence than CM-136. A non-significant interaction between treatment and storage condition was observed in both the parental lines (Table 44).

4.9.2 Effect of pre-sowing seed treatments on seedling emergence in February 2001

The field experiment conducted in February 2001 with *Rabi* 1998 produce seed stored under ambient and controlled conditions recorded significant differences with respect to pre-sowing treatments (Table 45). Pre-sowing seed treatment of Hydration-dehydration alone followed by HD + Captan and HD + Kalisena recorded significantly highest emergence i.e. 47.5%, 47.0% and 43.5%, respectively, in CM-135. Similarly, in CM-136, pre-sowing treatment of Hydration-dehydration alone followed by dry dressing with Captan, Kalisena and Captan alone significantly enhanced seedling emergence i.e. 63.0%, 61.0%, 60.0% and 58.0%, respectively. The lowest emergence 34.0% and 49.0% was recorded in untreated control in CM-135 and CM-136, respectively. The average germination (20.11% and 22.22% higher than untreated control) was recorded with the seed treatment with HD + Kalisena and Hydration-dehydration in CM-135 and CM-136 respectively. Nevertheless, seed stored under controlled condition, recorded significantly higher emergence by 45.28% and 30.30% over the ambient storage in CM-135 and CM-136, respectively. However, the parental line CM-136 recorded significantly higher (by 36.79%) emergence as compared to CM-135. The effect of pre-sowing treatment was more pronounced in February 2001 (18 months

Table 45: Seedling emergence (%) of maize CM-135 and CM-136 seeds (Rabi-1998 produce) after pre-sowing seed treatments in February-2001

Parental lines Treatments	CM-135			CM-136		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean
Kalisena	23.0 (28.60)	55.0 (48.07)	39.0 (38.34)	41.0 (39.61)	65.0 (53.74)	53.0 (46.68)
Bavistin	27.0 (31.27)	50.0 (45.00)	38.5 (38.14)	41.0 (39.80)	61.0 (51.39)	51.0 (45.59)
Captan	33.0 (35.02)	51.0 (45.58)	42.0 (40.30)	47.0 (43.27)	69.0 (56.20)	58.0 (49.74)
Hydration-Dehydration (HD)	32.0 (34.41)	63.0 (52.76)	47.5 (43.59)	52.0 (46.15)	74.0 (59.38)	63.0 (52.76)
HD + Kalisena	34.0 (35.64)	53.0 (46.73)	43.5 (41.18)	50.0 (45.00)	70.0 (56.82)	60.0 (50.91)
HD + Bavistin	27.0 (31.25)	50.0 (45.00)	38.5 (38.13)	46.0 (42.70)	64.0 (53.14)	55.0 (47.92)
HD + Captan	37.0 (37.43)	57.0 (49.04)	47.0 (43.24)	55.0 (47.87)	67.0 (54.98)	61.0 (51.43)
Control	23.0 (28.63)	45.0 (41.94)	34.0 (35.29)	40.0 (39.42)	58.0 (49.63)	49.0 (44.52)
Mean	29.0 (32.78)	53.0 (46.77)	41.0 (39.78)	46.0 (42.98)	66.0 (54.41)	56.0 (48.69)

Note : Figures in parenthesis indicates arcsine transformed values.

CD (P=0.05) :

For CM - 135, T = 3.2865 C = 1.6432 T x C = 4.6426

For CM - 136, T = 3.1055 C = 1.5527 T x C = 4.3869

Where,

C₁ = Ambient storage

C₂ = Controlled storage

T = Treatment

C = Conditions of storage

Table 46: Seedling emergence (%) of maize CM-135 and CM-136 seeds (Kharif-1999 produce) after pre-sowing seed treatments in February-2001

Parental lines Treatments	CM-135			CM-136		
	C ₁	C ₂	Mean	C ₁	C ₂	Mean
Kalisena	64.00 (53.14)	67.00 (54.99)	65.50 (54.06)	70.00 (56.82)	68.00 (55.58)	69.00 (56.20)
Bavistin	60.00 (50.79)	64.00 (53.15)	62.00 (51.97)	66.00 (54.38)	69.00 (56.21)	67.50 (55.29)
Captan	63.00 (52.57)	65.00 (53.74)	64.00 (53.16)	68.00 (55.62)	73.00 (58.73)	70.50 (57.17)
Hydration-Dehydration (HD)	75.00 (60.06)	76.00 (60.74)	75.50 (60.40)	80.00 (63.53)	79.00 (62.85)	79.50 (63.19)
HD + Kalisena	70.00 (56.86)	70.00 (56.82)	70.00 (56.84)	72.0 (58.08)	72.00 (58.08)	72.00 (58.08)
HD + Bavistin	66.00 (54.38)	73.00 (58.73)	69.50 (56.55)	70.00 (57.05)	76.00 (60.74)	73.00 (58.89)
HD + Captan	72.00 (58.07)	75.00 (60.06)	73.50 (59.07)	74.00 (59.38)	82.00 (65.07)	78.00 (62.22)
Control	58.00 (49.64)	60.00 (50.79)	59.00 (50.22)	62.00 (51.97)	64.00 (53.15)	63.00 (52.56)
Mean	66.00 (54.44)	69.00 (56.13)	67.50 (55.28)	70.50 (57.10)	73.00 (58.80)	71.50 (57.95)

Note : Figures in parenthesis indicates arcsine transformed values.

CD (P=0.05) :

For CM - 135, T = 3.494 C = 1.7455 T x C = NS
 For CM - 136, T = 3.2867 C = 1.6434 T x C = 4.6429

Where,

C₁ = Ambient storage
 C₂ = Controlled storage
 T = Treatment
 C = Condition of storage

old seed) than August 2000 (12 months old seed) over control in Rabi 1998 produce seeds.

The interaction effect between treatments and storage condition was significant in both the parental lines (Table 45).

The field study conducted in February 2001 revealed that the seedling emergence was lower as compared to seedling emergence in August 2000 in the seeds produced in *Kharif* 1999. Seed treatment of Hydration-dehydration and/or followed by dry dressing with Captan before sowing increased seedling emergence significantly over other treatments and untreated control in both the parental lines. Nevertheless, HD + Kalsena and HD + Bavistin also improved the seedling emergence over untreated control in both the parental lines. Among the treatments Hydration-dehydration recorded 21.85% and 20.75% higher emergence in CM-135 and CM-136, respectively, over the control. In CM-136, seed stored under ambient condition recorded 80.0% field emergence with pre-sowing Hydration-dehydration treatment. However, the genotypic differences pronounced with respect to seedling emergence as CM-136 recorded 71.5% as compared to 67.5% in case of CM-135. It was also observed that the seed stored under controlled conditions recorded higher emergence in CM-135 and CM-136 (4.35% and 3.42%, respectively) as compared to seed stored under ambient conditions. The lowest seedling emergence in untreated control was 59.0% and 63.0% in CM-135 and CM-136, respectively.

The interaction effect of seed treatment and storage condition was non-significant in CM-135 whereas, it was significant in CM-136 (Table 46).

Chapter 5

DISCUSSION

The seeds of parental lines, CM-135 (female) and CM-136 (male) of newly developed maize hybrid, 'Pusa Early Makka-1' produced in *Rabi* 1998 and *Kharif* 1999 obtained from Indian Agricultural Research Institute, Regional Station, Karnal, Haryana, having 9.0% moisture content were treated with slurry of fungicides, insecticides and their combinations and plant products. The treated seeds along with untreated controls were packed in cloth bags and stored under ambient conditions of Delhi and controlled storage conditions ($20 \pm 1^{\circ}\text{C}$ and $30 \pm 10\%$ RH) at Karnal. The seeds produced in *Rabi* 1998 were stored from July 1999 to Jan.-Feb., 2001. Similarly, the seeds produced in *Kharif* 1999 were stored from Jan. 2000 to Jan.-Feb., 2001. The observations were taken at 3 months interval for various seed quality parameters including seedling emergence in the field are being discussed below.

5.1 Seed moisture content

Seed moisture content is closely associated with all aspects of physiological seed quality. It relates directly to seed maturity, optimum harvest time and storability and final seed quality. Thus determination of seed moisture is important in commerce for both planting seeds and grain purposes. Hence, an attempt was made to assess the moisture of maize seeds

during ambient storage where there was no control on temperature and relative humidity in storage environment.

The initial moisture content of CM-135 and CM-136 seeds produce in *Rabi* 1998 and stored under ambient conditions was recorded to be 9.0 and 9.2 per cent, respectively. Fluctuations in moisture content from 10.1 to 12.0 per cent in CM-135 and from 10.2 to 12.0 per cent in CM-136 seeds were recorded during the period of Oct.-Nov., 1999 to Jan.-Feb., 2001 (Table 1). The seed moisture was increased to 12.0 per cent in the month of July-Aug., 2000 as the ambient temperature and relative humidity was high during the period (Appendix 1). Similarly, the seeds produced in *Kharif* 1999 and stored under ambient conditions had attained the moisture as high as 11.7 % in the month of July-Aug., 2000 and lowest 9.9% in the month of Oct.-Nov., 2000. However, in Oct-Nov., 2000, the moisture content decreased as the atmospheric relative humidity started decreasing. Overall, the moisture content recorded in *Kharif* 1999 produce seeds was comparatively less than the seed moisture recorded in *Rabi* 1998 produce seeds during the storage. In case of *Kharif* 1999 produce seeds, the plastic bin, where the seeds were stored was covered by polyethylene sheet with lid whereas; it was not in case of *Rabi* 1998 produce seeds. This could be the reason for recording higher moisture content and high fluctuations of moisture in *Rabi* 1998 produce seeds.

The fluctuations occurred in monthly temperature and prevailing atmospheric relative humidity, the corresponding changes in seed moisture

were observed in seeds stored under ambient conditions (Fig. 1). However, seed moisture remained below 9.0% when the seeds were stored under controlled conditions of $20 \pm 1^{\circ}\text{C}$ and $30 \pm 10\%$ RH. Lopez and Christensen (1963) reported that the seeds absorb ambient moisture continuously during storage. Cloth bag being pervious, allowed free exchange of air from the atmosphere. Hence, the treated and untreated seeds stored in cloth bags under ambient conditions showed fluctuations in moisture content as compared to seeds stored under controlled conditions. Similar results were also reported by Savitri *et al.* (1998).

This explains the appearance of more number of fungal colonies on seeds stored under ambient conditions as compared to seeds stored in controlled storage conditions. However, the combined effect of natural senescence and seed moisture manifested in reduction of germination, seedling dry weight, shoot and root length, vigour index and field emergence and increase in electrical conductivity in the seeds stored under ambient conditions. Moreno Martinez and Vidal-Gaona (1981) observed that the seeds with high moisture content had faster decline in germination and invasion of seeds by storage fungi than the seeds with low initial moisture content. High moisture, high temperature and relative humidity could be detrimental for the survival of seed in storage has been reported by Chandak (1990), Gowda and Bhole (1989), Jorge *et al.* (1988), Agrawal *et al.* (1981), Likhatchev (1977) and Christensen (1972).

Seeds stored under controlled conditions remained less affected as the seed moisture was below 9.0 per cent. Abba and Lovato (1999) suggested that the 20°C + 45-50% RH could be safe for at least one year of storage, during which moisture equilibrium of seed remained below 11.5% and viability and vigour were practically unaffected. Similar findings were also reported by Singh and Munda (1998) and Singh and Singh (1992).

5.2 Germination

Significant differences in seed vigour and germination were observed between the seed lots produced in *Rabi* 1998 and *Kharif* 1999 (Tables 3 to 6). In *Rabi* 1998 produce seeds, gradual but significant reduction in germination, throughout the storage period of 18 months, was observed in both the parental lines. After 18 months of storage, the germination was below Minimum Seed Certification Standard (80%) with the lowest germination of 68.0 % and 78.0 % in CM-135 and CM-136, respectively. Irrespective of storage conditions, the germination was 80.5% after 9 months and 81.5 % after 15 months of storage in CM-135 and CM-136, respectively. However, in controlled storage conditions, irrespective of seed treatments, the germination was maintained 80.0% after 12 months and 84.0% after 18 months in CM-135 and CM-136, respectively. As the storage period progressed the number of abnormal seedlings was also increased. Nevertheless, loss in germination was as high as 21.39% in CM-135 as compared to 17.02% in CM-136 after 18 months of storage (Table 3 and 4).

In *Kharif* 1999 produce seeds, irrespective of storage conditions, the seed germination was above Minimum Seed Certification Standard i.e. 88.0% and 90.5 % in CM-135 and CM-136, respectively after 12 months of storage (Table 5 and 6).

From the above results, it was concluded that the seeds produced in *Kharif* 1999 had higher initial vigour and deteriorated slowly and thus could be stored for longer period as compared to seeds produced in *Rabi* 1998. Both the parental lines produced in *Rabi* 1998 could not maintain germination above Minimum Seed Certification Standard for 18 months. However, seeds produced in *Kharif* 1999 recorded germination well above Minimum Seed Certification Standard in both the conditions as it was stored for 12 months only. Moreover, parental line CM-136 was found comparatively better storer as it recorded higher germination in both the season as compared to CM-135. The poor germinability of *Rabi* 1998 produce seed lot could be due to the presence of multiple stress cracked seed, which might have played significant role in bringing down the germination percentage. For this reason, after 18 months of storage, the seeds of CM-135 stored under ambient conditions were divided into three categories viz., seeds with no crack, one crack and multiple crack. It was found that the seeds with no crack had germination of 60.5% as compared to 49.0% and 33.0% in the seeds with one crack and more than one crack respectively. Similar findings were also reported by Naplava and Weingatman (1994) and Borba *et. al.* (1995) who found that the mechanical

damage during processing and formation of multiple stress cracks during drying at higher temperature than 45⁰C significantly reduced germination and seed quality. Similarly, in CM-136, less number of cracked seeds was found as compared to CM-135. However, low germination of seed stored under ambient condition could be a result of high moisture brought about by fluctuations in ambient relative humidity (Roberts, 1972) and/or temperature (Agrawal, 1974; Bottomley *et al.*, 1950; Chandak, 1990) or by natural senescence (Savitri *et al.*, 1994) and low initial vigour of the seed. Significant decline in germination in seeds stored under ambient conditions was also reported by Dey and Mukherjee (1986), Narayanaswamy and Manjunathan Swamy (1996) and Agrawal (1974). Similarly, Singh and Munda (1998) reported drastic reduction in germination after 8 months of storage under ambient conditions. Nevertheless, seeds stored under controlled storage conditions maintained significantly higher germination than that of seeds stored under ambient conditions. Singh and Singh (1992) reported that maize seeds could be stored for a longer period in a controlled storage than that stored under ambient conditions which is in conformity with the present findings.

In *Rabi* 1998 produce seeds, Captan alone and its combinations with Deltamethrin and Malathion recorded significantly higher germination (mean germination 83.5%) and were at par followed by Bavistin + Malathion (81.5%) in CM-135. Seed treatment with Captan alone and its

combinations with Deltamethrin and Malathion maintained germination above Minimum Seed Certification Standard (80.0%) when the seeds were stored under controlled conditions for 18 months. Similarly in the parental line CM-136, a significantly higher germination (92.5%) was recorded when the seeds were treated with Captan alone. The other treatments Captan + Deltamethrin, Econeem, Deltamethrin, Bavistin + Malathion and Captan + Malathion found equally effective and improved the germination as compared to untreated control.

The seed treatment with Captan alone maintained 84.5% germination after 18 months of storage in CM-136 irrespective of the storage conditions. Similarly, in CM-135, the germination was 82% irrespective of storage conditions for 12 months when the seed were treated with Captan, Captan + Deltamethrin and Captan + Malathion. However, seed treatment with Arappu leaf powder and Malathion was found to be less effective as they were infested with seed mycoflora and thereby recorded low germination in both the parental lines (Table 3 and 4).

In *Kharif* 1999 produce seeds, it was found that except Arappu leaf powder, all other treatments proved superior as they gave significantly higher germination as compared to untreated control. Among the treatments, Captan alone and its combination with Deltamethrin and Malathion were found to be superior in CM-135. Similarly, in case of CM-136, the seed treatment with Captan and its combination with Deltamethrin and Econeem

were found superior in improving germination percentage as compared to other treatments and untreated control (Table 5 and 6).

As such, seed treatment with Captan alone and its combination with Deltamethrin and Malathion followed by Econeem were found superior. Satyanarayana and Reddy (1994) noted that Captan + Malathion combination could maintain germination upto 15 months with minimum fungal flora. Similarly, Aguilera *et al.* (2000) reported significant increase in germination with the mixture of Captan, Deltamethrin and Pirimiphos-methyl. Nevertheless, seed treatment with Captan alone was found superior among the treatments. Similar findings were also reported by Saharan *et al.* (1972), Rao *et al.* (1973), Verma and Agrawal (1981), Falloon (1982), Mao *et al.* (1997), Paul and Mishra (1994) and Berzy, Zaborszky and Feher (1999). Contrary to this, Dey *et al.* (1988) observed that seed treatment with Bavistin was superior in improving germination percentage.

Seed treatment with Deltamethrin and Captan alone enhanced physiological quality of seed stored under controlled storage conditions reported by Carvalho *et al.* (1994) which corroborate the present findings.

Interaction between seed treatment and condition of storage as well as seed treatment and storage period were statistically non-significant. Similar were the observations of Rao *et al.* (1973), Agrawal (1974) and Varshney *et al.* (2001).

5.3 Seed vigour

Seed vigour is an important parameter used for testing the seed quality during marketing and storing the seed. It is a quality dependant on physiological potentiality, germinability and performance in the field with respect to percentage, rate and uniformity of seedling emergence which have indirect influence on maintenance of crop stand at harvest and yield. The various vigour tests studied during the investigation are discussed below.

5.3.1 Seedling dry weight

With the increase in storage period significant reduction in seedling dry weight irrespective of seed treatments and storage conditions were observed. In CM-135, the reduction in seedling dry weight was 31.63% as compared to 28.90% in CM-136 after 18 months of storage in *Rabi* 1998 produce seeds. Similarly, seeds produced in *Kharif* 1999 recorded significant reduction in seedling dry weight during the storage period of 12 months. Overall, parental line CM-136 recorded higher seedling dry weight as compared to CM-135. However, seed stored under controlled conditions recorded higher seedling dry weight as compared to seed stored under ambient conditions. The reduction in dry weight could be attributed to physiological changes occurred in seed during storage. Reduction in seedling dry weight during storage was also reported by Varshney *et al.* (2001), Krishnaveni (1984) and Quenum *et al.* (1998) and Ramalal *et al.* (1995).

In *Rabi* 1998 produce seed, Captan alone and its combination with Deltamethrin and Malathion and Bavistin + Deltamethrin were found superior as they recorded significantly higher seedling dry weight as compared to other treatments including untreated control in CM-135. Whereas, in CM-136, seed treated with Captan alone and its combination with Deltamethrin and Malathion, Bavistin + Deltamethrin, Econeem and Bavistin + Malathion were at par and gave significantly higher dry weight than other treatments. However, seed treatment with Bavistin and Malathion alone recorded low dry weight and were at par with untreated control in both the parental lines (Table 7 and 8).

In *Kharif* 1999 produce seeds, seedling dry weight increased significantly when the seeds were treated with Captan alone and its combination with Deltamethrin, as compared to other treatments in CM-135. Similarly, in CM-136, Captan, Captan + Deltamethrin, Bavistin + Deltamethrin, Econeem and Captan + Malathion were at par and recorded significantly higher seedling dry weight as compared to other treatments including untreated control (Table 9 and 10).

As such, seed treatment with Captan alone and its combination with Deltamethrin and Malathion followed by Bavistin + Deltamethrin and Econeem was found superior. Paul and Mishra (1994) also observed the positive influence of seed treatment with fungicide on maize seedling dry

weight. Similar findings were also reported by Cicero *et al.* (1992), Mao *et al.* (1997), Bhuiyah *et al.* (1995) and Varshney *et al.* (2001).

5.3.2 Seedling shoot and root length

In *Rabi* 1998 produce seeds, seedling shoot and root length decreased significantly in both the parental lines during 18 months of storage. The reduction in shoot and root length was rapid in both the parental lines. As such, there was 41.75% and 21.34% reduction in shoot and root length, respectively, after 18 months of storage in CM-135. Similarly, in CM-136, the reduction in shoot and root length after 18 months storage was 39.83% and 22.69% respectively (Table 11, 12, 15 and 16).

In *Kharif* 1999 produce seeds, gradual but significant reduction in seedling shoot and root length was observed during 12 months of storage in both the parental lines. However, the reduction in shoot length and root length was more in CM-135 as compared to CM-136 (Table 13, 14, 17 and 18).

As such, the reduction in seedlings shoot and root length was significant in both the parental lines during the storage which influenced in reduction of total seedling dry matter. Also, the parental line CM-136 recorded higher shoot and root length in both the season as compared to CM-135. It was also found that the seed stored under controlled conditions had recorded higher seedling shoot and root length as compared to ambient storage. Ravichandran (1995) reported that 25% reduction in root length coincided with 50% loss in germination in maize. Among the physiological

manifestation of seed deterioration, the delayed seed germination and speed of germination and total emergence of aged seed was evident. Nevertheless, Ramalal *et al.* (1995) and Krishnaveni (1984) reported a significant reduction in germination, root length, shoot length, dry matter and vigour index with response to period of ageing.

In *Rabi* 1998 produce seeds, seedling shoot and root length increased significantly when the seeds were treated with Captan alone, Captan + Deltamethrin, Bavistin + Malathion, Captan + Malathion, Bavistin + Malathion, Deltamethrin, Econeem and Arappu leaf powder as compared to Bavistin, Malathion alone and untreated control. Among the seed treatment Captan alone and its combination with Deltamethrin and Malathion and Bavistin + Malathion proved better which recorded significantly higher seedling shoot and root length in both the parental lines (Table 11, 12, 15 and 16).

In *Kharif* 1999 produce seeds, the seed treatment with Captan alone proved superior to all other treatment as the seedling shoot and root length was significantly higher in CM-135. The other treatments like Bavistin + Deltamethrin, Captan + Malathion, Captan + Deltamethrin, and Econeem were found superior and equally effective as compared to untreated control. Similarly, in CM-136, the seedling shoot and root length was found significantly higher when the seeds were treated with Bavistin + Deltamethrin and Captan + Malathion as compared to untreated control. Nevertheless,

Captan alone and its combination with Deltamethrin, Bavistin + Malathion and Econeem were found equally effective and were at par. However, seed treatment with Bavistin and Arappu leaf powder recorded significantly less shoot and root length and were at par with untreated control (Tables 13, 14, 17 and 18).

As such, the seed treatment with Captan alone and its combination with Deltamethrin and Malathion, Bavistin + Deltamethrin, Bavistin + Malathion and Econeem were found superior. However, seeds stored under controlled conditions recorded significantly higher seedling shoot and root length as compared to that of ambient conditions. Cicero *et al.* (1992) reported that seed treatments with fungicides including Captan alone and its combinations with Thiram and/or Carboxin exhibited increase in physiological and sanitary qualities of seeds including total shoot and root length. Similarly, Paul and Mishra (1994) observed that shoot and root length and dry weight of seedlings were significantly increased by the fungicides Captan, Thiram and Thiram + Captan treatments which is in conformity with the above findings. Similar results were earlier reported by Smith (1970), Mao *et al.* (1997) and Vallador *et al.* (1994).

5.3.3 Vigour index

Irrespective of seed treatments and storage conditions, reduction in vigour index was observed as the storage period progressed. Seed produced in *Rabi* 1998 had a rapid reduction in vigour index, as there was a 43.86 % and

41.09% loss in CM-135 and CM-136 respectively after 18 months of storage. Both the parental lines differed significantly indicating a genotypic difference as the vigour index was noted more in CM-136 as compared to CM-135. The maximum initial vigour index of 33080.64 and 38630.34, declined to minimum 18572.49 and 22758.37 in CM-135 and CM-136, respectively, after 18 months of storage (Table 19 and 20).

In *Kharif* 1999 produce seeds, the significant reduction in vigour index from initial 4869.5 to 3536.6 in CM-135 and from 4935.5 to 3796.1 in CM-136 was observed after 12 months of storage. In CM-135, the vigour index was reduced rapidly and the loss was 27.37% as compared to 23.09% in CM-136 after 12 months of storage. The interaction effect of storage period and condition of storage was found statistically significant in both the parental lines (Table 21 and 22).

Seedling vigour index, measured as medium plant length (MPL) was a useful vigour index, capable of clearly discriminating the diverse degrees of seed deterioration of the different environments and storage times (Abba and Lovato, 1999). However, the present results indicate significant differences in seedling vigour index in both the parental lines. The reduction in seed vigour was manifested by the reduction in seedling length, dry weight and germination. These results are in agreement with the findings of Narayanaswamy and Manjunatha Swamy (1996) and Kulkarni and Eshana (1988). However, significant reduction in vigour index with response to

period of ageing was reported by Krishnaveni (1984). Similar results were earlier reported by Deshpande, Kulkarni and Kurdikeri (1991).

The data indicate that the seeds stored under controlled conditions could be maintained at low levels of moisture content because of no effect of seasonal changes leading to slow degree of physiological changes in the seed. Further, low level of humidity and temperature maintained in controlled conditions have helped to maintain a greater persistence of chemicals resulting in effective control of pathogens, thereby, minimizing the seed deterioration. These factors explain maintenance of high level of vigour and viability in seeds stored under controlled conditions.

In *Rabi* 1998 produce seeds, the results revealed that seed treatment with Captan alone and its combinations with Deltamethrin and Malathion were found superior and recorded significantly higher vigour index as compared to other treatments. However, seed treatment with Bavistin + Deltamethrin, Bavistin + Malathion, Econeem, Deltamethrin and Arappu leaf powder were found superior as compared to seed treatment with Bavistin and Malathion alone and untreated controls in both the parental lines (Table 19 and 20).

In *Kharif* 1999 produce seeds, Captan alone and its combination with Deltamethrin was found most effective which recorded significantly higher vigour index as compared to other treatments including untreated control. Nevertheless, seed treatment with Captan + Malathion, Bavistin +

Deltamethrin, Bavistin + Malathion and Econeem maintained significantly higher vigour index as compared to untreated control. However, seed treatment with Arappu leaf powder was found less effective in both the parental lines (Table 21 and 22).

Seed treatment with a mixture of Captan, Deltamethrin and Pirimiphos-methyl had better vigour and quality reported by Oliveira *et al.* (1999) and Aguilera *et al.* (2000). Similarly, Smith (1970) reported that seed vigour could maintain higher vigour index for 12 months under storage when the maize seeds were treated with Ceresan, Coversan or Panogen. The present results corroborate the findings reported by Cicero *et al.* (1992), Paul and Mishra (1994) and Smiderle and Cicero (1999).

5.3.4 Accelerated ageing

Accelerated ageing test was conducted at $30 \pm 1^{\circ}\text{C}$ and $80 \pm 2\%$ RH for 10 days to the *Rabi* 1998 and *Kharif* 1999 produce seed lots before storage to know the pattern of deterioration and to assess the seed quality and storage potential. It is shown to be a good predictor of seed performance and that as the seeds age their performance in the accelerated ageing test declines (Saxena and Maheshwari, 1980).

The results (Table 23) indicate that the initial germination of parental lines CM-135 and CM-136 produced in *Rabi* 1998 was 86.0% and 92.0%, respectively, declined to 46.5% and 59.0% after 10 days of accelerated ageing. The parental line CM-135 lost 45.93% germinability as compared to 35.87% in

case of CM-136 after 10 days. With the increase in the period of accelerated ageing of maize seed at 40⁰C and 85 ± 2% RH, significant reduction in germination, vigour and increase in number of abnormal seedlings were recorded (Hussaini *et al.*, 1988). However, both parental lines withstood 5 days of accelerated ageing but the parental line CM-136 withstood for 10 days indicating higher vigour seed lot as compared to CM-135 seeds. The physiological changes in seeds subjected to accelerated ageing were largely similar to those natural ageing with the difference being the rate at which they occurred (Likhatchev *et al.*, 1984). Nevertheless, Gowda *et al.* (1996) found that under accelerated ageing (40⁰C and 100 % RH) seed germination was reduced to zero in 24 days. Similarly, Ramalal *et al.* (1995) reported that seed germination ranged from 81.9% with no accelerated ageing declined to 40.8% with 12 days of ageing treatment at 42⁰C and 90% RH.

Potential longevity of parental lines depended on the initial germination. Such association between potential longevity and initial viability was earlier reported in the seeds of a number of orthodox species (Ellis and Roberts, 1981). However, the initial germination of CM-135 and CM-136 of *Khariif* 1999 produce seed was 91.0% and 94.0% respectively, with minimum variation decreased to 58.0% and 63.0% after accelerated ageing of 10 days (Table 24). The difference is too small to differentiate the potential of longevity of these two parental lines. In natural ageing the decline was too small to correlate the accelerated ageing. However, in general, the rate at

which natural senescence occurred in *Kharif* 1999 produce seed indicates high vigour seed lot as compared to *Rabi* 1998 produce seed lot as seed was stored for longer period. Padma and Reddy (1999) observed significant and positive correlation between the germination results under natural and accelerated ageing in different inbred lines of maize. Nevertheless, Kurdikeri *et al.* (1998) reported that the germination, vigour index and seedling dry weight decreased but electrical conductivity increased as the period of accelerated ageing increased.

5.3.5 Cold test

The cold test is widely used in maize for assessing seed quality in order to select seed lots for sowing under harsh climatic conditions and for developing new maize hybrids with superior stand establishment (Wych and Liauer, 1997). The cold test is one of the oldest and most popular vigour tests for maize. This test is designed to stimulate conditions during field emergence of maize in cold and wet climatic conditions. Under these conditions the seeds either germinate slowly or do not germinate at all; and soil borne-pathogens are given an opportunity to attack the seed. Therefore, an attempt was made to test the vigour of two seed lots produced in *Rabi* 1998 and *Kharif* 1999.

Perusal of the Tables 25 and 26 revealed that, the seed treatment with Captan alone, Captan + Deltamethrin, Captan + Malathion, Bavistin + Deltamethrin and Bavistin + Malathion recorded emergence above the mean and not deviated indicating that the seed-borne and soil borne pathogens

played a little role in cold test in *Kharif* 1999 produce seed. The effect of fungicide and its combinations with insecticides may have interacted with the effect of soil, caused by the range of species of soil borne pathogens present in the soil (Woltz, 1997). Further, Woltz *et al.* (1998) stated that seed treatment with Captan increased germination and nearly eliminated differences among soil moisture level in cold test. Similarly, Pinto (1998) and Berzy *et al.* (1999) reported that seed dressing with Captan, Captan + Thiabendazole and Thiram + Thiabendazole not only had fungicidal effect, but also improved cold tolerance, leading to better seedling emergence in cold test which corroborate the present findings. However, Klokcar *et al.* (1995) reported reduction in total emergence with Carbosulfan + Mancozeb application in cold test.

The seed treatment with Bavistin, Econeem and Arappu leaf powder including untreated control had lower average germination percentage, which indicated that the soil borne-pathogen clearly decreased germination in cold test. The several factors like soil moisture, temperature, seed treatment and pathogens to be found in an un-sterilized germinating medium also have been reported to influence the results of cold test germination and pathogen response (Woltz *et al.*, 1998).

The significant differences were observed in both the parental lines produced in *Rabi* 1998 and *Kharif* 1999. Seed produced in *Rabi* 1998 had poor emergence in cold test as compared to seed lot produced in *Kharif* 1999. The

freshly harvested seed lot tested for cold tolerance after pre-storage treatment had emergence of 70.0% and 74.5% in CM-135 and CM-136 respectively, in *Kharif* 1999 parental lines seed. On the other hand, seed produced in *Rabi* 1998 recorded 45.0% and 50.5% average mean germination in CM-135 and CM-136 respectively when tested for cold tolerance after 5 months. This indicates that seed lot could not tolerate stress condition of low temperature and had low vigour and found badly infested with soil pathogens in an unsterilized soil. However, the parental line CM-136 was found moderately tolerant to cold stress, as it has recorded higher emergence as compared to the parental line CM-135. In general, it can be concluded that, the fresh seed lot having high vigour and tolerance to cold stress emerges well under cold test and poor seed lot emerges poor or does not emerge at all. Thus the seed lot produced in *Rabi* 1998 and *Kharif* 1999 can be differentiated for weak (poor) and high (strong) vigour seed lot in cold test respectively. Leist *et al.* (1997) reported that, it was possible to differentiate between weak and strong vigour seed lot using 7 days cold test. Nevertheless, Zarick *et al.* (1995) and Mahajan *et al.* (1992) differentiated inbred lines of maize for their resistance to cold test.

To guarantee good field emergence (at least 90%) the level of normal seedlings in the cold test should be at least 95%. Based on this value the seed quantity in testing trials could be fixed for desired plant stand (Waes and Van, 1995). In the present study, the average mean germination recorded in standard germination test and the field emergence in August, 2000 (Tables 39

and 40) had exhibited higher germination than the emergence in cold test which corroborate the findings of Waes and Van (1995). Cold test is not consistently reliable predictor of early field emergence (Buris and Navratic, 1979). However, Milosevic *et al.* (1994) and Lovato and Balboni (1997) reported close relationship of field emergence with the results of cold test.

5.3.6 Electrical conductivity (EC)

In *Rabi* 1998 produce seeds, the electrical conductivity (EC) values differed significantly in both the parental lines irrespective of seed treatments and storage conditions. The minimum EC values recorded initially in CM-135 (3.97) and CM-136 (3.55) were found to increase significantly to the maximum 7.14 and 6.45, respectively, after 18 months of storage. The rapid increase in EC value in the parental line CM-135 and CM-136 was observed after 9 months and 12 months of storage, respectively. In general, the parental line CM-135 recorded higher EC value as compared to the parental line CM-136. However, seed stored under ambient conditions showed higher EC values indicating low vigour and faster deterioration as compared to seed stored under controlled conditions.

Significant differences in treatments, storage period and conditions of storage and their interactions were observed in both the parental lines. In the parental line CM-135, seed treatment with Malathion and Arappu leaf powder recorded highest EC values i.e. 5.97 and 5.85, respectively, while the lowest EC value 4.89 was observed in an untreated control. Seed treatments

with Captan + Deltamethrin and Deltamethrin alone followed by untreated control recorded lowest EC values 4.36, 4.36 and 4.39, respectively, in CM-136 after 18 months of storage (Table 27 and 28).

In *Kharif* 1999 produce seeds, both the parental lines showed different responses to storage period. The EC value found to increase gradually as the storage period progressed. The initial EC values 2.81 and 2.52 were found to increase significantly to 4.18 and 3.84 in CM-135 and CM-136, respectively, after 12 months of storage. The seeds stored under controlled conditions recorded low EC values as compared to seeds stored under ambient conditions.

Significant differences in treatments, storage period, condition of storage and their interactions were observed in both the parental lines. The seed treatment with Arappu leaf powder recorded highest EC values 3.67 and 3.30 in CM-135 and CM-136, respectively. However, lowest EC values were recorded in an untreated control in both the parental lines. The seed treatment with Captan + Malathion, Captan + Deltamethrin and Bavistin + Malathion showed beneficial effect with both the parental lines (Table 29 and 30).

In general, as the storage period increased the EC values also increased. During storage some physiological changes might have occurred due to changes in moisture and natural senescence, which might have responsible for the leakage of seed leachate. Poor membrane structure and leaky cells are usually associated with deterioration in low vigour seed lots

were reported by Paul and Ramaswamy (1979). However, increase in EC value with respect to storage period was also reported by Deshpande, Kulkarni and Kurdikeri (1991). Nevertheless, Furguson *et al.* (1990), Dadlani *et al.* (1995) and Kalpana and Rao (1996) reported increased EC values of seed leachate as a result of increased permeability in different crop species with ageing.

The higher EC values recorded in the seeds treated with Econeem, Captan + Deltamethrin, Captan + Malathion, Deltamethrin, Bavistin + Deltamethrin, Bavistin + Malathion followed by Captan might be related to leaching of chemicals infused with the seeds as well as injurious effect of active ingredients on cell membrane. In spite of their higher EC values, seed treatments with these chemicals registered higher germination, dry matter, shoot and root length and vigour index. However, the botanical based product Arappu leaf powder had recorded highest EC value. Kurdikeri *et al.* (1993) observed that in spite of higher EC values with KH_2PO_4 and Bavistin + Thiram (slurry) treatments registered higher germination. Nevertheless, Vishwa Prasad *et al.* (2001) observed increased electrical conductivity irrespective of fungicide treatments during storage of maize hybrid for 16 months, which are in conformity with the present findings.

5.4 Seed health

Seed produced in Rabi 1998 recorded a total number of 12 fungal species namely, *Alternaria alternata*, *Aspergillus flavus*, *A. niger*, *A. oryzae*,

Cladosporium spp., *Curvularia lunata*, *C. pallescens*, *Drechslera hawaiiensis*, *D. tetramera*, *Epicoccum* spp., *Penicillium* spp. and *Rhizopus* spp. were encountered collectively on the seed of both the parental lines (Table 31 and 32). Similarly, seeds produced in *Kharif* 1999 exhibited all the fungi that recorded in *Rabi* 1998 produce seeds except *A. oryzae* which was replaced by *Fusarium moniliforme* (Table 33 and 34). The most predominantly encountered fungi on both the parental lines included *Alternaria alternata*, *Aspergillus* spp., *Curvularia lunata*, *Drechslera* spp., *Penicillium* spp. and *Rhizopus* spp. However, the storage fungi like *Penicillium* spp., *Aspergillus* spp. and *Rhizopus* spp., by and large kept on increasing with the storage period in untreated control. Lal and Saxena (1977), Handoo and Aulakh (1979) and Kommendahl and Windels (1986) recorded almost all the fungi on different maize cultivars, hybrids and their parental lines. The fungal incidence was comparatively higher on the seed stored under ambient storage than under controlled conditions, since the fungicides and insecticides remained active and the seed moisture was low in controlled conditions. However, the seed moisture kept on fluctuating under ambient condition resulting in the degradation of chemical used for seed treatments as compared to controlled storage. This could be the reason for recording higher incidence of seed mycoflora on seed stored under ambient conditions. However, the infestation of *Aspergillus niger* and *A. flavus* was nearly 100% in an untreated control and was responsible for recording lower germination and vigour in *Rabi* 1998 produce seeds. Christansen (1973) stated that storage fungi that invade seeds at moisture

content in equilibrium with relative humidity upto 85% grow very slowly at temperatures below 10⁰C. Irrespective of seed treatments and storage conditions, the presence of saprophytes went on increasing as the storage period progressed. Fungi and biodeterioration of maize seed in storage under different conditions were studied by Quenum *et al.* (1998) who reported that, among the high moisture content (16.6%) seeds, *Aspergillus* spp. were the main fungi, but in seeds with medium and low moisture content (13.6% and 10.3%), *Rhizopus*, *Aspergillus*, *Fusarium* and *Penicillium* species were common in storage. Nevertheless, Moreno-Martinez and Vidal-Gaona (1981) observed that seeds with higher moisture content had faster decrease in germination due to invasion of the seeds by storage fungi. Similar results were also reported by Qasem and Christensen (1958).

The seed treatments with different chemicals, in general exhibited a significant influence as the incidence of different fungi drastically reduced in both the parental lines and improved germination and vigour. Among the treatments, seed treated with Captan, Bavistin alone and their combinations with Deltamethrin and Malathion proved highly effective in eliminating almost all the fungi except some saprophytes which showed their presence as the storage period progressed. The other treatments like Econeem, Arappu leaf powder, Deltamethrin and Malathion alone were found comparatively less effective. The seed treated with Arappu leaf powder and Econeem recorded more storage fungi as the powder coated on seed and the active

ingredient might have failed to check the incidence of fungi. Paul and Mishra (1994) found that when the seeds were treated with different fungicides including Captan, the occurrence of fungi on the treated seeds was reduced and improved the germination. Satyanarayana and Reddy (1994) indicated that the Deccan maize hybrid could be stored upto 15 months with minimum fungal flora when the seeds were treated with Captan and its combination with Malathion. Similarly, Aguilera *et al.* (2000) reported that, a mixture of Captan, Deltamethrin and Pirimiphos-methyl had maintained better physiological quality of maize seeds. Dey *et al.* (1988) reported that maize seeds treated with Bavistin improved seed germination by elimination of fungi present on seeds. The reduction of storage fungi with different chemicals was also reported by Raju and Lal (1977), Cicero *et al.* (1992) and Moreno-Martinez and Ramirez (1985).

During storage, no natural infestation of storage insects was recorded in the treated seeds in both the conditions of storage. As the treated and untreated seeds were stored together under same plastic bin covered with lid could not find entry and environment for survival of insects. Similar results were also reported by Kurdikeri *et al.* (1993^a).

5.5 Persistence of fungicides and/or its combinations with insecticides on seed after storage

The persistence of fungicides and/or their combination with insecticides is of paramount importance as it determines the longevity of effectiveness of seed treatment during storage. Studies conducted by a galaxy

of researchers have revealed that seeds treated with systemic and non-systemic fungicides became biologically inactive and lost their fungicidal properties with the passage of storage period (Dharam Vir, 1983; Dharam Vir and Sharma, 1986; Nene and Thapliyal, 1993; Vyas, 1993 and Maude, 1996).

The results with regard to biological activity of fungicides and/or their combinations with insecticides indicated that the protectants were biologically active and had retained their fungicidal properties even after 18 months on seed when kept under ambient as well as controlled conditions (Table 36). The present investigations revealed that as the storage period progressed the area of inhibition zone produced by seed protectants decreased indicating degradation of protectants and loss of biological activity during storage. Gupta and Chatrath (1983) reported degradation of fungicides with increase in storage period when stored in cloth bags. Nevertheless, the fungicides used by Dharam Vir (1977 and 1980) lost their fungicidal properties after storage for one year.

The highest average initial inhibition zone of 2061.9 mm² was produced around the seed treated with Bavistin alone. Being a systemic fungicide, Bavistin present on seed diffused in the media inhibiting the growth of *Fusarium moniliforme* thereby produced larger inhibition zone. Mahajan (1997) observed best control of *F. moniliforme* by Thiram + Bavistin followed by Bavistin and Thiram alone for 180 days. However, Paul and

Mishra (1993) reported that Captan + Thiram was more effective than Bavistin, Captan and Diathane - M 45 against *F. moniliforme*.

The initial amount of Bavistin, Bavistin + Deltamethrin, Bavistin + Malathion, Captan, Captan + Deltamethrin and Captan + Malathion that retained on the seed soon after the treatment was 570, 565, 558, 585, 550 and 545 μg respectively. The corresponding average inhibition zones obtained from the seed treated with these protectants were 2061.9, 1789.9, 1904.15, 1923.5, 1643.05 and 1468.5 mm^2 respectively.

Perusal of the data revealed that after six months seed treated with Bavistin alone and stored under ambient conditions was highly effective as it showed biggest inhibition zone of 1607.38 mm^2 with only 430.00 μg of fungicide on the seed followed by Captan which have the second highest inhibition zone of 1589.60 mm^2 with 481.25 μg of fungicide remained on the seed. Similarly, though the amount of Captan remained on the seed stored under controlled conditions was 510.00 μg , the inhibition zone produced by it was comparatively small (1661.00 mm^2 average zone) which clearly shows that the Bavistin was most effective as it elaborated an inhibition zone of 1679.18 mm^2 with only 443.75 μg of fungicide retained on the seed after six month. Savitri *et al.* (1994) reported that, due to better persistence of residual toxicity of Thiram alone and/or its combinations with Malathion and Carbofuran and Bavistin + Malathion on the sorghum seed found most

effective against test insect *Rhyzopertha dominica* and storage fungal infestation for 18 months of storage.

After 12 months of storage, seed treated with Captan alone produced highest average inhibition zone of 1335.80 mm² and 1417.58 mm² under ambient and controlled storage conditions, respectively followed by Bavistin alone, where the average inhibition zone was 1225.00 and 1368.35 mm² under similar storage conditions, respectively. It is indicated that the efficacy of Bavistin has decreased after 12 months, while Captan maintained its fungicidal properties even after 18 months of storage. Saleh and Negm (1981) reported longer persistence of Carbendazim residue. However, Singh *et al.*, (1987) demonstrated that seed treatment with Bavistin resulted in very low persistence after 42 days. Pinho *et al.*, (1995) observed best control of *F. moniliforme* with Captan. Raju and Lal (1977) found that Captan effectively controlled the growth of *F. moniliforme* and *Cephalosporium acremonium*. Similar results have been obtained by Hoppe (1957) who got good control of both the fungi with this fungicide even at lower doses. Tadiouse *et al.* (1993) reported that the initial deposits of Thiram on maize seeds of 209 ppm decreased to 203, 200, 189, 183, 180, 171, 150, 147, 144, 126, 106 and 62 ppm after 1, 2, 3, 4, 5, 7, 14, 21, 28, 35, 42 and 50 days, respectively. Nevertheless, Singh *et al.* (1987) demonstrated that seed treatment with Bavistin resulted in very low persistence after 42 days.

After 18 months of storage, the seed treated with Captan exhibited highest inhibition zone. The combination of fungicides and insecticides

effectively controlled the storage fungi during 18 months of storage and recorded higher germination as compared to control. However, Bavistin, Bavistin + Deltamethrin and Bavistin + Malathion seems to be degraded faster as compared to Captan, Captan + Deltamethrin and Captan + Malathion. In storage, seed treatment with Captan alone and its combination with Deltamethrin and Malathion maintained physiological quality and protected seed from common fungi that encountered on seed during storage. Work done on fungicidal seed treatment of maize in India using non-systemic fungicides (Laxminarayan *et al.*, 1966) suggests the use of only Thiram or Captan for protection of seed from common fungi. Satyanarayan and Reddy (1994) indicated that Captan and Captan + Malathion protected the fungal flora in stored maize seed for 15 months. Nevertheless, Aguilera *et al.*, (2000) reported Captan + Deltamethrin had better physiological quality and increased germination. The efficacy of Captan against various seed borne fungi has been reported by other workers (Patil, 1980; Oliveira *et al.*, 1999; Reddy and Subbayya, 1981). Similarly, Ramirez-Gongalez and Moreno (1982) reported that the fungicide residue of Benomyl and Captan persisted on maize seed stored for 120 days prevent the growth of storage fungi.

In general, the inhibition zone produced around the treated seed stored under controlled condition was higher as compared to the seed stored under ambient conditions. It could be the result of fluctuation of seed moisture, temperature and relative humidity, which might have influenced the

degradation of protectants present on seed that were stored under ambient conditions. Degradation of pesticide influenced by storage conditions also reported by Raju and Chatrath (1978). Faster degradation of seed protectants under ambient condition as compared to moisture proof container was earlier reported by Dharam Vir and Sharma (1980) and Mahajan (1997).

5.6 Effectiveness of seed protectant against *Rhyzopertha dominica*

Samples of treated maize seeds stored under ambient conditions of temperature ranging from 5.4 to 40.1⁰C and relative humidity 36 to 92% and controlled storage conditions 20 ± 1⁰C and 30 ± 10% RH were taken after 3, 6, 9, 12, 15 and 18 months of storage. Mortality of test insect *Rhyzopertha dominica* was assessed after 1, 2, 3, 5 and 10 days exposure to the treated grain at ambient conditions in ventilated plastic vials. The LT₅₀ obtained by Probit method (Annexure 1) were analyzed by factorial RBD (Table 37).

Significant differences were recorded in different treatments, storage period, condition of storage and their interactions on the mortality of *Rhyzopertha dominica* throughout the storage period (Table 37).

The time required to obtain 50% mortality (LT₅₀) of test insect with each protectant increased during the storage period of 18 months. As expected there was a general tendency for the toxicity of the residue that present on seed to decrease with the passage of time. This would reflect gradual chemical decay of the residue and perhaps biological inactivation of

the residue of protectants applied to seeds during storage (Noble *et al.*, 1982; Hargreaves *et al.*, 1982; Samson and Parker, 1989).

The minimum effective rate of protectant for any given period of protection was a function of both its inherent potency and its rate of breakdown. Therefore, the order of effectiveness of the protectants depended on the period of protection desired. Malathion showed similar potency as Deltamethrin and remained effective for 12 months but it was found less effective during long-term storage. Degradation of Malathion and loss of its biological activity after 12 months was also observed by Salameh *et al.* (1977). Nevertheless, *R. dominica* is reported to be highly resistant to Malathion ($LC_{50}=0.01665$) as compared to Deltamethrin ($LC_{50}=0.00439$) (Srivastava *et al.*, 2000) and inability of the insects to walk, rather than death, was a consistent response criterion and low seed moisture (below 12 %) might have reduced the time for response and thereby obtained high mortality of insects. However, Sattigi *et al.* (1993) reported that Malathion at 8 ppm was effective upto 45 days after treatment (56.66 % mortality). Contrary to this Mutiro *et al.* (1992) reported ineffectiveness of Malathion in controlling insect pests.

Despite chemical decay and breakdown (Table 38) the potency of Deltamethrin was significantly superior among the protectants when tested against *R. dominica* and was found biologically active throughout the storage period. Deltamethrin recorded lowest LT_{50} values (less than 5 days) and gave nearly complete mortality of the test insect with 10 days exposure indicating

residual toxicity of Deltamethrin for a longer period. High toxicity of Deltamethrin to *R. dominica* reported by Samson and Parker (1989), Malarkodi and Srimathi (2001), Smiderle and Cicero (1999) who observed complete protection from test insect without affecting physiological quality of maize seed. Yadav and Singh (1994) reported protection of maize seed for 9 months by the seed treatment with Deltamethrin as compared to one month in case of Malathion. However, Bhuiyah *et al.* (1995) observed seed treatment with Deltamethrin and Malathion effectively protected maize seed for 9 months.

Fungicide-insecticide combinations viz., Captan + Deltamethrin, Captan + Malathion, Bavistin + Deltamethrin, Bavistin + Malathion and Malathion alone were found equally effective against *R. dominica* throughout the storage period when the seeds treated with these protectants were stored under controlled conditions. But the potency of these protectants remained effective for 15 months and thereafter their biological activity decreased when the treated seeds were stored under ambient conditions. The effectiveness of combinations of fungicides and insecticides have also been reported by Prakash and Kaurav, (1983); Ravindranath *et al.* (1990). However, Savitri *et al.* (1994) reported that Malathion and Carbofuron alone and their combination with Thiram and Bavistin were most effective against *R. dominica* for 18 months. In storage, complete protection from *R. dominica* was achieved by the seed treatment with Deltamethrin (Samson and Parker, 1989; Arthur, 1994).

Of the fungicides used Captan and Bavistin were found equally effective against *R. dominica* for a period of 9 and 12 months when the treated

seeds were stored under ambient and controlled storage conditions, respectively. The results obtained in the present studies on the efficacy of fungicides could be attributed to one or more combinations of the factors like antifeedant action. Similar findings were also reported by Savitri *et al.* (1994) with Thiram to control *R. dominica* in storage. The compatibility of certain pesticides in control of seed borne fungi and insect pests have been earlier reported by Savitri *et al.* (1998), Savitri *et al.* (1994), Kurdikeri *et al.* (1993) and Ravindranath *et al.* (1990).

The botanical based product Arappu leaf powder was found least effective and showed early degradation of material applied on seed. It had the potency similar to the fungicides used but the adults of test insect frequently bored and penetrated the maize seed. In this way the test insect may have avoided contact with superficial deposits of protectant on maize seed, resulting in lower potency than would be expected otherwise. Many insects are unable to infest certain plant because of the presence of particular noxious substances (Frankel, 1969). The neem tree, *Azadiracta indica*, is known to be rarely infested by insects (Bhatia and Sikka, 1957) and has repellent or antifeedant effects (Ruscoe, 1972, Jilani and Mallik, 1973, Leuschner, 1975). In the present study neem based commercial product Econeem however, remained effective for 12 and 15 months when the treated seeds were stored under ambient and controlled storage conditions respectively. Sharma (1995, 1999) reported that neem seed kernel powder (NSKP) at higher concentrations

gave protection against insect pests for longer period. However, neem oil completely protected the maize seed for 9 months. Similarly, Ketkar (1976) reported 50 to 70% less infestation by *Sitophilus oryzae*, *R. dominica* and *T. castaneum* due to application of neem oil.

Among the seed protectants tested against *R. dominica*, the order of potency (judged by LT_{50} values) was Deltamethrin > Captan + Deltamethrin > Captan + Malathion > Bavistin + Malathion > Bavistin + Deltamethrin > Econeem > Captan > Bavistin > Arappu leaf powder (Table 37).

The efficacy of protectants (in terms of mortality of test insect and LT_{50}) present on seed stored under controlled condition was significantly higher. This could possibly be due to better persistence and residual toxicity of the protectant that remained on seed. However, the potency of seed protectants decreased considerably when the treated seeds were stored under ambient conditions. The moisture content of seed is known to dramatically affect the persistence of many insecticides on stored seed as also the temperature affects the rate of degradation of pesticides and consequently decreases the biological activity of residue present on seed with the passage of storage time (John and Elizabeth, 1982; Dresmarchelier, 1978; Noble *et al.*, 1982 and Hargreaves *et al.*, 1982).

5.7 Persistence of Deltamethrin on seed after storage

Deltamethrin is considered to be a safe insecticide for seed treatment as it is effective at very low dosage and also found compatible with many

fungicides. Because of low mammalian toxicity and high efficacy, synthetic pyrethroids like Deltamethrin have gained popularity with farmers as suitable replacement of Malathion and other toxic organophosphorus insecticides, which are currently in use. Several researchers studied the persistence of Deltamethrin residues on vegetable fruits (Gajbhiye *et al.*, 1994 and Agnihotri *et al.*, 1985), its efficacy has not been studied on the seed under storage. Hence, an attempt was made to study the effect of this insecticide on seed quality and its biological effectiveness against *Rhyzopertha dominica* and seed mycoflora when the seeds stored for some time.

Perusal of the table 38 indicated that the initial deposit of Deltamethrin retained on the seed after treatment was found to be 0.8364 and 0.8437 ppm on the seed of CM-135 and CM-136 respectively. However, after 3 months of storage, the amount detected on the seeds of CM-135 and CM-136, when stored under ambient conditions was 0.7530 and 0.7584 ppm respectively. Similarly, the amount of residues detected on the CM-135 and CM-136 when stored under controlled condition was 0.7626 and 0.7591 ppm respectively. Thereafter the degradation of insecticide residues was observed over a period of 18 months. But its residues on the seed persisted at lower concentration even after 18 months. Franklin *et al.* (1994) reported that the Deltamethrin decayed quickly initially but there was no significant degradation during a storage period of 16 months.

After 18 months, the amount of residues present on the seed stored under ambient and controlled condition was (0.1425 and 0.1469 ppm) and (0.1941 and 0.1908 ppm) on the seed of CM-135 and CM-136, respectively. Thus, irrespective of storage conditions, the loss of deltamethrin was 76 to 83% after 18 months of storage. Hargreaves *et al.* (1982) reported that the biological activity of the Deltamethrin residues against *Sitophilus oryzae* (L.) declined to 78% of the initial value after 3 months, and to 65% after 15 months application. From the table 38, it can be conducted that, even after the 18 months, residues were effective and caused 100% mortality of *Rhyzopertha dominica*. At lower concentration also the efficacy was maintained throughout the storage period. Yadav and Singh (1994) reported persistence of Deltamethrin on maize for 6-9 months. Nevertheless, Samson, Parker and Jones (1989) indicated that even at lower dosage, the toxicity of Deltamethrin persisted for 36 week with 100% mortality of *R. dominica*.

The dissipation of Deltamethrin residues present on the seed stored under controlled conditions was comparatively low as compared to the seed stored under ambient conditions. Degradation of residue may be due to elapse of time, temperature and moisture content of the seed.

5.8 Seedling emergence of stored seed in the field

Seed produced in *Kharif* 1999 and *Rabi* 1998 stored under ambient and controlled conditions for 12 and 18 months, respectively, were tested for emergence in the field in *Kharif* (August 2000) and *Winter* (February 2001).

In a study of field emergence conducted in August 2000, seed produced in *Rabi* 1998 exhibited poor emergence in the field. The results showed that seed treatment with Captan + Malathion, Captan, Bavistin + Deltamethrin, Captan + Deltamethrin, Deltamethrin and Bavistin + Malathion recorded significantly higher emergence as compared to other treatments and untreated control in CM-135. However, in CM-136, the emergence was significantly higher in the seeds treated with Captan, Captan + Deltamethrin, Deltamethrin, Bavistin + Malathion, Captan + Malathion and Econeem and was at par. The parental line CM-136 recorded 19.53% higher germination as compared to CM-135 where, the mean germination was 64.0% and 51.5% respectively. Nevertheless, seeds stored under controlled condition had significantly high emergence in CM-135 and CM-136 as compared to seed stored under ambient conditions by 21.24% and 11.76% respectively.

The interaction effect of seed treatment and storage conditions was significant in both the parental lines (Table 39).

In another study of field emergence conducted in February 2001, the effect of storage period was pronounced which resulted into poor emergence of *Rabi* 1998 produce seeds (Table 41). The parental line CM-135 recorded poor emergence (42.5%) in the field as compared to parental line CM-136 that recorded 54.5% emergence giving around 22.02% higher emergence than CM-135. The seed treatment with Captan + Malathion, Captan + Deltamethrin, and Captan alone recorded significantly higher emergence as compared to

other treatments and untreated control in CM-135. Similarly, the seed treatment with Captan alone, Captan + Deltamethrin, Captan + Malathion and Deltamethrin exhibited significantly higher emergence and were at par in CM-136. The poor emergence (28.0%) in case of seed stored under ambient condition was noted as compared to seeds stored under controlled conditions (57.0%) in CM-135. Whereas, significantly higher emergence 67.0% was recorded in CM-136 when the seeds were stored under controlled conditions giving 37.31% higher emergence as compared to seed stored under ambient conditions (42.0%). In general, the field emergence in February 2001 was recorded low as compared to August 2000 because of seed deterioration after 18 months in storage.

The interaction effect between seed treatment and storage conditions was significant in both the parental lines (Table 41).

In a study conducted in August 2000 in the field, the *Kharif* 1998 produce seeds with pre-storage treatments stored under ambient and controlled conditions recorded good emergence as the initial seed vigour and standard germination was high (Table 40). It was found that seed treatment with Captan + Deltamethrin, Captan + Malathion, Captan alone, Bavistin + Deltamethrin and Bavistin + Malathion exhibited significantly higher emergence in CM-135. Irrespective of storage conditions, seed treatment with Captan + Deltamethrin or Captan + Malathion recorded more than 80% field emergence in CM-135. Similarly, in CM-136, seed treatment

with Captan + Malathion, Captan + Deltamethrin, Bavistin + Malathion and Captan alone increased seedling emergence remarkably high (more than 80.0%) irrespective of storage conditions and were at par. The mean germination was 74.5 and 77.5 per cent in the parental line CM-135 and CM-136, respectively. However, the seed stored under controlled conditions had a higher seedling emergence in the field as compared to seed stored under ambient conditions.

A non-significant interaction effect between seed treatment and storage conditions was observed in both the parental lines (Table 40).

In a study conducted in February 2001 for *Kharif* 1999 produce seeds, the results showed that seedling emergence was remarkably low as compared to that of August 2000. After 12 months of storage, the seedling emergence was improved remarkably with the seed treatment Captan alone and Captan + Deltamethrin followed by Captan + Malathion in both the parental lines (Table 42). However, seed treatment with Arappu leaf powder and Econeem was found least effective among the treatments. It was observed that the seed treatment with Captan was most effective which recorded 80.0% emergence irrespective of storage conditions in CM-136. Genotypic difference was also noted, as the seedling emergence was 7.63% high in CM-136 than CM-135. The mean seedling emergence was 65.5% and 70.5% in CM-135 and CM-136, respectively. Nevertheless, seed stored under controlled conditions recorded

significantly high emergence as compared to seed stored under ambient conditions.

A non-significant interaction between treatments and storage conditions was noted in CM-135 whereas it was significant in CM-136 (Table 42).

Overall seeds produced in *Rabi* 1998 and *Kharif* 1999 recorded higher seedling emergence in August 2000 than February 2001 in both the parental lines. The seed produced in *Kharif* 1999, however, had higher emergence as compared to seed produced in *Rabi* 1998. The high initial vigour, germination and low moisture could have resulted into higher emergence in both the season when the seeds were stored for 12 months in case of *Kharif* 1999 produce seeds. Field emergence conducted in August, 2000 had recorded higher emergence as compared to February 2001, because after August 2000, some deterioration might have occurred during subsequent storage period as indicated by reduction in dry matter, shoot and root length, vigour index, high electrical conductivity and high incidence of seed mycoflora due to high moisture content leading to natural senescence. The reduction in field emergence and plant survival percentage in aged seeds lot may be due to initial low vigour (Teckrony and Egli, 1991). Significant decline in germination percentage, after 180 days stored seeds, has also been reported by Dey and Mukherjee (1986) and Varshney *et al.* (2001). Nevertheless, parental line CM-136 had better storability as compared to CM-135.

The results also indicated that the seeds stored under controlled conditions maintained low moisture, high shoot and root length, dry matter, vigour index and low seed mycoflora leading to slow degree of physiological changes in seed, thereby minimizing the seed deterioration and recorded higher emergence as compared to seed stored under ambient conditions. Significant decline in emergence of seed stored under ambient conditions was also reported by Dey and Mukherjee (1986) and Narayana swamy and Manjunatha swamy (1996).

Differences in field emergence were observed among the treatments. Seed treatment with Captan alone, Captan + Deltamethrin, Captan + Malathion, Bavistin + Deltamethrin, Deltamethrin alone, Bavistin + Malathion followed by Econeen recorded significantly higher emergence as compared to untreated control in *Rabi* 199 produce seed. However, in case of *Kharif* 1999 produce seed, a significantly higher emergence was observed with the seed treatment of Captan alone, Captan + Deltamethrin, Captan + Malathion, Bavistin + Deltamethrin, Bavistin + Malathion, Bavistin alone followed by Econeem. The seed treatments, in general, improved the germination and vigour in stored seeds. Also, the field emergence in August 2000 was generally higher as compared to February 2001. The loss in germinability and vigour after 12 and 18 months storage of *Kharif* 1999 and *Rabi* 1998 produce seed, respectively, due to natural ageing and low temperature in February 2001 could be the reason of low emergence.

Berzy *et al.* (1999) reported that seed dressing with Captan not only had a fungicidal effect, but also improved cold tolerance, leading to better seedling emergence and increased yield. The present findings are in conformity with the results obtained by Mao *et al.* (1997), McGree *et al.* (1994), Wilson *et al.* (1993), Cicero *et al.* (1992) and Lim and Kinsey (1973). Contrary to this, Pinto (1998) reported that the fungicide treatment including Captan and Thiram and their combinations with insecticides was not efficient to increase seedling emergence in the field and sterile conditions.

5.9 Seedling emergence in the field after pre-sowing seed treatments

Hybrid maize seeds are generally stored for a period of six months before they are planted in the following season, while their parental lines once developed need to be maintained for a longer period. Because of non-availability of proper storage facilities in most parts of the country, majority of the stored seed get infected with different levels of mycoflora, which leads to deterioration of seed quality in more than one way (Christenson, 1980).

Besides storage conditions, packaging materials as well as seed moisture, relative humidity and temperature of storage environment influence seed viability in storage. Nevertheless, physiological deterioration and biochemical changes that occur after a considerable period of storage prevent seeds from normal germination and vigorous growth. Such seeds giving high germination in laboratory often fail to perform well across a wide range of soil type and environmental conditions. This would leads to monetary loss to seed traders and poor yield at farmers' field due to use of

low quality or below standard seeds. Under such circumstances, it may be imperative to depend on alternative to enhance vigour of stored seeds. Therefore a simple method of controlling physiological and pathological deterioration of seed would be of great help to cultivars. The beneficial effect of pre-sowing seed treatment with growth regulators, agro-chemicals, fungicides, water etc, was reported to increase seed quality in several crop species (Basu, *et al.*, 1974; Basu, 1976; Basu and Pal, 1979; Kurdikeri *et al.*, 1993 and Kulkarni and Eshanna, 1988). However, very few reports are available on the influence of seed treatment with fungicides on field emergence of stored maize seed. Hence, an attempt was made to study the effect of pre-sowing seed treatment on stored seeds in Aug. 2000 and Feb. 2001.

Performance of aged seeds

The findings of the present study (Table 43 to 46) indicated that the emergence was significantly higher in Aug. 2000 as compared to Feb. 2001, which is mainly due to its higher initial seed germination percentage and vigour. However, the beneficial effect of pre-sowing seed treatment was more pronounced in old or less viable seeds than fresh or viable seeds. As also, the field emergence was more influenced by seed treatment in *Rabi* 1998 produce seed than *Kharif* 1999 produce seeds over the untreated control. As on the whole, irrespective of seed treatments, the field emergence was enhanced by 20.59 and 14.29 per cent in CM-135 and CM-136 respectively in Feb. 2001 (18 months old seed) as compared to 15.29% (CM-135) and 13.76% (CM-136) in

Aug. 2000 (12 months old seed) over the untreated control in *Rabi* 1998 produce seeds. Similarly, in *Kharif* 1999 produce seeds, irrespective of seed treatments, the field emergence was increased by 14.41 and 13.49 per cent in CM-135 and CM-136, respectively, in Feb. 2001 (12 months old seeds) as compared to 11.54% (CM-135) and 8.97% (CM-136) over the untreated control in Aug. 2000 (8 months old seeds). These results are in conformity with the findings of Ravikumar (1981) and Kulkarni and Eshanna (1988). Similar results were also reported in maize by Kurdikeri *et al.*, (1993^c, 1995), who observed more beneficial response in 18 months old seeds than 12 months old seed due to seed invigouration.

The effect of storage condition was more pronounced in *Rabi* 1998 produce seed as the seed stored under controlled conditions and having been treated with pre-sowing seed treatments exhibited significantly higher emergence as compared to seed stored under ambient conditions. During ambient storage, natural ageing process could have impaired the physiological quality of seed when stored for longer period as compared to *Kharif* 1999 produce seeds. Loss of germinability during storage has been found to be closely associated with increase in membrane leakage (Abdul-Baki and Anderson, 1973), free fatty acidity and lipase activity (Dey and Mukherjee, 1986) and decrease in total activity of peroxidase (Mc Hargue, 1920) and dehydrogenase (Thorneberry and Smith, 1955). Significant decline in emergence of seed stored under ambient conditions was also reported by Dey and Mukherjee (1986); Narayana Swamy and Manjunatha Swamy (1996).

The effect of pre-sowing seed treatment was more pronounced on the seed stored under ambient conditions than controlled conditions in *Rabi* 1998 produce seeds. When *Rabi* 1998 produce seeds were stored under ambient conditions, the seedling emergence was enhanced irrespective of seed treatment by 26.09 and 15.00 per cent in CM-135 and CM-136, respectively, as compared to 17.98% (CM-135) and 13.79% (CM-136) in seed stored under controlled conditions over untreated control in Feb. 2001. However, such effect was not much pronounced in case of *Kharif* 1999 produce seeds.

Influence of pre-sowing seed treatments

Pre-sowing seed treatment of Hydration-dehydration and Hydration-dehydration followed by dry seed dressing with Captan improved the seedling emergence significantly over untreated control (Table 43 to 46). Direct benefits of 24 h priming to maize seeds included faster emergence, better stand, and a lower incidence of resowing, more vigorous plants, better drought tolerance, earlier flowering, earlier harvest and highest seed/grain yield reported by Harris *et al.* (1999). Nagar *et al.*, (1998) concluded that the hydroprimed seed of maize treated with or without 0.2% Thiram, increased speed of germination, emergence and improved the field stand and plant growth.

Hydration-dehydration alone increased the field emergence remarkably by 28.24% to 39.71% in *Rabi* 1998 produce seed and 17.93% to 27.97% in *Kharif* 1999 produce seed. Beneficial effect of presoaking in water

was also reported by Kurdikeri *et al.*, (1993, 1995); Kulkarni and Eshanna, (1988). Pre-soaking of aged seeds activates several metabolic changes responsible for the cellular repair (Berjak and Villiers, 1972), physiological advancement of seeds (Heydecker, 1974), increased enzymatic activity (Dey and Mukherjee, 1986). Rudrapal and Basu (1979) noticed that a significant reduction in lipid peroxidation reaction in hydrated-dehydrated seeds resulting in maintenance of better membrane integrity in wheat. Further Basu (1976) reported the concept of a protection from free radical damage to cellular component as a major reason of the beneficial effect of treatment.

Hydration-dehydration followed by dry seed dressing with Captan or Kalisena and Captan alone also gave beneficial effect to the seed and enhanced seedling emergence as compared to untreated control. Seed treatment with Hydration-dehydration + Captan increased the emergence by 17.43% to 38.23% in *Rabi* 1998 produce seed and by 8.97% to 24.58% in *Kharif* 1999 produce seeds. Wilson and Mohan (1992) reported increased in stand by 30% by seed treatment with Captan alone and 36% over Captan alone by Captan + Imazalil. Nevertheless, Captan not only had fungicidal effect, but also improved cold tolerance, leading to better seedling emergence and increased yield (Mao *et al.*, 1997; Berzy *et al.*, 1999; Wilson *et al.*, 1993). Seed primed with water, soaked in 3% KNO_3 followed by drying and seed treatment with Kalisena significantly improved emergence of maize (Nayak *et al.*, 2002).

The interaction effect of seed treatment and storage condition was significant in *Rabi* 1998 produce seed whereas it was non-significant in *Kharif* 1999 produce seed. From the present study it may be concluded that more beneficial responses were obtained in 18 months old seed than 12 months old due to seed treatment before sowing. Seed treatment prior to sowing by hydration-dehydration alone or followed by dressing with Captan found better seedling emergence and growth of plant over untreated control.

Chapter 6

SUMMARY

The seeds of parental lines, CM-135 (Female) and CM-136 (Male) of newly developed maize hybrid 'Pusa Early Makka-1' produced in *Rabi* 1998 and *Kharif* 1999, were obtained from Indian Agricultural Research Institute, Regional Station, Karnal, Haryana. The seeds having 9.0% moisture content were treated with slurry of fungicides, Captan (0.3%), Bavistin (0.3%), insecticides, Deltamethrin (0.04 ml/kg), Malathion (0.06 ml/kg) and their combinations, Captan + Deltamethrin (1:1), Captan + Malathion (1:1), Bavistin + Deltamethrin (1:1), Bavistin + Malathion (1:1), and plant products, Econeem (0.3%) and Arappu leaf powder (0.5%). The treated seeds along with untreated controls were packed in cloth bags and stored under ambient conditions of Delhi and controlled storage conditions ($20 \pm 1^{\circ}\text{C}$ and $30 \pm 10\%$ RH) at Karnal. Observations were recorded at 3 months interval from July 1999 to Jan-Feb. 2001 for *Rabi* 1998 produce seed and from Jan. 2000 to Jan.-Feb. 2001 for *Kharif* 1999 produce seeds. During investigations, the effect of pre-storage seed treatments on seed moisture, germination, seedlings dry weight, shoot and root length, vigour index, Accelerated ageing, cold test, electrical conductivity, seed health and field emergence were studied. Besides, effect of pre-sowing treatments on field emergence, the persistence of different fungicides and/or their combinations with insecticides after different storage periods was also investigated.

The major findings of the present investigations are summarized below:

1. A significant fluctuation in seed moisture ranging from 9.0 to 12.0% was observed when the seeds were stored under ambient conditions. However, the seed moisture remained below 9.0% when the seeds were stored under controlled conditions.
2. Irrespective of storage conditions and seed treatments, the seed germination, vigour and viability decreased significantly with the increase of storage period in both the parental lines produced in *Rabi* 1998 and *Kharif* 1999.
3. Seed stored under controlled conditions maintained low moisture, high germination, dry weight, shoot and root length, vigour index, low electrical conductivity, better persistence of chemical and low seed mycoflora as compared to seed stored under ambient conditions.
4. Irrespective of seed treatments and storage conditions, the germination was maintained above Minimum Seed Certification Standard (MSCS) for 9 and 15 months in the parental line CM-135 and CM-136, respectively, for *Rabi* 1998 produce seed. However, the seed treatments with Captan alone and its combinations with Deltamethrin and Malathion could maintain the germination above MSCS for 18 months in both the parental lines.

5. In *kharif* 1999 produce seeds, irrespective of storage condition seed treatments, the germination remained above MSCS when stored for 12 months in both the parental lines.
6. The parental line, CM-136 was found moderately tolerant to cold stress and withstood accelerated ageing for 10 days, recorded higher germination, vigour index, dry matter, shoot and root length and low electrical conductivity and performed better in the field as compared to the parental line CM-135.
7. Among the seed protectants evaluated, seed treatment with Captan alone, Captan + Deltamethrin and Captan + Malathion was found superior followed by seed treatment with Econeem, which improved the germination, dry weight, shoot and root length, vigour index and field emergence significantly as compared to untreated control. However, seed treatment with insecticide Malathion and Arappu leaf powder, a botanical based product, was found least effective.
8. Seed treatment with Captan and Bavistin alone and their combinations with Deltamethrin and Malathion was found compatible and eliminated almost all fungi that encountered on maize seed and remained biologically active against test organism *Fusarium moniliforme* during 18 months storage period. Nevertheless, Deltamethrin was found to be the best seed protectant against *Rhizopertha dominica* in bioassay.

9. Irrespective of storage conditions, the degradation of seed protectants on seed increased gradually with the increase of storage period.
10. Due to high initial vigour and germination, the seedling emergence of stored seed in August 2000 was higher as compared to the seedling emergence after subsequent storage period (February 2001). However, treated stored seed had improved the field emergence as compared to untreated control
11. Pre-sowing seed treatment with Hydration-dehydration alone and Hydration-dehydration followed by dry seed dressing with Captan, improved the seedling emergence significantly over untreated control. However, the effect of pre-sowing seed treatment was more pronounced in low vigour than high vigour seed.

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Appendix I

Monthly temperature and relative humidity recorded during June 1999 to March 2001

Months	Temperature (°C)			Relative humidity (%)		
	Max.	Min.	Mean	Max.	Min.	Mean
June	38.4	26.9	32.7	70.0	47.0	58.5
July	35.8	26.8	31.3	85.0	63.0	74.0
August	34.7	26.5	30.6	79.0	60.0	69.5
September	33.6	24.9	29.3	86.0	70.0	78.0
October	32.6	18.2	25.4	86.0	48.0	67.0
November	29.0	11.9	20.5	81.0	30.0	55.5
December	23.1	6.5	14.8	92.0	42.0	67.0
January	19.3	8.0	13.7	90.0	53.0	71.5
February	21.2	8.2	14.7	91.0	48.0	69.5
March	28.5	12.8	20.7	77.0	36.0	56.5
April	38.1	20.0	29.1	63.0	33.0	48.0
May	40.1	27.2	33.7	50.0	37.0	43.5
June	37.0	26.7	31.9	73.0	53.0	63.0
July	33.2	26.2	29.7	87.0	69.0	78.0
August	33.9	26.4	30.2	80.6	65.8	73.2
September	33.9	23.9	28.9	80.0	58.0	69.0
October	34.6	18.1	26.4	83.5	45.0	64.3
November	29.1	12.6	20.9	85.8	42.0	63.9
December	23.9	5.8	14.9	83.4	39.9	61.7
January	18.00	5.4	11.7	87.3	52.3	69.8
February	24.5	8.6	16.6	82.3	39.0	60.7
March	29.4	12.7	21.1	75.0	36.0	55.5

Annexure 1

Table 1: Response of *Rhyzopertha dominica* on residues of protectant on CM-135 seeds (1 to 10 days exposure of adults at 25°C) stored under controlled conditions

Treatment/ Storage period	LT 50	95 % confidence limit		Regression coefficient (b) slope ± (S.E.)	Intercept ± S.E.	χ^2
		Lower	Upper			
3 months						
Captan	3.05	1.889	4.897	2.234 ± (0.637)	3.916 ± (0.368)	0.86
Bavistin	3.06	1.825	5.099	2.089 ± (0.621)	3.984 ± (0.361)	0.67
Deltamethrin	1.13	0.027	2.089	1.524 ± (0.628)	4.919 ± (0.327)	0.62
Malathion	1.59	0.295	2.685	1.665 ± (0.613)	4.667 ± (0.328)	0.25
Econeem	2.87	1.737	4.526	2.231 ± (0.638)	3.978 ± (0.363)	0.40
Arappu leaf powder	3.09	1.706	5.554	1.869 ± (0.599)	4.084 ± (0.351)	0.37
Captan + Deltamethrin	1.53	0.390	2.489	1.858 ± (0.6420)	4.654 ± (0.332)	0.90
Captan + Malathion	1.38	0.244	2.307	1.787 ± (0.644)	4.748 ± (0.330)	0.53
Bavistin + Deltamethrin	1.76	0.737	2.698	2.141 ± (0.666)	4.472 ± (0.339)	0.78
Bavistin + Malathion	1.84	0.685	2.914	1.935 ± (0.638)	4.488 ± (0.335)	0.14
6 months						
Captan	3.35	1.821	6.719	1.748 ± (0.589)	4.083 ± (0.350)	0.20
Bavistin	3.61	2.038	7.578	1.760 ± (0.591)	4.020 ± (0.355)	0.25
Deltamethrin	1.54	0.382	2.506	1.840 ± (0.639)	4.656 ± (0.331)	0.80
Malathion	1.72	0.350	2.936	1.625 ± (0.602)	4.618 ± (0.327)	0.37
Econeem	2.69	1.529	4.294	2.113 ± (0.627)	4.091 ± (0.354)	0.15
Arappu leaf powder	3.33	1.906	6.225	1.872 ± (0.600)	4.022 ± (0.355)	0.56
Captan + Deltamethrin	1.84	0.680	2.933	1.921 ± (0.630)	4.489 ± (0.355)	0.13
Captan + Malathion	1.98	0.775	3.130	1.894 ± (0.621)	4.439 ± (0.335)	0.09
Bavistin + Deltamethrin	2.05	0.998	3.121	2.163 ± (0.652)	4.328 ± (0.344)	1.25
Bavistin + Malathion	2.15	0.985	3.408	1.980 ± (0.625)	4.341 ± (0.340)	0.40
9 months						
Captan	3.80	2.417	6.876	2.117 ± (0.626)	3.772 ± (0.379)	0.05
Bavistin	4.55	2.775	11.341	1.819 ± (0.603)	3.802 ± (0.735)	0.97
Deltamethrin	1.71	0.358	2.914	1.638 ± (0.604)	4.617 ± (0.3280)	0.39
Malathion	2.66	1.249	4.688	1.759 ± (0.592)	4.254 ± (0.340)	0.33
Econeem	3.09	1.507	6.257	1.644 ± (0.581)	4.194 ± (0.342)	0.07
Arappu leaf powder	4.02	2.079	13.549	1.484 ± (0.571)	4.103 ± (0.347)	0.19
Captan + Deltamethrin	2.27	0.975	3.748	1.831 ± (0.605)	4.349 ± (0.337)	0.36
Captan + Malathion	2.14	0.986	3.383	1.993 ± (0.626)	4.339 ± (0.340)	0.44
Bavistin + Deltamethrin	2.86	1.430	5.203	1.763 ± (0.591)	4.195 ± (0.343)	0.13
Bavistin + Malathion	2.13	0.356	4.119	1.399 ± (0.570)	4.540 ± (0.326)	0.07

Table 1 Contd.

Treatment/ Storage period	LT 50	95 % confidence		Regression coefficient (b) slope \pm (S.E.)	Intercept \pm S.E.	χ^2
		limit				
		Lower	Upper			
12 months						
Captan	4.68	3.074	9.379	2.176 \pm (0.645)	3.540 \pm (0.408)	0.28
Bavistin	4.90	3.033	12.828	1.853 \pm (0.611)	3.720 \pm (0.385)	0.20
Deltamethrin	2.38	0.3674	4.594	1.479 \pm (0.573)	4.443 \pm (0.329)	0.22
Malathion	3.10	1.713	5.615	1.861 \pm (0.599)	4.084 \pm (0.351)	0.33
Econeem	3.82	2.426	6.940	2.110 \pm (0.626)	3.771 \pm (0.380)	0.04
Arappu leaf powder	4.49	2.819	9.958	1.946 \pm (0.616)	3.730 \pm (0.384)	0.43
Captan + Deltamethrin	2.89	1.625	4.873	1.985 \pm (0.611)	4.084 \pm (0.352)	1.12
Captan + Malathion	2.67	1.253	4.735	1.750 \pm (0.591)	4.254 \pm (0.340)	0.32
Bavistin + Deltamethrin	3.10	1.713	5.615	1.861 \pm (0.599)	4.084 \pm (0.351)	0.38
Bavistin + Malathion	2.88	1.435	5.261	1.754 \pm (0.590)	4.195 \pm (0.343)	0.11
15 months						
Captan	5.29	3.301	14.837	1.879 \pm (0.619)	3.640 \pm (0.395)	0.07
Bavistin	6.02	3.881	16.522	2.075 \pm (0.658)	3.381 \pm (0.434)	1.18
Deltamethrin	2.75	0.394	8.448	1.224 \pm (0.554)	4.462 \pm (0.326)	0.43
Malathion	3.36	1.366	10.360	1.379 \pm (0.562)	4.274 \pm (0.366)	0.18
Econeem	4.57	2.714	12.567	1.729 \pm (0.595)	3.860 \pm (0.369)	0.18
Arappu leaf powder	5.57	3.238	27.257	1.599 \pm (0.593)	3.807 \pm (0.375)	0.47
Captan + Deltamethrin	3.12	1.504	6.527	1.614 \pm (0.578)	4.201 \pm (0.341)	0.08
Captan + Malathion	3.38	1.731	7.487	1.624 \pm (0.579)	4.140 \pm (0.345)	0.29
Bavistin + Deltamethrin	3.83	2.478	6.743	2.202 \pm (0.636)	3.715 \pm (0.386)	0.61
Bavistin + Malathion	3.31	2.004	5.731	2.055 \pm (0.617)	3.931 \pm (0.369)	0.84
18 months						
Captan	5.53	3.567	13.883	2.058 \pm (0.645)	3.471 \pm (0.419)	0.73
Bavistin	6.85	4.703	15.457	2.664 \pm (0.789)	2.773 \pm (0.559)	2.47
Deltamethrin	3.63	2.014	7.825	1.736 \pm (0.588)	4.027 \pm (0.359)	0.22
Malathion	3.72	1.807	11.481	1.461 \pm (0.568)	4.167 \pm (0.359)	0.28
Econeem	5.24	2.284	14.230	1.898 \pm (0.621)	4.167 \pm (0.343)	0.07
Arappu leaf powder	6.55	4.144	21.374	2.017 \pm (0.660)	3.634 \pm (0.396)	0.94
Captan + Deltamethrin	4.05	2.090	13.955	1.478 \pm (0.571)	3.354 \pm (0.440)	0.16
Captan + Malathion	4.24	2.544	9.971	1.801 \pm (0.599)	4.103 \pm (0.347)	0.29
Bavistin + Deltamethrin	4.49	2.819	9.958	1.946 \pm (0.616)	3.869 \pm (0.368)	0.43
Bavistin + Malathion	4.16	2.602	8.491	1.977 \pm (0.615)	3.730 \pm (0.384)	0.28

Table 2: Response of *Rhyzopertha dominica* on residues of protectant on CM-136 seeds (1 to 10 days exposure of adults at 25^oC) stored under controlled conditions

Treatment/ Storage period	LT 50	95 % confidence limit		Regression coefficient (b) slope \pm (S.E.)	Intercept \pm S.E.	χ^2
		Lower	Upper			
3 months						
Captan	2.44	1.113	4.109	1.819 \pm (0.601)	4.296 \pm (0.383)	0.58
Bavistin	3.32	1.898	6.151	1.879 \pm (0.600)	4.022 \pm (0.356)	0.60
Deltamethrin	1.38	0.244	2.306	1.787 \pm (0.644)	4.748 \pm (0.330)	0.53
Malathion	1.53	0.390	2.489	1.854 \pm (0.642)	4.654 \pm (0.332)	0.90
Econeem	2.87	1.737	4.526	2.234 \pm (0.638)	3.978 \pm (0.363)	0.40
Arappu leaf powder	3.09	1.706	5.554	1.869 \pm (0.599)	4.084 \pm (0.351)	0.37
Captan + Deltamethrin	1.13	0.027	2.089	1.524 \pm (0.628)	4.019 \pm (0.327)	0.64
Captan + Malathion	1.38	0.244	2.307	1.787 \pm (0.644)	4.748 \pm (0.330)	0.53
Bavistin + Deltamethrin	1.84	0.685	2.914	1.935 \pm (0.633)	4.488 \pm (0.385)	0.14
Bavistin + Malathion	1.65	0.449	2.681	1.818 \pm (0.629)	4.606 \pm (0.331)	1.25
6 months						
Captan	3.31	1.890	6.126	1.879 \pm (0.600)	4.024 \pm (0.355)	0.58
Bavistin	3.35	1.821	6.719	1.746 \pm (0.589)	4.083 \pm (0.349)	0.20
Deltamethrin	1.65	0.422	2.699	1.801 \pm (0.626)	4.607 \pm (0.301)	1.13
Malathion	1.89	0.815	2.915	2.081 \pm (0.649)	4.426 \pm (0.339)	0.83
Econeem	2.69	1.529	4.294	2.113 \pm (0.627)	4.091 \pm (0.534)	0.15
Arappu leaf powder	3.33	1.906	6.225	1.872 \pm (0.600)	4.022 \pm (0.355)	0.56
Captan + Deltamethrin	1.65	0.442	2.700	1.801 \pm (0.626)	4.608 \pm (0.331)	1.13
Captan + Malathion	1.72	0.350	2.936	1.625 \pm (0.602)	4.618 \pm (0.327)	0.37
Bavistin + Deltamethrin	1.98	0.775	3.169	1.894 \pm (0.621)	4.439 \pm (0.335)	0.09
Bavistin + Malathion	1.89	0.815	2.915	2.081 \pm (0.648)	4.426 \pm (0.339)	0.83
9 months						
Captan	4.01	2.068	13.445	1.483 \pm (0.517)	4.105 \pm (0.347)	0.18
Bavistin	4.29	2.455	12.020	1.651 \pm (0.585)	3.956 \pm (0.360)	0.96
Deltamethrin	1.70	0.354	2.899	1.639 \pm (0.604)	4.620 \pm (0.328)	0.37
Malathion	2.28	1.098	3.651	1.975 \pm (0.620)	4.291 \pm (0.341)	0.84
Econeem	3.58	2.021	7.441	1.766 \pm (0.591)	4.022 \pm (0.355)	0.23
Arappu leaf powder	3.61	2.038	7.578	1.759 \pm (0.591)	4.020 \pm (10.353)	0.25
Captan + Deltamethrin	2.11	0.879	3.397	1.886 \pm (0.615)	4.389 \pm (0.336)	0.69
Captan + Malathion	2.57	0.847	5.141	1.487 \pm (0.572)	4.390 \pm (0.331)	0.22
Bavistin + Deltamethrin	2.85	1.421	5.175	1.762 \pm (0.591)	4.198 \pm (0.343)	0.13
Bavistin + Malathion	2.43	1.105	4.084	1.819 \pm (0.601)	4.299 \pm (0.339)	0.55

Table 2 *Contd.*

Treatment/ Storage period	LT 50	95 % confidence limit		Regression coefficient (b) slope \pm (S.E.)	Intercept \pm S.E.	χ^2
		Lower	Upper			
12 months						
Captan	4.64	2.747	13.44	1.706 \pm (0.594)	3.862 \pm (0.369)	0.18
Bavistin	4.90	3.033	12.828	1.853 \pm (0.611)	3.720 \pm (0.385)	0.20
Deltamethrin	2.23	0.718	3.952	1.604 \pm (0.585)	4.442 \pm (0.331)	0.74
Malathion	2.59	0.855	3.251	1.479 \pm (0.571)	4.387 \pm (0.331)	0.21
Econeem	4.05	2.090	13.955	1.478 \pm (0.571)	4.103 \pm (0.347)	0.16
Arappu leaf powder	4.24	2.544	9.971	1.801 \pm (0.599)	3.870 \pm (0.368)	0.29
Captan + Deltamethrin	2.42	0.871	4.402	1.600 \pm (0.582)	4.378 \pm (0.332)	0.89
Captan + Malathion	2.69	1.529	4.294	2.113 \pm (0.627)	4.091 \pm (0.354)	0.15
Bavistin + Deltamethrin	3.10	1.713	5.615	1.861 \pm (0.599)	4.084 \pm (0.351)	0.33
Bavistin + Malathion	2.60	0.855	5.251	1.479 \pm (0.571)	4.387 \pm (0.331)	0.21
15 months						
Captan	4.91	2.972	14.255	1.764 \pm (0.602)	3.781 \pm (0.378)	0.28
Bavistin	5.29	3.301	14.837	1.879 \pm (0.619)	3.640 \pm (0.395)	0.07
Deltamethrin	3.05	0.679	11.719	1.230 \pm (0.553)	4.405 \pm (0.328)	0.85
Malathion	3.68	1.670	13.030	1.393 \pm (0.564)	4.212 \pm (0.339)	0.24
Econeem	4.94	3.048	13.354	1.834 \pm (0.609)	3.727 \pm (0.384)	0.21
Arappu leaf powder	6.00	3.527	30.912	1.643 \pm (0.603)	3.721 \pm (0.386)	0.19
Captan + Deltamethrin	3.35	1.540	8.418	1.494 \pm (0.570)	4.216 \pm (0.340)	0.82
Captan + Malathion	3.68	1.670	13.029	1.394 \pm (0.564)	4.212 \pm (0.339)	0.24
Bavistin + Deltamethrin	3.72	2.550	5.853	2.610 \pm (0.688)	3.509 \pm (0.415)	0.38
Bavistin + Malathion	3.75	1.805	12.202	1.442 \pm (0.567)	4.172 \pm (0.342)	0.30
18 months						
Captan	5.69	3.819	12.350	2.336 \pm (0.689)	3.236 \pm (0.458)	0.83
Bavistin	6.52	4.132	21.098	2.020 \pm (0.660)	3.355 \pm (0.440)	0.94
Deltamethrin	3.70	1.797	11.180	1.467 \pm (0.569)	4.167 \pm (0.343)	0.30
Malathion	4.37	2.441	14.138	1.576 \pm (0.580)	3.989 \pm (0.357)	0.76
Econeem	5.64	3.265	29.528	1.585 \pm (0.593)	3.809 \pm (0.375)	0.47
Arappu leaf powder	6.67	4.399	17.620	2.299 \pm (0.711)	3.105 \pm (0.486)	0.91
Captan + Deltamethrin	4.02	2.079	13.549	1.484 \pm (0.571)	4.103 \pm (0.347)	0.19
Captan + Malathion	4.39	2.855	8.612	2.132 \pm (0.635)	3.629 \pm (0.396)	0.27
Bavistin + Deltamethrin	4.62	2.737	13.214	1.710 \pm (0.594)	3.863 \pm (0.369)	0.17
Bavistin + Malathion	4.29	2.456	12.020	1.657 \pm (0.586)	3.956 \pm (0.360)	0.96

Table 3: Response of *Rhyzopertha dominica* on residues of protectant on CM-135 seeds (1 to 10 days exposure of adults at 25⁰C) stored under ambient conditions

Treatment/ Storage period	LT 50	95 % confidence limit		Regression coefficient (b) slope ± (S.E.)	Intercept ± S.E.	χ^2
		Lower	Upper			
3 months						
Captan	3.13	1.504	6.527	1.614 ± (0.578)	4.201 ± (0.341)	0.08
Bavistin	3.52	2.342	5.623	2.446 ± (0.664)	3.663 ± (0.395)	0.28
Deltamethrin	1.94	1.003	5.886	2.363 ± (0.686)	4.315 ± (0.349)	0.95
Malathion	2.23	1.256	3.286	2.397 ± (0.676)	4.170 ± (0.355)	1.98
Econeem	3.12	2.071	4.720	2.576 ± (0.680)	3.727 ± (0.390)	0.02
Arappu leaf powder	3.83	2.479	6.743	2.202 ± (0.636)	3.715 ± (0.387)	0.61
Captan + Deltamethrin	1.95	1.003	5.886	2.363 ± (0.686)	4.315 ± (0.349)	0.95
Captan + Malathion	1.84	0.929	4.702	2.427 ± (0.705)	4.358 ± (0.349)	0.75
Bavistin + Deltamethrin	2.11	0.884	3.409	1.885 ± (0.615)	4.388 ± (0.336)	2.99
Bavistin + Malathion	2.31	1.087	3.744	1.925 ± (0.614)	4.299 ± (0.340)	0.80
6 months						
Captan	3.38	1.731	7.487	1.624 ± (0.579)	4.140 ± (0.345)	0.30
Bavistin	3.64	2.041	7.825	1.736 ± (0.589)	4.027 ± (0.354)	0.22
Deltamethrin	2.22	1.256	3.286	2.397 ± (0.676)	4.170 ± (0.355)	1.98
Malathion	2.37	0.677	4.338	1.488 ± (0.574)	4.442 ± (0.329)	0.24
Econeem	3.32	1.898	6.155	1.879 ± (0.600)	4.022 ± (0.355)	0.60
Arappu leaf powder	4.02	2.078	13.549	1.484 ± (0.571)	4.103 ± (0.347)	0.19
Captan + Deltamethrin	1.97	0.778	3.147	1.907 ± (0.623)	4.438 ± (0.335)	0.11
Captan + Malathion	2.14	0.986	3.382	1.994 ± (0.626)	4.339 ± (0.340)	0.44
Bavistin + Deltamethrin	2.29	1.104	3.666	1.974 ± (0.620)	4.288 ± (0.341)	0.87
Bavistin + Malathion	2.13	0.356	4.119	1.398 ± (0.570)	4.539 ± (0.325)	0.07
9 months						
Captan	4.37	2.441	14.138	1.577 ± (0.580)	3.990 ± (0.357)	0.76
Bavistin	4.43	2.279	23.142	1.406 ± (0.568)	4.091 ± (0.348)	0.08
Deltamethrin	2.50	0.207	6.546	1.219 ± (0.555)	4.515 ± (0.324)	0.62
Malathion	3.64	2.041	7.825	1.736 ± (0.589)	4.027 ± (0.354)	0.22
Econeem	3.38	1.381	10.476	1.380 ± (0.562)	4.271 ± (0.336)	0.17
Arappu leaf powder	4.76	2.678	19.025	1.548 ± (0.581)	3.951 ± (0.360)	0.86
Captan + Deltamethrin	2.45	0.606	5.025	1.408 ± (0.567)	4.453 ± (0.328)	0.39
Captan + Malathion	2.76	0.406	8.575	1.224 ± (0.554)	4.460 ± (0.326)	0.43
Bavistin + Deltamethrin	2.83	1.054	6.129	1.474 ± (0.569)	4.334 ± (0.333)	0.98
Bavistin + Malathion	3.08	1.25	7.173	1.483 ± (0.569)	4.274 ± (0.336)	0.59

Table 3 *Contd.*

Treatment/ Storage period	LT 50	95 % confidence limit		Regression coefficient (b) slope \pm (S.E.)	Intercept \pm S.E.	χ^2
		Lower	Upper			
12 months						
Captan	5.24	3.284	14.230	1.898 \pm (0.621)	3.634 \pm (0.396)	0.07
Bavistin	6.06	3.546	33.337	1.627 \pm (0.602)	3.726 \pm (0.385)	0.21
Deltamethrin	3.71	1.665	14.093	1.374 \pm (0.562)	4.217 \pm (0.339)	0.25
Malathion	4.01	2.067	13.455	1.483 \pm (0.571)	4.105 \pm (0.347)	0.18
Econeem	4.52	2.764	10.952	1.838 \pm (0.605)	3.795 \pm (0.376)	0.58
Arappu leaf powder	6.06	3.546	33.337	1.627 \pm (0.602)	3.726 \pm (0.385)	0.21
Captan + Deltamethrin	3.71	1.665	14.093	1.374 \pm (0.562)	4.217 \pm (0.339)	0.25
Captan + Malathion	3.08	1.615	5.775	1.769 \pm (0.591)	4.137 \pm (0.347)	0.52
Bavistin + Deltamethrin	3.68	1.783	11.073	1.466 \pm (0.568)	4.170 \pm (0.342)	0.32
Bavistin + Malathion	3.72	1.807	11.481	1.461 \pm (0.568)	4.167 \pm (0.343)	0.28
15 months						
Captan	5.69	3.819	12.350	2.336 \pm (0.689)	3.236 \pm (0.458)	0.83
Bavistin	6.67	4.399	17.619	2.299 \pm (0.711)	3.105 \pm (0.486)	0.91
Deltamethrin	4.01	2.067	13.445	1.483 \pm (0.571)	4.105 \pm (0.347)	0.18
Malathion	5.64	3.265	29.528	1.585 \pm (0.593)	3.809 \pm (0.375)	0.47
Econeem	6.08	3.554	33.454	1.628 \pm (0.602)	3.726 \pm (0.385)	0.21
Arappu leaf powder	6.52	4.132	21.098	2.020 \pm (0.660)	3.355 \pm (0.440)	0.94
Captan + Deltamethrin	4.11	2.582	9.174	2.007 \pm (0.618)	3.768 \pm (0.379)	0.28
Captan + Malathion	4.22	2.532	9.819	1.807 \pm (0.599)	3.870 \pm (0.368)	0.32
Bavistin + Deltamethrin	3.93	2.298	8.750	1.778 \pm (0.594)	3.944 \pm (0.361)	0.61
Bavistin + Malathion	4.88	3.021	12.647	1.858 \pm (0.611)	3.721 \pm (0.385)	0.20
18 months						
Captan	6.52	4.132	21.098	2.020 \pm (0.660)	3.555 \pm (0.439)	0.94
Bavistin	7.79	4.792	37.209	1.987 \pm (0.683)	3.227 \pm (0.466)	1.34
Deltamethrin	4.29	2.455	12.020	1.651 \pm (0.585)	3.956 \pm (0.360)	0.96
Malathion	6.15	3.858	19.940	1.937 \pm (0.641)	3.472 \pm (0.420)	1.69
Econeem	6.52	4.132	21.098	2.020 \pm (0.660)	3.555 \pm (0.440)	0.94
Arappu leaf powder	7.80	4.793	37.209	1.987 \pm (0.683)	3.227 \pm (0.466)	1.38
Captan + Deltamethrin	5.26	3.580	10.328	2.420 \pm (0.692)	3.254 \pm (0.454)	0.73
Captan + Malathion	5.95	3.849	15.775	2.097 \pm (0.659)	3.376 \pm (0.435)	1.18
Bavistin + Deltamethrin	5.29	3.301	14.836	1.879 \pm (0.619)	3.640 \pm (0.395)	0.07
Bavistin + Malathion	5.24	3.284	14.230	1.898 \pm (0.621)	3.634 \pm (0.396)	0.07

Table 4: Response of *Rhyzopertha dominica* on residues of protectant on CM-136 seeds (1 to 10 days exposure of adults at 25⁰C) stored under ambient conditions

Treatment/ Storage period	LT 50	95 % confidence limit		Regression coefficient (b) slope ± (S.E.)	Intercept ± S.E.	χ^2
		Lower	Upper			
3 months						
Captan	2.84	1.430	5.077	1.788 ± (0.593)	4.190 ± (0.344)	1.10
Bavistin	3.06	1.783	5.170	2.028 ± (0.615)	4.016 ± (0.354)	1.54
Deltamethrin	1.60	0.129	2.905	1.447 ± (0.588)	4.703 ± (0.324)	1.74
Malathion	1.68	0.044	3.231	1.307 ± (0.573)	4.706 ± (0.322)	0.45
Econeem	2.52	0.506	5.694	1.331 ± (0.561)	4.461 ± (0.327)	1.51
Arappu leaf powder	3.07	1.282	7.116	1.482 ± (0.569)	4.278 ± (0.336)	0.60
Captan + Deltamethrin	1.97	0.010	4.352	1.176 ± (0.557)	4.653 ± (0.321)	0.36
Captan + Malathion	1.77	0.001	3.725	1.180 ± (0.561)	4.706 ± (0.320)	0.04
Bavistin + Deltamethrin	2.20	0.738	3.735	1.642 ± (0.589)	4.437 ± (0.331)	0.77
Bavistin + Malathion	2.03	0.609	3.480	1.651 ± (0.594)	4.491 ± (0.330)	1.30
6 months						
Captan	3.31	1.890	6.126	1.879 ± (0.600)	4.024 ± (0.355)	0.58
Bavistin	3.53	2.266	5.944	2.233 ± (0.637)	3.776 ± (0.380)	0.40
Deltamethrin	1.84	0.431	5.166	1.616 ± (0.596)	4.570 ± (0.328)	1.14
Malathion	2.33	0.488	4.673	1.396 ± (0.567)	4.488 ± (0.327)	0.22
Econeem	3.58	2.021	7.441	1.766 ± (0.591)	4.022 ± (0.355)	0.23
Arappu leaf powder	4.01	2.067	13.445	1.485 ± (0.571)	4.105 ± (0.347)	0.18
Captan + Deltamethrin	2.12	0.348	4.088	1.398 ± (0.570)	4.543 ± (0.325)	0.08
Captan + Malathion	1.97	0.001	4.468	1.153 ± (0.556)	4.659 ± (0.321)	0.35
Bavistin + Deltamethrin	2.57	0.847	5.141	1.486 ± (0.572)	4.390 ± (0.331)	0.22
Bavistin + Malathion	2.36	0.667	4.504	1.487 ± (0.574)	4.445 ± (0.329)	0.26
9 months						
Captan	4.29	2.455	12.020	1.651 ± (0.586)	3.956 ± (0.359)	0.96
Bavistin	4.69	2.76	14.116	1.686 ± (0.592)	3.869 ± (0.368)	0.19
Deltamethrin	2.58	0.856	5.176	1.486 ± (0.571)	4.387 ± (0.331)	0.23
Malathion	2.80	0.838	6.701	1.372 ± (0.562)	4.386 ± (0.330)	0.17
Econeem	4.02	2.079	13.549	1.484 ± (0.571)	4.103 ± (0.347)	0.19
Arappu leaf powder	4.94	3.048	13.354	1.834 ± (0.610)	3.727 ± (0.384)	0.21
Captan + Deltamethrin	2.58	0.856	5.176	1.487 ± (0.571)	4.387 ± (0.331)	0.23
Captan + Malathion	2.80	0.838	6.701	1.372 ± (0.562)	4.386 ± (0.330)	0.17
Bavistin + Deltamethrin	3.09	1.706	5.554	1.869 ± (0.599)	4.084 ± (0.351)	0.37
Bavistin + Malathion	2.86	1.430	5.203	1.763 ± (0.591)	4.195 ± (0.343)	0.13

Table 4 Contd.

Treatment/ Storage period	LT 50	95 % confidence limit		Regression coefficient (b) slope \pm (S.E.)	Intercept \pm S.E.	χ^2
		Lower	Upper			
12 months						
Captan	5.29	3.301	14.836	1.879 \pm (0.619)	3.640 \pm (0.395)	0.07
Bavistin	5.53	3.567	13.883	2.058 \pm (0.645)	3.471 \pm (0.419)	0.73
Deltamethrin	3.13	1.504	6.527	1.614 \pm (0.578)	4.201 \pm (0.341)	0.08
Malathion	4.01	2.067	13.445	1.483 \pm (0.571)	4.105 \pm (0.347)	0.18
Econeem	4.96	2.986	14.921	1.745 \pm (0.601)	3.787 \pm (0.377)	0.28
Arappu leaf powder	5.76	3.849	12.809	2.187 \pm (0.633)	3.988 \pm (0.362)	0.36
Captan + Deltamethrin	3.57	2.021	7.441	1.765 \pm (0.591)	4.022 \pm (0.355)	0.23
Captan + Malathion	4.36	2.352	16.313	1.503 \pm (0.574)	4.038 \pm (0.352)	0.69
Bavistin + Deltamethrin	4.20	2.523	9.775	1.803 \pm (0.599)	3.873 \pm (0.368)	0.32
Bavistin + Malathion	3.57	2.021	7.441	1.765 \pm (0.591)	4.022 \pm (0.355)	0.23
15 months						
Captan	5.76	3.849	12.809	2.310 \pm (0.687)	3.243 \pm (0.457)	0.84
Bavistin	6.03	3.881	16.522	2.075 \pm (0.658)	3.381 \pm (0.434)	1.18
Deltamethrin	3.59	2.029	7.477	1.766 \pm (0.591)	4.019 \pm (0.355)	0.25
Malathion	4.39	2.855	8.612	2.132 \pm (0.635)	3.629 \pm (0.396)	0.27
Econeem	5.64	3.265	29.529	1.585 \pm (0.593)	3.809 \pm (0.375)	0.47
Arappu leaf powder	6.52	4.132	21.098	2.020 \pm (0.660)	3.355 \pm (0.439)	0.94
Captan + Deltamethrin	4.62	2.737	13.214	1.711 \pm (0.594)	3.863 \pm (0.369)	0.17
Captan + Malathion	4.62	2.737	13.214	1.711 \pm (0.594)	3.863 \pm (0.369)	0.17
Bavistin + Deltamethrin	4.02	2.079	13.549	1.484 \pm (0.571)	4.103 \pm (0.347)	0.19
Bavistin + Malathion	4.22	2.532	9.819	1.807 \pm (0.599)	3.870 \pm (0.368)	0.32
18 months						
Captan	6.03	3.881	16.522	2.075 \pm (0.658)	3.381 \pm (0.434)	1.18
Bavistin	6.85	4.703	15.457	2.664 \pm (0.789)	2.773 \pm (0.559)	2.47
Deltamethrin	4.90	3.033	12.828	1.853 \pm (0.611)	3.720 \pm (0.385)	0.20
Malathion	5.32	3.608	10.659	2.392 \pm (0.689)	3.262 \pm (0.452)	0.75
Econeem	6.24	4.366	12.302	2.780 \pm (0.789)	2.788 \pm (0.551)	0.19
Arappu leaf powder	8.87	5.765	33.462	2.525 \pm (0.840)	2.606 \pm (0.620)	1.46
Captan + Deltamethrin	5.29	3.301	14.837	1.879 \pm (0.619)	3.640 \pm (0.395)	0.07
Captan + Malathion	5.76	3.849	12.809	2.310 \pm (0.687)	3.244 \pm (0.457)	0.84
Bavistin + Deltamethrin	5.53	3.567	13.883	2.058 \pm (0.645)	3.471 \pm (0.419)	0.73
Bavistin + Malathion	5.95	3.849	15.775	2.095 \pm (0.659)	3.376 \pm (0.435)	1.18

T-6961