SEED QUALITY ENHANCEMENT IN COWPEA (*Vigna unguiculata* (L.) WALP.) BY FILM COATING TECHNIQUE

By

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THESIS

Submitted in partial fulfilment of the requirement for the degree of

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2010

DECLARATION

I hereby declare that the thesis entitled **"Seed quality enhancement in cowpea (*Vigna unguiculata* (L.) Walp.) by film coating technique"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, fellowship or other similar title, of any other university or society.

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INTRODUCTION

1. INTRODUCTION

Vegetables are essential components of a balanced diet. They are called as protective food as their consumption can prevent several diseases (Thamburaj and Singh, 2005). India is the second largest producer of vegetables next only to Republic of China. In India, area under vegetables is about 7.98 million hectares and production and productivity in the country are 129.07 million tonnes and 16.2 tonnes/ha respectively (NHB, 2009). In Kerala, vegetables are cultivated in an area of 1.63 lakh hectares. Total production and productivity of vegetables in the state are 35.09 lakh tonnes and 21.5 tonnes/ha respectively (NHB, 2009).

Leguminous vegetables coming under the family *Fabaceae* are rich source of protein which is as high as 14 percent. Cowpea (*Vigna unguiculata* (L.) Walp.) is an important vegetable cultivated in Kerala throughout the year. Tender pods as well as dry seeds are commonly used for consumption. Cowpea is considered as a soil enriching crop and forms an important component in crop rotation. Problems in cowpea cultivation include poor germination of seeds, low vigour, non uniform crop stand, pest and disease incidence etc. Cowpea seeds lose its viability and vigour rapidly in storage due to physiological reasons, attack of pests (especially the pulse beetle) and pathogens.

In order to protect the seeds and seedlings from insects and diseases and also to increase the seed vigour, several seed treatment practices are recommended. But the conventional seed treatment practices have certain drawbacks, as they do not provide uniform application on each and every seed. Besides, dusting of the applied materials like pesticides leads to environmental pollution.

Film coating is the latest technique of seed treatment wherein a very thin, usually coloured layer is applied around the seed. Advantages of film coating technique include superior binding of applied materials (fungicides, pesticides, hormones, micronutrients etc.) and reduced leaching of materials. It also improves germination, vigour, storability and reduces seed deterioration in storage.

Moreover, the load of pesticides applied to protect the seed in storage can be reduced considerably by film coating and this technology is eco friendly. Film coating improves appearance of seed and facilitates uniform deposition of material on each seed forming a thin film around it encasing the seed treatment additives. It helps in application of accurate and controlled dosage of pesticides / fungicides, micronutrients / growth regulators / biological organisms etc. with high level of precision. The film coat also acts as physical barrier by reducing the leaching loss from the seed coverings and restricts oxygen diffusion to the embryo (Vanangamudi *et al.*, 2003).

With regard to value addition of vegetable seed, no work has been done in Kerala Agricultural University. Hence the study on "Seed quality enhancement in cowpea (*Vigna unguiculata* (L.) Walp.) by film coating technique" was undertaken in the Department of Olericulture, College of Horticulture, Vellanikkara during 2008-2010 with the following objectives.

- To standardise the dose and method of film coating.
- To study the effect of seed film coating in combination with insecticides, fungicides and biological agents on, seed quality and storage.
- To study the effect of seed film coating on growth, field performance and yield of cowpea.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Cowpea is an important crop extensively grown in Kerala. It is consumed both as tender pods and also as a pulse. It is a rich source of proteins, vitamin B and minerals. Some of the major problems in cowpea cultivation include poor germination, low vigour, non-uniform crop stand, pest and disease incidence. It is also a poor storer since it loses its viability and vigour rapidly during storage due to the attack of pests (especially the pulse beetle). Seed is one of the important basic inputs in agricultural production and use of quality seed increases the production and productivity of the crop. To protect the seed from the above problems, various seed treatment methods are followed. But the conventional seed treatment practices have certain drawbacks as they do not provide uniform application of materials on each and every seed and dusting of pesticides lead to environmental pollution. Seed film coating is one of the technology advocated to overcome the disadvantages of conventional seed treatment methods. Outcome of this method has not been studied in Kerala Agricultural University (KAU) till date. Hence this research project was formulated to study the effect of film coating technique on seed quality enhancement in cowpea.

2.1 Influence of film coating on seed quality.

Coating is a substance applied to the seed but does not obscure its shape. It is applied as a thin film that helps adhere and protect the fungicides and insecticides during the handling of seed. It helps in application of seed quality enhancement material directly on the seed. The film coated seeds also reduces the imbibition damage, improves germination and seedling emergence.

Results of the study conducted by Hwang and Sung (1991) revealed that soybean seeds coated with a hydrophilic polymer regulated the rate of water uptake, reduced imbibitional damage and improved the emergence of seedlings.

In rice (cv. IR-20) Dadlani *et al.*, (1992) reported that seedlings from polymer coated seeds recorded higher root length (34.80mm), shoot length

(170.20mm) and dry weight (52.80 mg per seedling) compared to that from uncoated seeds (33.63mm, 147.60mm and 48.30 mg per seedling respectively).

Zholbolsynova *et al.*, (1992) reported that seeds of wheat coated with polymers increased the yield from 0.93 tonnes to 1.62 tonnes per ha.

According to Joseph *et al.*, (1995), chickpea seeds treated with polymer coating @ 1.50 $g.kg^{-1}$ seed recorded higher yield (23.28 q/ha) over control (20.03 q/ha).

Cotton seeds treated with the polymer film coating-Landec Seed Coating recorded slow imbibition rate and reduced imbibitional damage. The reduction in imbibition rate protected the sensitive seed by lowering the electrical conductivity values and improved the germination performance when compared to the control seeds as reported by Struve and Hopper (1996).

In a study conducted by Chikkanna *et al.*, (2000) groundnut seed coated with hydrophilic polymer @ $20g.kg^{-1}$ seed showed increased germination, but further increase in the concentration of the polymer inhibited the germination and root and shoot growth.

According to Chachalis and Smith (2001), polymer coating in soybean seeds at the rate of 24.00mg per seed regulated the rate of water uptake, reduced imbibitional damage and improved germination and seedling emergence in flooding soil condition.

Almeida *et al.*, (2005) reported that broccoli seeds treated with film coating (hydroxy ethyl cellulose) showed no identifiable pronounced difference in germination compared to non coated seeds in relation to accelerated ageing of seeds and speed of germination in the soil.

Study conducted by Xiong *et al.*, (2005) revealed that seed film coating on cucumber with suitable concentrations of uniconazole (20-60mg/litre) significantly reduced the shoot height and promoted the root growth and dry matter accumulation, which were beneficial to obtain vigorous seedlings. Uniconazole in the seed coating film had no harmful effect on seed germination. The optimum concentration of uniconazole in coating film on the seeds was 60mg/litre.

Wang *et al.,* (2005) studied the effect of seed film coating with uniconazole (0.0075 per cent) on rape seed and found that it improved seedling growth and seedling establishment during water logging. It also significantly enhanced leaf dry weight and ratio of root to shoot length but decreased shoot height and stem dry weight.

A study conducted by Nisar *et al.,* (2006) revealed that film coated seeds of soybean showed slower deterioration as well as higher germination when compared to the control. Coated seeds also prevented proliferation of stored fungi over the period of storage.

Results of the study conducted by Patil *et al.,* (2006) revealed that coating of male sterile and maintainer line seeds of rice hybrids with water soluble polymers viz., (polykote or polyloc) @ 4ml per kg seed with or without fungicides resulted in significant improvement in germination, vigour and field emergence. It also improved seed coat lustre and minimized dehusking thus enhancing its planting value.

Cheng *et al.,* (2007) studied the effect of seed film coating on tomato with various concentrations (50, 150, 300 and 600 mg/litre) of paclobutrazol on seed germination and emergence rate, seedling height, stem width, seedling fresh and dry weight, quality index, root vigour and the content of proline. Seed film coating with 150-300 mg/litre paclobutrazol significantly reduced seedling height, increased stem width, seedling fresh and dry weight per plant, content of proline of leaves and promoted the quality index and root vigour, which was beneficial to obtain strong and vigorous seedlings. There were no significant influences on coated seed germination and emergence rate. The optimum concentration of paclobutrazol in the experiment was 150 mg/litre.

2.2. Effect of seed film coating in combination with insecticides, fungicides and biological agents on seed quality and storage.

2.2.1. Influence of fungicides on seeds

Casela *et al.,* (1979) reported that seed treatment of soybean with thiram and captan increased seed germination from 50 to 63 per cent.

Results of the study conducted by Nedrow and Horman (1980) revealed that soybean seeds treated with thiram (2g.kg^{-1} seed) and carboxin + thiram (2g.kg^{-1} seed) showed reduction in the infection of *Phomopsis sojae* and *Fusarium spp.* and improved the germination, but benomyl + thiram (2g.kg^{-1} seed) treatment was most effective in increasing the laboratory germination.

Among the thirteen seed dressing fungicides tested in French bean seeds, benlate, bavistin, vitavax, thiram and agrosan were found to be effective in increasing seed germination and reducing disease incidence (Sindhan and Bose 1981). Treated seeds recorded maximum germination (more than 78 per cent) compared to the control (53 per cent).

According to the study conducted by Mahendrapal and Grewal (1985) in pigeon pea, seed treatment with bavistin recorded higher germination (73 per cent) as compared to the conrol (56 per cent)

Pawar *et al.,* (1985) reported that paddy seeds treated with carbendazim recorded higher germination (93 per cent), root length (10.89 cm) and shoot length (9.82 cm) as compared to untreated control (60.50 per cent, 10.45 cm and 8.62 cm respectively).

Singh and Agarwal (1986) reported that dry seed treatment of soybean seeds with captan, thiram, bavistin + thiram against *Cercospora kikuchii* resulted in improved seed germination.

Results of the study conducted by Voroveni *et al.*, (1986) revealed that soybean seeds treated with thiram (@ 2g.kg^{-1} seed) showed higher seed germination and field emergence than untreated seeds.

Hunje *et al.*, (1990) reported that cowpea seeds treated with Dithane M-45 or thiram alone or in combination with malathion or BHC, improved germination and seedling vigour.

Sundaresh *et al.*, (1987) reported that soybean seeds showed significant improvement in germination under both *in vitro* (18.20 per cent) and *in vivo* (22.25 per cent) conditions when the seeds were treated with thiram (@ 4g.kg^{-1} seed) or Dithane M-45 (@ 3g.kg^{-1} seed) of seeds as compared to control (7.53 per cent).

Chilli seeds treated with captafol, thiram, aureofungin, topsin and vitavax each @ 0.3 per cent concentration improved the germination and seedling length (Dhyani *et al.*, 1991).

Singh (1992) reported that pre sowing treatment of soybean seeds in combination with carbendazim + thiram (1:1) @ 3g.kg^{-1} seed resulted in increased germination.

According to the study conducted by Gupta *et al.*, (1993), treatment of soybean seeds with fungicides like benlate, thiram and captan before accelerated ageing was better for maintenance of germination and prevention of fungal growth instead of treatment after accelerated ageing.

Study conducted by Ramdoss and Shivprakasam (1994) showed increased root length in the seedlings of cowpea seeds treated with carbendazim @ 2g.kg^{-1} seed.

Solanke and Kore (1994) reported that sorghum parental line "CS-3541" treated with thiram + carbendazim recorded higher germination (83 per cent), less seed mycoflora (8 per cent) as compared to other fungicidal seed treatment.

Sunflower (cv. LSH-1) seeds treated with thiram + carbendazim recorded higher germination (91 per cent) and less seed mycoflora (5.90 per cent) as compared to control (79.00 per cent and 9.00 per cent respectively) (Solanke *et al.*, 1997).

Vasundhara and Bommegouda (1999) reported that groundnut seeds treated with captan @ 3.0g.kg^{-1} seed recorded higher germination (85.23 per cent), vigour index (3051), field emergence and lowest electrical conductivity (292 µmhos/cm) as compared to control (73.07 per cent, 2182, 80.56 per cent and 394 µmhos/cm respectively).

Kalavathi *et al.*, (2000) reported that barnyard millet seeds treated with thiram @ 2.0g/kg of seeds maintained higher germination (91.00 per cent) and vigour index (1534) as compared to control (80.00 per cent and 1065 respectively).

In a study conducted by Sharma *et al.*, (2000) onion seed, treated with captan (0.2 per cent) showed enhanced seed germination as compared to control.

Muthuraj *et al.*, (2002) reported that soybean seeds treated with thiram (2g.kg^{-1} seed) improved germination (80.75 per cent) and field emergence (70.52 per cent) as compared to control (79.10 and 58.63 per cent respectively)

In a study conducted by Ravishankar *et al.*, (2002), maize seeds treated with Dithane M-45 recorded higher vigour index (985) as compared to control (703).

2.2.1.1. Influence of film coating with fungicides on seeds.

Petch *et al.*, (1991) treated carrot seeds with film coat in combination with metalaxyl in a single and multiple polymer binder layer at increasing rates of fungicides (10, 25, 50 and 100g a.i fungicide/kg seed). Results revealed that under greenhouse condition a single coat of metalaxyl (10g a.i/kg seed) gave highest plant survival, yield and control of cavity spot (caused by *Pythium* spp.) in infested soil equivalent to that from the commercially recommended metalaxyl drench treatment (1200g.ha^{-1}).

Laboratory germination and field emergence of pea seeds was studied by Kosters (1994) in 3 seed lots using film-coating with various combinations of fungicides *viz.*, oxadixyl + cymoxanil + carbendazim or metalaxyl + thiabendazol + thiram. The use of oxin-copper had no significant effect on field emergence if added to the mixtures. Thiram or thiram + oxin-copper did not lead to good field stands when used on the weaker lots.

Rivas *et al.*, (1998) studied the effect of film-coating polymers (certop) as a seed treatment either alone or in combination with captan on field emergence and final stand of two hybrids of maize. Polymers applied alone had no significant influence on emergence rate of either high or low vigour seeds in comparison with untreated controls but polymers in combination with captan were as effective as captan alone in increasing the rate of emergence and improving seedling height at early planting.

In onion seeds, polymer coating and pelleting with a fungicide cyromazine reduced the plant stand losses to the insect (onion fly) from 20-60 percent to 1 to 8 percent and also recorded higher germination and seedling vigour (Taylor *et al.*, 2001).

Study conducted by Vanangamudi *et al.*, (2003) revealed that in maize treatment of pink polykote (3g per kg of seed + fungicide + insecticide) increased the germination (98 per cent) and vigour index (82.91) as compared to untreated control (93 per cent and 64.54 respectively).

Higher germination was reported in bean seeds coated with polymer and fungicide as compared to control after two months of storage (Larissa *et al.*, 2004).

Wilson and Geneve (2004) reported that corn seeds coated with polymer and fungicide recorded higher germination (98.50 per cent), less number of abnormal seedlings (1.50 per cent) and lower conductivity values (41.60 μ mhos/g) as compared to control (89 per cent, 8.50 per cent and 51.40 μ mhos/g respectively). They also reported that fungicide treatment with or without film coating in sweet corn seeds was effective in improving seedling emergence only in the low vigour cultivar, irrespective of germination temperature. There was also enhanced the initial water uptake in film-coated seeds as compared to untreated seeds.

Trentini *et al.*, (2005) studied the effect of film-coating with AGL 205 3ml.kg^{-1} seed in combination with the fungicide Tegram, (17g a.i thiabendazole + 70g a.i thiram) at 1 and 2 ml.kg^{-1} seed on the physiological and sanitary quality of soybean seeds. Results of the study revealed that film-coating with AGL 205 and fungicide treatment had no significant effects on the physiological and sanitary quality of the harvested seeds.

In a study conducted by Arsego *et al.*, (2006) paddy seeds were film coated (CF Clear + colouring agent + binders) in combination with fungicides (carboxin + thiram or fludioxonil + metalaxyl) and gibberellic acid (GA; 0.25, 0.50 or 0.75g/50 kg of seeds). The results showed that CF Clear provided adequate coating on seeds. Coated seeds with carboxin + thiram improved seed quality, and among various concentration of GA, treatment @ 0.50 g/50 kg of seeds was recommended for seed coating.

2.2.2. Influence of insecticides on seeds

Mote (1993) reported that cotton seeds treated with imidacloprid improved the seed germination, root and shoot length compared to untreated control.

Brinjal seeds treated with imidacloprid (70 per cent WS) per kg of seeds showed positive influence on seedling height and chlorophyll content of leaves (Jarande and Dethe 1994).

Bhanot *et al.*, (1994) reported that mustard seeds treated with aldrin 30 EC @ 20ml per kg of seeds recorded higher germination (96.00 per cent) as compared to control (91.30 per cent).

Mote *et al.*, (1995b) reported that sorghum seeds treated with imidacloprid @ 2.0 per cent recorded higher germination (84 per cent), root length (15 cm) and shoot length (6.73 cm) as compared to control (78 per cent, 12 cm and 5.08 cm respectively).

Cotton seeds treated with imidacloprid recorded six per cent higher plant height (24.80 cm) and number of leaves (20.80) and took less days to reach 50 per cent flowering (57.00) as compared to control (16 cm, 10 and 60 days respectively) (Mote *et al.*, 1995a).

No reduction in germination capacity and field emergence was noticed in sugar beet seeds stored for more than a year on treating with imidacloprid (Schaufele *et al.*, 1996).

2.2.2.1. Influence of film coating on seeds with insecticides

Kosters and Brighton (1988) reported that film-coating with chlorfenvinphos on carrot seeds for protection against carrot fly (*Psila rosae*) was comparable to field applications of the same chemical, but much less a.i was required per hectare. In artificial inoculation experiments and natural infections of carrot seedlings with downy mildew spores (*Peronospora parasitica*), film-coating gave protection for 3 to 5 weeks depending on plant development.

A study was conducted to assess the protection against larvae of cabbage root fly (*Delia radicum*) in cauliflower by film-coating the seeds with insecticide *viz.*, isofenphos, chlorpyrifos and fonofos at 2 and 3 dosages of seed film-coating, and were compared with a conventional post-planting treatment (Ester *et al.*, 1994). Film-coating with fonofos was less effective in controlling larvae than the post-planting treatment. Chlorpyrifos @ 28.80g a.i/kg seed and isofenphos at 30g a.i/kg seed consistently gave as good control as post-planting treatment of each plant.

Brussels sprouts seeds (*Brassica oleracea* var. *gemmifera*) treated with various doses of insecticides *viz.,* chlorpyrifos, isofenphos and fonofos were film coated (Ester *et al.,* 1997) for controlling cabbage root fly. Results revealed that film coating containing chlorpyrifos 9.60g a.i per kg seed was effective in controlling the pest and it also resulted in efficient usage of pesticides without any loss.

Ester and Huiting (2001) reported that seed film-coating of winter leek (*Allium porrum*) with fipronil and other insecticides like imidacloprid showed effective control of onion thrips (*Thrips tabaci*) on the seedbed for twelve weeks and three weeks after transplanting. Diflubenzuron and methiocarb were not effective. Film-coated seeds with fipronil, diflubenzuron, imidacloprid and teflubenzuron gave acceptable control of the larvae of the onion fly (*Della radicum*), whereas coating with benfuracarb and methiocarb was only moderately effective. The use of fipronil and imidacloprid film-coated seeds resulted in sufficient protection against the leek moth (*Acrolepiopsis assectella*), at low population densities. The most effective insecticide, fipronil, was not phytotoxic.

A study was conducted by Ester *et al.,* (2003) to assess the control of the flax flea beetles (*Longitarsus parvulus*) and the large flax flea beetle (*Aphthona euphorbiae*) in fibre flax crop (*Linum usitatissimum*). The seeds were film-coated with insecticides (imidacloprid 70 per cent WS, fipronil 500g/litre FS, spinosad 480 SC and thiamethoxam 350g/litre FS). The treatment with the insecticides was compared with the standard spray application of parathion and with untreated seeds. Film-coated seeds with imidacloprid, fipronil and thiamethoxam gave sufficient protection against flea beetle, but spinosad was not effective to control the flea beetles. The fipronil, spinosad and thiamethoxam at 2.50 and 5g.kg^{-1} seed did not cause phytotoxicity. Imidacloprid at 8.75g and 17.5g and thiamethoxam at 10g and 20g resulted in a lower number of emerged plants.

In a study conducted by Ester *et al.*, (2003) cabbage and cauliflower seeds were film coated in combination with insecticides for controlling cabbage root fly larvae, flea beetle, cabbage aphid and caterpillars. Results showed that film coated seeds treated with spinosad was ineffective in controlling flea beetle and cabbage aphid whereas it gave a good control of cabbage fly larvae and caterpillars at the rates of 24g and 48g a.i per 100,000 seeds. Imidachloprid was ineffective in controlling cabbage root fly larvae and caterpillars whereas it gave a good control of flea beetle and cabbage aphids @ 70g a.i per 100,000 seeds. The combined application of these insecticides on seed is an environment friendly alternative for protecting brassica crops against pests.

Seeds of the cabbage (cv. Fresco) F-1 were film-coated with chlorpyrifos at 0, 9.60, 19.20 or 28.80g a.i/kg seed and examined for phytotoxic effects on germination in the laboratory as well as effectiveness against immature stages of cabbage maggot (*Delia radicum*) under greenhouse and field conditions (Jyoti *et al.*, 2003). Chlorpyrifos film-coated seed treatments did not adversely affect germination in the laboratory tests when plants were grown with peat soil in transplant cell trays and also provided significant plant protection against immature stages of cabbage maggot through several weeks after transplanting seedlings under greenhouse and field conditions.

A study by Yildrim and Hoy (2003) revealed that when onion seeds were film coated with insecticide (cyromazine 0.78 to 50g a.i/kg seed) in combination with entamopathogen (*Heterorhabditis bacteriophora*) @ 5-10 nematodes per larva and also individually treated with entamopathogen (*Heterorhabditis bacteriophora*) @ 10-160 nematodes per larvae against onion maggots, that there were no synergistic effects when used in combination. However, when these entamopathogen were used individually @ 10-160 nematodes per larvae, it resulted in significant mortality in both first and second instars of onion maggots.

Ester *et al.*, (2005) conducted a study in which film-coated cabbage seeds were treated with various insecticides *viz.*, chlorpyrifos, *Bacillus thuringiensis*, chlorfenapyr, cyromazine, fipronil and spinosad. Cauliflower (cv. Cassius) seeds film-coated with chlorpyrifos and spinosad gave lower plant weight than that from untreated seeds. Control of cabbage root fly by film coating containing chlorpyrifos, chlorfenapyr, cyromazine, fipronil or spinosad was as effective as a drench treatment after transplanting.

Jacob *et al.,* (2009) reported that film-coat application maintained the persistence and potency of imidacloprid on *Lycopersicon esculentum* (L.) Mill. seeds when stored under ambient and regulated environment in paper and aluminium packages.

2.2.3. Influence of film coating on seeds in combination with fungicides and insecticides

A study by Kotlinski (1997) revealed that film coating on seeds of bean, pea, onion and carrot with insecticides *viz.,* imidacloprid, teflubenzuron and prometryn applied together with fungicides Zaprawa, funaben, metalaxyl and vitavax tended to delay or prevent seed germination whereas treatments with carbosulfan with carbendazim + thiram and metalaxyl with the film coating preserved a high germination ability in treated seeds.

Kavitha (2006) reported that in maize, black gram, cotton, tomato and African marigold, seeds hardened with various chemicals and film coated with various fungicides, insecticides, biological agents and micronutrients at different concentration resulted in higher speed of germination, germination percentage, seedling vigour, dehydogenase and α-amylase activity and total chlorophyll content of seedlings under laboratory evaluation. Under pot culture experiment higher emergence, plant growth and yield was observed in treated seeds than in untreated seeds.

In a study conducted by Lima *et al.,* (2006) cotton seeds were treated with 2 types of commercial films (AG201 and TGBP1080), a mixture of fungicides carboxin+thiram and the insecticide imidacloprid at 2.5 and 2.5 $ml.kg^{-1}$ seed and 5 and 5 $ml.kg^{-1}$ seed respectively. The carboxin+thiram and imidacloprid treatment with (5 and 5ml.kg^{-1} seed) was efficient in controlling the fungi (*Aspergillus* sp, *Penicillium* sp, *Fusarium* sp, *Botryodiplodia theobromae* and *Rhizoctonia solani*) on the seeds. The film coating did not affect the germination, emergence and speed of emergence in high quality seeds.

2.2.4. Influence of film coating on seeds with biological agents

In a study conducted by Howell *et al.*, (1997) cotton seeds treated with fungicides or coated with latex sticker and air dried granules of *Trichoderma virens* were planted in seed plots. Results revealed that seedling stand was greater in *T. virens* + metalaxyl treated seed plots than untreated control and seeds treated with fungicides alone.

Whipps and Mc Quilken (2001) reported that film coating with *Coniothyrium minitans* on sunflower seeds infected with *Sclerotinia sclerotiorum* decreased the germination of conidia. It also showed that *C. minitans* had little effect on seedling diseases in tests conducted in a peat-soil mix, but completely suppressed apothecial production of sclerotia when placed in soil. The film-coating process decreased the germination of conidia recovered from sunflower seeds. After storage for a year at 10^0 C, *C. minitans* still grew from 97 per cent of the seeds, and can be efficiently used for commercial seed treatments for biological control of seedling diseases.

In onion film coated seeds in combination with insecticides (fipronil, spinosad, clothianidin or thiamethoxam) @ 25g and 50g a.i/kg of seed respectively provided excellent control of onion maggot ($\leq$ 5 per cent seedling loss) (Nault *et al.*, 2006).

Jetiyanon *et al.*, (2008) studied the film-coating of various crop seeds in combination with treated with *Bacillus cereus* RS87 spores. Both vegetative cells and spores of strain RS87 significantly promoted seed emergence, root length and plant height over the control treatments. The strain RS87 also produced IAA. The film coating of seeds with spores of *B. cereus* RS87 enhanced early plant growth.

In a study conducted by Muller and Berg (2008), rape seeds were treated with various seed treatment such as pelleting, film coating and bio-priming in combination with plant beneficial bacterium *Serratia plymuthica* (HRO-C48) to control verticillium wilt. Results showed that *Serratia* treatment using bio-priming and pelleting resulted in significant control in comparison to the non bacterized controls. Survival of HRO-C48 differed in different treatments and was the highest in bio-priming at 20^0C and in pelleting at 4^0C. The study proved that bio-priming resulted in stable and efficient formulation of *Serratia plymuthica* on rape seed.

Thobunluepop *et al.,* (2008) conducted a study in paddy where seeds were coated with various substances viz., captan, biological seed coating i.e. chitosan-lignosulphonate polymer (CL) and eugenol incorporated into chitosan-lignosulphonate polymer (E+CL). The study revealed improved seed germination, seedling establishment, plant growth and kernel yield in CL and E+CL coating.

Bell pepper seeds were coated with polymers in combination with microorganisms (*Trichoderma viridae, T. polysporhum, T. stromaticum, Beauveria bassiana, Metarhizium anisopliae*), mycorhizas, aminoacids, micronutrients and plant growth regulators in a study conducted by Diniz *et al.,* (2009). Inoculation with *Trichoderma viridae* increased germination and rate of seedling emergence whereas inoculation with *Trichoderma viridae, Metarhizium anisopliae* and mycorrhizas promoted better seedling development.

Storage study conducted in paddy seeds coated with various substances by Thobunluepop (2009) showed that captan treatment had better inhibitory effect on *Alternaria padwickii, Rhizoctonia solani, Curvularia* sp, *Aspergillus flavus* and *A.niger* than chitosan-lignosulphonate polymer (E+CL) whereas E+CL had better inhibitory effect against *Bipolaris oryzae* and *Nigrospora oryzae* as compared to other treatments. Study also reaveled that captan and eugenol incorporated into chitosan lignosulphate polymer were capable of inhibiting most of the fungi until 9 months of storage.

2.2.5. Influence of storage on seeds

Seeds lose their viability during storage and this depends on many factors such as environmental, genetic, pathological etc. Seed treatment with fungicides is one of the methods of protection since it reduces fungal invasion, reduces the growth of conidia, controls seed borne infection and protects seeds from the attack of soil borne pathogens.

2.2.5.1. Influence of fungicides on storage

Martinez and Ramirez (1985) reported that maize seeds treated with benomyl, captan, captafol, chlorothalannil, carbendazim and thiobendazole recorded 99 per cent germination after 330 days of storage as compared to 61 per cent in the untreated seeds.

In cowpea, seeds treated with thiram recorded higher germination (75.00 per cent) as compared to control (72.00 per cent) after 28 months of storage (Gupta and Dharmsingh, 1990).

In a study conducted in sorghum, seeds treated with rovral + bavistin recorded higher germination (82.50 per cent) and less incidence of seed mould (6.12 per cent) as compared to control (58.50 per cent and 46.00 per cent, respectively) (Asalmol and Patil, 1994).

Seeds stored for 18 months after seed treatment with thiram @ $2.5 g.kg^{-1}$ seed recorded higher germination (87.00 per cent) as compared to control (84.00 per cent) in okra (Reddy and Reddy, 1994) and sorghum (Savitri *et al.*, 1994) with values of 52.53 per cent and 41.55 per cent respectively.

Rao *et al.*, (1996) reported that groundnut seeds treated with thiram recorded significantly higher germination (85 per cent) over control (23.4 per cent) even after 24 months of storage.

Varied action of fungicides in controlling storage fungi in sunflower was reported by Thippeswamy and Lokesh (1997). Captan and Captafol were reported to be effective against seed mycoflora whereas Dithane M-45 failed to control seed mycoflora at the lower dosage and showed phytotoxic effect on seedlings at higher doses.

Savitri *et al.*, (1998) reported that groundnut seeds treated with thiram @ 3g.kg^{-1} seed of seeds and stored in cloth bag recorded higher germination (30.66 per cent) and vigour index (452) over control (0.1 per cent and 0.00 per cent respectively) after 18 months of storage.

Merwade (2000) reported that treatment of chickpea seeds with captan significantly increased germination (64.15 per cent), vigour index (1443) and seedling dry weight (1.73g) as compared to control (54.06 per cent, 1312, and 1.54g, respectively) after 10 months of storage.

Soybean seeds treated with thiram @ 2.0g/kg of seeds maintained germination above the seed certification standard (70 per cent) up to seven months of storage (Jawale *et al.*, 2001).

Gupta and Aneja (2004) reported that soybean seeds treated with thiram @2.5g/kg of seeds significantly maintained higher germination (46.30 per cent) as compared to control (36.90 per cent) after 15 months of storage.

2.2.5.2. Influence of insecticides on storage

Jain and Yadav (1989) reported that green gram seeds treated with Malathion dust of 40 ppm and stored at 10 per cent moisture content effectively controlled *Callosobruchus chinensis* and *Callosobruchus analis*.

Ramesh (1993) observed higher vigour in soybean seeds treated with Dithane M-45 @ 2.0g/kg of seeds and Malathion @ 5.0g/kg of seeds after 180 days of storage.

In green gram, seeds treated in combination with insecticides viz., fenvalarte 0.4D and endosulfan 4D (2, 3 and 4g.kg^{-1} seed) were reported to be superior in controlling storage pests as compared to control (Laxminarayan *et al.*, 1998).

Kumar and Santharam (2000) reported that cotton seeds treated with imidacloprid @ 7.0g.kg^{-1} seed recorded higher germination (80.0 per cent) even after 180 days of storage.

Bisong *et al.,* (2002) reported that seed treatment of green gram with higher doses of thiamethoxam and longer exposure resulted in higher mortalities of most of the storage beetles after six days exposure.

Choudhary and Dashad (2002) reported that chickpea seeds treated with endosulfan, monocrotophos and chloropyriphos provided maximum protection against storage pests, but endosulfan and chloropyriphos had no adverse effect on germination.

In black gram, seeds treated with Malathion 50 EC @ 0.5 per cent recorded significantly higher germination (87.66 per cent) over control (70.04 per cent) even after 180 days of storage (Deshpande *et al.,* 2004).

2.2.5.3. Influence of film coating on storage

In an experiment conducted by Costa *et al.,* (2001), carrot (*D. carota* cv. carandai-AG-106) seeds were film coated (Seripet) in combination with fungicides (captan + iprodione + thiram) along with lime, ground limestone or gypsum and stored for 9 months. Seeds treated with film coating alone significantly reduced seed germination and vigour. The seeds coated along with lime germinated well and were more vigorous up to 9 months of storage.

In a storage study conducted in maize by John and Bharathi (2006) seeds were film coated in combination with fungicides, insecticides, micronutrients and macronutrient and were stored for 10 months in gunny bags as well as 700 gauge polyethylene cover. The results showed the storability of film coated seed with polykote @ 3g, carbendazim @2g, imidacloprid @1ml, DAP @30g and micronutrient mixture @ 19.70g.kg^{-1} seed was poor as compared to control. The germination, seedling length, dry matter and vigour index decreased with increase in storage period both in gunny and polyethylene bags, while the protein, dehydrogenase activity and α amylase activity decreased with increase in storage period and electrical conductivity values increased continuously during the storage period.

In another experiment conducted in soybean and maize, seeds were treated with 6 different types of polymers (viz., PVC, Thermocol, PEG, Rosin, Lac and Ethyl Cellulose) and stored for 7 months (Pandey and Kumar 2006). Results indicated that PVC, Rosin, Lac and Ethyl Cellulose were effective in maintaining the storage quality of soybean seeds for 7 months. The best treatment was Ethyl Cellulose which could retain germination above 80 per cent in soybean in comparison with control (49 per cent) after 7 months of storage. In maize, the best treatment was Ethyl Cellulose which resulted in 96 percent germination in comparison with control (89 per cent) after 7 months of storage. Field emergence and vigour index values were also higher in the seeds coated with Ethyl Cellulose.

Giang and Gowda (2007) treated seeds of hybrid rice with synthetic polymers (Polykote TM, and Littles Polykote W Yellow) in combination with fungicides at recommended dosage. The seeds coated with littles polykote W yellow along with captan+ thiram+ gouch+ super red at $1ml.kg^{-1}$ seed and stored in polyethylene bag (700 gauge) recorded highest germination (85.67 per cent) as against the lowest recorded in cloth bag (62 per cent) at the end of the storage period.

In cotton, seeds were treated with film coating at various concentrations in combination with fungicides and insecticides at different ratios, packed in cloth bag and kept in ambient condition (Kunkur *et al.,* 2007). Film coating with thiram @ $1.5g.kg^{-1}$ seed and imidachloprid @ $7.5g.kg^{-1}$ seed recorded higher seed germination (77.40 per cent) followed by seed coating @ 5.0g per kg of seeds with thiram @1.5g/kg seeds (76.10 per cent) as compared to control (52.0 per cent) after 9 months of storage. The decline in germination with advancement in storage period may be attributed to ageing effect, loss of viability and storage condition.

Pereira *et al.*, (2007) conducted a study in which soybean seeds were film (AGL 205 or AGL 202) coated in combination with thiram + thiabendazole, packed in multilayer paper packages and stored for nine months under non-conditioned warehouse conditions. The results showed that thiram + thiabendazole coating had the best performance for germination during storage. The polymers did not affect the physiological quality of the seeds and it also promoted better adherence of the fungicides.

Basavaraj *et al.*, (2008) reported that film coated onion seeds with polymer clear (Polykote) at different concentration viz.,6 ml, 9 ml and 12 ml.kg^{-1} seed with and without fungicide (Thiram @ 2 g.kg^{-1} seed) were stored in polythene bag and aluminium pouch containers. Among the treatments, seeds coated with polymer @ 12 ml + thiram @ 2g.kg^{-1} seed recorded higher germination, vigour index, dry weight of seedlings, lower seed infection and electrical conductivity as compared to control. The seeds stored in aluminium pouch recorded higher seed quality parameters as compared to polyethylene bag throughout the storage period.

In a study conducted by Manjunatha *et al.*, (2008) in chillies the seeds were treated with film coating in combination with fungicides and stored in polyethylene bags for 12 months. Results revealed that the seeds coated with polymer @ 7.0g.kg^{-1} seed and thiram @2.0g.kg^{-1} seed recorded significantly higher germination and field emergence followed by the treatment of polymer @ 5.00g.kg^{-1} seed and thiram 2.0g.kg^{-1} seed. The control treatment recorded the lowest germination at the end of 12 months of storage.

Kavak and Eser (2009) reported that coating of onion seeds with hydrophilic polymers (linseed oil, polyethylene, daran 8600C and vinamul 3240) resulted in reducing imbibition. Seed coats (linseed oil, polyethylene and vinamul 3240) significantly reduced germination before and after storage in 85 per cent relative humidity (RH) for 10 weeks, as these coats formed a physical barrier to primary root protrusion.

2.2.6. Influence of Electrical conductivity (EC) on storage

Ghosh *et al.*, (1980) reported that loss of electrolyte into the imbibing medium increased with ageing and increased content of amino acids was observed in very old rice seeds.

Negative correlation between EC with germination and field emergence was reported by Urbaniak (1984). He also reported that EC is not the accurate estimate of seed quality in frenchbean.

Doijode (1985) reported that the losses of seed sugars, amino acids and leachate conductivity were directly proportional to ageing period and inversely proportional to seed germination of onion.

Increase in electrical conductivity in the leachates of groundnut seed subjected to accelerated ageing was reported by Singh and Khatra (1986). They also correlated decrease in seed viability with increase in leaching of sugars and amino acids.

Dey and Mukherjee (1986) reported that maize seeds subjected to accelerated ageing conditions showed loss of membrane permeability as evidenced by leachate of electrolytes from aged seeds as compared to the non aged seeds. The peroxidise activity of germinated embryo decreased gradually in aged seeds.

Nautiyal *et al.*, (1988) observed that loss of viability in groundnut was due to increase in EC, potassium and sugar content of seed leachates. They also found that reduced seedlings chlorophyll content and increased acid phosphate activity in germinating seeds was associated with loss in cell membrane integrity.

In French bean seeds, Pandey (1989) reported that membrane integrity loss as manifested by electrolyte and solute leakage increased steadily with increase in duration of ageing.

Manjunath (1993) noticed increased EC (307.50 to 1027.75 mmohs/cm) of seed leachate with decrease in vigour levels in groundnut.

Selva and Sen (1992) reported that in paddy, artificially aged embryo exhibited higher acid phosphates activity as compared to unaged and natural aged embryos. Alkaline phosphates activity was found to decrease under both natural and artificial ageing conditions.

Kalpana and Rao (1995) reported that in pigeon pea seeds, progressive loss in seed viability and vigour reduced water uptake, increased leakage of solutes and decline in respiratory activity were accompanied with ageing of seeds. These changes associated with ageing were interpreted as resultants of membrane deterioration.

Perez and Arguello (1995) reported that changes in membrane integrity associated with seed deterioration occurred first in the embryonic axes and can best be monitored by conductivity tests.

A study conducted by Taylor *et al.,* (1995) reported that a slight increase in amino acid leakage was noticed when onion, cabbage, tomato and pepper seeds were artificially aged at 45^0C temperature and 90 per cent relative humidity.

In sunflower, soybean and safflower, seeds underwent accelerated ageing treatment for 112 days resulting in increased leaching of soluble carbohydrates and amino acids as reported by Rai *et al.,* (1995).

Lin and Ferrari (1996) observed greater electrolyte conductivity in aged seeds and a significant correlation between vigour, germination and electrolyte conductivity for all the cultivars under study.

Biradar (1996) noticed increased electrical conductivity of seed leachate as the days of ageing increased in sunflower.

Faster decline in seed germination and seedling vigour was associated with greater leakage and higher production of volatile aldehydes in soybean (Shanmugavel *et al.,* 1996). Similar observations were also made by Nautiyal *et al.,* (1997) in groundnut during ageing.

A study conducted by Kunkur *et al.,* (2007) reported that in cotton at the end of 9 months of storage, electrical conductivity of stored seeds showed lower EC in seeds coated with (thiram @ 1.50g.kg^{-1} seed and imidacloprid @ 7.50g.kg^{-1} seed) 0.98 dSm^{-1} followed by seeds coated with (thiram 5.0g.kg^{-1} seed and thiram @ 1.50g.kg^{-1} seed) 1.05 dSm^{-1}.

Electrical conductivity of stored seeds showed a progressive increase with increase in storage period, the average initial EC value was 0.51 and the final value was 0.66 at the end of 10 months of storage as reported by (Basavaraj *et al.,* 2008) in onion.

In chilli a study was conducted by Manjunatha *et al.,* (2008) which revealed that electrical conductivity of seed leachate increased with increase in the storage period. Lower electrical conductivity was recorded in polymer having 7.0g.kg^{-1} seed (2.02dSm^{-1}) and thiram (2.0g.kg $^{-1}$ seed) followed by polymer having 5.0g.kg^{-1} seed (2.03dSm^{-1}) and thiram (2.0g.kg^{-1} seed) as compared to control (2.19 dSm^{-1}).

2.2.7. Influence of root and shoot length on storage

Metzer (1966) observed significant and positive correlation between germination and seedling length in soybean.

Studies conducted by Ching and Schoolcraft (1968) and Villiers (1972) proved that reduction in seedling length due to ageing was a result of disintegration of cellular membranes. These consequently impaired the growth of the seedlings by leaching of solutes and inter cellular disorganization.

A study conducted in peas and broad beans there was decrease in seedling length when viability fell below 60 per cent. Further, decrease in viability to about 30 per cent had little effect on seedling growth rate than that of control as reported by Abdulla and Roberts (1969).

Sorghum seeds, showed decrease in root and shoot growth with decreased levels of vigour during accelerated ageing as reported by (Carmago and Vaughan 1973).

In sorghum decline in germination induced through accelerated ageing affected the seedling length, seed vigour and field emergence as reported by (Gelmond *et al.*, 1978).

Hussaini *et al.*, (1988) reported that in maize, increase in the period of accelerated ageing (0 to 20 days) at 40^0C temperature and 85± 2 percent relative humidity significantly reduced root length from 11.70 to 5.50 cm and shoot length from 17 to 8.10 cm.

Ramamoothy *et al.*, (1989) observed that storability of maize inbreds and hybrids by subjecting to accelerated ageing from 9 to 14 days and noticed the reduction in root (21.50 to 18.80 cm) and shoot length (11.00 to 8.50 cm) was noticed due to ageing.

Manjunath (1993) reported that groundnut seeds with high initial germination exhibited higher root length (12.41 cm) and shoot length (8.16 cm).

In a study conducted by Pandian *et al.*, (1994) reported reduction in both root and shoot length in 23 genotypes of paddy seeds when they were subjected to accelerated ageing for five days.

Biradar (1996) observed that non aged seeds of sunflower recorded higher germination and greater shoot and root length and vigour indices while periodical accelerated ageing showed reduction in root length (15.75 to 12.11 cm) and shoot length (13.98 to 12.24 cm) and vigour indices during eight days of ageing.

In groundnut seeds, accelerated ageing from 0 to 12 days, decreased the hypocotyl length from 1.66 to 0.25 cm and root length from 7.16 to 1.25 cm (Nautiyal *et al.*, 1997).

2.2.8. Influence of Vigour index

A study conducted by Singh and Khatra (1986) in groundnut seeds stored in gunny bags and PAU storage bin at room temperature at low temperature on seedling vigour, resulted in decreased seedling vigour with increase in storage period irrespective of storage conditions, but the decrease was more in gunny bags than in PAU storage bins at room temperature, but storing seeds at low temperature was found to be the best than storing at room temperature.

In maize, Ramamoothy *et al.*, (1989) observed decline in seedling vigour index (2960 to 2020) with increased ageing period from 9 to 14 days. In sorghum similar trend was reported by Sundareswaran and Krishnasamy (1994).

Pandian *et al.,* (1994) reported that in 23 genotypes of paddy seeds subjected to accelerated ageing for 5 days there was significant reduction in vigour index.

Kalpana and Rao (1995) reported that pigeon pea seeds, showed progressive loss in seedling vigour due to accelerated ageing.

Kunkur *et al.,* (2007) reported that film coated cotton seeds, showed a decrease in vigour index as the storage period increased, the average initial vigour index value was (2501) and the final vigour index value was (1727).

A study by Basavaraj *et al.,* (2008) revealed film coated onion seeds showed higher vigour index (1169) at the end of 10 months of storage when they were stored in aluminium pouches as compared to polyethylene bags (1100).

Manjunatha *et al.,* (2008) reported that film coated chilli seeds showed a drastic decrease in vigour index (795) at the end of 12 months of storage as compared to initial vigour index (1554).

2.3. Effect of film coated treatments on growth, field performance and yield.

To assess the control of onion fly (*Delia antiqua*) a study was conducted by Ester and Vogel (1994) by film-coating leek seeds in combination with insecticides *viz.,* benfuracarb, carbofuran, imidacloprid and isofenphos and comparing with a conventional application of chlorfenvinphos to the seedbed and 2 spray applications of carbofuran. Results revealed that control of onion fly by benfuracarb when applied as a film coat was as effective as the conventional application and also germination of seeds film-coated with benfuracarb was comparable to the untreated controls.

A study conducted under field condition to control the larvae of the seed corn maggot (*Delia platura*) which showed that film coated snap bean seeds treated in combination with insecticides (dichlofenthion) resulted in 3 per cent attacked plants compared to 20 per cent in untreated seeds and 10 per cent in seeds coated with dichlofenthion (1.5 g/5000 seeds). There was no evidence of influence of seed colour on resistance (Neuvel *et al.,* 1996).

A study was conducted to assess the levels of the onion fly (*Delia antiqua*) under field condition in winter leek crop (*Allium porrum*) by film-coating seeds in combination with insecticides *viz.,* diflubenzuron, fipronil, imidacloprid and teflubenzuron (Ester 1999). Good control was achieved, whereas coating with benfuracarb and methiocarb was only moderately effective. The most effective insecticides, fipronil and teflubenzuron, were not phototoxic, whereas imidacloprid prevented some of the seeds from germinating. Benfuracarb and diflubenzuron had a slight phytotoxic effect.

French bean seeds were film-coated with various insecticides *viz.,* chlorpyrifos, furathiocarb, fipronil and novaluron which were compared along with the standard seed treatment of dichlofenthion and untreated seeds. Results showed that film coated seeds with chlorpyrifos in the formulations 75 WG, 250g/litre CS and LOS720 and fipronil 500 FS gave sufficiently good protection against the bean seed fly (*Delia platura* (Meig.)), under field conditions, but furathiocarb and novaluron were not effective. The fipronil and chlorpyrifos formulations 25 CS and LOS 275 did not cause phytotoxicity (Ester *et al.,* 2003.).

In a field study by Ester *et al.,* (2007), film coating on carrot seeds by single or in combination with clothianidin, spinosad or thiamethoxam or combined treatments using spinosad, beta-cyfluthrin, tefluthrin were compared with a standard chlorfenvinphos seed treatment and untreated seeds. Clothianidin and thiamethoxam applied at 10 and 20g a.i per 250,000 seeds resulted in similar or better control than the standard chlorfenvinphos seed treatment, but combined treatments using two insecticides did not improve control of carrot fly larvae.

Kaur and Bishnoi (2008) reported that film-coated canola (*Brassica napus* L.) seeds of cv. Jetton and Abilene were treated with fungicide Helix and Apron.

Film coating agent (CelGard) on cv. Abilene and (DiscoClear) on cv. Jetton. Film-coated seeds showed highest seedling establishment in all three soil types (sandy, silt, and clay loam). Helix along with film coating, gave higher seedling establishment (88.00 per cent in cv. Abilene and 85.00 per cent in cv. Jetton) as compared to other film coated treatments without Helix. Use of fungicide/pesticide further enhanced seedling establishment under field conditions.

Srivastava and Yadav (2006) reported that maize seeds cv. Shaktiman-1 were treated with film coating agent (polykote) in combination with fungicides *viz.*, thiram or carboxin or vitavax and insecticides imidacloprid which resulted in considerable improvement in germination (up to 8 per cent), seedling vigour 1870, field emergence and associated minimal fungal flora when treated with vitavax 200 @ 2.0g.kg^{-1} seed as compared to untreated control (minimal fungal flora by 11.00). It also showed that seed coating with vitavax was found to be effective against triticum leaf blight and sheath blight (*Rhizoctonia solani*).

MATERIALS AND METHODS

3. Materials and Methods

The present investigation was carried out in the Department of Olericulture, College of Horticulture Vellanikkara during the year 2009-2010 with the objective of studying the seed quality enhancement in cowpea (*Vigna unguiculata* (L.) Walp.) by film coating technique.

The site is located at 10^0 31^1 N latitude, 76^0 13^1 E longitude at an altitude of 22.25 m above Mean Sea Level. The area experiences typical warm humid tropical climate and receives an average rainfall of 2663 mm per year. The soil of the experiment site is lateritic in origin grouped under the textural class of sandy clay loam and acidic in reaction.

3.1. Variety

The high yielding cowpea variety Bhagyalakshmi developed by Kerala Agricultural University was selected for the study. This is a bush variety with medium long light green pods.

3.2. Experimental site

Studies on standardisation of the film coating technique and storage were carried out in the departmental laboratory. Field studies were conducted in the field under Department of Olericulture, Kerala Agricultural University, Vellanikkara during the year 2009-2010.

3.3. Film coat

Film coat comprises of binders, wax, pigments and stabilizers. Film coat liquid marketed by "Incotec" was used for treating the seeds.

3.4. Experimental details

3.4.1. Experiment- I: Standardization of the dose and method of applying the film coat.

Laboratory experiments to standardise of the dose of seed film coat and method of application of seed film coat on the seeds were conducted during 2009-10 in the Department of Olericulture, College of Horticulture, Vellanikkara.

Seeds were subjected to dry and wet methods of application of film coat. The details of the treatments are given below.

A. Dry method

Cowpea seeds were treated with film coat compound and the treated seeds were dried back to their original moisture content (10%). The dosage of treatments were as detailed below.

T_1- 5 ml per kg of seed

T_2- 10 ml per kg of seed

T_3- 15 ml per kg of seed

T_4- 20 ml per kg of seed

B. Wet method

In this method, seeds were soaked in water (for 2 minutes), taken out and treated with the film coat at the dosage specified below. The treated seeds were dried back to their original moisture content (10%).

T_5- 5 ml per kg of seed

T_6- 10 ml per kg of seed

T_7- 15 ml per kg of seed

T_8- 20 ml per kg of seed

3.4.1.2. Source of seeds

Cowpea seeds of Bhagyalakshmi variety obtained from seed store of Department of Olericulture were used for the experiment.

3.4.1.3. Design of experiment

The design of experiment adopted was a Complete Randomized Design (CRD) with three replications.

3.4.1.4. Collection of experimental data

The treated seed samples of both dry and wet methods were sown separately in germination trays and the following parameters were recorded.

3.4.1.4.1. Physical appearance

Various physical characters *viz.*, colour, lustre and uniformity of coating were observed in the treated seeds.

3.4.1.4.2. Germination per cent (%)

In each treatment germination was assessed adopting the sand method advocated by ISTA. Four hundred seeds from each treatment were sown in trays containing sterilized sand (4 replications with 100 seeds per replication). Daily observation of germination was recorded upto 8^{th} day. The initial (1^{st} count) and final (2^{nd} count) germination counts were made on fifth and eighth day of germination and expressed in per cent.

3.4.1.5.3. Shoot length (cm)

In each treatment, twenty normal seedlings were selected at random from each lot of each treatment from all the replications on eighth day. The shoot length was measured from the base of the primary leaf to the base of the hypocotyls and expressed in centimetre.

3.4.1.5.4. Root length (cm)

The root length of the normal seedlings selected for shoot length were recorded and expressed in centimetre.

3.4.1.5.5. Vigour index

The Vigour Index (VI) was calculated by adopting the method suggested by Abdul-Baki and Anderson (1973) and vigour index expressed in number.

Vigour Index- 1 = Germination (per cent) X Seedling length (cm)

Vigour Index- 2 = Germination (per cent) X Dry weight (g)

3.4.1.5.6. Speed of Germination

The daily germination count was taken up to the final count. The Speed of Germination (SG) was calculated by adopting the method suggested by Agarwal (2000) and expressed in number.

$$\text{Speed of Germination (SG)} = G_1/T_1 + G_2/T_2 + \ldots\ldots\ldots\ldots + G_n/T_n$$

Where, G_1, G_2,..... G_n are the number of seeds germinated each day.

T_1, T_2 ......T_n are the days of germination test

3.4.1.5.7. Days to fifty per cent germination

The number of days taken from sowing up to fifty per cent germination in each treatment was recorded.

3.4.2. Experiment II: Effect of seed film coating in combination with insecticides, fungicides and bio agents on seed quality parameters and storage.

3.4.2.1. Source of seeds

Freshly harvested untreated seeds of Bhagyalakshmi variety were obtained from seed store of Department of Olericulture to conduct this experiment. Based on experiment-I the best method of dry and wet seed film coating dosage was determined and included in experiment-II. Freshly harvested seeds of cowpea variety "Bhagyalakshmi" were used for this study. The treatments included in experiment-II were as follows.

3.4.2.2. Details of the treatments taken

A. Dry method (20 ml film coat per kg seed)

Treatments	Chemical	Dosage
T_1	Carbaryl (10per cent)	2g per kg of seed
T_2	Carbendazim	2g per kg of seed
T_3	Carbaryl (10per cent) + Carbendazim	(1g + 1g per kg of seed)
T_4	*Trichoderma*	4g per kg of seed
T_5	*Pseudomonas*	10g per kg of seed
T_6	*Trichoderma* + *Pseudomonas*	(2g + 5g per kg of seed)
T_7	Film coated control	-
T_8	Untreated control	-

B. Wet method (20 ml film coat per kg seed)

Treatments	Chemical	Dosage
T_1	Carbaryl (10per cent)	2g per kg of seed
T_2	Carbendazim	2g per kg of seed
T_3	Carbaryl (10per cent) + Carbendazim	(1g each per kg of seed)
T_4	*Trichoderma*	4g per kg of seed
T_5	*Pseudomonas*	10g per kg of seed
T_6	*Trichoderma* + *Pseudomonas*	(2g + 5g per kg of seed)
T_7	Film coated control	-
T_8	Untreated control	-

3.4.2.3. Method of seed treatment

Fresh untreated seeds were taken in an air tight plastic container. They were treated separately with film coating, Carbendazim, Carbaryl, *Trichoderma*, and *Pseudomonas* as per the treatment combination. The dose of the film coat used for seed treatment was based on the results of experiment-I. The container was closed tightly and shaken till the seeds were uniformly coated. The treated seeds were dried back to their original moisture content (10%).

3.4.2.4. Method of seed storage

The treated seeds were stored in high density polyethylene cover under ambient condition for twelve months. The observations were recorded at quarterly intervals.

3.4.2.5. Design of experiment

The design of the experiment adopted was CRD (Complete Randomized Design) with 3 replications.

3.4.2.6. Collection of experimental data

The treated seed samples were sown in germination trays and the following seed quality parameters were recorded *viz.,* Germination per cent (first and final count on 5^{th} and 8^{th} day respectively), Shoot length (cm), Root length (cm), Vigour index, Speed of germination and Days to fifty per cent germination. Observations on pest incidence and fungal attack were also recorded. Tests on electrical conductivity, dehydrogenase enzyme and protein content of the seed samples were also done.

3.4.2.6.1 Pest incidence

Observed for the incidence of pest in storage.

3.4.2.6.2 Fungal attack

Observed for the incidence of storage fungi.

3.4.2.6.3. Electrical conductivity (dSm^{-1})

In each treatment, five grams of seeds per replication were surface sterilized using 0.1 per cent mercuric chloride solution and rinsed with water thoroughly. These seeds were soaked in 25ml distilled water in a beaker and kept in an incubator maintained at 25 $\pm 10^{0}C$ temperature. After 24 hrs of soaking, the solution was decanted and the volume made up to 25 ml using distilled water. The electrical conductivity was recorded using the digital conductivity meter and expressed in decisimens per metre (dSm^{-1}).

3.4.2.6.4. Enzyme dehydrogenase test

Aqueous solution of 2, 3, 5- Triphenyl Tetrazolium Chloride (T.T.C- 0.25per cent) (pH 7.0) was prepared in 1000ml of Sorenson's phosphate buffer.

The buffer was prepared by mixing 400 ml of aqueous solution of A (9.078g KH_2PO_4/in 1 litre distilled water) with 600 ml of aqueous solution B (11.376g Na_2HPO_4/in 1 litre distilled water).

Seeds were preconditioned by soaking in water for 24 hours. The embryos of 10 seeds from each replication were removed carefully and placed over a filter paper in petridish. T.T.C was added to immerse the embryos and kept in darkness for 12 hours. The excess T.T.C solution was decanted and seeds thoroughly washed with distilled water. The colour was eluted from the stained embryos by steeping in 2ml of 2-methoxy ethanol (methyl cellulosolve) for 1 hour before decanting the solution. The intensity of red colour of the decanted solution was read in spectrophotometer at 470 nm.

3.4.2.6.5. Protein estimation (Lowry's method)

Reagents required

Reagent A- 2g Na_2CO_3 in 100ml 0.1 NaOH

Reagent B- 0.5g $CuSO_4.5H_2O$ in 100ml 1per cent Potassium Sodium Tartarate

Reagent C- 50ml of Reagent A and 1ml of Reagent B mixed prior to use.

Reagent D- 1 ml of Folin is mixed with 2 ml of water

Procedure

0.5g of seed sample was ground into fine powder and mixed with phosphate buffer of 7.0 pH. It was then centrifuged at 12,000 rpm for 15 minutes. 0.1 ml of decanted solution was made up to 1ml with water. 5 ml of Reagent C was added to all the test tubes, mixed well and kept for 10 minutes. 0.5 ml of Reagent D was added. After 30 minutes, the colour development was measured in spectrophotometer at 670 nm.

3.4.3. Experiment III: Effect of seed film coating on field performance and yield of cowpea.

3.4.3.1. Source of seeds

Film coated seeds (8 treatments mentioned in experiment-II) were used to study the field performance and yield of each treatment.

3.4.3.2. Design of experiment

The design of the experiment adopted was Randomised Block Design (RBD) with three replications.

3.4.3.3. Field experiment

The experiment comprised of eight treatments with three replication each. Sixty plants were raised per replication in a plot of $2.7m^2$ at a spacing of 0.3m x 0.15m following the package of practices recommendation of KAU, (2007).

3.4.3.4. Biometrical characters recorded.

The following observations were recorded on 10 plants selected at random per replication in each treatment.

3.4.3.4.1. Field germination

Field emergence was recorded on daily basis for a period of 8 days from sowing and expressed as per cent.

3.4.3.4.2. Days to fifty per cent germination

The number of days taken from sowing upto fifty per cent germination in each treatment was recorded and expressed as per cent.

3.4.3.4.3. Days to first harvest

The number of days taken form sowing to first harvest of the fruits in twenty plants per replication in each treatment was recorded and the mean number of days calculated.

3.4.3.4.4. Number of fruits per plant

Total number of fruits from twenty plants per replication in each treatment was counted and the mean number of fruits per plant calculated.

3.4.3.4.5. Average fruit length (cm)

Total length of twenty fruits per replication of each treatment was recorded and average fruit length calculated and expressed in centimetre.

3.4.3.4.6. Average fruit weight (g)

Weight of twenty fruits from each plant per replication was recorded and average fruit weight was calculated and expressed in grams (g).

3.4.3.4.7. Fruit yield per plant (g)

Total weight of fruits obtained from twenty plants per replication in each treatment was recorded and average calculated to obtain fruit yield per plant and expressed in gram (g).

3.4.3.4.8. Number of harvests

Number of harvests obtained from twenty plants in each treatment per replication was recorded.

3.4.3.4.9. Plot yield (kg)

The total yield of vegetable cowpea obtained from each replication of each treatment ($2.7m^2$) was recorded and expressed in kilogram (kg).

3.4.3.4.10. Pest and Disease incidence

Observed for the incidence of pest or diseases in the field.

RESULTS

4. RESULTS

The study on "Seed quality enhancement in cowpea (*Vigna unguiculata* (L.) Walp.) by film coating technique" comprises of three experiments *viz.,*

- Standardization of the dose and method of application of the film coat.
- Effect of seed film coating in combination with insecticides, fungicides and bio-agents on seed quality and storage.
- Effect of film coated treatments on growth, field performance and yield of cowpea.

Results of the above experiments are given below:

Experiment- I

4.1 Standardization of the dose and method of application of the seed film coat.

The results of the standardization of film coat with respect to various parameters *viz.,* physical appearance, initial germination per cent, final germination per cent, speed of germination, days for 50 per cent germination, root length, shoot length and vigour indices are presented below.

4.1.1. Physical appearance like colour, lustre and uniformity of coating.

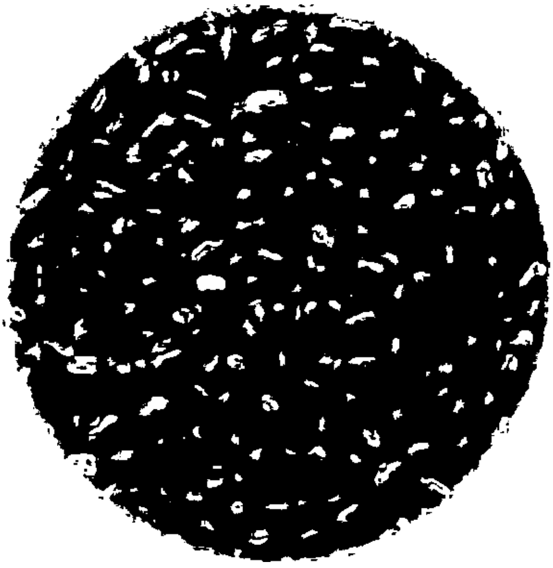
Effect of film coating on physical parameters *viz.,* colour and lustre is given in (Table 1a). The intensity of the colour, lustre and uniformity of coating was found to increase with increase in the dose of the film coat in both the methods of treatment. Bright colour, good lustre (shiny seeds) and uniformity of coating was obtained in T_4 (20 ml per kg of seed) and T_8 (20 ml per kg of seed) of dry and wet methods of film coating respectively. Colour, lustre and uniformity of coating were very low in T_1 and T_5 (5 ml per kg of seed) in the both methods of treatment. As the dose increased, there was improvement in physical appearance (Plate 1).

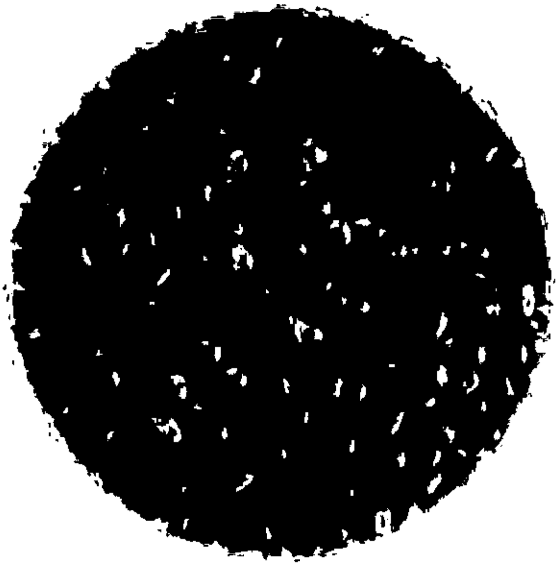
Table 1a: Effect of film coating on physical appearance on seed.

Treatments	Colour	Lustre	Uniformity of coating
Dry method T_1 (5 ml / kg seed)	Negligible Red	Not shining	Not uniform
T_2 (10 ml / kg seed)	Light Red	Not shining	Not uniform
T_3 (15 ml / kg seed)	Red	Slight shine	Almost uniform
T_4 (20 ml / kg seed)	Bright Red	Shiny	Uniform
Wet method T_5 (5 ml / kg seed)	Negligible Red	Not shining	Not uniform
T_6 (10 ml / kg seed)	Light Red	Not shining	Not uniform
T_7 (15 ml / kg seed)	Red	Slight shine	Almost uniform
T_8 (20 ml / kg seed)	Bright Red	Shiny	Uniform

Plate 1: Physical appearance of film coated seeds

Dry method:

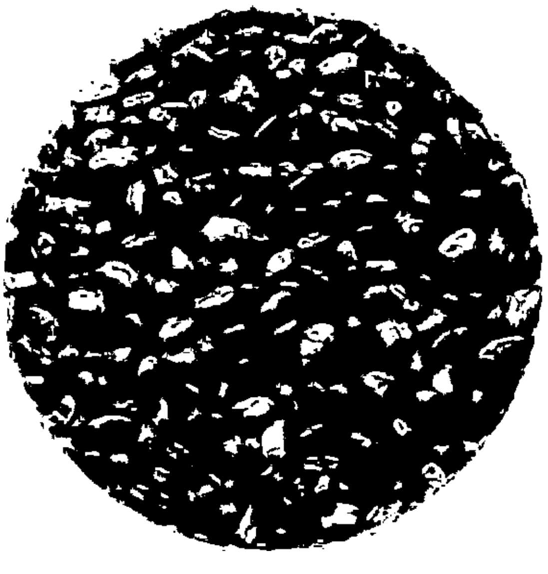


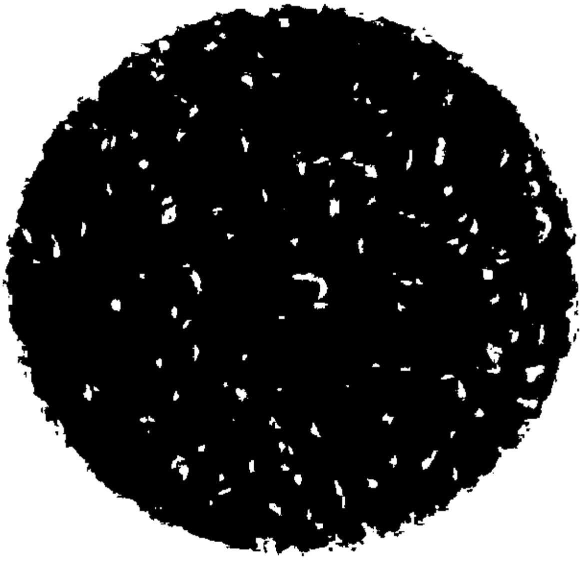


5ml/kg seed

20 ml/kg seed

Wet method:





5 ml /kg seed

20 ml/kg seed

4.1.2. Germination parameters.

In the dry method of film coating, the initial germination (1st count) was found to be highest in T_1 (77.33 per cent) followed by T_2 (72.67 per cent) and in wet method of coating, highest initial germination was obtained in T_7 (78.67per cent) followed by T_5 (74.67per cent). Initial germination were the lowest in T_4 (59.33 per cent) and T_8 (53.33 per cent) of dry and wet method respectively (Table 1b).

The final germination after eight days of sowing was found to be the highest in T_4 (88.00per cent) followed by T_3 (86.67per cent) of dry method and T_8 (85.33per cent) followed by T_7 (78.67per cent) of wet method. Final germination was found to be the lowest in T_5 (75.33per cent) and T_6 (74.00per cent) of wet method (Table 1b) (Plate 2).

The speed of germination, ranged from 51.35 (T_6) to 57.72 (T_7) and there was no significant difference between the treatments (Table 1b).

There was no significant difference between treatments with respect to days for 50per cent germination. Fifty per cent germination was attained on 2nd day after sowing in all the treatments except T_8 (Table 1b).

4.1.3. Root and Shoot length.

In dry method of seed treatment, long roots were observed in T_4 (13.83 cm) followed by T_3 (13.37 cm) whereas in wet method of seed treatment T_8 (13.69 cm) and T_7 (13.55 cm) recorded longest roots. Among the different treatments, length of root was found to be the lowest in T_1 (11.61 cm) (Table 1c).

Similarly in dry method of film coating, the shoot length was found to be the highest in T_4 (21.66 cm) followed by T_3 (21.00 cm) whereas T_8 (21.90 cm) followed by T_7 (21.68 cm) recorded highest values for shoot length in wet method of film coating. Shoot length values were found to be the lowest in T_1 (18.63 cm) (Table 1c).

Plate 2: Effect of film coating on germination per cent

1. **Dry method**

T1 (5 ml/kg seed)

T2 (10 ml/kg seed)

T3 (15 ml/kg seed)

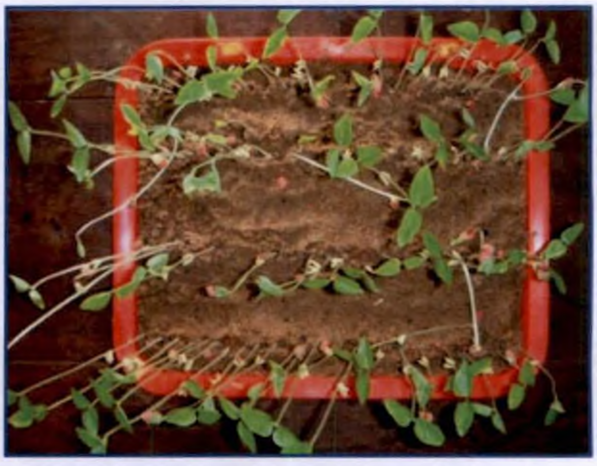
T4 (20 ml/kg seed)

2. **Wet method**

T5 (5 ml/kg seed)

T6 (10 ml/kg seed)

T7 (15 ml/kg seed)



T8 (20 ml/kg seed)

Table 1b: Effect of film coating on germination parameters.

Treatments		Initial Germination Per cent	Final Germination Per cent	Speed of Germination	Days to 50per cent Germination
Dry method	T_1	77.33 ^{ab}	78.67 ^{ab}	56.98 ^{a}	2.00 ^{a}
	T_2	72.67 ^{abc}	81.33 ^{ab}	56.43 ^{a}	2.00 ^{a}
	T_3	62.67 ^{cd}	86.67 ^{a}	56.80 ^{a}	2.00 ^{a}
	T_4	59.33 ^{d}	88.00 ^{a}	56.75 ^{a}	2.00 ^{a}
Wet method	T_5	74.67 ^{abc}	75.33 ^{b}	54.42 ^{a}	2.00 ^{a}
	T_6	64.67 ^{bcd}	74.00 ^{b}	51.35 ^{a}	2.00 ^{a}
	T_7	78.67 ^{a}	78.67 ^{ab}	57.72 ^{a}	2.00 ^{a}
	T_8	53.33 ^{d}	85.33 ^{a}	53.14 ^{a}	2.33 ^{a}

Same alphabets show homogenous effect.

Table 1c: Effect of film coating on shoot and root length and vigour indices.

Treatments		Shoot Length (cm)	Root Length (cm)	Vigour Index 1	Vigour Index 2
Dry method	T_1	18.63 ^{e}	11.61 ^{f}	2378 ^{d}	58.79 ^{d}
	T_2	20.04 ^{d}	12.59 ^{e}	2654 ^{bcd}	71.33 ^{abc}
	T_3	21.00 ^{bc}	13.37 ^{bc}	2979 ^{ab}	78.11 ^{a}
	T_4	21.66 ^{ab}	13.83 ^{a}	3125 ^{a}	81.33 ^{a}
Wet method	T_5	20.37 ^{cd}	12.99 ^{d}	2511 ^{cd}	64.83 ^{bcd}
	T_6	20.92 ^{bc}	13.31 ^{c}	2533 ^{cd}	59.70 ^{d}
	T_7	21.68 ^{ab}	13.55 ^{abc}	2803 ^{abc}	62.15 ^{cd}
	T_8	21.90 ^{a}	13.69 ^{ab}	3010 ^{ab}	72.70 ^{ab}

Same alphabets show homogenous effect.

4.1.4. Vigour indices.

Vigour index 1 was found to be highest in T4 (3125) followed by T3 (2979) in dry method and T8 (3010) followed by T7 (2803) in wet method. Lowest values for vigour index were observed in T1 (2378) and T5 (2511) of dry and wet methods respectively (Table 1c).

Vigour index 2 was found to be the highest in T4 (81.33) followed by T3 (78.11) of dry method and in wet method, T8 (72.70) recorded highest value for this character. Lowest values for vigour index-2 were recorded in T1 (58.79) and T6 (59.70) of dry and wet methods respectively (Table 1c).

Experiment- II

4.2. Effect of film coating in combination with insecticides, fungicides and bio-agents on seed quality and storage.

The best dose standardized in each method of film coating was selected for this experiment. T_4 in dry method and T_8 in wet method were found to be the best in experiment-I and therefore seed film coating using these methods were done after treatment with insecticides, fungicides, bio-agents and their combinations and compared with control. A portion of coated seeds were sown in field and the other half stored at ambient temperature. Results obtained in this experiment on seed quality parameters with respect to storage are given below.

4.2.1. Initial germination per cent (First count)

Initial germination per cent varied throughout the storage period. Among dry method of film coated seeds, the best treatment before storage (0^{th} month) was T_4 with 73 per cent germination in 5 days after sowing whereas lowest germination (38 per cent) was recorded in control (T_8). At 3 months storage period, initial germination per cent decreased from 36-46 per cent. There was no significant variation between treatments during this period. After 6 months storage period, T_5 recorded highest germination (41.67per cent) whereas untreated control recorded the lowest germination of 28.3per cent. After 9 months of storage, T_5 again recorded highest germination (31.61) and at the end of one year no significant variation was noticed among the treatments for germination (Table 2a).

In wet method of film coating, highest initial germination of 85 per cent was observed in T_4 before storage and no significant variation was found between other treatments during that period. After 3 months of storage, the initial germination per cent was in the range of 38-53 and at the end of 6 months, germination per cent reduced considerably with values in the range of 26-33per cent. No significant variation was noticed between treatments after 3 and 6 months of storage. At the end of 9 months, T_5 recorded the highest germination of 26per cent whereas T_8 (control) recorded very low per cent of 1.6per cent. At the end of 12 months, cowpea seeds did not germinate except T_5 (5 per cent germination) (Table 2b).

4.2.2. Final germination per cent (Final count)

Final germination decreased with increase in the storage period. The best treatment at 0 month (before storage) was T_4 with the highest germination per cent of 100 whereas T_8 recorded the lowest germination of 85per cent. After 3 months of storage, germination was found to decrease with highest value (95per cent) in T_5 and lowest in T_8 (81.67per cent). Germination per cent was more than 80per cent after 6 months of storage in all the treatments. After 9 months of storage, germination of seeds was less than 80per cent in all the treatments except T_5 with the highest value of 86.66per cent whereas T_8 recorded the lowest germination per cent of 53.33per cent. After 1 year of storage, germination per cent fell below minimum standard for seed certification in all the treatments except T_5 with a value of 71.67per cent (Table 2c).

Table 2a: Effect of film coating in combination with chemicals and bio-agents on initial germination of cowpea seed (dry method of film coating).

Treatments	Initial germination per cent (1st count)				
	0 month	3 months	6 months	9 months	12 months
T_1	43.33 [b]	40.00 [a]	33.33 [ab]	23.33 [ab]	16.67 [a]
T_2	40.00 [b]	40.00 [a]	35.00 [ab]	21.67 [b]	15.00 [a]
T_3	46.67 [b]	40.00 [a]	35.00 [ab]	20.00 [b]	16.67 [a]
T_4	73.33 [a]	43.33 [a]	40.00 [ab]	23.33 [ab]	18.33 [a]
T_5	50.00 [ab]	46.67 [a]	41.67 [a]	31.67 [a]	25.00 [a]
T_6	43.33 [b]	45.00 [a]	35.00 [ab]	21.67 [b]	18.33 [a]
T_7	40.00 [b]	38.33 [a]	35.00 [ab]	20.00 [b]	16.67 [a]
T_8	38.33 [b]	36.67 [a]	28.33 [b]	16.67 [b]	13.33 [a]

Same alphabets show homogenous effect.

Table 2b: Effect of seed film coating in combination with chemicals and bio-agents on initial germination of cowpea seed (wet method of film coating).

Treatments	Initial germination per cent (1st count)				
	0 month	3 months	6 months	9 months	12 months
T_1	63.33 [b]	41.67 [a]	31.67 [a]	20.00 [ab]	0
T_2	45.00 [b]	40.00 [a]	30.00 [a]	21.67 [ab]	0
T_3	50.00 [b]	41.67 [a]	31.67 [a]	23.33 [ab]	0
T_4	85.00 [a]	43.33 [a]	31.67 [a]	23.33 [ab]	0
T_5	53.33 [b]	53.33 [a]	33.33 [a]	26.67 [a]	5.00
T_6	65.00 [b]	41.67 [a]	30.00 [a]	21.67 [ab]	0
T_7	60.00 [b]	40.00 [a]	31.67 [a]	18.33 [b]	0
T_8	48.33 [b]	38.33 [a]	26.67 [a]	1.66 [c]	0

Same alphabets show homogenous effect.

Table 2c: Effect of seed film coating in combination with chemicals and bio-agents on final germination of cowpea seed (dry method of film coating).

Treatments	Final germination per cent (Final count)				
	0 month	3 months	6 months	9 months	12 months
T_1	93.33 ^{b}	85.00 ^{bc}	85.00 ^{ab}	78.33 ^{ab}	33.33 ^{b}
T_2	95.00 ^{b}	91.67 ^{ab}	85.00 ^{ab}	78.33 ^{ab}	35.00 ^{b}
T_3	95.00 ^{b}	90.00 ^{ab}	85.00 ^{ab}	80.00 ^{ab}	36.67 ^{b}
T_4	100.0 ^{a}	91.67 ^{ab}	83.33 ^{abc}	80.00 ^{ab}	35.00 ^{b}
T_5	96.67 ^{b}	95.00 ^{a}	91.67 ^{a}	86.66 ^{a}	71.67 ^{a}
T_6	93.33 ^{b}	88.33 ^{abc}	81.67 ^{bc}	76.67 ^{ab}	31.67 ^{b}
T_7	91.67 ^{b}	85.00 ^{bc}	81.67 ^{bc}	71.67 ^{ab}	31.67 ^{b}
T_8	85.00 ^{c}	81.67 ^{c}	75.00 ^{c}	53.33 ^{c}	28.33 ^{b}

Same alphabets show homogenous effect.

In wet method of seed treatment, the best treatment at 0 month (before storage) was T_4 with highest germination per cent of 100 whereas T_8 recorded the lowest germination of 90per cent only. After 3 months of storage, germination was found to decrease with highest value (90.0per cent) in T_5 and lowest in T_8 (77.00per cent). Germination per cent was more than 80 after 6 months of storage in all the treatments except controls with the highest value of 87.00per cent in T_5 and lowest value of 75.00per cent in T_8. After 9 months of storage, germination of seeds was less than the minimum per cent specified in the seed standards in all the treatments. After one year of storage, seeds lost viability except T_5 which recorded 10per cent germination (Table 2d) (Plate 3).

4.2.3. Speed of germination

During storage, in dry method of seed coating, T_4 exhibited significantly high speed of germination (58.95) whereas no difference was noticed among other treatments. After 3 months period of storage, variation was noticed among the treatments for this character with highest value of 40.97 in T_4 and lowest in T_8 (34.81). At the end of 6 months, speed of germination was found to be maximum in T_5 (37.54) followed by T_4 and T_3 whereas untreated control (T_8) recorded lowest value for this character (28.99). After 9 and 12 months of seed storage, T_5 exhibited highest value for speed of germination recording 35.1 and 29.35 respectively (Table 2e).

In wet method, speed of germination decreased with storage period. At 0 month storage period, T_4 recorded highest value (51.73) whereas T_8 recorded the lowest value of 39.50. At 3 months storage, speed of germination was found to be maximum in T_5 (42.65) and no significant variation was noticed among other treatments in that period. At 6 months storage period, T_5 again was found superior to all the other treatments showing highest value of 32.79. T_8 recorded the lowest value for speed of

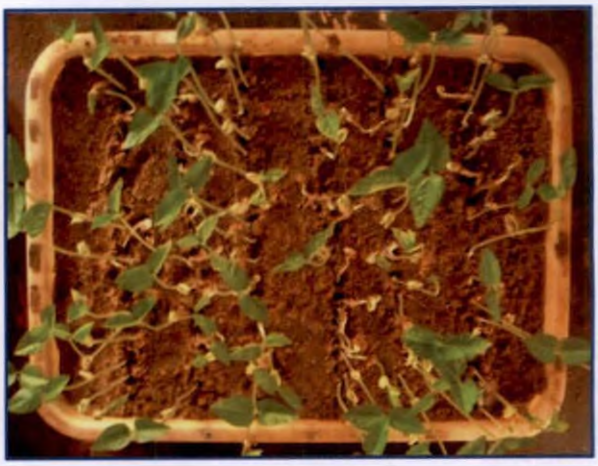
Table 2d: Effect of seed film coating in combination with chemicals and bio-agents on final germination per cent of cowpea seed (wet method of film coating).

Treatments	Final germination per cent (Final count)				
	0 month	3 months	6 months	9 months	12 months
T_1	93.33 ^{ab}	83.33 ^{abc}	82.33 ^{abc}	48.33 ^{ab}	0
T_2	90.00 ^{b}	85.00 ^{ab}	82.00 ^{ab}	45.00 ^{ab}	0
T_3	95.00 ^{ab}	86.67 ^{ab}	80.33 ^{abc}	46.67 ^{ab}	0
T_4	100.0 ^{a}	81.67 ^{abc}	80.33 ^{abc}	46.67 ^{ab}	0
T_5	95.00 ^{ab}	90.00 ^{a}	87.00 ^{a}	48.33 ^{a}	10.00
T_6	95.00 ^{ab}	81.67 ^{abc}	80.33 ^{abc}	41.67 ^{ab}	0
T_7	91.67 ^{b}	80.00 ^{bc}	77.00 ^{bc}	36.67 ^{b}	0
T_8	90.00 ^{b}	77.00 ^{c}	75.00 ^{c}	21.66 ^{b}	0

Same alphabets show homogenous effect.

Plate 3: Effect of film coating on germination and vigour of seedlings

At 0 month storage (Dry and Wet method)



T4 (*Trichoderma* 4g/ kg seed) **T8 (Untreated control)**

At 6 months storage (Dry and Wet method)

T5 (*Pseudomonas* 10g/ kg seed) **T8 (Untreated control)**

At 12 months storage (Dry and Wet method)

T5 (*Pseudomonas* 10g/ kg seed) **T8 (Untreated control)**

Table 2e: Effect of seed film coating in combination with chemicals and bio-agents on speed of germination of cowpea seed (dry method of film coating).

Treatments	Speed of germination				
	0 month	3 months	6 months	9 months	12 months
T_1	48.29 [b]	36.42 [bc]	32.37 [bc]	29.19 [b]	12.68 [b]
T_2	45.03 [b]	39.16 [ab]	32.65 [bc]	29.95 [ab]	12.93 [b]
T_3	46.98 [b]	37.07 [abc]	33.48 [ab]	29.79 [ab]	14.57 [b]
T_4	58.95 [a]	40.97 [a]	34.10 [ab]	30.55 [ab]	13.69 [b]
T_5	47.75 [b]	39.66 [ab]	37.54 [a]	35.10 [a]	29.35 [a]
T_6	46.63 [b]	38.11 [abc]	32.64 [bc]	29.01 [b]	12.43 [b]
T_7	46.27 [b]	35.94 [bc]	32.22 [bc]	26.94 [b]	12.15 [b]
T_8	48.40 [b]	34.81 [c]	28.99 [c]	19.32 [b]	10.12 [b]

Same alphabets show homogenous effect.

germination (27.02) during this period. After 9 months of storage, T_5 recorded highest value (19) and T_7 and T_8 recorded the lowest values of 11.29 and 0.91respectively. At the end of 12 months T_5 recorded a value of 4.63 whereas no germination was obtained in other treatments (Table 2f).

4.2.4. Days for 50% germination

Number of days required for obtaining 50per cent germination increased with increase in the storage period. The best treatment during the month of storage (0 months) was T_4 which took only 3.33 days to attain 50per centgermination whereas T_2, T_7 and T_8 took 4.00 days to obtain 50per cent germination. After 3 months of storage, 50per cent germination was obtained in 3.33 days in T_5. T_2, T_3, T_4 and T_1, T_7 and T_8 took 4.00 days to achieve 50per cent germination. At the end of 6 months of storage, 50per cent germination was obtained by 4 days in all the treatments. After 9 months of storage, T_5 took 4 days to reach 50per cent germination whereas other treatments took 4.33-4.66 days. At the end of 9 months of storage T_8 germination did not reach 50 per cent. After 1 year of storage, only T_5 obtained 50per cent germination in 4.66 days whereas in all other treatments, germination was less than 50per cent (Table 2g).

In wet method of seed treatment, also the days required to attain 50per cent germination increased with increase in the storage period. The best treatments during the month of storage (0 months) took 3.00 days only for getting 50 per cent germination which included all treatments except T_2 and T_3 which took 3.66 days to obtain 50per cent germination. After 3 months of storage, all the treatments except T_5 (3 days) took more number of days for getting 50per cent germination. After 6 months of storage, 50per cent germination was obtained in 4 days in all the treatments except T_5 (3.66 days). After 9 months of storage, none of the treatments attained 50per cent germination (Table 2h).

Table 2f: Effect of seed film coating in combination with chemicals and bio-agents on speed of germination of cowpea seed (wet method of film coating).

Treatments	Speed of germination				
	0 month	3 months	6 months	9 months	12 months
T_1	44.54 ^{bc}	36.92 ^{b}	29.77 ^{ab}	15.99 ^{ab}	0
T_2	40.43 ^{bc}	37.91 ^{b}	30.33 ^{ab}	15.00 ^{ab}	0
T_3	42.54 ^{bc}	38.40 ^{b}	30.39 ^{ab}	15.92 ^{ab}	0
T_4	51.73 ^{a}	37.40 ^{b}	29.56 ^{ab}	15.92 ^{ab}	0
T_5	45.66 ^{b}	42.65 ^{a}	32.79 ^{a}	19.00 ^{a}	4.63
T_6	45.59 ^{b}	37.54 ^{b}	29.70 ^{ab}	13.74 ^{ab}	0
T_7	43.77 ^{bc}	36.63 ^{b}	29.13 ^{ab}	11.29 ^{b}	0
T_8	39.50 ^{c}	34.66 ^{b}	27.02 ^{b}	0.91 ^{c}	0

Same alphabets show homogenous effect.

Table 2g: Effect of seed film coating in combination with chemicals and bio-agents on days to 50per cent germination of cowpea seed (dry method of film coating).

Treatments	Days to 50% germination				
	0 month	3 months	6 months	9 months	12 months
T_1	3.66 ^{ab}	4.00 ^{a}	4.00 ^{a}	4.66 ^{a}	0
T_2	4.00 ^{a}	3.66 ^{ab}	4.00 ^{a}	4.33 ^{ab}	0
T_3	3.66 ^{ab}	3.66 ^{ab}	4.00 ^{a}	4.33 ^{ab}	0
T_4	3.33 ^{b}	3.33 ^{b}	4.00 ^{a}	4.33 ^{ab}	0
T_5	3.66 ^{ab}	3.66 ^{ab}	4.00 ^{a}	4.00 ^{b}	4.66
T_6	3.66 ^{ab}	3.66 ^{ab}	4.00 ^{a}	4.33 ^{ab}	0
T_7	4.00 ^{a}	4.00 ^{a}	4.00 ^{a}	4.66 ^{a}	0
T_8	4.00 ^{a}	4.00 ^{a}	4.00 ^{a}	0 ^{c}	0

Same alphabets show homogenous effect.

Table 2h: Effect of seed film coating in combination with chemicals and bio-agents on days to 50per cent germination of cowpea seed (wet method of film coating).

Treatments	Days to 50% germination				
	0 month	3 months	6 months	9 months	12 months
T_1	3.00 [b]	4.00 [a]	4.00 [a]	0	0
T_2	3.66 [a]	3.66 [ab]	4.00 [a]	0	0
T_3	3.66 [a]	3.66 [ab]	4.00 [a]	0	0
T_4	3.00 [b]	3.66 [ab]	4.00 [a]	0	0
T_5	3.00 [b]	3.00 [b]	3.66 [b]	0	0
T_6	3.00 [b]	3.66 [ab]	4.00 [a]	0	0
T_7	3.00 [b]	4.00 [a]	4.00 [a]	0	0
T_8	3.00 [b]	4.00 [a]	4.00 [a]	0	0

Same alphabets show homogenous effect.

4.2.5. Root and shoot length

4.2.5.1. Root length

During the month of storage, T_4 exhibited maximum root length (13.96 cm) whereas T_1 and T_8 recorded lowest values for root length. At the end of 3 months, root length was found to be maximum in T_4 (13.85 cm) and T_7 and T_8 recorded the lowest value of root length in that period. Significant variation was noticed for this character at the end of 6 months of storage with highest value in T_4 (13.01 cm) followed by T_5 (12.36 cm). After 9 months of storage, T_4 and T_5 recorded maximum root length of 12 cm whereas no significant variation was noticed among other treatments for this character at this storage period. After 12 months of storage, root length was minimum (9 cm) in T_7 and T_8 whereas T_4 and T_5 recorded maximum root length (11.68 cm and 11.36 cm respectively) (Table 2i).

In wet method of seed coating, before storage (0 month), no significant difference was noticed between the treatments for root length. At 3 and 6 months after storage, root length was found maximum in T_4 and minimum in T_8 and the root length decreased from 13.56 (3 month) to 12.49 cm (6 month) in T_4. After 9 months of storage, maximum value of 10.25 was observed for this character in T_5 and minimum value of 8.22 cm was recorded in T_8. After 12 months of storage, germination was observed only in T_5 and root length recorded in that treatment was 8.52 cm (Table 2j).

4.2.5.2. Shoot length

In dry method of seed coating, before storage (0month) maximum shoot length observed was 23.36 cm (T_4) and it reduced gradually and reached to 17.77 cm in T_8 at the end of 12 months storage. During the month of storage and after 3, 6 and 9 months of storage T_4 was the best treatment recording highest value for shoot length and T_8 recorded the lowest value for shoot length. After 12 months of storage, shoot

Table 2i: Effect of seed film coating in combination with chemicals and bio-agents on root length (cm) of cowpea seed (dry method of film coating).

Treatments	Root length (cm)				
	0 month	3 months	6 months	9 months	12 months
T_1	12.89 [b]	12.48 [ab]	11.42 [bc]	11.03 [b]	10.34 [bc]
T_2	13.13 [ab]	12.57 [ab]	11.15 [c]	11.09 [b]	10.31 [bc]
T_3	13.30 [ab]	12.32 [ab]	12.10 [abc]	11.08 [b]	10.45 [bc]
T_4	13.96 [a]	13.85 [a]	13.01 [a]	12.75 [a]	11.68 [a]
T_5	13.40 [ab]	12.80 [ab]	12.36 [ab]	12.11 [a]	11.36 [ab]
T_6	13.20 [ab]	12.36 [ab]	11.77 [bc]	10.98 [b]	10.35 [bc]
T_7	13.32 [ab]	12.19 [b]	11.90 [bc]	10.74 [b]	9.60 [c]
T_8	12.83 [b]	11.91 [b]	11.63 [bc]	10.58 [b]	9.53 [c]

Same alphabets show homogenous effect.

Table 2j: Effect of seed film coating in combination with chemicals and bio-agents on root length (cm) of cowpea seed (wet method of film coating).

Treatments	Root length (cm)				
	0 month	3 months	6 months	9 months	12 months
T_1	13.34 [a]	13.04 [ab]	11.58 [ab]	9.25 [ab]	0
T_2	13.11 [a]	13.07 [ab]	12.06 [ab]	9.66 [ab]	0
T_3	13.23 [a]	13.18 [ab]	11.74 [ab]	9.68 [ab]	0
T_4	13.98 [a]	13.56 [a]	12.49 [a]	9.62 [ab]	0
T_5	13.33 [a]	12.27 [ab]	11.89 [ab]	10.25 [a]	8.52
T_6	13.15 [a]	12.84 [ab]	11.44 [ab]	8.60 [ab]	0
T_7	13.13 [a]	12.67 [ab]	10.90 [ab]	8.46 [ab]	0
T_8	12.77 [a]	12.11 [b]	10.32 [b]	8.22 [b]	0

Same alphabets show homogenous effect.

Table 2k: Effect of seed film coating in combination with chemicals and bio-agents on shoot length (cm) of cowpea seed (dry method of film coating).

Treatments	Shoot length (cm)				
	0 month	3 months	6 months	9 months	12 months
T_1	21.75 bc	20.75 abc	19.61 ab	19.58 abc	19.04 ab
T_2	22.12 abc	21.65 abc	20.45 ab	19.53 abc	19.33 ab
T_3	22.88 ab	21.21 abc	20.58 ab	20.20 ab	19.21 ab
T_4	23.36 a	22.35 a	21.11 a	20.66 a	19.65 ab
T_5	22.09 abc	21.96 ab	20.65 ab	20.00 ab	19.82 a
T_6	20.72 c	20.07 bc	19.92 ab	19.01 bc	18.62 bc
T_7	21.07 c	19.89 bc	19.86 ab	19.02 bc	18.59 bc
T_8	20.86 c	19.67 c	18.73 b	18.35 c	17.77 c

Same alphabets show homogenous effect.

length recorded the maximum value of T_5 (19.82 cm) and T_8 the minimum value of 17.77 cm (Table 2k).

In wet method of seed coating, at 0 month, T_4 recorded the maximum shoot length (23.62 cm) and T_8 which recorded the minimum shoot length (20.66 cm). After 3 months of storage, the shoot length was ranged from 19 to 21 cm, having the lowest value in control (19.8 cm) and highest in T_3 and T_5. After 6 months of storage, shoot length reduced with maximum value of 20.78 cm in T_5. At the end of 9 months of storage, there was considerable variation among the shoot length, having a maximum value of 20.24 cm in T_5 and minimum of 18.73 cm in T_8. After 12 months of storage, shoot length in T_5 was 19.62 cm (Table 2l).

4.2.6. Vigour indices.

4.2.6.1. Vigour index-1.

Vigour index-1 decreased with increase in the storage period. The best treatment in 0 month (before storage) was T_4 (3732) followed by T_3 and T_5. T_8 exhibited the lowest vigour index value (3032). At 3 months interval, the best treatment was T_4 (3131) and T_5 (3125) whereas T_7 and T_8 recorded lowest value for vigour index in that period. After 6 months of storage, T_5 (2694) recorded maximum vigour index whereas minimum vigour index was observed in T_8 (1974). After 9 months of storage, T_4 (2171) and T_5 (2303) recorded highest vigour index whereas T_7 and T_8 recorded lower values of vigour index. At the end of one year, T_5 alone recorded the highest vigour index value (1917) whereas significant variation was not observed among other treatments (Table 2m).

In wet method of seed coating, the best treatment in 0 month (before storage) was T_4 (3760), followed by T_3 and T_5 whereas T_8 recorded the lowest vigour index (2839). At 3, 6 and 9 months after storage, vigour index values were found to be the highest in T_5 decreasing from 3097 to 1179. Among the treatments, T_8 followed by T_7

Table 21: Effect of seed film coating in combination with chemicals and bio-agents on shoot length (cm) of cowpea seed (wet method of film coating).

Treatments	Shoot length (cm)				
	0 month	3 months	6 months	9 months	12 months
T_1	21.22 [ab]	20.63 [ab]	20.37 [ab]	19.83 [ab]	0
T_2	21.94 [ab]	20.97 [ab]	20.62 [ab]	19.73 [abc]	0
T_3	22.37 [ab]	21.08 [a]	20.42 [ab]	19.57 [bc]	0
T_4	23.62 [a]	20.86 [ab]	20.32 [ab]	19.73 [abc]	0
T_5	22.45 [ab]	21.14 [a]	20.78 [a]	20.24 [a]	19.62
T_6	21.32 [ab]	20.41 [ab]	20.13 [ab]	19.54 [bc]	0
T_7	21.03 [ab]	20.36 [ab]	19.81 [ab]	19.24 [c]	0
T_8	20.56 [b]	19.80 [b]	19.34 [b]	18.73 [d]	0

Same alphabets show homogenous effect.

Table 2m: Effect of seed film coating in combination with chemicals and bio-agents on vigour index-1 of cowpea seed (dry method of film coating).

Treatments	**Vigour index-1**				
	0 month	**3 months**	**6 months**	**9 months**	**12 months**
T_1	3233 [bc]	2660 [bcd]	2325 [b]	1936 [ab]	685 [b]
T_2	3344 [bc]	2968 [ab]	2373 [b]	1938 [ab]	744 [b]
T_3	3442 [ab]	2858 [abc]	2444 [ab]	2035 [ab]	789 [b]
T_4	3732 [a]	3131 [a]	2497 [ab]	2171 [a]	784 [b]
T_5	3431 [ab]	3125 [a]	2694 [a]	2303 [a]	1917 [a]
T_6	3163 [bc]	2705 [bcd]	2272 [b]	1848 [ab]	627 [b]
T_7	3151 [bc]	2562 [cd]	2273 [b]	1688 [b]	612 [b]
T_8	3032 [c]	2422 [d]	1974 [c]	1115 [c]	510 [b]

Same alphabets show homogenous effect.

recorded the lowest values for vigour index during storage. At the end of one year, T_5 recorded a vigour index of 271 (Table 2n).

4.2.6.2. Vigour index-2.

In dry method significant difference was noticed between treatments for this character during storage. The best treatment in 0 month (before storage) was T_4 (90.00) followed by T_5 and T_6 with values of 84.58 and 82.98 respectively. Vigour index-2 was found to be the lowest in T_8 (69.97) followed by T_7 (77) at 0 months of storage. At the end of 3 months, maximum vigour index-2 was observed in T_5 (82.25) and minimum in T_8 (64.95). After 6 months of storage, T_5 recorded the highest value for vigour index-2 (74.45) whereas other treatments did not show significant variation. At 9 months of storage, no significant variation was noticed between treatments for vigour index-2 and at the end of one year, T_5 recorded the highest vigour index-2 (50.88). The study showed a decrease in vigour index-2 with increase in storage period with values decreasing from 90 (T_4) at 0 month storage to 8.0 (T_7) at the end of 12 month storage period (Table 2o).

In wet method, the best treatment before storage (0 month) was T_4 (88.67) and T_8 recorded lowest vigour index-2 (73.67). After 3 months storage T_3 and T_5 recorded highest vigour index-2 values of 76.57 and 79.22 respectively. This was followed by T_1, T_2, T_4, T_6 and T_7 whereas T_8 recorded the lowest value of vigour index-2 (64.18). At the end of 6 months, highest values for vigour index-2 was obtained in T_5 (66.53) and T_2 (61.13) and lowest value in T_8 (50.77). After 9 months of storage, the vigour index-2 values of all the treatments considerably with highest value in T_5 (28.32) and lowest in untreated control (T_8). After one year, T_5 recorded a vigour index-2 value of 1.87 (Table 2p).

Table 2n: Effect of seed film coating in combination with chemicals and bio-agents on vigour index-1 of cowpea seed (wet method of film coating).

Treatments	Vigour index-1				
	0 month	3 months	6 months	9 months	12 months
T_1	3190 ^{bc}	2806 ^{abc}	2181 ^{ab}	971 ^{ab}	0
T_2	3160 ^{bc}	2889 ^{abc}	2290 ^{ab}	882 ^{ab}	0
T_3	3380 ^{ab}	2971 ^{ab}	2198 ^{ab}	930 ^{ab}	0
T_4	3760 ^{a}	2812 ^{abc}	2246 ^{ab}	939 ^{ab}	0
T_5	3400 ^{ab}	3097 ^{a}	2455 ^{a}	1179 ^{a}	271
T_6	3271 ^{ab}	2716 ^{bc}	2154 ^{ab}	749 ^{ab}	0
T_7	3131 ^{bc}	2640 ^{cd}	1994 ^{bc}	601 ^{b}	0
T_8	2839 ^{c}	2392 ^{d}	1781 ^{c}	44 ^{c}	0

Same alphabets show homogenous effect.

Table 2o: Effect of seed film coating in combination with chemicals and bio-agents on vigour index-2 of cowpea seed (dry method of film coating).

Treatments	Vigour index-2				
	0 month	3 months	6 months	9 months	12 months
T_1	78.98 ^{b}	68.37 ^{bc}	63.35 ^{b}	55.32 ^{a}	8.80 ^{b}
T_2	78.23 ^{b}	75.05 ^{ab}	64.47 ^{b}	54.47 ^{a}	10.58 ^{b}
T_3	81.52 ^{b}	71.82 ^{bc}	63.82 ^{b}	56.38 ^{a}	11.92 ^{b}
T_4	90.00 ^{a}	71.03 ^{bc}	62.33 ^{b}	56.25 ^{a}	10.02 ^{b}
T_5	84.58 ^{ab}	82.25 ^{a}	74.45 ^{a}	60.13 ^{a}	50.88 ^{a}
T_6	82.98 ^{ab}	71.67 ^{bc}	62.10 ^{b}	51.60 ^{a}	7.98 ^{b}
T_7	77.00 ^{bc}	69.63 ^{bc}	61.38 ^{b}	47.60 ^{a}	8.01 ^{b}
T_8	69.97 ^{c}	64.95 ^{c}	55.67 ^{b}	26.52 ^{b}	9.06 ^{b}

Same alphabets show homogenous effect.

Table2p: Effect of seed film coating in combination with chemicals and bio-agents on vigour index-2 of cowpea seed (wet method of film coating).

Treatments	Vigour index-2				
	0 month	3 months	6 months	9 months	12 months
T_1	80.28 ^{bc}	70.07 ^{ab}	57.20 ^{abc}	19.25 ^{abc}	0
T_2	78.58 ^{bc}	72.62 ^{ab}	61.13 ^{ab}	16.48 ^{abc}	0
T_3	82.25 ^{ab}	76.57 ^{a}	59.30 ^{abc}	20.53 ^{ab}	0
T_4	88.67 ^{a}	70.58 ^{ab}	59.50 ^{abc}	18.45 ^{abc}	0
T_5	82.97 ^{ab}	79.22 ^{a}	66.55 ^{a}	28.32 ^{a}	1.87
T_6	82.37 ^{ab}	72.42 ^{ab}	57.78 ^{abc}	13.35 ^{abc}	0
T_7	78.20 ^{bc}	69.62 ^{ab}	55.93 ^{bc}	7.96 ^{bc}	0
T_8	73.67 ^{c}	64.18 ^{b}	50.77 ^{c}	0.13 ^{c}	0

Same alphabets show homogenous effect.

4.2.7. Pest incidence

Pest attack by pulse beetle (*Callosobruchus chinensis*) was found in the later part of the storage period. No pest was noticed up to 6 months of storage in dry method of coating. At the end of 9 months of storage period, pulse beetle was noticed in untreated control treatment (T_8) and the per cent incidence of pest was 6.90per cent. After 12 months of storage, pest attack was observed in T_7 and T_8 with an incidence of 2.14 per cent and 8.57 per cent respectively (Table 2q).

In wet method of coating there was no occurrence of pest during the storage period (Table 2r).

4.2.8. Fungal attack

No fungal attack was noticed during the storage period both in dry as well as in wet method of seed treatment.

4.2.9. Electrical conductivity

Electrical conductivity values increased with increase in storage period. In dry method of seed coating, there was no significant difference between the treatments for this parameter during the storage period. The best treatment in 0 month (before storage) was T_4 with the lowest value for EC. At 3 months storage period, lower values for EC was obtained in T_4 and T_5 (0.59 and 0.63) whereas EC values were higher in T_7 and T_8. After 6 months storage, T_5 recorded lowest value (0.92) and T_8 recorded highest value (1.32). At the end of 9 months storage, T_5 was found to be the best treatment with the lowest value of EC (1.25) whereas T_8 recorded the highest EC value (1.67). After 12 months storage, T_5 recorded lowest EC value (1.49) followed by T_2 (1.54) and T_3 (1.60) whereas T_8 recorded the highest EC value (1.81) (Table 2s).

Table 2q: Effect of seed film coating in combination with chemicals and bio-agents on pest incidence of cowpea seed (dry method of film coating).

Treatments	Pest incidence (%)				
	0 month	3 months	6 months	9 months	12 months
T_1	0	0	0	0^{b}	0^{b}
T_2	0	0	0	0^{b}	0^{b}
T_3	0	0	0	0^{b}	0^{b}
T_4	0	0	0	0^{b}	0^{b}
T_5	0	0	0	0^{b}	0^{b}
T_6	0	0	0	0^{b}	0^{b}
T_7	0	0	0	0^{b}	2.14^{b}
T_8	0	0	0	6.90^{a}	8.57^{a}

Same alphabets show homogenous effect.

Table 2r: Effect of seed film coating in combination with chemicals and bio-agents on pest incidence of cowpea seed (wet method of film coating).

Treatments	Pest incidence				
	0 month	3 months	6 months	9 months	12 months
T_1	0	0	0	0	0
T_2	0	0	0	0	0
T_3	0	0	0	0	0
T_4	0	0	0	0	0
T_5	0	0	0	0	0
T_6	0	0	0	0	0
T_7	0	0	0	0	0
T_8	0	0	0	0	0

Same alphabets show homogenous effect.

Table 2s: Effect of seed film coating in combination with chemicals and bio-agents on electrical conductivity of cowpea seed (dry method of film coating).

Treatments	Electrical conductivity (dSm^{-1})				
	0 month	3 months	6 months	9 months	12 months
T_1	0.50^{a}	0.72^{abc}	1.06^{bc}	1.36^{bc}	1.66^{ab}
T_2	0.51^{a}	0.69^{abc}	1.22^{b}	1.42^{b}	1.54^{b}
T_3	0.56^{a}	0.67^{abc}	1.02^{bc}	1.48^{b}	1.60^{b}
T_4	0.45^{a}	0.59^{c}	1.06^{bc}	1.44^{b}	1.64^{ab}
T_5	0.55^{a}	0.63^{c}	0.929^{c}	1.25^{c}	1.49^{b}
T_6	0.54^{a}	0.67^{bc}	0.99^{bc}	1.35^{bc}	1.66^{ab}
T_7	0.49^{a}	0.81^{ab}	1.01^{bc}	1.44^{b}	1.68^{ab}
T_8	0.52^{a}	0.84^{a}	1.32^{a}	1.67^{a}	1.81^{a}

Same alphabets show homogenous effect.

In wet method also, there were no statistical differences between the treatments for the EC values observed during the month of storage. After 3 months storage, lower value for EC was obtained in T_5 (0.60) whereas EC values were higher in T_7 and T_8 recording 0.82 and 0.88 respectively. After 6 months storage, T_5 recorded lowest value (0.99) and T_8 recorded the highest value (1.43). After 9 months storage, maximum values of EC were recorded in T_8 (1.72) and T_7 (1.58). At the end of 12 months storage, all the treatments except T_8 were on par with each other. T_8 recorded an EC value of (1.92) (Table 2t).

4.2.11. Enzyme dehydrogenase test

Enzyme dehydrogenase values decreased with increase in storage period. The highest value for dehydrogenase at 0 month (before storage) was observed in T_4 (3.32) followed by T_5 and lowest in T_8 (2.20). After 3 months storage, T_4 recorded the highest value (2.92). After 6 and 9 months storage, T_4 and T_5 recorded maximum values for this enzyme and T_7 and T_8 recorded the lowest. At the end of 1 year, T_4 showed highest value whereas T_8 recorded lowest value (Table 2u).

In wet method also, a reduction in the value of dehydrogenase enzyme was noticed over the period of storage. The highest value in 0 month (before storage) was T_4 (3.17) and T_7 and T_8 recorded the lowest values. At the end of 3 months, T_4 and T_5 recorded maximum values for this character and minimum value was observed in T_7 and T_8. After 6 months storage, T_4 and T_5 exhibited highest values for dehydrogenase (> 2.0) whereas T_8 recorded the lowest value (1.42) followed by T_7 (1.58). At the end of 9 months storage, highest value was recorded in T_5 (1.64) and lowest in T_8 (1.09). After one year, the values for dehydrogenase were found to be decrease in all the treatments with the lowest value in T_8 (0.66) (Table 2v).

Table 2t: Effect of seed film coating in combination with chemicals and bio-agents on electrical conductivity of cowpea seed (wet method of film coating).

Treatments	Electrical conductivity (dSm^{-1})				
	0 month	3 months	6 months	9 months	12 months
T_1	0.58^{a}	0.73^{abc}	1.29^{abc}	1.52^{b}	1.68^{b}
T_2	0.61^{a}	0.73^{abc}	1.08^{abc}	1.55^{ab}	1.63^{b}
T_3	0.62^{a}	0.73^{abc}	1.16^{abc}	1.53^{b}	1.64^{b}
T_4	0.54^{a}	0.66^{bc}	1.26^{abc}	1.52^{b}	1.67^{b}
T_5	0.57^{a}	0.60^{c}	0.99^{c}	1.42^{b}	1.65^{b}
T_6	0.59^{a}	0.67^{bc}	1.03^{bc}	1.44^{b}	1.67^{b}
T_7	0.60^{a}	0.82^{ab}	1.37^{ab}	1.58^{ab}	1.70^{b}
T_8	0.62^{a}	0.88^{a}	1.43^{a}	1.72^{a}	1.92^{a}

Same alphabets show homogenous effect.

Table 2u: Effect of seed film coating in combination with chemicals and bio-agents on dehydrogenase enzyme of cowpea seed (dry method of film coating).

Treatments	**Dehydrogenase enzyme (O.D value)**				
	0 month	**3 months**	**6 months**	**9 months**	**12 months**
T_1	2.98^{abc}	2.63^{ab}	2.33^{ab}	1.78^{b}	1.36^{c}
T_2	2.81^{bc}	2.52^{ab}	2.38^{ab}	1.60^{cd}	1.38^{bc}
T_3	2.72^{bc}	2.63^{ab}	2.39^{ab}	1.81^{b}	1.41^{abc}
T_4	3.32^{a}	2.92^{a}	2.56^{a}	2.07^{a}	1.65^{a}
T_5	3.14^{ab}	2.61^{ab}	2.44^{a}	2.06^{a}	1.63^{ab}
T_6	2.80^{bc}	2.33^{b}	2.26^{ab}	1.68^{bc}	1.30^{cd}
T_7	2.57^{cd}	2.31^{b}	1.80^{bc}	1.47^{d}	1.07^{dc}
T_8	2.20^{d}	2.10^{b}	1.67^{c}	1.28^{c}	0.97^{c}

Same alphabets show homogenous effect.

Table 2v: Effect of seed film coating in combination with chemicals and bio-agents on dehydrogenase enzyme of cowpea seed (wet method of film coating).

Treatments	Dehydrogenase enzyme (O.D value)				
	0 month	3 months	6 months	9 months	12 months
T_1	2.77 ^{abc}	2.41 ^{ab}	1.91 ^{bc}	1.39 ^{abc}	0.87 ^{bc}
T_2	2.79 ^{abc}	2.33 ^{abc}	1.77 ^{cd}	1.21 ^{bc}	0.78 ^{c}
T_3	2.61 ^{bc}	2.31 ^{abc}	1.91 ^{bc}	1.58 ^{ab}	1.16 ^{a}
T_4	3.17 ^{a}	2.77 ^{a}	2.32 ^{a}	1.58 ^{ab}	1.19 ^{a}
T_5	3.05 ^{ab}	2.77 ^{a}	2.41 ^{a}	1.64 ^{a}	1.22 ^{a}
T_6	2.66 ^{bc}	2.45 ^{ab}	2.00 ^{b}	1.35 ^{abc}	1.02 ^{ab}
T_7	2.55 ^{c}	2.12 ^{bc}	1.58 ^{dc}	1.21 ^{bc}	0.81 ^{bc}
T_8	2.50 ^{c}	1.87 ^{c}	1.42 ^{c}	1.09 ^{c}	0.66 ^{c}

Same alphabets show homogenous effect.

4.2.10. Protein estimation

Protein content in the seed decreased with increase in storage period. In the dry method of seed coating, except T_4 (17.87 g/100g seed) no significant variation was observed among other treatments before storage. After 3 months, seed protein content was found to be maximum in T_5 (17.36) and minimum in T_8 (16.23). At the end of 6 months, T_5 recorded maximum values for seed protein (16.23) whereas T_7 and T_8 recorded the lowest value for protein content. At 9 and 12 months period of storage, T_5 recorded the highest value and T_8 recorded the lowest value for this character (Table 2w).

In wet method also, reduction in the content of protein was observed during storage. Before storage, T_4 recorded maximum value for protein and T_8 recorded minimum values. At the end of 3 months, highest protein content of 16.76 g/100g seed was observed in T_4 and T_1, T_2, T_7 and T_8 recorded lowest values. After 6 months of storage, T_4 recorded the highest values and T_8 recorded the lowest value for protein content. After 9 months storage, T_4 recorded highest content of protein and lowest content was observed in T_8. After one year T_5 recorded the highest protein content and the lowest was observed in T_8 (Table 2x).

Experiment- III

4.3 Effect of seed film coating in combination with chemicals and bio-agents on growth, field performance and yield of cowpea.

4.3.1. Field germination.

In dry method of seed coating, T_5 recorded maximum field emergence of 96.6per cent.

In wet method of seed treatment, no significant difference was noticed between treatments for germination with maximum value in T_5 (95per cent). All the treatments

Table 2w: Effect of seed film coating in combination with chemicals and bio-agents on protein content of cowpea seed (dry method of film coating).

Treatments	Protein (g/100g seed)				
	0 month	3 months	6 months	9 months	12 months
T_1	17.04 ^{ab}	16.51 ^{ab}	15.62 ^{abc}	14.82 ^{b}	14.20 ^{ab}
T_2	17.22 ^{ab}	16.79 ^{ab}	15.64 ^{abc}	15.07 ^{ab}	14.15 ^{ab}
T_3	17.05 ^{ab}	16.72 ^{ab}	15.66 ^{ab}	15.22 ^{ab}	14.18 ^{ab}
T_4	17.87 ^{a}	16.74 ^{ab}	15.92 ^{ab}	15.10 ^{ab}	14.06 ^{ab}
T_5	17.01 ^{ab}	17.36 ^{a}	16.23 ^{a}	15.63 ^{a}	14.83 ^{a}
T_6	17.21 ^{ab}	16.76 ^{ab}	15.60 ^{bc}	14.75 ^{b}	14.31 ^{ab}
T_7	16.78 ^{b}	16.33 ^{b}	15.34 ^{bc}	14.67 ^{b}	13.76 ^{b}
T_8	16.58 ^{b}	16.23 ^{b}	15.04 ^{c}	13.90 ^{c}	12.94 ^{c}

Same alphabets show homogenous effect.

Table 2x: Effect of seed film coating in combination with chemicals and bio-agents on protein content of cowpea seed (wet method of film coating).

Treatments	Protein (g/100g seed)				
	0 month	3 months	6 months	9 months	12 months
T_1	17.03 ^{ab}	16.02 ^{bc}	15.52 ^{ab}	15.06 ^{b}	14.04 ^{b}
T_2	16.52 ^{ab}	15.88 ^{bc}	15.64 ^{ab}	15.08 ^{b}	14.12 ^{ab}
T_3	16.49 ^{ab}	16.10 ^{b}	15.70 ^{ab}	15.06 ^{b}	14.15 ^{ab}
T_4	17.39 ^{a}	16.76 ^{a}	15.95 ^{a}	15.54 ^{a}	14.60 ^{a}
T_5	16.57 ^{ab}	16.13 ^{b}	15.72 ^{ab}	15.12 ^{b}	14.28 ^{ab}
T_6	16.46 ^{b}	16.10 ^{b}	15.34 ^{ab}	14.97 ^{b}	14.05 ^{b}
T_7	16.44 ^{b}	15.82 ^{bc}	15.40 ^{ab}	14.82 ^{b}	13.90 ^{b}
T_8	16.38 ^{b}	15.44 ^{c}	14.70 ^{b}	14.33 ^{c}	12.58 ^{c}

Same alphabets show homogenous effect.

in wet method recorded above 85per cent germination. Germination was lowest in T_8 of both methods of seed treatment (86.6per cent in dry method and 85per cent in wet method) (Table 3a).

4.3.2. Days to 50 per cent germination.

In the dry method of seed treatment, 50per cent germination was obtained in 3-4 days. T_2 (3.66 days) was earlier than all other treatments with respect to days to 50 per cent germination.

In wet method of seed treatment 50per cent germination was obtained in 4-5 days. Except T_1, other treatments took 4 to 4.66 days to reach 50per cent germination whereas T_1 obtained 50per cent germination in 5.66 days only (Table 3a).

4.3.3. Days to first harvest.

In dry method of seed treatment, the days to first harvest was found to be earliest in T_4, T_5 and T_6 (53 days) followed by T_1, T_2 and T_3 (55 days) and it was late in T_7 (57 days) and T_8 (59 days).

In wet method of seed treatment, no significant difference was observed among the treatments for this character. Both film coated control (T_7) and untreated control (T_8) took more number of days to first harvest (Table 3b).

4.3.4. Number of fruits per plant.

Number of fruits per plant was found to be the highest in T_4 (12.79) followed by T_5 (12.66) in dry method of seed treatment whereas lowest number of fruits per plant was obtained in T_7 and T_8 (control) with values of 9.85 and 9.49 respectively.

In wet method of seed treatment, the treatments were on par with each other with respect to number of fruits obtained from a plant varied from 11-17 with the

Table 3a: Effect of film coating in combination with chemicals and bio-agents on seed germination parameters.

Treatments	Field Germination		Days for 50% Germination	
	Dry method	Wet method	Dry method	Wet method
T_1	88.33 [ab]	88.33 [a]	4.00 [ab]	5.66 [a]
T_2	90.00 [ab]	90.00 [a]	3.66 [b]	4.33 [b]
T_3	91.67 [ab]	88.33 [a]	4.00 [ab]	4.33 [b]
T_4	93.33 [ab]	93.33 [a]	4.00 [ab]	4.00 [b]
T_5	96.60 [a]	95.00 [a]	4.00 [ab]	4.00 [b]
T_6	88.33 [ab]	88.33 [a]	4.00 [ab]	4.00 [b]
T_7	88.33 [ab]	90.00 [a]	4.00 [ab]	4.00 [b]
T_8	86.67 [b]	85.00 [a]	4.33 [a]	4.66 [b]

Same alphabets show homogenous effect.

Table 3b: Effect of film coating in combination with chemicals and bio-agents on days to first harvest and fruits per plant.

Treatments	Days to 1st harvest		Number of fruits per plant	
	Dry method	Wet method	Dry method	Wet method
T_1	55.00 [ab]	56.33 [a]	12.21 [ab]	12.59 [a]
T_2	55.00 [ab]	53.67 [a]	10.68 [ab]	12.68 [a]
T_3	55.00 [ab]	53.00 [a]	11.22 [ab]	17.36 [a]
T_4	53.00 [b]	53.00 [a]	12.79 [a]	15.59 [a]
T_5	53.00 [b]	53.00 [a]	12.66 [a]	16.37 [a]
T_6	53.00 [b]	55.67 [a]	10.20 [ab]	16.76 [a]
T_7	57.00 [ab]	55.67 [a]	9.85 [b]	12.13 [a]
T_8	59.00 [a]	57.00 [a]	9.49 [b]	11.87 [a]

Same alphabets show homogenous effect.

highest number in T_3 (17.36) followed by T_6 (16.76) and T_5 (16.37) and lowest number in T_8 (11.87) (Table 3b).

4.3.5. Fruit length.

In dry method of seed coating, T_5 and T_4 recorded the highest value for fruit length (> 20 cm) and lowest value for fruit length was observed in T_8 (18.70 cm).

In wet method of seed treatment, T_4 recorded highest value for fruit length (21.02 cm) followed by T_5 (20.58 cm). The lowest fruit length was recorded in T_8 (18.75 cm) (Table 3c).

4.3.6. Average fruit weight.

Average fruit weight was found to be the highest in T_5 (5.49g) and T_4 (5.32g) in dry method of seed treatment which was followed by T_1, T_2, T_3 and T_6. The lowest value for average fruit weight in this method was recorded in T_7 (3.67g) and T_8 (3.63g).

In wet method of seed treatment, highest fruit weight was obtained in T_4 (5.25g) and it was followed by T_1, T_2, T_3, T_5 and T_6. Lowest fruit weight was observed in T_7 (3.85g) and T_8 (3.84g) (Table 3c).

4.3.7. Fruit yield per plant.

Fruit yield per plant was found to be the highest in T_5 (69.67g) followed by T_4 (62.50g) in dry method of seed treatment and lowest fruit yield per plant was recorded in control treatments of T_7 and T_8 with values of 35.62g and 34.12g respectively. In wet method of seed treatment, maximum yield per plant was obtained in T4 (78.06g) followed by T_5 (68.51g), T_3 (68.15g) and T_6 (67.73g). Fruit yield was found to be the lowest in T_7 and T_8 with 46.54g and 45.71g respectively (Table 3d).

Table 3c: Effect of film coating in combination with chemicals and bio-agents on fruit length and average fruit weight.

Treatments	Fruit length (cm)		Average fruit weight (g)	
	Dry method	Wet method	Dry method	Wet method
T_1	19.52 ^{ab}	19.81 ^{abc}	4.42 ^{ab}	4.52 ^{ab}
T_2	19.42 ^{ab}	18.82 ^{bc}	4.52 ^{ab}	4.15 ^{ab}
T_3	19.47 ^{ab}	19.81 ^{abc}	4.73 ^{ab}	4.00 ^{ab}
T_4	20.14 ^{ab}	21.02 ^{a}	5.32 ^{a}	5.25 ^{a}
T_5	20.52 ^{a}	20.58 ^{ab}	5.49 ^{a}	4.14 ^{ab}
T_6	19.72 ^{ab}	20.13 ^{abc}	4.85 ^{ab}	4.12 ^{ab}
T_7	19.54 ^{ab}	19.39 ^{abc}	3.67 ^{b}	3.85 ^{b}
T_8	18.70 ^{b}	18.75 ^{c}	3.63 ^{b}	3.84 ^{b}

Same alphabets show homogenous effect.

Table 3d: Effect of film coating in combination with chemicals and bio-agents fruit yield per plant and number of harvests.

Treatments	Fruit yield per plant (g)		No. of harvests	
	Dry method	Wet method	Dry method	Wet method
T_1	56.18 ^{ab}	57.17 ^{ab}	4.33 ^{a}	4.33 ^{a}
T_2	48.53 ^{bc}	52.83 ^{ab}	5.00 ^{a}	4.66 ^{a}
T_3	53.84 ^{abc}	68.15 ^{ab}	4.66 ^{a}	4.33 ^{a}
T_4	62.50 ^{ab}	78.06 ^{a}	5.00 ^{a}	5.00 ^{a}
T_5	69.67 ^{a}	68.51 ^{ab}	4.33 ^{a}	4.66 ^{a}
T_6	49.96 ^{abc}	67.73 ^{ab}	4.33 ^{a}	5.00 ^{a}
T_7	35.62 ^{c}	46.54 ^{b}	5.00 ^{a}	5.00 ^{a}
T_8	34.12 ^{c}	45.71 ^{b}	4.66 ^{a}	4.66 ^{a}

Same alphabets show homogenous effect

4.3.8. Number of harvests.

There were no significant differences among the treatments for this character in both methods of seed treatment. Number of harvests ranged from 4-5 in both the methods of seed coating with maximum number of harvests (5) in T_2, T_4 and T_5 in dry method and T_4, T_5 and T_6 in wet method (Table 3d).

4.3.9. Plot yield.

Total vegetable yield obtained per plot (2.7 m^2) was found to be the highest in T_5 (3.53kg) followed by T_4 (2.99kg) in dry method of seed coating. Plot yield was found to be the lowest in the control plots of T_7 and T_8 (1.38kg and 1.27kg respectively).

Significantly higher yield was obtained in T_4 (3.85kg) in wet method of seed treatment followed by T_5 (3.44kg), T_3 (3.15kg) and T_6 (3.06kg). Lowest vegetable yield was recorded in T_7 (2.01kg) and T_8 (1.81kg) (Table 3e).

4.3.10. Pest incidence.

No pest incidence (aphid) was found in T_3 (0per cent) of both dry and wet methods of seed treatment whereas untreated control (T_8) of both methods recorded highest (5per cent) pest incidence (aphid). Pest incidence (aphid) was low (1.66per cent) in T_1 and T_2 in both methods of seed treatment whereas T_4 and T_5 recorded a pest incidence (aphid) of 3.33per cent (Table 3e).

4.3.11. Disease incidence.

In dry method of seed treatment, T_8 recorded highest incidence of disease (collar rot) (8.33per cent) followed by T_7 (5.66per cent) and T_4 (5per cent). No disease incidence was found in T_3 and very low disease incidence of 1.66per cent was observed in T_2, T_5 and T_6.

Table 3e: Effect of film coating in combination with chemicals and bio-agents on plot yield.

Treatments	Plot yield (kg/2.7m^2)	
	Dry method	Wet method
T_1	2.47 ^{b}	2.55 ^{abc}
T_2	2.11 ^{bc}	2.30 ^{bc}
T_3	2.44 ^{b}	3.15 ^{abc}
T_4	2.99 ^{ab}	3.85 ^{a}
T_5	3.53 ^{a}	3.44 ^{ab}
T_6	2.10 ^{bc}	3.06 ^{abc}
T_7	1.38 ^{c}	2.01 ^{c}
T_8	1.27 ^{c}	1.81 ^{c}

Same alphabets show homogenous effect.

In wet method of seed coating, T_8 (6.66per cent) had the highest incidence of disease (collar rot) followed by T_5 (1.66per cent) whereas, T_4, T_6 and T_7 recorded 3.33per cent of disease incidence. No incidence of disease was observed in T_2 and T_3 (Table 3e).

Table 3e: Effect of film coating in combination with chemicals and bio-agents on pest and disease incidence.

Treatments	Pest incidence (%)		Disease incidence (%)	
	Dry method	Wet method	Dry method	Wet method
T_1	1.66 ^{b}	1.66 ^{b}	5.00 ^{ab}	5.00 ^{ab}
T_2	1.66 ^{b}	1.66 ^{b}	1.66 ^{b}	0.00 ^{c}
T_3	0.00 ^{c}	0.00 ^{c}	0.00 ^{c}	0.00 ^{c}
T_4	3.33 ^{ab}	3.33 ^{ab}	3.33 ^{ab}	3.33 ^{ab}
T_5	3.33 ^{ab}	3.33 ^{ab}	1.66 ^{b}	1.66 ^{b}
T_6	3.33 ^{ab}	3.66 ^{a}	1.66 ^{b}	3.33 ^{ab}
T_7	3.33 ^{ab}	5.00 ^{a}	5.66 ^{b}	3.33 ^{ab}
T_8	5.00 ^{a}	5.00 ^{a}	8.33 ^{a}	6.66 ^{a}

Same alphabets show homogenous effect.

DISCUSSION

5. DISCUSSION

Results of the present study on "Seed quality enhancement in cowpea (*Vigna unguiculata* (L.) Walp.) by film coating technique" are discussed under the following heads.

5.1 Standardization of the dose and method of application of the film coat.

5.2 Effect of film coating in combination with insecticides, fungicides and bio-agents on seed quality and storage.

5.3 Effect of film coated treatments on growth, field performance and yield of cowpea.

Experiment- I

5.1 Standardization of the dose and method of application of the film coat.

The results of the study indicated that the film coat does not have any adverse effect on seed quality parameters *viz.* germination per cent, vigour etc. Dose of the film coat and method of coating are very important since they significantly influence the quality of the seed and good results were obtained from both dry and wet method of coating.

Differences for physical appearance like colour, lustre and uniformity of coating were observed among various treatments. In both dry and wet method of coating, the dose of 20ml film coat for one kilogram of seed (T_4 and T_8) gave good results. As the dose of the film coat increased, the colour, lustre and uniformity of coating also increased. Thus T_4 and T_8 had bright red colour, good lustre (shiny seeds) and uniform coating and these parameters showed poor results in T_1 and T_5 of dry and wet method where the dose of the film coat used was 5ml per kilogram of seed. One of the objectives of film coating is to obtain attractive appearance for the seed which is achieved from T_4 and T_8 in the present study. Similar results of increase in seed coat lustre by the application of water soluble polymers in hybrid rice seed was reported by Patil *et al.,* (2006).

Initial germination per cent was above 70 in T_1, T_2, T_5 and T_7 where low dose of the film coat was used. But the final germination per cent was found to be the highest in T_4 and T_8 where the highest concentration of the film coat (20ml) was used. This is probably because the film coat uniformly coated around the seed, regulated moisture absorption and reduced imbibitional damage as reported by many workers. Uniform coating depends on the correct dose of the film coat which is clear from the results of this study. T_4 and T_8 exhibited higher germination 9.83 per cent and a 10% increase in germination over T_1 and T_5 (Fig. 1a). Similar results of increased germination in hydrophilic polymer (20g/kg seed) coated groundnut seed was reported by Chikkanna *et al.*, (2000). Chachalis and Smith (2001) reported that polymer coated soybean seeds regulated the rate of water uptake, reduced imbibitional damage and improved germination. Nisar *et al.*, (2006) observed higher germination per cent and reduced seed deterioration in film coated seeds of soybean when compared to control. Kunkur *et al.*, (2007) also reported increased germination in the seeds of cotton treated with polymer coating.

Though significant variation was observed among the treatments for germination, no variation was observed for speed of germination between the treatments. Values of this parameter were on par in both dry and wet methods of treatment. This may be due to the difference in initial and final germination per cent in different treatments and also the treatments with highest dose of the film coat had low initial germination per cent. The lowest initial germination per cent was observed in T_4 (59.33) and T_8 (53.33) (Fig. 1b).

The days for 50% germination also did not show any significant differences between the treatments. On an average, all the treatments took 2.0 days for obtaining 50% germination except T_8 which had taken 2.33 days for reaching 50% germination. This may be due to the difference in initial and final germination per cent in different treatments and also the treatments with highest dose of the film coat had low initial germination per cent. Length of root and shoot showed significant differences among the treatments, the highest root length

Fig 1a: Effect of film coating on germination per cent

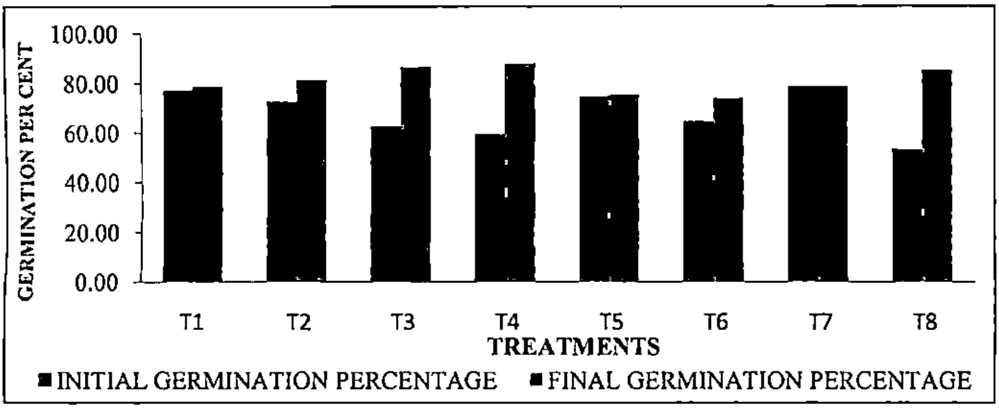


Fig 1b: Effect of film coating on speed of germination

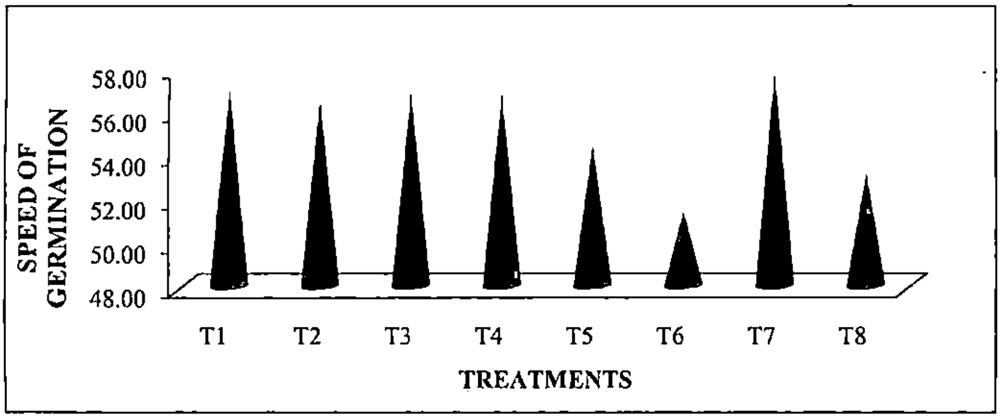
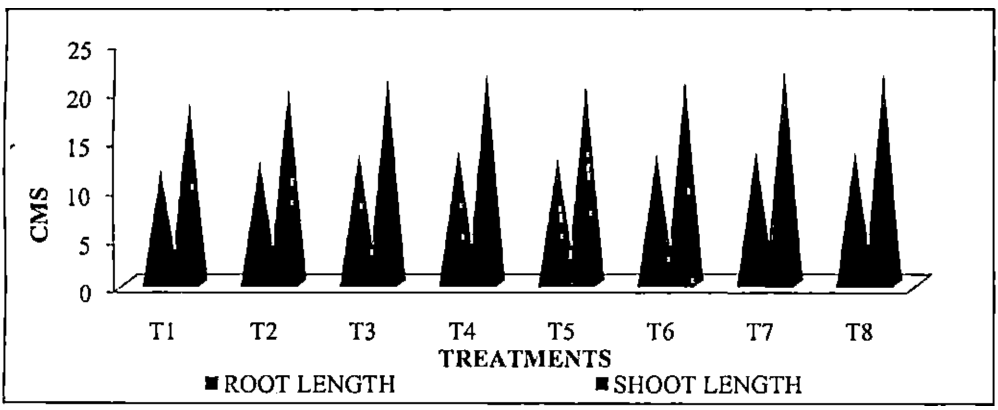


Fig 1c: Effect of film coating on root and shoot length



was obtained in T_4 (13.83 cm) in dry method and T_8 (13.69 cm) in wet method. Similarly the shoot length was found to be maximum in T_4 (21.66 cm) of dry method and T_7 and T_8 of wet method (Fig. 1c). The maximum root and shoot length was obtained in the seeds treated with the highest dose of the film coat and this is due to the favourable effect of film coat on the seeds which enhanced the growth and development of seed in a time span as compared to other treatments. Similar results of higher seedling length as compared to uncoated seeds were obtained by Dadlani *et al.,* (1992) in polymer coated rice (cv. IR-20) seeds. A study conducted by Xiong *et al.,* (2005) revealed that seed film coating on cucumber with suitable concentrations of uniconazole (20-60 mg/litre) significantly reduced the shoot height and promoted the root growth. Chikkanna *et al.,* (2000) observed that groundnut seed coated with hydrophilic polymer (20g per kg of seed) had increased root and shoot growth. Similar results of improved seedling growth were also quoted by Wang *et al.,* (2005) who studied the effect of seed film coating with uniconazole (0.0075%) on rape seed.

The vigour index-1 having the highest value in T_4 (3125) of dry method and T_8 (3010) of wet method (Fig. 1d). Vigour index-2 was found to be the highest in T_4 (81.33) of dry method and T_8 (72.70) of wet method. Vigour indices are based on certain parameters like seedling length, germination per cent and dry weight. Higher values of these parameters resulted in an increase in vigour index also. Similar results of increased vigour were reported by Kunkur *et al.,* (2007) in film coated seeds of cotton. (Fig. 1e).

Experiment- II

5.2 Effect of seed film coating in combination with chemicals and bio-agents on seed quality and storage.

Film coated seeds (with carbaryl, carbendazim and their combination and bio-agents like *Trichoderma*, *Pseudomonas* and their combination) were stored in polythene bag at ambient temperature for a period of one year. The effect of these

Fig 1d: Effect of film coating on vigour index-1

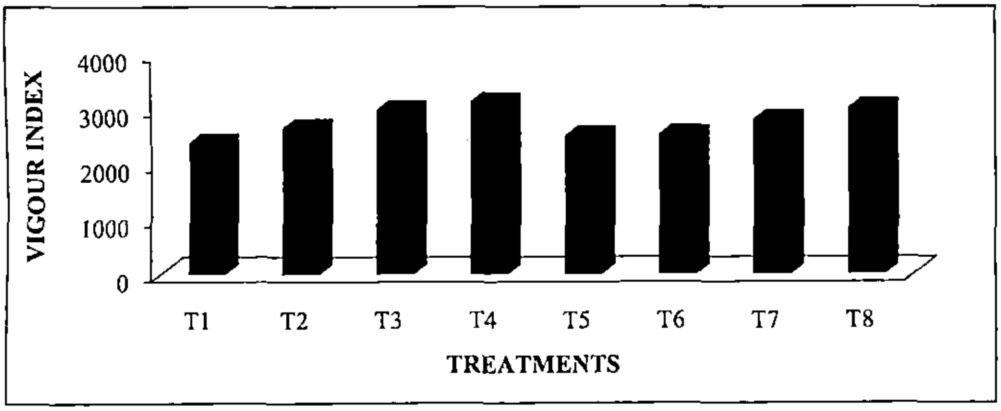


Fig 1e: Effect of film coating on vigour index-2

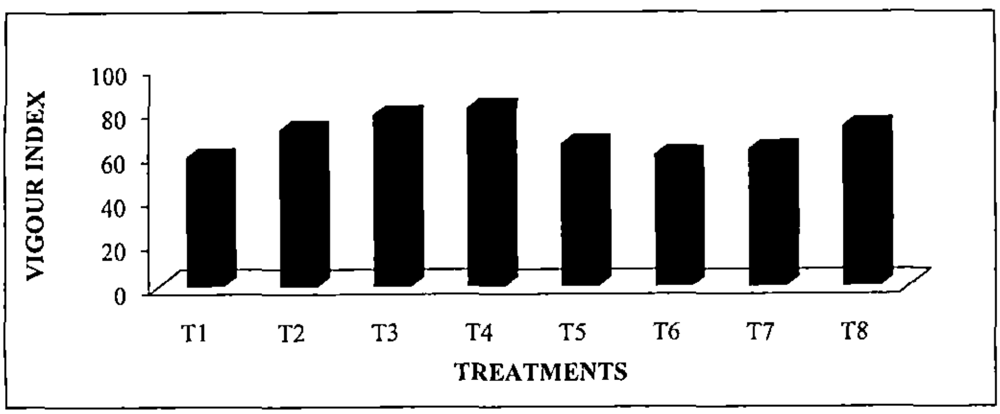
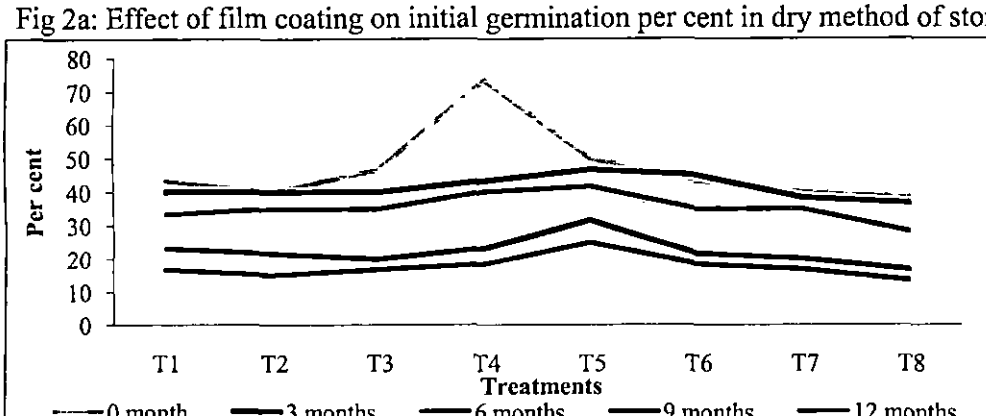


Fig 2a: Effect of film coating on initial germination per cent in dry method of storage



treatments on storability, pest and disease incidence of the seed was assessed for a period of 12 months.

Results of the study indicated that the initial germination (first count) of seeds declined over the storage period. The best treatment at 0 month (before storage) in dry method of film coating was T_4 with 73% germination which decreased to 43%, 40%, 23% and 18% at the end of 3, 6, 9 and 12 months respectively. After 6, 9 and 12 months of storage T_5 recorded highest germination (41%, 31% and 25% respectively) and remained as the best treatment during the entire storage period (Fig 2a). In wet method of seed coating, the best treatment at 0 month (before storage) was T_4 (85%) and subsequently T_5 recorded maximum germination per cent at 3, 6, 9 and 12 months of storage. After one year of storage, none of the treatments germinated except T5 (Fig. 2b).

The final germination per cent calculated at the end of 8 days of sowing declined gradually with increase in the storage period. Before storage (0 month) T_4 recorded the highest germination (100%) which later reduced to 91%, 83%, 80%, and 35% at the end of 3, 6, 9 and 12 months of storage. After 3, 6, 9 and 12 months of storage period, T_5 maintained highest germination when compared to other treatments even though reduction in germination per cent was noticed over storage period. The recommended germination per cent as per minimum standard for seed certification was maintained in all other treatments except T_7 (film coated control) and T_8 (untreated control) at the end of 9 months of storage. Lowest germination was always observed in untreated control throughout the storage period. The decline in germination per cent with advance in storage period may be attributed to the ageing effect, loss of viability and storage condition (Fig 2c).

Similar to the observations noticed in dry method, T_4 recorded 100% germination before storage in wet method also. T_5 was superior to all the treatments over the storage period. At the end of 9 months of storage, germination per cent in all the treatments was below the seed certification standards. The best treatment (T_5) at the end of 6 and 9 months showed 16% higher in germination

Fig 2b: Effect of film coating on initial germination per cent in wet method of storage

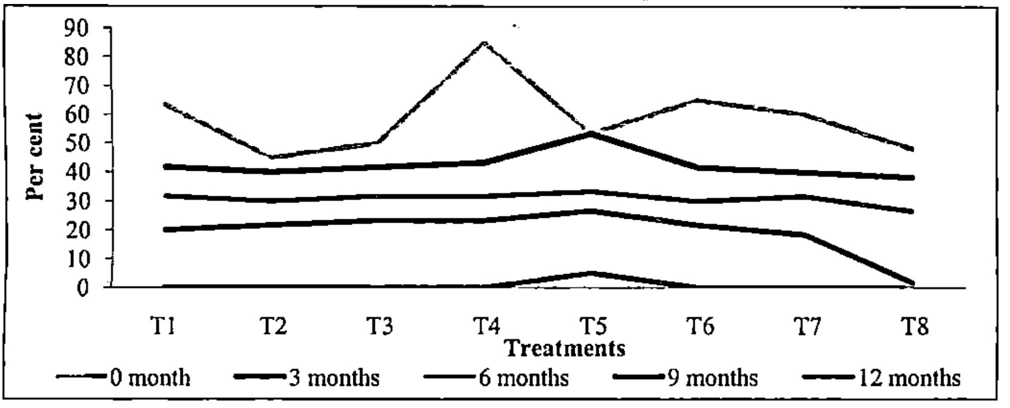


Fig 2c: Effect of film coating on final germination per cent in dry method of storage

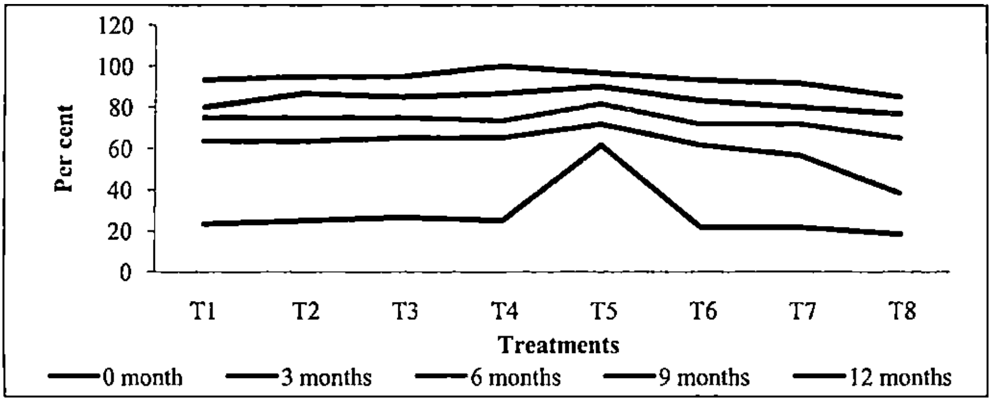
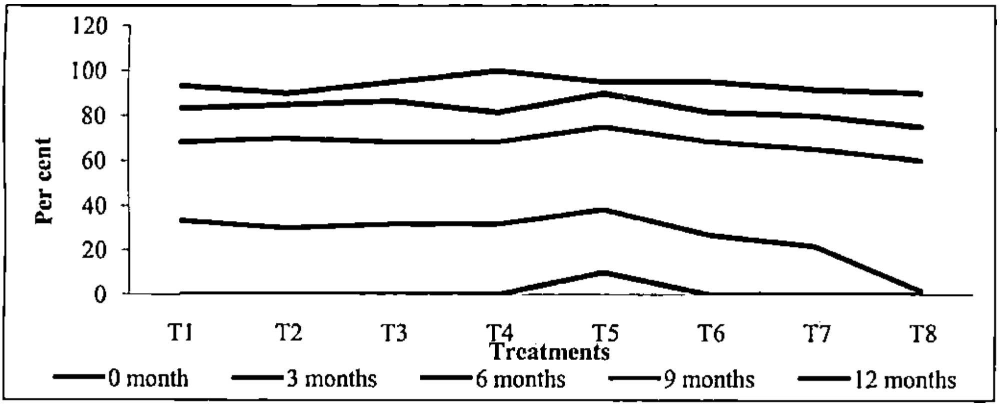


Fig 2d: Effect of film coating on final germination per cent in wet method of storage



over control (T_8). In wet method, no germination was noticed at the end of 12 months in all the treatments except *Pseudomonas* treated seeds (T_5). During the storage periods, lowest germination was observed in control treatments of T_7 and T_8 (Fig. 2d). Similar results of low germination in untreated control in storage period as against the polymer coated and treated seeds were recorded in hybrid rice seeds (KRH-2) by Giang and Gowda (2007). It is known that the application of bioagents has a positive effect in promoting growth of plants. In amaranthus the increase in germination may be due to the production of phytohormones like auxins, gibberlins, cytokinins and indole acetic acid which plays an important role in growth promotion was reported by Uppala (2007). A study conducted by Priyadarshini (2003) showed better growth promoting efficiency with *Trichoderma spp.* in amaranthus. Similar results of reduced germination in untreated seeds at the end of storage period (9 months) was reported by Costa *et al.,* (2001) in carrot when compared to fungicide coated seeds. Another study conducted by John and Bharathi (2006) in maize seeds which were film coated in combination with fungicides, insecticides, micronutrients and macronutrient and stored for 10 months in gunny bags as well as 700 gauge polyethylene cover indicated similar results to the present study where a decrease in germination with increase in storage period was noticed. Film coated seeds with chemicals at the end of 12 months of storage recorded significantly higher germination as compared to untreated control (lowest germination) in the studies conducted by Kunkur *et al.,* (2007) in cotton and Manjunatha *et al.,* (2008) in chilli.

The speed of germination also decreased with increase in the storage period. In dry method, the best treatment at 0 month (before storage) and 3 months after storage was T_4 recording a speed of 58.95 and 40.97 respectively. Later at the end of 6, 9 and 12 months of storage T_5 recorded highest value for this character (Fig 2e). In wet method, the best treatment in 0 month (before storage) was T_4 (51.73) and later T_5 was found to be superior to all other months of storage. Hence T_4 (with *Trichoderma*) and T_5 (with *Pseudomonas*) were found to be the best treatments over the period of storage (Fig. 2f).

Fig 2e: Effect of film coating on speed of germination in dry method of storage

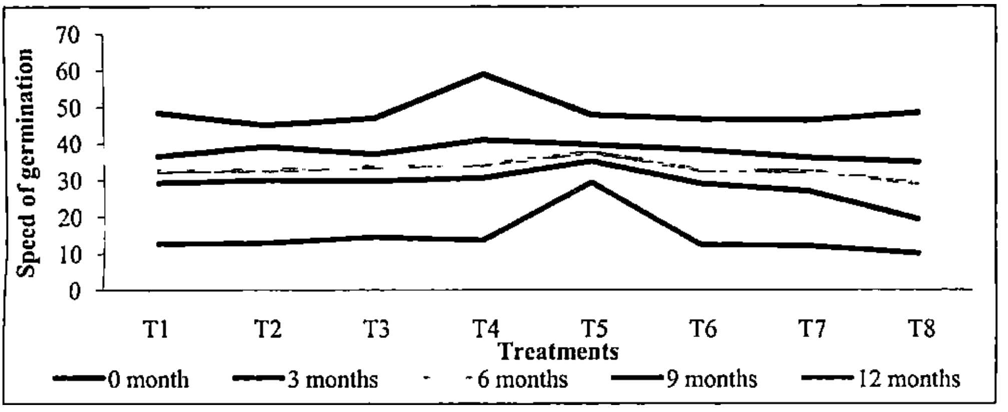


Fig 2f: Effect of film coating on speed of germination in wet method of storage

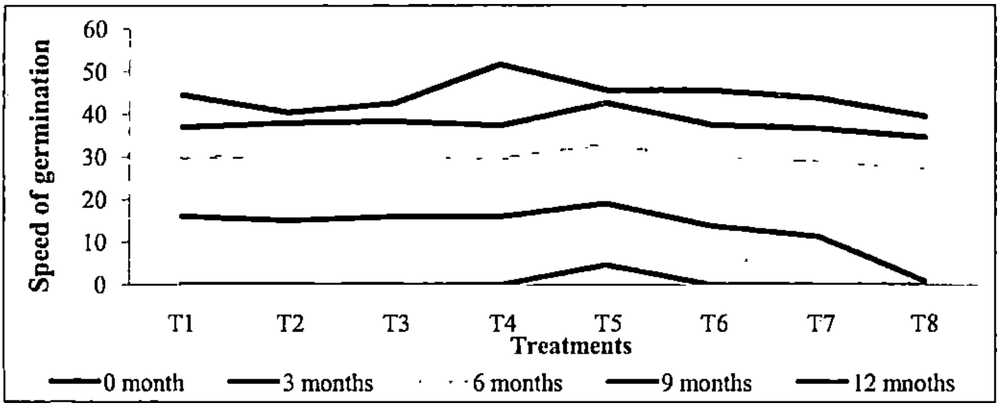
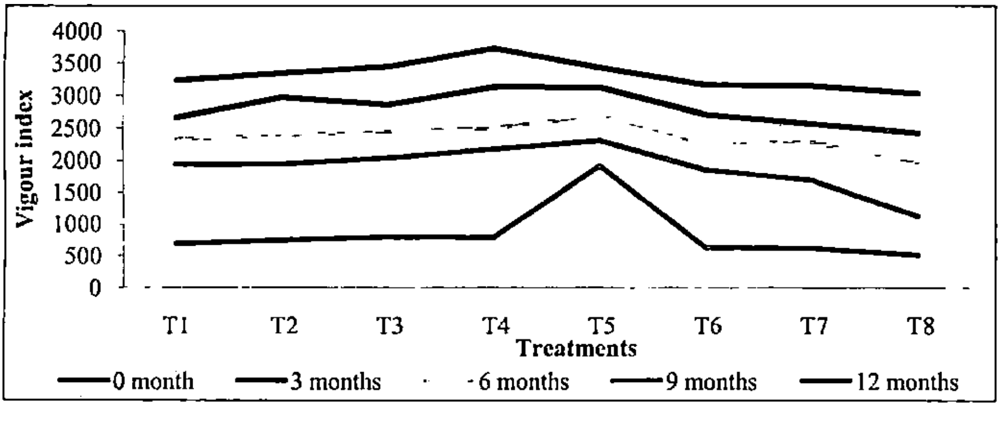


Fig 2g: Effect of film coating on vigour index-1 in dry method of storage



Number of days for achieving 50% germination increased with increase in the storage period. Throughout the storage period, T_4 and T_5 took less number of days to reach 50% germination. The best treatment at 0 month (before storage) and 3 months of storage was T4 and T_5 respectively which had taken 3.33 days to reach 50% germination. After 6 months storage, all the treatments took 4.00 days to reach 50% germination whereas T_5 was the lone treatment to reach 50% germination within 4 days at the end of 9 months of storage. After one year of storage, 50 percent germination was achieved only in T_5 in 4.66 days. Due to the ageing effect on seeds over the storage period and due to the loss of viability, the seeds fail to reach 50% germination. In wet method, most of the treatments attained 50% germination in 3 days and at 3 and 6 months of storage, T_5 took less number of days (3 and 3.66 respectively) to reach 50% germination. After 9 months of storage, none of the treatments attained 50% germination.

In dry method of seed treatment, the root length was found to be maximum in T_4 throughout the storage period and minimum root length was observed in T_7 and T_8. In wet method of seed treatment, T_4 showed it's superiority for the root length during early period upto 6 months of storage and later T_5 was found to be the best treatment. In both the methods of seed coating, the root length decreased over storage period which is an indicator of low vigour. In case of shoot length, T_4 was considered as the best treatment in dry method with a higher shoot length of 23.36cm, 22.35cm, 21.11cm and 20.66cm at 0, 3, 6, and 9 months storage period as compared to others. In wet method, T_5 was found to be the best treatment with higher shoot lengths at 3, 6, 9 and 12 months of storage with values of 21.14cm, 20.78cm, 20.24cm and 19.62cm. In all cases, shoot length decreased with increase in storage period and control treatments recorded lowest value for this character. Similar results of decrease in seedling length with increase in storage period was reported by John and Bharathi (2006) in a study with maize seeds film coated in combination with chemicals and nutrients and stored for 10 months. Kunkur *et al.*, (2007) also reported decrease in root and shoot length over the storage period in cotton seeds and kept in ambient storage condition.

Vigour index-1 is a function of seedling length and germination per cent. In dry method, T_4 and T_5 were found to be the best treatments from the results of one year storage study recording higher vigour index-1 values (Fig. 2g). In wet method, T_5 was the best treatment during the storage period except at 0 month. In both cases, T_8 (untreated control) recorded the lowest vigour index-1 values followed by T_7 (film coated control) (Fig. 2h). Higher vigour index observed in certain treatments is due to the highest germination per cent throughout the storage period and higher seedling length.

In both methods of seed treatments, T_5 recorded maximum vigour index-2 during 3, 6, 9 and 12 months of storage whereas T_4 was found to be the best at 0 month of storage (Fig 2i). One year storage study in film coated and treated cowpea seeds revealed that *Pseudomonas* and *Trichoderma* can extend the storage life of seeds with higher germination and vigour. Untreated seeds always recorded poor germination and vigour. Film coated seeds (without any material) were better than untreated seeds on their performance (germination and vigour) (Fig. 2j). This indicates that film coating alone can influence germination and vigour of seeds to some extent. Similar results were obtained in a study conducted by Basavaraj *et al.*, (2008) where film coated onion seeds, showed higher vigour index (1169) at the end of 10 months of storage than untreated control. Vigour indices were found to decrease with increase in storage period in all the treatments. Kunkur *et al.*, (2007) also reported decrease in vigour index as the storage period increased, from 2501 to 1727 in the seeds of cotton treated with polymer coating. Similar results of drastic decrease in vigour index (795) as compared to initial vigour index (1554) at the end of 12 months of storage was reported by Manjunatha *et al.*, (2008) in a study with film coated chilli seeds.

Pest incidence was nil in all the treatments at the end of 6 months storage period. At the end of 9 months of storage, pest incidence of 6.66% was noticed in untreated control (T_8) only. After 12 months of storage, film coated control (T_7) and untreated control recorded pest incidence of 2.14% and 8.57% respectively. All other treatments where film coated seeds were treated with various chemicals

Fig 2h: Effect of film coating on vigour index-1 in wet method of storage

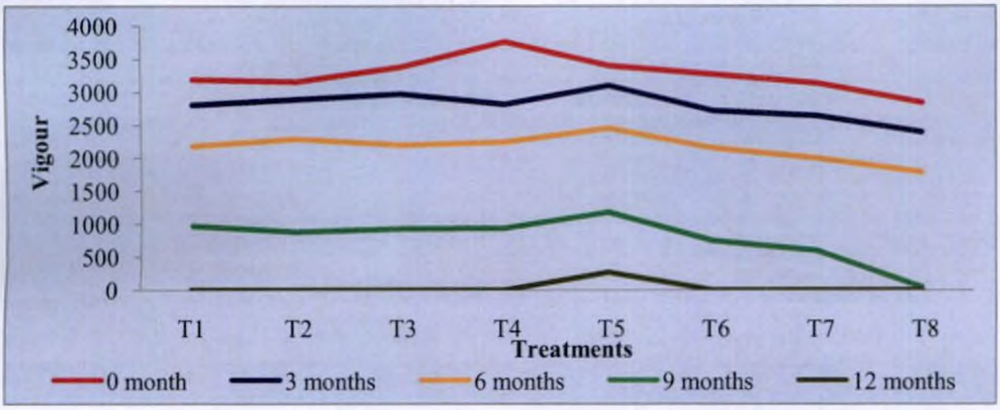


Fig 2i: Effect of film coating on vigour index-2 in dry method of storage

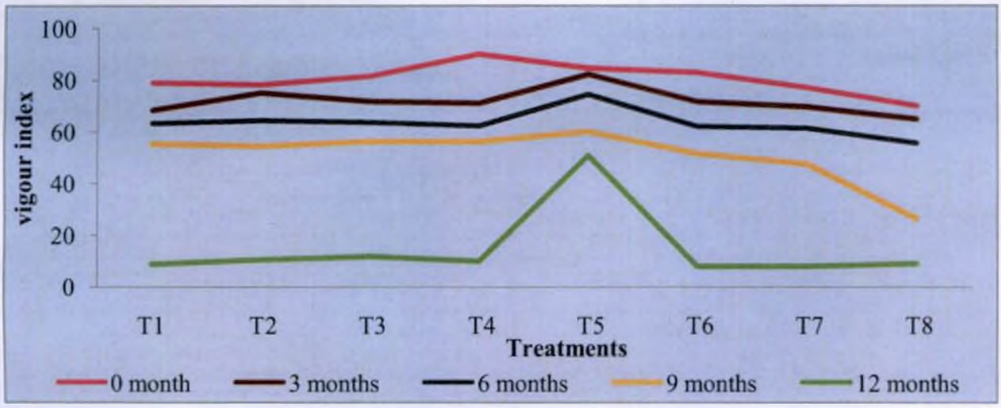
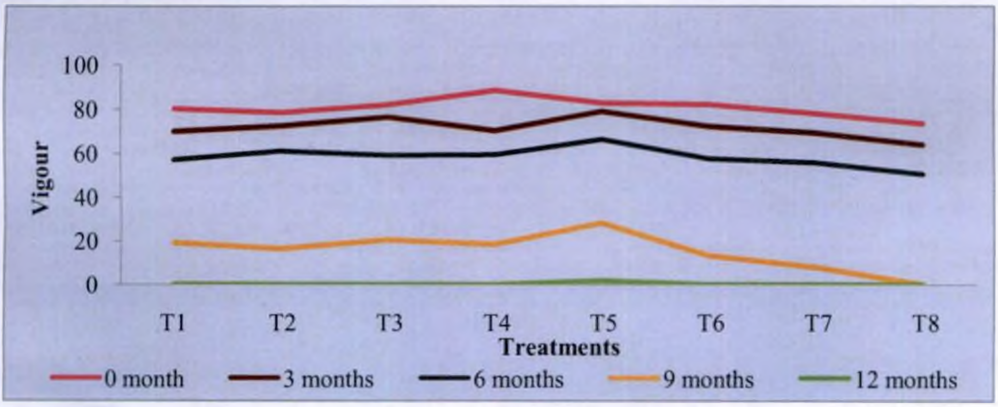


Fig 2j: Effect of film coating on vigour index-2 in wet method of storage



(carbaryl, carbendazim and their combination) and bio-agents (*Trichoderma*, *Pseudomonas* and their combination) gave protection against pests throughout the storage period. Similar results were reported by Laxminarayan *et al.,* (1998), green gram seeds, treated in combination with insecticides viz., fenvalarte 0.4D and endosulfan 4D (2, 3 and 4g/kg of seed) were reported to be superior in controlling storage pests as compared to control. Bisong *et al.,* (2002) reported that seed treatment on green gram with higher doses of thiamethoxam and longer exposure resulted in higher mortalities of most of the storage beetles after six days exposure. Choudhary and Dashad (2002) reported that chickpea seeds treated with endosulfan, monocrotophos and chloropyriphos provided maximum protection against storage pests, but endosulfan and chloropyriphos had no adverse effect on germination.

Electrical conductivity (EC) value of the leachate is an indication of the viability and vigour of the seed. In the present study, values of EC increased in all the treatments with an increase in storage period. Among the treatments in dry method, T_5 was found to be the best followed by T_4 since these treatments recorded lowest EC values throughout the storage period (Fig 2k). In wet method of seed coating, T_5 is found to be the best treatment over others in the storage period as evident from the lowest values observed in this. In both methods of coating, highest EC value was found in untreated control (T_8). A definite relation between electrical conductivity and germination was observed since treatments with low EC value had showed higher germination per cent. In this study, film coated seeds with *Pseudomonas* (T_5) followed by *Trichoderma* (T4) with low EC value gave high germination and vigour (Fig 2l). Similar findings were quoted by Kunkur *et al.,* (2007) in cotton where treated seeds (thiram + imidacloprid) showed lower EC than untreated seeds in storage and also EC values increased from 0.98 dSm^{-1} (in the best treatment) to 1.50 dSm^{-1} at the end of 9 months of storage. Basavaraj *et al.,* (2008) also reported that in onion, electrical conductivity of stored seeds showed a progressive increase with increase in storage period, the average initial EC value was 0.51 dSm^{-1} and at the end of 10 months of storage

Fig 2k: Effect of film coating on electrical conductivity in dry method of storage

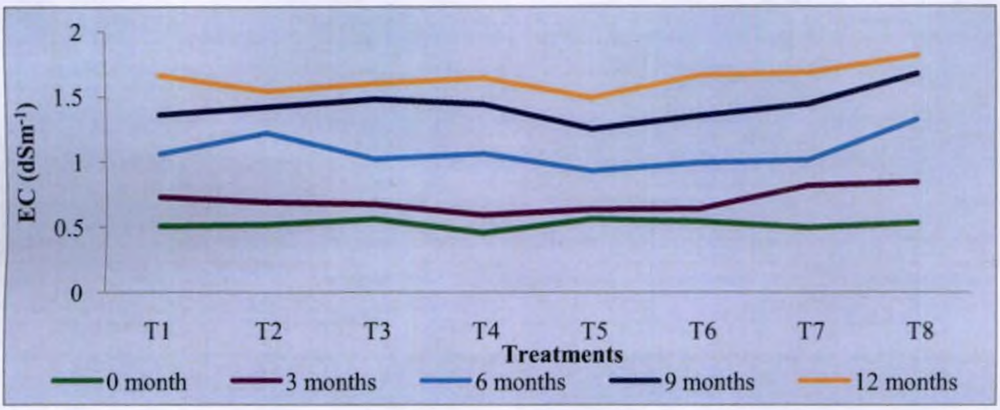


Fig 2l: Effect of film coating on electrical conductivity in wet method of storage

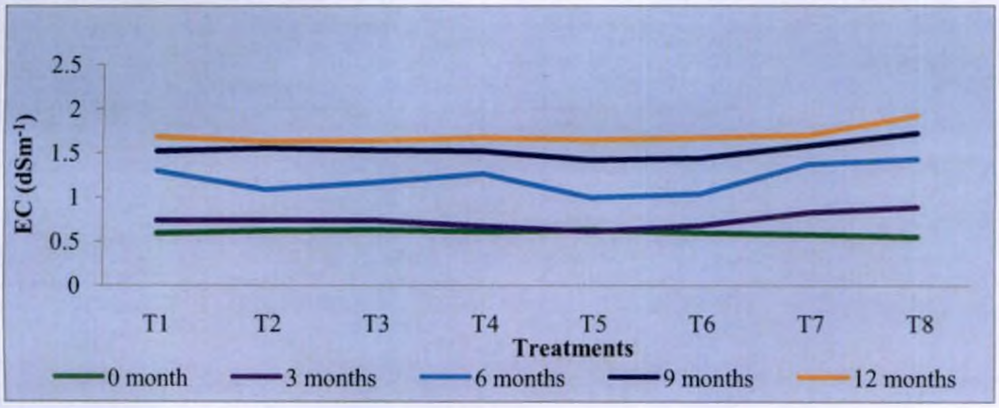
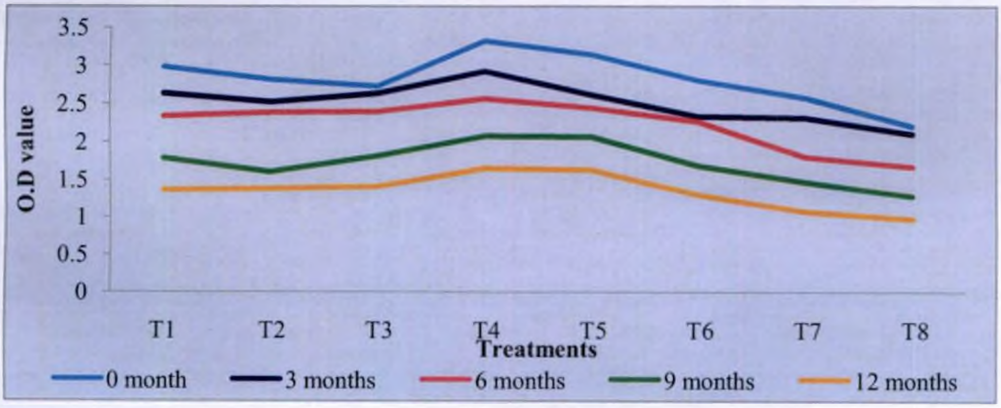


Fig 2m: Effect of film coating on dehydrogenase enzyme in dry method of storage



the final value was 0.66 dSm^{-1}. Manjunatha *et al.,* (2008) reported that in chilli, electrical conductivity of seed leachate increased as the storage period increased. In their study, lower electrical conductivity was recorded in polymer and thiram treated seeds (2.02 dSm^{-1}) as compared to control (2.19 dSm^{-1}).

Dehydrogenase enzyme activity is a direct indicator of viability of seeds. The red coloured stain indicates viable seeds and lower the colour shows lower viability of seeds. Activity of the enzyme "dehydrogenase" decreased with increase in the storage period. In dry method of seed treatment, highest activity of the enzyme was observed in T_4 with values of 3.32, 2.92, 2.56, 2.07 and 1.65 at 0, 3, 6, 9 and 12 months of storage. The 2nd best treatment was found to be T_5 whereas film coated T_7 and untreated control (T_8) recorded lowest values for this enzyme throughout storage period (Fig 2m). In wet method of seed treatment also, same trend was noticed where T_4 and T_5 performed better among others in storage (Fig 2n). Similar results of decreased dehydrogenase activity were reported by John and Bharathi (2006) in maize seeds film coated with chemicals and nutrients.

Protein estimation of seeds during storage period indicated a decrease in seed protein content with increase in the storage period. In dry method of seed treatment, T5 had higher protein content than other treatments with values of 17.36 g, 16.23, 15.63 and 14.83 g in 100g seed at 3, 6, 9 and 12 months of storage (Fig 2o). In wet method of treatment, T_4 was considered as the best treatment throughout the storage period (Fig. 2p).

Experiment- III

5.3 Effect of film coated treatments (with chemicals and bio-agents) on growth, field performance and yield of cowpea.

The field germination was found to be the highest in T_5 of both dry (96.6) and wet (95.0) methods though significant difference was not observed between the treatments in wet method. T_4 was the next best treatment with 93.33% germination. In both cases, film coated control (T_7) was superior in germination than untreated control without film coating (T_8) (Fig. 3a). This indicates that film

Fig 2n: Effect of film coating on dehydrogenase enzyme in wet method of storage

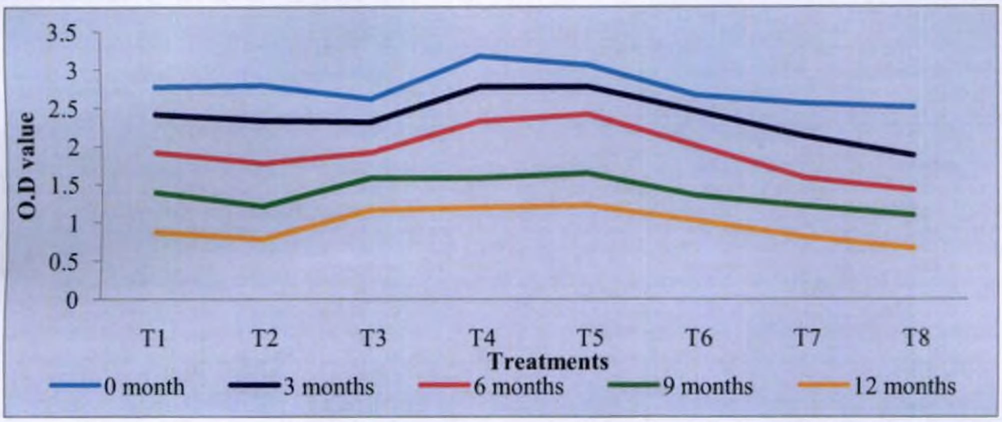


Fig 2o: Effect of film coating on protein (g/100g seed) in dry method of storage

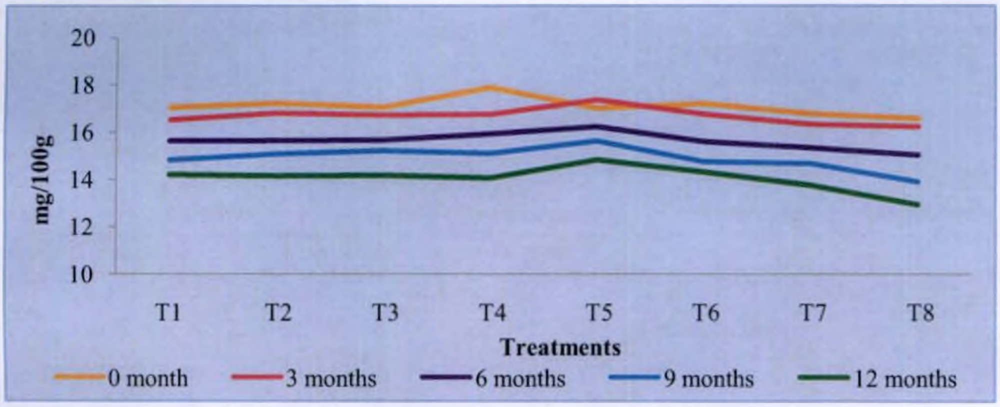
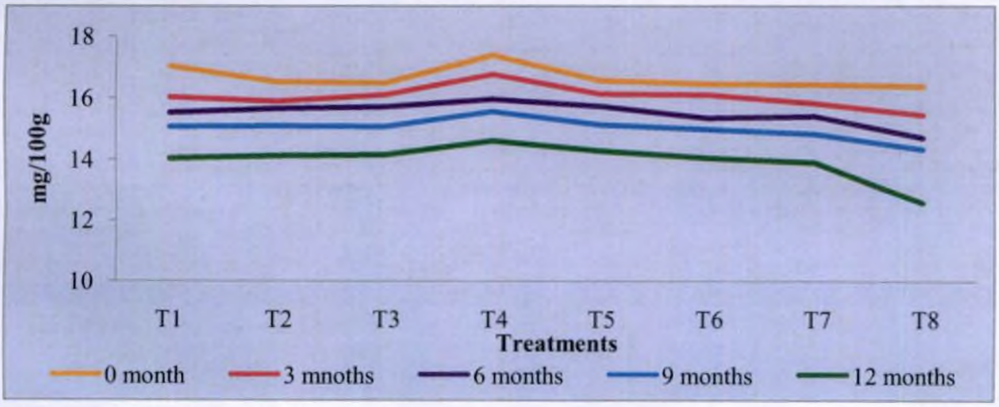


Fig 2p: Effect of film coating on protein (g/100g seed) in wet method of storage



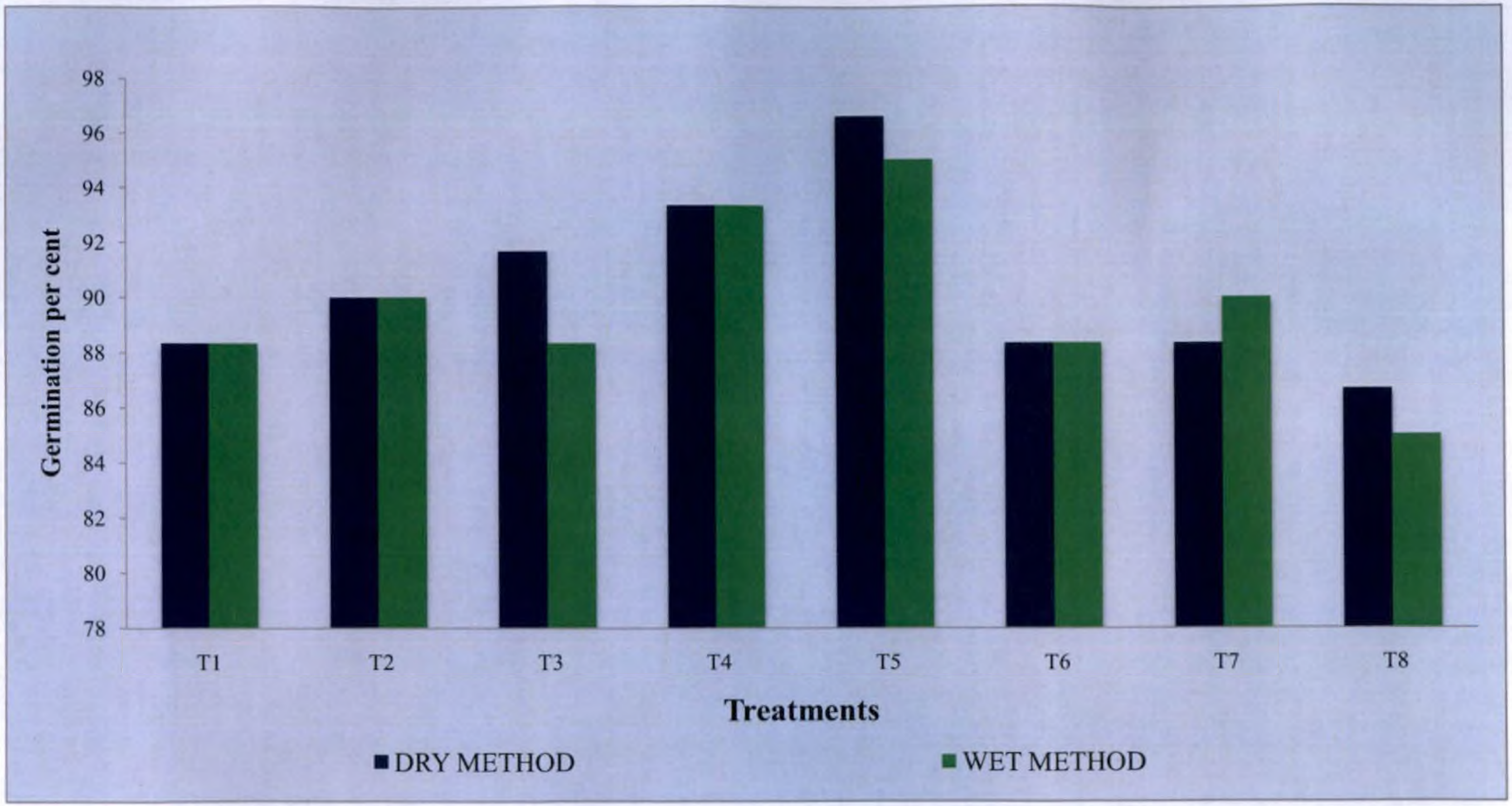


Fig. 3a: Effect of film coating on field germination per cent

coating of the seed alone can increase germination to a certain extent. Treatments with biological agents along with film coating outperformed all other treatments under field condition as revealed from the higher germination per cent in T_5 followed by T_4. This may be due to the production of phytohormones like auxins, gibberlins, cytokinins and indole acetic acid which plays an important role in growth promotion. Diniz *et al.,* (2009) reported that coating bell pepper seeds with polymers in combination with microorganisms (*Trichoderma viridae, T. polysporhum, T. stromaticum, Beauveria bassiana, Metarhizium anisopliae*), mycorhizas, aminoacids, micronutrients and plant growth regulators increased the per cent of germination and rate of seedling emergence.

Use of chemicals like carbaryl and carbendazim also gave good field germination for the treated seeds. Similar results of improved germination and vigour was reported by many scientists. Srivastava and Yadav (2006) in a study on maize seeds reported increased germination when treated with film coating agent in combination with fungicides and insecticides. Their study also indicated considerable improvement in seedling vigour and field emergence by 10.50 per cent as compared to untreated control. Kaur and Bishnoi (2008) reported that film-coated canola with fungicide gave highest seedling establishment in all three soil types (sandy, silt, and clay loam). Thobunluepop *et al.,* (2008) observed improved seed germination, seedling establishment, plant growth and kernel yield in paddy seeds coated with various substances *viz.,* captan and bio-agents. Lima *et al.,* (2006) reported that even when cotton seeds were treated with a mixture of fungicides (carboxin + thiram) and the insecticide imidacloprid at 2.5+2.5 ml/kg, no reduction in germination, emergence and speed of emergence was noticed in high quality seeds.

The days for 50% germination did not show much difference between the treatments tried. The best treatment in dry method was T_2 (3.66) followed by all other treatments (4 days) except T_8 which took longer time (4.33 days) to obtain 50% germination. In wet method, all treatments except T_1 attained 50% germination earlier. Delay in germination in T_8 may be due to the absence of film coat with the seed. This shows the superiority of the film coating on seeds which promotes germination. Film coated seed can absorb more moisture which enhances the germination indirectly as compared to control which had taken 4.33 and 4.66 days to reach 50% germination in both dry as well as wet methods.

Number of days to first harvest was earliest in T_4, T_5 and T_6 in dry method which took 53 days from sowing whereas T_3, T_4 and T_5 also took the same number of days (53) from sowing to first harvest in wet method also. This indicates that treatments where bio-agents are used for coating performed better than chemically treated treatments except T_3 [Carbaryl + Carbendazim (1g + 1g per kg seed)] which was the lone treatment performed equally.

Number of fruits obtained from a plant was found to be higher in film coated and treated seeds with bio agents whereas the untreated control recorded less number of fruits in both methods of seed treatment.

Fruit length had shown significant differences between treatments and T_5 (20.52cm) of dry method and T_4 (21.02cm) of wet method had the maximum length as compared to others. Length of fruits in untreated control (T_8) was very low (18.7cm) in both methods of coating and at the same time film coated control (T_7) recorded higher value for fruit length (19cm) than T_8. Average fruit weight was highest in T_4 and T_5 (>5g) of dry method and T_4 (5.25) of wet method (Fig. 3b). This may be due to the increased fruit length in these treatments. All treatments were on par with respect to number of harvests in both dry and wet method of film coating. Maximum fruit yield per plant was recorded in T_5 (69g) followed by T_4 in dry method and T_4 (78g) followed by T_5 in wet method (Fig. 3c). Enhanced yield in these treatments may be due to the favourable effect of bio-agents on increasing soil fertility and also due to the increase in fruit length, more number of harvests and average fruit weight as compared to other treatments. Significantly low yield was recorded in both control treatments (T_7 and T_8) and the reasons for this include lowest number of fruits per plant, less fruit length and low fruit weight.

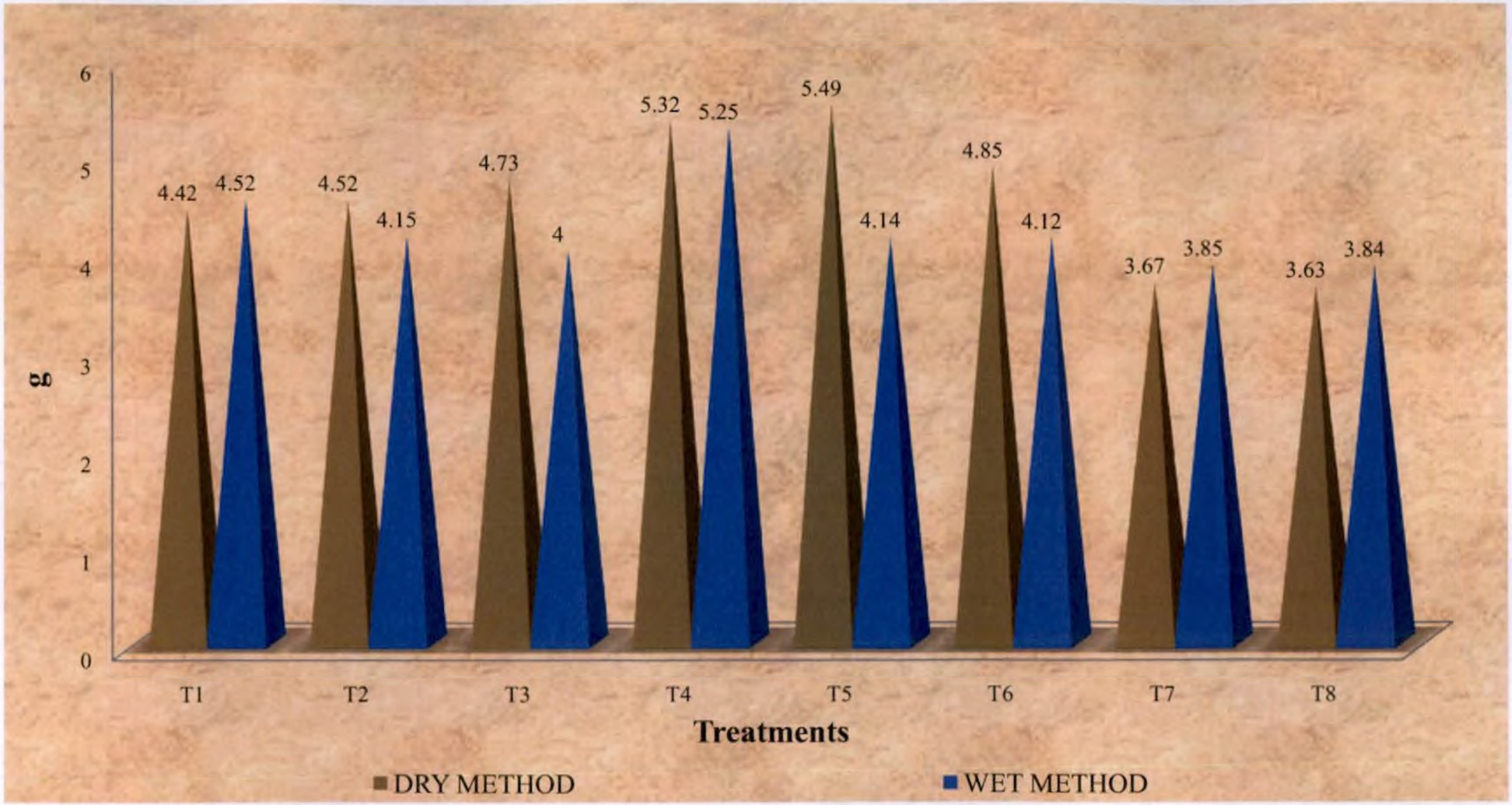


Fig 3b: Effect of film coating on average fruit weight in field

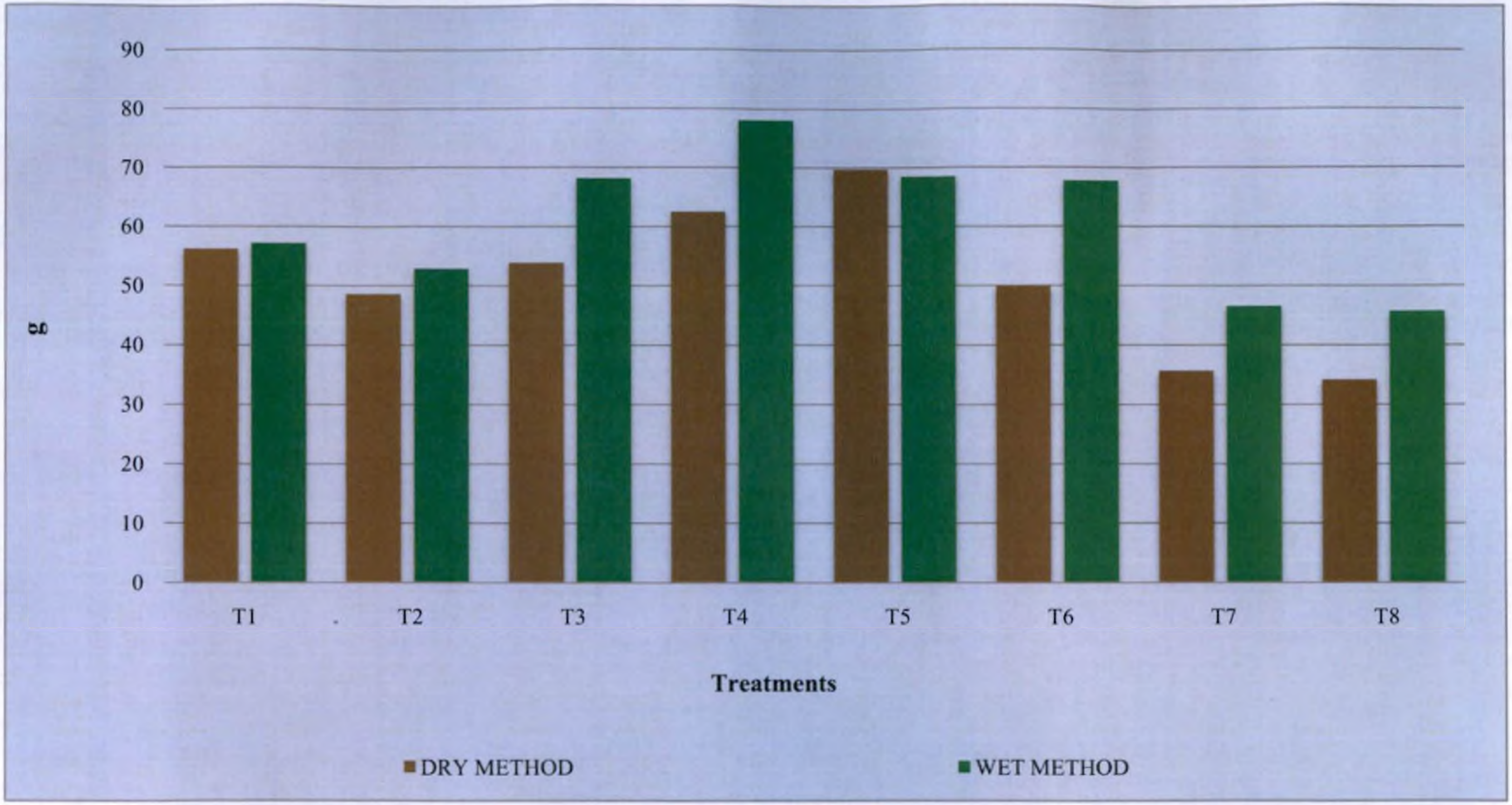


Fig 3c: Effect of film coating on fruit yield per plant in field

Plot yield obtained from an area of $2.7m^2$ was highest in T_5 (3.5kg) and probable per hectare yield of 13.07t/ha of dry method and T_4 (3.85kg) the probable per hectare yield being 14.26t/ha of wet method. The 2nd best treatment giving highest yield was T_4 in dry method (2.9kg) and T_5 (3.44kg) of wet method. These treatments had outperformed other treatments especially the control treatments with respect to yield. This is due to the production of phytohormones like auxins, gibberlins, cytokinins and indole acetic acid which plays an important role in growth promotion by the bio agents namely *Trichoderma* and *Pseudomonas*. In addition, overall increase in fruit length, number of fruits, average fruit weight and fruit yield per plant resulted in increased plot yield (Fig. 3d).

Per hectare yield was found to be the highest in T_5 ($13.07t.ha^{-1}$) followed by T_4 ($11.07\ t.ha^{-1}$) in dry method of seed treatment. In wet method of seed treatment, T_4 was found to be the highest with a value of $14.26\ t.ha^{-1}$ followed by T_5 ($12.47\ t.ha^{-1}$) as compared to untreated control (T_8) having $4.70\ t.ha^{-1}$ and $6.70\ t.ha^{-1}$ in both dry and wet method respectively (Table 3g). The maximum benefit cost ratio was observed in T_5 (2.18) in dry method and T_4 (2.35) of wet method as compared to untreated control (T_8) having a ratio of 1.10 and 1.39 in both dry and wet method of film coating (Fig. 3e). Similar results were reported by Joseph *et al.,* (1995) in a study in chickpea seeds treated with polymer coating (@ 1.50 g per kg seed) which recorded higher yield (23.28 q/ha) as that of control (20.03 q/ha). Results of study by Zholbolsynova *et al.,* (1992) showed that seeds of wheat coated with polymers increased the yield from 0.93 tonnes to 1.62 tonnes per ha.

Pest incidence was comparatively low in the experimental field. No pest incidence (0%) was noticed in T3 where film coated seeds were treated with carbaryl and carbendazim. However, T_8 (5%) of dry method and T_7 and T_8 (5%) of wet method recorded the maximum incidence of pest (aphid) as the seeds of these treatments are not coated with any protectant material against the pests and hence were easily vulnerable to the pest attack. Pest incidence was less in treatments where the seeds are film coated with either fungicide or insecticide or

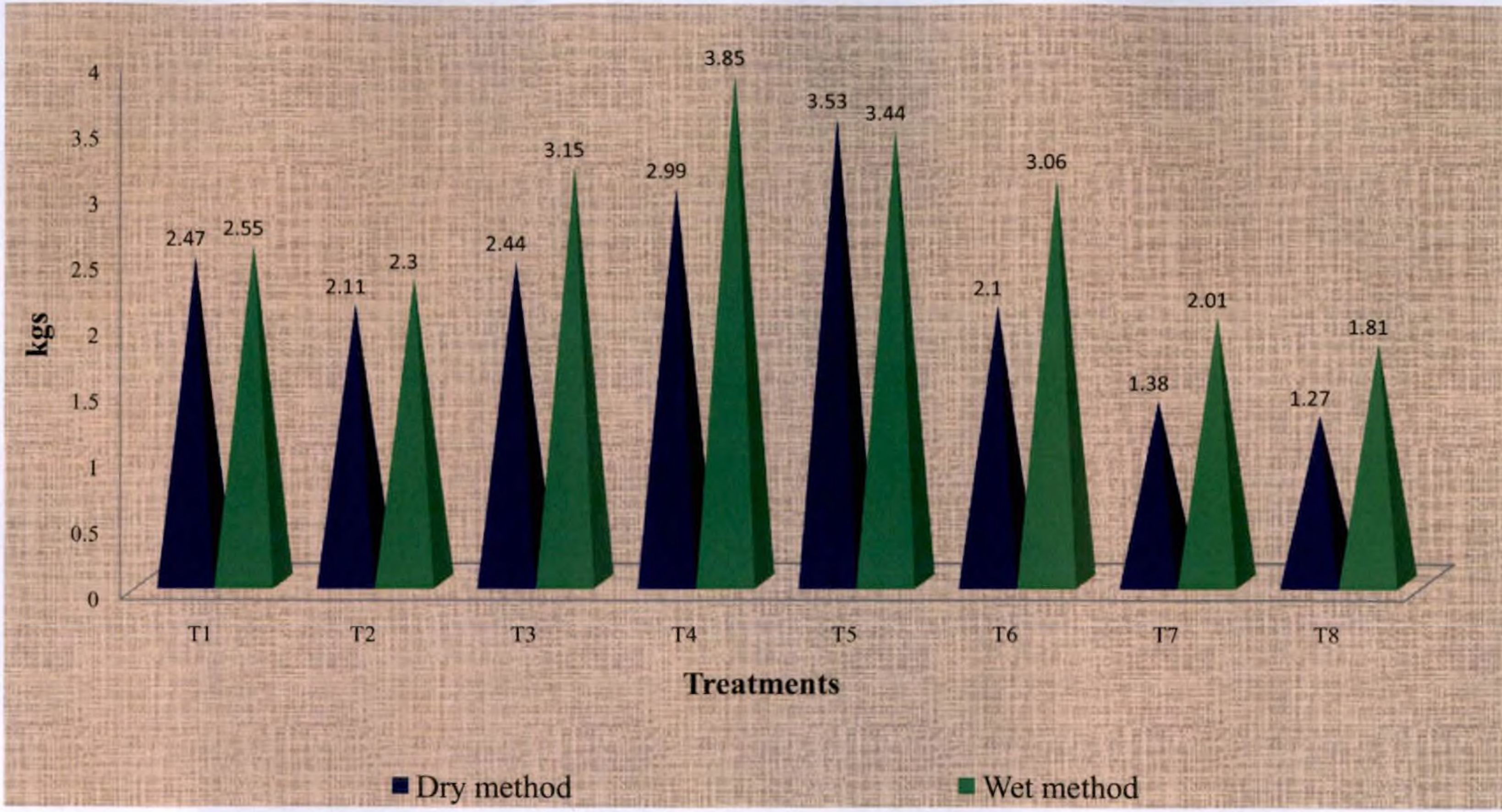


Fig 3d: Effect of film coating on plot yield ($2.7m^2$)

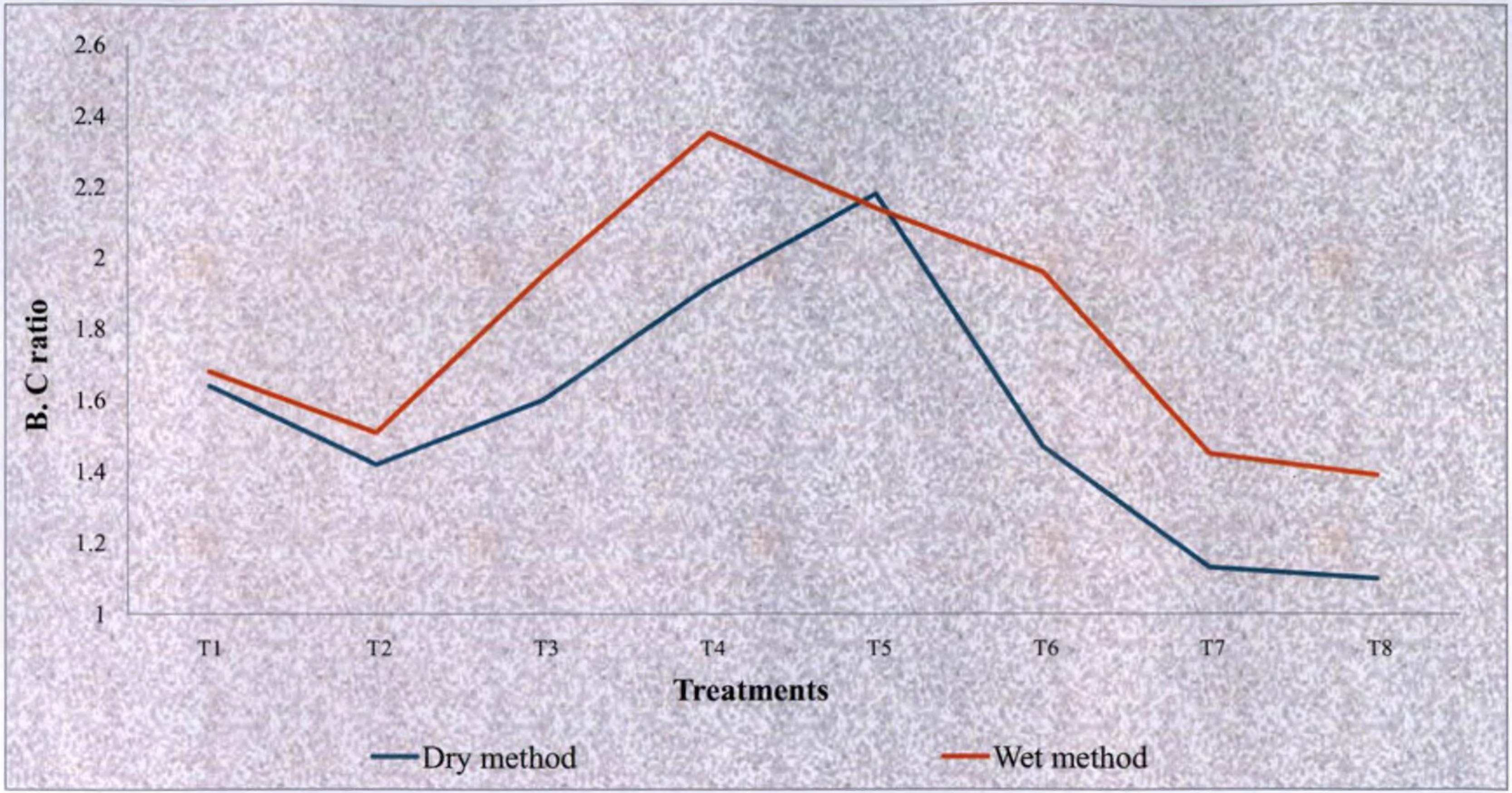


Fig 3e: Effect of film coating on benefit cost ratio

Table 3g: Effect of film coating in combination with chemicals and bio-agents on yield/ha.

Treatments	Yield (t/ha)	
	Dry method	Wet method
T_1	9.15 ^{b}	9.44 ^{abc}
T_2	7.81 ^{bc}	8.52 ^{bc}
T_3	9.04 ^{b}	11.67 ^{abc}
T_4	11.07 ^{ab}	14.26 ^{a}
T_5	13.07 ^{a}	12.74 ^{ab}
T_6	7.78 ^{bc}	11.33 ^{abc}
T_7	5.11 ^{c}	7.44 ^{c}
T_8	4.70 ^{c}	6.70 ^{c}

Same alphabets show homogenous effect.

bio-agents or combination of these. It is clear from the results that chemicals or bio-agents have beneficial effect on the seed by protecting it against pests. Similar results of pest control with the use of chemicals were reported by Ester (1999) in a study conducted in leek crop (*Allium porrum*) to assess the levels of onion fly (*Delia antiqua*) by film-coating the seed with various insecticides. Another study conducted by Ester *et al.*, (2003) in French bean seeds which were film-coated with various insecticides revealed that film coated seeds with chlorpyrifos and fipronil gave sufficiently good protection against the bean seed fly (*Delia platura* (Meig.)) than untreated seeds under field conditions. Ester *et al.*, (2007) reported that film coating of carrot seeds with single or combination of insecticides gave better control against pests than untreated seeds.

No disease incidence was observed in T_3 of both methods of seed coating and T2 of wet method whereas, highest disease incidence was recorded in T_8 of both methods. Absence of disease in T_3 is due to the protection given by the combination of chemicals carbaryl and carbendazim applied to the seed. Use of bio-agents like *Trichoderma* (T_4) and *Pseudomonas* (T_5) and combination of these two (T_6) did not give sufficient protection from diseases in field condition, but comparatively less incidence when compared with untreated control (T_8). Highest disease incidence in T_8 is due to the absence of any material on the seed which can give protection against diseases. Similar results were observed in a study conducted by Kaur and Bishnoi (2008) where film coated canola (*Brassica napus* L.) seeds with fungicides / insecticides showed increased seedling establishment under field conditions. Results of study by Srivastava and Yadav (2006) showed that film coated maize seeds in combination with fungicides gave protection against leaf blight and sheath blight (caused by *Rhizoctonia solani*) as compared to untreated control.

Following results of the study on "Seed quality enhancement in cowpea (*Vigna unguiculata* (L.) Walp.) by film coating technique" indicates that seed treated with 20ml film coat per kg seed can give bright colour, lustre and uniform coating, high germination and vigour. Storage studies for one year revealed higher germination and vigour in seeds treated with bio-agents *viz.*, *Trichoderma* and *Pseudomonas* when compared to untreated seeds. Germination and vigour was found to decrease with increase in storage period. Field evaluation experiment indicated high germination, fruit length, average fruit weight and yield in seeds treated with bio-agents as compared to controls (film coated and untreated).

Future line of work

- The results of the study suggests further improvement by incorporating new chemicals, micro nutrients and growth regulators for further enhancement of storage life of seeds.
- Field performance of the treated and stored seeds at definite intervals of storage needs to be assessed.
- Influence of temperature and RH on seed viability and vigour needs to be investigated.

SUMMARY

6. SUMMARY

The investigation on "Seed quality enhancement in cowpea (*Vigna unguiculata* (L.) Walp.) by film coating technique" was conducted during 2009-2010 in the Department of Olericulture, College of Horticulture, Vellanikkara. The cowpea variety "Bhagyalakshmi" was used for the particular study. The laboratory experiments were laid out in Completely Randomized Design (CRD). Field experiment was laid out in Randomized Block Design (RBD). The results of the three experiments are summarised below:

Experiment: 1

1. The bright colour, good lustre (shiny seeds) and uniformity of coating was obtained in T_4 (20 ml per kg of seed) and T_8 (20 ml per kg of seed) of dry and wet methods respectively. As the dose of the polymer increased, colour development, lustre and uniformity of coating were found to increase.

2. T_7 of wet method (78.67 per cent) was superior to all other treatments with respect to initial germination followed by T_1 (77.33 per cent) of dry method. Values for initial germination were the lowest in T_4 (59.33 per cent) and T_8 (53.33 per cent) of dry and wet method respectively.

3. The final germination, (last count) was found to be the highest in T4 (88.00 per cent) of dry method and T_8 (85.33 per cent) of wet method and least in T_1 (78.67 per cent) and T_6 (74.00 per cent) of dry and wet method respectively.

4. Between the two methods of film coating speed of germination ranged from 51.35 (T_6 of wet method) to 57.72 (T_7 of wet method). However there was no significant difference among treatments with respect to this character.

5. No significant differences were seen among the different treatments in days for 50per cent germination. All treatments took 2 days to obtain 50per cent germination except T_8 (2.33).

6. In dry method of seed treatment, highest values for root length and shoot length were observed in T_4 (13.83 cm and 21.66 cm) whereas in wet method of seed treatment T_8 (13.69 cm and 21.90 cm) recorded highest values for root and shoot length. These were significantly superior to all the treatments.

7. T_4 with the highest vigour index-1 (3125) and vigour index-2 (81.33) was significantly superior to all the treatments.

Experiment: 2

8. In dry method of seed treatment, the initial germination varied from 73 per cent to 18.3 per cent during storage period. T_4 (0 month) was superior to all the treatments before storage whereas T_5 was found superior overall treatments during 3, 6, 9 and 12 months of storage. In wet method of seed treatment, initial germination varied from 85per cent to 5per cent at the end of one year storage.

9. In dry method of seed treatment, the final germination varied from 100 per cent in T_4 before storage to 72 per cent in T_5 at the end of one year storage period whereas in wet method of seed treatment, the germination varied from 100 per cent in T_4 (0 month storage) to 10 per cent in T_5 (12 months period). Germination of film coated control was higher than untreated control. T_5 was significantly superior to all the other treatments under dry and wet method of film coating.

10. The speed of germination varied from 58.95 in T_4 at 0 month storage to 29.35 in T_5 after one year of storage in dry method, whereas in wet method of seed treatment, speed of germination varied from 51.73 in T4 at 0 moth storage to 4.63 in T_5 after one year storage period respectively. T_5 was significantly superior to all the other treatments in both dry and wet methods of film coating from 6 months of storage.

11. Number of days required for obtaining 50 per cent germination increased with increase in the storage period. In dry method, number of days to obtain 50 per cent germination increased from 3.33 days to 4.66 days (after one year of storage) and in wet method, it increased from 3.0 to 4.0 days, but after 9 months of storage, none of the treatments attained 50 per cent germination.

12. The root length decreased with increase in storage period in both the methods. In dry method, it decreased to 11.68cm from 13.96cm in T_4, whereas in wet method of seed treatment, root length decreased from 13.98cm to 8.52cm. Similarly shoot length also decreased from 23.36cm to 19.82cm in dry method, and from 23.62 cm to 19.62 cm in wet method of film coating.

13. The vigour indices decreased continuously with increase in the storage period. In dry method, vigour index-1 decreased from 3732 (T_4) to 1917 (T_5), whereas in wet method of seed treatment, the values decreased from 3760 (T_4) to 271 (T_5). Similarly in vigour index-2 the values decreased from 90 (T_4) to 50.88 in T_5 of dry method and from 88.67 at 0 month in T_4 to 1.85 in T_5. After 3 months of storage T_5 was significantly superior to all the treatments in dry and method.

14. No pest attack was noticed up to 6 months of storage under dry method of coating. At the end of 9 months of storage period, pulse beetle was noticed in untreated control treatment (T_8) having an incidence of 6.90 per cent. At the

end of 12 months of storage, pest attack was observed in T_7 and T_8 with the values of 2.14 and 8.57 per cent. In wet method of coating, there was no occurrence of pest throughout the storage period.

15. No fungal attack was noticed throughout the storage period, both in dry as well as in wet method of seed treatment.

16. Electrical conductivity values increased with increase in storage period in both the methods. In dry method of seed treatment, it increased from 0.45 in T_4 at 0 month to 1.81dSm^{-1} in T_8 after one year of storage. In wet method, it increased from 0.54 to 1.92dSm^{-1} after one year storage. T_5 in both methods of film coating exhibited significantly low EC values between 3 and 12 months of storage.

17. Enzyme dehydrogenase values decreased with increase in storage period. It decreased to 1.65 after one year of storage from 3.32 (O.D) in T_4 at 0 month in dry method of film coating, whereas in wet method of seed treatment, it decreased to 1.22 in T_5 after one year of storage from 3.17 (O.D) in T_4 at 0 month storage. The enzymatic activity was significantly higher in T_4 of dry method and T_5 in wet method.

18. Protein content in the seed decreased with increase in storage period. In the dry method of seed coating, the values decreased from 17.87g/100g seed in T_4 at 0 month storage to 14.83g/100g seed in T_5 after one year storage, whereas in wet method of seed treatment, the values also decreased from 17.39 in T_4 at 0 month to 14.60g/100g seed after one year storage. Protein content was found to significantly superior in T5 (dry method) and T4 (wet method).

Experiment: 3

19. In dry method of seed coating, T_5 recorded significant superior field germination of 96.6 per cent over other treatments. In wet method of seed treatment, no significant difference was noticed between treatments and a maximum of 95 per cent germination was obtained in T_5. All the treatments in wet method recorded above 85 per cent germination.

20. In dry method of seed treatment, the days to 50 per cent germination was found to be significantly early in T_2 (3.66) followed by other treatments (4.00) except T_8 (4.33). In wet method of seed treatment 50 per cent germination was obtained in 4-5 days. All treatments except T_1 were on par with each other. Except T_1, other treatments took 4-4.66 days to reach 50 per cent germination whereas T_1 obtained 50 per cent germination in 5-6 days.

21. In dry method of seed treatment, T4, T5 and T6 was found to be significantly early with respect to the days to first harvest and it was late in T_7 (57 days) and T_8 (59 days). In wet method of seed treatment, no significant difference was observed among the treatments. T_3, T_4 and T_5 took 53 days to reach first harvest whereas T_8 took 57 days to reach first harvest.

22. Number of fruits per plant was significantly high in T_4 (12.79) and T_5 (12.66) in dry method of seed treatment. In wet method of seed treatment, number of fruits obtained was found to be the highest in T_3 (17.36) and lowest in T_8 (11.87). All treatments were on par with each other in case of wet method.

23. In dry method of seed coating, T_5 recorded significantly high fruit length. It showed highest fruit length (>20 cm) and lowest value was observed in T_8

(18.70 cm). In wet method of seed treatment, T_4 recorded highest value for fruit length (21.02 cm) and was significantly superior over other treatments.

24. Average fruit weight was found to be the highest in T_5 (5.49g) and T_4 (5.32g) were significantly superior to all treatments in dry method. In wet method of seed treatment, highest fruit weight was obtained in T_4 (5.25g) and lowest fruit weight was observed in T_7 (3.85g) and T8 (3.84g). In wet method T_4 was found to be significantly superior to other treatments.

25. Fruit yield per plant was found to be the highest in T_5 (69.67g) in dry method of seed treatment and lowest fruit yield was recorded in control (T_8) with 34.12g per plant. In wet method of seed treatment, maximum yield per plant was obtained in T_4 (78.06g) and the fruit yield was found to be the lowest in T_8 with 45.71g per plant. T_5 and T_4 were significantly superior to all other treatments respectively in dry and wet method of treatment.

26. Number of harvests ranged from 4-5 in both the methods of seed coating with maximum number of harvests (5) in T_2, T_4 and T_5 in dry method and T_4, T_5 and T_6 in wet method. No significant differences were noticed among the treatments for this character in both methods of seed treatment.

27. Plot yield was found to be significantly high in T_5 (3.53kg) of dry method of seed coating and lowest in T_8 with a value of 1.27 kg respectively. Significantly higher yield was obtained in T_4 (3.85kg) in wet method of seed treatment whereas T_8 (1.81kg) recorded in lowest vegetable yield.

28. Pest incidence was very low in treated and film coated seeds. Untreated control (T_8) of both methods recorded highest (5 per cent) pest incidence. No pest incidence was found in T_3 of both dry and wet methods of seed treatment.

29. No disease incidence was noticed in T_3 of both methods of seed treatment. The highest incidence of disease was observed in untreated with values of 8.33 per cent and 6.66 per cent in dry and wet methods respectively. Disease incidence in film coated control (T_7) was less than untreated control (T_8) in both methods of seed treatment.

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* Originals not seen

SEED QUALITY ENHANCEMENT IN COWPEA (*Vigna unguiculata* (L.) WALP.) BY FILM COATING TECHNIQUE

By

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ABSTRACT OF THE THESIS

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ABSTRACT

ABSTRACT

Film coating is the latest seed coating technique adopted for application of protectants, nutrients and growth regulators onto the seed. The study on "Seed quality enhancement in cowpea (*Vigna unguiculata* (L.) Walp.) by film coating technique" was undertaken in the Department of Olericulture, College of Horticulture, Kerala Agricultural University with the objective of standardising the dose and method of film coating, studying the effect of film coating in combination with insecticides, fungicides and bio agents on seed quality during storage and also to study the effect of seed film coating on growth, field performance and yield of cowpea.

Results revealed that film coating the seed @ 20ml.kg^{-1} seed gave good colour, lustre and uniform coating over the seed. With respect to germination parameters, T_4 (20ml.kg^{-1} seed) and T_8 (20ml.kg^{-1} seed) were found to be the best treatments recording maximum values for germination (88 per cent and 85 per cent). The speed of germination, ranged from 51.35 (T_6) to 57.72 (T_7) and there was no significant difference between the treatments. With respect to days for 50% germination there was no significant difference between treatments. Seedling lengths (root + shoot) and vigour indices were the highest in T_4 (34.49cm and 3125) and T_8 (35.59cm and 3010) of dry and wet method of seed treatment.

These two treatments T_4 (dry) and T_8 (wet) were used to study the effect of seed film coating in combination with insecticides, fungicides and bio agents on seed quality during storage. Irrespective of the methods followed, all the treatments showed a decrease in germination, speed of germination, seedling length and vigour indices with an increase in the storage period. In dry method of seed coating, in all the treatments seeds were viable even after one year of storage although the germination per cent was below the minimum standard for seed certification. Results of the storage study indicated the superiority of T_5 (*Pseudomonas* 10g.kg^{-1} seed) and T_4 (*Trichoderma* 4g.kg^{-1} seed) where bio agents

were used for seed coating with highest values of germination and vigour. In T_5, the germination percentage decreased from 96 to 86 % in dry method and from 95 to 87% in wet method at 0 and 9 months of storage respectively. The speed of germination decreased with increase in storage period ranging from 58.95 to 29.35 in dry method of film coating and 51.73 to 4.63 in wet method of film coating. Vigour index-1 values were high in T_4 and T_5 (> 3400) during 0^{th} month storage and it decreased considerably with increase in storage period. Treated seeds were free from pest attack throughout the storage period. Attack of pulse beetle (*Callosobruchus chinensis*) was noticed in the stored seeds in later stage in untreated control of dry method. No incidence of fungal attack was noticed throughout the storage period.

Biochemical studies conducted in stored seeds revealed an increase in values of electrical conductivity of the leachate, lower the leachate value higher will be the vigour of seeds. Decrease in seed protein content and activity of dehydrogenase enzyme with increase in storage period indicated the loss of vigour in stored seeds. Seeds coated with *Pseudomonas* @10 g per kg seed (T_5) followed by seed treatment with *Trichoderma* @ 4g per kg seed (T_4) were best with respect to maintaining viability and vigour of the seeds throughout the storage period as compared to controls (film coated and untreated).

Film coated seeds were planted in the field to study their field performance, growth, yield, pests and disease incidence etc. Under field condition, germination was more than 95 per cent in seeds treated with *Pseudomonas*. In both wet and dry methods of treatment, seeds coated with bio-agents performed better over other treatments with respect to parameters *viz.,* field germination, number of fruits, fruit length, average fruit weight and yield. Fruit yield per plant and plot yield were highest in seeds coated with bio agents like *Pseudomonas* and *Trichoderma* having a value of 3.27kg and 3.85kg per $2.7m^2$ as compared to untreated control having a value of (1.27 and 1.81kg per $2.7m^2$). Under field condition, seeds treated with chemicals gave maximum protection against pest and diseases whereas highest incidence of pest and diseases were noticed in untreated seeds.