A Review Combination of fungicide and polymer coating and packaging materials on improve germination rate and improve uniformity of seedling emergence of different seeds during storage

Abstract

Seed coating is a method of encasing seeds in adhesive materials to improve germination and performance while lowering cost. Seed coating has been widely used in agriculture as an efficient way to reduce biotic and abiotic stressors, hence boosting crop growth, productivity, and health, in order to satisfy the demands of the development of precision agriculture. Plant-beneficial microorganisms include *Trichoderma, rhizobium, arbuscular mycorrhizal fungusfungi* and plant growth-promoting bacteria. Fungicide seed treatment is easy, affordable, and efficient. Additionally, it is well known that the selection of chemicals for seed treatment also has a favourable impact on seed viability and vigour during germination storage. Seed coating polymers are utilised in conjunction with active components like fungicides and insecticides. A new era of biocontrol techniques has recently begun. By utilising hostile microbes to fight seed-borne illnesses, new technology is being developed. Beneficial fungus like *Trichoderma harzianum* and *Trichoderma viride* are among the bioagents most powerful and efficient fungus- and soil-borne pathogen suppressants such as seedling blight, collar rot, stem rot, root rot, dry root rot, and their use may can effectively manage each of these illnesses, and thus encourage crop growth and yield.

Key Words : Polymer coating, Packaging, Bioagents, Seeds.

Introduction

Seed is classed as a poor storer since it loses viability within a year of being stored at room temperature. Because seed is a living thing, it is vulnerable to a variety of environmental pressures that affect its quality. The viability and vigour of seeds in storage vary not only from species to species and variety to variety, but are also influenced by a variety of physicochemical factors such as moisture content, atmospheric relative humidity, temperature, initial seed quality, physical and chemical composition of seed, gaseous exchange, storage structure, packaging materials, seed production location and techniques, and so on temperature, initial moisture content of seeds, and relative humidity are among the key factors impacting seed quality during storage, resulting in significant changes De Vitis, Marcello, *et al.* (2020).

Seed degradation Fungi linked with stored seeds, on the other hand, are primarily responsible for deterioration of quality and loss in germination potential. Seed deterioration is connected with the ageing phenomena, which has been characterised as an irreversible degrading shift in the quality of a seed after it has reached its maximum quality level, and seed deterioration begins soon after the plant attains physiological maturity.

One of the many elements influencing seed storability that decreases vigour and germination is the degradation of protein, carbohydrates, and other food reserves by seed microflora. It is recommended to treat the seeds with fungicides and store them in proper conditions because seeds are an effective medium for the survival and spread of diseases, which can result in yield and viability losses.

Quality seed is essential for successful agriculture, which necessitates that each seed be easily germinable and produce a vigorous seedling in order to deliver a higher yield. Seed coating technology has improved rapidly over the last two decades and now provides a realistic method of improving seeds. Seed coating is the process of applying a beneficial chemical directly on a seed to form a thin, homogenous coating without affecting the seed's size or shape. Many crops, including grains, have benefited from seed coating. The seed industry swiftly adopted seed coating with natural or synthetic polymers. All necessary compounds, such as herbicides, inoculants, protectors, nutrients, plant growth promoters, hydrophobic and hydrophilic substances, and nutrients, can be included. Because the seeds are hygroscopic, their quality is affected by changes in environmental conditions such as relative humidity and temperature. To combat these factors, it is best to store the seeds in moisture vapour proof containers such as polythene bags, aluminium foil pouches, and tin boxes, among others. It will be extremely beneficial to the seed industry and farming community to learn how to effectively preserve seeds by treating the seed. It is necessary to identify a compatible fungicide with a polymer coat and polymer colours, as well as appropriate containers in mustard (Rana *et al*., 2001), maize (Baxter and Waters, 1986 a and b, and John, 2003), and maize (Baxter and Waters, 1986 a and b, and John, 2003), and germination, seedling vigour, growth, and yield enhancement (Ramya, 2003).

Aside from the environment in which the seeds are stored, packing materials are critical for extending the shelf life of the seeds. Some packing materials are impermeable to moisture, whereas others are permeable. The viability of various packaging materials for the secure long-term storage of seeds under different crop kinds must be investigated.

Mycoflora on seeds

In 145 seed samples from Pakistan's most significant leguminous crops, Rauf (2000) utilised the blotter paper method to discover 24 seed-borne fungus from various genera. Alternaria alternata, *Ascochyta sp.*, Colletotrichum sp., Fusarium sp., and M. phaseolina were the most common and well-known pathogenic fungi in these crops. Soybean and chickpea seeds contained the greatest amounts of seed mycoflora, followed by mungbean, pea, and lentil seeds.

Dorna *et al.* (2005) investigated the effects of using fungicides or a biological product called Promot, which contains Trichoderma koningii and T. harzianum spores, as well as osmo and hydropriming of onion seeds. Conclusion Fungicides, both alone and in combination with osmo and hydropriming, controlled naturally existing fungus far more successfully than Promot.

Nawar (2007). according to In-vitro antagonistic effect of Trichoderma harzianum on root-rot pathogens demonstrated the presence of clear antagonistic activity between them, coated with *T. harzianum* and benlate had a significant lower percentage of infection (pre, post, dead plants and developed plants), significantly longer in height and better plant growth parameters. *T. harzianum* applied as soil or seed treatments enhancing the total microbial flora of squash rhizosphere.

Shovan *et al*. (2008) observed that the blotter method was proven to be effective for detecting fungus in soybean seeds. Fungi found in soybean seed samples included Alternaria alternata, Aspergillus flavus, Aspergillus niger, Chaetomium globosum, Colletotrichum dematium, Curvularia lunata, Fusarium oxysporum, Macrophomina phaseolina, Penicillium sp., and Rhizopus stolonifer.

Ekefan *et al.* (2009) observed that the seeds were treated with T. harzianum isolates, the incidence of C. capsici was significantly (P 0.05) lower with benomyl followed by Th-G treated seeds than with the other treatments. Th-G treatment exhibited the highest effect (P 0.05) on the radial development and speculation of C. capsici, followed by Th-I, benomyl, and Th-F. The percentage of germination in control and benomyl-treated seeds was significantly (P 0.05) higher than in other treatments.

Elwakil *et al.* (2009) reported by the examination of 26 seed samples from six different cultivars of faba beans, There were 20 fungal species identified from 13 genera. These include

Aspergillus flavus, Aspergillus niger, Aspergillus ochraceus, Pencillium digitatum, P. italicum, Alternaria alternate, Botrytis faba, Cephalosporium sp., Cladosporium cladosporioides, and Epic Stemphylium globuliferum, Trichothecium roseum, Fusarium oxysporum.

Afzal *et al.* (2010) identified "13 phytopathogenic fungal species from seven sunflower cultivars using agar and blotter paper methods, including A. alternata, A. flavus, A. fumigatus, A. niger, C. lunata, Drechslera tetramera, Fusarium solani, Fusarium moniliforme, M. phaseolina, Mucor, Pencillium, and Rh Seed germination was reduced by 10-20% and seedling mortality was reduced by 10-12% by the isolated fungi".

Khan *et al.* (2012) investigated the disease's prevalence in Jammu and Kashmir, as well as disease treatment by bio-control agents and fungicides, as well as the occurrences of dry root rot of chickpea caused by R. bataticola. In the laboratory, three bio-control agents were examined. Trichoderma viride, Trichoderma harzianum, and Pseudomonas flouresecense were the most effective against the pathogen. Rhizoctonia

Ismail *et al.* (2012) discovered eleven seed-borne fungus taxa in 15 cauliflower seed samples, including Alternaria spp., Helminthosporium spp., Aspergillus flavus, Rhizopus spp., Curvularia spp., Aspergillus niger (4.6 percent), Cercospora spp., Fusarium spp., and Chaetomium spp.

Ramesh *et al.* (2013) investigated the soybean seed mycoflora method yielded six fungi, whereas the agar plate and blotter paper approaches yielded 11 fungi. Pathogenic fungi that were often isolated included M. phaseolina, F. oxysporum, A. flavus, A. niger, Phoma sp., and Sclerotinia sclerotiorium. Fungi isolated less frequently were F. solani, F. moniliforme, Rhizopus sp., Botrytis cinerea, and Cercospora kikuchi.

Anwar *et al.* (2013) observed that "the identify E-358, DB-1601, 849-294D, Loopa, HS-16, 95-I, and Faisal. Among the eight soybean cultivars screened for seed-borne fungus were Soybean and Centennial. The isolation frequencies of the fungi differed between cultivars as well as between naturally infected and artificially decontaminated seeds. Among the common fungal genera isolated during this study were Absidia, Aspergillus, Mucor, Curvularia, Drechslera, Fusarium, Phoma, Rhizopus, and Penicillium. Infested seeds were less likely than uninfested seeds to contain Aspergillus, Penicillium, and Fusarium"**.**

Rathod and Pawar (2013) observed that "the fungi isolated from the soybean variety durga included Aspergillus flavus, Aspergillus niger, Aspergillus fumigatus, Alternaria tenuis, Fusarium oxysporum, Penicillium notatum, Sclerotium rolfsii, Mucor mucedo, Curvularia lunata, Cladosporium herbarum, Drechslera oryzae, and Rhizopus s The effect of various fungicides such as thiram, captan, and copper oxycholoride on the incidence of seed-borne fungus and how they affected seed germination was evaluated. Copper oxychloride was discovered to increase germination rates while lowering mycoflora when seeds were treated with fungicides. Fungicides are applied to the seeds to kill the soybean mycoflora that is carried in the seeds".

Ambika *et al.* (2014) found that polymer coated seeds germinated at a rate of 79% when compared to untreated control seeds (71%).

Alemu (2014) found five different species of fungi from four different genera that can grow on soybean seeds: Aspergillus flavus, Aspergillus niger, Fusarium spp., Penicillium sp., and Rhizopus spp.

Tareen *et al.* (2014) studied seed-borne mycoflora on ten tomato cultivars and found four extremely aggressive seed-borne fungus, Aspergillus niger, Alternaria alternata, F. moniliforme, and F. oxysporum, to be harmful. Machenahalli *et al.* (2014) analysed seed-borne fungi using the classic blotter method and discovered Alternaria alternata, Fusarium sporotrichioides, and Fusarium oxysporum, as well as Colletotrichum capsici, C. gloeosporioides, and C. acutatum.

Chaudhari *et al.* (2017) observed that the Pigeon pea (Cajanus cajan L.) seeds mycoflora was researched, and the influence on seed germination and seedling growth under pot conditions was determined. The blotter method revealed the connection of nine fungus belonging to six taxa, namely Aspergillus niger, Aspergillus flavus, Fusarium oxysporum, Fusarium moniliforme, Fusarium udum, and Alternaria alternata. When compared to untreated controls, seed mycoflora and their culture filtrate caused a significant reduction in germination percentage and seedling growth.nata, Fusarium sporotrichioides, and F. oxysporum, as well as Colletotrichum capsici, C. gloeosporioides, and C. acutatum.

H. O. Bamidele (2019) observed that the aframomum melegueta seed extracts were found to be effective in inhibiting the colony growth of Aspergillus niger, Aspergillus flavus, Rhizopus stolonifer, and Rhizoctonia species in a study on the antifungal potency of Aframomum melegueta seed extracts on postharvest rot fungi of two citrus species.

Feeding and oviposition deterrent, repellence, growth disruption, poor fitness, and sterility are all described by **A. Plata-Rueda *et al.* (2020).**

Infection of mature seeds by such pathogens, according to **Eric Gyasi *et al.* (2022), could** result in mycotoxin contamination, loss of viability, and seed deterioration. The purpose of this study was to discover seed-borne fungus on 200 cowpea accessions stored in cold storage at the CSIR-Plant Genetic Resources Research Institute (PGRRI) in Ghana. Aqueous extracts of Piper nigrum seeds, Xylopia aethiopica seeds, Aframomum melegueta seeds, and fresh leaves of Cymbopogon citratus were also tested for antifungal activity against the principal seed-borne fungus discovered on cowpea seeds.

Seed polymer coating's impact on storability

According to Taylor *et al.* (2001), covering onion seeds with a polymer film and pelleting them with catazine and a fungicide reduced plant stand losses from onion fly from 20 to 60 percent to 1 to 8 percent while also resulting in improved germination and seedling vigour. According to Jitendra *et al.* (2007), polymer coated seeds showed higher germination rates than the control and decayed at a slower rate than the control. It was determined that polymer coating is useful in enhancing the fungal infestation and enhancing the general seed quality during storage to increase the storability of seed. According to a study by Avelar *et al.*, 2012 film coating on corn seeds efficiently lowers skips and duplicate seeds, minimises dust production from the seeds, and minimises insecticide leaching during seed treatment. Among natural plant extracts, seeds treated with 160ml/l beetroot extract gave the highest rate of germination, followed by seeds treated with hibiscus and heena extract. Rao and Sharma (2012) reported that tomato seeds of variety Pusa ruby seed coated with 0.5 percent Congo red and Jade green, 0.75 percent diechem and bromocresol green, and 1 percent Sky blue and diechem were found to be effective in enhancing seed quality. When seedlings were covered with blue polykote at a rate of 5g per kg of seed, their speed and emergence were at their highest**.**

Seed polymer coating with fungicides. Several fungicides, insecticides and bioagents have been found to be effective in combination with polymer for controlling seed borne pathogens and insect pests and to enhance the seed quality.

Evaluating results of seed coating polymers containing fungicides, insecticides, and bioagents during storage

The three major types of seed coating equipment: dry powder applicator, rotary coater and drum coater used to produce five seed coatings: dry coating, seed dressing, film coat, entrustment and seed pellet.

Kumhar and Jain (2001) reported that in fungicides, bavistin (0.2%), thiram (0.25%), captan (0.25%), and raxil (0.2%) treatments gave higher seed germination up to 90, 88, 86, and 84% and minimum pre-and post-emergence mortality ranging from 0-2.0, 2.39-3.0, 3.64-7.0, and 1.25-6.0%, respectively, as compared to 70% germination and 17.45 to 24.0% pre- and Trichoderma viride, T. harzianum (@4 g/kg seed), Aloevera, and Euphorbia antiquorum (at 100% concentration) gave germination rates of up to 78, 76, 75, and 78%, respectively, and pre- and post-emergence mortality rates of 7.8-14.0, 9.26-16.0, 10.7-18.0, and 7.77-15.0%.

According to Gupta (2002), reported that the mancozeb and Thiram are effective fungicides that can be used as seed treatments to keep seeds healthy and viable during storage under ambient circumstances.

Vanangamudi *et al.* (2003) discovered that maize pink polykote @ 3.00 g per Kg of seed + fungicide + insecticide performed best in terms of germination (98.00%) and all parameters when compared to the control (93.00 and 60.54, respectively).

Larissa *et al.* (2004) discovered that bean seeds treated with the polymer and fungicide germinated better (89.00%) than control (75.00%) after two months of storage.

Wilson and Geneve (2004) found that polymer and fungicide-coated maize seeds had higher germination (98.50%), fewer aberrant seedlings (1.50%), and lower conductivity values.

Singh *et al.* (2004) investigated eight systemic and non-systemic fungicides/fungicidal combinations in vitro, including Carbendazim + Thiram, Benomyl + Thiram, Carbendazim, Benomyl, Captan, Thiram, Indofil M-45, and Difolatan. Carbendazim + Thiram, Benomyl + Thiram, Carbendazim, and Benomyl were found to completely remove the mycoflora associated with the seed. Seed-borne infections harmed seed germination and seedling vigour in terms of root length, shoot length, and seedling fresh weight. Carbendazim + Thiram and Benomyl + Thiram treatments resulted in increased germination and seedling vigour. However, seed treatment with Difolatan was the least effective in enhancing seed germination and seedling vigour.

Huynh and Ashok (2005) conducted tests to assess the in vivo and in vitro efficiency of chemical seed treatment against Bipolaris oryzae and other seed-borne fungus Mancozeb, Thiram, Bavistin, and Vitavax were applied to the seeds at 2.5 g/kg, while Neem oil, Palmarosa oil, Polykote, and Seedkare Orange were applied at 1ml/kg. Treated seeds were subsequently placed in 700-gauge polythene bags and stored at room temperature in the IARI Division of Seed Science and Technology. The study found that seeds treated with Vitavax, Thiram, and Mancozeb retained germination above MSCS (80%) after six months of storage, whereas other chemicals did not.

Kunkur *et al.* (2007) found that seed coating with polymer at 5 g kg-1 of seed, thiram at 1.5 g kg-1 of seed, and imidacloprid at 7.5 g kg-1 of seed resulted in higher cotton germination percentage, field emergence, root length, shoot length, seedling vigour index, dry matter, and lower electrical conductivity when compared to untreated seeds.

Manjunatha *et al.* (2008) studied seeds coated with polymer @ 7.0 g kg-1 and thiram @ 2.0 g kg-1 of seed and found that they had significantly higher germination (69.44%) and field emergence (66.14%) than the control, which had the lowest germination (71.08%) and field emergence (38.15%) at the end of 12 months of chilli storage.

Rajeswari and Meena Kumarai (2009) reported that soybean cv. JS -335, thiram + carbendazim seed treatment resulted in a considerable increase in germination (91%), seed vigour (2630), and nil fungal colonies, followed by T. viride (91%, 2601, and 5%) over untreated seeds (77%, 2470, and 20%), respectively.

According to **Lugwig and Paulo (2011),** fungicide application reduced fungal incidence and increased seed germination, vigour, and health.

Raikar *et al*. (2011) reported that during 2006-07, the University of Agricultural Sciences, Dharwad conducted an experiment to understand the effect of organic and integrated management practises of seed production and storage containers, as well as organic (insecticide and fungicide) and organic (botanicals) as seed treatments, on seed viability of scented rice cv. Mugad sugandha. Seeds of scented rice treated with insecticide (malathion @ 10 g/kg seed) and fungicide (thiram @ 2 g/kg seed), calcium oxychloride (5 g/kg seed), arappu leaf powder (25 g/kg seed) and stored in polythene bag (0.1 mm thickness) retained germination (more than MSCS) and seedling vigour for more than 20 months under Dharwad ambient conditions (Mugad).

Storage fungus caused deterioration in soybean and safflower oil, according to **Kakde and Chava (2012).** Storage fungus significantly reduced the free fatty acid content and iodine value of soybean and safflower.

To evaluate the storability of polymer coated hybrid rice seeds, **Rettinassababady *et al.* (2012)** conducted a study on seed coating with synthetic polymer (polykote) alone, in combination with flowable Thiram, and Vitavax 200 (powder formulation polykote comprising Carboxin, Thiram, colour, and filler) (KRH 2). And they conclude that among the treatments, seeds coated with Vitavax 200 had the highest germination rate, followed by seeds coated with flowable Thiram, while seeds coated with polymer alone had the lowest germination rate.

Avelar *et al*. (2012) reported that the researchers investigated the effect of pesticidal seed treatments on maize (Zea mays L.) seed germination and vigour, as well as greenhouse emergence, in the presence of Fusarium graminearum Schw. Apron® XL (metalaxyl), thiram (thiram), Celest® XL (fludioxonil, metalaxyl), and Apron® Star 42 WS were used to treat maize seeds (thiamethoxam, metalaxyl, difenoconazole). Apron® Star 42 WS and Celest® XL considerably reduced the proportion of sick plants harvested from F. graminearum-inoculated soil. The vigour tests revealed that none of the pesticides tested had a negative effect on the seeds, and that plant biomass in the presence of the pathogen, F. graminearum, rose after the pesticides were applied to the seeds, with the exception of seeds treated with Apron.

Oyekale *et al*. (2012) reported that the storability of pre-treated sesame seeds was investigated, as well as the effects of inorganic and organic seed treatments on the vitality and vigour of sesame seeds during storage. Two hundred grammes of sesame seeds were treated separately with indicated quantities of neem leaf powder, Dress force powder, Dry pepper powder, and untreated seeds as the control; each treatment was placed in an airtight container and stored in a wooden cabinet at 26.5°C and 80% RH for 18 weeks. The NLP and DPP treatments had higher mean seed germination rates of 89.53% and 82.35%, respectively, than the DFP (46.47%) and control treatments (80.76). When compared to DFP, NLP improved seedling vigour index (339.24) throughout storage time (99.74).

Sharma *et al.* (2013) examined the degree of biochemical changes in soybean seeds during natural ageing and found that both protein and oil content reduced after 180 days of storage. as compared to DFP over the storage duration (99.74).

Choudhary *et al*. (2013) reported that the goal of this study was to determine how different chemical and biocidal agents affected the germination and seedling vigour of C. capsici-infected chilli seeds. Safeda leaves extract, Neem seed extract, tulsi leaves extract, Thiram, Captan, and Bavistin were found to have superior and considerably higher seed germination than other treatments and the control. Among the many bioagents utilised in the investigation, seed treated with T. viride had the highest percentage of seed germination (82.35%). T. polysporum had the lowest pre and post-emergence mortality (2.65% and 6.10%), followed by T. viride (6.00% and 6.80%). Bavistin was the most successful, with 93.00% (68.00% in control) seed germination, no pre or post emergence mortality, and a seedling vigour index of 506.85, which was higher than the control.

Sultana and Ghaffar (2013) reported that the *fusarium oxysporum,* the source of seed rot, seedling and root infection in bottle gourd and cucumber, was controlled using fungicides, microbial antagonists, and oilcakes in vitro and in vivo. Fungicidal treatment of bottle gourd and cucumber seeds that had been experimentally infested with F. oxysporum reduced seedling mortality and root infection considerably. Trichoderma harzianum, T. viride, Gliocladium virens, Bacillus subtilis, and Stachybotrys atra, as microbial antagonists, considerably reduced seedling mortality and root rot infection of F. oxysporum in bottle gourd and cucumber. In vitro and in vivo tests T. harzianum was shown to be the most efficient in reducing cucumber seedling mortality and root infection.

Suma and Srimathi (2014) worked on polymer coating and discovered that seed coated with polymer @ 4 g kg-1 seed enhanced germination to 89%, followed by seed coated with polymer @ 3 g kg-1 seed (87 per cent). Other characteristics including as root length, shoot length, dry matter production, and vigour index were similarly higher in polymer-coated seeds (4 g kg-1 seed).

Verma and Verma (2014) conducted a laboratory experiment to assess the effect of various seed coating materials and storage containers on germination, seedling vigour, and packaging material suitability for soybean seed of variety PS 1024, and bimonthly observations on germination and seedling vigour were recorded. And it was discovered that after the eighth month of storage, germination and vigour index in polythene bag stored seeds were higher.

Waghe *et al.* (2014) reported that six fungicides at 500, 1000, 2000, and 2500 ppm, five botanicals at (10 and 20%), and premade formulations of four bioagents were taken; three fungal antagonists were examined in vitro and in vivo against Among the fungicides, treatment with SAAF at 2000 ppm resulted in the greatest inhibition (90.36%), followed by Mancozeb at 2500 ppm (88.88%). Maximum inhibition was seen with neem (63.05 and 68.88%), as well as karanj (56.38 and 63.60%) at 10 and 20% doses. T. harzianum was shown to be the most efficient fungal bioagent, with the highest mycelial growth inhibition (72.22%), followed by T.viride (70.27%). Fungicide seed treatment with SAAF at 3 g/kg seed + two sprays of SAAF were found to be effective under field conditions.

According to **Almeida (2014),** the concentration range of 200 to 400 g a.i., 100/kg of 350 grammes of active component thiamethoxam seed yielded the maximum germination and seed vigour values for both rice cultivars after 12 months of storage.

Gholve *et al*. (2014) conducted tests to evaluate the bioefficacy of nine fungicides (at 500, 1000, and 1500 ppm), ten plant extracts / botanicals (at 10, 15, and 20%), and seven bioagents against P. ultimum. Metalaxyl was shown to be the most efficient of the fungicides tested, with an 84.22% mean growth suppression of the test pathogen. Captan + metalaxyl and carbendazim + Mancozeb were the second and third best fungicides discovered, with mean growth inhibition of 82.42 and 62.88%, respectively. Garlic was the most studied plant.

Singh *et al.* (2014) reported that the efficacy of various treatment strategies, including carbendazim, benomyle, vitavax, neem, garlic, and T. harzianum, was investigated for the occurrences of seed-borne fungus in two genotypes of mungbean stored for 180 and 360 days. Among all treatments, carbendazim, benomyle, and vitavax had the lowest occurrences of seed-borne fungus.

Keawkham *et al.* (2014) investigated the germination index and hybrid cucumber seed germination of polymer (hydroxypropyl methylcellulose) coated seed to seed dressing with insecticides metalaxyl and imidacloprid. Seed germination of polymer coated seed maintained at room temperature for 8 months fell by 58 and 46%, respectively, compared to 13 and 11% for seed dressed treatments studied in the laboratory and greenhouse. The polymer seed covering of hybrid cucumber was found to be incompatible in this investigation.

Kumari *et al.* (2014) reported that the seed coated with plant protection agents alone or in combination with polymer lost viability during storage under ambient conditions before six months. It was concluded that under ambient storage circumstances, chilli seeds may be preserved viable for 6 months when coated with polymer alone and for 12 months when uncoated.

Pawar *et al.* (2015) investigated the reduction in association of seed-borne fungi and enhancement of germination of soybean (Glycine max (L.) Merill) using four varieties JS 335, JS 9305, JS 9560, and NRC 12 with two storage categories (seeds stored in bins and seeds stored in bags) and fungicides Thiram (0.25%), Captan (0.25%), Carbendazim (0.1%), Thiram + Carb

Effect of seed treatments and packaging materials on storability and seed health.

Seed is a living thing, and ageing is an unavoidable process that occurs whether the seed is in the mother plant or in storage. This process cannot be controlled by implementing appropriate and enhanced storage methods and novel technology. Under ambient storage circumstances, seeds packed in moisture impermeable containers performed better than seeds packed in moisture pervious containers. Because moisture content fluctuates more in moisture pervious containers than moisture vapour proof containers, the prevailing atmospheric relative humidity and temperature have a significant impact on seed longevity.

Singh and Dadlani (2003) investigated that after six months of storage, soybean cultivars PK-327 and JS-71-05 exhibited germination rates of 89 and 99%, respectively, in polythene bags, whereas in cloth bags, the rates were 13 and 35%, respectively. Polythene bags maintained germinability above 70% for 14 months, whereas cloth bags lost germination after four months. There was also a significant improvement in seedling dry weight of 57.6 and 40.1 mg after 6 and 14 months of storage in polylined cloth bags, as compared to dry weight of 47.4 mg and 14.5 mg, respectively, in cloth bags, and electrical conductance of the seed leachates increased in cloth bags as compared to polythene bags.

Saxena *et al*. (2004) investigated that the effect of seed treatment with various fungicides and/or biocontrol agents on seed germination, post-emergence rotting, disease severity, grain weight and yield should be investigated. The findings on the effect of four fungicides on radial development of the fungus revealed that regardless of concentration, all fungicides suppressed radial growth of the pathogen. Captan was shown to be the most effective non-systemic fungicide, blocking total radial development of the fungus at a dose of 50 g/ml, followed by Thiram 00g/ml. At 10g/ml, vitavax and carbendazim reduced pathogen radial development in the system. Both bioagents, Trichoderma harzianum and Pseudomonas fluorescens, were able to inhibit the growth of R. solani in dual culture after 120 and 72 hours, respectively. Treatment of seeds

According to **Pessu *et al.* (2005),** soybean seeds stored in polythene bags and metal tins minimise seed deterioration by maintaining germinability to an appreciable level of 58.7 - 86% at the end of a 12-month storage period, as opposed to soybean seeds stored in bamboo bins and clay pots, whose germination means dropped to zero after four months of storage.

Giang and Gowda (2007) found that seed coated with Little's polykote W yellow, captan + thiram + gouch + super red at 1 ml/kg and stored in a polythene bag (700 gauge) had better germination (85.67%) than seed placed in a cotton bag untreated (62%). Polykote W yellow + captain + thiram + gouch treated seeds placed in a polythene bag were documented by polymer little.

Malimath and Merwade (2007) investigated that the superiority of a 700 gauge polythene bag for keeping garden pea seeds was demonstrated by higher germination and vigour index with decreased seed moisture, seed infection, and EC of seed leachate throughout a ten-month ambient storage period.

Patil and Shekhargouda (2007) discovered that seed storage containers had a substantial impact on seed storability. Throughout storage, seeds housed in polythene bags had increased germinability (83.9% at the conclusion of storage). When compared to the cloth bag, these seeds showed a modest drop in germination. Similarly, even after 12 months of storage, the other quality parameters, dry weight of seedlings and vigour index, were better with seeds maintained in plastic bags. Thiram-treated seeds (2.0 g/kg) had higher seed germinability throughout storage. At the

Basavaraj *et al*. (2008) discovered that experiment was carried out to investigate the effect of fungicide and polymer film coating on the storability of onion seeds. Seeds were film coated with polymer clear (Polykote) at different concentrations, namely 6 ml, 9 ml, and 12 ml per kg of seeds with and without fungicide (Thiram @ 2 g/kg of seeds) and stored in polythene bags and aluminium pouch containers. When compared to the control, seed coating with polymer @ 12 ml + thiram @ 2 g per kg of seeds resulted in higher germination, vigour index, dry weight of seedlings, and lower seed infection and electrical conductivity. Throughout the storage period, seeds stored in an aluminium pouch had higher seed quality metrics than seeds housed in a polythene bag.

Ryavalad *et al*. (2009) found that delinted seed treated with imidacloprid and stored in polythene bags has increased germination and vitality for a longer period of time.

Shashibhaskar *et al.* (2009) conclude that seeds pelleted with carbendazim and stored in a polyethylene bag (T1C2) had higher germination (75.75%), seedling length (24.83 cm), vigour index (1862), dry matter production (34.20 mg), dehydrogenase activity (0.303 OD value), speed of germination (21.07) with less moisture content (6.56%), EC value of seed leachate (0.481

Gupta (2010) found that the storage was evaluated using integration of multiple treatments such as storage containers (jute bags/polylined jute bags), storage conditions (ambient/LTLH i.e. low temperature, low humidity, or regulated), and seed dressings (captan/thiram). After 60 months of seed treatment, the germination rate of seeds stored under LTLH conditions (86.1%) and in polylined jute bags (75.3%) was substantially greater than that of seeds stored under ambient conditions (61.9%) and in jute bags (72.8%). Thiram/captan treatment also boosted seed germination by 7% when compared to the untreated control.

Raikar *et al*. (2011) found that “during 2006-07, the University of Agricultural Sciences, Dharwad conducted an experiment to understand the effect of organic and integrated management practises of seed production and storage containers, as well as organic (insecticide and fungicide) and organic (botanicals) as seed treatments, on seed viability of scented rice cv. Mugad sugandha. Seeds of scented rice treated with insecticide (malathion @ 10 g/kg seed) and fungicide (thiram @ 2 g/kg seed), calcium oxychloride (5 g/kg seed), arappu leaf powder (25 g/kg seed) and stored in polythene bag (0.1 mm thickness) retained germination (more than MSCS) and seedling vigour for more than 20 months under Dharwad (Mugad) ambient conditions”.

Satish kumar *et al.* (2011) conducted a 12-month storage experiment under ambient settings and concluded that polythene bag 700 gauge had higher germination (82.50%), vigour index (790) than paper bag at the end of the 12-month storage period.

Chattha *et al.* (2014) proposed that seed stored in gunny, cloth, and plastic bags performed better in terms of temperature, moisture content, and germination capability than seed housed in metal and clay containers.

Monira *et al.* (2012) discovered that at the conclusion of seed storage, soybean seeds housed in fabric bags decay faster than seeds stored in polythene bags. The cloth-bagged seeds had a high moisture content, a low germination percentage, root and shoot length, and a seedling vigour index.

Rettinassababady *et al*. (2012) evaluate that the storability of polymer coated hybrid rice seeds, a study was conducted on seed coating with synthetic polymer (polykote) alone, in conjunction with flowable Thiram, and Vitavax 200 (powder formulation polykote comprising Carboxin, Thiram, colour, and filler) (KRH 2). And they concluded that, when comparing storage containers, seeds stored in polythene bags had lower pathogen infection than seeds housed in fabric bags.

Tame *et al*. (2013) stated that discrepancies in performance between treatments might be attributed to differences in storability as a function of temperature and relative humidity

Quais *et al.* (2013) indicated that the optimum storage container for radish seed to retain quality is a polythene bag. However, metal tin containers have also been found to be useful for radish seed storage. As a result, polythene bags and metal tin containers may be advised for general use.

Akter *et al.* (2014) studied “the influence of three storage containers (tin container, polythene bag, and cloth bag) and five storage durations (0, 15, 30, 45, and 60 days) on the seed quality of soybean at Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur from April 2013 to June 2013”.

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Kumar *et al.* (2014) found that “the seeds treated with chlorax and stored in a two layer polythene bag retained seed germination and seedling vigour for more than ten months under ambient circumstances in Dharwad, and same treatments can be used to store marigold seeds to maintain viability”.

The study was conducted by **Kamara *et al.* (2014)** to “determine the effects of seed treatments containing neem leaf powder, pepper fruit powder, camphor, groundnut oil, and wood ash in combination with five different packaging materials (cloth bag, paper bag, glass bottle, polythene bags, and plastic container) on the viability and germination vigour of cowpea seeds. After storage, seed stored in plastic containers exhibited the highest vigour and germination percentage (61.1 and 77.1%, respectively), followed by seed stored in glass bottles (60.3 and 72.2%, respectively)”.

Tiwari and Das (2014) found that the plant species, seeds placed in cloth bags had the lowest germination percentage.

Verma and Verma (2014) conducted a laboratory experiment to assess the effect of various seed coating materials and storage containers on germination, seedling vigour, and packaging material suitability for soybean seed of variety PS 1024, and bimonthly observations on germination and seedling vigour were recorded. After 8 months of storage, germination and vigour index in polythene bag kept seeds were significantly higher; among seed coating treatments, polymer coating @ 3 ml/ kg had the highest %germination, followed by vitavax 200 @ 2 g/ kg.

Keawkham *et al*. (2014) found that the germination index and hybrid cucumber seed germination of polymer (hydroxypropyl methylcellulose) coated seed to seed dressing with pesticides, metalaxyl and imidacloprid, were compared. Seed germination of polymer coated seed maintained at room temperature for 8 months fell by 58 and 46%, respectively, compared to 13 and 11% for seed dressed treatments studied in the laboratory and greenhouse. The polymer seed covering of hybrid cucumber was not compatible with seed viability during storage at 25 °C and 75% RH, according to this study.

Rathinavel (2014) studied the effect of storage temperature and seed treatment on the viability of cotton cv. LRA5166 in storage. At each level, the extent of the decline was less in seeds treated with carrier-based cultures of Pseudomonas fluorescence, Trichoderma viride, or carbendazim than in untreated seeds.

Pawar *et al*. (2015) conducted to evaluate the reduction in association of seed-borne fungi and enhancement of germination of soybean (Glycine max (L.) Merill) using four varieties JS 335, JS 9305, JS 9560, and NRC 12 with two storage categories (seeds stored in bins and seeds stored in bags) by treatment with fungicides Thiram (0.25%), Captan (0.25%), Carbendazim (0.1%), Thiram + Carbendazim Thiram (77.5%), Thiram + Carbendazim (76.4%), and T. viride (76.4%) showed the least association of mycoflora and increased percent germination.

Sehga *et al*. (2016) conducted to “Before planting, many crops' seeds are frequently treated with fungicides and pesticides. Farmers today also have to deal with a different task. The issue of intensifying climate change is one that is brought on by drought even in areas where it had not previously been common. Due to reduced seed germination, plant growth, and fruiting in drought circumstances, drought is a significant abiotic stress that jeopardises the effectiveness of agricultural production".

Lamichhane *et al*. (2020) establishment of crop yields is hampered by the early growth of robust juvenile plants and seed germination. To prevent damage from insect pests and plant pathogens, it is normal practise in agriculture to apply pesticides to safeguard germination of seeds and young plants during the early growth period. Before planting, many crops' seeds are frequently treated with fungicides and pesticides.

Ludwig *et al*. (2020) studied "the effect Polymer seed coatings are thought of as an inventive way to deal with the shortage of water during seed germination, but they can also reduce the potency of plant protection agents used in seed dressing. Additionally, it has been demonstrated in earlier research on sand matrices that polymer seed coating can reduce the leaching of pesticides from the surfaces of seeds. This process is influenced by the physicochemical characteristics of the soil, including its organic matter content, pH, and humidity, as well as pesticide characteristics, particularly solubility".

Park *et al*. (2020) studied the additional research is required to address this problem for SAP-coated seeds. The retention of pesticides by polymer is also affected by its molecular weight and chemical structure (polarity, branching, and side chain length). Publications reporting modifications in pesticide effectiveness against soilborne diseases in polymer-coated seeds are scarce. Several studies on the infestation of storage fungi on seeds treated with polymer, fungicide.

Antalová *et al*. (2020) found that the Fusarium culmorum (W.G. Sm.) Sacc. strain employed in this experiment belonged to the tribe VURV-F 494 collection of agriculturally important fungi at the Crop Research Institute in Prague-Ruzyne, Czech Republic. For use as an inoculum, mycelium was freshly cultivated on potato dextrose agar (PDA; Duchefa Biochemie, Haarlem, The Netherlands) in Petri dishes at 22 ^{0}C for 7 or 28 days in the dark.

Jarecki *et al*. (2021) investigated "the impact of five SAPs, including polyacrylamide, sodium polyacrylate, and three commercial products, on the physiological parameters of plants under drought conditions and the germination of Caragana korshinskii legume seeds. They noticed that these SAPs had a favourable impact on the proportion and intensity of seed germination".

Sikder *et al*. (2021) found that using hybrid synthetic-biopolymer SAPs, which combine the desirable chemical features of synthetic polymers, such as mechanical strength, high water capacity, and stability, with natural polymers' cheaper cost and biological safety Because they are biodegradable and can be found in agricultural waste, proteins are currently receiving a lot of attention as a replacement for synthetic SAPs.

Capezza *et al*. (2021) investigated "they can also supplement with nutrients that can be delivered under controlled conditions or act as biostimulants themselves. While the majority of research on SAP has centred on increasing their water retention capacity, their potential function in plant protection increases the likelihood of widespread adoption in agricultural practice".

Thakur *et al*. (2022) investigated that the seeds treated with polymer plus vitavax 200 at 2 g/kg of seed had greater germination percentage (95.00), seedling length (17.58 cm), seedling dry weight (0.0138 g), vigour index-I (1670) and vigor-II (1.311), speed of germination (19.98), and weight of 100 seeds (5.54 g). Field emergence (87.33) was comparable to untreated control at 2 g/kg of vitavax 200. Wheat seed can either be treated with polymer @ 3 ml/kg of seed Plus vitavax 200 @ 2 g/kg of seed or vitavax 200 @ 2 g/kg of seed to maintain seed quality and improve storability.

Arief *et al*. (2022) studied the Compared to Anjasmoro, Argomulyo, and Burangrang, Grobogan is the soybean variety with the fastest diminishing germination after storage. During storage, soybean seeds exhibited the best physical and physiological properties when packaged in 0.7 mm PE plastic bags covered in plastic sacks. All soybean cultivars and packaging methods saw declining soybean quality due to the longer storage duration. the quality of soybean seeds held up well during storage for up to 6 months at room temperature, with the lowest germination rate of 80%.

Talha *et al*. (2022) found that the seed coating technology has a long history of enhancing the quality of seeds. Better stand establishment, growth, and development are associated with high-quality seeds and the main goal of achieving a bigger yield. Using the right seed coating chemical in the right concentration can improve stand establishment and seedling vigour. One or two simple seed coverings serving as a panacea for all restrictions to early seedling growth and development are not going to be able to alleviate the issues seedlings confront during the establishment phase, as is abundantly obvious from much of the literature examined.

Conclusion

Coated seed has several advantages and benefits for forage, oilseed, and other crops. These include the most effective pre-inoculation approach now in use, the starter fertiliser package contained in the coat, which provides significant benefits to the seedling, and the fact that it is a cost-effective, efficient way of seed treatment. Coating is the simplest, safest, and most efficient way to treat any seed with virtually any seed treatment. Various microbial antagonists, Rhizobium meliloti, Aspergillum niger, and Trichoderma harzianum, were examined for their biological potential in the laboratory after covering the seeds with gum arabic, glucose, sugar, and mallases. Root rot fungi include *Macrophomina phaseolina, Fusarium spp*., and *Rhizoctonia solani* on okra and sunflower plants. In comparison to the control, the germination and effectiveness of each biocontrol agent plant growth. Weights allocated to quality characteristics significantly enhanced the yield of a seed. Seed coating is a revolutionary technology that is becoming more popular in industrialised countries due to the benefits it provides to farmers. It improves the sowing process by allowing precise sowing and the establishment of an appropriate stand; it uniformizes the format of the seeds; it allows the adhesion of products necessary for germination, such as the absorption of water and gases, as well as hormones that aid in germination and emergence; it adds micronutrients; and, among other things, it allows the seed to be protected against diseases and insects.

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