EFFECT OF PLANT PRODUCTS AND CONTAINERS ON STORAGE POTENTIAL OF MAIZE HYBRID Cv. ARJUN

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By

ASHA A. M.

DEPARTMENT OF SEED SCIENCE AND TECHNOLOGY
COLLEGE OF AGRICULTURE, DHARWAD
UNIVERSITY OF AGRICULTURAL SCIENCES,
DHARWAD – 580 005

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I. INTRODUCTION

Maize (*Zea mays* L) is one of the most versatile important emerging crops having wider adaptability under varied agro-climatic conditions. Globally, maize is known as “king of crops” because of its highest genetic yield potential among the cereals.

It is cultivated on nearly 150 m ha in about 160 countries having wider diversity of soil, climate, biodiversity and management practices that contributes 36 per cent (854.67 m t) in the world production. The United States of America (USA) is the largest producer of maize contributing nearly 35 per cent of the total production in the world with the highest productivity ($\geq$ 9.6 t ha^{-1}) which is double than the global average (4.92 t ha^{-1}).

In India, maize ranks third position among the important cereal crops next to rice, wheat with 21.73 m t production and grown on an area of 8.55 m ha with productivity of 2540 kg per ha (Anon., 2011).

The predominant maize growing states of our country that contributes more than 80 per cent of the total maize production are Andhra Pradesh, Karnataka, Rajasthan, Maharashtra, Bihar, Uttar Pradesh, Madhya Pradesh, Himachal Pradesh. Apart from these states maize is also grown in Jammu and Kashmir and North-Eastern States. Karnataka is one of the major maize producing states in the country cultivated in an area of 1.287 m ha, production of 4.44 m t and with an average productivity of 3633 kg per ha being much higher than the national productivity (Anon., 2011).

In the chain of seed production and supply of good quality seeds, storage of seeds assumes a greater importance as the “seed saved is seed produced” an old adage holds good even today. In this context, maintenance of viability of maize seeds assumes a greater importance.

Seeds are the living entity and as such they lose viability and vigour and gradually die with time which is a ubiquitous phenomenon found in all kinds of living things. In storage, number of biotic and abiotic factors influence storage potential of seeds and results in gradual seed deterioration and ultimately to death of the seeds. Seed deterioration has been ascribed to physical, physiological, biochemical and pathological detrimental changes occurring in seeds leading to death and has been characterized as inexorable, irreversible, inevitable, minimal at the time of physiological maturity and variable among the kinds of seeds, varieties and seed lots (Delouche, 1973). However, rate of seed deterioration could be slowed down by certain seed treatments with fungicides, insecticides, chemicals, growth regulators, halogen compounds, low cost and non hazardous botanicals etc. so as to preserve the seed quality to a desired period (Rudrapal and Basu, 1981). As the pre-storage chemical seed treatments are being costly, health hazardous, etc., in recent years the traditional practice of seed treatment with botanicals gaining momentum among the persons concerned with protection of seed during storage. Hence there is a need to ascertain the influence of seed treatments with non health hazardous botanicals on storage potential of maize seeds.

Further storage potential of seeds is also influenced by kind of storage containers used for packaging of seeds. Generally storing of seeds in suitable containers especially of moisture impervious containers seems to be a novel approach in this regard to extend storability of seeds more than a year (Doijoide, 1988).

Storage of seeds in vacuum is of controversial issue and beneficial result are variable (Tao, 1989). Beneficial influence of an anerobic environment of vacuum packaging including prevention of an aerobic microorganism, decreased respiration, decreased hydrodrolytic enzymes and decreased production of free radical on account of oxygenated lipid peroxidation by decreasing deleterious effect of oxygen have been documented (McDonald, 1999). Hermatic storage in sealed container is practiced only for high value and low volume crops under controlled conditions or for storage of seeds in gene banks. However studies on storage potential of maize seeds in vacuum under ambient storage conditions are absolutely very limited.

Hence, there is a need to ascertain the combined influence of seed treatments and storage containers with or without air (vacuum) on seed quality during storage of maize seeds. Such investigations may be helpful to the seed growers and marketers for better storage of seeds.

The present storage study entitled “Effect of plant products and containers on storage potential of maize hybrid cv. Arjun” under ambient storage conditions of Dharwad (Karnataka State) was initiated with the following objectives.

i. To ascertain the influence of seed treatment with botanicals on storage potential of maize seeds.

ii. To ascertain the influence of packaging with or without vacuum on maize seed quality during seed storage.

iii. To ascertain the combined influence of botanicals and packaging with or without vacuum on storage potential of maize seeds.

II. REVIEW OF LITERATURE

A critical comprehensive review of literature is inevitable for any scientific investigation. A proper understanding of the problem requires a thorough review of the existing knowledge of the problem.

The information on storage of maize seeds to preserve viability and vigour from harvest to next planting season is of prime importance in any seed production programme.

The research data on storability of maize seeds and quality under ambient storage conditions is very much scanty. Certain seed treatments and storage containers are known to influence the storability of seeds in several crops. Hence, research conducted on storage potential of seed during storage in maize and other related crops is also included in this review of literature. The storage potential is under genetic control but modified by environmental factors. The various factors that influence storability are accounted with relevant references as under.

2.1 Genetic influence on storability

Viability and vigour of stored seed varies between and among varieties as the genetic factor influences the storability of seed. The seeds of different cultivars possess different physical, physiological and chemical composition which influences the longevity of seed during storage (Delouche, 1973).

Varietal differences in storability of maize seeds have been reported under ambient storage conditions. Seeds of Ganga-2, Ganga-5 and Jawahar stored better for 11 months, but Vikram for nine months without loss of germination (Agrawal, 1974).

Kurdikeri (1991) reported that maize hybrids differed in storability under ambient storage conditions of Bangalore. Among the hybrids Ganga safed-2 maintained viability up to 13 months followed by Deccan 103 up to 11 months while, MMH-6 only up to 5 months.

Kharb *et al*. (1998) observed that the soybean genotypes F-49, M0-40, PK-262 and Durga deteriorated at faster rates and considered them as poor storers. Whereas, Kulitur, JS-8021, JS-8759, JS-8918 Punjab-1, KB-92, NRC-2, MACS-335 and Pusa-20 as good storers as these genotypes maintained the germination percentage above the certification standards (70%) after nine months of storage.

Among the three groundnut varieties tested, TMV-2 stored for more than 12 months followed by JL-24 and ICGS-11 with or without seed treatment (Vasundhara and Bommegowda, 1999).

Kurdikeri *et al*. (2003) observed significant varietal differences for germination in groundnut .Among six genotypes of groundnut stored in cloth bag under ambient conditions of Dharwad, cvs. DH-330, JL-24, TMV-2 and ICGS-76 maintained satisfactory germination (70%) as per the minimum seed certification standards up to 15 months while, Mardur local and DH-40 maintained germination up to 11 and 9 months respectively.

Ransingh *et al.* (2011) reported that among the groundnut varieties SB XI was found to be better in storage than TAG-24 and TG-26, maintaining germination above the minimum seed certification standard (70%) up to 240 days where, it was maintained for 180 days in TAG-24 and TG-26.

2.2 Causes of seed deterioration

Delouche (1973) defined seed deterioration as summation of all physical, physiological, biochemical changes occurring in a seed which ultimately lead to its death. He also characterized seed deterioration as inexorable, irreversible, inevitable, minimal at the time of physiological maturity and variable among the seed kinds, varieties, between seed lots of same variety and among individual seeds.

The process of seed deterioration is a matrix of interrelated events that are associated with various biochemical changes that lead to death. But all deteriorative processes are not necessarily irreparable or irreversible (Anderson, 1973).

Many researchers agreed that the seed deterioration is a progressive process which has far reaching consequences (Ellis and Roberts, 1981 and Ghosh *et al*., 1981). Generally, seed viability and vigour are maximum at the time of physiological maturity. After physiological maturity, seeds begin to deteriorate at varying rates depending on the conditions of storage environment (Roberts and Ellis, 1980).

During seed deterioration including controlled deterioration, the root apical meristem was the first tissue to be damaged restricting longitudinal root growth (Argerich *et al.,* 1989).

2.2.1 Physiological and Biochemical manifestation of seed deterioration

Deterioration is a universal phenomenon in any living beings, which involves a series of changes and finally ends with death of seeds. The process is the result of a complex interaction of time, environmental factors, intrinsic constituents and mechanisms in the seed itself.

Delouche (1973) and Copeland (1988) have highlighted the consequences of deteriorative changes in seed which include membrane degradation, accumulation of toxic metabolites, decreased enzymatic activity, lipid auto-oxidation, failure of repair mechanisms, genetic degradation, reduced yield, finally loss of germination or death. Some of the major physiological and biochemical events of deterioration are presented below.

2.2.2 Membrane degradation

Phospholipids form the major constituents of cell membrane. Koostra and Harrington (1969) showed that decline in phospholipids owing to their oxidation may be the cause of leaky cell membranes. Damage to cellular membranes and other essential orgenells by auto-oxidation are presumed as one of the possible reasons for seed senescence (Saha *et al.,* 1990).

The leachate of seed measured by electrical conductivity (Perry, 1969; Bradnock and Mathews, 1970; Roberts, 1972 and Powell and Mathews, 1986) was shown to be associated with the loss of vigour and viability. Increased leachate was related to low metabolic activity of seed (Abdul-Baki and Anderson, 1972). Srivastava and Gill (1975) and Agrawal (1980) related the increase in electrical conductivity of seed leachates to the increased seed deterioration. Further, Ghosh *et al*. (1981) demonstrated in aged seeds by the extent of leakage of cytoplasmic components in to the external medium when the seeds were soaked in water which was related to damage to cell membranes. Krishnaveni and Ramasamy (1985) reported that the electrical conductivity and the leaching of free amino acids and sugars significantly increased with the increase in storage periods of maize seeds which was ascribed to the membrane deterioration.

An increase in membrane permeability due to degradation of cellular membrane and greater leakage of sugars, amino acids and inorganic solutes from the seed which leads to senescence (Abdul-Baki and Anderson, 1972).

Evidences from ultra structural and cytochemical investigations indicated the increased membrane aberrations in aged seeds of maize strongly support the loss of viability during storage (Berjack and Villers, 1972).

It is widely accepted that loss in cellular membrane integrity is one of the chief causes for loss of viability, presumably, a loss in membrane integrity under unfavourable conditions of storage lead to increased leaching of seed constituents and thus loss in viability (Ching and Schoolcraft, 1968 and Sen, 1977).

Villiers (1980) indicated that the most common and consistent ultra structural changes in all the cell organelles was the loss in integrity of membranes.

Meng (1993) reported that when soybean seeds were naturally aged or artificially aged seed deterioration caused damage to cell structure and function of cell membrane leading to increased electrical conductivity and reduced germination and also respiration rate.

Shanmugavel *et al*. (1995) noticed that decline in seed germination and seedling vigour was associated with greater electrolytes leakage and higher production of volatile aldehydes in soybean seeds stored in muslin cloth at 70 per cent relative humidity and at 35^0C for one to five weeks.

Vieira *et al*. (1999) reported that decline in seed germination, field emergence and seedling vigour was found to be negatively correlated with greater electrolyte leakage in soybean.

Peroxidation of unsaturated fatty acid of biomembrane leads to leaching of electrolytes and other solutes in soybean (Singh and Dadlani, 2003).

2.2.3 Free radical damage

A free radical is an atom or group of atoms with an unpaired electron, which posses the ability of donating or receiving an atom. The hydroxyl (–OH) and super oxide ($O^-{}_2$) are the two most important radicals believed to cause most damaging biological action. The free radical damage is an important aspect of seed deterioration and has a close relationship between the loss of vigour and viability of seeds (Basu *et al.,* 1975).

Ageing has been partially attributed to the accumulation of free radicals produced by the faulty metabolic process (Tappel, 1973). Under very dry conditions lipids are subjected to direct auto-catalytic attack by enzymically and non-enzymically leading to the production of hydroperoxides, other oxygenated fatty acids and free radicals (Justice and Bass, 1978). The free radicals are unstable and may react with and damage nearby molecules. Stored seed subjected to lipid peroxidation showed consistant attack by oxygen, forming hydro peroxides, other oxygenated fatty acids and free radicals, which are unstable and may react with and damage nearby molecules. The total amount of oxygenated fatty acid generated would be proportional to the age of seed (Wilson and McDonald, 1986).

Basu (1993) reported that lipid peroxidation and free radicals formation are the major causes for the deterioration of oil seeds in storage.

Hendry (1993) reviewed the role of oxygen and free radical generation on seed longevity and presented evidence that supported the role of oxygen in favoring the free radical hypothesis.

2.2.4 Enzyme activity

Loss of viability of seeds has been correlated to enzymatic activity. Abdul-Baki (1980) reported that respiratory and associated enzymes *viz.,*peroxidase, glutamic acid oxidase and catalase activity of hydrolytic enzymes *viz.,* phytases, proteases and phosphatases; the increase of these enzymes was associated with degradation of organellar membranes, nucleopreoteins etc. Declined peroxidase activity with increased storage time has been observed in Gukfolyia seeds (Nkang, 1988). Free radicals and hydrogen peroxides are produced from various metabolic reactions and could be destroyed by the activity of scavenging enzymes like catalase and hydrogen peroxidase. Peroxidase activity decrease appreciably with aeging, making the seed more sensitive to the effect of oxygen and free radicals in membrane unsaturated fatty acids and to the production of secondary lipid peroxidation products *viz.,* monaldehyde and lipid conjugates.

Francis and Coolbear (1988) reported that the accumulation of phospholipase activity in aged tomato seeds, which acts on membrane phospholipids and release fatty acids, indicating the loss of membrane phospholipids and subsequent lipid peroxidation. Decreased peroxidase activity was observed due to natural aeging.

During deterioration a marked changes in the content and activity of certain respiratory enzymes such as catalase, peroxidase, dehydrogenase, cytochrome oxidase and glutamicacid decorboxylase was noticed with decline in viability (Chauhan *et al.,* 1984). Association of loss of viability with enzymatic activity was reported in sorghum (Perl and Feder, 1978); sunflower (Dey and Basu, 1982) and wheat (Bhattacharya and Mandi, 1985).

Baily *et al.* (2002) observed increased changes in the activities of antioxidant enzymes and lipoxygenase in sunflower seeds of different vigour.

2.2.5 Changes in the chemical constituents

In stored seed the food reserves deplete with the advance in period of storage on account of physiologyical, biochemical, enzymatic activity and pathogenicity of storage fungi besides insect attack. Maize seeds being rich in carbohydrates content and di and oligosaccharides which stabilize membrane intensity undergo bio-chemical changes.

Ching and Schoolcraft (1968) related seed ageing leading to loss of seed viability and vigour to physiological and chemical differences in seeds.

Koostra and Harrington (1969) reported that seed deterioration occurred due to decrease in phospolipid content of biomembranes with age of seed. Seeds infected with fungi resulted in increase of fatty acid content on account of lipase enzyme secreted by storage fungi (Christensen and Kauffmann, 1969).

Seed viability has been related to chemical composition and storage food reserves. Delouche (1973) classified protein rich seeds as good, starch rich seeds as medium and oilseeds as poor storers under ambient storage condition.

However in colder regions where temperatures at time of planting are lower, some high lysine genotypes of maize may show slower growth and also poorer germination (Brown, 1975).

Jones and Tsai (1977) opined that zein is more rapidly mobilized than other protein during germination, thus accounting for seed of opaque–2 genotypes germinating somewhat more slowly than normal ones.

John (1983) related seed deterioration to protein degradation and decomposition of protein and lipids leading to decreased seed germination and decreased seedling vigour or death of seeds.

Chauhan *et al*. (1984) enumerated causes of seed deterioration leading to loss of viability in aged seed and related to biochemical changes in soybean and barley. Decrease in total carbohydrate, reducing and non reducing sugar content with increase in duration of ageing was observed.

Crowe *et al.* (1992) observed decrease in oligosaccharides during storage, which are responsible for membrane stabilization because of a non enzymatic browning reaction between the carbonyl groups of carbohydrates and amino groups of amino acids and proteins. Sucrose and raffinose levels declined in stored seeds of maize, although the monosaccharide, glucose, fructose and galactose diminished more precipitously.

Shanmugavel *et al.* (1995) has revealed viability in soybean seeds to the level of polyunsaturated fatty acid content and did not observe any significant change in oil content as a consequence of seed ageing.

Seeds with high oil levels have often been associated with shorter longevity and greater deterioration than seeds with high starch content (Copeland and McDonald, 2001).

In recent years, new seed technologies have been developed that alter the nutrient composition (oil, protein, starch, amino acids, fatty acids, phosphorus) of maize to improve grain quality for livestock feed and other end uses. New specialty maize hybrids used in value added grain production include Top Cross high oil maize (HOM), nutritionally enhanced Nitrides and Supersede maize, high lysine maize, and low phytate maize. As transgenic maize development accelerates, more specialty maize types are likely to be released in the future offering additional nutritional enhancements and modifications of kernel composition. Some of the changes in the composition of the maize kernel may adversely affect seed viability and vigor (Thomison *et al*., 2002).

2.2.6 Impaired protein and RNA synthesis

Failure of protein synthesis, especially during first hour of imbibition in aged seeds, damage to ribosomes, loss of enzyme activity, loss of DNA and or mRNA can occur at the ageing lesions (Osborne *et al*., 1980). Some or all of these factors probably serve to reduce the overall ability of aged seeds to synthesize protein. Membrane surface degradation, usual site of protein synthesis, may also serve as an important factor in contributing loss of activity.

2.2.7 Chromosomal aberrations

Aberration of chromosomes is one of the changes associated with seed ageing, which are also referred as mutagenic effects. Some of the chromosome aberrations in the aged seeds include fragmentation, bridges, fusion ring formation of chromosomes and variation in nuclear size.

Roberts *et al.* (1967) revealed that chromosomal damages in seeds is accelerated by temperature, moisture content and duration of storage and chromosome breakage is probably also induced by increased concentration of oxygen. Kristov and Krishtova (1978) related the degree of deterioration or ageing to the spectrum of chromosome aberration in maize. The deteriorated seeds contained more chromosomal aberrations and the incidence of chromosome breakages during anaphase was highly correlated with the loss of viability.

Rao and Roberts (1990) recorded the meiotic abnormality in lettuce plants grown from aged seeds increased with a decrease in viability of the seed lot.

2.2.8 Accumulation of toxic metabolites

Dey and Sirkar (1968) implicated that accumulation of number of phenolics, supraoptimal concentration of indoleacetic acid and abscissic acid to the loss of rice seed viability. Mukyopadyay *et al.* (1983) recorded a large accumulation of the polyamine spermine in non-viable rice embryos.

Accumulation of toxic products of respiration such as ethanol and acetaldehyde and lipid peroxidation leading to production of lipid hydroperoxides and cytotoxic volatile aldehydes were reported by Wilson and McDonald (1986) and Sur and Basu (1990).

2.3 Storage environment

In storage, seed moisture content, relative humidity, temperature, pests and diseases affect storage potential of seeds, the pertinent reviews on these aspects are detailed below.

Harrington (1960) proposed a thumb rule for seed storage, according to him, the sum of per cent relative humidity and the temperature in degree Fahrenheit should not exceed hundred for safe storage.

Christensen (1969) revealed that seeds of sunflower stored at moisture content of 10, 12 and 14 per cent and temperature of 3-5, 8-10 and 27-28^{0}C invasion by fungi and decrease in germinability were proportional to increasing moisture content, temperature and storage time.

A significant negative correlation was observed between seed moisture content and the viability in sorghum, bajra and maize seed (Nagarajan and Karivaratharaju, 1976).

Halder and Gupta (1980) observed that sunflower seeds deteriorated completely within 90 days when kept at 95 per cent relative humidity and at 28$\pm$1^{0}C but remained fully viable for 120 days at 80 per cent relative humidity.

Dange and Patil (1984) indicated that deterioration of groundnut genotypes in storage at different relative humidity (62, 72, 85 and 93%) differed significantly and they can be stored at 62 per cent relative humidity without loss in viability for considerable time.

Nautiyal and Joshi (1991) reported that, viability and vigour of the rabi/summer groundnut could be maintained satisfactorily for more than 8 months by lowering the moisture content using $CaCl_2$ desiccant.

Gao-Ping Ping *et al.* (1996) reported that seeds of five soybean varieties stored at temperature of –4, 0, 4^{0}C and at room conditions for 8 years to determine their retension capacity of vigour. They found that the seeds stored at room temperature showed faster decline in vigour as compared to the seeds stored at lower temperature.

Nkang and Umar (1997) reported that the temperature of 25-30^{0}C and relative humidity of 55-66 per cent found to be optimum for better storage of soybean seeds.

Narayanaswamy (2003) reported that groundnut seeds at 8.00 to 9.53 per cent moisture content could be stored for 8 months without losing its germination under ambient conditions at Bangalore.

Dejene (2004) reported that sorghum seed stored in warm temperature and concomitant high relative humidity in the store reduced seed viability due to an increased degree of invasion by seed-borne/ storage fungi.

2.3.1 Seed mycoflora

Seed pathologists strongly believe that seeds loose viability mainly due to invasion of fungi during storage which cause substantial decline in seed quality and quantity. However, their role in causing loss of seed viability was considered debatable until recently several deleterious effects on seed quality *viz.,* reduction in germination, discolouration, health hazards *etc.* have been reported (Barton, 1961 and Christensen, 1976).

Christensen and Kauffmann (1969) reported that even under limited moisture conditions where fungi and other microorganisms cannot grow, storage fungi adversely affect the seed by bringing down the seed viability, seedling vigour and also affect the chemical composition of seeds.

Kulik and Schoen (1982) reported that *F. moniliforme*, though present on maize seed as surface contaminant or internally infested, had no apparent effect on germination, vigour and field emergence. Growth and yield were not affected in the *F. moniliforme* infected samples.

Saxena and Karan (1991) reported gradual loss of protein and carbohydrate content of sesame and sunflower seeds due to *A. flavus* and *A. niger* during storage.

Paul and Mishra (1994) reported that maize seeds were infected by six dominant fungi *viz., Alternaria alternata*, *Aspergillus flavus*, *Fusarium moniliforme*, *Penicillium expansum*, *Rhizopus nigricans* and *Trichoderma viridae* which resulted in reduced seed weight. The highest reduction in seed weight was caused by fungi belonging to *Aspergillus* sp.

Krishnamurthy and Raveesha (1996) identified 38 species of fungi in cultivars of soybean. Among them, *Aspergillus, Pencillium, Rhizopus* and *Nigricans* were most commonly occurring storage fungi which reduce seed germination and seedling vigour and cause a variety of symptoms on seedling.

Savithri *et al*. (1998) recorded 203 fungal colonies per 100 seeds in groundnut stored in cloth bag and storage fungi such as *Aspergillus flavus, A. niger, Rhizopus stolonizer, Rhizoctonia bataticola* and *Fusarium monilforme* were found to be predominant in storage.

Ravishankar *et al*. (2002) evaluated for the occurrence of seed mycoflora and germination for maize. It showed high incidence of *Aspergillus flavus* (44%) *A. niger* (36%) *Fusarium moniliforme* (25%). Fungi like *Verticillium albo-atrum* (0%), *Trichoderma harzianum*(0), *Sclerotium rolfsii* (0%), *Botryodiplodia theobrmae* (0%) reduced seed germination to a lesser extent. Maize seeds treated with *Sclerotium rolfsii* resulted in higher percentage (28 %) of abnormality in seedlings.

Krishnappa *et al*. (2003) reported that groundnut pods stored in gunny bag had recorded maximum infection (18.3% in JL-24 and 16.17 % in TMV-2) of *A. flavus, A. niger, Fusarium* spp and *Pencillium* spp respectively, which caused reduction in germination and vigour index.

Somda *et al*. (2008) reported that seed born pathogen in maize reduced the seed germination and also noticed the trasmition of seed mycoflora from seed to seedlings.

Abdusalam and Shenge (2011) concluded that level of moisture content in stored seeds affects both the grade and storability of sorghum seeds and also has been observed to be an opportunity for microbial activity which increases the rate of seed damage.

Najibullah and Muhammad (2011) studied on effect of seed mycoflora on maize seeds for a period of six month revealed that there was decrease in association of field fungi, whereas, storage fungi increased during the storage period. This leads to reduction in germination, vigour index, and also resulted in more abnormal seedlings and dead (rotted) seeds.

2.3.1 Storage pests

Evans (1987) reported that insect infestation of maize grains leads to the reduction in both quality and quantity of harvested crops and in most cases pre-disposes the stored grains to secondary attack by disease causing pathogens.

Losses to maize and dried cassava caused by this pest could be as high as 36 – 40% and 70 - 80%, respectively over a period of six months of storage (Golob, 1988).

Jilania *et al*. (1989) noticed that germination and vigor of stored rice seed was significantly reduced by *Rhizopertha dominica* infestation. Decreased seed germination was about 34%, 51% and 66% with 6, 7, and 8 weeks of infestation, respectively and also the shoot length and dry weights of seedling grown from infested seed decreased significantly with an increase in their duration of infestation.

Baloch (1992) reported that rice weevil *Sitophilus oryzae* L. (Colepotera: Curculionidae) is a serious pest of various food grains like rice, wheat and maize under storage.

Jood and Kapoor (1994) reported substantial loss of vitamins, thiamine, riboflavin and niacin at 25% and above grain infestation by this insect pest.

In qualitative losses the total soluble sugar, reducing sugar, non reducing sugar and starch contents of wheat, maize and sorghum grains were affected adversely at 25%, 50% and 75% insects infestation caused by *Trogoderma grainarium* and *R. dominica* separately or by mixed population. *R. dominica* significantly reduced available carbohydrates at 50% and 75% infestation (Sudesh *et al*., 1996). Rice weevil cause heavy losses of stored food grain quantitatively and qualitatively throughout the world (Arannilewa *et al*., 2002).

Ahmed *et al*. (2003) reported thant the pest damaged seed will loose their germinating capacity completely.

Tadele *et al*. (2011) assessed comparative grain damage and weight loss in maize due *Prostephanus truncatus* and *Sitophilus zeamais* at ten varying population densities (5, 10, 15, 20, 25, 30, 35, 40, 45 and 50 insects per 200 g grain) and three storage durations (30, 60 and 90 days). The final result obtained with insect densities, per cent grain damage, flour (dust) produced and weight loss due to *P. truncatus* exceeded that of the *S. zeamais*.

2.4 Effect of seed treatments on seed storability

2.4.1 Neem leaf powder

Different neem products containing different neem compounds are having various applications including antialergic, anti-inflammatory, insecticidal, nematicidal, antidermatic, antiviral and antifungal and many other biological activities. More than 135 compounds have been isolated from different parts of neem. Azadirachtin proved to be very good to fight against many pests. The important compounds in neem are Azadirachtin, Salanin, Nimbin and Malentroil which have feeding deterrence, repellence, ovipositional inhibition and growth regulating activities against a great variety of insects (Jacobson, 1983). Azadirachtin is highly oxygenated C-secomeliacins isolated from neem seed and having strong antifeedant activity. Likewise synthetic pesticides, it does not kill insect directly but repels or reduces the feeding of many pest insects. The main constituent from neem (Azadirachtin) has been found very effective insecticide. Neem cake which can be made from neem leaves has multiple uses such as fertilizer, live stock feed and natural pesticide. Neem cake found very much effective as fertilizer because it not only provides nitrogen but also inhibits the nitrification process (Anuraj Kshirsagar and Vaishali Dhanwe, 2011).

Jotwani and Sircar (1965) in India were the first to demonstrate that powdered neem kernel when mixed with wheat seed at a proportion of 1-2 to 100 (wt/wt) parts satisfactorily protected against *S. oryzae*, *R. dominica*, and *Trogoderma granarium* for 270, 320, and 380 days, respectively.

Jilani and Su (1983) indicated the repellent activity of neem leaf powder to *S. granarius* and *R. dominica* on wheat seeds. It was reported that the average number of *R. dominica* adult emergence was 3.08, 5.16 and 20.16 with neem leaf powder used at 2.0 and 1.0 per cent and untreated control, respectively. This repellent activity of neem leaf powder was supported by Banarjee and Nigam (1985).

Chander and Ahmed (1983) reported that neem leaf powder at 5 per cent (w/w) protected the wheat seeds against *S. oryzae* infestation for three months.

Muda (1984) reported that mixing neem leaves with paddy grain in a proportion of 2 to 100 parts (wt/wt), bag treatment with 2% neem leaf water extract (wt/wt), or placing barriers of neem leaves between bags and storage floor, significantly reduced the infestation by *S. oryzae* and *R. dominica* and damage to paddy grain stored in 40 kg jute bags for 3 months.

Savitri *et al.* (1994) reported that treating sorghum seeds with ABC dust at 5.0 g per kg followed by melathion at 3.0 g per kg was able to control *R. dominica* and maintained high seed germination and vigour compared to neem leaf powder at 5.0 g per kg and karanj oil at 5 ml per kg throughout the storage period of 18 months.

Hossain *et al.* (1994) observed that soybean seeds coated with neem leaf powder showed excellent control of seed borne disease of *colletotrichum dematum* and maintained better seed health during the storage period.

Pal and Basu (1995) reported that wheat seeds treated with neem leaf powder @ 2g per kg of seed recorded maximum germination and seedling vigour after seven months of storage under ambient condition.

Isman (1995) showed that neem provides better control of the larvae at their different developmental stages particularly soon after emergence from eggs, while the mid stage instars and late instars are affected less.

Zeringue and Bhatnagar (1996) reported that nonvolatile, somewhat heat labile constituents in neem leaf extract, when added to fungal growth medium before inoculation, blocked aflatoxin biosynthesis in *Aspergillus flavus* and *A. parasiticus*. Practical applications of this finding may eliminate pre-harvest contamination of crops with aflatoxins.

Aminivder Kaur *et al.* (1999) studied the effect of six agro-forestry tree species on seed germination and seedling growth of certain wheat varieties and reported that *Azadirachta indica* and other species of agro-forestry reduced the germination, germination rate index, plumule length and vigour index compared to control in all the varieties of wheat. But, the seedling dry weight was inhibited by all the leaf extract except *A. indica*.

Sharma (1999) reported that neem seed kernel powder used at 4% and neem leaf powder used at 5% protected the maize, for 5 months, against *Rhizopertha dominica* and *Trogoderma granarium*. Neem oil (1%) was found to be toxic to *Tribolium castaneum* and *Sitophilus oryzae*, while the neem oil (2%) effectively reduced the emergence of F_1 and F_2 progeny of all the pests and completely protected maize up to 9 months.

Arati (2000) reported that bengalgram seeds treated with neem leaf powder recorded higher germination (65.91%) and vigour index (1282) compared to control at the end of 10 months of storage period.

Zaidi *et al*. (2003) compared extracts of neem, turmeric and sweet flag as insect repellents against *Sitotroga cerealella,* under laboratory conditions and found that the acetone-extract of neem was the most effective botanical insecticide in wheat.

Seeds treated with neem leaf powder @ 100 g per kg of seed recorded the germination of 94.0 per cent and seed damage was 12.0 per cent over control (81.0% and 24.7%, respectively) after 6 months of storage in wheat (Anon., 2004).

Sunilkumar *et al.* (2005) reported that, neem leaf powder at 1.0 per cent dosage was not effective in protecting the sorghum grains after 30 days of storage against *S. oryzae*.

Singh and Singh (2005) reported that among seven botanicals evaluated significantly less seed damage of 4.47 per cent was recorded in neem kernel seeds @ 10 g per kg seeds due to *R. dominica* in wheat.

Biswas and Biswas (2006) evaluated the effectiveness of some non-edible oils as grain protectants and their subsequent effect on rice seed germination. Neem (*A. indica*), karanj (*P. glabra* [*P. pinnata*]), aripple (*Lantana camara* L.), eucalyptus (*E. citriodora*), palas (*Butea frondosa* (Lam.) Taubert. [*B. monosperma*]), citronella (*Cymbopogon nardus* (L.) Rendle) and anona (*A. squamosa*) were applied at concentrations of 2.5 and 5.0 ml per kg seed. Citronella and neem oils were the most effective in reducing rice weevil (*S. oryzae*) infestation, whereas aripple oil was the most effective in increasing rice seed germination

Samuel *et al.* (2008) reported that maize seeds treated with neem leaf extract controled *Aspergillus spp, Fusarium spp and Rhizopus spp* effectively and recorded highest germination (100%), maximum root and shoot length with highest vigour index.

Kudachi and Balikai (2009) reported that among 14 botanical powder tried for the management of lesser grain borer (*R. dominica*) in sorghum, *A. calamus* at 1 per cent was found to be significantly superior in protecting sorghum grains from *R. dominica* up to 180 days after treatment followed by *A.squamosa* seed powder (5%) melathion (5%) and *A. indica* seed powder (5%) with minimum seed damage and weight loss, higher germination percentage and maximum adult mortality.

Mweshi *et al*. (2010) reported that among five plant extracts at dosages, neem leaf powder significantly reduced insect number, adult emergence of larger grain borer (*Prostephanus truncatus*) of stored grain pulses.

Duruigbo (2010) assessed the viability of maize and cowpea seed treated with neem powder, black pepper, pepper fruit seed powder, soybean oil and palm oil by storing in an air tight plastic container for 12 week. The results indicated that beneficial influence on mean seed germination percentage was higher (95%) with neem powder in maize and in cowpea (85%).

2.4.2 Castor leaf powder

Salas (1985) showed that castor oil at 10 ml per kg of maize seeds gave 100 per cent adult mortality of *S. oryzae* after three hours without affecting the viability of treated seeds.

Okonkwo and Okoye (1992) controlled the *Callosobruchus maculatus* (F.) effectively in stored cowpeas, with the application of dried ground leaves of *Ricinus communis* (L.) as an admixture in Nigeria. One to five grams of dry ground castor leaves, mixed with 300 g cowpea seeds, achieved mortality up to 100 per cent in 7 days. After 48 h only 20 per cent mortality was recorded with 5g. The seed were protected from damage for more than 3 months.

Emana (1999) and Asmare (2002) evaluated the efficacy of local plant materials including datura, chenopodium, endod, neem, croton, and castor against maize weevil. They reported that the treatments resulted in high percentage of adult mortality, reduced progeny emergence and low percent grain damage.

Ahmed (2000) reported that efficacy of castor-seed extract as an insecticide, against *Sitophilus oryzae.* He found it to be inhibiting cholinesterase and peroxidase enzymes in the insect body and the enzyme-inhibition levels varied differently in adult insects, at different exposure times and with the extracts taken with different solvents.

2.4.3 Pongamia leaf powder

pongamia contain alkaloids, demethoxy-kanugin, gamatay, glabrin, glabrosaponin, kaempferol, kankone, kanugin, karangin, neoglabrin, pinnatin, pongamol, pongapin, quercitin, saponin, β-sitosterol and tannin. Seeds have 19.0% moisture, 27.5% fatty oil, 17.4% protein, 6.6% starch, 7.3% crude fibre and 2.4% ash (Duke, 1983).

Gupta *et al.* (1989) found that there was no adverse effect of neem and honge oil on germination of wheat seeds even after 12 months of storage.

Nargis and Thiagarajan (1991) reported that tomato seeds pelleted with arappu leaf powder @ 300 mg per kg and pungamia leaf powder @ 200 mg per kg recorded higher germination percentage, seedling vigour index and field emergence over control.

Nargis (1995) reported that, the accelerated aged to tomato cv. PKM-1 seeds pelleted with pongamia and arappu leaf powder showed better performance in laboratory and field conditions compared to control.

Merwade (2000) reported that chickpea seeds treated with leaf powder of neem, yakke, lakke and pongamia (@ 10 g/kg seeds) showed higher germination, seedling length, seedling dry weight, viogur index and lower electrical conductivity of seed leachate throughout during the storage period of 10 months.

Vyakaranahal *et al*. (2000) reported that pongamia leaf powder (40 g/kg) seed treatment maintained significantly higher seed germination, root length, shoot length and vigour index compared to control after accelerated ageing at 45± 1°C temperature and 95± 1 per cent RH for 4 days in sunflower restorer lines (RHA-857, RLC-2, RLC-4, VI-46 and V-94).

Arati (2000) reported the pongamia leaf powder (5 g/kg seeds) seed treatment recorded higher germination, field emergence, root length, shoot length, vigour index and lower electrical conductivity of seed leachate compared to control during storage of chickpea seeds.

Sundareswaran *et al*. (2003) reported that the performance of pongamia leaf powder was better because of its anti-oxidant property that controls deterioration rate of seeds both under field condition and storage period.

Krishnasamy (2003) reported that the common botanicals used for pelleting are arappu (*Albizzia amara*), pongamia (*Pongamia pinnata*), notchi (*Vitex negundo*), prosopis (*Prosopis juliflora*), neem (*Azadirachta indica*).

These leaf powders contain an auxin like substances, which regulates the growth and initial establishment.

Ravi Hunje (2007) reported that among the plant bioproducts, chilli seeds treated with pongamia leaf powder (40g/kg of seed) recorded maximum seed quality parameters like germination, field emergence, root length, shoot length, vigour index and lower electrical conductivity over neem leaf powder (10g/ kg of seed) and sweet flag rhizome powder (10g/kg of seed) treatment up to 20 months storage period.

Yankanchi and Lendi (2009) evaluated the efficiency of leaf powders of *Tridax procumbens, Withania somnifera, Pongamia pinnata* and *Gliricidia maculata*, against pulse beetle. All plant leaf powders showed 100% ovicidal activity at 20 mg/g seed.

2.4.4 Tulsi leaf powder

Banarjee and Nigam (1985) observed repellent effect in leaves of tulsi (*Ocimum basilicum* L.) against stored grain pests.

Awuah (1996) successfully used leaf powder of tulsi in inhibiting mould development and aflatoxin production on stored soybean for 9 months.

Bekele *et al.* (1996) showed that ground leaves of *Ocimum suave* was a source of repellents and toxicants against the maize weevil *S. zeamais*, the lesser grain borer *Rhizopertha dominica* and the angoumois grain moth *Sitotroga cerealella*.

Keita *et al*. (2001) reported that powders made from essential oils of different basils provided complete protection against *C. maculatus*, and also did not show significant effect on the seed germination rate.

Biswas *et al.* (2002) and Prothitirat and Gritranapan (2006) stated that the use of extracts of *Agadirachta indica, Zingiber officinalis, Curcuma longa, Ocimum sanctum, Terminalia chebula and Catharanthus roseus etc.* were also well documented which can be exploited in control of fungicide resistant pathogen.

Awuah and Ellis (2002) reported the effective use of powders of leaves of *O. grattisimum* and cloves of *Syzygium aromaticum* combination with some packaging materials to protect groundnut kernels artificially inoculated with *A. parasiticus.*

Singh and Punam Kumari (2005) reported that tulsi leaf powder increased the mortality rate of *Trogoderma granarium* (Everts) with increasing doses and duration of exposure. However, absolute mortality was not observed. Tulsi did not affect the viability of grains.

Sohail Ahmed and Naima Din (2009) conclude that chickpea seed treated with leaf powder of tulsi and lantana at different concentrations of 0.5g, 1g, 1.5g, and 2g. Both botanicals found effective in controlling pulse beetle at higher concentration.

Yusuf *et al.* (2011) evaluated insecticidal activities of seven plant materials (1-5g/100g cowpea seeds) such as citrus peel powder (CPP), *Acacia* leaf powder (ALP), *Occimum* leaf powder (OLP), mahogany bark powder (MBP), hot pepper powder (HPP), ginger powder (GP) and mahogany wood ash (MWA) and a synthetic insecticide, pirimiphos-methyl dust (PMD) (0.1-0.5g/100g cowpea seeds) as standard. Results showed that MWA was superior at all rates of application in reducing cowpea seed weight loss and seed damage. The effectiveness of the treatments in succession was MWA> PMD> GP> HPP>MBP>OLP>ALP>CPP. Remaining botanicals effective rate of 5g/100g cowpea seeds, than by 2-3g/100g. There was no significant difference among treatments in the germinability.

2.5.5 Mandrin peel powder

Don-Pedro (1985) reported that the fruit peels of some citrus species have been reported to have insecticidal properties against insect pests.

Sudesh Jood *et al.* (1993) treated maize seeds with neem oil and powder of neem leaf and neem kernel, citrus leaf, garlic bulb and pudina leaf @ 1 and 2 per cent level against larvae of *Trogoderma granarium.* Neem kernel powder and oil provided complete protection to seeds for six months. Whereas, substantial insect infestation (7-19%) were noticed after three months and also in different treatments like 35 per cent neem, 43 per cent citrus and 62 per cent garlic after six months. The moisture, ash, fibers, fat, protein and carbohydrates of treated kernels remained unaffected after one month of storage.

Shukla *et al.* (2000) found that the essential oil extracted from the epicarp of *C. sinensis* exhibited strong fungitoxicity against *A. flavus* and *E. citriodora* also showed fungitoxic effect against *A. flavus*.

Ashamo and Odeyemi (2001) reported that maize germination was unaffected when treated with petroleum ether extracts of different plants including pepper corns (*Piper guineense*), orange peel (*Citrus sinensis*) and peanut seeds (*Arachis hypogea*).

Tripathi *et al.* (2003) Essential oil derived from orange peels is known to have toxic, feeding deterrent, and poor development effects on lesser grain borer, rice weevils and red floor beetle

Krishnamurthy and Shashikala (2006) observed soybean seeds treated with natural products such as leaf powder of *W. somnifera, H. suaveolens*, peel powder of *C. sinensis*, *C.medica* pongamia cake etc. significantly inhibited *A. flavus* and aflatoxin B1 production the latter which inhibits seed germination and seedling growth.

Mbah and Okoronkwo (2008) evaluated dried and pulverized leaves of *Chromolaena odorata* and fruit peel of *Citrus limon* at the rate of 15, 10, and 5 g per 100 g seeds of maize cultivar JZSR and concluded that both plant products were found to be effective in controlling *S. zeamais.*

Emearsor and Okorie (2010) evaluated sweet orange (*C. sinensis*) rind powder and oil for the control of maize weevil (*S. zeamais*) feads at different doses. They reported that between the two products, rind oil treatment resulted in significant mortality of adult (*S. zeamais*) and greater reduction in grain damage.

Abdullahi *et al*. (2010) carried out bioassays at the different concentrations of citrus peel powders (2, 4, 6 and 8g). Insect mortality was observed after every 24 hours interval. The result of the study indicated that the highest dose of the citrus peel powders (8g) recorded the highest mortality of the insect after every 24hours.

2.4.6 Bhajje powder

Jilani (1984) reported that sweet flag at 0.25, 0.5 and 1.0 per cent caused, cent per cent mortality of *R. dominica* in wheat seeds.

Tiwari (1993) found that sweet flag significantly reduced the grain infestation and F1 progeny production of *S. oryzae* in wheat when used at 0.5 per cent. Again he reported that with *A. calamus* at 0.5 per cent in wheat grain against *R. dominica* resulted in 80 per cent suppression.

Seed treatment of dried and ground rhizome of sweet flag at 50 g/kg of wheat against *S. oryzae* reduced the damage of stored grains to 5.4 per cent as against 33 per cent in the untreated control (Paneru *et al.,* 1997).

Kalasagond (1998) found that sweet flag rhizome powder at 0.6 per cent caused cent per cent mortality of *S. oryzae* and complete protectant up to 240 days. Sweet flag powder @ 5 per cent was found to be most effective grain protectant even up to 45 days after treatment resulting in 100 per cent mortality. It reduced to 97.5 per cent at 90 days treatment.

Biradar (2000) studied the mortality of *S. oryzae* consequent to the impregnation of gunny bags with botanicals. Sweet flag rhizome extract @ 5 per cent v/v at 30 days after storage offered 100 per cent mortality. Among different treatments tested sweet flag rhizome extract protected up to 90 days of storage in wheat.

Patil (2000) reported that chickpea seeds treated with sweet flag rhizome powder recorded higher germination (66.74%), seedling dry weight (157 mg), vigour index (1312) and 100 seed weight (15.54 g) and lower EC (1.47 dSm^{-1}). While, these were 64.17 per cent, 144 mg, 12.0 g, 13.5 g and 1.86 dSm^{-1} respectively in control at the end of 10 months of storage.

Umoetok (2000) investigated the toxicity of the powder of *A. calamus* against three species of insect pests (*S. oryzae*, *Tribolium castaneum* (Herbst) and *R. dominica*) of stored products in the laboratory. The results indicated that only *S. oryzae* and *R. dominica* were susceptible to the test products wherein 100 per cent *S. oryzae* and 90 per cent *R. dominica* died within 16 days. No mortality was observed in case of *T. castaneum*.

Yadav and Bhargava (2002) conducted laboratory studies to determine the effect of botanical insecticides, namely neem (*A. indica*) extract, undi (*Calophyllum inophyllum* L.) extract, karanj (*Pongamia glabra* Vent. [*P. pinnata*]) extract, eucalyptus (*Eucalyptus spp.*) oil and lemon grass [*Cymbopogon flexuosus* (Steudel) Watson] oil at 0.1, 0.5, and 1.0 ml per 100 g sorghum seeds, on the stored product pest *C. cephalonica*. Neem extract at 1.0 ml per 100 g seeds resulted in the longest total life cycle (57.8 days), highest reduction in adult emergence (85.7%), lowest number of eggs laid per female, highest reduction in egg viability (65.3%) and shortest longevity for males (3.3 days) and females (4.8 days). There was no observed adverse effect on the germination of sorghum seeds at any interval.

Umoetok and Gerard (2003) reported that, the mortality observed on *R. dominica* indicated that 25 g of *A. calamus* powder resulted in significantly higher percentage mortality (83.22%) than pirimiphos-methyl that gave 56.65.0 per cent and rotenone caused 36.4 per cent mortality.

Sunilkumar (2003) found that sweet flag was highly protective up to 180 days against *S. oryzae* @ 10 per cent dosage showing less than one per cent seed damage in sorghum.

Yevoor (2003) also observed similar results in the management *S. oryzae,* who reported that sweet flag powder @ 2 per cent caused zero per cent seed damage.

Deshpande *et al.* (2004) observed that blackgram seeds treated with sweet flag rhizome powder recorded significantly higher germination (93%), seedling vigour index (2275) whereas, in control they were 89.66 per cent germination and 1201 vigour index respectively.

Sunilkumar *et al.* (2005) noticed that sweet flag was highly protective up to 180 days against *S. oryzae* @ 10 per cent dosage and showed less than one per cent seed damage in sorghum.

Ravi Nandi *et al.* (2008) revealed that pigeon pea seeds treated with the tablet form of sweet flag rhizome powder along with cow dung ash as a carrier at 15 and 20 per cent concentration reduced the egg laying. The sweet flag rhizome powder at four per cent concentration reduced the seed damage with 16.33 per cent as against 41.11 per cent in untreated check after 120 days after storage.

Channabasavanagowda *et al.* (2008) reported that wheat seed treated with sweetflag @ 10 g per kg of seeds recorded higher germination percentage (87.00%) and other seed quality parameters were significantly higher and low insect infestation was found till the end of 10 months of storage.

Asha and Deepak (2009) observed that antimicrobial activity of *A. calamus* rhizome and leaf extracts.

Kudachi and Balikai (2009) reported that among 14 botanical powder tried for the management of lesser grain borer (*R. dominica*) in sorghum, *A. calamus* at 1% was found to be significantly superior in protecting sorghum grains from *R. dominica* up to 180 days after treatment followed by *A.squamosa* seed powder (5%) melathion (5%) and *A. indica* seed powder (5%) with minimum seed damage and weight loss, higher germination percentage and maximum adult mortality.

2.4.7 Arappu powder

Nargis (1995) reported that pelleting of tomato seeds with pongamia and arappu leaf powder showed better performance in laboratory and field conditions compared to control.

Vasantha (1995) reported that pigeonpea seeds treated with arappu leaf powder prior to storage showed good effect on germination, seedling vigour and stored better up to ten months without loss of viability.

Muruganathan (1996) observed that cotton seeds pelleted with arappu leaf powder showed more viability and vigour compared to unpelleted seeds.

Ahmed (1997) in onion found that seed coat with arappu leaf powder @ 500 gram per kg increased the seed vigour and germinability.

Patil (2000) reported that seed treatment with arappu leaf powder recorded higher germination (65.91%) and vigour index (1282) when compared to control at the end of 10 months of storage period in Bengal gram.

Srimathi *et al.* (2000) found that soybean seeds pelleted with nutrients using arappu leaf powder as a filler material excelled over others in germination.

Raikar *et al*. (2011) reported that seeds treated with leaf powder of neem, pongamia, arappu, yekke and bajje and stored in polyethylene bag maintained satisfactory germination up to 20 months under ambient condition; among them arappu leaf powder showed higher seedling vigour parameters.

Sathiya *et al.* (2011) evaluated the effect of botani

cals seed treatment on productivity of three major oilseeds. Seeds of all three oil seed crops pelleting with arappu, neem and pungam leaf powder, and vasambu rhizome powder @ 200 g kg–1 of seed resulted in enhanced seed yield and seed quality such as oil content, germination percentage, seedling length, dry matter production and vigor index when compared to control.

2.4.8 Parthenium

Allelopathic effects of leachates from leaf, stem flower and roots of *Parthenium hysterophorus* is due to the presence of phenolic compounds (caffeic, p-coumaric acid, p-hydroxy benzoic acid, parthenin and vanillic acid). The mixture of these phenolic acids as well as individual compounds inhibited the germination and vigor index (Rajan, 1973; Sasikumar *et al*., 2002).

Srivastava *et al.* (1985) revealed that aqueous extracts of leaves and inflorescences inhibited the germination and seedling growth of barley, wheat and peas.

Patil and Hedge (1988) isolated and purified parthenin from leaves of *P. hysterophorus* and demonstrated that this compound significantly decreased the germination of wheat seeds and adversely affected seedling growth.

Parthenium hysterophoorus leachates obtained from the leaves, stem and flowers significantly inhibited the plumule growth of cowpea. While, in sorghum only radical growth was affected. The inhibition was attributed to the unsaturated lactones found in plant parts. (Swaminathan *et al*., 1990).

Singh and Sangeeta (1991) reported that foliar leachates of *Parthenium hysterophorus* reduced root and shoot elongation of paddy and wheat

Dhawan and Dhawan (1995) have demonstrated that the germination and yields of traditional Indian pulse crops (guar, black and green gram) were reduced when these were grown in soils previously infested by parthenium weed.

Tefera (2002) also reported that 10 per cent leaf aqueous extract of *Parthenium hysterophorus* resulted in complete failure of seed germination in *Eragostis tef*.

Batish *et al.* (2002) reported germination inhibition of *Amaranthus viridis, Chenopodium murale* and *Ageratum conyzoides* by *Parthenium hysterophorus*.

Leaf and seed powder treatments of *D. stramonium*, *J. curcas*, *P. dodecondra* and *P. hysterophurus* were effective in reducing F1 progeny production by different storage insect pests of cereal crops (Asmare, 2002 and Shaheen, 2006).

2.4.9 Wood ash

Pawar (1980) reported that 1.25 cm layer of cow dung ash at the top was effective in protecting seeds from *C. chinensis* in tanks and barrel. Further, mixing with 30 per cent wood ash was also effective against *S. oryzae* and *S. cerealella* in maize.

Chiranjeevi (1991) found cowdung ash as most effective in reducing the percentage seed damage and increasing protection against bruchid infestation of greengram seeds compared to other wood ashes.

Sudheer Reddy *et al*. (1993) studied the influence of inert materials on incidence of insect pests on sorghum seeds for 12 months storage period. The seed damage due to *Rhizopertha dominica* at 12 months period was 0.0, 35.7, 49.5, 0.0, 0.0, 7.0, 0.5, 0.0 in seeds treated with cowdung ash at 200 and 400 g, wood ash at 200 and 400 g, inert clay at 5 and 10 g , activated clay at 10 g and melathion dust @ 3 g per kg seeds respectively.

Sharma (1995) recommended treatment of maize seeds with neem leaf powder (100 g/kg) and ash (10g/kg) which act as good antifeedant, repellent and oviposition deterrent against *Rhizopertha dominica* in maize. Number of weeviled grains after three months was 18.3 per cent as against 33.7 per cent in control. However, cob ash was observed inefficient after nine months of storage by showing 90 per cent weeviled grains.

Kalasagond (1998) found that, ash (30 cm top layer) and activated kaolin (1.2%) found to be highly effective which caused cent per cent adult mortality of *S. oryzae* and *R. dominica*. This was followed by 30 per cent ash admixture which was found to be moderately effective further preventing F1 progeny and grain weight loss.

Sivasrinivasu (2001) found cent per cent mortality of rice weevil at 28 days after storage in sorghum treated with 30 per cent ash and observed no weight loss for 90 days of storage period.

Hakbijl (2002) reported the use of ash from burnt cow dung as an insecticide against *T. castaneum*, *S. granarius* and *Cryptolestes ferrugineus* larvae.

Yevoor (2003) reported that ash was not effective to maize grains which showed less than 50 per cent adult mortality at 30 DAT and zero per cent adult mortality at 150 and 180 DAT.

Adekunle and Uma (2005) mentioned that wood ash is used as a means of biological control which is generally favored as a method of storing seeds because it does not have any of those disadvantages of chemicals and tend to be more durable in its effect.

Girma Demissie *et al.* (2008) treated maize seed with mineral industrial filter cake, silicove and wood ash at various doses and found that silicose and wood ash were found to be effective against maize weevil with high mortality of insects without affecting germination of maize genotypes.

Ntonifor *et al*. (2011) reported that insect infested maize seed mixed with *chenopodium ambrosioides* powder alone and in combination with wood ash against *S. zeamais* which caused mortality and protected the grain from damage within one to months of storage.

2.4.10 Thiram

Agrawal (1974) reported that seed treatment with thiram did not affect the storage life of maize seeds.

Moreno-Martinez and Ramirez (1985) reported that maize seeds treated with bavistin and thiram (125 to 750 ppm) offered good protection while untreated seeds were invaded by storage fungi and registered low germination.

Misra and Dharamvir (1990) studied the efficacy of fungicides against heavy inoculum in presence of certain fungi causing discolouration of paddy seeds. They observed that seed treatment with 0.3 per cent phenylmercury acetate, captan, carboxin, carbendazim+ thiram, carbendazin, thiram protected the seeds resulting in a distinct improvement in germination rate.

Paul and Mishra (1994) stated that all kinds of fungicides controlled the occurrence of fungi in treated seeds and improved the germination percentage. Among various fungicides, thiram + captan was found to be most successful in controlling seed infection (2%) and improving seed germination (96%), shoot and root length and dry weight of seedling also increased significantly by fungicide treatment in maize.

Ashok Gaur *et al.* (2000) found that the pearl millet seed treatment with thiram @ 0.30 per cent considerably reduced the seed borne fungi *Curularia trifoli, Curularia pallescens, Fusarium maniformae* and *Penicillium* spp. Among the seed treatment thiram was found to be most effective in extending the storage life of the seeds.

Vijay Kumar (2007) observed that among the different treatment combinations, the seeds coated with thiram @ 1.5g/kg of seed and imidachloprid @ 7.5g/ kg of seed recorded significantly higher germination (77 %) followed by seed coating with polymer @ 5.00 g kg-1 of seeds and thiram @ 1.50 g kg-1 of seeds as compared to control (52 %).

Monel *et al*. (2011) reported in sorghum Cv.Nirmal-21 that among treated seeds with fungicides such as thiram, carbendazim, mancozeb, copper oxychloride, capton, and captafol, at 2.5g/kg seed, thiram treated seeds maintained highest germination than other fungicides.

2.5 Effect of storage containers on storability

Seed storage is an integral part of seed production programme. Seeds of many field crops are produced with greater care and cost. Hence, a good storage is essential to keep them alive and vigourous until required for subsequent sowing season. Seed is said to be in storage in various stages from harvest to sowing, further the left over seeds are to be stored without appreciable decline in quality in order to meet the further demand.

The packaging materials used are decided by kind and quantity of seed to be packed, the type of package, duration of storage, storage temperature and relative humidity of the storage area etc. Storage of orthodox group of seeds is done in different containers such as moisture pervious and impervious containers.

2.5.1 Polyethylene and cloth bag

Singh and Tripathi (1968) in maize seeds revealed that seeds with lower moisture content (10-12%) stored in sealed moisture proof containers maintained viability for longer period than those stored in moisture pervious containers.

Kurdikeri (1991) reported that the viability of maize seeds stored in polythene bag was maintained for 17 months, while seeds stored in cloth bag maintained viability only for 13 months.

Biradar (2001) recorded significantly higher germination (3.9%), shoot length (7.79 cm), root length (8.44 cm) and lower EC (293.6 µmhos/cm) in greengram seeds stored in polythene bag compared to those stored in cloth bag (79.8%, 6.37 cm, 6.94 cm and 305.8 µmhos/cm respectively) at the end of 12 months period.

Channakeshava *et al.* (2001) revealed that African tall fodder maize seeds stored in moisture impervious containers maintained the initial moisture content (8 ± 1%) and registered higher germination (74-91.5%) as compared to seeds stored in moisture pervious containers (Cloth and gunny bags).

Tammanagouda (2002) revealed significantly higher germination (71.15%), root length (11.14 cm), shoot length (8.11 cm) and lower moisture content (9.21%) and seed infestation (34.10%) in the greengram seeds stored in polythene bag as compared to those in cloth bag at the end of 10 months storage period.

Singh and Dadlani (2003) stored two cultivars of soybean PK-327 and JS-71-05 in cloth bag and polythene bag (700 gauge). They reported that, high germination percentage of 94 per cent in JS-71-05 and 84 per cent in PK-327 was maintained for 14 months in seeds packed in polythene bag whereas, it fell to 3 per cent and 1 per cent respectively in seeds packed in cloth bag after 8 months.

Krishnappa *et al.* (2003) recorded that groundnut pods stored in the high density polyurethrane bag recorded higher germination (70.33%) at the end of 14 months of storage and lesser storage fungi infection of 5.5 per cent.

Basave Gowda and Nanjareddy (2008) reported that groundnut pods produced during rabi or summer and stored for eight months in polylined (300 gauge) gunny bag (PLGB) + silica gel (30g/kg pod) and in PLGB + calcium oxychloride (10g/kg pod). All were on par with each other by recording higher germination and with other seed quality parameters as compared to seeds stored in cloth bag and polythene bag.

Nataraj *et al.* (2011) revealed that sunflower hybrid seeds stored in polythene bag (700 gauge) recorded higher germination (80%), vigour index (1869), total dehydrogenase activity (1.258) and lower electric conductivity of leachate (194.53d Sm^{-1}) compared to cloth bag.

Ransing, *et al.* (2011) revealed that ground nut stored in the form of pods could maintain germination above minimum seed certification standards up to 240 days than kernals up to 180 days, where the polylined cloth bags were best container for storage of ground nut pods compared to cloth bags.

Raiker *et al.* (2011) reported that storability of scented rice seeds stored in polyethylene bag maintained viability as per certification standards for more than 20 months compared to those stored in cloth bag with higher seedling vigour index and low E.C.

2.5.2 Vacuum

Roberts (1972b) hypothesized that seed longevity is controlled mainly by three major factors moisture content, temperature and oxygen concentration in the storage environment. High oxygen pressure promotes and low pressure represses denaturation of constituents. Storage under low oxygen pressure, e.g. in vacuum or in CO_2 at temperatures prevents insects, fungi and micro-organisms development.

Nunez *et al.* (1986) reported that anaerobic environment of vacuum packaging prevents the growth of spoilage microorganisms especially aerobic ones which are responsible for off odor, slime and texture changes.

Tao (1989) reviewed the literature and concluded that the benefit from vacuum storage is limited and variable. Hence, it should not be used for conservation by multi-crop gene banks.

McDonald (1999) suggested that eliminating O_2 from the seed storage atmosphere might decrease the initiation of free radicals, which should extend seed longevity by reducing lipid peroxidation and generation of additional damaging compounds.

Kumar and Sreenarayanam (2000) opained that the reduction of protein, rehydration ratio and increase in moisture content was comparatively higher in ordinary heat sealed storage against vacuum packaging which was attributed to the lower activity of proteinase.

Rao and Sastry (2002) stored sorghum and bajra seeds of 6, 10 and 14 per cent moisture content in hermetically sealed in aluminium foil envelops containg air or vacuum and stored at 35°C and 50°C. There was a gradual loss in germination rate under all storage conditions. Seeds stored under the higher temperature of 50°C and/or high MC (14%) deteriorated faster than with other treatments. Pearl millet seeds survived longer than sorghum under similar conditions of storage.

Analysis of variance of the estimates of half-life for the viability of seeds showed significant effects of MC, vacuum packing and their interaction on seed survival at 50℃ ($P < 0.001$). Seeds dried to 6% MC retained viability longer than those stored at 10% and 14% MC. Vacuum packing further enhanced seed longevity at 6% MC but not at 10 or 14% MC.

Chiu *et al*. (2003) reported the effects of partial vacuum storage on longevity and free radical processing systems of primed *sh*-2 seeds. Primed sweet corn seeds were vacuum-packed and stored at 25 ℃ for up to 12 months. The longevity of 15 ℃-primed seeds showed higher viability and vigor than non-primed control seeds when they were stored under non-vacuum conditions. Partial vacuum storage proved useful in extending the longevity and seed vigour of 15 ℃-primed seeds for up to 12 months. The improved longevity was related to the decreased free radicals-mediated peroxidative responses.

Guberac *et al*. (2003) stored seeds of four species (winter wheat, winter barley, spring oat, and maize) in hermetic glass containers at an air temperature of 20 ℃ and a relative humidity of 65 per cent. The germination level decreased for all cereals, on average by 38 %, over the 5 years of storage. The highest germination values were found for wheat seeds (84.75 %) and the lowest (36.0 %) germination values for maize seeds.

Barzali *et al*. (2005) evaluated the influence of temperature and storage atmosphere on storability of rye seeds (*Secale cereale* L.). Seeds of 5.5% moisture content were kept at −15, 0 and 10℃ in hermetically sealed glasses filled with air, CO_2, N_2, and under vacuum. Germination tests were accomplished after 1, 5, 15, 17 and 26 years of storage. In addition, seed and seedling vigour traits were determinated for the material stored 26 years. The germinability and viability were highest at −15℃ followed by 10℃ and 0℃, and also highest under vacuum and N_2 as opposed to air and CO_2. Vacuum packed seed gave the highest values for shoot dry weight, seedling dry weight, shoot length, root length, and seedling length.

Sanjeev and Ramesh (2006) reported that although vacuum or gas packaging can be used to extend the shelf life and keeping quality of food, aerobic spoilage can still occur in such packaged products, depending on the level of residual oxygen in the package head space.

Sastry *et al*. (2007) reported that ground nut seed stored at very low moisture content (1.7 to 3.4%) and at 35^0C either in sealed air or vacuum maintained viability up to 288 weeks.

Ellis and Hong (2007) studied the effect of hermetic or open storage on the sensitivity of timothy (*Phleum pratense* L.) and sesame (*Sesamum indicum* L.) longevity in relation to moisture content. They concluded that the deleterious effect of oxygen on seed longevity increases as seed MC decreases and confirmed that hermetic packaging is preferable for long-term seed storage.

Abdulla and Nusr (2009) reported that an increased moisture content of stored chilli in the jute bags, compared with vacuum packaging due to no exchange of gases in vacuum packed bag.

III. MATERIAL AND METHODS

The storage experiment was conducted on maize with different seed treatments and storage containers to ascertain their influence on storage potential under ambient storage conditions in the Department of Seed Science and Technology, University of Agricultural Sciences, Dharwad during 2011-12. The details of materials used and the techniques adopted during the course of present investigations are described in this chapter.

3.1 General description

3.1.1 Location

The storage experiment was conducted under the ambient conditions in the laboratory of the Department of Seed Science and Technology, University of Agricultural Sciences, Dharwad. Which lies between $15^0 21^0$ North latitude and $76^0 7$ East longitude at an altitude of 678 m above the mean sea level.

3.1.2 Climatic condition

The mean meteorological data from Jan 2011 to April 2012 were collected from the meteorological observatory of the Main Agricultural Research Station, Dharwad and presented in Table 1. During the investigation period (January 2011 to January 2012) the mean maximum temperature of 37.6^0C was noticed during April and the mean minimum temperature was 13.7^0C during December. The relative humidity during storage period varied between 87 to 44 per cent during January 2011 to January 2012 respectively.

3.1.3 Seed source

Freshly harvested, two months old seeds of maize were obtained from the Krishi Vigyan Kendra Bagalkot, University of Agricultural Sciences, Dharwad for conducting the storage study. The seeds were sun dried to around 8.0 per cent moisture content before conducting the storage studies.

3.2 Details of the experiment

3.2.1 Treatment details

The storage experiment consisted of totally 33 treatment combinations involving eleven seed treatments and three containers, replicated four times. The details of the experiment are furnished below (Plate 1).

Factor – I: Seed treatments (T)

T_1 : Neem leaf powder @ 10g/kg of seeds

T_2 : Castor leaf powder @ 10g/kg of seeds

T_3 : Pongamia leaf powder @ 10g/kg of seeds

T_4 : Tulsi leaf powder @ 10g/kg of seeds

T_5 : Mandrin peel powder @ 10g/kg of seeds

T_6 : Sweet flag rhizome powder @ 10g/kg of seeds

T_7 : Arappu leaf powder @ 10g/kg of seeds

T_8: Parthenium leaf powder @ 10g/kg of seeds

T_9 : Wood ash @ 10g/kg of seeds

T_{10}: Thiram @ 2g/kg of seeds

T_{11} : Control

Factor – II: Seed containers (C)

C_1 : Cloth bag

C_2 : Polythene bag (700 gauge)

C_2:Vacuum package (multilayer polythene bags of 350×180×150 mm)

Treatment combinations:

T_1C_1	T_5C_1	T_9C_1
T_1C_2	T_5C_2	T_9C_2
T_1C_3	T_5C_3	T_9C_3
T_2C_1	T_6C_1	$T_{10}C_1$
T_2C_2	T_6C_2	$T_{10}C_2$
T_2C_3	T_6C_3	$T_{10}C_3$
T_3C_1	T_7C_1	$T_{11}C_1$
T_3C_2	T_7C_2	$T_{11}C_2$
T_3C_3	T_7C_3	$T_{11}C_3$
T_4C_1	T_8C_1	
T_4C_2	T_8C_2	
T_4C_3	T_8C_3	

3.2.2 Design of the experiment

The laboratory experiment was conducted under Completely Randomized Design (CRD).

3.2.3 Number of replications: Four.

3.3 Seed treatment procedures

Before imposing treatments seed moisture content was brought to at 8 per cent by sun drying. The seeds were treated by dry dressing with botanicals *viz.,* leaf powders of neem, castor, pongamia, tulsi, mandarin peel, sweet flag rhizome, and arappu and wood ash @ of 10g/kg of seeds. The thiram was slurry treated @ 2g/kg of seeds. The treated seeds were stored in cloth bag, polythene bag and vacuum sealed containers.

3.4 Method of storage

After treating seeds as per the treatments schedule, 350 g of seeds were vacuum packed in multilayer polythene bags of 350×180×150 mm dimension using vacuum packaging machine OLPACK 510, Interprise Breussel S.A., Belgium make and in polythene bag (700 gauges) and 5kg seeds in cloth bag separately. Sufficient number of polythene and vacuum bags was tightly tied and were stored under ambient conditions for 12 months in the laboratory at the department of Seed Science and Technology, University of Agricultural Science, Dharwad (Plate 2).

3.5 Observations recorded

The required quantity of seeds were drawn randomly at monthly intervals from each container as per the treatment schedule for taking observations on seed quality parameters as detailed below.

3.5.1 Germination (%)

The germination test was conducted on four hundred seeds in four replications of 100 seeds each as per the ISTA procedure (Anon., 2007) using between paper method.

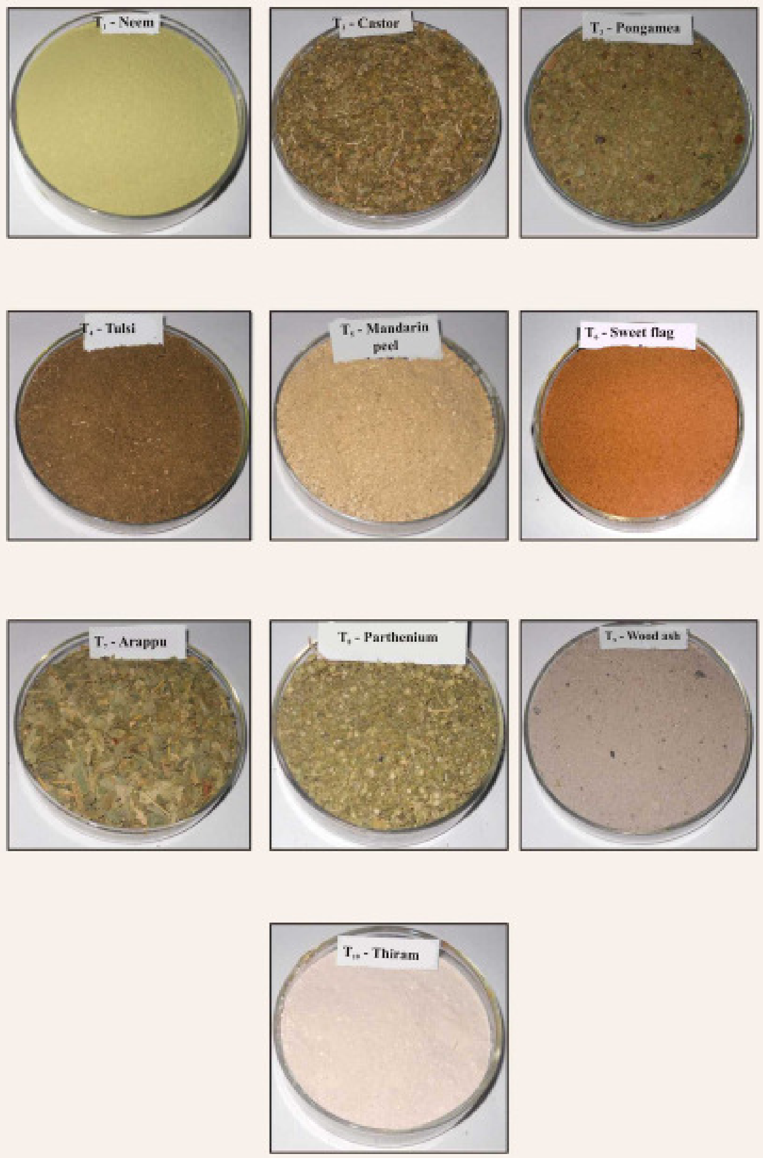

Plate 1: Botanicals seed treatment

Plate 1. Botanicals seed treatment

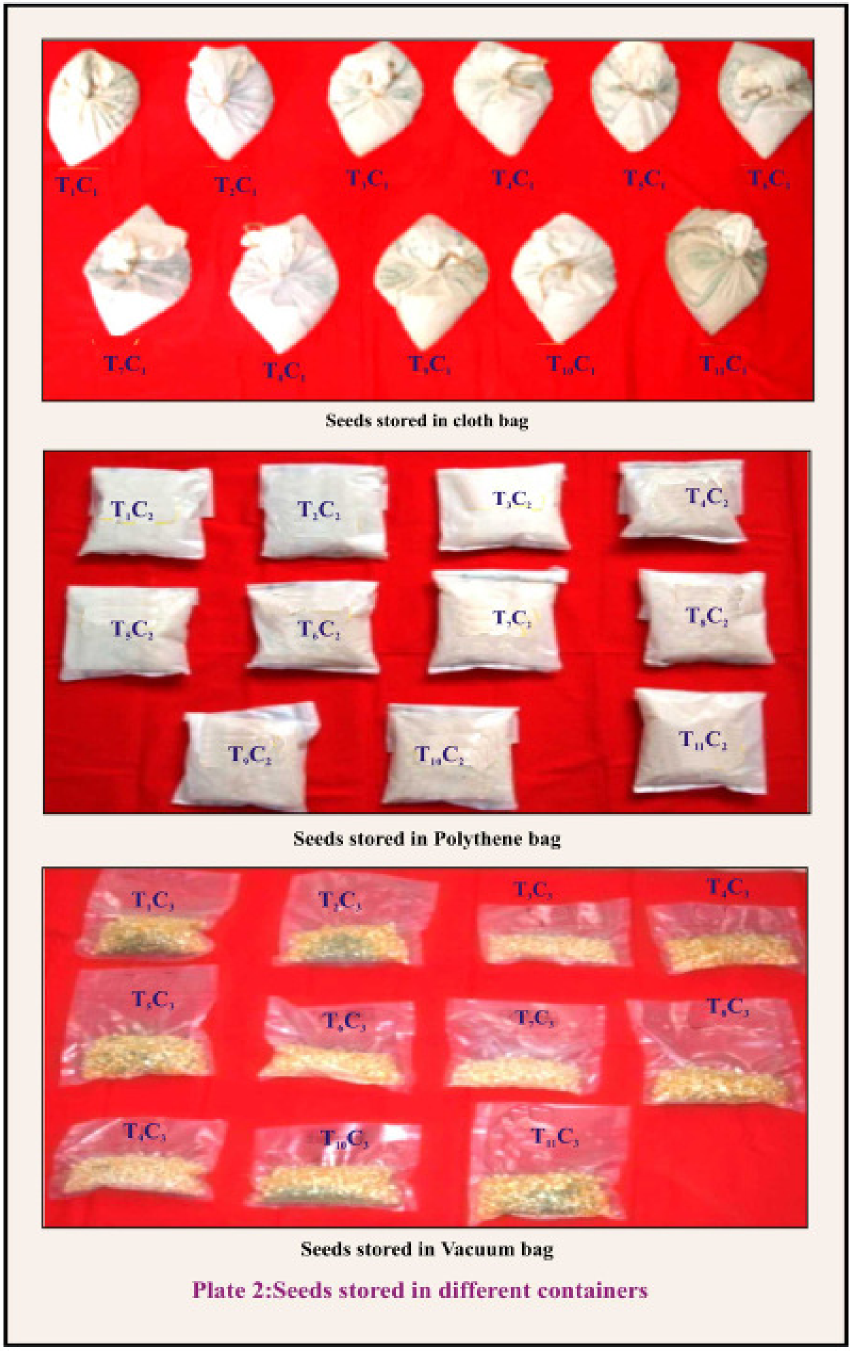

Plate 2. Seeds stored in different containers

The rolled paper towels were placed at slant position in a seed germination cabinet maintained at a constant temperature of 25 ± 1^0C and $95\pm$ 1 per cent relative humidity. The number of normal seedlings were counted at the end of fourth and seventh day (I and II count respectively) and expressed in percentage.

3.5.2 Field emergence (%)

Four hundred seeds were drawn randomly from each treatment as per treatments schedule and 100 seeds were sown in four replications on a well prepared seed bed of 2x1 m size at adequate soil moisture conditions. Seeds were sown uniformly to a depth of 2-3 cm with a spacing of 20 cm between the rows and 10 cm between the plants. The number of seedlings emerged at least 4 cm above the soil surface on 15^{th} day after sowing were counted and average was expressed as per cent field emergence.

3.5.3 Root length (cm)

The same ten normal seedlings used for shoot length measurement were used for root measurement. The root length of each seedling was measured from collar region to the tip of primary root and the average root length was expressed in centimetre.

3.5.4 Shoot length (cm)

From the germination test, ten normal seedlings were selected randomly from each treatment and the shoot length was measured from the base of primary leaf to collar region and the mean shoot length was expressed in centimetre.

3.5.5 Vigour index

The seedling vigour index was computed by adopting the following formula as suggested by Abdul-Baki and Anderson (1973) and expressed in number.

Vigour index = Germination (%) x Seedling length (cm)

3.5.6 Seedling dry weight (mg)

The same ten normal seedlings used for shoot and root length measurement were put in butter paper packet and kept in an oven maintained at $80^0 \pm 1^0$C for 24 hours. After drying, the seedlings were kept for cooling in desiccators and the seedling dry weight was recorded and was expressed in milligrams (Anon., 2007).

3.5.7 Electrical conductivity (EC) of seed leachate (dSm^{-1})

Four replications of 5 g seed material from each treatment in four replications were drawn randomly and weighted up to two decimal places. The seeds were treated with acetone for half a minute and washed thoroughly for several times with distilled water and then soaked in 25 ml distilled water in beaker. The beakers were kept in an incubator at 25 ± 1^0C for 24 hours along with blank. The EC of seeds leachate was measured in the digital conductivity meter and after subtracting the EC value of distilled water (blank) from the value obtained from the seed leachate, the actual EC due to the electrolyte (leachate) was measured and expressed in dSm^{-1}.

3.5.8 Moisture content (%)

The moisture content of seeds was determined by the oven dry (103 ± 1^0C for 17 hours) method as per ISTA rules (Anon., 2007). The moisture content on wet basis was determined and expressed in percentage using the following formula.

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

Where

M_1 – Weight of the empty metal box (g)

M_2 – Weight of empty metal box with seed sample before drying (g)

M_3 – Weight of empty metal box with seed sample after drying (g)

3.5.9 Seed infection (%)

Storage fungi present on seeds were tested using blotter method as prescribed by ISTA (Anon., 2007). Ten seeds were placed equidistantly on three layered moistened blotter taken in sterilized petri plates. Each treatment was replicated four times. They were incubated at 20 ± 2° C for seven days with alternate cycles of 12 h in near ultraviolet light (NUV) range and for the remaining 12 h in dark. On eighth day the plates were examined under stereobionocular microscope (50X) for the presence of seed borne fungi. The number of infected seeds were counted and expressed in percentage; besides this kind of fungi present were also identified and documented (Anon., 2007).

3.5.10 Seed infestation (%)

One hundred seeds from each treatment and in four replications were taken to determine the insect (*Rhizopertha dominica, Sitophilus zeamais*) infestation level in maize seeds. The percentage of damaged seeds was worked out as per the method prescribed by ISTA Rules (Anon., 2007).

3.6 Statistical analysis

The data collected from the experiment was analysed statistically by adopting the procedure as described by Sundarajan *et al.* (1972) and critical differences were calculated at one per cent level, wherever, F test was significant. The data on germination percentage was transformed into Arcsine square root percentage values (Snedecor and Cochran, 1967).

Table 1. Monthly meteorological data during the research period (2011-2012) recorded at MARS, University of Agricultural Sciences, Dharwad

Month	Rainfall (mm)		Rainy days		Temperature (°C) maximum		Temperature (°C) minimum		Relative humidity (%)	
	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
January	0	-	-	-	28.2	-	12.5	-	59	-
February	21.6	-	1	-	32.4	-	14	-	48	-
march	0.8	-	-	-	35.6	-	18.6	-	44	-
April	77.40	-	3.0	-	34.90	-	20.20	-	57	-
May	66.00	-	6.0	-	34.70	-	21.30	-	61	-
June	194.00	-	14.0	-	27.30	-	21.36	-	84	-
July	131.00	-	14.0	-	26.90	-	20.60	-	85	-
August	124.40	-	13.0	-	26.20	-	20.70	-	87	-
September	828.00	-	11.0	-	28.10	--	19.90	-	80	-
October	49.70	-	8.0	-	29.90	-	19.50	-	73	-
November	4.60	-	1.0	-	29.80	-	15.80	-	55	-
December	0.00	-	0.0	-	29.60	-	13.70	-	57	-
January	-	0.00	-	0.0	-	29.80	-	13.90	-	62
February	-	0.00	-	0.0	-	32.80	-	16.10	-	44
march	-	0.00	-	0.0	-	35.80	-	18.50	-	43
April	-	56.60	-	7.0	-	35.70	-	21.20	-	-
Total	**1475.10**	**56.60**	**71.00**	**7.0**	**363.6**	**134.1**	**218.16**	**69.7**	**790**	**149**

IV. EXPERIMENTAL RESULTS

The laboratory experiment was conducted on "Effect of plant products and containers on storage potential of maize hybrid cv. Arjun" at the Department of Seed Science and Technology, University of Agricultural Sciences, Dharwad during January 2011-2012. The results generated on various seed quality parameters viz., germination, field emergence, seedling length, vigour index, seedling dry weight, electrical conductivity, moisture content, seed infection and seed infestation are presented in this chapter.

4.1 Influence of botanicals and packaging materials on storage potential of maize hybrid

4.1.1 Germination (%)

The data on germination percentage as influenced by treatments, containers and their interaction effects is presented in a Table 2 and depicted in Fig. 1a and 1b.

Due to treatments

The germination percentage differed significantly from fourth month onwards up to the end of storage period irrespective of containers. Among seed treatments, significantly higher germination was noticed in seed treated with thiram (97.17%), arappu (97.08%), neem (96.75%) and sweet flag rihizome powder (96.67%) at sixth month. Similar trend was followed up to 14th month of storage. At the end of 14 months of storage maximum (90.33%) germination was recorded in thiram followed by arappu (88.00%), neem (86.67%), and sweet flag (86.00%) as compared to control (66.33%). Satisfactory germination (90%) as per the minimum seed certification standards was maintained for 14 months in thiram, for 13 months in arappu and neem and for 12 months in sweet flag, for 11 months in wood ash, for 10 months in castor, pongamia, tulsi and mandarin and for 8 month in control.

Due to containers

The germination percentage was found to differ significantly among the containers from 6th month onwards of storage period. The seeds stored in vacuum sealed bag recorded significantly maximum germination (97.02%) fallowed by polythene bag (96.09%) and was minimum (95.27%) in cloth bag at 6th month of storage. Similar trend was noticed throughout the storage period of fourteen months. The seed stored in vacuum sealed bag maintained significantly higher germination (90.50%) fallowed by polyethylene bag (82.91%) and was lower in cloth bag (69.36%) after 14th month of storage. Satisfactory germination as per the minimum seed certification standards (90%) was maintained up to 14 months in vacuum, 11 months in polythene and for 9 months in case of cloth bag.

Due to interactions

The germination percentage was found to differ significantly due to interaction of treatments and containers from 11th month onwards. The seeds treated with thiram and stored in vacuum sealed bag ($T_{10}C_3$) recorded significantly highest (98.50 to 94.00%) germination fallowed by T_7C_3 (98.25 to 93.00%) and T_1C_3 (98.25 to 92.00%) and was lowest in control $T_{11}C_3$ (98.00 to 86.00%) followed by seed treatment with $T_{10}C_2$ (98.50 to 92.00%), T_7C_2 (98.50 to 91.00%), T_1C_2 (98.00 to 90.00%) and lowest in $T_{11}C_2$ (97.75 to 73.00%) from initial month to end of 14 months of storage respectively.

In general all the seed treatments stored in cloth bag recorded significantly lowest germination compared to polythene bag and vacuum in all the months of storage and latter were at par with each other.

At the end of 14 months of storage, all the seeds treated and stored in cloth bag recorded significantly less germination compared to polythene and vacuum conditions. The germination of seeds treated with thiram, neem, arappu, sweet flag and wood ash and stored in vacuum and polythene bag were at par with each other.

In vacuum sealed containers satisfactory germination as per the minimum seed certification standard was maintained for 14 months in all the seed treatments except castor and control which maintained for 13 months.

Table 2. Germination percentage as influenced by treatments, containers and their interactions effect during storage of maize hybrid cv. Arjun

Treatments	Months after storage															
	3rd month				4th month				5th month				6th month			
	C_1	C_2	C_3	**Mean**	C_1	C_2	C_3	**Mean**	C_1	C_2	C_3	**Mean**	C_1	C_2	C_3	**Mean**
T_1	98.00 (82.01)*	98.25 (82.47)	98.25 (82.60)	**98.42 (82.71)**	98.25 (82.47)	98.00 (82.01)	98.25 (82.60)	**98.42 (82.71)**	96.75 (80.03)	97.00 (80.49)	98.00 (82.01)	**97.25 (80.84)**	96.00 (78.62)	96.75 (79.71)	97.50 (81.15)	**96.75 (79.83)**
T_2	97.50 (81.02)	98.00 (82.01)	98.00 (82.21)	**98.00 (82.08)**	98.00 (82.01)	98.00 (82.01)	98.00 (82.21)	**98.00 (82.08)**	95.75 (78.55)	96.00 (79.15)	97.00 (80.49)	**96.25 (79.40)**	94.25 (76.23)	95.00 (77.11)	96.50 (79.36)	**95.25 (77.57)**
T_3	97.25 (80.56)	97.75 (81.41)	97.75 (81.41)	**97.67 (81.42)**	97.75 (81.75)	97.75 (81.41)	97.50 (81.08)	**97.67 (81.42)**	96.25 (79.30)	96.50 (79.64)	97.25 (80.81)	**96.67 (79.92)**	95.00 (77.17)	96.00 (78.62)	96.75 (79.71)	**95.92 (78.50)**
T_4	98.00 (82.01)	98.00 (82.01)	98.25 (82.60)	**98.08 (82.21)**	98.00 (82.01)	98.25 (82.60)	98.00 (82.01)	**98.08 (82.21)**	96.00 (79.15)	96.25 (79.30)	97.00 (80.49)	**96.42 (79.65)**	94.75 (76.82)	95.75 (78.31)	96.25 (78.97)	**95.58 (78.03)**
T_5	97.50 (80.10)	97.50 (81.27)	97.75 (81.62)	**97.42 (80.99)**	97.50 (81.27)	97.00 (80.10)	97.75 (81.62)	**97.42 (80.99)**	96.25 (79.30)	96.75 (80.03)	97.50 (81.15)	**96.83 (80.16)**	95.25 (77.46)	96.00 (78.62)	97.50 (81.15)	**96.25 (79.08)**
T_6	98.00 (82.01)	98.25 (82.47)	98.75 (83.66)	**98.17 (82.36)**	98.00 (82.01)	98.25 (82.47)	98.75 (83.66)	**98.17 (82.36)**	96.75 (80.03)	97.00 (80.49)	97.75 (81.55)	**97.17 (80.69)**	96.00 (78.62)	96.75 (79.82)	97.75 (80.76)	**96.67 (79.74)**
T_7	98.50 (83.07)	98.50 (83.07)	98.25 (82.47)	**98.42 (82.87)**	98.50 (83.07)	98.50 (83.07)	98.25 (82.47)	**98.42 (82.87)**	97.00 (80.49)	97.50 (81.15)	98.25 (82.47)	**97.58 (81.37)**	96.25 (79.01)	97.00 (80.42)	98.00 (82.01)	**97.08 (80.48)**
T_8	97.50 (81.02)	97.50 (80.95)	98.00 (82.01)	**97.58 (81.17)**	97.25 (80.56)	97.50 (80.95)	98.00 (82.01)	**97.58 (81.17)**	95.75 (78.55)	96.25 (79.44)	97.00 (80.49)	**96.33 (79.50)**	94.50 (76.51)	95.25 (77.46)	96.50 (79.31)	**95.42 (77.76)**
T_9	97.25 (80.56)	97.75 (81.62)	98.00 (82.01)	**97.67 (81.32)**	97.75 (81.41)	97.25 (80.56)	98.00 (82.01)	**97.67 (81.32)**	96.50 (79.64)	97.00 (80.49)	97.50 (81.15)	**97.00 (80.43)**	95.50 (77.77)	96.50 (79.36)	97.00 (80.49)	**96.33 (79.21)**
T_{10}	98.50 (83.07)	98.50 (83.07)	98.50 (83.07)	**98.50 (83.07)**	98.50 (83.07)	98.50 (83.07)	98.50 (83.07)	**98.50 (83.07)**	97.25 (80.69)	97.25 (81.55)	98.50 (83.07)	**97.83 (81.77)**	96.50 (79.57)	97.00 (80.42)	98.00 (82.01)	**97.17 (80.66)**
T_{11}	97.25 (80.56)	97.75 (81.55)	98.00 (82.01)	**97.58 (81.52)**	97.50 (81.02)	97.75 (81.55)	98.00 (82.01)	**97.58 (81.52)**	95.25 (77.95)	96.00 (79.15)	96.75 (80.10)	**96.00 (79.07)**	94.00 (75.94)	95.00 (77.11)	96.00 (78.62)	**95.00 (77.23)**
Mean	**97.91 (81.87)**	**98.00 (81.80)**	**98.09 (82.25)**	**97.96 (81.97)**	**97.91 (81.87)**	**98.00 (81.80)**	**98.09 (82.25)**	**97.96 (81.97)**	**96.32 (79.43)**	**96.73 (80.08)**	**97.50 (81.25)**	**96.85 (80.25)**	**95.27 (77.61)**	**96.09 (78.81)**	**97.02 (80.32)**	**96.13 (78.92)**
For comparing means of	S.Em±		CD at 1%		S.Em±		CD at 1%		S.Em±		CD at 1%		S.Em±		CD at 1%	
Treatments (T)	0.27		NS		0.13		NS		0.31		NS		**0.33**		**1.23**	
Containers (C)	0.51		NS		0.24		NS		0.62		NS		**0.63**		**2.36**	
Interaction (T×C)	0.89		NS		0.42		NS		1.03		NS		1.10		NS	

Contd..

.Treatments	Months after storage															
	7th month				**8th month**				**9th month**				**10th month**			
	C_1	**C_2**	**C_3**	**Mean**	**C_1**	**C_2**	**C_3**	**Mean**	**C_1**	**C_2**	**C_3**	**Mean**	**C_1**	**C_2**	**C_3**	**Mean**
T_1	95.00 (77.17)	96.50 (79.24)	97.25 (80.81)	**96.25 (79.07)**	94.00 (74.79)	96.00 (78.97)	97.00 (80.67)	**94.75 (78.15)**	92.00 (73.85)	95.00 (77.11)	96.00 (78.51)	**94.33 (76.49)**	92.00 (73.63)	94.75 (76.97)	96.00 (78.58)	**94.25 (76.40)**
T_2	93.25 (75.26)	94.50 (76.58)	95.75 (78.19)	**94.50 (76.68)**	92.00 (75.10)	93.25 (75.94)	95.00 (77.63)	**93.92 (76.22)**	90.50 (72.20)	92.75 (74.67)	94.50 (76.51)	**92.58 (74.46)**	90.00 (71.71)	91.50 (73.08)	94.00 (76.08)	**91.83 (73.62)**
T_3	94.00 (76.16)	95.25 (77.46)	96.50 (79.24)	**95.25 (77.62)**	93.00 (75.07)	94.75 (77.77)	96.25 (79.29)	**94.33 (77.38)**	91.50 (73.32)	93.00 (74.72)	94.50 (76.51)	**93.00 (74.85)**	91.00 (72.67)	92.00 (73.79)	93.00 (74.85)	**92.00 (73.77)**
T_4	93.75 (75.81)	95.00 (77.17)	96.00 (78.51)	**94.92 (77.16)**	92.50 (75.07)	93.75 (76.20)	95.50 (78.24)	**94.30 (76.50)**	90.25 (71.96)	93.00 (74.72)	94.50 (76.51)	**92.58 (74.40)**	90.00 (71.71)	91.75 (73.37)	94.00 (76.08)	**91.92 (73.72)**
T_5	94.25 (76.39)	95.50 (77.77)	96.50 (79.24)	**95.42 (77.80)**	93.25 (75.34)	95.00 (76.82)	96.25 (78.90)	**95.00 (77.02)**	90.75 (72.60)	93.50 (75.41)	95.00 (77.24)	**93.08 (75.08)**	91.25 972.81)	93.00 (74.85)	94.25 (76.39)	**92.83 (74.69)**
T_6	94.75 (77.03)	96.00 (78.51)	96.75 (79.71)	**95.83 (78.41)**	93.75 (74.79)	95.50 (77.43)	96.50 (79.29)	**95.58 (77.17)**	92.00 (73.85)	94.50 (76.51)	95.50 (77.85)	**94.00 (76.07)**	91.00 (72.67)	93.75 (75.79)	94.25 (76.32)	**93.00 (74.93)**
T_7	95.75 (78.12)	97.00 (80.21)	97.50 (81.15)	**96.75 (79.83)**	94.75 (75.67)	96.50 (79.64)	97.00 (80.56)	**95.00 (78.62)**	92.75 (74.51)	95.25 (77.56)	96.75 (79.64)	**94.92 (77.23)**	92.00 (73.79)	95.00 (77.14)	96.25 (78.90)	**94.42 (76.61)**
T_8	93.00 (75.02)	94.75 (76.89)	96.00 (78.51)	**94.58 (76.81)**	92.50 (75.10)	93.25 (75.89)	95.00 (77.68)	**94.17 (76.22)**	90.75 (72.42)	93.00 (74.89)	94.75 (76.82)	**92.83 (74.71)**	90.25 (71.96)	91.50 (73.17)	94.00 (76.08)	**91.92 (73.74)**
T_9	93.50 (75.55)	95.75 (78.16)	96.75 (79.71)	**95.33 (77.81)**	93.50 (75.60)	95.00 (76.76)	96.50 (79.64)	**95.59 (77.33)**	91.75 (73.38)	94.25 (76.23)	95.25 (77.53)	**93.75 (75.72)**	91.50 (73.23)	93.50 (75.36)	94.50 (76.58)	**93.17 (75.06)**
T_{10}	96.00 (78.51)	97.00 (80.21)	97.75 (81.41)	**96.92 (80.04)**	95.00 (76.82)	96.75 (79.57)	97.50 (81.41)	**95.25 (79.27)**	93.00 (74.72)	95.75 (78.16)	96.75 (79.64)	**95.17 (77.51)**	94.00 (76.08)	95.25 (77.46)	96.50 (79.36)	**95.25 (77.63)**
T_{11}	92.00 (73.80)	94.25 (76.39)	95.50 (77.80)	**93.92 (76.00)**	90.00 (70.86)	93.25 (75.89)	95.00 (77.63)	**92.75 (74.79)**	80.50 (63.80)	91.50 (73.19)	94.00 (75.94)	**88.67 (70.98)**	76.00 (60.86)	91.00 (72.67)	92.00 (73.63)	**86.33 (69.05)**
Mean	**94.11 (76.26)**	**95.59 (78.05)**	**96.57 (79.48)**	**95.42 (77.93)**	**93.13 (74.93)**	**94.57 (77.35)**	**96.14 (79.18)**	**94.48 (77.15)**	**90.52 (72.42)**	**93.77 (75.74)**	**95.23 (77.52)**	**93.17 (75.23)**	**89.91 (71.92)**	**93.00 (74.88)**	**94.43 (76.62)**	**92.45 (74.47)**
For comparing means of	S.Em±		CD at 1%		S.Em±		CD at 1%		S.Em±		CD at 1%		S.Em±		CD at 1%	
Treatments (T)	0.35		1.31		0.32		1.18		0.36		1.32		0.41		1.51	
Containers (C)	0.68		2.51		0.61		2.26		0.68		2.53		0.78		2.90	
Interaction (T×C)	1.17		NS		1.05		NS		1.18		NS		1.35		NS	

Treatments	Months after storage															
	11th month				12th month				13th month				14th month			
	C_1	**C_2**	**C_3**	**Mean**	**C_1**	**C_2**	**C_3**	**Mean**	**C_1**	**C_2**	**C_3**	**Mean**	**C_1**	**C_2**	**C_3**	**Mean**
T_1	90.00 (71.60)	94.25 (76.37)	95.00 (77.21)	**93.08 (75.06)**	85.00 (67.29)	94.00 (76.03)	94.00 (76.03)	**91.00 (73.12)**	84.00 (66.62)	92.50 (74.18)	93.50 (75.36)	**90.00 (72.05)**	78.00 (62.03)	90.00 (71.86)	92.00 (74.18)	**86.67 (69.36)**
T_2	78.25 (62.23)	90.00 (71.60)	92.00 (73.76)	**86.75 (69.20)**	70.00 (56.83)	83.00 (65.74)	91.00 (72.64)	**81.33 (65.07)**	68.00 (55.56)	78.00 (62.04)	90.00 (71.79)	**78.67 (63.13)**	62.00 (51.97)	74.00 (59.40)	88.00 (69.79)	**74.67 (60.39)**
T_3	82.00 (64.98)	90.50 (72.12)	93.25 (75.07)	**88.50 (70.72)**	76.00 (60.73)	87.00 (68.90)	92.00 (73.90)	**85.00 (67.84)**	74.00 (59.39)	85.00 (67.36)	90.75 (72.37)	**83.25 (66.38)**	70.00 (56.79)	80.00 (63.52)	90.00 (71.74)	**80.00 (64.02)**
T_4	80.00 (63.52)	90.00 (71.60)	92.75 (74.40)	**87.58 (69.84)**	72.00 (58.07)	86.00 (68.07)	91.00 (72.64)	**83.00 (66.26)**	70.00 (56.79)	84.00 (66.62)	90.25 (72.06)	**81.42 (65.16)**	65.00 (53.78)	79.00 (62.76)	90.00 (71.86)	**78.00 (62.80)**
T_5	84.00 (66.44)	90.75 (72.42)	93.50 (75.32)	**89.42 (71.39)**	80.00 (63.48)	88.00 (69.79)	92.50 (74.40)	**86.83 (69.22)**	76.00 (60.76)	86.00 (68.11)	91.00 (72.81)	**84.33 (67.23)**	70.00 (56.89)	82.00 (65.02)	90.50 (72.52)	**80.83 (64.81)**
T_6	88.00 (69.82)	94.00 (75.98)	94.00 (75.98)	**92.00 (73.92)**	84.00 (66.49)	93.00 (74.81)	94.00 (75.89)	**90.33 (72.40)**	82.00 (64.95)	92.00 (73.61)	93.00 (74.70)	**89.00 (71.09)**	76.00 (60.74)	90.00 (71.86)	92.00 (73.900	**86.00 (68.83)**
T_7	91.00 (72.66)	95.00 (77.21)	96.25 (79.01)	**94.08 (76.29)**	86.00 (68.07)	94.00 (76.03)	95.00 (77.11)	**91.67 (73.74)**	85.00 (67.36)	93.00 (74.68)	94.00 (75.92)	**90.67 (72.65)**	80.00 (63.52)	91.00 (72.67)	93.00 (75.06)	**88.00 (70.42)**
T_8	78.00 (62.06)	90.00 (71.60)	93.00 (74.78)	**87.00 (69.48)**	70.50 (57.13)	84.00 (66.49)	91.00 (72.64)	**81.83 (65.42)**	68.25 (55.72)	80.00 (63.77)	90.25 (72.00)	**79.50 (63.83)**	63.00 (52.56)	77.00 (61.37)	90.00 (71.74)	**76.67 (61.89)**
T_9	86.00 (68.08)	94.00 (75.98)	94.00 (75.98)	**91.33 (73.34)**	82.00 (64.92)	90.00 (71.60)	93.00 (74.85)	**88.33 (70.46)**	80.00 (63.77)	86.50 (68.51)	92.00 (73.61)	**86.17 (68.63)**	74.00 (59.37)	84.00 (66.51)	90.00 (71.61)	**82.67 (65.83)**
T_{10}	93.02 (74.78)	95.00 (77.21)	96.25 (79.01)	**94.75 (77.00)**	89.00 (70.64)	94.00 (76.03)	95.00 (77.11)	**92.67 (74.59)**	86.00 (68.05)	93.75 (75.55)	94.00 (75.90)	**91.25 (73.17)**	85.00 (67.25)	92.00 (73.90)	94.00 (75.98)	**90.33 (72.38)**
T_{11}	68.00 (55.56)	90.00 (71.60)	91.00 (72.66)	**83.00 (66.61)**	58.00 (49.61)	80.00 (63.48)	90.00 (71.60)	**76.00 (61.56)**	50.00 (45.00)	76.00 (60.67)	90.00 (71.79)	**72.00 (59.15)**	40.00 (39.15)	73.00 (58.74)	86.00 (68.11)	**66.33 (55.34)**
Mean	**83.48 (66.52)**	**92.14 (73.97)**	**93.73 (75.74)**	89.78 (72.08)	**77.50 (62.11)**	**88.45 (70.63)**	**92.59 (74.44)**	86.18 (69.06)	**74.84 (60.36)**	**86.07 (68.65)**	**91.70 (73.48)**	84.20 (67.50)	**69.36 (56.73)**	**82.91 (66.15)**	**90.50 (72.41)**	80.92 (65.10)
For comparing means of	S.Em±		CD at 1%		S.Em±		CD at 1%		S.Em±		CD at 1%		S.Em±		CD at 1%	
Treatments (T)	0.33		1.24		0.35		1.31		0.42		1.58		0.49		1.81	
Containers (C)	0.64		2.37		0.67		2.50		0.81		3.02		0.93		3.47	
Interaction(T×C)	**1.11**		**4.11**		1.17		4.33		1.41		5.23		1.62		6.01	

.NS – Non significant

*Figures in the parenthesis are arcsine transformed values

.**Botanicals (T)**

.T_1 : Neem leaf powder @ 10g/kg seed
T_2 : Castor leaf powder @ 10g/kg seed
T_3 : Pongamia leaf powder @ 10g/kg
T_4 : Tulsi leaf powder @ 10g/kg seed
T_5 : Mandrin peal powder @10g/kg seed
T_6 : Bhajje powder @ 10g/kg seed
T_7 : Arappu powder @ 10g/kg seed
T_8 : Parthenium@ 10g/kg seed
T_9 : Wood ash @ 10g/kg seed
T_{10} : Thiram@ 2g/kg seed
T_{11} : Control

Containers (C)

C_1 : Cloth bag
C_2 : Polyethylene bag
C_3 : Vacuum packaging

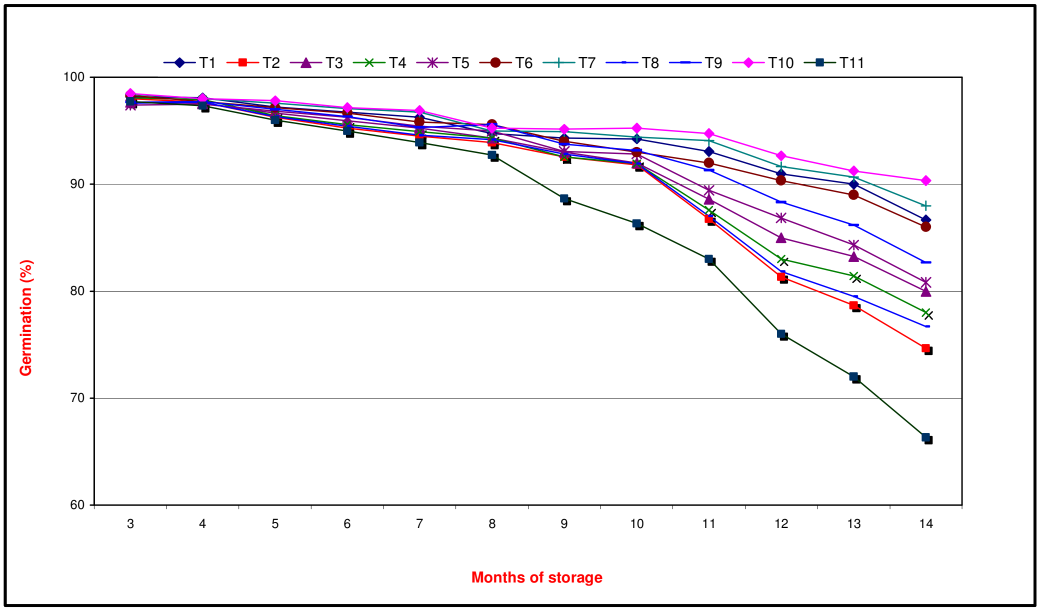

Fig. 1a: Effect of treatments on germination percentage during storage period of maize hybrid (Arjun)

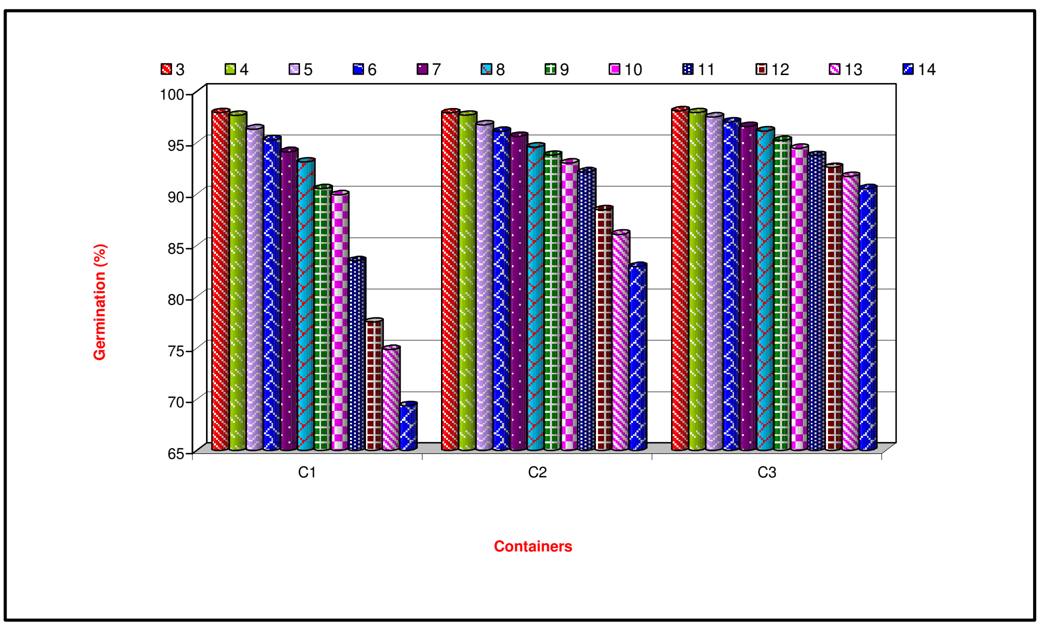

Fig. 1b: Effect of contianers on germination percentage during storage period of maize hybrid (Arjun)

In polythene bags the seeds treated with thiram, arappu, neem and sweet flag maintained satisfactory germination for 14 months, followed by wood ash for 12 months. The seed treated with castor, pongamia, tulsi, mandarin, parthenium and control maintained for 11 months.

In cloth bag the seeds treated with neem, arappu and thiram maintained satisfactory germination for 11 months while, castor, pongamia, tulsi, mandarin, sweet flag, parhenium, and wood ash maintained for 10 months and control (absolute) maintained for only 8 months.

4.1.2 Field emergence (%)

The data on field emergence as influenced by treatments, containers and their interaction effects are presented in Table 3.

Due to treatments

Treatments differed significantly in field emergence only from 7^{th} month of storage onwards. The field emergence was significantly highest (93.75%) in seed treated with thiram and lowest (90.42%) in control after seventh month of storage. Similar trend was noticed up to 14^{th} month of storage. At the end of 14^{th} month of storage, significantly highest (83.17%) field emergence was recorded in thiram followed by arappu (80.83%), neem (79.50%), sweet flag (86.00%) and wood ash (82.67%) and was lowest (59.17%) in control.

Due to containers

The per cent field emergence showed a significant difference among the containers in all the storage months except first four months. The field emergence percentage in vacuum sealed container was significantly maximum (95.20%) followed by polythene bag (94.59%) and the lowest (93.30%) was in cloth bag after 5^{th} month of storage. Consistent decrease in field emergence was noticed up to the end of storage period. Field emergence was more (83.32%) in vacuum followed by polythene bag (75.82%) and was less (61.86%) in cloth bag at the end of 14 months of storage.

Due to interactions

The interaction effects of treatments and containers were found significant on field emergence from ninth month onwards till the end of storage period. It was significantly highest (87.00%) in seed treated with thiram and stored in vacuum sealed container ($T_{10}C_3$) followed by T_7C_3 (86.00%), T_1C_3 (85.00%), T_6C_3 (85.00%), T_9C_3 (83.00%) and and lowest in $T_{11}C_3$ (79.00%) at the end of fourteen month of storage. Similar trend was followed in seed treated with thiram (85.00%), arappu (84.00%), neem leaf powder (83.00%), sweet flag (82.00%) and wood ash (77.00%) when stored in polythene bag after twelve month of storage and was less (66.00%) in control. The treated seeds stored in cloth bag ($T_{10}C_1$) recorded significantly highest (77.50%) field emergence followed by T_7C_1 (72.50%), T_1C_1 (72.50%), T_6C_1 (68.50%), T_9C_3 (66.50%) and was lowest (32.50%) in T_1C_1, at the end of fourteen month of storage.

4.1.3 Root length (cm)

The data on root length as influenced by varieties, seed treatments and containers and their interactions are presented in Table 4.

Due to seed treatments

The root length differed significantly due to seed treatments irrespective of containers from second months after storage. Among seed treatments, significantly higher (23.43 to 20.18 cm) root length was recorded with thiram (T_{10}) followed by arappu (23.31 to 19.73 cm) , neem (23.22 to 19.45 cm), sweet flag (23.18 to 19.03 cm), wood ash (22.80 to 18.75 cm) and control (21.82 to 16.80 cm) after 4^{nd} month to fourteen month of storage respectively.

Due to containers

The root length was significantly influenced by containers from 5^{th} month after storage. It was significantly more (22.72 cm) with the seeds stored in vacuum sealed container followed by polythene bag (22.22 cm) and less in cloth bag (22.09 cm) at fifth month. At the end of 14^{th} months seed stored in vacuum recorded maximum (18.94 cm) root length followed by polythene bag (18.57 cm) and was minimum in cloth bag (17.65 cm).

Table 3. Field emergence (%) as influenced by treatments, containers and their interactions effect during storage of maize hybrid cv. Arjun

.Treatments	Months after storage															
	3rd month				4th month				5th month				6th month			
	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean
T_1	97.00 (80.03)*	97.25 (80.03)	97.25 (80.49)	**97.00 (80.18)**	96.00 (79.44)	96.50 (79.44)	96.75 (79.75)	**96.58 (79.54)**	93.75 (76.06)	94.75 (76.90)	95.75 (78.31)	**94.75 (77.09)**	92.50 (74.58)	93.25 (76.27)	95.00 (77.11)	**93.58 (75.99)**
T_2	96.00 (78.70)	96.50 (79.44)	96.75 (79.90)	**96.00 (79.34)**	95.50 (78.14)	95.75 (78.38)	96.00 (78.70)	**95.75 (78.41)**	92.75 (74.51)	93.75 (75.57)	94.50 (76.62)	**93.67 (75.57)**	90.50 (72.71)	91.00 (72.91)	92.50 (74.35)	**91.33 (73.32)**
T_3	97.00 (80.35)	97.00 (80.35)	97.00 (80.35)	**97.00 (80.35)**	96.00 (78.70)	96.00 (78.70)	96.25 (79.04)	**96.08 (78.81)**	93.00 (74.96)	94.25 (76.23)	95.00 (77.17)	**94.08 (76.12)**	91.50 (73.47)	92.50 (75.09)	94.25 (76.16)	**92.75 (74.91)**
T_4	96.50 (79.44)	96.50 (79.44)	96.75 (79.75)	**96.50 (79.54)**	95.75 (78.41)	96.00 (78.75)	96.00 (78.75)	**95.92 (78.64)**	93.00 (74.70)	94.00 (75.89)	94.75 (76.90)	**93.92 (75.83)**	91.25 (73.27)	92.00 (74.33)	93.75 (75.57)	**92.33 (74.39)**
T_5	97.00 (80.10)	97.00 (80.10)	97.00 (80.10)	**97.00 (80.10)**	96.25 (78.90)	96.25 (78.90)	96.25 (78.90)	**96.25 (78.90)**	93.25 (74.97)	94.50 (76.62)	95.25 (77.50)	**94.33 (76.36)**	91.75 (73.68)	92.50 (74.58)	95.00 (77.17)	**93.08 (75.14)**
T_6	96.75 (79.64)	96.75 (79.64)	97.00 (80.03)	**96.75 (79.77)**	96.50 (79.29)	96.50 (79.29)	96.50 (79.29)	**96.50 (79.29)**	93.75 (75.55)	94.75 (76.85)	95.50 (77.85)	**94.67 (76.75)**	92.50 (74.58)	92.75 (74.74)	94.75 (76.85)	**93.33 (75.39)**
T_7	96.50 (80.03)	97.00 (80.03)	97.00 (80.03)	**96.50 (80.03)**	96.25 (78.97)	96.50 (79.29)	96.75 (79.64)	**96.50 (79.30)**	94.00 (75.89)	96.25 (78.90)	96.00 (79.43)	**95.42 (78.07)**	92.75 (74.97)	93.50 (76.70)	95.50 (77.85)	**93.92 (76.51)**
T_8	96.00 (79.75)	96.75 (79.75)	96.75 (79.75)	**96.75 (79.75)**	96.00 (78.68)	96.00 (78.68)	96.00 (78.68)	**96.50 (78.68)**	92.75 (74.40)	94.00 (75.89)	94.75 (76.85)	**93.83 (75.71)**	91.00 (73.07)	91.75 (73.79)	94.00 (76.08)	**92.25 (74.31)**
T_9	97.00 (80.03)	97.00 (80.03)	97.00 (80.03)	**97.00 (80.03)**	96.50 (79.29)	96.50 (79.29)	96.50 (79.29)	**96.50 (79.29)**	93.50 (75.42)	94.75 (76.85)	95.25 (77.56)	**94.50 (76.61)**	91.00 (73.25)	93.00 (75.55)	94.50 (76.51)	**92.83 (75.10)**
T_{10}	97.00 (80.49)	97.50 (80.95)	97.50 (80.95)	**97.25 (80.79)**	96.50 (80.03)	97.00 (80.03)	97.00 (80.03)	**97.00 (80.03)**	94.25 (76.23)	95.75 (78.31)	96.25 (78.90)	**95.42 (77.81)**	93.00 (75.55)	94.50 (77.63)	95.50 (77.80)	**94.33 (76.99)**
T_{11}	96.00 (78.97)	96.50 (79.29)	96.50 (79.29)	**96.25 (79.18)**	95.50 (77.95)	95.75 (78.41)	96.00 (78.68)	**95.75 (78.35)**	92.25 (73.86)	93.75 (75.55)	94.25 (76.23)	**93.42 (75.21)**	90.00 (71.93)	91.00 (72.81)	92.25 (73.90)	**91.08 (72.88)**
Mean	**96.61 (79.77)**	**96.86 (79.91)**	**96.95 (80.06)**	**96.73 (79.91)**	**96.00 (78.89)**	**96.25 (79.01)**	**96.36 (79.16)**	**96.26 (79.02)**	**93.30 (75.14)**	**94.59 (76.69)**	**95.20 (77.57)**	**94.36 (76.47)**	**91.61 (73.73)**	**92.52 (74.95)**	**94.27 (76.30)**	**92.80 (74.99)**
For comparing means of	S.Em±		CD at 5%		S.Em±		CD at 5%		S.Em±		CD at 5%		S.Em±		CD at 5%	
Treatments (T)	0.26		NS		0.34		NS		**0.35**		**1.08**		0.71		2.34	
Containers (C)	0.50		NS		0.66		NS		0.67		NS		1.35		NS	
Interaction (T×C)	0.86		NS		1.13		NS		1.17		NS		2.34		NS	

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Contd…..

Treatments	Months after storage															
	7th month				8th month				9th month				10th month			
	C_1	C_2	C_3	**Mean**	C_1	C_2	C_3	**Mean**	C_1	C_2	C_3	**Mean**	C_1	C_2	C_3	**Mean**
T_1	91.50 (73.13)	93.00 (74.73)	94.25 (76.23)	**92.92 (74.70)**	90.00 (71.60)	91.75 (73.45)	93.75 (75.55)	**91.83 (71.60)**	88.00 (69.76)	90.50 (72.07)	93.00 (74.75)	**90.50 (72.19)**	87.00 (68.87)	89.50 (71.14)	91.50 (73.08)	**89.33 (71.03)**
T_2	89.75 (71.43)	90.25 (71.88)	92.00 (73.79)	**90.67 (72.37)**	88.00 (69.79)	89.00 (70.75)	91.75 (73.33)	**89.58 (69.79)**	86.50 (68.46)	88.00 (69.76)	90.50 (72.07)	**88.33 (70.09)**	84.00 (66.46)	86.00 (68.05)	88.00 (69.76)	**86.00 (68.09)**
T_3	90.50 (72.12)	91.75 (73.36)	93.50 (75.44)	**91.92 (73.64)**	89.00 (70.66)	93.00 (72.12)	93.00 (74.70)	**90.83 (70.66)**	87.50 (69.30)	89.25 (70.87)	91.50 (73.08)	**89.42 (71.09)**	86.25 (68.25)	86.75 (68.66)	88.50 (70.200	**87.17 (69.04)**
T_4	90.25 (71.89)	91.50 (73.08)	93.50 (75.44)	**91.75 (73.47)**	88.50 (70.29)	89.50 (71.22)	92.25 (73.96)	**90.08 (70.29)**	86.25 (68.25)	88.50 (70.20)	90.75 (72.31)	**88.50 (70.25)**	85.00 (67.22)	86,50 (68.46)	88.50 (70.20)	**86.67 (68.63)**
T_5	90.75 (72.35)	92.00 (73.72)	94.00 (76.18)	**92.25 (74.08)**	89.25 (70.99)	90.75 (72.35)	93.00 (74.68)	**91.00 (70.99)**	86.75 (68.66)	89.50 (71.14)	92.00 (73.61)	**89.42 (71.14)**	86.25 (68.25)	87.75 (69.52)	89.75 (71.37)	**87.92 (69.71)**
T_6	91.25 (72.87)	92.50 (74.22)	94.25 (76.42)	**92.67 (74.50)**	89.75 (71.45)	91.25 (72.87)	93.25 (75.45)	**91.42 (71.45)**	88.00 (69.76)	90.00 (71.58)	92.50 (74.11)	**90.17 (71.82)**	86.25 (68.25)	88.50 (70.20)	91.00 (72.55)	**88.58 (70.33)**
T_7	92.25 (73.95)	93.50 (75.34)	95.00 (77.17)	**93.58 (75.48)**	90.75 (72.35)	92.25 (74.11)	93.75 (75.98)	**92.25 (72.35)**	88.75 (70.43)	90.75 (72.33)	93.75 (75.53)	**91.08 (72.77)**	87.50 (69.30)	89.75 (71.37)	91.75 (73.36)	**89.67 (71.34)**
T_8	89.50 (71.22)	91.25 (72.87)	93.50 (75.32)	**91.42 (73.14)**	88.50 (70.29)	89.00 (70.70)	91.75 (73.33)	**89.75 (70.29)**	86.75 (68.66)	88.50 (70.20)	90.75 (72.33)	**88.67 (70.40)**	85.25 (67.43)	86.25 (68.25)	88.75 (70.43)	**86.75 (68.70)**
T_9	90.00 (71.59)	92.25 (73.96)	94.25 (76.47)	**92.17 (74.01)**	89.50 (71.19)	90.75 (72.35)	93.25 (75.07)	**91.17 (71.19)**	87.75 (69.52)	89.75 (71.37)	92.25 (73.86)	**89.92 (71.58)**	86.50 (68.46)	88.25 (69.96)	90.00 (71.57)	**88.25 (70.00)**
T_{10}	92.50 (74.22)	93.50 (75.34)	95.25 (77.51)	**93.75 (75.69)**	91.00 (72.64)	91.50 (73.08)	94.25 (76.19)	**92.25 (72.64)**	89.00 (70.64)	91.25 (72.81)	93.75 (75.55)	**91.33 (73.00)**	88.00 (69.76)	90.00 (71.58)	92.00 (73.61)	**90.00 (71.65)**
T_{11}	89.00 (70.66)	90.00 (71.65)	92.25 (74.03)	**90.42 (72.11)**	86.00 (68.05)	89.00 (70.78)	91.75 (73.34)	**88.92 (68.05)**	76.50 (61.01)	87.00 (68.87)	90.00 (71.57)	**84.50 (67.15)**	71.00 (57.43)	85.75 (67.83)	87.50 (69.31)	**81.42 (64.86)**
Mean	**90.66 (72.31)**	**91.95 (73.65)**	**93.80 (75.82)**	**92.14 (73.93)**	**89.11 (70.84)**	**90.48 (72.16)**	**92.89 (74.69)**	**90.83 (70.84)**	**86.52 (68.59)**	**89.36 (71.02)**	**91.89 (73.53)**	**89.26 (71.04)**	**84.82 (67.24)**	**87.73 (69.55)**	**89.75 (71.40)**	**87.43 (69.40)**
For comparing means of	S.Em±		CD at 5%		S.Em±		CD at 5%		S.Em±		CD at 5%		S.Em±		CD at 5%	
Treatments (T)	0.36		1.10		0.35		1.15		0.17		0.54		0.17		0.55	
Containers (C)	**0.69**		**1.93**		0.67		2.14		0.33		0.99		0.33		1.02	
Interaction (T×C)	1.19		NS		1.15		NS		**0.57**		**1.76**		0.57		1.84	

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Treatments	Months after storage															
	11th month				12th month				13th month				14th month			
	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean
T_1	84.00 (66.47)	89.00 (70.64)	90.50 (72.05)	**87.83 (69.72)**	79.00 (62.73)	88.00 (69.76)	89.50 (71.10)	**85.50 (67.86)**	77.00 (61.35)	86.00 (68.05)	88.50 (70.20)	**83.83 (66.53)**	70.50 (57.11)	83.00 (65.68)	85.00 (67.28)	**79.50 (63.36)**
T_2	72.25 (58.21)	85.75 (67.83)	87.00 (68.87)	**81.67 (64.97)**	64.00 (53.13)	84.00 (66.43)	86.00 (68.05)	**78.00 (62.54)**	61.00 (51.36)	71.50 (57.74)	85.00 (67.24)	**72.50 (58.78)**	54.50 (47.59)	67.00 (54.94)	81.00 (64.17)	**67.50 (55.57)**
T_3	76.00 (60.68)	86.25 (68.25)	89.00 (70.66)	**83.75 (66.53)**	70.00 (56.79)	85.50 (67.64)	88.00 (69.74)	**81.17 (64.73)**	67.00 (54.94)	78.50 (62.38)	85.75 (67.84)	**77.08 (61.72)**	62.50 (52.24)	73.00 (58.73)	83.00 (65.68)	**72.83 (58.88)**
T_4	74.00 (59.34)	86.00 (68.05)	88.00 (69.74)	**82.67 (65.71)**	66.00 (54.34)	85.00 (67.24)	87.00 (68.87)	**79.33 (63.48)**	63.00 (52.54)	77.50 (61.71)	85.25 (67.43)	**75.25 (60.56)**	57.50 (49.32)	72.00 (58.06)	82.00 (64.92)	**70.50 (57.43)**
T_5	78.00 (62.04)	87.25 (69.09)	89.75 (71.37)	**85.00 (67.50)**	74.00 (59.39)	86.25 (68.25)	88.75 (70.41)	**83.00 (66.02)**	69.00 (56.17)	79.50 (63.09)	86.00 (68.05)	**78.17 (62.43)**	62.50 (52.24)	75.00 (60.06)	83.50 (66.08)	**73.67 (59.46)**
T_6	82.00 (64.92)	88.00 (69.76)	90.25 (71.81)	**86.75 (68.83)**	78.00 (62.03)	87.00 (68.87)	89.25 (70.87)	**84.75 (67.26)**	75.00 (60.06)	85.50 (67.63)	88.00 (69.74)	**82.83 (65.81)**	68.50 (55.86)	82.00 (64.92)	85.00 (67.24)	**78.50 (62.67)**
T_7	85.25 (67.43)	89.25 (70.87)	90.75 (72.31)	**88.42 (70.20)**	80.00 (63.77)	88.25 (69.97)	89.75 (71.37)	**86.00 (68.37)**	78.00 (62.03)	86.50 (68.48)	89.00 (70.66)	**84.50 (67.06)**	72.50 (58.39)	84.00 (66.43)	86.00 (68.05)	**80.83 (64.29)**
T_8	72.25 (58.21)	85.75 (67.83)	87.50 (69.33)	**81.83 (65.13)**	64.50 (53.43)	84.75 (67.04)	86.50 (68.45)	**78.58 (62.97)**	61.25 (51.51)	73.50 (59.03)	85.25 (67.43)	**73.33 (59.32)**	55.50 (48.16)	70.00 (56.79)	82.00 (64.90)	**69.17 (56.62)**
T_9	80.00 (63.44)	87.75 (69.52)	90.00 (71.58)	**85.92 (68.18)**	76.00 (60.76)	86.75 (68.68)	89.00 (70.66)	**83.92 (66.70)**	73.00 (58.73)	80.00 (63.45)	87.00 (68.87)	**80.00 (63.68)**	66.50 (54.65)	77.00 (61.35)	83.00 (65.71)	**75.50 (60.57)**
T_{10}	87.00 (68.87)	89.50 (71.12)	91.00 (72.55)	**89.17 (70.85)**	83.00 (65.77)	90.00 (70.20)	**90.00 (71.58)**	**87.17 (69.18)**	79.00 (62.74)	87.25 (69.08)	89.00 (70.66)	**85.08 (67.49)**	77.50 (61.70)	85.00 (67.22)	87.00 (68.87)	**83.17 (65.93)**
T_{11}	62.00 (51.95)	85.25 (67.43)	86.50 (68.46)	**77.92 (62.61)**	52.00 (46.15)	85.00 (65.67)	85.00 (67.22)	**73.33 (59.68)**	43.00 (40.97)	69.50 (56.53)	84.00 (66.43)	**65.50 (54.64)**	32.50 (34.68)	66.00 (54.34)	79.00 (62.74)	**59.17 (50.58)**
Mean	**77.52 (61.96)**	**87.25 (69.13)**	**89.11 (70.79)**	**84.63 (67.29)**	**71.50 (58.03)**	**86.09 (68.16)**	**88.07 (69.85)**	**81.89 (65.34)**	**67.84 (55.67)**	**79.57 (63.38)**	**86.61 (68.59)**	**78.01 (62.55)**	**61.86 (51.99)**	**75.82 (60.77)**	**83.32 (65.97)**	**73.67 (59.58)**
For comparing means of	S.Em±		CD at 5%		S.Em±		CD at 5%		S.Em±		CD at 5%		S.Em±		CD at 5%	
Treatments (T)	0.16		0.56		0.27		0.91		0.20		0.66		0.25		0.81	
Containers (C)	0.30		0.99		0.51		1.68		0.33		1.18		0.47		1.43	
Interaction (T×C)	0.52		1.76		0.89		2.75		0.67		2.14		0.82		2.54	

NS – Non significant

*Figures in the parenthesis are arcsine transformed values

.**Botanicals (T)**

.T_1 : Neem leaf powder @ 10g/kg seed
T_2 : Castor leaf powder @ 10g/kg seed
T_3 : Pongamia leaf powder @ 10g/kg
T_4 : Tulsi leaf powder @ 10g/kg seed
T_5 : Mandrin peal powder @10g/kg seed
T_6 : Bhajje powder @ 10g/kg seed
T_7 : Arappu powder @ 10g/kg seed
T_8 : Parthenium@ 10g/kg seed
T_9 : Wood ash @ 10g/kg seed
T_{10} : Thiram@ 2g/kg seed
T_{11} : Control

Containers (C)

C_1 : Cloth bag
C_2 : Polyethylene bag
C_3 : Vacuum packaging

Table 4. Root length (cm) as influenced by treatments, containers and their interactions effect during storage of maize hybrid cv. Arjun

.Treatments	Months after storage															
	3rd month				4th month				5th month				6th month			
	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean
T_1	23.10	23.20	23.25	**23.18**	23.25	23.10	23.30	**23.22**	22.58	22.88	22.98	**22.81**	22.28	22.70	23.00	**22.66**
T_2	22.48	22.50	22.60	**22.53**	22.13	21.90	22.10	**22.04**	21.23	21.70	22.25	**21.73**	20.98	21.28	21.65	**21.30**
T_3	22.70	22.73	22.83	**22.75**	22.35	22.48	22.68	**22.50**	21.98	22.25	22.58	**22.27**	21.45	22.00	22.35	**21.93**
T_4	22.50	22.58	22.68	**22.58**	22.38	22.38	22.58	**22.44**	21.65	20.18	22.53	**21.45**	21.23	21.73	22.08	**21.68**
T_5	23.03	23.08	23.13	**23.08**	22.80	22.63	22.83	**22.75**	22.10	22.43	22.78	**22.43**	21.60	22.13	22.48	**22.07**
T_6	23.10	23.20	23.30	**23.20**	23.08	23.10	23.35	**23.18**	22.43	22.60	22.95	**22.66**	21.80	22.53	21.88	**22.07**
T_7	23.38	23.40	23.45	**23.41**	23.23	23.33	23.38	**23.31**	22.88	23.15	23.55	**23.19**	22.53	21.88	23.28	**22.56**
T_8	22.40	22.45	22.58	**22.48**	21.98	22.18	22.38	**22.18**	21.53	21.88	22.23	**21.88**	21.08	21.45	21.80	**21.44**
T_9	23.08	23.15	23.25	**23.16**	22.63	22.78	23.00	**22.80**	22.38	22.50	22.85	**22.58**	21.95	22.40	21.75	**22.03**
T_{10}	22.33	23.53	23.58	**23.52**	23.23	23.38	23.70	**23.43**	23.00	23.30	23.38	**23.23**	22.80	23.05	23.45	**23.10**
T_{11}	22.28	22.28	23.43	**22.68**	21.60	21.83	22.03	**21.82**	21.25	21.53	21.88	**21.55**	20.63	21.10	21.45	**21.06**
Mean	**22.76**	**22.92**	**23.10**	**22.96**	**22.60**	**22.64**	**22.85**	**22.70**	**22.09**	**22.22**	**22.72**	**22.34**	**21.66**	**22.02**	**22.29**	**21.99**
For comparing means of	S.Em±		CD at 1%		S.Em±		CD at 1%		S.Em±		CD at 1%		S.Em±		CD at 1%	
Treatments (T)	0.13		NS		0.13		NS		**0.12**		**0.43**		0.10		0.36	
Containers (C)	0.25		NS		**0.24**		**0.89**		0.22		0.82		0.19		0.70	
Interaction (T×C)	0.43		NS		0.42		NS		0.38		NS		0.32		NS	

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Treatments	Months after storage															
	7th month				**8th month**				**9th month**				**10th month**			
	C_1	**C_2**	**C_3**	**Mean**	**C_1**	**C_2**	**C_3**	**Mean**	**C_1**	**C_2**	**C_3**	**Mean**	**C_1**	**C_2**	**C_3**	**Mean**
T_1	22.05	22.43	22.83	**22.43**	21.65	22.00	22.40	**22.02**	21.33	21.68	22.08	**21.69**	21.00	21.38	21.78	**21.38**
T_2	20.48	20.90	21.25	**20.88**	19.95	20.58	20.93	**20.48**	19.65	20.15	20.50	**20.10**	19.05	19.65	19.98	**19.56**
T_3	21.05	21.60	21.95	**21.53**	20.85	21.20	21.55	**21.20**	20.65	21.00	21.35	**21.00**	20.00	20.55	20.90	**20.48**
T_4	20.78	21.45	21.78	**21.33**	20.40	20.98	21.33	**20.90**	20.10	20.55	20.90	**20.52**	19.45	20.10	20.45	**20.00**
T_5	21.30	21.83	22.18	**21.77**	21.10	21.43	21.78	**21.43**	20.90	21.23	21.58	**21.23**	20.40	20.83	21.18	**20.80**
T_6	21.68	22.20	22.55	**22.14**	21.48	21.90	22.25	**21.88**	21.28	21.70	22.03	**21.67**	20.88	21.23	21.58	**21.23**
T_7	22.35	22.60	23.00	**22.65**	22.03	22.15	22.55	**22.24**	21.70	21.88	22.28	**21.95**	21.15	21.50	21.90	**21.52**
T_8	20.88	21.00	21.35	**21.08**	20.33	20.78	21.13	**20.74**	19.88	20.33	20.68	**20.29**	19.38	19.83	20.18	**19.79**
T_9	21.75	22.00	22.35	**22.03**	21.40	21.78	22.13	**21.77**	21.05	21.45	21.78	**21.43**	20.75	20.98	21.33	**21.02**
T_{10}	22.53	22.78	23.20	**22.83**	22.23	22.38	22.80	**22.47**	21.83	22.08	22.50	**22.13**	21.40	21.78	22.20	**21.79**
T_{11}	20.23	20.78	21.10	**20.70**	19.85	20.40	20.75	**20.33**	19.50	20.05	20.40	**19.98**	18.95	19.58	19.93	**19.48**
Mean	**21.37**	**21.78**	**22.14**	**21.76**	**21.02**	**21.41**	**21.78**	**21.41**	**20.71**	**21.10**	**21.46**	**21.09**	**20.22**	**20.67**	**21.03**	**20.64**
For comparing means of	S.Em±		CD at 1%		S.Em±		CD at 1%		S.Em±		CD at 1%		S.Em±		CD at 1%	
Treatments (T)	0.10		0.38		0.11		0.43		0.10		0.38		0.12		0.46	
Containers (C)	0.19		0.72		0.22		0.82		0.20		0.74		0.23		0.87	
Interaction (T×C)	0.34		NS		0.38		NS		0.34		NS		0.41		NS	

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Treatments	Months after storage															
	11th month				12th month				13th month				14th month			
	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean
T_1	20.50	21.03	21.45	**20.99**	20.00	20.63	21.03	**20.55**	19.65	20.23	20.63	**20.17**	18.98	19.48	19.90	**19.45**
T_2	18.65	19.13	19.50	**19.09**	17.95	18.60	18.95	**18.50**	16.98	18.18	18.53	**17.89**	16.05	17.43	17.78	**17.08**
T_3	19.43	20.18	20.53	**20.04**	18.83	19.60	19.95	**19.46**	18.03	18.83	19.18	**18.68**	17.20	18.20	18.55	**17.98**
T_4	18.75	19.98	20.35	**19.69**	18.43	19.43	19.78	**19.21**	17.46	18.68	19.03	**18.39**	16.48	17.90	18.25	**17.54**
T_5	19.85	20.48	20.85	**20.39**	19.33	19.88	20.23	**19.81**	18.50	19.28	19.63	**19.13**	17.70	18.68	19.03	**18.47**
T_6	20.43	20.75	21.15	**20.78**	19.78	20.28	20.63	**20.23**	19.43	19.78	20.13	**19.78**	18.55	19.10	19.45	**19.03**
T_7	20.75	21.10	21.53	**21.13**	20.33	20.75	21.15	**20.74**	20.00	20.40	20.80	**20.40**	19.28	19.75	20.15	**19.73**
T_8	18.93	19.33	19.78	**19.34**	18.33	18.83	19.18	**18.78**	17.33	18.33	18.68	**18.11**	16.33	17.53	17.88	**17.24**
T_9	20.25	20.53	20.88	**20.55**	19.83	20.05	20.40	**20.09**	18.98	19.50	19.85	**19.44**	18.15	18.88	19.23	**18.75**
T_{10}	21.00	21.38	21.80	**21.39**	20.60	20.98	20.40	**20.66**	20.10	20.68	21.10	**20.63**	19.70	20.20	20.63	**20.18**
T_{11}	18.35	19.00	19.35	**18.90**	17.58	18.50	18.83	**18.30**	16.68	17.88	18.23	**17.59**	15.75	17.15	17.50	**16.80**
Mean	**19.72**	**20.26**	**20.65**	**20.21**	**19.18**	**19.77**	**20.05**	**19.67**	**18.46**	**19.25**	**19.61**	**19.11**	**17.65**	**18.57**	**18.94**	**18.39**
For comparing means of	S.Em±		CD at 1%		S.Em±		CD at 1%		S.Em±		CD at 1%		S.Em±		CD at 1%	
Treatments (T)	0.07		0.25		0.07		0.23		0.07		0.23		0.06		0.22	
Containers (C)	0.13		0.48		0.12		0.40		0.12		0.41		0.13		0.41	
Interaction (T×C)	0.22		NS		0.22		NS		0.21		NS		0.20		NS	

NS - Non significant

.**Botanicals (T)**

.T_1 : Neem leaf powder @ 10g/kg seed
T_2 : Castor leaf powder @ 10g/kg seed
T_3 : Pongamia leaf powder @ 10g/kg seed
T_4 : Tulsi leaf powder @ 10g/kg seed
T_5 : Mandrin peal powder @ 10g/kg seed
T_6 : Bhajje powder @ 10g/kg seed
T_7 : Arappu powder @ 10g/kg seed
T_8 : Parthenium@ 10g/kg seed
T_9 : Wood ash @ 10g/kg seed
T_{10} : Thiram@ 2g/kg seed
T_{11} : Control

Containers (C)

C_1 : Cloth bag
C_2 : Polyethylene bag
C_3 : Vacuum packaging

Due to Interactions

The interactions between seed treatments and containers did not differ significantly on root length throughout the storage period. However the root length was numerically more in $T_{10}C_3$ (23.58 to 20.63 cm) followed by T_7C_3 (23.45 to 20.15 cm) and T_1C_3 (23.25 to 19.90 cm) and comparatively less root length were observed throughout the storage period in seeds stored in cloth bag $T_{10}C_1$ (22.28 to 19.70 cm) followed by T_7C_1 (23.38 to 19.28 cm), T_1C_1 (23.25 to 19.90 cm) and least in $T_{11}C_1$ (22.28 to 15.75 cm) from 3rd month to 14th month of storage.

4.1.4 Shoot length (cm)

The data on shoot length as influenced by seed treatments and containers and their interactions are presented in Table 5.

Due to seed treatments

The shoot length differed significantly after 8th month of storage due to seed treatments. Among seed treatments, significantly higher (20.87 to 17.24 cm) shoot length was recorded with thiram (T_{10}) followed by arappu (20.53 to 16.69 cm), neem leaf powder (20.29 to 16.33 cm), sweet flag (20.15 to 15.90 cm), wood ash (20.03 to 15.60 cm) and lower was in control (19.21 to 12.52 cm) after sixth month to fourteen month of storage respectively.

Due to containers

The shoot length was significantly influenced by containers. It was significantly higher (21.21 cm) with the seed stored in vacuum sealed container followed by polyethylene bag (20.94 cm) after third month of storage. Similar trend was followed up to 14 months. At the end of 14th month significantly maximum (15.95 cm) shoot length was in C_3 followed by C_2 (15.10 cm) and was minimum in C_1 (14.24 cm).

Due to interactions

The shoot length due to interactions of treatments and containers (T×C) did not differ significantly during entire period of storage. However numerically more (22.45 cm) shoot length was recorded in seeds treated with thiram and stored in vacuum containers ($T_{10}C_3$) followed by T_7C_3 (22.08 cm), T_1C_3 (21.98 cm) and was less (21.43 cm) in $T_{11}C_1$ at the 3rd month of storage. Similar trend was maintained after the 14 months of storage. It was numerically maximum (17.83, 17.23 and 16.88 cm) with $T_{10}C_3$, T_7C_3, and T_1C_3 respectively and was minimum (11.05 cm) with T_{11} C_1 after the 14th month of storage.

4.1.5 Vigour index

The data on vigour index as influenced treatments, containers and their interaction effects are presented in Table 6 and depicted in Fig. 2a and 2b.

Irrespective of treatments and containers, the vigour index was found to decrease from initial 4376 to 2737 at the end of 14 months of storage.

Due to treatments

The vigour index differed significantly in all the months of storage. After 3rd month of storage vigour index was significantly maximum (4479) with thiram followed by arappu (4477), neem (4436), sweet flag (4433), wood ash (4378) and was minimum (4342) with control. The same trend was maintained at the end of 14th month of storage. The seed treated with thiram recorded significantly highest (3384) vigour index followed by arappu (3206), neem (3105), sweet flag (3006), wood ash (2847) and lowest (1981) was recorded in control at the end of fourteen months of storage period.

Due to containers

Vigour index statistically differed significantly after 5th month of storage period due to containers. It was significantly maximum (4283) with vacuum containers followed by polythene bag (4175) and was minimum (4128) after 5th month of storage. Similar trend was seen in all the months of storage.

Table 5. Shoot length (cm) as influenced by treatments, containers and their interactions effect during storage of maize hybrid cv. Arjun

.Treatments	Months after storage															
	3^{rd} month				4^{th} month				5^{th} month				6^{th} month			
	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean
T_1	21.80	22.00	22.15	**21.98**	21.63	21.95	22.10	**21.89**	21.00	21.28	21.38	**21.22**	20.65	20.65	21.13	**20.81**
T_2	21.20	21.28	21.36	**21.28**	21.00	21.11	21.31	**21.14**	20.50	20.70	20.90	**20.70**	19.88	20.38	20.88	**20.38**
T_3	21.50	21.30	21.53	**21.44**	21.40	21.50	21.31	**21.40**	20.10	20.80	21.10	**20.67**	20.18	20.65	21.03	**20.62**
T_4	21.43	21.90	22.00	**21.78**	21.33	21.30	21.95	**21.53**	20.55	20.75	21.05	**20.78**	20.10	20.55	20.90	**20.52**
T_5	21.50	21.56	22.10	**21.72**	21.43	21.50	21.73	**21.55**	20.75	20.90	21.20	**20.95**	20.23	20.78	21.08	**20.69**
T_6	21.70	21.80	22.15	**21.88**	21.58	21.72	21.95	**21.75**	20.80	21.08	21.33	**21.07**	20.50	20.80	21.13	**20.81**
T_7	21.90	22.05	22.30	**22.08**	21.72	21.95	22.10	**21.92**	21.20	20.53	21.83	**21.18**	20.95	21.15	21.25	**21.12**
T_8	21.41	21.48	21.50	**21.46**	21.15	21.35	21.45	**21.32**	20.50	20.78	20.98	**20.75**	19.95	20.40	20.80	**20.38**
T_9	21.50	21.60	21.93	**21.68**	21.31	21.58	21.64	**21.51**	20.73	20.98	21.30	**21.00**	20.33	20.88	21.10	**20.77**
T_{10}	22.25	21.15	22.45	**21.95**	22.20	22.10	21.88	**22.06**	21.90	21.85	21.15	**21.63**	21.33	21.48	21.78	**21.53**
T_{11}	21.11	21.80	22.00	**21.63**	21.30	21.75	21.86	**21.64**	20.40	20.68	21.08	**20.72**	19.85	20.33	20.65	**20.28**
Mean	**21.57**	**21.63**	**21.95**	**21.71**	**21.46**	**21.62**	**21.75**	**21.61**	**20.77**	**20.94**	**21.21**	**20.97**	**20.36**	**20.73**	**21.06**	**20.72**
For comparing means of	S.Em±		CD at 1%		S.Em±		CD at 1%		S.Em±		CD at 1%		S.Em±		CD at 1%	
Treatments (T)	0.11		NS		0.12		NS		0.13		NS		**0.14**		**0.51**	
Containers (C)	0.21		NS		0.23		NS		0.25		NS		0.26		NS	
Interaction (T×C)	0.37		NS		0.41		NS		0.39		NS		0.41		NS	

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Treatments	Months after storage															
	7th month				8th month				9th month				10th month			
	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean
T_1	20.37	20.63	20.85	**20.62**	19.90	20.33	20.65	**20.29**	19.30	19.83	20.15	**19.76**	18.95	19.40	19.68	**19.34**
T_2	19.10	19.80	20.76	**19.89**	18.50	19.55	20.45	**19.50**	17.65	18.60	19.55	**18.60**	16.73	17.78	18.68	**17.73**
T_3	19.73	20.23	20.53	**20.16**	19.23	19.85	20.33	**19.80**	18.70	19.32	19.85	**19.29**	17.90	18.50	19.10	**18.50**
T_4	19.55	20.18	20.40	**20.04**	18.98	19.58	20.23	**19.59**	18.30	19.05	19.76	**19.04**	15.55	18.30	18.60	**17.48**
T_5	19.80	20.30	20.60	**20.23**	19.40	19.93	20.50	**19.94**	18.95	19.55	20.15	**19.55**	18.23	18.88	19.28	**18.79**
T_6	20.15	20.55	20.78	**20.49**	19.70	20.15	20.60	**20.15**	19.30	19.85	20.15	**19.77**	18.88	19.35	19.53	**19.25**
T_7	20.85	21.03	21.30	**21.06**	20.30	20.50	20.80	**20.53**	19.95	20.15	20.41	**20.17**	19.35	19.55	19.85	**19.58**
T_8	19.35	19.99	20.60	**19.98**	18.73	19.43	20.28	**19.48**	17.90	18.65	19.55	**18.70**	17.18	17.88	18.73	**17.93**
T_9	19.96	20.50	20.79	**20.42**	19.53	20.03	20.55	**20.03**	19.10	19.64	20.15	**19.63**	18.63	19.15	19.43	**19.07**
T_{10}	20.91	21.11	21.55	**21.19**	20.65	20.83	21.13	**20.87**	20.28	20.40	21.08	**20.58**	19.80	19.98	20.18	**19.98**
T_{11}	19.10	19.70	20.40	**19.73**	18.30	19.23	20.10	**19.21**	17.30	18.55	19.55	**18.47**	16.40	17.55	18.50	**17.48**
Mean	**19.90**	**20.36**	**20.78**	**20.35**	**19.38**	**19.94**	**20.51**	**19.94**	**18.79**	**19.42**	**20.03**	**19.41**	**17.96**	**18.75**	**19.23**	**18.65**
For comparing means of	S.Em±		CD at 1%		S.Em±		CD at 1%		S.Em±		CD at 1%		S.Em±		CD at 1%	
Treatments (T)	0.07		0.63		0.07		0.24		0.06		0.20		0.07		0.23	
Containers (C)	0.15		NS		**0.13**		**0.47**		0.12		0.45		0.12		0.44	
Interaction (T×C)	0.22		NS		0.22		NS		0.21		NS		0.22		NS	

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Treatments	Months after storage															
	11th month				12th month				13th month				14th month			
	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean
T_1	18.10	18.48	19.30	**18.63**	17.65	18.04	18.20	**17.96**	16.70	17.40	17.58	**17.23**	15.70	16.40	16.88	**16.33**
T_2	15.78	16.83	17.75	**16.78**	14.40	15.80	17.05	**15.75**	13.35	14.60	15.93	**14.63**	12.01	13.90	14.60	**13.50**
T_3	17.00	17.60	18.20	**17.60**	16.10	16.85	17.55	**16.83**	15.43	16.15	16.93	**16.17**	14.13	14.85	15.63	**14.87**
T_4	16.70	17.45	18.13	**17.43**	15.75	16.50	17.35	**16.53**	14.65	15.45	16.38	**15.49**	13.55	14.35	15.28	**14.39**
T_5	17.53	18.18	18.80	**18.17**	16.95	17.55	18.15	**17.55**	15.85	16.60	17.38	**16.61**	14.45	15.18	15.98	**15.20**
T_6	17.90	18.35	18.98	**18.41**	16.95	17.58	18.30	**17.61**	16.10	16.90	17.20	**16.73**	15.20	15.88	16.63	**15.90**
T_7	18.75	19.15	19.50	**19.13**	18.14	18.45	18.75	**18.45**	17.25	17.60	18.35	**17.73**	16.20	16.65	17.23	**16.69**
T_8	16.30	16.98	17.83	**17.03**	15.40	16.30	17.55	**16.42**	14.13	15.25	16.65	**15.34**	12.63	13.75	15.15	**13.84**
T_9	17.70	18.23	18.75	**18.23**	16.75	17.30	18.05	**17.37**	15.98	16.60	17.00	**16.53**	15.00	15.55	16.25	**15.60**
T_{10}	19.00	19.33	19.63	**19.32**	18.45	18.73	19.05	**18.74**	17.60	17.88	18.73	**18.07**	16.70	17.20	17.83	**17.24**
T_{11}	15.35	16.50	17.50	**16.45**	14.08	15.60	16.85	**15.51**	12.60	14.30	15.00	**13.97**	11.05	12.45	14.05	**12.52**
Mean	**17.28**	**17.91**	**18.58**	**17.92**	**16.42**	**17.15**	**17.89**	**17.16**	**15.42**	**16.25**	**17.01**	**16.23**	**14.24**	**15.10**	**15.95**	**15.10**
For comparing means of	S.Em±		CD at 1%		S.Em±		CD at 1%		S.Em±		CD at 1%		S.Em±		CD at 1%	
Treatments (T)	0.06		0.22		0.06		0.21		0.05		0.17		0.05		0.14	
Containers (C)	0.11		0.42		0.11		0.40		0.10		0.36		0.11		0.33	
Interaction (T×C)	0.21		NS		0.22		NS		0.21		NS		0.23		NS	

NS - Non significant

.Botanicals (T)

.T_1 : Neem leaf powder @ 10g/kg seed
T_2 : Castor leaf powder @ 10g/kg seed
T_3 : Pongamia leaf powder @ 10g/kg seed
T_4 : Tulsi leaf powder @ 10g/kg seed
T_5 : Mandrin peal powder @ 10g/kg seed
T_6 : Bhajje powder @ 10g/kg seed
T_7 : Arappu powder @ 10g/kg seed
T_8 : Parthenium@ 10g/kg seed
T_9 : Wood ash @ 10g/kg seed
T_{10} : Thiram@ 2g/kg seed
T_{11} : Control

Containers (C)

C_1 : Cloth bag
C_2 : Polyethylene bag
C_3 : Vacuum packaging

Table 6. Vigour Index as influenced by treatments, containers and their interactions effect during storage of maize hybrid cv. Arjun

Treatments	Months after storage															
	3rd month				4th month				5th month				6th month			
	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean
T_1	4412	4429	4461	**4434**	4397	4426	4449	**4424**	4216	4283	4346	**4281**	4128	4201	4328	**4219**
T_2	4280	4290	4309	**4293**	4205	4193	4254	**4217**	3995	4071	4186	**4084**	3851	3952	4080	**3961**
T_3	4319	4304	4325	**4316**	4266	4300	4289	**4285**	4050	4154	4247	**4150**	3938	4094	4194	**4075**
T_4	4304	4370	4378	**4351**	4272	4269	4375	**4305**	4050	3939	4227	**4072**	3916	4006	4175	**4032**
T_5	4341	4330	4421	**4364**	4290	4302	4367	**4320**	4123	4192	4288	**4201**	4005	4140	4241	**4129**
T_6	4390	4421	4489	**4433**	4354	4380	4440	**4391**	4183	4237	4327	**4249**	4055	4216	4175	**4149**
T_7	4460	4477	4495	**4477**	4415	4414	4468	**4432**	4276	4258	4458	**4331**	4193	4166	4444	**4268**
T_8	4271	4283	4320	**4275**	4215	4232	4294	**4247**	4023	4105	4191	**4106**	3864	3958	4115	**3979**
T_9	4357	4351	4427	**4378**	4295	4346	4353	**4332**	4159	4218	4304	**4227**	4049	4180	4151	**4127**
T_{10}	4502	4401	4534	**4479**	4451	4456	4466	**4458**	4366	4413	4385	**4388**	4251	4319	4461	**4344**
T_{11}	4219	4313	4451	**4342**	4172	4237	4278	**4229**	3965	4050	4155	**4057**	3825	3923	4007	**3919**
Mean	**4350**	**4361**	**4419**	**4376**	**4303**	**4323**	**4367**	**4331**	**4128**	**4175**	**4283**	**4195**	**4007**	**4105**	**4215**	**4109**
For comparing means of	S.Em±		CD at 1%		S.Em±		CD at 1%		S.Em±		CD at 1%		S.Em±		CD at 1%	
Treatments (T)	19		NS		19		NS		**23**		**84**		16		59	
Containers (C)	**38**		**141**		37		136		44		162		30		112	
Interaction (T×C)	66		NS		63		NS		75.41		NS		52.34		NS	

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Treatments	Months after storage															
	7th month				8th month				9th month				10th month			
	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean
T_1	4029	4155	4248	**4144**	3863	4073	4186	**4041**	3740	3944	4054	**3913**	3704	3892	4008	**3868**
T_2	3694	3847	4023	**3854**	3586	3770	3938	**3764**	3378	3592	3784	**3585**	3276	3470	3681	**3476**
T_3	3833	3983	4099	**3972**	3733	3921	4041	**3898**	3602	3750	3893	**3748**	3509	3633	3762	**3635**
T_4	3778	3953	4049	**3927**	3672	3821	3977	**3823**	3467	3683	3843	**3665**	3205	3566	3713	**3495**
T_5	3875	4023	4128	**4009**	3787	3917	4068	**3924**	3616	3813	3967	**3799**	3570	3726	3851	**3716**
T_6	3967	4104	4192	**4088**	3828	4006	4135	**3989**	3736	3926	4029	**3897**	3655	3848	3731	**3744**
T_7	4137	4231	4319	**4229**	3967	4126	4215	**4103**	3864	4003	4130	**3999**	3776	3936	4054	**3922**
T_8	3741	3884	4027	**3884**	3641	3778	3943	**3787**	3428	3625	3811	**3621**	3344	3495	3705	**3515**
T_9	3901	4069	4174	**4048**	3837	3961	4129	**3975**	3684	3871	3994	**3849**	3631	3794	3893	**3773**
T_{10}	4170	4256	4374	**4267**	4062	4169	4293	**4175**	3914	4067	4216	**4066**	3912	4005	4118	**4012**
T_{11}	3621	3811	3964	**3798**	3397	3723	3889	**3670**	2962	3529	3756	**3416**	2728	3422	3579	**3243**
Mean	**3886**	**4029**	**4145**	**4020**	**3761**	**3933**	**4074**	**3923**	**3581**	**3800**	**3952**	**3778**	**3483**	**3708**	**3827**	**3672**
For comparing means of	S.Em±		CD at 1%		S.Em±		CD at 1%		S.Em±		CD at 1%		S.Em±		CD at 1%	
Treatments (T)	22		82		16		60		25		94		23		81	
Containers (C)	43		160		31		116		48		179		42		155	
Interaction (T×C)	74		NS		54		NS		84		NS		**72**		**268**	

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Treatments	Months after storage															
	11th month				12th month				13th month				14th month			
	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean
T_1	3519	3755	3906	**3727**	3201	3636	3687	**3508**	3053	3478	3572	**3368**	2706	3229	3381	**3105**
T_2	2723	3282	3477	**3160**	2264	2855	3275	**2798**	2061	2556	3097	**2571**	1740	2318	2850	**2303**
T_3	3031	3456	3649	**3378**	2649	3170	3454	**3091**	2478	2971	3275	**2908**	2193	2645	3076	**2638**
T_4	2892	3380	3587	**3286**	2459	3091	3380	**2977**	2247	2867	3198	**2771**	1953	2552	3018	**2508**
T_5	3186	3540	3736	**3488**	2906	3293	3546	**3248**	2604	3085	3368	**3019**	2238	2777	3166	**2727**
T_6	3408	3719	3811	**3646**	3082	3519	3660	**3420**	2912	3375	3472	**3253**	2559	3144	3316	**3006**
T_7	3631	3861	3984	**3825**	3310	3685	3790	**3595**	3164	3534	3680	**3459**	2834	3310	3474	**3206**
T_8	2780	3313	3541	**3212**	2380	2953	3341	**2892**	2146	2695	3185	**2675**	1824	2408	2975	**2402**
T_9	3305	3685	3766	**3585**	2999	3362	3575	**3312**	2800	3123	3392	**3105**	2454	2895	3194	**2847**
T_{10}	3757	3904	4025	**3895**	3475	3730	3748	**3651**	3242	3615	3744	**3534**	3096	3441	3614	**3384**
T_{11}	2332	3248	3407	**2996**	1837	2726	3211	**2591**	1460	2446	2990	**2299**	1073	2158	2711	**1981**
Mean	**3142**	**3558**	**3717**	**3473**	**2778**	**3274**	**3515**	**3189**	**2561**	**3068**	**3361**	**2997**	**2243**	**2807**	**3161**	**2737**
For comparing means of	S.Em±		CD at 1%		S.Em±		CD at 1%		S.Em±		CD at 1%		S.Em±		CD at 1%	
Treatments (T)	26		95		26		96		28		101		27		99	
Containers (C)	49		183		50		184		53		193		52		190	
Interaction (T×C)	85		317		86		316		92		340		92		334	

NS - Non significant

.**Botanicals (T)**

.T_1 : Neem leaf powder @ 10g/kg seed
T_2 : Castor leaf powder @ 10g/kg seed
T_3 : Pongamia leaf powder @ 10g/kg seed
T_4 : Tulsi leaf powder @ 10g/kg seed
T_5 : Mandrin peal powder @ 10g/kg seed
T_6 : Bhajje powder @ 10g/kg seed
T_7 : Arappu powder @ 10g/kg seed
T_8 : Parthenium@ 10g/kg seed
T_9 : Wood ash @ 10g/kg seed
T_{10} : Thiram@ 2g/kg seed
T_{11} : Control

Containers (C)

C_1 : Cloth bag
C_2 : Polyethylene bag
C_3 : Vacuum packaging

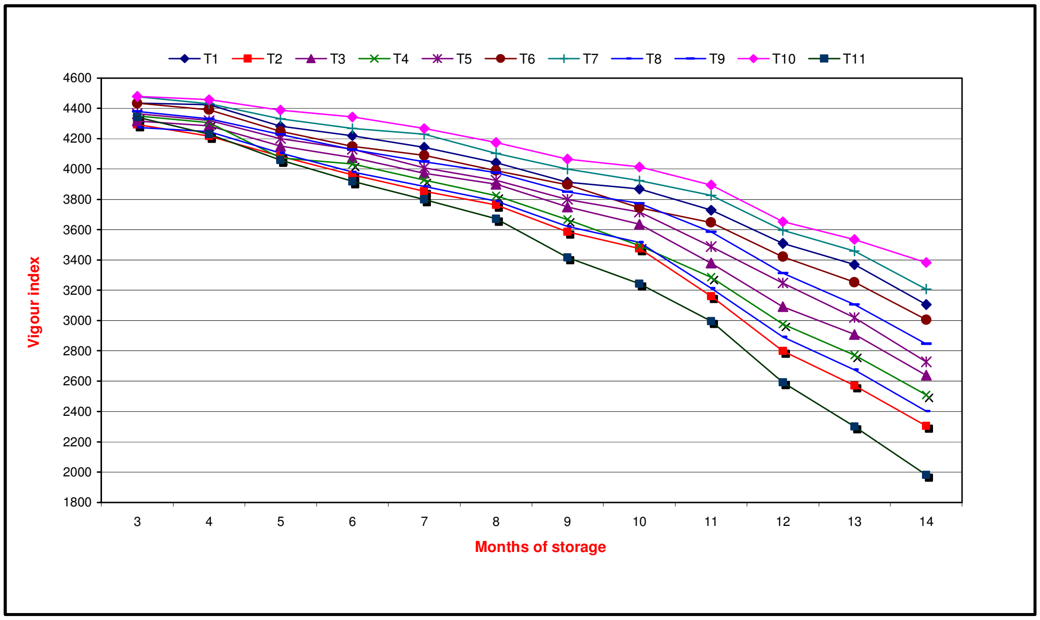

Fig. 2a: Effect of treatments on vigour index during storage period of maize hybrid (Arjun)

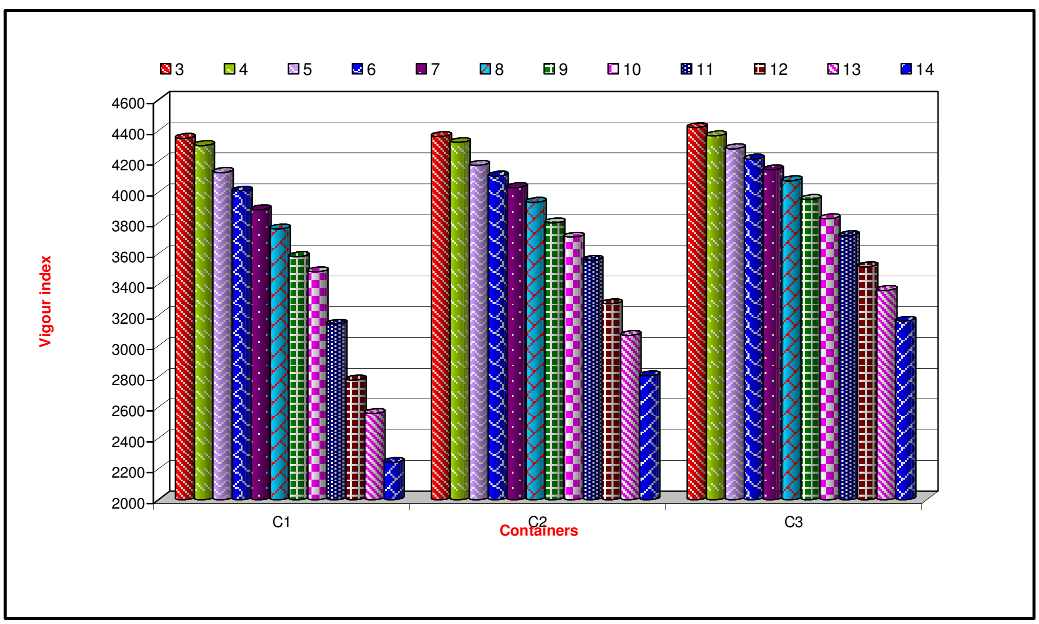

Fig. 2b: Effect of contianers on vigour index during storage period of maize hybrid (Arjun)

At the end of 14 months of storage maximum (3161) vigour index was recorded in seed stored in vacuum followed by polythene bag (2807) and was minimum (2243) in control.

Due to interactions

The interactions between seed treatments and containers (T×C) recorded statistical differences on vigour index from 9th month onwards of seed storage. Among interactions significantly highest (4118) vigour index was recorded in $T_{10}C_3$ followed T_7C_3 (4054), T_1C_3 (4008), and lowest (2728) in $T_{11}C_1$ after 10th month of storage. Similar trend was noticed throughout the period of storage. After 14th month of storage seedling vigour index was significantly highest (3614) in $T_{10}C_3$ followed by T_7C_3 (3474) and T_1C_3 (3381) and lowest (1073) was in $T_{11}C_1$.

4.1.6 Seedling dry weight (mg)

The data on seedling dry weight as influence by treatments and containers and their interactions are presented in Table 7.

The mean seedling dry weight decreased from 2.32 to 1.61 g after 3rd month to 14th of storage.

Due to seed treatments

There was significant difference on dry weight of seedling in all the months of storage due to the effect of seed treatments. The thiram treated seeds recorded higher (2.60 g and 2.02 g) dry weight of seedlings followed by T_7 (2.52 g and 1.96 g), T_1 (2.51g and 1.91g), T_6 (2.40 g and 1.86 g), T_9 (2.35 g to 1.82 g), and lowest (2.06 g and 1.61 g) was in control (T_{11}) at third and fourteen months of storage respectively.

Due to containers

Dry weight of seedlings differed significantly from 4th month to till the end of storage period of 14 months. After 4th month of storage it was significantly maximum (2.32 g) with vacuum containers and minimum (2.25 g) with cloth bag container. The seed stored in vacuum sealed container recorded significantly maximum (1.88 g) seedling dry weight compared to polythene bag (1.79 g) and was minimum (1.63 g) in cloth bag at the end of the storage period.

Due to interactions

Due to interactions between seed treatments and containers (TxC) significant differences on seedling dry weight was recorded only at 7th, 8th and 14th month of storage. Maximum (2.17 g) dry weight was recorded in thiram treated seed and stored in vacuum sealed container ($T_{10}C_3$) followed by T_7C_3 (2.10 g), T_1C_3 (2.07 g) and $T_{11}C_3$ (1.63 g) and minimum (1.31 g) seedling dry weight was in $T_{11}C_1$ at the end of storage period.

4.1.7 Electrical conductivity (dSm^{-1})

The results on electrical conductivity as influenced by seed treatments and containers and their interactions are presented in Table 8.

Due to seed treatments

In general, the mean EC increased from 0.253 to 0.531dSm^{-1} after 3rd to 14th month of storage. The electrical conductivity differed significantly throughout the storage period. It was significantly lowest (0.237 dSm^{-1}) in thiram and highest (0.266) in control after the third month of storage. Similar trend was followed throughout the period of storage up to fourteen months of storage. At the end of fourteen months of storage, significantly lowest (0.461 dSm^{-1}) EC was recorded in thiram and highest (0.658 dSm^{-1}) was in control; the EC, values in the remaining treatments were in between of these treatments.

Due to containers

The electrical conductivity was significantly influenced by containers throughout the storage period. After 3rd month of storage seeds stored in vacuum recorded significantly less (0.232 dSm^{-1}) EC and was more in cloth bag (0.271 dSm^{-1}).

Table 7. Dry matter (g) as influenced by treatments, containers and their interactions effect during storage of maize hybrid cv. Arjun

Treatments	**Months after storage**															
	3rd month				**4th month**				**5th month**				**6th month**			
	C_1	**C_2**	**C_3**	**Mean**	**C_1**	**C_2**	**C_3**	**Mean**	**C_1**	**C_2**	**C_3**	**Mean**	**C_1**	**C_2**	**C_3**	**Mean**
T_1	2.50	2.51	2.52	**2.51**	2.49	2.50	2.51	**2.50**	2.38	2.40	2.49	**2.42**	2.33	2.36	2.46	**2.38**
T_2	2.10	2.12	2.13	**2.12**	2.09	2.11	2.12	**2.11**	2.03	2.09	2.10	**2.07**	1.98	2.05	2.07	**2.03**
T_3	2.24	2.27	2.29	**2.27**	2.23	2.26	2.28	**2.26**	2.18	2.20	2.26	**2.21**	2.13	2.16	2.23	**2.17**
T_4	2.17	2.20	2.22	**2.20**	2.16	2.19	2.21	**2.19**	2.11	2.16	2.19	**2.15**	2.06	2.12	2.16	**2.11**
T_5	2.31	2.31	2.33	**2.32**	2.30	2.30	2.32	**2.31**	2.25	2.27	2.30	**2.27**	2.20	2.23	2.27	**2.23**
T_6	2.40	2.40	2.41	**2.40**	2.39	2.39	2.40	**2.39**	2.34	2.38	2.38	**2.37**	2.29	2.34	2.35	**2.33**
T_7	2.49	2.51	2.55	**2.52**	2.48	2.50	2.54	**2.51**	2.43	2.46	2.52	**2.47**	2.38	2.42	2.49	**2.43**
T_8	2.14	2.16	2.16	**2.15**	2.11	2.15	2.15	**2.14**	2.06	2.12	2.13	**2.10**	2.01	2.08	2.10	**2.06**
T_9	2.34	2.35	2.36	**2.35**	2.33	2.34	2.35	**2.34**	2.32	2.33	2.33	**2.33**	2.27	2.29	2.30	**2.29**
T_{10}	2.58	2.60	2.62	**2.60**	2.54	2.59	2.61	**2.58**	2.49	2.51	2.59	**2.53**	2.44	2.47	2.56	**2.49**
T_{11}	2.04	2.07	2.08	**2.06**	2.03	2.06	2.07	**2.05**	1.96	2.04	2.05	**2.02**	1.91	2.00	2.02	**1.98**
Mean	**2.30**	**2.32**	**2.33**	**2.32**	**2.29**	**2.31**	**2.32**	**2.31**	**2.23**	**2.27**	**2.30**	**2.27**	**2.18**	**2.23**	**2.27**	**2.23**
For comparing means of	S.Em±		CD at 1%		S.Em±		CD at 1%		S.Em±		CD at 1%		S.Em±		CD at 1%	
Treatments (T)	0.01		NS		**0.01**		**0.03**		0.01		0.03		0.01		0.03	
Containers (C)	**0.01**		**0.03**		0.01		0.03		0.02		0.06		0.02		0.06	
Interaction (T×C)	0.03		NS		0.03		NS		0.02		NS		0.03		NS	

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Treatments	Months after storage															
	7^{th} month				8^{th} month				9^{th} month				10^{th} month			
	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean
T_1	2.26	2.32	2.41	**2.33**	2.20	2.26	2.36	**2.27**	2.14	2.20	2.33	**2.22**	2.05	2.16	2.27	**2.16**
T_2	1.91	2.01	2.02	**1.98**	1.85	1.95	1.97	**1.92**	1.79	1.89	1.94	**1.88**	1.70	1.85	1.88	**1.81**
T_3	2.06	2.12	2.18	**2.12**	2.00	2.06	2.13	**2.06**	1.94	2.00	2.11	**2.02**	1.85	1.96	2.04	**1.95**
T_4	1.99	2.08	2.11	**2.06**	1.93	2.02	2.06	**2.00**	1.87	1.96	2.03	**1.95**	1.78	1.92	1.97	**1.89**
T_5	2.13	2.19	2.22	**2.18**	2.07	2.13	2.17	**2.12**	2.00	2.07	2.14	**2.07**	1.92	2.03	2.08	**2.01**
T_6	2.22	2.30	2.30	**2.27**	2.16	2.24	2.25	**2.22**	2.10	2.18	2.20	**2.16**	2.01	2.14	2.16	**2.10**
T_7	2.31	2.38	2.44	**2.38**	2.25	2.32	2.39	**2.32**	2.19	2.26	2.36	**2.27**	2.10	2.22	2.30	**2.21**
T_8	1.94	2.04	2.05	**2.01**	1.88	1.98	2.00	**1.95**	1.82	1.92	1.97	**1.90**	1.73	1.88	1.91	**1.84**
T_9	2.20	2.25	2.25	**2.23**	2.14	2.19	2.20	**2.18**	2.08	2.13	2.17	**2.12**	1.99	2.09	2.11	**2.06**
T_{10}	2.37	2.43	2.50	**2.43**	2.31	2.37	2.47	**2.38**	2.25	2.31	2.43	**2.33**	2.16	2.27	2.37	**2.27**
T_{11}	1.84	1.96	1.97	**1.92**	1.78	1.90	1.92	**1.87**	1.72	1.84	1.89	**1.82**	1.63	1.80	1.83	**1.75**
Mean	**2.11**	**2.19**	**2.22**	**2.17**	**2.05**	**2.13**	**2.17**	**2.12**	**1.99**	**2.07**	**2.14**	**2.07**	**1.90**	**2.03**	**2.08**	**2.00**
For comparing means of	S.Em±		CD at 1%		S.Em±		CD at 1%		S.Em±		CD at 1%		S.Em±		CD at 1%	
Treatments (T)	0.01		0.03		0.01		0.03		0.02		0.06		0.01		0.02	
Containers (C)	0.02		0.06		0.02		0.05		0.03		0.10		0.02		0.06	
Interaction (T×C)	**0.04**		**0.15**		**0.04**		**0.11**		0.05		NS		0.03		NS	

Contd.

Treatments	Months after storage															
	11th month				12th month				13th month				14th month			
	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean
T_1	2.14	2.20	2.33	**2.22**	1.89	2.02	2.15	**2.02**	1.82	1.97	2.11	**1.97**	1.75	1.92	2.07	**1.91**
T_2	1.79	1.89	1.94	**1.87**	1.54	1.71	1.76	**1.67**	1.47	1.66	1.72	**1.62**	1.40	1.61	1.68	**1.56**
T_3	1.94	2.00	2.11	**2.02**	1.69	1.82	1.92	**1.81**	1.62	1.77	1.88	**1.76**	1.55	1.72	1.84	**1.70**
T_4	1.87	1.96	2.03	**1.95**	1.62	1.78	1.85	**1.75**	1.55	1.73	1.81	**1.70**	1.48	1.68	1.77	**1.64**
T_5	2.01	2.07	2.14	**2.07**	1.76	1.89	1.96	**1.87**	1.69	1.84	1.92	**1.82**	1.62	1.79	1.88	**1.76**
T_6	2.10	2.18	2.20	**2.16**	1.85	2.00	2.04	**1.96**	1.78	1.95	2.00	**1.91**	1.71	1.90	1.96	**1.86**
T_7	2.19	2.26	2.36	**2.27**	1.94	2.08	2.18	**2.07**	1.87	2.03	2.14	**2.01**	1.81	1.98	2.10	**1.96**
T_8	1.82	1.92	1.97	**1.90**	1.57	1.74	1.79	**1.70**	1.50	1.69	1.75	**1.65**	1.43	1.64	1.71	**1.59**
T_9	2.08	2.13	2.17	**2.13**	1.83	1.95	1.99	**1.92**	1.76	1.90	1.95	**1.87**	1.69	1.85	1.91	**1.82**
T_{10}	2.25	2.31	2.43	**2.33**	2.00	2.13	2.25	**2.13**	1.93	2.08	2.21	**2.07**	1.86	2.03	2.17	**2.02**
T_{11}	1.72	1.84	1.89	**1.82**	1.47	1.66	1.71	**1.61**	1.40	1.61	1.67	**1.56**	1.31	1.56	1.63	**1.61**
Mean	**1.99**	**2.07**	**2.14**	**2.07**	**1.74**	**1.89**	**1.96**	**1.87**	**1.67**	**1.84**	**1.92**	**1.81**	**1.60**	**1.79**	**1.88**	**1.77**
For comparing means of	S.Em±		CD at 1%		S.Em±		CD at 1%		S.Em±		CD at 1%		S.Em±		CD at 1%	
Treatments (T)	0.01		0.02		0.01		0.02		0.01		0.02		0.01		0.02	
Containers (C)	0.01		0.03		0.01		0.04		0.01		0.03		0.01		0.03	
Interaction (T×C)	0.02		NS		0.02		NS		0.02		NS		**0.02**		**0.06**	

NS - Non significant

.**Botanicals (T)**

.T_1 : Neem leaf powder @ 10g/kg seed
T_2 : Castor leaf powder @ 10g/kg seed
T_3 : Pongamia leaf powder @ 10g/kg seed
T_4 : Tulsi leaf powder @ 10g/kg seed
T_5 : Mandrin peal powder @ 10g/kg seed
T_6 : Bhajje powder @ 10g/kg seed
T_7 : Arappu powder @ 10g/kg seed
T_8 : Parthenium@ 10g/kg seed
T_9 : Wood ash @ 10g/kg seed
T_{10} : Thiram@ 2g/kg seed
T_{11} : Control

Containers (C)

C_1 : Cloth bag
C_2 : Polyethylene bag
C_3 : Vacuum packaging

Table 8. Electrical conductivity (dSm^{-1}) as influenced by treatments, containers and their interactions effect during storage of maize hybrid cv. Arjun

.Treatments	Months after storage															
	3rd month				4th month				5th month				6th month			
	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean
T_1	0.268	0.246	0.225	**0.246**	0.270	0.256	0.235	**0.254**	0.274	0.259	0.240	**0.258**	0.286	0.268	0.244	**0.266**
T_2	0.282	0.267	0.243	**0.264**	0.290	0.273	0.257	**0.273**	0.300	0.283	0.262	**0.282**	0.324	0.295	0.269	**0.296**
T_3	0.270	0.262	0.238	**0.257**	0.283	0.264	0.246	**0.264**	0.295	0.266	0.256	**0.272**	0.295	0.284	0.260	**0.280**
T_4	0.273	0.266	0.240	**0.260**	0.285	0.267	0.249	**0.267**	0.299	0.270	0.257	**0.275**	0.312	0.287	0.267	**0.289**
T_5	0.269	0.255	0.233	**0.252**	0.279	0.260	0.245	**0.261**	0.291	0.265	0.255	**0.270**	0.290	0.279	0.260	**0.276**
T_6	0.269	0.249	0.226	**0.248**	0.273	0.257	0.239	**0.256**	0.283	0.263	0.243	**0.263**	0.305	0.270	0.249	**0.275**
T_7	0.265	0.243	0.219	**0.242**	0.264	0.254	0.226	**0.248**	0.270	0.256	0.234	**0.253**	0.283	0.265	0.240	**0.263**
T_8	0.277	0.267	0.242	**0.262**	0.288	0.260	0.260	**0.269**	0.290	0.275	0.260	**0.275**	0.318	0.291	0.268	**0.292**
T_9	0.269	0.250	0.229	**0.249**	0.276	0.259	0.243	**0.259**	0.288	0.264	0.246	**0.266**	0.309	0.276	0.252	**0.279**
T_{10}	0.256	0.240	0.215	**0.237**	0.250	0.242	0.224	**0.239**	0.262	0.251	0.228	**0.247**	0.275	0.260	0.236	**0.257**
T_{11}	0.285	0.267	0.246	**0.266**	0.296	0.279	0.260	**0.278**	0.305	0.292	0.275	**0.291**	0.337	0.309	0.280	**0.309**
Mean	**0.271**	**0.256**	**0.232**	**0.253**	**0.278**	**0.261**	**0.244**	**0.261**	**0.287**	**0.268**	**0.251**	**0.268**	**0.303**	**0.280**	**0.257**	**0.280**
For comparing means of	S.Em±		CD at 1%		S.Em±		CD at 1%		S.Em±		CD at 1%		S.Em±		CD at 1%	
Treatments (T)	0.001		0.002		0.001		0.002		0.001		0.002		0.001		0.003	
Containers (C)	0.002		0.005		0.002		0.005		0.002		0.005		0.002		0.005	
Interaction (T×C)	0.003		NS		0.003		NS		0.003		NS		0.003		0.009	

Contd…….

Treatments	Months after storage															
	7th month				8th month				9th month				10th month			
	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean
T_1	0.320	0.273	0.250	**0.281**	0.373	0.285	0.260	**0.306**	0.404	0.315	0.263	**0.327**	0.485	0.335	0.275	**0.365**
T_2	0.373	0.312	0.277	**0.321**	0.430	0.324	0.294	**0.349**	0.566	0.348	0.300	**0.405**	0.648	0.368	0.309	**0.442**
T_3	0.355	0.293	0.268	**0.305**	0.399	0.316	0.275	**0.330**	0.502	0.324	0.279	**0.368**	0.582	0.342	0.288	**0.404**
T_4	0.363	0.299	0.272	**0.311**	0.413	0.310	0.279	**0.334**	0.513	0.329	0.287	**0.376**	0.607	0.357	0.295	**0.420**
T_5	0.350	0.284	0.263	**0.299**	0.390	0.304	0.272	**0.322**	0.493	0.322	0.274	**0.363**	0.566	0.349	0.282	**0.399**
T_6	0.330	0.276	0.255	**0.287**	0.386	0.294	0.266	**0.315**	0.418	0.319	0.269	**0.335**	0.496	0.339	0.274	**0.370**
T_7	0.310	0.268	0.248	**0.275**	0.368	0.274	0.257	**0.300**	0.397	0.306	0.259	**0.321**	0.479	0.323	0.265	**0.356**
T_8	0.369	0.301	0.273	**0.314**	0.420	0.310	0.290	**0.340**	0.548	0.342	0.304	**0.398**	0.635	0.362	0.307	**0.435**
T_9	0.330	0.279	0.257	**0.289**	0.394	0.299	0.260	**0.318**	0.468	0.320	0.271	**0.353**	0.526	0.346	0.279	**0.384**
T_{10}	0.306	0.267	0.244	**0.272**	0.346	0.270	0.250	**0.289**	0.373	0.300	0.256	**0.310**	0.462	0.318	0.261	**0.347**
T_{11}	0.386	0.325	0.288	**0.333**	0.460	0.349	0.310	**0.373**	0.585	0.363	0.315	**0.421**	0.673	0.383	0.320	**0.459**
Mean	**0.345**	**0.289**	**0.263**	**0.299**	**0.398**	**0.303**	**0.274**	**0.325**	**0.479**	**0.326**	**0.280**	**0.362**	**0.560**	**0.347**	**0.287**	**0.398**
For comparing means of	S.Em±		CD at 1%		S.Em±		CD at 1%		S.Em±		CD at 1%		S.Em±		CD at 1%	
Treatments (T)	0.001		0.003		0.001		0.003		0.002		0.006		0.002		0.006	
Containers (C)	0.002		0.005		0.003		0.009		0.003		0.009		0.003		0.009	
Interaction (T×C)	0.003		0.009		0.004		0.013		0.004		0.015		0.005		0.017	

Contd.

Treatments	Months after storage															
	11th month				12th month				13th month				14th month			
	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean
T_1	0.525	0.344	0.283	**0.384**	0.595	0.364	0.282	**0.414**	0.716	0.385	0.294	**0.465**	0.755	0.404	0.302	**0.487**
T_2	0.788	0.389	0.311	**0.496**	0.828	0.406	0.318	**0.517**	0.939	0.427	0.320	**0.562**	1.028	0.441	0.338	**0.602**
T_3	0.672	0.372	0.298	**0.447**	0.709	0.388	0.304	**0.467**	0.813	0.399	0.306	**0.506**	0.832	0.422	0.314	**0.523**
T_4	0.697	0.383	0.306	**0.462**	0.767	0.393	0.315	**0.492**	0.828	0.411	0.317	**0.519**	0.837	0.426	0.325	**0.529**
T_5	0.646	0.366	0.291	**0.434**	0.702	0.380	0.299	**0.460**	0.797	0.394	0.302	**0.498**	0.826	0.418	0.309	**0.518**
T_6	0.554	0.349	0.286	**0.396**	0.654	0.369	0.290	**0.438**	0.725	0.389	0.296	**0.470**	0.784	0.408	0.304	**0.499**
T_7	0.513	0.339	0.279	**0.377**	0.573	0.359	0.287	**0.406**	0.664	0.378	0.292	**0.445**	0.723	0.397	0.296	**0.472**
T_8	0.705	0.386	0.309	**0.467**	0.785	0.399	0.329	**0.504**	0.886	0.419	0.312	**0.539**	0.985	0.436	0.329	**0.583**
T_9	0.616	0.358	0.290	**0.421**	0.696	0.378	0.297	**0.457**	0.767	0.391	0.301	**0.486**	0.806	0.413	0.307	**0.509**
T_{10}	0.508	0.331	0.275	**0.371**	0.558	0.353	0.281	**0.397**	0.619	0.364	0.284	**0.422**	0.698	0.393	0.292	**0.461**
T_{11}	0.823	0.412	0.326	**0.520**	0.913	0.425	0.343	**0.560**	0.984	0.446	0.346	**0.592**	1.156	0.465	0.354	**0.658**
Mean	**0.641**	**0.366**	**0.296**	**0.434**	**0.707**	**0.383**	**0.304**	**0.465**	**0.794**	**0.400**	**0.306**	**0.500**	**0.857**	**0.420**	**0.315**	**0.531**

For comparing means of	S.Em±	CD at 1%	S.Em±	CD at 1%	S.Em±	CD at 1%	S.Em±	CD at 1%
Treatments (T)	0.002	0.006	0.002	0.006	0.001	0.003	0.002	0.007
Containers (C)	0.003	0.010	0.004	0.011	0.003	0.010	0.004	0.014
Interaction (T×C)	0.005	0.019	0.005	0.019	0.006	0.022	0.006	0.022

NS - Non significant

.**Botanicals (T)**

.T_1 : Neem leaf powder @ 10g/kg seed
T_2 : Castor leaf powder @ 10g/kg seed
T_3 : Pongamia leaf powder @ 10g/kg seed
T_4 : Tulsi leaf powder @ 10g/kg seed
T_5 : Mandrin peal powder @ 10g/kg seed
T_6 : Bhajje powder @ 10g/kg seed
T_7 : Arappu powder @ 10g/kg seed
T_8 : Parthenium@ 10g/kg seed
T_9 : Wood ash @ 10g/kg seed
T_{10} : Thiram@ 2g/kg seed
T_{11} : Control

Containers (C)

C_1 : Cloth bag
C_2 : Polyethylene bag
C_3 : Vacuum packaging

Similar trend was obtained in all the months of storage. The seed stored in vacuum sealed container (C_3) recorded lower (0.315 dSm^{-1}) electrical conductivity as compared to polythene bag (0.420 dSm^{-1}) and in cloth bag it was higher (0.857 dSm^{-1}) at the end of fourteen months of storage.

Due to interactions

The interaction effects of treatments and containers were found significant from 6th month after storage up to 14th month. Among interactions significantly maximum (0.337dSm^{-1}) EC was recorded in $T_{11}C_1$ followed by T_2C_1 (0.324 dSm^{-1}) and was minimum (0.236 dSm^{-1}) with $T_{10}C_3$ and T_7C_3 (0.240 dSm^{-1}) followed by T_1C_3 (0.244 dSm^{-1}) after the 6th month of storage. Similar trend of EC among containers were recorded in entire storage period.

At the end of 14th month of storage significantly highest EC was recorded in $T_{11}C_1$ (1.156 dSm^{-1}) followed by T_2C_1 (1.028 dSm^{-1}) and lowest (0.292 dSm^{-1}) in $T_{10}C_{3.}$

4.1.8 Moisture content (%)

The data on seed moisture content as influenced by treatments and containers and their interactions during storage of maize seeds are presented in Table 9.

Due to treatments

The mean moisture content varied from 8.32 to 9.61 per cent after third month to 14 months of storage irrespective of treatments and containers

There was significant difference in moisture content from second to fourteen month of storage. The moisture content of the seeds treated with thiram (T_{10}) was minimum (8.15 to 9.29%) followed by arappu (T_7) (8.20 to 9.33%), neem (T_1) (8.22 to 9.38%), sweet flag (T_6) (8.23 to 9.50%), wood ash (T_9) (8.30 to 9.62%) and maximum (8.45 to 9.99%) in control (T_{11}) respectively.

Due to containers

The moisture content differed significantly from fourth month to end of the storage period due to containers. The moisture content was significantly lowest (8.29%) in vacuum sealed container followed by polythene bag (8.26%) and was highest in cloth bag (8.35%) after second month of storage. Similar trend was followed up to fourteen months of storage. Significantly minimum (8.73%) moisture was recorded in vacuum sealed container followed by polythene bag (9.39%) and was maximum (10.72%) in cloth bag after fourteen months of storage.

Due to interaction

Significant difference in moisture content was observed from 9th month up to end of storage period due to interactions of seed treatments and containers (T×C). The moisture content was lower (8.70%) in $T_{10}C_3$ and highest in $T_{11}C_1$ (8.96%) after the ninth month of storage. Similar trend was followed in all the month of storage. The lower (8.51%) moisture content was recorded in $T_{10}C_3$ and higher (11.40%) in $T_{11}C_1$ at the end of 14 months of storage.

4.1.9 Seed infection (%)

The results of seed infection as influenced by treatments and containers and their interactions are presented in Table 10.

Due to treatments

There was significant difference in seed treatments after third month to 14th month of storage on seed infection. The seeds treated with thiram recorded lowest (0% and 4.90%) infection followed by arappu (0% and 6.42%), neem (0.01% and 6.42%), sweet flag (0.01% and 7.75%) and wood ash (0.02% to 7.75%) and was highest in control (0.70% and 8.38%) at the third and fourteen month of storage period respectively.

Table 9. Moisture content (%) as influenced by treatments, containers and their interactions effect during storage of maize hybrid cv. Arjun

Treatments	Months after storage															
	3rd month				4th month				5th month				6th month			
	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean
T_1	8.30	8.27	8.24	**8.27**	8.27	8.20	8.18	**8.22**	9.52	8.40	8.27	**8.73**	10.13	8.55	8.36	**9.01**
T_2	8.39	8.38	8.34	**8.37**	8.49	8.33	8.28	**8.37**	9.99	8.58	8.41	**8.99**	10.60	8.76	8.50	**9.29**
T_3	8.32	8.30	8.32	**8.31**	8.59	8.29	8.30	**8.39**	9.84	8.51	8.39	**8.91**	10.45	8.68	8.48	**9.20**
T_4	8.38	8.35	8.34	**8.36**	8.62	8.31	8.31	**8.41**	9.87	8.50	8.40	**8.92**	10.48	8.71	8.49	**9.23**
T_5	8.32	8.28	8.32	**8.31**	8.53	8.26	8.27	**8.35**	9.78	8.49	8.36	**8.88**	10.39	8.63	8.45	**9.16**
T_6	8.36	8.34	8.26	**8.32**	8.26	8.23	8.20	**8.23**	9.51	8.44	8.29	**8.75**	10.12	8.56	8.38	**9.02**
T_7	8.30	8.29	8.23	**8.27**	8.23	8.19	8.17	**8.20**	9.48	8.37	8.26	**8.70**	10.09	8.50	8.35	**8.98**
T_8	8.37	8.34	8.33	**8.35**	8.64	8.31	8.37	**8.44**	9.89	8.55	8.46	**8.97**	10.50	8.73	8.55	**9.26**
T_9	8.33	8.29	8.29	**8.30**	8.43	8.24	8.23	**8.30**	9.75	8.48	8.32	**8.85**	10.36	8.60	8.41	**9.12**
T_{10}	8.31	8.23	8.13	**8.22**	8.21	8.10	8.13	**8.15**	9.46	8.33	8.22	**8.67**	10.07	8.48	8.31	**8.95**
T_{11}	8.46	8.41	8.39	**8.42**	8.45	8.35	8.33	**8.38**	9.95	8.61	8.48	**9.01**	10.56	8.79	8.57	**9.31**
Mean	**8.35**	**8.32**	**8.29**	8.32	**8.43**	**8.26**	**8.25**	8.31	**9.73**	**8.48**	**8.35**	8.85	**10.34**	**8.64**	**8.44**	9.14
For comparing means of	S.Em±		CD at 1%		S.Em±		CD at 1%		S.Em±		CD at 1%		S.Em±		CD at 1%	
Treatments (T)	0.03		NS		**0.03**		**0.10**		0.03		0.11		0.03		0.11	
Containers (C)	0.05		NS		**0.05**		**0.18**		0.06		0.21		0.06		0.22	
Interaction (T×C)	0.09		NS		0.09		NS		0.10		NS		0.10		NS	

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Treatments	Months after storage															
	7th month				8th month				9th month				10th month			
	C_1	C_2	C_3	**Mean**	C_1	C_2	C_3	**Mean**	C_1	C_2	C_3	**Mean**	C_1	C_2	C_3	**Mean**
T_1	10.25	8.81	8.50	**9.19**	10.37	8.95	8.64	**9.32**	10.45	9.23	8.73	**9.47**	10.30	9.14	8.67	**9.37**
T_2	10.82	9.04	8.64	**9.50**	11.07	9.41	8.78	**9.75**	11.30	9.67	8.89	**9.95**	11.15	9.41	8.83	**9.80**
T_3	10.69	8.91	8.62	**9.41**	10.94	9.28	8.76	**9.66**	11.17	9.54	8.87	**9.86**	11.02	9.30	8.81	**9.71**
T_4	10.73	8.94	8.63	**9.43**	10.98	9.33	8.77	**9.69**	11.21	9.59	8.88	**9.89**	11.06	9.35	8.82	**9.75**
T_5	10.64	8.90	8.59	**9.38**	10.89	9.24	8.73	**9.62**	11.12	9.45	8.84	**9.80**	10.97	9.24	8.78	**9.66**
T_6	10.37	8.86	8.52	**9.25**	10.62	9.00	8.66	**9.43**	10.85	9.34	8.76	**9.65**	10.70	9.19	8.70	**9.53**
T_7	10.19	8.75	8.49	**9.14**	10.32	8.86	8.63	**9.27**	10.37	9.19	8.71	**9.42**	10.24	9.11	8.65	**9.33**
T_8	10.75	8.98	8.69	**9.47**	11.00	9.38	8.83	**9.74**	11.24	9.62	8.94	**9.93**	11.09	9.38	8.88	**9.78**
T_9	10.61	8.87	8.55	**9.34**	10.86	9.14	8.69	**9.56**	11.10	9.39	8.80	**9.76**	10.95	9.20	8.74	**9.63**
T_{10}	10.16	8.68	8.45	**9.10**	10.27	8.80	8.59	**9.22**	10.32	9.12	8.70	**9.38**	10.22	9.05	8.64	**9.30**
T_{11}	10.99	9.16	8.71	**9.62**	11.44	9.45	8.85	**9.91**	11.74	9.75	8.96	**10.15**	11.57	9.43	8.90	**9.97**
Mean	**10.56**	**8.90**	**8.58**	**9.35**	**10.80**	**9.17**	**8.72**	**9.56**	**10.99**	**9.45**	**8.83**	**9.75**	**10.84**	**9.26**	**8.77**	**9.62**
For comparing means of	S.Em±		CD at 1%		S.Em±		CD at 1%		S.Em±		CD at 1%		S.Em±		CD at 1%	
Treatments (T)	0.03		0.10		0.03		0.11		0.03		0.11		0.03		0.10	
Containers (C)	0.06		0.22		0.06		0.23		0.06		0.23		0.06		0.22	
Interaction (T×C)	0.10		NS		0.11		NS		**0.11**		**0.40**		0.11		0.41	

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Treatments	Months after storage															
	11th month				12th month				13th month				14th month			
	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean
T_1	10.20	8.76	8.60	**9.19**	10.04	8.76	8.42	**9.07**	10.12	9.15	8.52	**9.26**	10.23	9.28	8.62	**9.38**
T_2	11.00	9.11	8.78	**9.63**	10.78	9.11	8.58	**9.49**	10.89	9.36	8.68	**9.64**	11.00	9.52	8.86	**9.79**
T_3	10.87	9.13	8.76	**9.59**	10.65	9.13	8.56	**9.45**	10.76	9.29	8.66	**9.57**	10.87	9.43	8.77	**9.69**
T_4	10.91	9.18	8.77	**9.62**	10.69	9.18	8.57	**9.48**	10.80	9.30	8.67	**9.59**	10.91	9.47	8.81	**9.73**
T_5	10.82	9.03	8.73	**9.53**	10.60	9.03	8.53	**9.39**	10.71	9.26	8.63	**9.53**	10.82	9.38	8.72	**9.64**
T_6	10.55	8.87	8.65	**9.36**	10.33	8.87	8.45	**9.22**	10.44	9.18	8.55	**9.39**	10.55	9.31	8.65	**9.50**
T_7	10.14	8.71	8.56	**9.14**	10.04	8.71	8.40	**9.05**	10.09	9.13	8.50	**9.24**	10.20	9.22	8.56	**9.33**
T_8	10.94	9.07	8.83	**9.61**	10.72	9.07	8.63	**9.47**	10.83	9.36	8.73	**9.64**	10.94	9.50	8.84	**9.76**
T_9	10.80	8.96	8.69	**9.48**	10.58	8.96	8.49	**9.34**	10.69	9.22	8.59	**9.50**	10.80	9.36	8.70	**9.62**
T_{10}	10.12	8.68	8.50	**9.10**	10.02	8.68	8.39	**9.02**	10.07	9.00	8.49	**9.19**	10.18	9.17	8.51	**9.29**
T_{11}	11.40	9.15	8.85	**9.80**	11.18	9.15	8.65	**9.66**	11.29	9.38	8.75	**9.81**	11.40	9.61	8.95	**9.99**
Mean	**10.71**	**8.97**	**8.70**	**9.46**	**10.51**	**8.97**	**8.52**	**9.32**	**10.61**	**9.24**	**8.62**	**9.49**	**10.72**	**9.39**	**8.73**	**9.61**
For comparing means of	S.Em±		CD at 1%		S.Em±		CD at 1%		S.Em±		CD at 1%		S.Em±		CD at 1%	
Treatments (T)	0.03		0.10		0.03		0.11		0.03		0.11		0.03		0.10	
Containers (C)	0.06		0.22		0.06		0.22		0.06		0.21		0.05		0.19	
Interaction (T×C)	0.11		0.40		0.10		0.37		0.10		0.36		0.09		0.33	

NS - Non significant

.**Botanicals (T)**

.T_1 : Neem leaf powder @ 10g/kg seed
T_2 : Castor leaf powder @ 10g/kg seed
T_3 : Pongamia leaf powder @ 10g/kg seed
T_4 : Tulsi leaf powder @ 10g/kg seed
T_5 : Mandrin peal powder @ 10g/kg seed
T_6 : Bhajje powder @ 10g/kg seed
T_7 : Arappu powder @ 10g/kg seed
T_8 : Parthenium@ 10g/kg seed
T_9 : Wood ash @ 10g/kg seed
T_{10} : Thiram@ 2g/kg seed
T_{11} : Control

Containers (C)

C_1 : Cloth bag
C_2 : Polyethylene bag
C_3 : Vacuum packaging

Table 10. Seed infection (%) as influenced by treatments, containers and their interactions effect during storage of maize hybrid cv. Arjun

Treatments	Months after storage															
	3rd month				4th month				5th month				6th month			
	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean
T_1	0.02	0.00	0.00	**0.01**	0.63	0.23	0.00	**0.29**	2.63	1.73	0.84	**1.73**	3.63	2.63	0.99	**2.42**
T_2	0.48	0.45	0.24	**0.39**	1.36	0.96	0.56	**0.96**	3.36	2.46	1.40	**2.41**	4.66	3.36	1.55	**3.19**
T_3	0.05	0.02	0.00	**0.02**	0.93	0.53	0.34	**0.60**	2.93	2.03	1.18	**2.05**	3.93	2.93	1.33	**2.73**
T_4	0.07	0.04	0.01	**0.04**	1.04	0.64	0.38	**0.69**	3.04	2.14	1.22	**2.13**	4.04	3.04	1.37	**2.82**
T_5	0.10	0.07	0.04	**0.07**	0.87	0.47	0.27	**0.54**	2.87	1.97	1.11	**1.98**	3.87	2.87	1.26	**2.67**
T_6	0.03	0.00	0.00	**0.01**	0.76	0.36	0.12	**0.41**	2.76	1.86	0.96	**1.86**	3.76	2.76	1.11	**2.54**
T_7	0.01	0.00	0.00	**0.00**	0.48	0.08	0.00	**0.19**	2.48	1.58	0.77	**1.61**	3.48	2.48	0.82	**2.26**
T_8	0.15	0.12	0.09	**0.12**	1.13	0.73	0.43	**0.76**	3.13	2.23	1.27	**2.21**	4.13	3.13	1.42	**2.89**
T_9	0.05	0.02	0.00	**0.02**	0.82	0.42	0.22	**0.49**	2.82	1.92	1.06	**1.93**	3.82	2.82	1.21	**2.62**
T_{10}	0.04	0.00	0.00	**0.01**	0.40	0.00	0.00	**0.13**	2.40	1.50	0.00	**1.30**	3.40	2.40	0.00	**1.93**
T_{11}	0.95	0.92	0.22	**0.70**	1.69	0.99	0.29	**0.99**	3.69	2.49	1.13	**2.44**	5.69	3.39	1.28	**3.45**
Mean	**0.18**	**0.15**	**0.05**	**0.13**	**0.92**	**0.49**	**0.24**	**0.55**	**2.92**	**1.99**	**0.99**	**1.97**	**4.04**	**2.89**	**1.12**	**2.68**
For comparing means of	S.Em±		CD at 1%		S.Em±		CD at 1%		S.Em±		CD at 1%		S.Em±		CD at 1%	
Treatments (T)	0.00		0.01		0.00		0.02		0.01		0.03		0.02		0.07	
Containers (C)	0.00		0.00		0.00		0.01		0.01		0.03		0.01		0.03	
Interaction(T×C)	0.00		0.01		0.01		0.03		0.02		0.07		0.03		0.09	

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Treatments	Months after storage															
	7th month				8th month				9th month				10th month			
	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean
T_1	4.93	3.13	0.10	2.72	5.63	3.33	1.30	3.42	6.13	4.23	1.90	4.09	6.63	5.73	2.50	4.95
T_2	6.36	3.86	0.66	3.63	7.36	5.26	1.86	4.83	8.26	6.16	2.46	5.63	8.66	7.96	3.06	6.56
T_3	5.23	3.43	0.44	3.03	5.93	4.53	1.64	4.03	7.13	5.53	2.24	4.97	7.83	6.53	2.84	5.73
T_4	5.34	3.54	0.48	3.12	6.04	4.64	1.68	4.12	7.24	5.64	2.28	5.05	7.94	6.64	2.88	5.82
T_5	5.17	3.37	0.37	2.97	5.87	4.47	1.57	3.97	7.07	5.47	2.17	4.90	7.77	6.47	2.77	5.67
T_6	5.06	3.26	0.22	2.85	5.76	4.36	1.42	3.85	6.96	5.36	2.02	4.78	7.66	6.36	2.62	5.55
T_7	4.78	2.98	0.10	2.62	5.48	3.18	0.99	3.22	5.48	5.08	1.30	3.95	6.08	5.38	2.50	4.65
T_8	5.43	3.63	0.53	3.20	6.13	4.73	1.73	4.20	7.33	5.73	2.33	5.13	8.03	6.73	2.93	5.90
T_9	5.12	3.32	0.32	2.92	5.82	4.42	1.52	3.92	7.02	5.42	2.12	4.85	7.72	6.42	2.72	5.62
T_{10}	4.70	2.90	0.00	2.53	5.00	3.10	0.00	2.70	5.40	4.00	0.03	3.14	5.60	4.50	0.63	3.58
T_{11}	7.19	3.89	0.39	3.82	7.89	6.29	2.29	5.49	8.69	7.19	3.29	6.39	9.69	7.99	3.79	7.16
Mean	5.39	3.39	0.33	3.04	6.08	4.39	1.45	3.98	6.97	5.44	2.01	4.81	7.60	6.43	2.66	5.56
For comparing means of	S.Em±		CD at 1%		S.Em±		CD at 1%		S.Em±		CD at 1%		S.Em±		CD at 1%	
Treatments (T)	0.01		0.03		0.01		0.03		0.02		0.07		0.02		0.07	
Containers (C)	0.02		0.07		0.03		0.10		0.03		0.09		0.04		0.14	
Interaction (T×C)	0.04		0.15		0.05		0.19		0.06		0.22		0.07		0.24	

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Treatments	Months after storage															
	11th month				**12th month**				**13th month**				**14th month**			
	C_1	**C_2**	**C_3**	**Mean**	**C_1**	**C_2**	**C_3**	**Mean**	**C_1**	**C_2**	**C_3**	**Mean**	**C_1**	**C_2**	**C_3**	**Mean**
T_1	7.13	6.23	3.20	5.52	7.63	6.73	3.62	5.99	8.33	6.83	4.00	6.39	8.73	7.13	4.60	6.82
T_2	9.26	8.96	3.56	7.26	10.16	9.66	4.76	8.19	9.86	9.46	5.16	8.16	9.96	9.46	5.46	8.29
T_3	8.43	7.03	3.34	6.27	8.93	7.53	4.54	7.00	9.63	8.33	4.94	7.63	9.83	8.73	5.24	7.93
T_4	8.54	7.14	3.38	6.35	9.04	7.64	4.58	7.09	9.74	8.44	4.98	7.72	9.94	8.84	5.28	8.02
T_5	8.37	6.97	3.27	6.20	8.87	7.47	4.47	6.94	9.57	8.27	4.87	7.57	9.77	8.67	5.17	7.87
T_6	8.26	6.86	3.12	6.08	8.76	7.36	4.32	6.81	9.46	8.16	4.72	7.45	9.66	8.56	5.02	7.75
T_7	6.48	5.98	2.93	5.13	7.28	6.38	3.20	5.62	7.78	6.68	3.60	6.02	8.38	6.98	3.90	6.42
T_8	8.63	7.23	3.43	6.43	9.13	7.73	4.63	7.16	9.83	8.53	5.03	7.80	9.93	8.93	5.33	8.06
T_9	8.32	6.92	3.22	6.15	8.82	7.42	4.42	6.89	9.52	8.22	4.82	7.52	9.52	8.62	5.12	7.75
T_{10}	6.20	5.00	0.87	4.02	6.70	5.63	0.93	4.42	7.04	6.00	1.00	4.68	7.20	6.50	1.00	4.90
T_{11}	9.69	8.99	4.28	7.65	10.99	9.89	4.28	8.39	10.00	9.69	4.69	8.13	10.00	9.94	5.19	8.38
Mean	8.12	7.03	3.15	6.10	8.76	7.59	3.98	6.77	9.16	8.06	4.35	7.19	9.36	8.40	4.67	7.47
For comparing means of	S.Em±		CD at 1%		S.Em±		CD at 1%		S.Em±		CD at 1%		S.Em±		CD at 1%	
Treatments (T)	0.02		0.06		0.02		0.07		0.02		0.07		0.03		0.10	
Containers (C)	0.04		0.12		0.05		0.17		0.05		0.18		0.05		0.18	
Interaction (T×C)	0.07		0.20		0.08		0.29		0.08		0.30		0.09		0.32	

NS - Non significant

.Botanicals (T)

.T_1 : Neem leaf powder @ 10g/kg seed
T_2 : Castor leaf powder @ 10g/kg seed
T_3 : Pongamia leaf powder @ 10g/kg seed
T_4 : Tulsi leaf powder @ 10g/kg seed
T_5 : Mandrin peal powder @ 10g/kg seed
T_6 : Bhajje powder @ 10g/kg seed
T_7 : Arappu powder @ 10g/kg seed
T_8 : Parthenium@ 10g/kg seed
T_9 : Wood ash @ 10g/kg seed
T_{10} : Thiram@ 2g/kg seed
T_{11} : Control

Containers (C)

C_1 : Cloth bag
C_2 : Polyethylene bag
C_3 : Vacuum packaging

Table 11. Insect damage (%) as influenced by treatments, containers and their interactions effect during storage of maize hybrid cv. Arjun

.Treatments	Months after storage															
	3rd month				4th month				5th month				6th month			
	C_1	C_2	C_3	**Mean**	C_1	C_2	C_3	**Mean**	C_1	C_2	C_3	**Mean**	C_1	C_2	C_3	**Mean**
T_1	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	**0.00 (0.00)**	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	**0.00 (0.00)**	0.15 (2.22)	0.00 (0.00)	0.00 (0.00)	**0.05 (0.74)**	0.62 (4.52)	0.02 (0.81)	0.00 (0.00)	**0.21 (1.78)**
T_2	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	**0.00 (0.00)**	0.11 (1.90)	0.00 (0.00)	0.00 (0.00)	**0.04 (0.63)**	1.38 (6.75)	0.11 (1.90)	0.00 (0.00)	**0.50 (2.88)**	5.38 (13.41)	2.38 (8.87)	0.00 (0.00)	**2.59 (7.43)**
T_3	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	**0.00 (0.00)**	0.04 (1.15)	0.00 (0.00)	0.00 (0.00)	**0.01 (0.38)**	1.02 (5.80)	0.04 (1.15)	0.00 (0.00)	**0.35 (2.31)**	2.33 (8.78)	1.33 (6.62)	0.00 (0.00)	**1.22 (5.13)**
T_4	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	**0.00 (0.00)**	0.05 (1.28)	0.00 (0.00)	0.00 (0.00)	**0.02 (0.43)**	1.21 (6.32)	0.05 (1.28)	0.00 (0.00)	**0.42 (2.53)**	2.52 (9.13)	1.52 (7.08)	0.00 (0.00)	**1.35 (5.41)**
T_5	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	**0.00 (0.00)**	0.04 (1.15)	0.00 (0.00)	0.00 (0.00)	**0.01 (0.38)**	0.67 (4.70)	0.04 (1.15)	0.00 (0.00)	**0.24 (1.95)**	1.98 (8.09)	0.98 (5.68)	0.00 (0.00)	**0.99 (4.59)**
T_6	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	**0.00 (0.00)**	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	**0.00 (0.00)**	0.10 (1.81)	0.00 (0.00)	0.00 (0.00)	**0.03 (0.60)**	0.54 (4.21)	0.00 (0.00)	0.00 (0.00)	**0.18 (1.40)**
T_7	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	**0.00 (0.00)**	0.02 (0.81)	0.00 (0.00)	0.00 (0.00)	**0.01 (0.27)**	0.21 (2.63)	0.02 (0.81)	0.00 (0.00)	**0.08 (1.15)**	0.86 (5.32)	0.08 (1.62)	0.00 (0.00)	**0.31 (2.31)**
T_8	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	**0.00 (0.00)**	0.05 (1.28)	0.00 (0.00)	0.00 (0.00)	**0.02 (0.43)**	1.91 (7.94)	0.05 (1.28)	0.00 (0.00)	**0.65 (3.08)**	3.22 (10.34)	2.22 (8.57)	0.00 (0.00)	**1.81 (6.30)**
T_9	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	**0.00 (0.00)**	0.04 (1.15)	0.00 (0.00)	0.00 (0.00)	**0.01 (0.38)**	1.14 (6.13)	0.04 (1.15)	0.00 (0.00)	**0.39 (2.43)**	1.18 (6.24)	1.11 (6.05)	0.00 (0.00)	**0.76 (4.09)**
T_{10}	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	**0.00 (0.00)**	0.03 (0.99)	0.00 (0.00)	0.00 (0.00)	**0.01 (0.33)**	0.25 (2.87)	0.03 (0.99)	0.00 (0.00)	**0.09 (1.29)**	0.95 (5.59)	0.11 (1.90)	0.00 (0.00)	**0.35 (2.50)**
T_{11}	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	**0.00 (0.00)**	0.91 (5.47)	0.00 (0.00)	0.00 (0.00)	**0.30 (1.82)**	2.61 (9.30)	1.53 (7.11)	0.00 (0.00)	**1.38 (5.47)**	6.61 (14.90)	3.61 (10.95)	0.00 (0.00)	**3.41 (8.62)**
Mean	**0.00 (0.00)**	**0.00 (0.00)**	**0.00 (0.00)**	0.00 (0.00)	**0.12 (1.38)**	**0.00 (0.00)**	**0.00 (0.00)**	0.04 (0.46)	**0.97 (5.13)**	**0.17 (1.53)**	**0.00 (0.00)**	0.38 (2.22)	**0.86 (8.23)**	**0.08 (5.29)**	**0.00 (0.00)**	0.31 (4.51)
For comparing means of	S.Em±		CD at 1%		S.Em±		CD at 1%		S.Em±		CD at 1%		S.Em±		CD at 1%	
Treatments (T)	0.00		NS		**0.00**		**0.01**		0.01		0.03		0.01		0.03	
Containers (C)	0.00		NS		**0.00**		**0.01**		0.01		0.02		0.02		0.07	
Interaction (T×C)	0.00		NS		**0.01**		**0.02**		0.02		0.07		0.03		0.11	

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Treatments	Months after storage															
	7th month				8th month				9th month				10th month			
	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean	C_1	C_2	C_3	Mean
T_1	0.93 (5.53)	0.20 (2.56)	0.00 (0.00)	**0.38 (2.70)**	1.93 (7.99)	0.40 (3.63)	0.00 (0.00)	**0.78 (3.87)**	3.36 (10.56)	0.85 (5.29)	0.00 (0.00)	**1.40 (5.28)**	5.36 (13.39)	1.30 (6.55)	0.00 (0.00)	**2.22 (6.64)**
T_2	2.66 (9.39)	3.18 (10.27)	0.00 (0.00)	**1.95 (6.55)**	10.66 (19.06)	3.78 (11.21)	0.00 (0.00)	**4.81 (10.09)**	18.66 (25.59)	4.38 (12.08)	0.00 (0.00)	**7.68 (12.56)**	24.20 (29.47)	4.98 (12.89)	0.00 (0.00)	**9.73 (14.12)**
T_3	6.12 (14.32)	2.13 (8.39)	0.00 (0.00)	**2.75 (7.57)**	7.12 (15.48)	2.73 (9.51)	0.00 (0.00)	**3.28 (8.33)**	10.12 (18.55)	10.12 (10.51)	0.00 (0.00)	**4.48 (9.69)**	16.12 (23.67)	3.93 (11.43)	0.00 (0.00)	**6.68 (11.70)**
T_4	7.84 (16.26)	2.32 (8.76)	0.00 (0.00)	**3.39 (8.34)**	8.84 (17.30)	2.92 (9.84)	0.00 (0.00)	**3.92 (9.05)**	11.84 (20.13)	3.52 (10.81)	0.00 (0.00)	**5.12 (10.31)**	17.84 (24.99)	4.12 (11.71)	0.00 (0.00)	**7.32 (12.23)**
T_5	5.86 (14.01)	1.78 (7.67)	0.00 (0.00)	**2.55 (7.23)**	6.86 (15.18)	2.38 (8.87)	0.00 (0.00)	**3.08 (8.02)**	7.36 (15.74)	2.98 (9.94)	0.00 (0.00)	**3.45 (8.56)**	13.36 (21.44)	3.58 (10.91)	0.00 (0.00)	**5.65 (10.78)**
T_6	0.41 (3.67)	0.03 (0.99)	0.00 (0.00)	**0.15 (1.55)**	1.41 (6.82)	0.21 (2.63)	0.00 (0.00)	**0.54 (3.15)**	2.78 (9.60)	0.66 (4.66)	0.00 (0.00)	**1.15 (4.75)**	4.78 (12.63)	1.11 (6.05)	0.00 (0.00)	**1.96 (6.23)**
T_7	2.58 (9.24)	0.26 (2.92)	0.00 (0.00)	**0.95 (4.06)**	4.98 (12.89)	0.46 (3.89)	0.00 (0.00)	**1.81 (5.59)**	5.98 (14.15)	1.06 (5.91)	0.00 (0.00)	**2.35 (6.69)**	7.98 (16.41)	1.66 (7.40)	0.00 (0.00)	**3.21 (7.94)**
T_8	8.68 (17.13)	3.02 (10.01)	0.00 (0.00)	**3.90 (9.05)**	9.68 (18.13)	3.52 (10.81)	0.00 (0.00)	**4.40 (9.65)**	11.68 (19.98)	4.02 (11.57)	0.00 (0.00)	**5.23 (10.52)**	18.18 (25.24)	4.52 (12.28)	0.00 (0.00)	**7.57 (12.50)**
T_9	4.44 (12.16)	1.91 (7.94)	0.00 (0.00)	**2.12 (6.70)**	6.44 (14.70)	0.00 (8.93)	0.00 (0.00)	**2.95 (7.88)**	7.92 (16.35)	2.91 (9.82)	0.00 (0.00)	**3.61 (8.72)**	10.22 (18.64)	3.41 (10.64)	0.00 (0.00)	**4.54 (9.76)**
T_{10}	3.56 (10.88)	0.36 (3.44)	0.00 (0.00)	**1.31 (4.77)**	5.76 (13.89)	0.56 (4.29)	0.00 (0.00)	**2.11 (6.06)**	6.76 (15.07)	1.16 (6.18)	0.00 (0.00)	**2.64 (7.08)**	8.76 (17.22)	1.76 (7.62)	0.00 (0.00)	**3.51 (8.28)**
T_{11}	6.56 (14.84)	5.23 (13.22)	0.00 (0.00)	**3.93 (9.35)**	13.56 (21.61)	5.73 (13.85)	0.00 (0.00)	**6.43 (11.82)**	20.56 (26.96)	6.23 (14.45)	0.00 (0.00)	**8.93 (13.81)**	27.88 (31.87)	6.73 (15.04)	0.00 (0.00)	**11.54 (15.64)**
Mean	**4.51 (11.59)**	**1.86 (6.93)**	**0.00 (0.00)**	**2.12 (6.17)**	**7.02 (14.82)**	**2.28 (7.95)**	**0.00 (0.00)**	**3.10 (7.59)**	**9.73 (17.52)**	**2.83 (9.20)**	**0.00 (0.00)**	**4.19 (8.91)**	**14.06 (21.36)**	**3.37 (10.23)**	**0.00 (0.00)**	**5.81 (10.53)**
For comparing means of	S.Em±		CD at 1%		S.Em±		CD at 1%		S.Em±		CD at 1%		S.Em±		CD at 1%	
Treatments (T)	0.01		0.03		0.02		0.06		0.02		0.06		0.02		0.07	
Containers (C)	0.03		0.10		0.03		0.10		0.04		0.13		0.05		0.18	
Interaction (T×C)	0.05		0.17		0.06		0.21		0.07		0.23		0.08		0.31	

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Treatments	Months after storage															
	11th month				12th month				13th month				14th month			
	C_1	C_2	C_3	**Mean**	C_1	C_2	C_3	**Mean**	C_1	C_2	C_3	**Mean**	C_1	C_2	C_3	**Mean**
T_1	10.36 (18.78)	1.80 (7.71)	0.00 (0.00)	**4.05 (8.83)**	15.36 (23.07)	2.30 (8.72)	0.00 (0.00)	**5.89 (10.60)**	20.36 (26.82)	2.65 (9.37)	0.00 (0.00)	**7.67 (12.06)**	23.68 (29.12)	3.00 (9.97)	0.00 (0.00)	**8.89 (13.03)**
T_2	29.74 (33.05)	5.48 (13.54)	0.00 (0.00)	**11.74 (15.53)**	34.74 (36.12)	5.98 (14.15)	0.00 (0.00)	**13.57 (16.76)**	39.74 (39.08)	6.38 (14.63)	0.00 (0.00)	**15.37 (17.90)**	43.37 (41.19)	6.78 (15.09)	0.00 (0.00)	**16.72 (18.76)**
T_3	22.12 (28.06)	4.43 (12.15)	0.00 (0.00)	**8.85 (13.40)**	27.12 (31.38)	4.93 (12.83)	0.00 (0.00)	**10.68 (14.74)**	32.12 (34.52)	5.33 (13.35)	0.00 (0.00)	**12.48 (15.96)**	35.56 (36.61)	5.73 (13.85)	0.00 (0.00)	**13.76 (16.82)**
T_4	23.84 (29.23)	4.62 (12.41)	0.00 (0.00)	**9.49 (13.88)**	28.84 (32.48)	5.12 (13.08)	0.00 (0.00)	**11.32 (15.19)**	33.84 (35.57)	5.52 (13.59)	0.00 (0.00)	**13.12 (16.39)**	37.42 (37.72)	5.92 (14.08)	0.00 (0.00)	**14.45 (17.27)**
T_5	19.36 (26.10)	4.08 (11.65)	0.00 (0.00)	**7.81 (12.59)**	24.36 (29.58)	4.58 (12.36)	0.00 (0.00)	**9.65 (13.98)**	29.36 (32.81)	4.98 (12.89)	0.00 (0.00)	**11.45 (15.24)**	32.68 (34.87)	5.38 (13.41)	0.00 (0.00)	**12.69 (16.09)**
T_6	9.78 (18.22)	1.61 (7.29)	0.00 (0.00)	**3.80 (8.50)**	14.78 (22.61)	2.11 (8.35)	0.00 (0.00)	**5.63 (10.32)**	19.78 (26.41)	2.51 (9.12)	0.00 (0.00)	**7.43 (11.84)**	21.89 (27.90)	2.91 (9.82)	0.00 (0.00)	**8.27 (12.57)**
T_7	13.98 (21.96)	2.16 (8.45)	0.00 (0.00)	**5.38 (10.14)**	18.98 (25.83)	2.66 (9.39)	0.00 (0.00)	**7.21 (11.74)**	23.98 (29.32)	3.03 (10.02)	0.00 (0.00)	**9.00 (13.12)**	27.49 (31.62)	3.40 (10.63)	0.00 (0.00)	**10.30 (14.08)**
T_8	24.68 (29.79)	5.02 (12.95)	0.00 (0.00)	**9.90 (14.25)**	29.68 (33.01)	5.52 (13.59)	0.00 (0.00)	**11.73 (15.53)**	34.68 (36.08)	5.92 (14.08)	0.00 (0.00)	**13.53 (16.72)**	38.34 (38.26)	6.32 (14.56)	0.00 (0.00)	**14.89 (17.61)**
T_9	16.72 (24.14)	3.91 (11.40)	0.00 (0.00)	**6.88 (11.85)**	21.72 (27.78)	4.41 (12.12)	0.00 (0.00)	**8.71 (13.30)**	26.72 (31.13)	4.81 (12.67)	0.00 (0.00)	**10.51 (14.60)**	30.36 (33.44)	5.21 (13.19)	0.00 (0.00)	**11.86 (15.54)**
T_{10}	14.76 (22.59)	2.26 (8.65)	0.00 (0.00)	**5.67 (10.41)**	19.76 (26.39)	2.76 (9.56)	0.00 (0.00)	**7.51 (11.99)**	24.76 (29.84)	3.16 (10.24)	0.00 (0.00)	**9.31 (13.36)**	28.38 (32.19)	3.56 (10.88)	0.00 (0.00)	**10.65 (14.36)**
T_{11}	35.20 (36.39)	7.23 (15.60)	0.00 (0.00)	**14.14 (17.33)**	42.20 (40.51)	7.73 (16.14)	0.00 (0.00)	**16.65 (18.89)**	49.21 (44.54)	8.13 (16.57)	0.00 (0.00)	**19.11 (20.37)**	54.11 (47.36)	8.53 (16.98)	0.00 (0.00)	**20.88 (21.45)**
Mean	**20.05 (26.21)**	**3.87 (11.07)**	**0.00 (0.00)**	**7.97 (12.43)**	**25.23 (29.89)**	**4.37 (11.85)**	**0.00 (0.00)**	**9.87 (13.91)**	**30.42 (33.28)**	**4.77 (12.41)**	**0.00 (0.00)**	**11.73 (15.23)**	**33.94 (35.48)**	**5.16 (12.95)**	**0.00 (0.00)**	**13.03 (16.14)**
For comparing means of	S.Em±		CD at 1%		S.Em±		CD at 1%		S.Em±		CD at 1%		S.Em±		CD at 1%	
Treatments (T)	0.03		0.10		0.03		0.11		0.04		0.14		0.04		0.15	
Containers (C)	0.06		0.20		0.07		0.25		0.07		0.26		0.08		0.30	
Interaction (T×C)	0.10		0.37		0.11		0.42		0.13		0.48		0.14		0.52	

NS - Non significant

*Figures in the parenthesis are arcsined transformed values

.**Botanicals (T)**

.T_1 : Neem leaf powder @ 10g/kg seed
T_2 : Castor leaf powder @ 10g/kg seed
T_3 : Pongamia leaf powder @ 10g/kg seed
T_4 : Tulsi leaf powder @ 10g/kg seed
T_5 : Mandrin peal powder @ 10g/kg seed
T_6 : Bhajje powder @ 10g/kg seed
T_7 : Arappu powder @ 10g/kg seed
T_8 : Parthenium@ 10g/kg seed
T_9 : Wood ash @ 10g/kg seed
T_{10} : Thiram@ 2g/kg seed
T_{11} : Control

Containers (C)

C_1 : Cloth bag
C_2 : Polyethylene bag
C_3 : Vacuum packaging

Due to containers

Seed infection statistically differed significantly from initial month to end of storage due to containers. Significantly lowest (0.05 to 4.67%) and highest (0.18 to 9.36%) seed infection was recorded in vacuum and cloth bag respectively at 3^{rd} and 14^{th} month of storage.

Due to interactions

The interactions between seed treatments and containers recorded statistical differences on seed infection in all the months of storage. Significantly highest seed infection was recorded in $T_{11}C_1$ (0.95 and 10%) followed by T_2C_1 (0.48 and 9.96%), T_8C_1 (0.15 and 9.93%) and no infection was seen in $T_{10}C_3$ (0.00%) at third and fourteen months of storage period.

4.1.10 Insect damage (%)

The results of insect damage as influenced by treatments and containers and their interactions are and presented in Table 11.

Due to treatments

There was significant difference in treatments after fourth month to fourteen month of storage on seed infestation. The seeds treated with sweet flag (8.27%) recorded lowest pest damage followed by neem (8.89%), arappu (10.30%), thiram (10.65%) and highest was in control (20.88%) at the end of fourteen months of storage period.

Due to containers

Seed infestations statistically differed from initial month to end of storage due to containers. Significantly lowest (5.16%) and highest (33.94%) seed infestation was recorded in polythene and cloth bag respectively and there was no infestation were observed in vacuum throughout the month of storage.

Due to interactions

The interaction between seed treatments and containers recorded statistical difference on seed infestation in all the months of storage. Significantly highest seed infestation was recorded in $T_{11}C_1$ (54.11%) followed by T_2C_1 (43.37%), T_8C_1 (38.34%) and there was no infestation were observed in all the seed treatments stored in vacuum package.

V. DISCUSSION

Maize belongs to poaceae family and is one of the major food and industrial crops of the world. Indian economy continued to receive great support through this commercial crop known as “The king of crops” worldwide. The quality of seed is at its highest when it completes structural and functional development and attains physiological maturity on plant itself. Thereafter, it deteriorates inevitably, irreparably and irreversibly at varying rates (Delouche, 1973). Seed storage has become the most integral part of seed production programme as the seeds are to be protected and saved until next planting seasons. Hence, the “seed saved is seed produced'' an old adage holds good even today. Since agriculture is season bound, the storage of seeds has become inevitable for a farmer, seed producer and breeder as the case may be it is a quite ubiquitous natural phenomenon that the seed being living entity looses its viability and vigour under storage as any biological unit due to many subtle detrimental changes such as physico-chemical changes, faulty metabolism and accumulation of cytotoxic aldehydes (Tappel, 1973 and Wilson and Mc Donald, 1986) besides biotic and abiotic factors during storage. However, seed deterioration could be slowed down to some extent by treating them with certain fungicides, pesticides, chemicals and botanicals which are known to alleviate seed deterioration during storage and to extend storage life of seed (Basu, 1993).

The information on influence of plant products on storability of maize seed is meagre. Therefore, the present study was initiated by treating seeds with 10 seed protectants (botanicals) and stored in three different containers namely cloth bag, polythene bag (700 gauge) and vacuum sealed containers for 14 months from January 2011 to January 2012 under ambient storage conditions at the Department of Seed Science and Technology, College of Agriculture, University of Agricultural Sciences, Dharwad.

The required quantity of seed samples were randomly drawn for taking monthly observations on germination percentage, field emergence, root length, shoot length, vigour index, seedling dry weight, electrical conductivity of seed leachate, seed moisture content, seed health and insect damage and the results of the study are discussed in this chapter.

Influence of storage period

Most of the earlier storage studies in several crops have indicated that seeds age deteriorate with the advance in storage period resulting in gradual decline in seed quality traits and finally result in death of seeds. The influence of storage environment on storage potential has been documented by Roberts (1972b) and Roberts and Ellis (1980).

Results of the present study revealed that there was a gradual decline in seed quality traits such as germination percentage, field emergence, root length, shoot length, vigour index, seedling dry weight, moisture content and marked increase in electrical conductivity of seed leachate during entire storage period (Table 2, 3, 4, 5, 6, 7, 9 and 8) with significant increase in the percentage of pest and disease incidences from initial to 14 months period. Similar findings were also reported in maize (Kurdikeri, 1991 and Hanegave, 2009), in rice (Yogalakshmi *et al*., 1996), in pearlmillet (Ashok Gaur *et al.,* 2000), in sorghum (Savitri, *et al.,* 1994; Sunilkumar *et al*., 2005; Jadhav, 2006; Navi *et al*., 2006 and Kudchi and Balekai, 2009), in sobyean (Deshpande *et al*., 2010) and in bengalgram (Vimala and Pushpamma, 1983; Merwade, 2000 and Kulkarni *et al*., 2008).

Influence of seed treatments

The seed deterioration and death of seed is a ubiquitous phenomenon in all living things which is inevitable, irreversible and inexorable and variable among kinds of seeds, varieties and seed lots (Delouche, 1973). The mechanism of seed deterioration which is the final stage of ageing process is still an enigma.

However, the rate of seed deterioration could be slowed down to some extent by certain seed treatments with chemical, growth regulators, botanicals etc. (Basu, 1993). The loss of seed viability judged by per cent germination is the last phase of physiological manifestation of decline in seed quality during storage.

In the present study, maize seeds treated with different botanicals and stored in different packaging materials for 14 months. The results of the present study revealed that the mean germination gradually decreased from 97.91 per cent at initial month to 80.92 per cent at 14 months of storage irrespective of seed treatments and containers. Germination percentage differed significantly due to different seed treatments from 6th month onwards to till the end of the 14 months of storage (Table 2, fig 1). Among the seed treatments, the seeds treated with thiram maintained higher (98.50 to 90.33%) followed by arappu (98.25 to 88.00%), neem (98.42 to 86.67%), sweet flag (98.17 to 86.00%) and wood ash (97.67 to 82.67%) germination after initial month to 14 months of storage respectively. The beneficial response on germination noticed with thiram seed treatment is mainly due to its antifungal property against storage fungi. The present results are in close agreement with the reports of Agrawal (1974), Stankovic (1984), Moreno-Martinez and Ramirez (1985), Kurdikeri (1991), Paul and Mishra (1994) and Hanegave, (2009) in maize.

Now a day's botanicals are widely used in place of fungicides and pesticides for seed treatment to protect seeds against pests and diseases during storage. Botanicals contain complex bioactive phytochemicals with synergistic/potentiating interactions and have insecticidal, fungicidal, repellent, fumigating and other properties (Jilani *et al*., 1988; Tripathi *et al*., 2003; Krishnamurthy and Shashikala, 2006; Asawalam *et al*., 2008; Samuel *et al*., 2008; Srivastav and Kalman 2008; Sohail and Naima, 2009 and Ntonifor *et al*., 2011). Further, botanicals are known to induce reduction of lipid peroxidation and changes in biochemical activities and increase free sugars during germination (Khan *et al*., 1996), besides antioxidant property (Sundareswaran *et al*., 2003).

Higher germination noticed with arappu may be related to presence of auxin like substance "Saponin" which acts as a precursor of gibberelic acid a potent promoter of α-amylase enzyme in starchy seed. Arappu also contains physiological and bioactive substances which interact synergistically with amino acids especially tryptophan to form IAA (indole acetic acid), activation of embryo and germination of seeds (Krishnasamy and Basaria Begam, 2003; Krishnasamy, 2003).

Similarly beneficial influence of neem seed treatment on germination observed may be ascribed to presence of chemical compounds such as nimolicinol, isolimolicinolide, azadirachtin, azadirachtol, nimlinone, nimbocinol, nimbocinone, nimocin etc. (Tewari, 1992) which resulted in lesser insect damage as noticed in the present study. Neem is also reported to contain "gedunin" compound having antifungal property (Sadri *et al*., 1983) antioxidant and antilipid per-oxidation property (Vijayakumar *et al.,* 1991) in onion; (Sharanamma, 2002) in chilli and (Krishnasamy and Basaria Begam, 2003) in blackgram. Similar higher germination has been reported in maize by Sumuel *et al*. (2008) and Duruigbo (2010) with neem seed treatment.

With respect to sweet flag, higher germination noticed may be related to its antioxidant property of β-asarone which acts as a scavenger of free radicals and inhibit seed deterioration (Devi and Ganjwal, 2011); to its antifeedent and antimicrobial activity (Asha *et al*., 2009, Kudachi and Balikai, 2009). Similar beneficial results with other different botanicals on germination were reported by Pawer (1980), Vimala and Pushpamma (1983), Jilania *et al*. (1989), Sharma (1995), Merwade (2000), Biradar (2000) in rice, Sudesh Jood *et al*. (2004), Deshpande *et al*. (2004 and 2010) and Kulkarni *et al*. (2008) in bengalgram and by Moyin-Jesu (2010) and Ntonifor *et al.* (2011) in maize.

The remaining test botanicals of the present study such as parthenium, tulsi and orange peel powder showed relatively higher germination compared to control which may be due to their lesser efficacy as insecticide and fungicide and vary in their protection levels (Asawalam *et al.,* 2008) or residual effect lasted may be of shorter period due to rapid degradation and volatization of bioactive compounds (Niber, 1994). Inability of these botanicals to offer a longer duration of protection could be as a result of powder settling at the bottom of containers (Niber, 1994 and Ntonifor *et al*., 2011).

In the present study, field emergence was found to differ significantly due to seed treatments from seventh month onwards to end of 14 months (Table 3). The mean field emergence declined from 96.61 to 72.83 per cent at initial month to end of storage respectively.

The seed treatments were found to differ in their efficiency with respect to the field emergence trait. Among seed treatments thiram followed by arappu, neem, sweet flag and wood ash recorded higher per cent field emergence (83.17%, 80.83%, 79.50%, 78.50%, and 75.50% respectively) at the end of 14 months of storage. The beneficial influence of these seed treatment noticed in the present study may be due to higher germination on account of better protection offered as antifungal, insecticidal, antioxidation properties. The results are similar to the findings of Dileepkumar *et al*. (2009) in cowpea; Channabasavanagowda *et al*. (2008) in wheat and Raikar *et al*. (2011) in rice. On the other hand, remaining test botanicals though recorded higher field emergence compared to control were found to be less efficient. The botanicals are reported to differ in their efficacy owing to their differences in chemical compounds (Asawalam *et al*., 2008) or their lesser residual effect, (Niber, 1994).

Seed quality is judged by seedling vigour parameters like root and shoot length, vigour index and seedling dry weight. Generally, higher the seedling length, vigour index and seedling dry weight, higher is the seed quality. In the present study, all the seedling vigour parameters differed significantly due to various seed treatments (Table 4, 5, 6, and 7). The root length, shoot length, vigour index and seedling dry weight were markedly more in thiram, arappu, neem, sweet flag and wood ash compared to control throughout the storage period. They were significantly more in thiram (20.18 cm, 17.24 cm, 3384, and 2.02 g) followed by arappu (19.73 cm, 16.69 cm, 3206 and 1.96 g), neem (19.45 cm, 16.33 cm, 3105 and 1.91 g), sweet flag (19.03 cm, 15.90 cm, 3006 and 1.86 g) and wood ash (18.75 cm, 15.60 cm, 2847 and 1.82g) at the end of 14 months compared to control (16.80 cm, 12.52 cm, 1981 and 1.61 g) respectively.

The beneficial influence noticed with these botanicals may be related to their protective nature, antifungal, insecticidal property besides synergistic effect with amino acids in germinating seeds to protect the root apical meristems tissue from damage and enhance longitudinal root growth (Argerich *et al*., 1989), to bring about enhancement of seedling growth with higher seedling dry matter accumulation (Krishnasamy and Basaria Begam, 2003; Krishnasamy, 2003). Some of the botanicals are known to contain bio-active ingredient like “saponin” in arappu; “azadiractin” in neem (Dubey and Kumar, 2003); “β-asarone” in sweet flag (Devi and Ganjwal 2011); “Linalool” in tulsi; “Limonene” in citrus peel (Don-Pedro 1985); these ingredients synergistically interact with amino acids especially tryptophan to form Indol acetic acid (IAA) in germinating seeds to bring about enhancement of seedling growth. Further it is also related to physiologically active substance present in botanicals which might have stimulated the embryo and associated structure having to development of stronger root and shoot system with high vigour index (Ahmed Raza, 1997), growth and initial establishment (Krishnasamy, 2003). The results are in agreement with the findings of Renugadevi *et al*. (2008) in clusterbeen; Kavitha *et al*. (2009) in chilli; Dileepkumar *et al*. (2009) in cowpea; Raikar *et al*. (2011) in Rice; Nargis and Thiagarajan (1991); Paul and Mishra (1994); Samuel *et al*. (2008) and Duruigbo (2010) in maize who have also reported beneficial influence of botanicals on seedling vigour parameters.

Generally, electrical conductivity of seed leachates is negatively correlated with the seed viability and vigour. As seed ages, the cell and cell organelle membranes become weak and leaky on account of decrease in phospholipids of membranes content due to either enzymic or non enzymic lipid oxidation or due to fungi and insect activities (Ching and Schoolcraft, 1968; Koostra and Harrington, 1969 and Chauhan, 1984). The mean electrical conductivity was found to increase from 0.253dSm^{-1} at initial month to 0.531dSm^{-1} at 14th month of storage irrespective of seed treatments and containers. Kurdikeri (1991) and Hanegave (2009) in maize also noticed similar higher electrical conductivity with the increase in storage period.

The results of the present study showed that electrical conductivity was found to increase with the increase in storage period in all the seed treatments over containers. However, different seed treatments showed differential influence on EC values. Among various seed treatments, the lowest electrical conductivity was recorded in seeds treated with thiram (0.237 to 0.461 dSm^{-1}), arappu (0.242 to 0.472 dSm^{-1}), neem (0.246 to 0.487d Sm^{-1}), sweet flag (0.248 to 0.499 dSm^{-1}) and wood ash (0.249 to 0.509 dSm^{-1}) respectively compared to control (0.266 to 0.658 dSm^{1}) (Table 8) from initial month to at the end of twelve month of storage period.

The differential E.C values recorded among the seed treatments indicated that the nature and extent of membrane protection offered may not be same for all the treatments, thus resulting in difference in E.C value (Kurdikeri, 1991) in maize. Similar differences in EC values in seeds treated with different botanicals were reported by Biradar (2000) in wheat; Merwade (2000); Arati (2000); Patil (2000) and Deshpande *et al.* (2004); in chick pea; Sunilkumar *et al*. (2005), in sorghum; Channabasavanagowda *et al*. (2008) in wheat; Raikar *et al*. (2011) in rice. The results obtained with some of the test botanicals which accounted for low EC values having higher germination and seed vigour parameters corroborate with the hypothesis of lower the EC higher is the seed quality (Shanmugavel *et al*., 1995; Vieira *et al*., 1999).

The storage potential of seeds is mainly affected by seed moisture content during storage. Generally, at higher seed moisture content seed deterioration occurs more rapidly owing to more invasion of fungi, increased activity of storage pests, higher metabolic and enzymatic activity. Further, seed moisture content is a function of relative humidity and it fluctuates concomitantly with the changes in atmosphere. In the present study, seeds treated with thiram recorded lower moisture content (8.13 to 9.29 %) followed by arappu (8.23 to 9.33%), neem (8.27 to 9.38%), sweet flag (8.36 to 9.50%), wood ash (8.30 to 9.62%) compared to the other seed treatments and control (8.46 to 9.99%). Perhaps relatively lower moisture content recorded in these treatments may be due to the fact that they act as physical barrier for migration of moisture. The mean moisture content over seed treatments and containers varied between 8.32% at initial month to 9.61% at the 14th month of storage. Since in these botanicals treated seeds were found to be low moisture content. Whereas seed germination and seedling vigour parameters were also found to be maximum, the results of the present study also corroborate the hypothesis of negative correlation between moisture content and seed quality parameters during storage (Nagarajan and Karivaratharaju, 1976). These results are in agreement with the findings of Kurdikeri (1991), Channakeshava *et al*. (1996) in maize; Channabasavanagowda *et al*. (2008) in wheat; Khatun *et al*. (2011) in lentil; Raikar *et al*. (2011) in rice.

The pathologists strongly believe that, the loss of viability and vigour of stored seeds is mainly due to invasion of storage fungi (Christensen 1976 and Roberts, 1972b). Christensen and Kauffmann (1969) mentioned that fungi not only caused qualitative and quantitative losses of seeds, but also increased the moisture content of the seed in storage and bring biochemical changes leading to increase of free fatty acid content, depletion of food reserves in seed and cause rapid death of seeds within shorter period of time. Moulds are known to affect the quality of seeds by reducing the nutritional value and germination potential, imparting off-flavours and off-colours as well as producing mycotoxins (Sauer, 1988 and Najibullah and Muhammad, 2011). It has been well established that seed treatment with fungicide and botanicals offer better protection against storage fungi owing to fungicidal, antiaflatoxin and mycotoxin properties (Shukla *et al*., 2000; Krishnamurthy and Shashikala, 2006; Asawalam *et al*., 2008).

In the present study, it is observed that seed infection was significantly the lowest with thiram (4.90%) followed by arappu (6.42%), neem (6.82%), sweet flag (7.75%) and wood ash (7.75%) but highest in control (8.38%) at the end of storage period (Table 9). The most predominant storage fungi were found to be *Aspergillus flavas* , *Aspergillus niger*, *penicillium spp.* The present results are in consonance with the results of Srinivasan *et al*. (2001), Udoh *et al*. (2000), Ravishankar *et al*. (2002), Somda *et al*. (2008), Samuel *et al*. (2008) in maize; Bankole and Adebanjo (2003), Neeta *et al*. (2008), Kudachi and Balikai (2009), Monel *et al*. (2011) in sorghum. The lesser incidences of fungi noticed with the test botanicals and thiram fungicide may be accounted for their antimicrobial property resulting in better protection of seed quality during entire period of storage. Neem contains various antifungal and fungicidal compounds in seeds and leaves such as nimbin, nimbidin, salannin, but the most important of these compounds is azadirachtin (Awuah, 1996; Lokesh and Ravi, 2003, Samuel *et al*., 2008).

Similarly, the entomologist equally believes that loss of viability of seeds is mainly due to storage insects and pests resulting in qualitative and quantitative damage. Studies on germination and vigor of stored cereal seeds was significantly reduced by *Rhyzopertha dominica*, *Sitophilus oryzae*, *Trogoderma granarium*, *Sitotroga cerealella* etc.

The shoot length and dry weights of seedling grown from infested seeds decreased significantly with increase in their duration of infestation (Jilania *et al.,* 1989). The damaged seeds are often vulnerable to further damages caused by secondary pests and fungi (Mukherjee and Nandi, 1993). It has been reported to be an important biotic factor responsible for grain heating and spoilage, especially when the grain is stored in damp or at damp places (Sinha, 1971).

In the present study, the pest infestation was noticed only after fourth month of storage (0.04%) which gradually increased to 13.03% over a period of 14 months of storage. Irrespective of containers, minimum (8.27%) infestation was recorded in sweet flag followed by arappu (8.89%), neem (10.30%), thiram (10.65%) and wood ash (11.86%) at the end of 14 month of storage. On the contrary, maximum pests infestation was observed in control (20.88%) followed by castor (16.72%), tulsi (14.45%) and parthenium (14.89) (Table 11). The lowest pest infestation observed with these botanicals may be attributed to their antifeedent, ovicidal, larvicidal, repellent, pesticidal, and toxic properties due to presence of active compounds like "Saponin" in arappu; "Azadiractin" in neem (Dubey and Kumar, 2003); "β-asarone" in sweet flag (Devi and Ganjwal, 2011); "Linalool" in tulsi; "Limonene" in citrus peel (Don-Pedro, 1985) which resulted in better control of storage pest via different modes of action during storage. The results are in agreement with the findings of Muda and Cribb (1999), Devi and Mohandas (1982), Murray *et al*. (1999), Anwar *et al*. (2005), Nikpay (2006), Moravvej and Abbar (2008), Girma Demissie *et al*. (2008) and Aboua *et al*. (2010) with different botanicals. On the contrary pest infestation was not markedly controlled by other remaining botanicals compared to control which may be due to their less persistence toxicity, early biodegradability and evaporation of volatile compounds besides lesser residual effect (Ntonifor *et al*., 2011).

Influence of containers

Generally seeds stored in moisture impervious containers like polythene bag, alluminium foil containers, vacuum sealed containers etc., store for longer period compared to those stored in moisture pervious containers like cloth bag, paper bag, jute bag etc., under ambient storage condition. The concept of storing seeds in moisture impervious sealed containers is to prevent mainly the migration of moisture content in stored seeds. In sealed hermatic storage conditions, the seeds retain viability and vigour for longer period owing to lesser fluctuation of moisture content and temperature, decreased oxygen and enrichment of cardon di-oxide in the containers. On the contrary, some believe that vacuum packaging would harm the seeds due absence of oxygen and life of seed could be extended only by keeping out the natural elements such as excessive moisture and oxygen (Tao, 1989 and Anon, 2009).

Now a day's vacuum packaging is preferred for storing fruits and vegetables and is extended for storing of high value and low volume seeds and germplasm seeds under hermetic seed storage. The vacuum packaging with anaerobic condition prevents the yeasts, moulds and insects, which are major spoilage agents of seeds and grains (Hyde *et al*., 1973; Magan and Lacey, 1984 and Nunez *et al*., 1986). The seeds stored in sealed containers either partially or completely anaerobic (devoid of O_2) conditions store for longer period due to decreased oxidative processes, autoxidation of lipids, decreased generation of lower free radicals, cytotoxic aldehydes and depletion of protective antioxidants and food reserves (Pattee *et al*., 1981; Vertucci and Roos, 1990 and Deepa *et al*., 2011). The highest quality of seeds in storage can be maintained by minimizing oxygen concentration, seed moisture content and temperature (Roberts, 1973; Bailly, 2004; Hong and Kim, 2004; Rao *et al.,* 2006 and Sastry, 2007).

Among the storage containers, the seeds stored in vacuum sealed container maintained significantly higher germination from fifth month of storage till the end of 14 months of storage (97.50 to 90.50%) followed by polythene bag (96.73 to 82.91%) and was less in cloth bag (96.32 to 69.36%) (Table 2). Higher level of germination maintained in seeds stored in vacuum sealed containers may be related to lesser moisture fluctuation, to reduced autoxidation and depletion of food reserves, higher anti-oxidative and lowering reactive oxygen species (ROS) damage, besides lower pest and fungal activity *etc* (Roberts, 1973; McDonald, 1999; Guberac *et al.,* 2003; Chiu *et al.,* 2003; Bailly, 2004; Hong and Kim, 2004; Rao *et al*., 2006; Ellis and Hong, 2007 and Deepa *et al.,* 2011).

Likewise, the seeds stored in polythene bag also maintained viability of seeds for longer period owing to lesser fluctuation of moisture content, lesser pest and disease as evident in the present study McDonald (1986), Handry (1993) and Ellis and Hong (2007) hypothesized that O_2 and reactive oxygen species (ROS) cause deleterious effect by damaging protein, lipid and starch constituents, damage lipid bilayer membrane, enhance lipid peroxidation and exhaustion of antioxidants resulting in more rapid seed deterioration and opined that hermatic packaging is preferable for long term seed storage than cloth bags in maintaining various seed quality parameters (Hong and Kim, 2004).

Among seed containers vacuum and polythene bags recorded higher per cent field emergence (83.82 and 75.82%) respectively and was lower in cloth bag (61.86%) (Table 3) at the end of 12 months of storage. Higher field emergence recorded with vacuum and polythene bag containers is mainly due to higher per cent germination and better seed quality parameter with less pest and diseases as evident in the present study. The results of the present study corroborate with findings of Kurdikeri (1991) and Channakeshava *et al*. (2001) in maize; Raikar *et al*. (2011) in paddy and Sastry *et al*. (2007) in ground nut.

The seedling vigour parameters such as root length, shoot length, vigour index and seedling dry matter accumulation were significantly higher (18.39 cm, 15.95 cm, 3161 and 1.88 g) in seeds stored in vacuum packaging followed by those stored in polythene bag (18.94 cm, 15.10 cm, 2807 and 1.79 g) compared to cloth bag (17.65 cm, 14.24 cm, 2243 and 1.63 g) (Table 4, 5, 6 and 7 respectively) at the end of 14 months of storage. The seed packaging in vacuum and polythene bag showed their superiority in maintaining seedling vigour parameters. The plastic films or polythene sheets have a passive function providing protection against external damage due to attack by micro and macro organisms, against fluctuation of moisture and against penetration of insects (Shukla *et al*., 1993 and Riudavets *et al*., 2007).

The higher seedling vigour parameters observed with vacuum and polythene bag containers may be due to lesser seed deterioration on account of lesser autoxidation of lipids, lesser moisture content, lesser free radicals and lesser activity of pests and diseases. The findings are in agreement with the reports of Roberts (1973); Hyde *et al*. (1973); Bass and Stanwood (1977); Justice and Bass (1978); Jilania *et al*. (1989); Magan and Lacey (1984); Ellis (1998); McDonald (1999); Chiu *et al*. (2003); Bailly (2004) and Ellis and Hong (2007).

The electrical conductivity was significantly lower in seeds stored in vacuum sealed containers (0.315 dSm^{-1}) followed by polythene bag (0.420 dSm^{-1}) and was higher in cloth bag (0.857 dSm^{-1}) at the end of 14 months of storage (Table 8). Higher EC values recorded in seeds stored in cloth may be due to higher level of seed deterioration on account of age induced membrane damage of various cell and cell organelles (Roberts, 1973; McDonald, 1999; Yeh *et al.,* 2005 and Sastry *et al*., 2007). Further, higher leachates in stored seeds obtained may be on account of pest and disease (Channabasavanagowda *et al*. 2008) in wheat and Raikar *et al.* (2011) in rice. On the contrary, lower E.C values recorded in seeds stored in vacuum and polythene bag packaging is mainly due to lesser seed deterioration on account of lesser biotic and abiotic factors (Hyde *et al*., 1973; Magan and Lacey, 1984 and Mbata *et al*., 2004).

The seeds are hygroscopic in nature and gain or lose moisture content depending on previous or impervious nature of containers in which they are stored. Among containers the seeds stored in vacuum sealed container recorded significantly lesser moisture (8.73%) followed by polythene (9.39%) whereas higher moisture content in seeds stored in cloth bag (10.72%) at the end of 14 months of storage (Table 9). Seeds stored whether in vacuum packaging or polythene (700 guage) bags are unlikely to absorb moisture and oxygen from the atmosphere due to their property of film used for packaging and maintain lower moisture and oxygen and as such they are unlikely to suffer because of higher oxidation (Hong and Kim, 2004).

Further, the moisture contain in cloth bags may fluctuate much and reach higher than the required and this would facilitate higher activity of pests and diseases (Sinha, 1971 and Riudavets *et al*., 2007).

With respect to seed health studies, the level of fungi infection was less (4.67%) in vacuum followed by polythene (8.40%) and was markedly more (9.36%) in cloth bag at the end of storage period.

Likewise the per cent insect damage noticed was Nil in vacuum packaging followed by polythene bag (5.16 %) and was higher in cloth bag (33.94%) at the end of storage period. This is mainly because of lesser O_2 and moisture content in seeds stored vacuum and polythene bag as evident in the present study (Table 10 and 11) due to which storage pests and diseases were minimum accounting for lesser seed deterioration and resulting for longer viability the results consonance with the results of Navarro *et al*. (2005); Sastry *et al*. (2007); Channabasavanagowda *et al*. (2008) in wheat; Schwember and Bradford (2011) in lettuce and Deepa *et al*. (2011) in chilli.

The anaerobic conditions generated within sealed containers inhibit aerobic moulds, yests and insects which are major spoilage of seeds (Hyde *et al*., 1973; Magan and Lacey, 1984; Nunez *et al*., 1986 and Navarro *et al*., 2005). Oxygen supports the growth of aerobic microorganisms; thus, the removal of oxygen from the modified atmosphere will decrease the microbial shelf life (Sanjeev and Ramesh, 2006) and hence, its low initial mold counts. The results support the same with a notably zero per cent population of mold in vacuum packed bags when compared to cloth bag. Further in vacuum due to higher pressure insect's eggs are very sensitive to oxygen stress which in turn leads to more mortality of insects in egg stage only. The results are in agreements with the ealier findings of Mbata *et al*. (2004); Sanjeev and Ramesh (2006); Roshny (2007) and Remya (2007); Deepa *et al*. (2011) in different kinds of stored seeds.

Interaction effects on seed quality

The germination percentage was found to differ significantly due to interactions of treatments and containers (T×C) from 11^{th} month onwards. The seed treated with all the treatments and stored in cloth bags recorded significantly less germination compare to polythene and vacuum containers up to end of 14 months of storage.

The germination percentage of seeds treated with thiram, arappu, neem, sweet flag and wood ash were stored in polythene and vacuum containers were on par with each other but were significantly superior over cloth bag from 11^{th} to 14 months of storage (fig.1). The superiority of polythene and vacuum packaging in maintaining higher germination over cloth bag may be related to the combined beneficial influence of protective nature of seed treatments and impervious nature of polythene bag together which resulted in decreased seed deterioration owing to lesser fluctuation of seed moisture content, lesser pest and disease (Roberts, 1973b; McDonald, 1999; Hong and Kim, 2004; Ellis and Hong, 2007 and Deepa *et al*., 2011).

Likewise the field emergence was also significantly more in all the seed treatments when packed in polythene and vacuum containers compared to cloth bags.

The seedling vigour parameters such as root length, shoot length, vigour index (Fig.2), seedling dry weight and with lower EC and moisture content, seed infection and insect damage at the end of storage period compared to seeds stored in cloth bags. This may be due to the fact that these botanicals offer protection against detrimental changes associated with deterioration on account of lesser moisture fluctuations in impervious containers due to which higher seed quality parameters have been observed. The combined beneficial influence of seed treatments and packaging materials on various seed quality parameters was reported earlier by Merwade (2000) in chick pea; Sunilkumar *et al.* (2005) in sorghum; Channabasavanagowda *et al*. (2008) in wheat and Raikar *et al*. (2011) in rice. Several studies have also indicated that seed stored under anerobic conditions (vacuum) or polythene bag the rate of seed deterioration would be minimal due to lesser moisture content and pest and disease activity and lesser physiological and biochemical changes (Roberts, 1973a; Hyde *et al*., 1973; Mbata *et al*., 2004 and Navarro *et al*., 2005).

Viability as per the Minimum Seed Certification Standards

In the present study irrespective of seed treatments and containers satisfactory germination (90%) as per the Minimum Seed Certification Standards was maintained in maize seeds up to eleven months after storage.

Among the treatments, only thiram maintained satisfactory germination (90%) up to fourteen months after storage followed by arappu and neem up to thirteen months; sweet flag for ten months and wood ash for nine months. The seeds treated with castor, pongamia, tulsi, mandarin and parthenium maintained up to 12 months while in control up to 8 months only.

Among the containers, seeds stored in cloth bag maintained viability only up to ninth month and seeds stored in polythene bag maintained up to eleven months; while vacuum sealed containers maintained up to fourteen months.

In the interactions of treatments and containers (TxC), satisfactory germination as per the minimum seed certification standards was maintained for 14 months in all the treatments except castor and control stored in vacuum which maintained for 13 months.

In polythene bag the seeds treated with neem, arappu, sweet flag and thiram maintained satisfactory germination up to 14 months; wood ash for ten months; castor, pongamia, tulsi, mandarin, parthenium and control maintained up to 11 months.

In cloth bag seeds treated with neem, arappu and thiram maintained satisfactory germination up to 11 months; castor, pongamia, tulsi, mandarin, parthenium, sweet flag and wood ash maintained for ten months while control maintained up to eight month months only.

Future line of work

1. The storage studies may be conducted with other plant products (botanicals), chemicals etc. for enhancing storability of maize seeds.
2. The similar storage studies may be conducted on other field and vegetable crops of high value and low volume crops.
3. The study on other gases and vacuum packaging may be initiated in low volume and high value crops.
4. Studies on bio-chemical and ultra structural changes associated with seed deterioration with botanical seed treatment need to be studied.
5. Studies on the standard formulation and right dose of botanicals for applications are needed.

Practical application

Based on the results of the present study the following recommendations could be made for practical application for the benefit of farmers, seed grower, seed companies etc.

1. The seeds of maize may be treated with thiram, arappu, neem, sweet flag powder, wood ash and packed in vacuum or polythene bag (700 gauge) for storage more than fourteen months under ambient storage condition without loss of viability and vigour.
2. Vacuum packaging could be practiced for extending storage potential of maize beyond 14 months, by high value and low volume crops.
3. The farmers can treat the seeds with neem, arappu, sweet flag, pongamia, tulsi, wood ash and castor for storage of seeds for another one season only.

VI. SUMMARY AND CONCLUSIONS

The results generated from storage study entitled “Effect of plant products and containers on storage potential of maize hybrid cv. Arjun” conducted during 2011-12 are summarized below.

The experiment consisted eleven seed treatments *viz*., neem leaf powder (T_1), castor leaf powder (T_2), pongamia leaf powder (T_3), tulsi leaf powder (T_4), mandarin peel powder (T_5), sweet flag powder (T_6), arappu leaf powder (T_7), parthenium leaf powder (T_8), wood ash (T_9), thiram (T_{10}) and control (T_{11}) and three containers *viz*., cloth bag (C_1), polythene bag (C_2) and vacuum packaging (C_3). The seed samples were treated as per the treatments and packed in containers and stored under ambient storage conditions for twelve months.

The seed samples were drawn at monthly intervals for ascertaining the seed quality parameters *viz*., germination, field emergence root length and shoot length, vigour index, seedling dry weight, electrical conductivity of seed leachate, moisture content and seed health.

1. The Maize Hybrid Cv. EH-434042 (Arjun) maintained satisfactory germination (90%) above the minimum seed certification standards up to the end of 10^{th} month of storage with higher seedling vigour parameters irrespective of seed treatments and containers.
2. Among the seed treatments, seeds treated with thiram recorded higher seed quality parameters followed by arappu, neem, sweet flag powder and wood ash throughout the storage period. Seeds treated with thiram maintained higher germination and field emergence (90.33% and 83.17%, respectively) at the end of twelve month of storage with higher root and shoot length, vigour index, seedling dry weight, with lower moisture content and electrical conductivity per cent seed infection and seed damage.
3. The seeds treated with thiram maintained satisfactory germination up to 14 months of storage followed by arappu and neem up to 13 months.
4. Among the containers seeds stored in vacuum and polythene bags maintained satisfactory germination as per the Minimum Seed Certification Standards up to twelve and nine months of storage respectively compared to cloth bag which maintained up to seven months.
5. In the interactions of treatments and containers (TxC), seeds treated with neem, pongamia, tulsi, mandarin, sweet flag, arappu, parthenium, wood ash and thiram stored in vacuum maintained germination as per the Minimum Seed Certification Standards up to twelve months while, seeds treated with castor and untreated (control) maintained up to 13 months.
6. In polythene bag seed treated with sweet flag, arappu, neem and thiram maintained satisfactory germination up to 14 months, wood ash up to 12 months and pongamia, tulsi, mandarin, sweet flag, arappu, parthenium and control up to 11 months.
7. In cloth bag seed treated with thiram, arappu and neem maintained up to 11 months while, castor, pongamia, tulsi, mandrin, sweet flag, parthenium and wood ash maintained up to 10 months where in absolute control it was for only 8 months.
8. The moisture content, seed infection and infestation were minimum in seeds stored in vacuum and polythene bags compared to control.

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EFFECT OF PLANT PRODUCTS AND CONTAINERS ON STORAGE POTENTIAL OF MAIZE cv. ARJUN

ASHA A. M. **2012** **Dr. M. B. KURDIKERI**
MAJOR ADVISER

ABSTRACT

An investigation was undertaken to ascertain the storage potential of maize seeds with ten seed treatments and three packing materials. Seeds with initial 8.0 per cent moisture content were treated with powders of neem leaf, castor leaf, pongamia leaf, tulsi leaf, mandarin peel, sweet flag, arappu leaf, parthenium leaf, wood ash, thiram and control and packed in three containers *viz.*, cloth bag, polythene bag (700guage) and vacuum packaging and stored under ambient conditions. The maize cv. Arjun recorded higher germination, field emergence, vigour index, seedling dry weight, lower electrical conductivity, moisture content, seed infection and seed infestation at the end of 14 months of storage irrespective of containers and treatments.

Among the seed treatments, seed treated with thiram recorded higher germination (90.33%), field emergence, vigour index (3384), seedling dry weight, lower electrical conductivity, moisture content seed infection (4.90%) and seed infestation (10.65%) compared to other seed treatments at the end of storage period.

Seeds packed in vacuum packaging recorded higher germination (90.50%), speed of germination, lower electrical conductivity, moisture content, seed infection and seed infestation as compared to seeds stored in cloth bag and polythene bag at the end of 14 months of storage.

In the interactions of seed treatments and containers (TxC) seed treated with thiram and stored in vacuum packaging and polythene bag maintained higher germination (90.33 and 82.82%, respectively), field emergence, vigour index, seedling dry weight, lower electrical conductivity, moisture content and seed infection at the end of 14 months of storage.