EFFECT OF SEED COATING ON SEED LONGEVITY IN RICE (*Oryza sativa* L.)

THESIS

By

AMANDEEP SINGH
(A-2017-30-076)

Submitted to

CHAUDHARY SARWAN KUMAR
HIMACHAL PRADESH KRISHI VISHVAVIDYALAYA
PALAMPUR – 176 062 (H.P.) INDIA

in

Partial fulfilment of the requirements for the degree

of

MASTER OF SCIENCE IN AGRICULTURE

(DEPARTMENT OF SEED SCIENCE AND TECHNOLOGY)
(SEED SCIENCE AND TECHNOLOGY)

2019

Dr. K.C. Dhiman
Principal Scientist

Department of Seed Science and Technology,
College of Agriculture, CSK HPKV,
Palampur (H.P.) India – 176062

CERTIFICATE – I

This is to certify that the thesis entitled, **"Effect of seed coating on seed longevity in rice (*Oryza sativa* L.)"** submitted in partial fulfillment of the requirements for the award of the degree of **Master of Science (Agriculture)** in the discipline of **Seed Science and Technology** of CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur is a bonafide research work carried out by **Amandeep Singh (Admission No. A-2017-30-076)** son of **S. Raghbir Singh** and **Smt. Gurwinder Kaur** under my supervision and that no part of this thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of this investigation have been fully acknowledged.

Place : Palampur
Dated : July, 2019

(Dr. K.C. Dhiman)
Major Advisor

CERTIFICATE- II

This is to certify that the thesis entitled, **"Effect of seed coating on seed longevity in rice (*Oryza sativa* L.)"** submitted by **Amandeep Singh (Admission No. A-2017-30-076)** son of S. Raghbir Singh to the CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur in partial fulfillment of the requirements for the degree of **Master of Science (Agriculture)** in the discipline of **Seed Science and Technology** has been approved by the Advisory Committee after an oral examination of the student in collaboration with an External Examiner.

(Dr. K.C. Dhiman) Chairperson Advisory Committee	( ) External Examiner
(Dr. R.K. Kapila) Member	(Dr. (Mrs.) Daisy Basandrai) Member
(Dr. P. N. Sharma) Member	(Dr. Kamal Dev Sharma) Dean's nominee

Head of the Department

Dean, Postgraduate Studies

ACKNOWLEDGEMENTS

At the outset, the time has come for me to gather the words for expressing my gratitude towards all those who helped me in building my career.

With the overwhelming sense of legitimate pride and genuine obligation which gives me exuberant pleasure and privilege to express my eternal gratitude to my learned and revered advisor ***Dr. K.C. Dhiman,*** *Principal Scientist (Seed Science and Technology) for his excellent and praiseworthy guidance, keen interest, adroit admonition, juvenile encouragement and parental affection during whole course of my study and particularly at times of research and preparation of this manuscript. I will always remain indebted to him.*

I express my sincere gratitude to the worthy members of my advisory committee Dr. R.K. Kapila (Professor, Department of Seed Science and Technology), Dr. (Mrs.) Daisy Basandrai (Principal Scientist, Rice and Wheat Research Station, Malan), Dr. P.N. Sharma (Principal Scientist, Department of Plant Pathology), Dr. Kamal Dev Sharma (Professor, Department of Agricultural Biotechnology), for their inspiring guidance and critical assessment of the manuscript.

I own a great deal of appreciation and gratitude to Dr. Rajesh Kanwer (Assitant Professor) for their advice during course of study and providing help in one or other way.

Thanks are due to the Head Department of Seed Science and Technology, Dean, Post Graduate Studies, Dean, COA and CSK Himachal Pradesh Krishi Vishvavidyalaya authorities for providing me necessary facilities and help during the course of investigation.

I take this opportunity to convey my sincere thanks to all the Professors of Department of Seed Science and Technology for providing unconditional helping hand whenever needed at various stages of this investigation and my studies.

I can hardly overlook the co-operation, timely help, moral support extended by my friends ***Rajveer,*** *Kang, Gurkanwal, Kulveer, Malwa, Arsh, Baghel, Jaspreet, Zaildar, Khosa, Ishav, Bhallan Y, Narinder Y, Rana Y, Sukhchain, Paviter, Navdeep,* ***Gurpreet Sidhu*** *and my seniors who boosted me up in periods of mental stress and strain.*

I would like to thankful to my classmates Avneesh Prashar, Ayush Paul, Ahmud Shah and Arshia for their help during the course of investigation.

My special thanks to ***Surinder Bai****, Dass Uncle, Department of Seed Science and Technology for their helping hand in the laboratory.*

Every effort is motivated by ambition and all ambitions have an inspiration behind. I owe this place to my beloved parents ***S. Raghbir Singh*** *and* ***Smt. Gurwinder Kaur*** *whose constant inspiration, blessings, everlasting love and innumerable sacrifices have encouraged me in every step of my life.*

Acknowledgements are inherently endless & incomplete, and I request indulgence from many friendly & helpful people whom I could not name here, due to paucity of space.

Needless to say, all omissions and errors are mine.

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Place: Palampur ***(Amandeep Singh)***

Dated: July 2019

TABLE OF CONTENTS

LIST OF ABBREVIATIONS USED

Sr. No.	Abbreviation	Meaning
1.	%	Per cent
2.	/	Per
3.	a.m.s.l	Above mean sea level
4.	CD	Critical Difference
5.	$CaCl_2$	Calcium chloride
6.	Cm	Centimeter
7.	Cu	Copper
8.	cv.	Cultivar
9.	DM	Dimethoate
10.	DAP	Diammonium Phosphate
11.	E	East
12.	et al.	et alii (and others)
13.	Etc	Et cetera
14.	Fig.	Figure(s)
15.	G	Gram
16.	GA_3	Gibberellic acid
17.	Ha	Hectare
18.	HDPE	High Density Polyethylene
19.	H	Hours
20.	i.e.	Id est (that is)
21.	ISTA	International Seed Testing Association
22.	Kg	Kilogram
23.	L	Litre
24.	M	Meter
25.	Max.	Maximum
26.	Mg	Miligram
27.	Min.	Minimum
28.	Mm	Millimeter
29.	Mn	Manganese
30.	MSCS	Minimum Seed Certification Standards
31.	^0C	Degree Celsius
32.	P	Page
33.	pH	Puissance de hydrogen (ion concentration)
34.	Pp	Pages
35.	Q	Quintal
36.	RH	Relative Humidity
37.	spp.	Species (plural)
38.	viz.,	Vi delicet (namely)
42.	Zn	Zinc
43.	$ZnSo_4$	Zinc sulphate

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

Department of Seed Science and Technology
CSK Himachal Pradesh Krishi Vishvavidyalaya
Palampur-176 062 (HP)

Title of thesis:	Effect of seed coating on seed longevity in rice (*Oryza sativa* L.)
Name of student:	Amandeep Singh
Admission number:	A-2017-30-076
Major discipline:	Seed Science and Technology
Minor discipline(s):	Genetics and Plant Breeding
Date of thesis submission:	July, 2019
Total pages of the thesis:	86
Major Advisor:	Dr. K.C. Dhiman

ABSTRACT

The present investigation was undertaken to evaluate the effect of seed coating for seed longevity and to identify the effective seed coating treatment for enchancing seed longevity of rice by evaluating different seed quality parameters in Seed Technology Laboratory, CSK HPKV, Palampur. The experimental material consisted of HPR-1068 variety of rice, seeds of which were coated during December 2015 and nine different treatments along with untreated control in three replications were stored in Completely Randomized Design (CRD) for thirty six months (December 2015 to December 2018) after packing in HDPE (high density polyethylene) interwoven bags. For the present study, the evaluation of seed quality parameters was made at bimonthly intervals for twelve months (25^{th} to 36^{th} month) i.e from January 2018 to December 2018. The treatments comprised of T_1 - untreated control, T_2 - polymer (Polykote) @ 3 ml/kg of seed diluted in 5 ml of water, T_3 - flowable thiram @ 2.4 ml/kg of seed, T_4 - polymer + flowable thiram @ 2.4 ml/kg of seed, T_5 - vitavax 200 @ 2 g/kg of seed, T_6 - polymer + vitavax 200 @ 2 g/kg of seed, T_7 - imidacloprid (Gaucho) @ 4 ml/kg of seed, T_8 - polymer + imidacloprid (Gaucho) @ 4 ml/kg of seed, T_9 - polymer + flowable thiram @ 2.4 ml/kg of seed + imidacloprid (Gaucho) @ 4 ml/kg of seed and T_{10} - polymer + vitavax 200 @ 2 g/kg of seed + imidacloprid (Gaucho) @ 4 ml/kg of seed. At the end of storage period (36 months), recorded data revealed that irrespective of seed coating, seed deteriorated and the vigour declined probably with increased fungal infection and aging of seed. On the basis of present study, it can be concluded that T_6 - polymer + vitavax 200 @ 2 g/kg of seed and T_4 - polymer + flowable thiram @ 2.4 ml/kg of seed were found significantly superior for all seed quality parameters viz., germination (%) - first count (%), final count (%), speed of germination, seedling length (cm), seedling dry weight (g), seedling vigour index-I, seedling vigour index -II, electrical conductivity (m mho/cm/g) and field emergence (%) over T_1 - untreated control. The treatments, polymer coating @ 3 ml/kg of seed + vitavax 200 @ 2 g/kg of seed and polymer coating @ 3 ml/kg of seed + flowable thiram @ 2.4 ml/kg of seed could maintain the germination percentage above Indian Minimum Seed Certification Standards (IMSCS) upto 32 months of storage and thus these two treatments can be used for long term storage of paddy seeds.

(Amandeep Singh)	**(Dr. K.C. Dhiman)**
Student	**Major Advisor**
Date: July, 2019	**Date: July, 2019**

Head of the Department

1. INTRODUCTION

Rice (*Oryza sativa* L.) is a major dietary staple food for higher percentage of the world's population particularly in Asia. It is the agricultural commodity with the third-highest worldwide production, after sugarcane and maize. Since a large portion of maize crops are grown for purposes other than human consumption, rice is the most important grain with regard to human nutrition and caloric intake, providing more than one fifth of the calories consumed worldwide by humans. It is the predominant dietary energy source for 17 countries in Asia and the Pacific, 9 countries in North and South America and 8 countries in Africa (Sharma and Dhiman, 2017). India is one of the world's largest producers of white rice and brown rice, accounting for 20% of all world rice production. Rice is India's pre-eminent crop, and is the staple food of the people of the eastern and southern parts of the country. The regions cultivating this crop in India are western coastal strip, the eastern coastal strip, covering all the primary deltas, Assam plains and surrounding low hills, foothills and Terai region - along the Himalayas and states like West Bengal, Bihar, eastern and western Uttar Pradesh, eastern Madhya Pradesh, northern Andhra Pradesh and Odisha, Punjab, Haryana and Kashmir. Rice is being grown in all the districts of Himachal Pradesh except Kinnaur and Lahaul & Spiti with maximum 65% acreage in Kangra and Mandi districts (Sharma and Dhiman, 2017). It is a good source of energy, help infighting several diseases, rich in selenium, high in manganese, rich in naturally-occurring oils, rich in anti-oxidants, high in fibre, source of a slow-release sugar and a perfect baby food.

In India, rice area, production and productivity are 43.79 million hectares, 112.91 million tonnes and 2.58 tonnes/hectare, respectively during 2017-18 (Anonymous 2018a). In Himachal Pradesh, it occupies an area of 73.7 thousand hectares with a production of 130.5 thousand tonnes and productivity of 17.71 quintals/hectare (Anonymous 2018b) and has a lot of scope for further expansion in terms of area and production. The crop is grown during *kharif* season in low and mid hills of Himachal Pradesh and primarily used as cereal by the hill farmers.

Production of good quality seed is entrenched with well planned systemic field activity, good number of working hours of highly skilled professionals, quality control and assurance mechanism making it more labour intensive and high input cost requiring exercise than the normal crop production. The previous statement necessitates that every seed once develop transform into a healthy plant. This idea could perspire, if adequate attention is laid on seed storage paradigm. Further eratic rainfall trend, monsoon failure, high level of biotic and abiotic stresses and other natural calamities are likely to aggravate pressure on seed production and multiplication chain which could have detrimental impact on marketing and seed replacement rate. To avoid such threat there is need to produce abundant quantities of quality seed during favorable season and safely store them in order to cater the need for deficient times.

The seeds are viable regenerative propagule that needs to be stored after harvest till the next sowing or until further use. It is estimated that 80 percent of certified seeds produced in India require storage for atleast one planting season and 20 percent of seed is carried over subsequent sowings (Bal, 1976).

Maintenance of seed vigour and viability during storage is a matter of prime concern. In general, there are differences among species and also among varieties within a species with respect to loss of viability during storage of rice. In storage, the viability and vigour of the seeds not only vary from genera to genera and variety to variety, but it is also regulated by many physiological factors like 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, etc. (Doijode, 1990). Apart from this, microflora is also responsible for the degradation of protein, carbohydrates and other food reserves resulting in reduction of vigour and germination potential. Deterioration of seed is further associated with ageing phenomenon which has been defined as an irreversible degradation changes in the quality of a seed after it has reached its physiological maturity (Abdul - Baki and Anderson 1973).

Deterioration of seed during storage is inevitable and leads to different changes at various levels viz., impairment or shift in metabolic activity, compositional changes, decline or change in enzyme activities, phenotypic, cytological changes apart from quantitative losses. Owing to the prevailing sub-tropical climate in the major parts of the country, seeds of most crop species show rapid deterioration and rice is no exception. The seeds are found to be sensitive to various insect-pest infestation and fungal infection.

The rate of seed deterioration can be slowed down either by storing the seeds under controlled conditions or by imposing polymer film coating along with seed treatment chemicals. As the controlled condition involves huge cost, seed treatment remains the best alternative approach to maintain the seed quality. Recently, various quality enhancement treatments are given to the seeds before storage and sowing. Among these, seed coating is one of the techniques wherein external materials, *viz.*, polymers, fungicides and insecticides are applied directly on the seed to enhance the quality and production potential of seed without significantly increasing the size or weight of the seed and obscuring the seed shape (Kumar, 2007a).

The polymer film coat provides protection from the stress imposed by accelerated ageing, which includes fungal invasion. The coat is thin (8 μ m), simple to apply, diffuses rapidly and non-toxic to the seedlings during germination. It improves plant stand and emergence of seeds, helps in accurate application of the chemical, reduces chemical wastage and helps to make room for including all required ingredients, protectants, nutrients, plant growth promoters, hydrophobic/hydrophilic substance and oxygen suppliers etc. By encasing the seed within a thin film of biodegradable polymer, the adherence of seed treatment to the seed can be improved, ensures dust free handling, making treated seed both useful and environment friendly. Polymer coating makes sowing operation easier due to the smooth flow of seeds. Currently seed coating polymers are being used by seed companies along with active ingredients such as insecticides and fungicides. This helps in improving the resistance of seeds towards pest and diseases in the much warranted juvenile stage, besides improves the seedling vigour.

Research on storability of rice in India is of recent origin. With the development of organized seed production and marketing system, seeds men are becoming aware of the problems of seed storage and thereby systematic research has been initiated. In Himachal Pradesh, the information on storability of rice seeds is inadequate. With this in view, the current research was formulated to investigate the utility of coating of seed with polymer alone, in combination with fungicides and insecticide for improving the storability and to know the effect of these treatments on seed quality in rice with the following objectives.

- To evaluate the seed coating treatments for seed longevity in rice and
- to identify the effective seed coating treatments for enhancing seed longevity of rice.

2. REVIEW OF LITERATURE

Rice (*Oryza sativa* L.) is an important cereal crop. Everyone agrees that the real value of a seed is the genetic material that it hides inside. But there is a reason these days to look at what is on the outside of a seed as well. Seed deterioration is an irreversible, inexorable and inevitable process. But the rate of seed deterioration could be slowed down either by storing the seeds under controlled conditions or by imposing seed treatment with polymer coating along with seed treatment chemicals (Duan and Burris 1997). The seeds during storage are found to be sensitive to various insect-pest infestation and fungal infection. This in turn results in poor establishment of the crop in the field and low productivity. A number of treatments have been developed that protect the seeds from a variety of hazards, including from pests to stress conditions. Seed coating technology has developed rapidly during the past two decades and provides an economical approach to seed quality enhancement, especially for larger seeded agronomic and horticulture crops. An advantage of seed coating is that the seed enhancement material is placed directly on the seed without obscuring the seed shape. Seed coatings with natural or synthetic polymers have gained rapid acceptance by the seed industry as a much safer and reliable method of fungicide or insecticide seed treatment. These coatings are extremely thin, which allows multiple layers on the seed with only 1 to 10% increase in seed weight. The film coating provides a uniform, yet precise placement of chemicals at much lower rates than the traditional seed treatment systems and offers the opportunity to add many enhancement layers as needed to improve seed performance.

The literature pertaining to different aspects of the present investigation has been reviewed under following headings:

2.1 Effect of seed coating on seed quality during storage

2.2 Effect of packaging material on seed quality

2.1 Effect of seed coating on seed quality during storage

Seed coating can be done with fungicides, microbial treatments and insecticides. It is one of the techniques wherein external material viz., polymers, fungicides and insecticides are applied directly on seed to enhance the quality and production potential of seed without significantly increasing size or weight of the seed and obscuring the seed shape. This kind of plasticizer polymer form flexible film that prevents dusting off and loss of fungicide during handling and is readily soluble in water (hydrophilic) so as not to impede with normal germination (Sherin and John 2003). The application of polymers to seed serves as an extra exterior shell in order to give the desired seed characteristics viz., quick or delayed water uptake and enhanced germination that would be beneficial for better emergence and establishment in the given condition (Taylor et al. 1988). Film coating provides protection from the stress imposed by accelerated ageing, which include fungal invasion. It improves plant stand and emergence of seeds, and this technique is recommended for high value agricultural crops (Sherin and John 2003).

Seed coating is thin, simple to apply, diffuses rapidly and non-toxic to the seedling during germination. It improves plant stand and emergence of seeds, accurate application of the chemical reducing chemical wastage, helps to make room for including all required ingredients, protectants, nutrients, plant growth promoters, hydrophobic/hydrophilic substance, oxygen suppliers etc. By encasing the seed within a thin film of biodegradable polymer, the adherence of seed treatment to the seed is improved, ensures dust free handling, making treated seed both useful and environment friendly. The polymer film may act as physical barrier, which has been reported to reduce the leaching of inhibitors from the seed coverings and may restrict oxygen diffusion to the embryo (Vanagamudi et al. 2003). Suitability of these polymers with varied concentrations for enhanced storage of seeds needs to be studied. The film is readily water soluble so as not to impede germination. The film coated seeds reduce imbibition damage and improve germination and seed storage period will increase without loss of viability.

Grover and Bansal (1970) reported that the maximum protection to anthracnose infected chilli seeds were recorded in case of Thiram, Bisdithane and

Brassicol, when used as seed dressing chemicals at 0.20, 0.25 and 0.30 per cent concentration, respectively. The seedling stand was found much higher (98% and 96%) in case of chilli seeds, treated with Thiram and Bisdithane, respectively than that of Brassicol (92%) and the highest per cent of disease control (82 and 76%) was recorded in Thiram and Brassicol treated seeds, respectively than that of Bisdithane (73%) treated seeds.

Kaul (1972) reported that french bean seed treated with Captan @ 3 g/kg of seed maintained germination at 90 per cent after 48 months of storage, whereas it was 48 per cent in control.

Pillaryarsamy et al. (1973) observed that chilli seeds of cv. K_1 treated with Thiram @ 2 g/kg of seed, when stored in plastic containers, recorded higher germination (70%) over the control (37%) up to 300 days of storage.

Maholay and Sohi (1982) reported that bitter gourd seeds treated with Captan @ 2 g/kg of seed maintained 100 per cent germination after 14 months of storage over control (40%).

Evlakova (1985) observed that pelleting of delinted cotton seeds with Carboxymethyl cellulose polymer film increased germination by 24.50 per cent compared to untreated seeds.

West et al. (1985) indicated that polymer coated seeds could provide protection from physical damage during handling and planting. It also protects fluctuations in seed moisture content due to climatic changes.

Hwang and Sung (1991) reported that coating the seeds with a hydrophilic polymer regulated the rate of water uptake, reduced imbibitional damage and improved the emergence of soybean seeds.

Dadlani et al. (1992) found that rice cv. IR-20 seeds coated with polymer and fungicide recorded higher root length (34.80 mm), shoot length (170.20 mm) and dry weight of seedling (52.80 g/seedlings) as compared to control (33.63 mm, 147.60 mm and 48.30 g/seedling, respectively).

Krishnasamy and Suthanthir (1992) observed that brinjal seeds treated with Bavistin were superior in germination (56%) to those treated with Thiram (45%) or Mancozeb (47%) and the lowest germination (44%) was noticed in control.

Reddy and Reddy (1994) treated the seeds of eggplant with Thiram (2.5 g/kg), Delsan (1 ml/kg) and Captan (2.5 g/kg) and observed that the Thiram maintained the highest germination up to 21 months of storage.

Chaudhry et al. (1995) observed the effect of polymers in maize (*Zea mays* L.) and soybean (*Glycine max* L.), and concluded that polymers had a marked influence on increasing germination of both maize and soybean crops.

Struve and Hopper (1996) reported that cotton seeds coated with polymer recorded slower imbibition rate, reduced the imbibitional damage, lowered the electrical conductivity values and improved the seed germination.

Duan and Burris (1997) concluded that the polymer film acts as a physical barrier thus reducing the leaching of inhibitors from the seed covering and restricting the oxygen diffusion to the embryo and thereby restricting the ageing effect in stored sugar beet seeds.

Savitri et al. (1998) reported that seed treatment with Thiram @ 3 g/kg seeds controlled seed borne fungi effectively and also protected seeds of groundnut from the attack of *Coregra cephalonica* for a considerable period and maintained seed viability and vigour up to 18 months in polythene bags.

Song and Lee (1998) studied the effect of seed coating with polymers on electrical conductivity, germination percentage, seedling growth and seedling establishment rate in direct sown rice and observed that the Klucel, Maltrin, and Waterlock polymer treated seeds exhibited significant increase in germination percentage, seedling growth and seedling establishment.

Malarkodi and Dharamalingam (1999) observed that bajra seeds treated with hitron @ 5 g/kg seeds lead to high germination (80%), vigour index (2318) and minimum storage fungi infection i.e. 19 per cent after eight months of storage.

Chikkanna et al. (2000) reported that groundnut seed coated with hydrophilic polymer @ 20 g/kg of seed increased the germination percentage, but further increase in the concentration of polymer, inhibited the germination, root and shoot growth.

Chachalis and Smith (2001) reported that coating of soybean seed with 24 mg of polymer (Vinamul 3650) regulated the rate of water uptake, reduced the imbibition damage, improved the germination per cent and seedling emergence.

Taylor et al. (2001) reported that film coating of polymer and pelleting with catazime and fungicide in onion seeds reduced the plant stand losses due to onion fly from 20-60 per cent to 1-8 per cent and also recorded higher germination and seedling vigour.

Sherin and John (2003) reported that seeds of maize treated with polymer @ 3 g/kg of seed dissolved in 5 ml of water recorded higher germination per cent, speed of emergence, seedling growth and dehydrogenase activity.

Gupta and Aneja (2004) found that soybean seeds treated with Thiram @ 2.5 g/kg of seeds significantly maintained higher germination (46.30%) compared to control (36.90%) after 15 months of storage.

Wilson and Geneve (2004) suggested that corn seed coated with polymer and fungicide recorded higher germination (98.50%), lesser number of abnormal seedlings (1.50%) and lower conductivity readings (41.60 µ mho/g) compared to control (89%, 8.50% and 51.40 µ mho/g, respectively).

Almeida et al. (2005) reported the effect of polymer coating on germination and vigour of broccoli seeds. The surface of coated seeds presented uniform distribution and spreading of the polymer film.

Kunkur (2005) observed that seed coating with Thiram @ 1.5 g + polymer @ 5 g/kg of seeds recorded higher germination, vigour index, rate of germination and seedling dry weight in cotton seeds throughout the storage period.

Sherin et al. (2005) conducted an experiment with the seeds of maize cv. Co1 to standardize optimum dosage of seed coating polymer (polykote) and reported that slurry film coating of seed @ 3 g/kg of seed was found optimum and effective in improving physical appearance and increasing physiological and biological parameters of seed.

Sud et al. (2005) studied the effect of pre-storage fungicidal treatments on seed health and viability of kidney bean (*Phaseolus vulgaris* L.) treated with Bavistin + TMTD, Baylaton, Captan and Thiram. They observed that all fungicidal treatments for the first four months of storage either enhanced or maintained the seed germination and vigour at same level as was recorded at initial stages, but a decline was recorded thereafter.

Geetharani et al. (2006) observed that the seedling length and vigour index of chilli were significantly higher in seeds coated with polymer @ 7 g/kg of seed and Thiram @ 2 g/kg of seed (T_7), followed by T_6 (polymer @ 5 g/kg and Thiram @ 2 g/kg of seed) as compared to all the treatments and the lowest seedling length, seedling dry weight and vigour index recorded in T_1 (uncoated seeds) at the end of 12 months of storage. They further reported that slurry coating of chilli seeds with polymer (3 g/kg seed) along with carbendazim (2 g/kg seed) and halogen mixture (3 g/kg seed) enhanced the germination and vigour index values by 24 per cent, whereas, the pathogen infection was reduced by 1 per cent compared to uncoated seeds. This treatment also enhanced the field emergence by 29 per cent.

Kunkur et al. (2006) studied the effect of seed coating with polymer, fungicide and insecticide on seed quality in cotton during storage of nine months and observed that the seeds coated with Thiram @ 1.50 g/kg of seed and Imidacloprid @ 7.50 g/kg of seed recorded significantly higher germination (77.40%), followed by 76.10% germination of seeds coated with polymer @ 5 g/kg of seeds and Thiram @ 1.50 g/kg of seeds as compared to control (52%).

Giang and Gowda (2007) observed the effect of seed coating with synthetic polymer and chemicals such as Captan, Thiram, Gaucho and Super red on seed quality and storability of hybrid rice (*Oryza sativa* L.). They observed that coated seeds stored in polythene bag recorded the highest germination in comparison to the seeds stored in cloth bag.

Kumar et al. (2007a) reported the effect of polymer seed coating on soybean seed quality enhancement and observed that polymer coated seeds in general deteriorated at slower rate and exhibited higher germination percentage over control. The coating also prevented the proliferation of storage fungi over an elevated period and moisture content of seed showed significant negative correlation with seed germination and seed vigour.

Kumar et al. (2007b) revealed that chemical coated cotton seeds recorded significantly higher germination up to nine months of storage as compared to control. Among the different treatment combinations, higher germination was recorded for seed coated with polymer @ 5 g/kg and Thiram @ 1.5 g/kg of seeds (77%) as compared to control (52%).

Polimero et al. (2007) studied seed coating effects with fungicide and polymer on soybean seed quality and seedling performance in the laboratory as well as in the field and concluded that coating provided better uniformity to the seeds and did not affect its quality.

Basavaraj et al. (2008) observed the effect of fungicide and polymer film coating on storability of onion seeds. The seeds were film coated with polymer (polykote) at different concentrations with and without fungicide and stored in polythene bag and aluminium pouch containers. Among the treatments, seed coating with polymer @ 12 ml + Thiram @ 2 g/kg of seeds recorded higher germination, vigour index, dry weight of seedlings and lower seed infection and electrical conductivity as compared to control.

Kaur and Bishnoi (2008) revealed that coating winter canola seeds with polymers, increased seedling establishment and use of fungicide/pesticide with polymers further enhanced seedling establishment.

Manjunatha et al. (2008) reported that the chilli seeds coated with polymer @ 7 g/kg and Thiram @ 2 g/kg of seed recorded significantly highest germination and field emergence as compared to control which recorded the lowest germination and field emergence at the end of twelve months of storage.

Suresh and Renganayaki (2008) recorded higher root length (28.30 cm), shoot length (12.70 cm), dry matter production (1.83 g) and vigour index (4015) in maize seed coated with red polykote @ 6 ml/kg of seed.

Thobunluepop et al. (2009) evaluated on physiological and biochemical basis of rice seed storability using seeds treated with fungicide (Captan), biological fungicide polymers (chitosan - lignosulphonate polymer and eugenol incorporated into chitosan - lignosulphonate polymer) and un-coated seeds as control. After 12 months storage, seed moisture content and seed water activity increased that affected the germination rate, seedling vigor, seedling dry weight, shoot and root length and seedling growth rate.

Mrda et al. (2010) observed effect of storage period and chemical treatment with fungicides and insecticides on seed germination of three commercial hybrids of sunflower. The results indicated that all three hybrids treated with fungicides and the control had a significantly higher germination than hybrids treated with insecticides.

Patil and Sajjan (2010) reported efficacy of different fungicidal treatment against grain smut in sorghum seeds. Seeds were inoculated with grain smut spores and subsequently after two days, treated with fungicides as treatments T_1 (Carboxin + Thiram @ 3 g/kg), T_2 (Sulphur @ 3 g/kg), T_3 (Thiram @ 3 g/kg), T_4 (Captan @ 3 g/kg), T_5 (Carbendazim + Iprodione @ 3 g/kg), T_6 (Carbendazim @ 3g/kg), T_7 (Captan + Hexaconazole @ 3 ml/kg), T_8 (Sulphur + Thiram @ 1.50 g + 1.50 g/kg) and control. They observed that T_1 treatment had more germination (73.75%) and seedling vigour index (2469) as compared to control (65.25% and 1891, respectively).

Avelar et al. (2011) studied the storability and quality of soybean seed, treated with fungicide, insecticide, and with liquid and powder polymer. They observed that all the coating material protected the seeds during storage except powder polymer which reduced seed germination.

Ludwig et al. (2011) studied seed quality of stored soybean seed after coating with polymer, fungicide and insecticide and observed that germination was negatively affected by using fungicides but the combination of fungicide and polymer had no effect on germination, however, combination of polymer, fungicide and insecticidal application reduced fungus incidence and insect infestation.

Raikar et al. (2011) conducted a storage experiment on rice seed coated with inorganic (fungicides and insecticides) and organic (botanicals) and observed that treated seeds retained germination more than MSCS and seedling vigour after 20 months of storage period under ambient conditions.

Baig et al. (2012) studied the effect of fungicides and polymer coating on storability of soybean seeds. The seed treated with Vitavax coupled with polymer (5 g/kg of seed) recorded higher germination, vigour index, dry weight of seedling, and lower electrical conductivity and seed infection throughout the storage, followed by seed treatment with Bavistin coupled with polymer for maintaining higher seed quality parameters.

Reddy and Patil (2012) studied the effect of pre sowing invigoration seed treatments on seed quality and crop establishment in sunflower hybrid KBSH-1. The different pre-sowing invigoration seed treatments showed differential response for all the seed quality, growth and yield parameters. Among the treatments, seeds treated with 2 per cent $CaCl_2$ for 12 hours and drying back to original moisture content at room temperature recorded significantly higher germination percentage (86.60%), seedling vigour index (2243) and field emergence (81.50%) followed by GA_3 treatment and water hydration.

Mohammad (2012) studied the effect of polymer film coating along with fungicide on seed quality of maize and revealed that the seed treatment with polymer @ 3 ml/kg + vitavax @ 2 g/kg of seed significantly increased seedling length, seedling dry weight, vigor index I, vigour index II, field emergence and observed no seed infection after eight months of storage.

Rettinassababady et al. (2012) studied the role of polymer coating on seed quality status of hybrid rice (*Oryza sativa* L.) during storage under coastal ecosystem by coating with synthetic polymer alone and in combination with flowable thiram and vitavax. Results indicated that among the treatments, seeds coated with vitavax recorded maximum germination, followed by seeds coated with flowable thiram.

Kumar et al. (2013) studied the effect of seed polymer coating on quality of pigeon pea and revealed that seed quality parameters viz., 100-seed weight, germination percentage, seedling length, seedling dry weight and vigour index were found to be higher in seeds obtained from T_8 (Deltamethrin 2.8 EC @ 0.3 ml/kg seeds + Vitavax power @ 3 g/kg seed + polymer seed coating @ 5 ml/kg seeds) as compared to other treatments.

Pathare (2013) worked on the efficacy of insecticide seed treatment on cotton seed germination and vigour index during storage, and recorded higher germination percentage, field emergence, root length, shoot length, seedling vigour index, dry matter, lower electrical conductivity in the seeds treated with Thiram @ 1.50 g/kg of seed and Imidacloprid @ 7.50 g/kg of seed, followed by seed coating with polymer @ 5.00 g/kg of seeds and Thiram @ 1.50 g/kg of seeds.

Rufino et al. (2013) treated wheat seed with zinc, fungicide and polymer, and concluded that the germination of wheat seeds was positively influenced by the treatment with fungicide, when applied in combination with zinc and polymer.

Sushma (2013) worked on the effect of polymer coating and chemical seed treatment on seed storability and field performance of chickpea, and revealed that the treatment combination of polymer coated seed @ 10 ml/kg along with Deltamethrin 2.8 EC @ 0.4 ml/kg of seed + Vitavax power @ 2 g/kg of seed recorded significantly higher seed germination (98.88%), shoot and root length (8.39 cm and 15.63 cm), seedling vigour index (2093), seedling dry weight (263.32 g), test weight (177.12 g) and lower EC value (0.831 dSm^{-1}) as compared to T_1 (untreated seeds) at the end of storage period.

Taye et al. (2013) conducted an experiment to evaluate the effect of chemical seed treatment on germination, emergence and seedling vigour of maize under laboratory involving four treatments (three fungicides and one untreated) and observed that fungicides, namely, Ridomil, Mancozeb and Metalaxyl at a rate of 2.50 g/kg of seed improved the seedling height, average leaf number, fresh and dry weight of maize seedling as compared to untreated seeds.

Ambika et al. (2014) observed that CORH 3 hybrid rice seeds coated with polymer maintained storage potential by recording higher germination, vigour index, without any pathogen and insect infestation after nine months of storage.

Badiger et al. (2014) studied the impact of synthetic polymer coating and chemicals seed treatment on seed longevity of cotton seed (*Gossypium hirsutum* L.) and found that cotton seed coated with polykote @ 3 ml/kg + Vitavax 200 @ 2 ml/kg of seeds maintain germination and other seed quality parameters for ten months of storage, when stored in the polythene bag (400 gauge).

Harish et al. (2014) studied the effect of seed treatments on seed quality parameters of tomato seeds and concluded that seeds treated with Vitavax @ 2 g + polymer coating @ 20 ml/kg of seeds recorded significantly higher seed germination (76.38%), vigor index (1414), lesser EC (0.578 dSm^{-1}) and moisture content (7.03%) at the end of storage period.

Kaushik et al. (2014) studied the effect of polymer film coating on seed quality of maize and revealed that the seed treatment with polymer @ 9 ml + Thiram @ 2 g/kg of seed significantly increased shoot length, root length, seedling length, seed viability, seedling fresh weight and vigor index after six months of storage.

Keawkham et al. (2014) studied the effect of polymer seed coating and seed dressing with pesticides viz., Metalaxyl and Imidacloprid on seed quality and storability of hybrid cucumber and observed that seed germination of polymer coated seeds stored under ambient conditions for eight months decreased to 58% and 46%, as compared to 13% and 11% for seed dressed treatments, respectively.

Patil et al. (2014) evaluated the impact of seed treatment chemicals on seed storability in pigeonpea (*Cajanuscajan* (L.) Millsp.) and concluded that Thiram @ 3 g/kg of seed + spinosad @ 0.04 ml/kg treated seeds, when stored in super bag, recorded significantly higher germination (83.50%), seedling length (30.43 cm), seedling dry weight (28.90 mg), seedling vigour index-I (2555) and II (24.27) and lowest seed moisture 8.45 (%) at the end of sixth months of storage period compared to control.

Rettinassababady and Ramanadane (2014) studied seed quality status of polymer-coated Bt-cotton (*Gossypium* sp.) during storage and observed that germination percentage of seeds treated with Royal flow + Imidachoprid (90%) were at par with Vitavax 200 (88.5%) and Flowable Thiram alone (89%) excelled other treatments, irrespective of containers and period of storage. Seed coating with polykote coupled with Royal flow, Imidacloprid and Vitavax 200 effectively controlled the seed infection.

Shakuntala et al. (2014) worked on the influence of polymer coating on storage quality of sunflower seeds and found that storability of sunflower (RSFH-130) was improved by treating the seeds with polymer seed coating @ 5 g/kg of seeds +

Vitavax (Carboxin 37.5% + Thiram 37.5%) @ 2 g/kg of seeds + Imidacloprid @ 5 g/kg of seeds after fourteen months of seeds storage in polythene bag.

Udabal et al. (2014) studied the effect of six seed treatments, T_1: Sweet flag rhizome powder (5 g/kg), T_2: Neem leaf powder (10 g/kg), T_3: Custard apple seed powder (10 g/kg), T_4: Deltamethrine (40 mg/kg), T_5: Vitavax (3 g/kg) and T_6: Control (without any seed treatments) on storability of sunflower (*Helianthus annuus* L.) seeds and reported that seeds treated with Vitavax (3 g/kg) recorded significantly higher seed germination (84.37%), 100-seed weight (4.36 g), root and shoot length (17.66 cm and 16.25 cm, respectively), vigour index (2865), lower electrical conductivity (232 dSm^{-1}) and seed moisture content (9.14%) at the end of eleven months of seed storage as compared to other treatments.

Usha and Dadlani (2014) studied the enhancement of planting value and storage performance of different cultivars of soybean seeds by pretreatment and found that polymer coating with fungicides viz., Polykote + Thiram and Royalflow were most effective in enhancing the germination, seedling growth and field emergence in all the cultivars of soybean.

Verma and Verma (2014) conducted an experiment on seed coating material (Polykote, Flowable Thiram and Vitavax) and storage containers (HDPE and cloth bags) on germination and seedling vigour of soybean. They observed maximum germination (%) and vigour in polymer coating @ 3 ml/kg of seed, followed by Vitavax 200 @ 2 g/kg of seed treatment, which was significantly higher than rest of the coated treatment including untreated control seeds.

Wani et al. (2014) worked on the effect of seed treatments and packing materials on seed quality parameters of maize during storage and observed that seeds treated with Captan recorded higher germination (80%) and vigour index (2161).

Ananthi et al. (2015) studied the effect of seed treatment on seed and seedling quality characters in red gram and reported that seed hardening with 100 ppm $ZnSo_4$ and coating with polymer @ 3 ml/kg of seed, Bavistin @ 2 g/kg of seed and Imidacloprid @ 1 ml/kg of seed along with *Pseudomonas fluorescencs* @ 10 g/kg of seed and *Rhizobium* recorded highest germination percentage than the control.

Desai et al. (2015) studied the effect of seed coating on storability of soybean (*Glycine max* L. Merill) and revealed that the seed treated with polymer and Vitavax maintained storability above minimum seed certification standards (MSCS) for 270 days and also exhibited higher vigour index, lower electrical conductivity and less seed mycoflora.

Manikandan and Srimathi (2015) conducted an experiment on the effect of seed treatments and containers on storability of grain amaranthus (*Amaranthus hypochondriacus* L.) cv. Suvarna and revealed that seeds treated with Carbendazim and Imidacloprid @ 2 g/kg of seed and 100 mg/kg of seed, respectively, maintained maximum germination of 97 per cent after six months of seed storage in poly-laminated aluminum foil pouch.

Rathinavel (2015) worked on the storability of cotton (*Gossypium hirsutum* L.) seeds through polymer coating under ambient storage condition and revealed that seeds coated with polymer @ 3 ml/kg + Thiram @ 2.5 g/kg + Super red @ 5 ml/kg + Cruiser @ 5 g/kg of seeds was found superior in preserving seed quality parameters viz., germination (%), seedling vigour, field emergence and lesser seed infection over untreated seeds, when stored at ambient conditions for 26 months after packing in polythene bag (700 gauge).

Veraja and Rai (2015) studied the effect of polymer coating, chemicals and biocontrol agent on storability of black gram (*Vigna mungo* L.). Seeds after treating with six treatments viz., [T_1: Polymer coat, T_2: Polymer + Thiram, T_3: Polymer + Imidacloprid, T_4: Polymer + Thiram + Imidacloprid, T_5: Polymer + Thiram + Imidacloprid + *Trichoderma viride* and T_6: Control] were packed in cloth bag (C_1) and polythene bag of 700 gauge thickness (C_2), and stored at ambient conditions. The recorded results showed that germination percentage, root length, shoot length, seedling length, seedling dry weight, seedling vigour indices and protein content were high in T_5C_2 as compared to all other treatments, Moreover total fungal colonies and moisture content were found to be less in same treatment T_5C_2.

Jacob et al. (2016) reported that tomato seeds coated with hydrophilic polymer maintained the quality over a longer storage period than non-coated seeds, irrespective of the packaging material and storage conditions.

Thakur and Dhiman (2016) studied the effect of seed coating with synthetic polymer and additives on soybean seed quality parameters viz., germination percentage (first and final count), seedling length (cm), seedling dry weight (g), seedling vigour index - I, seedling vigour index - II and observed that polymer @ 3 ml/kg + flowable thiram @ 2.4 ml/kg of seed recorded significantly higher germination percentage (first and final count), seedling length (cm), seedling dry weight (g), seedling vigour index - I, seedling vigour index - II, followed by polymer + vitavax @ 2 g/kg of seed over untreated control after 12 months of storage of seeds.

Manoharapaladagu et al. (2017) studied the effect of seed coating on chilli during storage and observed that seeds treated with polymer @ 7 ml/kg + thiram @ 2 g/kg of seed recorded significant superiority over untreated control for all seed quality parameters viz., germination (%) – first count (%), final count (%), seedling length (cm), seedling dry weight (g), seedling vigour index - I, seedling vigour index - II after 6 months of storage of seeds.

Goswami et al. (2017) conducted an experiment on the effect of seed coating material (polykote, flowable thiram and vitavax) and storage containers (cloth bags and polythene bags) on root length (cm), shoot length (cm), seedling fresh weight (g) and seedling dry weight (g). They observed significantly higher seedling root length, shoot length, seedling fresh weight and seedling dry weight by polymer + vitavax 200 @ 2g/kg seed treatment followed by flowable thiram @ 2.4 ml/kg in comparison to untreated control.

Sharma et al. (2017) studied the effect of coating on seed quality in HQPM 1 hybrid maize during storage and observed that seeds treated with polymer @ 3 ml/kg + vitavax 200 @ 2 g/kg of seed recorded significant superiority over untreated control for all seed quality parameters viz., germination (%) - first count (%), final count (%), seedling length (cm), seedling dry weight (g), seedling vigour index - I, seedling vigour index - II after 12 months of storage of seeds.

Sharma and Dhiman (2017) studied the effect of seed coating with synthetic polymer and additives on paddy seed quality parameters viz., germination percentage (first and final count), seedling length (cm), seedling dry weight (g), seedling vigour index - I, seedling vigour index - II and observed that Polymer @ 3 ml/kg + vitavax

200 @ 2 g/kg of seed recorded significantly higher germination percentage (first and final count), seedling length (cm), seedling dry weight (g), seedling vigour index - I, seedling vigour index - II, followed by polymer + vitavax @ 2 g/kg of seed over untreated control after 12 months of storage of seeds.

Padhi et al. (2017) studied the effect of seed coating materials on storability of paddy seeds on seed quality and observed that seeds treated with polymer @ 4ml + vitavax 200 2g/kg of seed recorded significant superiority over untreated control for all seed quality parameters viz., germination percentage (first and final count), speed of germination, root length (cm), shoot length (cm), root dry weight (g), shoot dry weight (g), vigour index - I and vigour index - II after 7 months of storage of seeds.

Patel et al. (2017) recorded that soybean seeds treated with Mancozeb @ 2g/kg of seeds resulted in significantly higher germination as compared to control during 2 years storage period.

Dixit et al. (2018) recorded that wheat seeds treated with Polymer @ 3 ml/kg + Thiram @ 2 g/kg + Quick root @ 2 g/kg of seed showed significantly highest germination (79.33%), seedling length (10.12 cm), seedling dry weight (0.183 g), SVI - I (802.81) and SVI - II (14.15) at the end of twelve months of storage period.

2.2 Effect of packaging material on seed quality

Seed is a living entity and ageing is an inevitable process beyond the physiological maturity, whether the seed is on the mother plant or in storage. Generally, seeds packed in moisture impervious containers will store better than in the moisture pervious containers under ambient storage conditions. The prevailing atmospheric relative humidity and temperature will influence greatly the longevity of seeds since more fluctuation in moisture content occurs in moisture pervious containers than moisture vapour proof containers. In order to prevent the quantitative and qualitative losses due to several biotic and abiotic factors during storage, several methods are being adopted, such as seed treatment with suitable chemicals or plant products and storing the seeds in safe containers, besides sanitation of the storage place (Doijode 1988). To combat these factors effectively, storing the seeds in vapour proof containers like polythene bag, aluminum foils, tins or any sealed containers is found to be more useful in maintaining the desired quality of seeds for longer period (Singh and Singh 1992), unlike those stored in moisture pervious containers like cloth bag and gunny bag (Singh et al. 1988).

Karivaratharaju et al. (1987) reported that the seeds of brinjal cv. MPD-1 with seven per cent moisture content treated with Captan gave 80 per cent and 82 per cent germinability after storing for 21 months in cloth bags and polythene bags (700 gauge), respectively.

Anuradha and Agrawal (1989) stored the seeds of tomato, carrot and onion in cloth bag under ambient condition whose initial germination per cent was 97, 59 and 97, respectively and noticed the germination percentage of 78, 22 and 3, respectively at the end of storage period of 13, 22 and 28 months, respectively.

Singh and Singh (1990) found that the onion seeds stored in cloth bags exhibited lower germination percentage compared to sealed storage.

Gupta et al. (1993) found that the per cent germination of chilli (cv. Pusa Jwala) seeds treated with 0.25 per cent Thiram (Thiride) remained above the certification standard (60%) up to 19 months after seed harvest, when stored in tin container (73%) as against 10 months when stored in cloth bag (62%).

Palanisamy et al. (1995) revealed that the moringa seed germination decreases progressively as the storage period increased. Among the different treatments, seed treated with Captan @ 2 g/kg of seeds could be able to maintain higher germination (60%) even after twelve months of storage. In general, the seeds stored in polythene bag recorded higher seed germination (63%) than the seeds stored in cloth bag (58%) at the end of twelve months of storage.

Yogalakshmi et al. (1996) observed that rice hybrid seeds stored in polythene bag could maintain minimum germination standard (80%) up to eight months of storage, while it was up to six months in seeds stored in cloth bags. They further reported that higher seedling dry weight (117 g) and lower EC (87.6 dSm^{-1}) were recorded in seeds stored in polythene bag than the seeds stored in cloth bags which were 110 g and 105.40 dSm^{-1}, respectively at the end of twelve months of storage.

Kotreppagouda (1997) reported that the chilli seeds treated with Bavistin @ 1.0 g/kg of seed and stored in polythene bag registered higher germination of 53.64 per cent, while control recorded 49.31 per cent at the end of six months of storage period.

Vinitha (2006) observed that tomato seeds coated in sequence with 6.0 g white red polykote + Carbendazim @ 2 g + Dimethoate @ 5 ml/kg of seed and stored in aluminium foil pouch maintained better seed quality in terms of higher germination (89%), root (12.10 cm) and shoot length (6.10 cm), dry matter (0.029 g) and vigour index (1625) up to 12 months of storage under ambient conditions.

Narayanareddy (2008) concluded that among the pre-sowing invigouration seed treatments, the seeds treated with 50 ppm GA_3 recorded significantly higher seed quality parameters viz., germination (99.60%), seedling vigour index (3066) and lower electrical conductivity (0.390 dSm^{-1}) and it also recorded higher field emergence (93.50%), followed by $CaCl_2$ and water hydration.

Naguib et al. (2011) conducted an experiment to study the effect of packaging materials and storage periods on viability and vigour of seed and changes of some chemical components during storage in wheat seed and observed that wheat seed stored in aluminum and polyester bags showed high seed germination, seedling vigor and kept nutrient contents, and therefore they could delay seed quality deterioration compared with plastic and clothes bags.

Chattha et al. (2012) studied the effect of different packing materials and storage conditions on the viability of wheat seed (TD-1 variety) for a storage period of ten months and observed that wheat seed stored in gunny, cloth and plastic bags were good in respect of temperature, moisture content and germination capacity in comparison with those stored in metal and earthen bins.

Kumar et al. (2014) studied the effect of seed treatments Thiram, Neem leaf extract and Calcium oxychloride ($CaOCl_2$) and containers [Cloth bag, single layer polythene bag and double layer polythene bag] on seed quality of marigold during 10 months storage and reported that seed treated with chlorax and stored in double layer polythene bag recorded significantly higher germination (49.25%), vigour index (281) at the end of ten months storage period.

Rao et al. (2015) reported that seeds coated with polykote @ 3 ml/kg of seed along with vitavax 200 showed higher germination percentage (74% and 73%) when seeds were stored in polythene bag & cloth bag, respectively over a period of twelve months while untreated seeds recorded lower germination percentage (53% and 56%).

Autade and Ghuge (2018) observed that seeds of soybean were stored in HDPE bags showed highest germination (55.81), seedling length (18.7 cm), seedling dry weight (0.93 g), vigour index - I (1181.71), vigour index - II (60.42) and less electrical conductivity (1.83) than the seeds stored in gunny and cloth bags after 210 days of storage period.

Siddarudh et al. (2019) observed that rice seeds coated with polymer stored in super grain bag for 16 months, showed significant higher percentage of germination (85%), root length (22.4 cm) and shoot length (12.9 cm) as compared to treated seeds stored in jute bags.

3. MATERIALS AND METHODS

The experiment to study the effect of seed coating on seed longevity in rice during storage was conducted in Seed Technology Laboratory of Department of Seed Science and Technology, College of Agriculture, Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishvavidyalaya, Palampur. The details of the material used and techniques adopted during the course of the investigation are presented in this chapter.

3.1 General description

3.1.1 Location of experimental site

3.1.2 Climatic conditions

3.1.3 Seed source

3.2 Experimental details

3.2.1 Effect of seed coating on quality attributes

3.2.1.1 Treatment details

3.2.1.2 Storage container

3.2.1.3 Experimental design

3.2.1.4 Method of seed coating

3.2.1.5 Method of storage

3.2.1.6 Collection of data

3.2.2 Statistical analysis

3.1 General description

3.1.1 Location of experimental site

The investigation involved laboratory experiment. The experiment was carried out from January 2018 to December 2018 in the Seed Technology Laboratory of Department of Seed Science and Technology, CSKHPKV, Palampur.

3.1.2 Climatic conditions

The climate of the region is characterized as wet temperate with mild summers (March to June) and cool winters. The average rainfall of the area ranges 2500 mm to 3000 mm. Major portion of the rainfall i.e. about 75 per cent is received during monsoon period from June to September. The mean monthly temperature and relative humidity during the period of experiment was recorded at Seed Technology Laboratory of Department of Seed Science and Technology, College of Agriculture, CSK HPKV, Palampur (Appendix- I).

3.1.3 Seed source

The experimental material consisted of well graded seeds of *kharif* 2015 harvest of rice variety HPR 1068, which were initially procured from Rice and Wheat Research Centre Malan (Kangra).

3.2 Experimental details

3.2.1 To study the effect of seed coating on seed longevity during storage

In order to study the effect of seed coating on seed longevity in paddy, the following treatments were studied.

3.2.1.1 Treatment Details

T_1 - control (uncoated seeds)

T_2 - polymer coating (Polykote @ 3 ml/kg of seed, diluted with 5 ml of water for proper application of polymer)

T_3 - flowable thiram (Royal flow 40 SC) @ 2.4 ml/kg seed

T_4 - polymer + flowable thiram (Royal flow 40 SC) @ 2.4 ml/kg seed

T_5 - vitavax 200 (containing Thiram 37.5% and Carboxil 37.5%) @ 2 g/kg seed

T_6 - polymer + vitavax 200 (containing Thiram, 37.5% and Carboxil, 37.5%) @ 2 g/kg of seed

T_7 - imidacloprid (Gaucho) @ 4 ml/kg seed

T_8 - polymer + imidacloprid (Gaucho) @ 4 ml/kg seed

T_9 - polymer + flowable thiram (Royal flow 40 SC) @ 2.4 ml/kg seed + imidacloprid (Gaucho) @ 4 ml/kg seed

T_{10} - polymer + vitavax 200 (containing Thiram, 37.5% and Carboxil, 37.5%) @ 2g/kg of seed + Imidacloprid (Gaucho) @ 4 ml/kg seed

T_1 - control

T_2 - polymer coating

T_3 - flowable thiram

T_4 - polymer + flowable + thiram

T_5 - vitavax 200

T_6 - polymer + vitavax 200

T_7 - imidacloprid

T_8 - polymer + imidacloprid

T_9 - polymer + flowable thiram + imidacloprid

T_{10} - polymer + vitavax 200 + imidacloprid

Plate 3.1 Seed coated with polymer, fungicide and insecticide

3.2.1.2 Storage container

HDPE (high density polyethylene) interwoven bag.

3.2.1.3 Design of experiment

The design of the experiment adopted was Completely Randomized Design (CRD) and replicated three times.

3.2.1.4 Time and Method of seed coating

Seed coating was done during 2015 on freshly harvested seed. One kilogram of seeds per treatment were stored in HDPE (high density polyethylene) interwoven bag. The uncoated seeds were used as control, T_1. In T_2, polykote was poured on the seeds @ 3 ml/kg of seeds, diluted with 5 ml of water. In T_3, flowable thiram was applied on seeds @ 2.4 ml/kg of seeds, in T_4, both polykote @ 3 ml/kg of seeds, diluted with 5 ml of water and flowable thiram @ 2.4 ml/kg of seeds were applied on the seeds, in T_5, vitavax 200 @ 2 g/kg of seeds was applied on the seeds, in T_6, both polykote @ 3 ml/kg of seeds diluted in 5 ml of water and vitavax 200 @ 2 g/kg of seeds were applied on the seeds, in T_7, seeds were coated with imidacloprid @ 4 ml/kg of seeds, in T_8, both polykote @ 3 ml/kg of seeds and imidacloprid @ 4 ml/kg of seeds were applied on the seeds, in T_9, polykote @ 3 ml/kg of seeds, diluted with 5 ml of water, followed by flowable thiram @ 2.4 ml/kg of seeds and imidacloprid @ 4 ml/kg of seeds were applied on the seeds and in $T_{10,}$ polykote @ 3 ml/kg of seeds, diluted with 5 ml of water, followed by vitavax 200 @ 2 g/kg of seeds and imidacloprid @ 4 ml/kg of seeds were applied manually to ensure uniform coating. After coating the seeds of different treatments were kept for shade drying for 72 hours at room temperature and moisture content brought to the original i.e. around 10 % before packing of seeds for storability.

3.2.1.5 Methods of storage

The coated seeds of various treatments were packed in HDPE (high density polyethylene) interwoven bags and stored under ambient condition for thirty six months (December 2015 to December 2018) in Seed Technology Laboratory of the

Department of Seed Science and Technology, CSKHPKV, Palampur. For the present study, the evaluation of seed quality parameters was made at bimonthly intervals for twelve months (25^{th} to 36^{th} months) i.e. from January 2018 to December 2018.

3.2.1.6 Collection of Data

The seeds were drawn at random from the each treatment bag at bimonthly intervals for analysing the seed quality parameters as detailed below:

Germination percentage

Germination test was conducted using 100 seeds drawn at random from each treatment replication-wise (three replications) by adopting Blotter paper method as described by ISTA procedures (Anonymous 1999). Seeds were incubated in germinator. The temperature of 25±1°C and RH of 90 per cent was maintained during the germination test.

First count (%) and final count (%) was taken for each treatment of every replication. The first count was taken on 7^{th} day, while final count was taken on 14^{th} day from the day when germination test was performed. The germination percentage was calculated as:

$$\text{Germination Percentage (first and final count)} = \frac{\text{Number of germinated seeds}}{\text{Number of seeds kept for germination}} \times 100$$

Speed of germination

One hundred seeds from each treatment of three replications were taken randomly and grown in petriplates by adopting blotter paper method. The daily germination count was made up to the final count. The germination vigour index (GVI) was calculated using the following formula and expressed in number.

$$GVI = \frac{n1}{d1} + \frac{n2}{d2} + \cdots + \frac{n}{d}$$

Where n1, n2 … n are the number of seeds germinated

d1, d2…d are the days to germination

Seedling length (cm)

Ten normal seedlings were randomly selected from each treatment in each of three replications during final count and length of the seedlings was measured from the tip of the primary leaf to the root tip and mean seedling length was expressed in centimeters.

Seedling dry weight (g)

The same ten normal seedlings which were used for seedling length measurements were put in butter paper pocket and kept in hot air oven at 70°C for 18 hours. The dry weight of the seedlings was recorded and expressed in grams.

Seedling vigour index

The seeding vigour index was calculated by adopting the method suggested by Abdul- Baki and Anderson (1973) and expressed in number by using following formulae.

Seedling vigour index - I = Germination (%) × Seedling length (cm)

Seedling vigour index - II = Germination (%) × 10 Seedlings dry weight (g)

Field emergence (%)

One hundred seeds were drawn randomly from each treatment. The seeds were sown in well prepared soil at 3 to 5 cm depth and covered with soil. Field emergence count was taken on the 14th day after sowing and the emergence percentage was calculated taking into account the number of seedlings emerged above the soil surface.

$$\text{Field emergence (\%)} = \frac{\text{Number of seedlings emerged}}{\text{Total number of seeds sown}} \times 100$$

Test weight (g)

Test weight was taken at bimonthly intervals. One thousand randomly sampled seeds from each treatment in each of three replications were weighed and expressed in grams.

Moisture content (%)

A seed sample of weight 170 g (as per specification of moisture meter) was drawn randomly from bags of each treatment in each of three replications and then moisture content in percentage was recorded with the moisture meter (Non - Destructive Moisture Meter PM 600).

Electrical conductivity (m mho/cm/g)

Five grams of seeds from each treatment of three replications were weighed. Then these seeds were soaked in 50 ml distilled water in a beaker and kept in an incubator maintained at 25 ± 1°C temperature. After 17 hours of soaking, the solution was decanted and electrical conductivity of the solution was measured using digital conductivity meter and expressed in m mho/cm/g.

Seed infection (%)

Storage fungi present on seeds were tested using blotter method as prescribed by ISTA. Twenty five seeds of each treatment replication-wise were placed equidistantly on two layered moistened blotter paper taken in petri plates. Each treatment was replicated three times. They were incubated at 20 ± 2°C for fourteen days. On fourteenth day, the plates were examined under stereobionocular microscope (50X) for the presence of seed borne fungi. The number of infected seeds was counted and expressed in percentage. Besides, the kinds of fungi present were also identified.

Seed infestation (%)

Three hundred seeds in each of the three replications from each treatment were taken to determine the insect infestation level in paddy seeds. The infested seeds were counted and results were expressed in percentage.

3.2.2 Statistical analysis

The laboratory data were statistically analyzed using Completely Randomized Design (CRD), as per Panse and Sukhatme (1984). The critical differences between the treatments were worked out at five per cent significance (Sundararaj et al.1972). The data on germination (%) and field emergence (%) were transformed into arcsine root percentage and transformed data were used for statistical analysis. The data on fungal infection (%) and insect infestation (%) were transformed into square root percentage and transformed data were used for statistical analysis.

4. RESULTS AND DISCUSSION

Seed deterioration and ageing of seed are inevitable, inexorable and irreversible process, but seed deterioration rate can be slowed down either by storing the seeds under controlled condition or by imposing seed treatment with polymer coating along with seed treatment chemicals. As the seed storage under controlled condition involves huge cost, the seed treatment remains the best alternative approach to maintain the seed quality.

The results of the experiment conducted to know the effect of seed coating on seed quality and to identify the effective seed coating treatments for enhancing seed longevity of rice are presented in this chapter.

4.1 Effect of seed coating on seed quality during storage

4.1.1 Germination (%)

4.1.1.1 Germination (%) - First count

The results on germination percentage - first count as influenced by seed coating treatments during twelve months (25^{th} to 36^{th}months) of storage period are presented in Table 4.1.1.1 and depicted in Fig. 4.1.

Germination percentage declined in all the treatments gradually with advancement in the storage period. The mean germination percentage (first count) in the beginning and at the end of storage period was 77.50 per cent and 69.73 per cent, respectively.

The germination percentage (first count) due to seed coating treatments varied significantly for different storage periods. After 26 months of storage, significantly highest germination percentage (first count) was recorded for treatment T_6 - polymer + vitavax 200 @ 2 g/kg of seed (81.00%) which was at par with T_4 - polymer + flowable thiram @ 2.4 ml/kg of seed (80.67%), followed by T_5 - vitavax 200 @ 2 g/kg of seed (79.33%), T_{10} - polymer + vitavax 200 @ 2 g/kg of seed + imidacloprid (Gaucho) @ 4 ml/kg of seed (78.33%), T_3 - flowable thiram @ 2.4 ml/kg of seed (77.67%), T_9 - polymer + flowable thiram @ 2.4 ml/kg of seed + imidacloprid (Gaucho) @ 4 ml/kg of seed (76.67%), T_8 - polymer + imidacloprid (Gaucho) @ 4 ml/kg of seed (76.33%), T_7 - imidacloprid (Gaucho) @ 4 ml/kg of seed (75.67%) and T_2 - polykote @ 3 ml/kg of seed (75.33%), while the lowest germination was recorded for T_1 - untreated control (74.00%).

Table 4.1.1.1 Effect of seed coating treatments on germination (%) - first count during storage in paddy

Treatment	Months after storage					
	26	28	30	32	34	36
T_1	74.00	72.67	70.33	70.00	69.33	65.67
	(59.35)	(58.48)	(57.00)	(56.79)	(56.37)	(54.13)
T_2	75.33	74.00	72.00	71.67	71.00	67.33
	(60.22)	(59.35)	(58.05)	(57.84)	(57.42)	(54.14)
T_3	77.67	77.33	75.00	74.33	73.00	70.00
	(61.80)	(61.57)	(60.00)	(59.56)	(58.70)	(56.79)
T_4	80.67	80.33	77.33	77.67	76.67	73.00
	(63.92)	(63.68)	(61.57)	(61.80)	(61.12)	(58.70)
T_5	79.33	78.67	76.33	75.67	74.67	71.67
	(62.96)	(62.49)	(60.89)	(60.44)	(59.78)	(57.84)
T_6	81.00	80.67	77.67	78.00	77.00	73.33
	(64.16)	(63.92)	(61.80)	(62.03)	(61.35)	(58.91)
T_7	75.67	75.00	73.00	72.33	71.33	68.00
	(60.44)	(60.00)	(58.70)	(58.27)	(57.63)	(55.55)
T_8	76.33	75.67	73.67	73.00	72.00	68.67
	(60.89)	(60.44)	(59.13)	(58.70)	(58.05)	(55.96)
T_9	76.67	76.33	74.00	73.33	72.33	69.00
	(61.12)	(60.89)	(59.35)	(58.91)	(58.27)	(56.17)
T_{10}	78.33	78.00	75.67	75.00	74.00	70.67
	(62.26)	(62.03)	(60.44)	(60.00)	(59.35)	(57.21)
Mean	77.50	76.87	74.50	74.10	73.13	69.73
	(61.71)	(61.29)	(59.69)	(59.41)	(58.80)	(56.64)
SE(m±)	0.272	0.314	0.293	0.294	0.306	0.303
CD (5%)	0.80	0.93	0.86	0.87	0.90	0.89

Figures in parentheses indicate arc sine values

T_1 - control (untreated seeds)
T_2 - polymer coating (polykote @ 3 ml/kg of seed, diluted with 5 ml of water)
T_3 - flowable thiram (Royal flow 40 SC) @ 2.4 ml/kg seed
T_4 - polymer + flowable thiram (Royal flow 40 SC) @ 2.4 ml/kg seed
T_5 - vitavax 200 (containing thiram 37.5% and carboxil 37.5%) @ 2 g/kg seed
T_6 - polymer + vitavax 200 (containing thiram 37.5% and carboxil 37.5%) @ 2 g/kg of seed
T_7 - imidacloprid (Gaucho) @ 4 ml/kg seed
T_8 - polymer + imidacloprid (Gaucho) @ 4 ml/kg seed
T_9 - polymer + flowable thiram (Royal flow 40 SC) @ 2.4 ml/kg seed + imidacloprid @ 4 ml/kg seed
T_{10} - polymer + vitavax 200 (containing thiram 37.5% and carboxil 37.5%) @ 2 g/kg of seed + imidacloprid (Gaucho) 4 ml/kg seed

T_1 - control

T_2 - polymer coating

T_3 - flowable thiram

T_4 - polymer + flowable

T_5 - vitavax 200

T_6 – polymer + vitavax 200

T_7 - imidacloprid

T_8 - polymer + imidacloprid

T_9 - polymer + flowable thiram +imidacloprid

T_{10} - polymer + vitavax 200 +imidacloprid

Plate 4.1 Germination (final count) after 26 months of storage

The same pattern was recorded till the end of the storage period. Two superior treatments, which showed significantly higher germination percentage (first count) over T_1 - untreated control (65.67%) at the end of storage (36 months) were treatment T_6 - polymer + vitavax 200 @ 2 g/kg of seed (73.33%), which was at par with T_4 - polymer + flowable thiram @ 2.4 ml/kg of seed (73.00%), while the lowest germination was recorded for treatment T_1 - untreated control (65.67%).

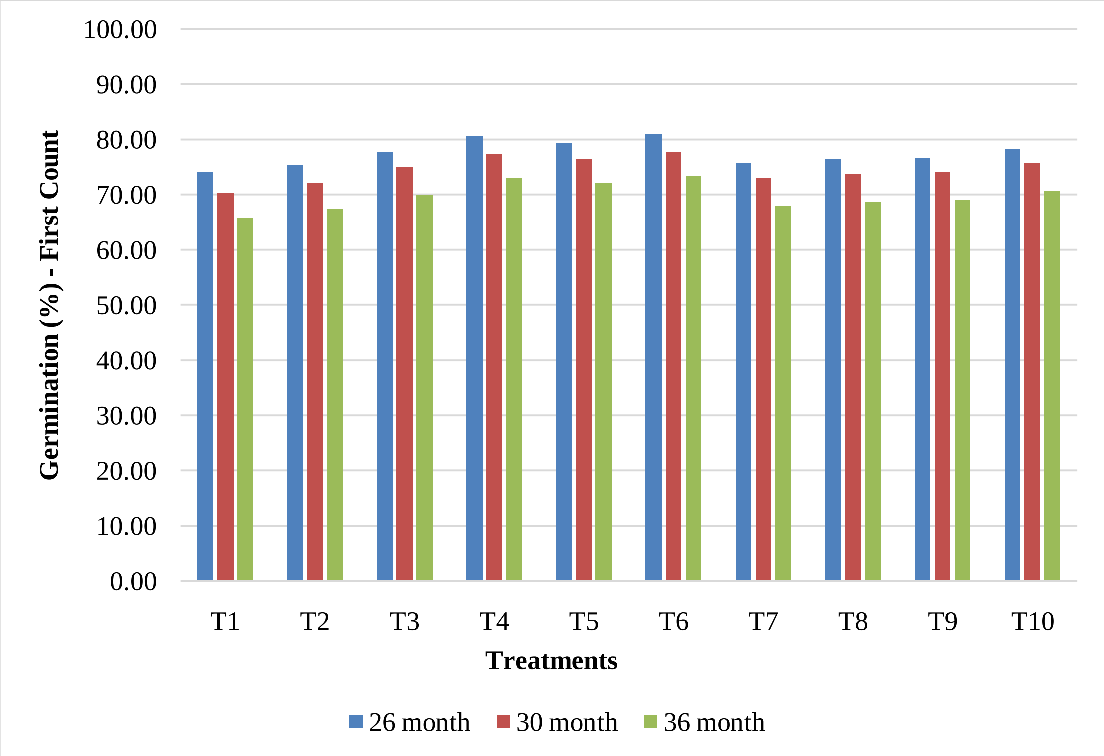

Fig.4.1 Effect of seed coating treatments on germination (%) - first count during storage in paddy

The germination percentage (first count) declined gradually with the advancement of storage for all the treatment combinations which may be attributed to the ageing effect leading to the depletion of stored food that leads to starvation of meristematic tissue and decline in synthetic activity of embryo, apart from death of seed because of fungal invasion, fluctuating temperature, relative humidity and storage container in which seed were stored. Coating of seeds with polymer, insecticide and fungicides protected the seed from influence of above factors resulting in maintenance of seed viability for a comparatively longer period.

At the end of storage period the germination percentage (first count) in treatment of polymer and vitavax 200 (T_6) was 7.66 per cent more than control (T_1).

Similar results were reported by Thakur and Dhiman (2016) in soybean seeds who observed that seeds treated with polymer of seed and flowable thiram @ 2.4 ml/kg of seed shows significantly higher germination percentage (first count) over untreated control at the end of one year of storage. Sharma et al. (2017) in maize observed that seeds treated with polymer + vitavax 200 @ 2 g/kg of seed recorded significantly higher germination percentage (first count) over untreated control at the end of one year of storage, Sharma and Dhiman (2017) in paddy observed that seeds treated with polymer + vitavax 200 @ 2 g/kg of seed recorded significantly higher germination percentage (first count) over untreated control at the end of one year of storage, Rathinavel (2015) observed that cotton seeds coated with polymer @ 3 ml/kg + Thiram @ 2.5 g/kg + Super red @ 5 ml/kg + Cruiser @ 5 g/kg of seeds resulted in significantly higher germination percentage (first count) as compared to untreated control at the end of 26 months of storage period, Patel et al. (2017) recorded that soybean seeds treated with Mancozeb @ 2g/kg of seeds resulted in significantly higher germination percentage (first count) as compared to control during 2 years storage period, Dixit et al. (2018) observed that wheat seeds coated with Polymer @ 3g/kg + Thiram @ 2 g/kg + Quick root @ 2 g/kg of seed showed significantly highest values of germination at the end of 12 months.

4.1.1.2 Germination (%) - Final count

The results on germination percentage - final count as influenced by seed coating treatments after twelve months (25^{th} to 36^{th} months) of storage period are presented in Table 4.1.1.2 and depicted in Fig. 4.2.

Germination percentage declined in all the treatments gradually with advancement in the storage period. The mean germination percentage during final count in the beginning and end of the storage period was 80.40 per cent and 72.23 per cent, respectively.

The germination percentage (final count) due to seed coating treatments varied significantly for different storage periods. After 26 months of storage, significantly highest germination percentage (final count) was recorded for treatment T_6 - polymer + vitavax 200 @ 2 g/kg of seed (84.33%), which was at par with T_4 - polymer + flowable thiram @ 2.4 ml/kg of seed (84.00%), T_5 - vitavax 200 @ 2 g/kg

Table 4.1.1.2 Effect of seed coating treatments on germination (%) - final count during storage in paddy

Treatment	Months after storage					
	26	28	30	32	34	36
T_1	76.33	76.00	74.67	73.33	70.33	67.33
	(60.89)	(60.67)	(59.78)	(58.91)	(57.00)	(55.14)
T_2	77.67	77.33	76.33	74.67	72.00	68.67
	(61.80)	(61.57)	(60.89)	(59.78)	(58.05)	(55.96)
T_3	80.67	80.33	79.00	77.33	75.00	73.00
	(63.92)	(63.68)	(62.73)	(61.57)	(60.00)	(58.70)
T_4	84.00	83.67	82.33	80.67	78.33	75.00
	(66.43)	(66.16)	(65.15)	(63.92)	(62.26)	(60.00)
T_5	82.00	81.67	80.33	78.67	76.33	73.67
	(64.90)	(64.65)	(63.68)	(62.49)	(60.89)	(59.13)
T_6	84.33	84.00	82.67	81.00	78.67	75.33
	(66.69)	(66.43)	(65.40)	(64.16)	(62.49)	(60.22)
T_7	78.67	78.33	77.00	75.33	73.00	71.33
	(62.49)	(62.26)	(61.35)	(60.22)	(58.70)	(57.63)
T_8	79.33	79.00	77.67	76.00	73.67	72.00
	(62.96)	(62.73)	(61.80)	(60.67)	(59.13)	(58.05)
T_9	79.67	79.33	78.00	76.33	74.00	72.67
	(63.20)	(62.96)	(62.03)	(60.89)	(59.35)	(58.48)
T_{10}	81.33	81.00	79.67	78.00	76.00	73.33
	(64.40)	(64.16)	(63.20)	(62.03)	(60.67)	(58.91)
Mean	80.40	80.07	78.77	77.13	74.73	72.23
	(63.77)	(63.53)	(62.60)	(61.46)	(59.85)	(58.22)
SE(m±)	0.291	0.334	0.295	0.291	0.310	0.272
CD (5%)	0.86	0.98	0.86	0.86	0.92	0.80

Figures in parentheses indicate arc sine values

T_1 - control (untreated seeds)
T_2 - polymer coating (polykote @ 3 ml/kg of seed, diluted with 5 ml of water)
T_3 - flowable thiram (Royal flow 40 SC) @ 2.4 ml/kg seed
T_4 - polymer + flowable thiram (Royal flow 40 SC) @ 2.4 ml/kg seed
T_5 - vitavax 200 (containing thiram 37.5% and carboxil 37.5%) @ 2 g/kg seed
T_6 - polymer + vitavax 200 (containing thiram 37.5% and carboxil 37.5%) @ 2 g/kg of seed
T_7 - imidacloprid (gaucho) @ 4 ml/kg seed
T_8 - polymer + imidacloprid (Gaucho) @ 4 ml/kg seed
T_9 - polymer + flowable thiram (Royal flow 40 SC) @ 2.4 ml/kg seed + imidacloprid @ 4 ml/kg seed
T_{10} - polymer + vitavax 200 (containing thiram 37.5% and carboxil 37.5%) @ 2 g/kg of seed + imidacloprid (Gaucho) 4 ml/kg seed

T_1 - control

T_2 - polymer coating

T_3 - flowable thiram

T_4 - polymer + flowable

T_5 - vitavax 200

T_6 - polymer + vitavax 200

T_7 - imidacloprid

T_8 - polymer + imidacloprid

T_9 - polymer + flowable thiram +imidacloprid

T_{10} - polymer + vitavax 200 +imidacloprid

Plate 4.2 Germination (final count) at the end of 36 months

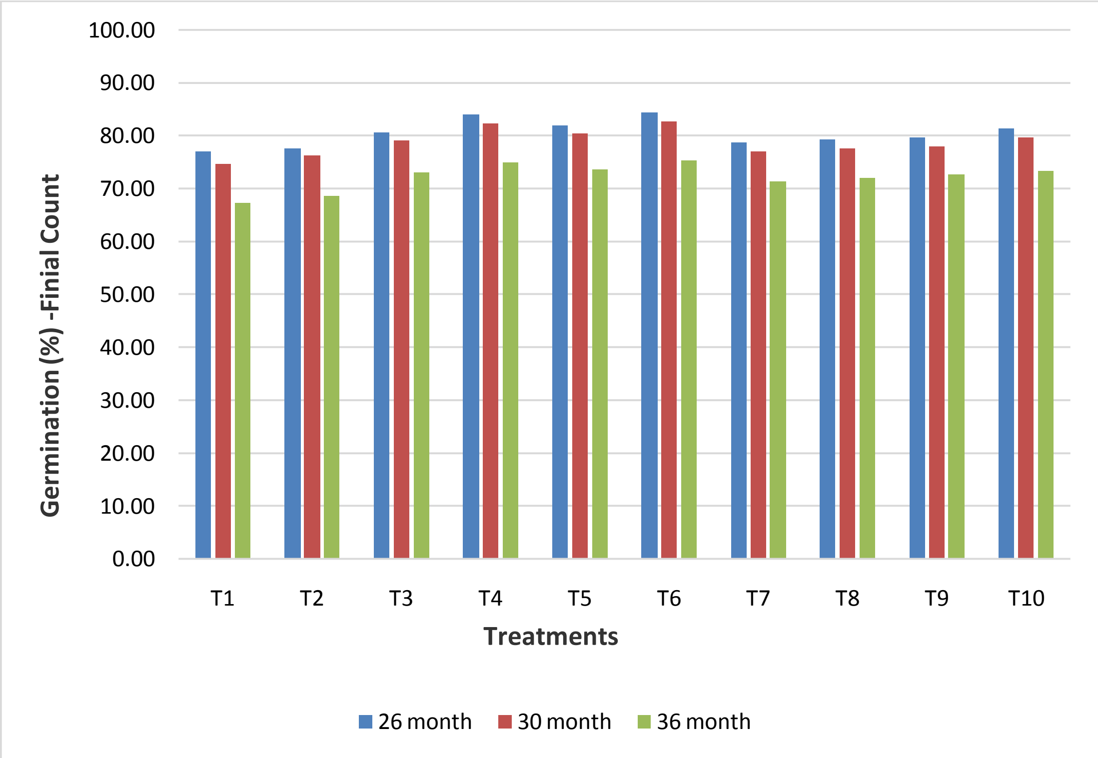

Fig.4.2 Effect of seed coating treatments on germination (%) - final count during storage in paddy

of seed (82.00%), T_{10} - polymer + vitavax 200 @ 2 g/kg of seed + imidacloprid (Gaucho) @ 4 ml/kg of seed (81.33%), T_3 - flowable thiram @ 2.4 ml/kg of seed (80.67%), T_9 - polymer + flowable Thiram @ 2.4 ml/kg of seed + imidacloprid (Gaucho) @ 4 ml/kg of seed (79.67%), T_8 - polymer + imidacloprid (Gaucho) @ 4 ml/kg of seed (79.33%), T_7 - imidacloprid (Gaucho)@ 4 ml/kg of seed (78.67%) and T_2 - polykote @ 3 ml/kg of seed (77.67%), while the lowest germination (%) was recorded in T_1 - untreated control (76.33%). The same pattern was recorded till the end of the storage period.

Significantly higher germination percentage (final count) over T_1 - untreated control (67.33%) at the end of storage (36 months) was recorded for treatment T_6 - polymer + vitavax 200 @ 2 g/kg of seed (75.33%) which was at par with T_4 - polymer + flowable Thiram @ 2.4 ml/kg of seed (75.00%), while the lowest germination was recorded for treatment T_1 - untreated control (67.33%).

The decline in germination percentage (final count) over the storage period may be attributed to ageing effect leading to depletion of food reserves, fungal invasion, fluctuating temperature, relative humidity and storage containers in which seeds were stored.

At the end storage period the germination percentage (final count) in treatment of polymer and vitavax 200 (T_6) was 8.00 per cent more than control (T_1), which was having maximum germination percentage (final count) till the end of storage period. The results are in accordance with the findings of Thakur and Dhiman (2016) in soybean seeds who observed that seeds treated with polymer @ 3.0 ml/kg of seed and flowable thiram @ 2.4 ml/kg of seed shows significantly higher germination percentage (final count) over untreated control at the end of one year of storage. Padhi et al. (2017) observed that paddy seeds treated with polymer @ 4ml + vitavax 200 @ 2g/kg of seed recorded significantly higher germination percentage over untreated control after 7 months of storage, Sharma et al. (2017) observed that maize seeds treated with polymer + vitavax 200 @ 2 g/kg of seed recorded significantly higher germination percentage (final count) over untreated control at the end of one year of storage, Rathinavel (2015) observed that cotton seeds coated with polymer @ 3 ml/kg + Thiram @ 2.5 g/kg + Super red @ 5 ml/kg + Cruiser @ 5 g/kg of seeds resulted in significantly higher germination percentage (final count) as compared to untreated control at the end of 26 months of storage period, Patel et al. (2017) recorded that soybean seeds treated with Mancozeb @ 2g/kg of seeds resulted in significantly higher germination as compared to control during 2 years of storage period, Dixit et al. (2018) observed that wheat seeds coated with Polymer @ 3g/kg + Thiram @ 2 g/kg + Quick root @ 2 g/kg of seed showed significantly highest values of germination at the end of 12 months of storage.

4.1.2 Speed of germination

The results recorded on speed of germination as influenced by seed coating treatments during twelve months (25^{th} to 36^{th} months) of storage period are presented in table 4.1.2.

Irrespective of the seed coating treatments, the speed of germination continued to decrease during storage period. On an average the speed of germination in the beginning and end of the storage period was 9.85 and 7.95, respectively.

Table 4.1.2 Effect of seed coating treatments on speed of germination during storage in paddy

Treatments	Months after storage					
	26	28	30	32	34	36
T_1	9.00	8.80	8.43	8.10	7.57	6.87
T_2	9.20	8.93	8.60	8.27	7.80	7.13
T_3	9.90	9.70	9.40	9.10	8.70	8.10
T_4	10.60	10.30	10.03	9.63	9.33	8.83
T_5	10.30	10.13	9.80	9.50	9.10	8.60
T_6	10.80	10.50	10.30	9.83	9.50	9.00
T_7	9.40	9.20	8.80	8.40	7.97	7.33
T_8	9.53	9.37	9.00	8.57	8.10	7.50
T_9	9.70	9.50	9.20	8.80	8.27	7.70
T_{10}	10.10	9.93	9.57	9.30	8.87	8.40
Mean	9.85	9.64	9.31	8.95	8.52	7.95
SE(m±)	0.056	0.049	0.058	0.049	0.047	0.049
CD (5%)	0.16	0.15	0.17	0.15	0.14	0.15

T_1 - control (untreated seeds)
T_2 - polymer coating (polykote @ 3 ml/kg of seed, diluted with 5 ml of water)
T_3 - flowable thiram (Royal flow 40 SC) @ 2.4 ml/kg seed
T_4 - polymer + flowable thiram (Royal flow 40 SC) @ 2.4 ml/kg seed
T_5 - vitavax 200 (containing thiram 37.5% and carboxil 37.5%) @ 2 g/kg seed
T_6 - polymer + vitavax 200 (containing thiram 37.5% and carboxil 37.5%) @ 2 g/kg of seed
T_7 - imidacloprid (Gaucho) @ 4 ml/kg seed
T_8 - polymer + imidacloprid (Gaucho) @ 4 ml/kg seed
T_9 - polymer + flowable thiram (Royal flow 40 SC) @ 2.4 ml/kg seed + imidacloprid @ 4 ml/kg seed
T_{10} - polymer + vitavax 200 (containing thiram 37.5% and carboxil 37.5%) @ 2 g/kg of seed + imidacloprid (Gaucho) 4 ml/kg seed

The speed of germination varied significantly throughout the storage period till the end. After 26 months of storage, significantly higher speed of germination was recorded in treatment T_6 - polymer + vitavax 200 @ 2 g/kg of seed (10.80), followed by T_4 - polymer + flowable thiram @ 2.4 ml/kg of seed (10.60), T_5 - vitavax 200 @ 2 g/kg of seed (10.30), T_{10} - polymer + vitavax 200 @ 2 g/kg of seed + imidacloprid (Gaucho) @ 4 ml/kg of seed (10.10), T_3 - flowable thiram @ 2.4 ml/kg of seed (9.90), T_9 - polymer + flowable thiram @ 2.4 ml/kg of seed + imidacloprid (Gaucho) @ 4 ml/kg of seed (9.70), T_8 - polymer + imidacloprid (Gaucho) @ 4 ml/kg of seed (9.53), T_7 - imidacloprid (Gaucho) @ 4 ml/kg of seed (9.40) and T_2 - polykote @ 3 ml/kg of seed (9.20) as compared to T_1 - untreated control (9.00).

The same pattern was recorded till the end of the storage period and significantly higher speed of germination was recorded in T_6 - polymer + vitavax 200 @ 2 g/kg of seed (9.00), followed by T_4 - polymer + flowable thiram @ 2.4 ml/kg of seed (8.83) over T_1 - untreated control (6.87).

Speed of germination decreased with the increasing storage period. Higher speed of germination was recorded for polymer and chemical treated seeds. This may be due to protection of seeds from fungal infection and insect attack. Similar findings were reported by Kunkur (2005) who observed that seed coated with thiram @ 1.5 g + polymer @ 5 g/kg of seeds recorded higher speed of germination in cotton seeds after seven months of storage period. Sharma et al. (2017) studied the effect of coating on seed quality in HQPM 1 hybrid maize during storage and observed that seeds treated with polymer + vitavax 200 @ 2 g/kg of seed recorded significantly higher speed of germination over untreated control at the end of one year of storage. Sharma and Dhiman (2017) in paddy observed that seeds treated with polymer + vitavax 200 @ 2 g/kg of seed recorded significantly higher speed of germination over untreated control at the end of one year of storage. Padhi et al. (2017) observed that paddy seeds treated with polymer @ 4 ml + vitavax 200 @ 2g/kg of seed recorded significantly higher speed of germination percentage over untreated control after 7 months of storage.

4.1.3 Seedling length (cm)

The results on seedling length (cm) as influenced by seed coating treatments during twelve months (25^{th} to 36^{th} months) of storage period are presented in Table 4.1.3.

Table 4.1.3 Effect of seed coating treatments on seedling length (cm) during storage in paddy

Treatment	Months after storage					
	26	28	30	32	34	36
T_1	9.03	8.83	8.53	7.83	7.23	6.50
T_2	9.17	9.00	8.67	8.10	7.50	6.77
T_3	9.60	9.47	9.20	8.70	8.27	7.47
T_4	9.77	9.67	9.50	9.13	8.63	7.83
T_5	9.73	9.63	9.40	8.97	8.50	7.77
T_6	9.90	9.83	9.67	9.30	8.80	8.07
T_7	9.23	9.07	8.80	8.37	7.63	6.90
T_8	9.40	9.17	8.93	8.50	7.90	7.07
T_9	9.47	9.30	9.03	8.60	8.10	7.30
T_{10}	9.67	9.50	9.37	8.80	8.43	7.60
Mean	9.50	9.35	9.11	8.63	8.10	7.33
SE(m±)	0.042	0.046	0.045	0.049	0.047	0.048
CD (5%)	0.12	0.14	0.13	0.15	0.14	0.14

T_1 - control (untreated seeds)
T_2 - polymer coating (polykote @ 3 ml/kg of seed, diluted with 5 ml of water)
T_3 - flowable thiram (Royal flow 40 SC) @ 2.4 ml/kg seed
T_4 - polymer + flowable thiram (Royal flow 40 SC) @ 2.4 ml/kg seed
T_5 - vitavax 200 (containing thiram 37.5% and carboxil 37.5%) @ 2 g/kg seed
T_6 - polymer + vitavax 200 (containing thiram 37.5% and carboxil 37.5%) @ 2 g/kg of seed
T_7 - imidacloprid (Gaucho) @ 4 ml/kg seed
T_8 - polymer + imidacloprid (Gaucho) @ 4 ml/kg seed
T_9 - polymer + flowable thiram (Royal flow 40 SC) @ 2.4 ml/kg seed + imidacloprid @ 4 ml/kg seed
T_{10} - polymer + vitavax 200 (containing thiram 37.5% and carboxil 37.5%) @ 2 g/kg of seed + imidacloprid (Gaucho) 4 ml/kg seed

Irrespective of seed coating treatments, the seedling length (cm) decreased progressively with advancement in the storage period. Average seedling length recorded at the beginning and the end of storage was 9.50 cm and 7.33 cm, respectively.

The seedling length due to seed coating treatments varied significantly for all the months of storage period. After 26 months of storage, significantly maximum seedling length (cm) was recorded in treatment T_6 - polymer + vitavax 200 @ 2 g/kg of seed (9.90 cm), followed by T_4 - polymer + flowable Thiram @ 2.4 ml/kg of seed (9.77 cm), T_5 - vitavax 200 @ 2 g/kg of seed (9.73 cm), T_{10} - polymer + vitavax 200 @ 2 g/kg of seed + imidacloprid (Gaucho) @ 4 ml/kg of seed (9.67 cm), T_3 - flowable thiram @ 2.4 ml/kg of seed (9.60 cm), T_9 - polymer + flowable thiram @ 2.4 ml/kg of seed + imidacloprid (Gaucho) @ 4 ml/kg of seed (9.47 cm), T_8 - polymer + imidacloprid (Gaucho) @ 4 ml/kg of seed (9.40 cm), T_7 - imidacloprid (Gaucho) @ 4 ml/kg of seed (9.23 cm) and T_2 - polykote @ 3 ml/kg of seed (9.17 cm) as compared to T_1 - untreated control (9.03 cm).

The same pattern was recorded till the end of the storage period and significantly higher seedling length (cm) as compared to T_1 - untreated control (6.50 cm) at the end of storage (36 months) was recorded in treatment T_6 - polymer + vitavax 200 @ 2 g/kg of seed (8.07 cm), followed by T_4 -polymer + flowable thiram @ 2.4 ml/kg of seed (7.83 cm).

At end of storage period seedling length (cm) of polymer and vitavax (T_6) coated seeds were 1.57 cm more as compared to uncoated seeds (T_1). It can be due to better initial growth of seedlings in seed coated with polymer and fungicide, as it prevents fungal invasion leading to better germination and subsequent higher seedling length. The decline in seedling length irrespective of coating treatments may be attributed to age induced decline in germination and toxic metabolites which may have hindered the seedling growth. Similar results were reported by Kaushik et al. (2014) who studied the effect of polymer film coating on seed quality of maize and revealed that the seed treatment with polymer @ 9 ml + thiram @ 2 g/kg of seed exhibited significantly higher seedling length over untreated seeds at the end of six months of storage. Thakur and Dhiman (2016) reported significantly higher seedling length in soybean seeds treated with polymer @ 3ml /kg and flowable thiram @

2.4 ml/kg of over untreated seeds at the end of one year of storage period, Sharma et al. (2017) recorded significantly higher seedling length in maize seeds treated with polymer @ 3ml /kg + vitavax 200 @ 2 g/kg of seed over untreated seeds at the end of one year of storage. Sharma and Dhiman (2017) in paddy observed that seeds treated with polymer + vitavax 200 @ 2 g/kg of seed recorded significantly higher seedling length over untreated control at the end of one year of storage. Patel et al. (2017) recorded that soybean seeds treated with Mancozeb @ 2 g/kg of seeds resulted in significantly higher seedling length as compared to control during 2 years storage period and Padhi et al. (2017) observed that paddy seeds treated with polymer @ 4 ml + vitavax 200 2 g/kg of seed recorded significantly higher seedling length over untreated control after 7 months of storage.

4.1.4 Seedling dry weight (g/10 seedlings)

The results recorded on seedling dry weight (g/10 seedlings) as influenced by seed coating treatments during twelve months (25^{th} to 36^{th} months) of storage period are presented in Table 4.1.4.

Irrespective of seed coating treatments, the seedling dry weight continued to decrease from initial to last month of the storage period. On an average the dry weight of ten seedlings in the beginning and end of the month of the storage period was 0.053 g and 0.042 g, respectively. The seedling dry weight varied significantly throughout the storage period till the end. After 26 month of storage, significantly more seedling dry weight (g) was recorded in treatment T_6 - polymer + vitavax 200 @ 2 g/kg of seed (0.059 g), which was at par with T_4 - polymer + flowable thiram @ 2.4 ml/kg of seed (0.058 g), followed by T_5 - vitavax 200 @ 2 g/kg of seed (0.057 g), T_{10} - polymer + vitavax 200 @ 2 g/kg of seed + imidacloprid (Gaucho) @ 4 ml/kg of seed (0.055 g), T_3 - flowable thiram @ 2.4 ml/kg of seed (0.053 g), T_9 - polymer + flowable thiram @ 2.4 ml/kg of seed + imidacloprid (Gaucho) @ 4 ml/kg of seed (0.052 g), T_8 - polymer + imidacloprid (Gaucho) @ 4 ml/kg of seed (0.051 g) and T_7 - imidacloprid (Gaucho) @ 4 ml/kg of seed (0.050 g), as compared to T_1 - untreated control (0.048 g). The same pattern was recorded till the end of the storage period and significantly higher seedling dry weight (g) was recorded in T_6 - polymer + vitavax 200 @ 2 g/kg of seed (0.048 g), which was at par with T_4 - polymer + flowable thiram @ 2.4 ml/kg of seed (0.046 g) over T_1 - untreated control (0.035 g).

Table 4.1.4 Effect of seed coating treatments on seedling dry weight (g/10 seedlings) during storage in paddy

Treatment	Months after storage					
	26	28	30	32	34	36
T_1	0.048	0.047	0.045	0.043	0.040	0.035
T_2	0.049	0.048	0.046	0.044	0.042	0.037
T_3	0.053	0.052	0.050	0.048	0.046	0.042
T_4	0.058	0.057	0.055	0.054	0.051	0.046
T_5	0.057	0.055	0.053	0.052	0.050	0.045
T_6	0.059	0.058	0.056	0.055	0.052	0.048
T_7	0.050	0.049	0.047	0.045	0.043	0.039
T_8	0.051	0.050	0.048	0.046	0.044	0.040
T_9	0.052	0.051	0.049	0.047	0.045	0.041
T_{10}	0.055	0.053	0.052	0.050	0.048	0.044
Mean	0.053	0.052	0.050	0.048	0.046	0.042
SE(m±)	0.0004	0.0005	0.0004	0.0005	0.0005	0.0005
CD (5%)	0.0013	0.0014	0.0012	0.0015	0.0014	0.0015

T_1 - control (untreated seeds)
T_2 - polymer coating (polykote @ 3 ml/kg of seed, diluted with 5 ml of water)
T_3 - flowable thiram (Royal flow 40 SC) @ 2.4 ml/kg seed
T_4 - polymer + flowable thiram (Royal flow 40 SC) @ 2.4 ml/kg seed
T_5 - vitavax 200 (containing thiram 37.5% and carboxil 37.5%) @ 2 g/kg seed
T_6 - polymer + vitavax 200 (containing thiram 37.5% and carboxil 37.5%) @ 2 g/kg of seed
T_7 - imidacloprid (Gaucho) @ 4 ml/kg seed
T_8 - polymer + imidacloprid (Gaucho) @ 4 ml/kg seed
T_9 - polymer + flowable thiram (Royal flow 40 SC) @ 2.4 ml/kg seed + imidacloprid @ 4 ml/kg seed
T_{10} - polymer + vitavax 200 (containing thiram 37.5% and carboxil 37.5%) @ 2 g/kg of seed + imida ml/kg seed

It indicates that there is positive effect of seed coating polymer which could be effective for better storage of seeds. The dry matter production of seedling is the ultimate manifestation of physiological vigour. This is a physiological phenomenon influenced by reserve metabolites, enzyme activities and growth regulators. These results are in conformity with findings of Thakur and Dhiman (2016) who observed significantly higher seedling dry weight in soybean seeds treated with polymer and flowable thiram @ 2.4 ml/kg of over untreated seeds at the end of one year of storage period, Sharma et al. (2017) in maize observed significantly higher seedling dry weight in seeds treated with polymer + vitavax 200 @ 2 g/kg of seed over untreated seeds at the end of one year of storage, Sharma and Dhiman (2017) in paddy observed significantly higher seedling dry weight in seeds treated with polymer + vitavax 200 @ 2 g/kg of seed over untreated seeds at the end of one year of storage. Padhi et al. (2017) observed that rice seeds treated with polymer @ 4 ml + vitavax 200 2g/kg of seed recorded significantly higher root dry weight over untreated control after 7 months of storage and Patel et al. (2017) recorded that soybean seeds treated with Mancozeb @ 2 g/kg of seeds resulted in significantly higher seedling dry weight as compared to control during 2 years storage period.

4.1.5 Seedling vigour index - I

The results recorded on vigour index - I as influenced by seed coating during twelve months (25^{th} to 36^{th} months) of storage period are presented in Table 4.1.5 and depicted in Fig. 4.3.

Irrespective of seed coating treatments, the vigour of stored seed decreased gradually with advancement in the storage period. Mean vigour index recorded at the beginning and the end of storage was 767 and 530, respectively.

The seedling vigour index varied significantly throughout the storage period. After 26 months of storage, significantly higher seedling vigour index - I was recorded in treatment T_6 - polymer + vitavax 200 @ 2 g/kg of seed (836), followed by T_4 - polymer + flowable thiram @ 2.4 ml/kg of seed (819), T_5 - vitavax 200 @ 2 g/kg of seed (802), T_{10} - polymer + vitavax 200 @ 2 g/kg of seed + imidacloprid (Gaucho) @ 4 ml/kg of seed (789), T_3 - flowable thiram @ 2.4 ml/kg of seed (774), T_9 - polymer + flowable thiram @ 2.4 ml/kg of seed + imidachloprid (Gaucho) @ 4 ml/kg

Table 4.1.5 Effect of seed coating treatments on Seedling vigour index - I during storage in paddy

Treatment	Months after storage					
	26	28	30	32	34	36
T_1	691	676	643	574	509	438
T_2	716	696	656	605	540	465
T_3	774	760	727	673	620	545
T_4	819	809	782	736	672	588
T_5	802	787	755	705	649	572
T_6	836	826	799	753	692	608
T_7	729	710	678	630	557	492
T_8	749	724	694	646	582	509
T_9	758	738	705	656	599	530
T_{10}	789	769	746	686	641	557
Mean	767	750	718	667	607	530
SE(m±)	3.97	5.67	4.69	5.35	6.17	4.51
CD (5%)	11.71	16.74	13.86	15.80	18.21	13.13

T_1 - control (untreated seeds)
T_2 - polymer coating (polykote @ 3 ml/kg of seed, diluted with 5 ml of water)
T_3 - flowable thiram (Royal flow 40 SC) @ 2.4 ml/kg seed
T_4 - polymer + flowable thiram (Royal flow 40 SC) @ 2.4 ml/kg seed
T_5 - vitavax 200 (containing thiram 37.5% and carboxil 37.5%) @ 2 g/kg seed
T_6 - polymer + vitavax 200 (containing thiram 37.5% and carboxil 37.5%) @ 2 g/kg of seed
T_7 - imidacloprid (gaucho) @ 4 ml/kg seed
T_8 - polymer + imidacloprid (Gaucho) @ 4 ml/kg seed
T_9 - polymer + flowable thiram (Royal flow 40 SC) @ 2.4 ml/kg seed + imidacloprid @ 4 ml/kg seed
T_{10} - polymer + vitavax 200 (containing thiram 37.5% and carboxil 37.5%) @ 2 g/kg of seed + imidacloprid (Gaucho) 4 ml/kg seed

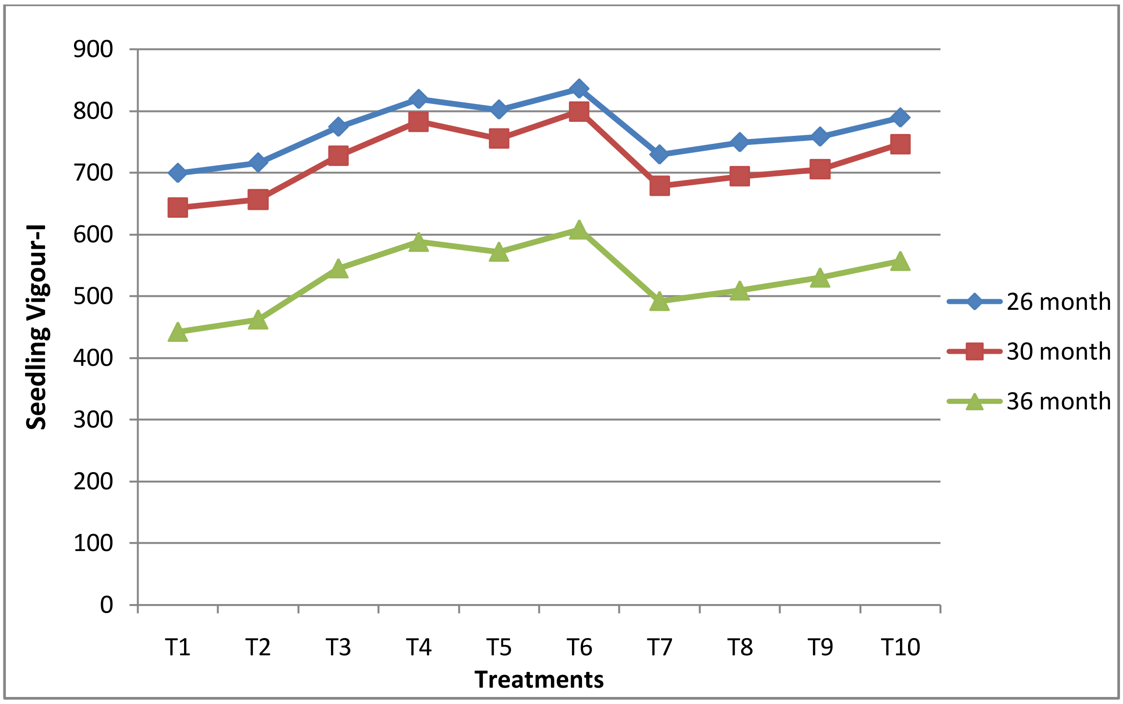

Fig. 4.3 Effect of seed coating treatments on vigour index - I during storage in paddy

of seed (758), T_8 - polymer + imidacloprid (Gaucho) @ 4 ml/kg of seed (749), T_7 - imidacloprid (Gaucho) @ 4 ml/kg of seed (729) and T_2 - polykote @ 3 ml/kg of seed (716) as compared to T_1 - untreated control (691). The same pattern was recorded till the end of the storage period. Highest seedling vigour index - I was recorded in T_6 - polymer + vitavax 200 @ 2 g/kg of seed (608), followed by T_4 - polymer + flowable thiram @ 2.4 ml/kg of seed (588) over T_1 - untreated control (438) at the end of storage period of 36 months.

The dry matter production of seedling is the ultimate manifestation of physiological vigour. The decrease in the vigour index may be due to decline in germination, decrease in seedling length and seedling dry weight. Higher vigour index in polymer and vitavax 200 (T_6) is due to more germination, seedling length, lower infection by storage fungi and no infestation by insects. The polymer coating provides protection from the biological stress, which includes fungal invasion.

These results are in conformity with the findings of Kunkur (2005) who observed that seed coating with Thiram @ 1.5 g + polymer @ 5 g/kg of seeds recorded higher vigour index in cotton seeds after seven months of storage period, Rathinavel (2015) observed that cotton seeds coated with polymer @ 3 ml/kg + Thiram @ 2.5 g/kg + Super red @ 5 ml/kg + Cruiser @ 5 g/kg of seeds resulted in significantly higher vigour as compared to untreated control at the end of 26 months of storage period, Thakur and Dhiman (2016) observed significantly higher seedling vigour index in soybean seeds treated with polymer @ 3 ml/kg and flowable thiram @ 2.4 ml/kg of over untreated seeds at the end of one year of storage period, Padhi et al. (2017) reported that rice seeds treated with polymer @ 4 ml + vitavax 200 @ 2 g/kg of seed recorded significantly higher vigour index over untreated control after 7 months of storage. Patel et al. (2017) recorded that soybean seeds treated with Mancozeb @ 2g/kg of seeds resulted in significantly higher seedling vigour index - I as compared to control during 2 years storage period. Sharma et al. (2017) observed that maize seeds treated with polymer + vitavax 200 @ 2 g/kg of seed recorded significant higher vigour index - I over untreated control at the end of one year of storage and Sharma and Dhiman (2017) in paddy observed that seeds treated with polymer + vitavax 200 @ 2 g/kg of seed recorded significantly higher vigour index - I over untreated control at the end of one year of storage.

4.1.6 Seedling vigour index - II

The computed vigour index, which is the totality of seed performance, has been regarded as a good index to measure the quality of seed lots. With increase in storage period, there was decrease in vigour index, irrespective of seed coating treatment.

The results recorded on seedling vigour index - II as influenced by seed coating treatments during twelve months (25^{th} to 36^{th} months) of storage period are presented in Table 4.1.6 and depicted in Fig. 4.4.

Seedling vigour index - II declined gradually with the advancing storage period. Average vigour index - II recorded at the beginning and the end of the storage was 4.29 and 3.01, respectively.

Table 4.1.6 Effect of seed coating treatments on Seedling vigour index - II during storage in paddy

Treatment	Months after storage					
	26	28	30	32	34	36
T_1	3.69	3.57	3.39	3.18	2.84	2.36
T_2	3.83	3.54	3.54	3.29	3.02	2.52
T_3	4.28	4.10	3.95	3.71	3.43	3.04
T_4	4.86	4.77	4.53	4.36	3.97	3.49
T_5	4.67	4.46	4.34	4.06	3.82	3.29
T_6	4.98	4.90	4.60	4.46	4.09	3.59
T_7	3.91	3.81	3.62	3.37	3.16	2.78
T_8	4.05	3.92	3.75	3.50	3.24	2.86
T_9	4.12	4.02	3.85	3.59	3.33	2.98
T_{10}	4.50	4.29	4.12	3.90	3.67	3.23
Mean	4.29	4.15	3.97	3.74	3.46	3.01
SE(m±)	0.044	0.045	0.037	0.045	0.048	0.035
CD (5%)	0.13	0.13	0.11	0.13	0.14	0.10

T_1 - control (untreated seeds)
T_2 - polymer coating (polykote @ 3 ml/kg of seed, diluted with 5 ml of water)
T_3 - flowable thiram (Royal flow 40 SC) @ 2.4 ml/kg seed
T_4 - polymer + flowable thiram (Royal flow 40 SC) @ 2.4 ml/kg seed
T_5 - vitavax 200 (containing thiram 37.5% and carboxil 37.5%) @ 2 g/kg seed
T_6 - polymer + vitavax 200 (containing thiram 37.5% and carboxil 37.5%) @ 2 g/kg of seed
T_7 - imidacloprid (Gaucho) @ 4 ml/kg seed
T_8 - polymer + imidacloprid (Gaucho) @ 4 ml/kg seed
T_9 - polymer + flowable thiram (Royal flow 40 SC) @ 2.4 ml/kg seed + imidacloprid @ 4 ml/kg seed
T_{10} - polymer + vitavax 200 (containing thiram 37.5% and carboxil 37.5%) @ 2 g/kg of seed + imidacloprid (Gaucho) 4 ml/kg seed

The seedling vigour index - II due to seed coating treatments differed significantly throughout the storage period. After 26 months of storage, significantly higher seedling vigour index - II over T_1 - untreated control (3.69) was recorded in treatment T_6 - polymer + vitavax 200 @ 2 g/kg of seed (4.98), which was at par with T_4 - polymer + flowable thiram @ 2.4 ml/kg of seed (4.86), followed by T_5 - vitavax 200 @ 2 g/kg of seed (4.67), T_{10} - polymer + vitavax 200 @ 2 g/kg of seed + imidacloprid (Gaucho) @ 4 ml/kg of seed (4.50), T_3 - flowable thiram @ 2.4 ml/kg of seed (4.28), T_9 - polymer + flowable thiram @ 2.4 ml/kg of seed + imidacloprid (Gaucho) @ 4 ml/kg of seed (4.12), T_8 - polymer + imidacloprid (Gaucho) @ 4 ml/kg of seed (4.05), T_7 - imidacloprid (Gaucho) @ 4 ml/kg of seed (3.91) and T_2 - polykote @ 3 ml/kg of seed (3.83), while the lowest seedling vigour index - II was recorded in T_1 - untreated control (3.69). At the end of the storage period, significantly higher vigour index - II was recorded in T_6 - polymer + vitavax 200 @ 2 g/kg of seed (3.59) which was at par with T_4 - polymer + flowable thiram @ 2.4 ml/kg of seed (3.49) as compared to T_1 - untreated control (2.36).

The seedling vigour index due to seed coating treatments varied significantly at all the months of storage period. Higher vigour index recorded in polymer and vitavax (T_6) was due to more germination, seedling dry weight, lower infection by storage fungi and no infestation by insects. Similar results were reported by Patel et al. (2017) who recorded that soybean seeds treated with Mancozeb @ 2g/kg of seeds resulted in significantly higher seedling vigour index - II as compared to control during 2 years storage period. Padhi et al. (2017) reported that rice seeds treated with polymer @ 4ml + vitavax 200 @ 2g/kg of seed recorded significantly higher vigour index - II over untreated control after 7 months of storage. Sharma et al. (2017) observed that seeds treated with polymer + vitavax 200 @ 2 g/kg of seed recorded significantly higher vigour index over untreated control after 12 months of storage. Rathinavel (2015) observed that cotton seeds coated with polymer @ 3 ml/kg + Thiram @ 2.5 g/kg + Super red @ 5 ml/kg + Cruiser @ 5 g/kg of seeds resulted in significantly higher vigour index - II as compared to untreated control at the end of 26 months of storage period.

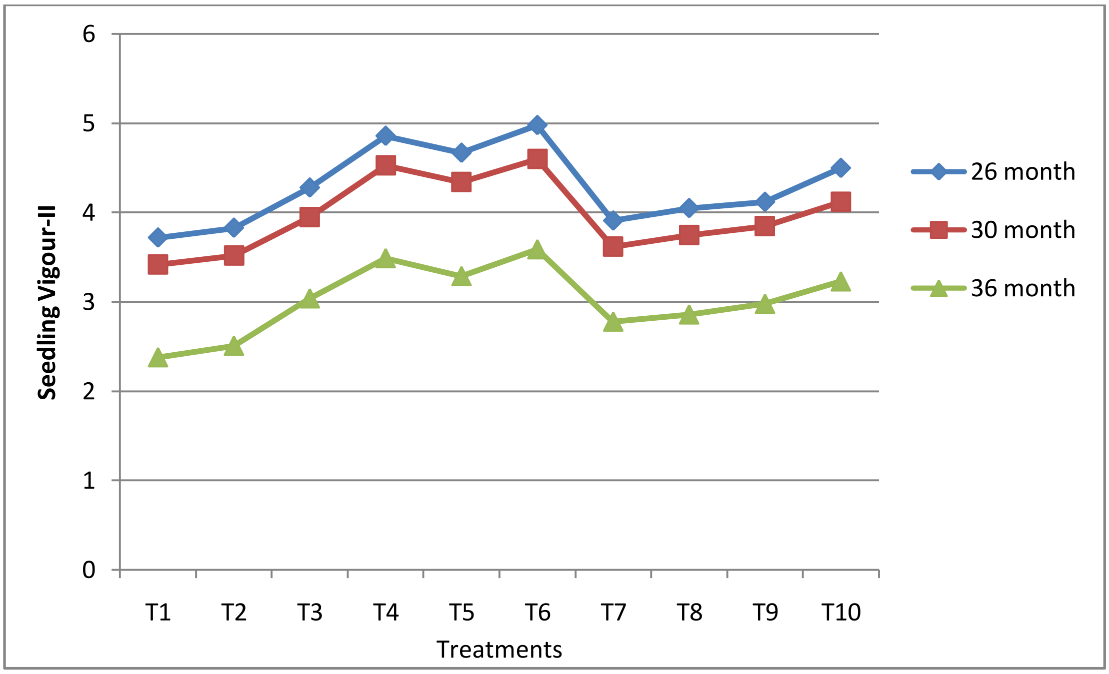

Fig. 4.4 Effect of seed coating treatments on vigour index - II during storage in paddy

4.1.7 Field emergence (%)

The results recorded on field emergence (%) as influenced by seed coating treatments during twelve month (25^{th} to 36^{th} months) of storage period are presented in Table 4.1.7.

The field emergence declined gradually with advancing storage period due to different seed coating treatments. On an average, the field emergence recorded at the beginning and end of the storage period was 67.97 per cent and 61.43 per cent, respectively.

Field emergence due to seed coating treatments varied throughout the storage period. After 26 months of storage, significantly higher field emergence (%) over T_1 - untreated control (62.00%) was recorded in treatment T_6 - polymer + vitavax 200 @ 2 g/kg of seed (71.67%), which was at par with T_4 - polymer + flowable thiram @ 2.4 ml/kg of seed (71.00%) followed by T_5 - vitavax 200 @ 2 g/kg of seed (69.00%), T_{10} - polymer + vitavax 200 @ 2 g/kg of seed + imidacloprid (Gaucho) @ 4 ml/kg of seed (68.33%), T_3 - flowable thiram @ 2.4 ml/kg of seed (67.00%), T_9 - polymer + flowable thiram @ 2.4 ml/kg of seed + imidacloprid (Gaucho) @ 4 ml/kg of seed (66.33%), T_8 - polymer + imidacloprid (Gaucho) @ 4 ml/kg of seed (65.67%) and T_7 - imidacloprid (Gaucho) @ 4 ml/kg of seed (65.00%) and T_2 - polykote @ 3 ml/kg of seed (63.67%), while the lowest field emergence (%) was recorded in T_1 - untreated control (62.00%). The same pattern was recorded till the end of the storage period and significantly higher field emergence (%) was recorded in T_6 - polymer + vitavax 200 @ 2.4 ml/kg of seed (66.00%) which was at par with T_4 - polymer + flowable thiram @ 2.4 ml/kg of seed (65.33%) as compared to T_1 - untreated control (56.67%).

Field emergence (%) also declined with the advancing storage period through all the months, irrespective of seed coating treatments. This could be due to decrease in germination, seedling vigour, seed ageing, seed deterioration and loss of seed viability over a period of storage. Treatments T_6 - polymer + vitavax 200 @ 2 g/kg of seed (71.67%) and T_4 - polymer + flowable thiram @ 2.4 ml/kg of seed (71.00%) showed significantly higher field emergence over control after 26 months of storage. Higher field emergence was recorded in chemical treated seeds which may be due to protection of seeds from microorganisms and in turn help in establishment of seedling in the field condition. The results recorded for field emergence are similar to the findings of Rathinavel (2015) who observed that cotton seeds coated with polymer @ 3 ml/kg + Thiram @ 2.5 g/kg+ Super red @ 5 ml/kg + Cruiser @ 5 g/kg of seeds resulted in significantly higher field emergence as compared to untreated control at the end of 26 months of storage period. Thakur and Dhiman (2016) in soybean seeds observed that seeds treated with polymer @ 3.0 ml/kg of seed and flowable thiram @ 2.4 ml/kg of seed shows significantly higher field emergence over untreated control at the end of one year of storage. Sharma et al. (2017) in maize observed that seeds treated with polymer + vitavax 200 @ 2 g/kg of seed resulted in significantly higher field emergence over untreated control at the end of one year of storage. Sharma and Dhiman (2017) in paddy observed that seeds treated with polymer + vitavax 200 @ 2 g/kg of seed resulted in significantly higher field emergence over untreated control at the end of one year of storage.

Table 4.1.7 Effect of seed coating treatments on field emergence (%) during storage in paddy

Treatment	Months after storage					
	26	28	30	32	34	36
T_1	62.00	60.67	60.00	58.67	57.33	56.67
	(51.94)	(51.16)	(50.71)	(49.99)	(49.22)	(48.83)
T_2	63.67	62.33	61.33	60.33	58.67	58.33
	(52.93)	(52.14)	(51.75)	(50.96)	(49.99)	(49.80)
T_3	67.00	65.00	64.00	63.00	62.33	61.33
	(54.94)	(53.73)	(53.13)	(52.54)	(52.14)	(51.55)
T_4	71.00	69.00	68.33	67.00	66.33	65.33
	(57.42)	(56.17)	(55.76)	(54.94)	(54.53)	(53.93)
T_5	69.00	67.00	66.33	65.00	64.33	64.00
	(56.17)	(54.94)	(54.53)	(53.73)	(53.33)	(53.13)
T_6	71.67	69.67	69.00	67.67	67.00	66.00
	(57.84)	(56.58)	(56.17)	(55.35)	(54.94)	(54.33)
T_7	65.00	63.00	62.33	61.00	60.33	59.33
	(53.73)	(52.54)	(52.14)	(51.36)	(50.96)	(50.38)
T_8	65.67	63.67	63.00	61.67	61.00	60.00
	(54.13)	(52.93)	(52.54)	(51.75)	(51.36)	(50.77)
T_9	66.33	64.33	63.67	62.33	61.67	60.67
	(54.53)	(53.33)	(52.93)	(52.14)	(51.75)	(51.16)
T_{10}	68.33	66.33	65.00	64.33	63.67	62.67
	(55.76)	(54.53)	(53.73)	(53.33)	(52.93)	(52.34)
Mean	67.97	65.10	64.33	63.10	62.27	61.43
	(54.94)	(53.81)	(53.34)	(52.61)	(52.12)	(51.62)
SE(m±)	0.309	0.306	0.283	0.301	0.234	0.292
CD (5%)	0.91	0.87	0.83	0.89	0.69	0.86

Figures in parentheses indicate arc sine values

T_1 - control (untreated seeds)

T_2 - polymer coating (polykote @ 3 ml/kg of seed, diluted with 5 ml of water)

T_3 - flowable thiram (Royal flow 40 SC) @ 2.4 ml/kg seed

T_4 - polymer + flowable thiram (Royal flow 40 SC) @ 2.4 ml/kg seed

T_5 - vitavax 200 (containing thiram 37.5% and carboxil 37.5%) @ 2 g/kg seed

T_6 - polymer + vitavax 200 (containing thiram 37.5% and carboxil 37.5%) @ 2 g/kg of seed

T_7 – imidacloprid (Gaucho) @ 4 ml/kg seed

T_8 - polymer + imidacloprid (Gaucho) @ 4 ml/kg seed

T_9 - polymer + flowable thiram (Royal flow 40 SC) @ 2.4 ml/kg seed + imidacloprid @ 4 ml/kg seed

T_{10} - polymer + vitavax 200 (containing thiram 37.5% and carboxil 37.5%) @ 2 g/kg of seed + imidacloprid (Gaucho) 4 ml/kg seed

4.1.8 Test weight (g)

The recorded test weight as influenced by seed coating treatments during twelve months (25th to 36th months) of storage period is presented in Table 4.1.8.

Test weight (g) increased and decreased gradually during the storage period as per fluctuations in the prevalent temperature and humidity. On an average test weight recorded at the beginning and end of the storage period was 27.40 g and 27.60 g.

After 26 months, significantly highest test weight was recorded for treatment T_{10} - polymer + vitavax 200 @ 2 g/kg of seed + imidacloprid @ 6 ml/kg of seed (27.80 g), which was at par with T_9 - polymer + flowable Thiram @ 2.4 ml/kg of seed + imidacloprid (Gaucho) @ 4 ml/kg of seed (27.70 g), followed by T_6 - polymer + vitavax 200 @ 2 g/kg of seed (27.57 g), T_5 - vitavax 200 @ 2 g/kg of seed (27.50g), T_8 - polymer + imidacloprid (Gaucho) @ 4 ml/kg of seed (27.40 g), T_7 - imidacloprid (Gaucho) @ 4 ml/kg of seed (27.33 g), T_4 - polymer + flowable Thiram @ 2.4 ml/kg of seed (27.27 g), T_3 - flowable thiram @ 2.4 ml/kg of seed (27.23 g) and T_2 - polykote @ 3 ml/kg of seed (27.20g) over T_1 - untreated control (27.03g). The same pattern was recorded till the end of the storage period and significantly higher test weight was recorded for T_{10} - polymer + vitavax 200 @ 2 g/kg of seed + imidacloprid @ 6 ml/kg of seed (28.07 g), which was at par with T_9 - polymer + flowable thiram @ 2.4 ml/kg of seed + imidacloprid (Gaucho) @ 4 ml/kg of seed (27.97 g), followed by T_6 - polymer + vitavax 200 @ 2 g/kg of seed (27.83 g) and T_5 - vitavax 200 @ 2 g/kg of seed (27.73 g).

The test weight of the seed varied gradually with the advancement of storage period. In storage conditions especially at night, relative humidity fluctuates and as a result there is deviation in seed moisture content equilibrium with the surrounding atmosphere. The seed weight tends to alter itself with this fluctuation in equilibrium. Similar findings were reported by Sushma (2013) who reported that chickpea seeds treated with polymer @ 10 ml/kg along with Deltamethrin 2.8 EC @ 0.4 ml/kg of seed + Vitavax @ 2 g/kg of seeds recorded significantly higher 100 seed weight as compared to untreated seeds after 4 months storage period, Udabal et al. (2014) reported that sunflower seeds treated with vitavax 3 g/kg of seeds resulted in significantly higher 100 seed weight over untreated seeds after 11 months of

Table 4.1.8 Effect of seed coating treatments on test weight (g) during storage in paddy

Treatment	Months after storage					
	26	28	30	32	34	36
T_1	27.03	26.93	27.13	27.43	27.23	27.13
T_2	27.20	27.10	27.30	27.60	27.37	27.27
T_3	27.23	27.13	27.40	27.70	27.47	27.30
T_4	27.27	27.20	27.50	27.77	27.53	27.47
T_5	27.50	27.33	27.80	28.10	27.90	27.73
T_6	27.57	27.43	27.90	28.23	27.97	27.83
T_7	27.33	27.27	27.60	27.90	27.70	27.60
T_8	27.40	27.30	27.70	28.10	27.83	27.67
T_9	27.70	27.57	28.07	28.40	28.17	27.97
T_{10}	27.80	27.60	28.20	28.53	28.23	28.07
Mean	27.40	27.29	27.66	27.98	27.74	27.60
SE(m±)	0.047	0.045	0.054	0.049	0.039	0.039
CD (5%)	0.14	0.13	0.16	0.15	0.12	0.12

T_1 - control (untreated seeds)
T_2 - polymer coating (polykote @ 3 ml/kg of seed, diluted with 5 ml of water)
T_3 - flowable thiram (Royal flow 40 SC) @ 2.4 ml/kg seed
T_4 - polymer + flowable thiram (Royal flow 40 SC) @ 2.4 ml/kg seed
T_5 - vitavax 200 (containing thiram 37.5% and carboxil 37.5%) @ 2 g/kg seed
T_6 - polymer + vitavax 200 (containing thiram 37.5% and carboxil 37.5%) @ 2 g/kg of seed
T_7 - imidacloprid (Gaucho) @ 4 ml/kg seed
T_8 - polymer + imidacloprid (Gaucho) @ 4 ml/kg seed
T_9 - polymer + flowable thiram (Royal flow 40 SC) @ 2.4 ml/kg seed + imidacloprid @ 4 ml/kg seed
T_{10} - polymer + vitavax 200 (containing thiram 37.5% and carboxil 37.5%) @ 2 g/kg of seed + imidacloprid (Gaucho) 4 ml/kg seed

storage period and Sharma (2017) reported that paddy seeds treated with polymer + vitavax 200 @ 2 g/kg of seed + imidachloprid @ 6 ml/kg of seed, resulted in significantly higher test weight over untreated seeds at the end of one year of storage period.

4.1.9 Moisture content (%)

The results on moisture content (%) as influenced by coating treatments during twelve months (25^{th} to 36^{th} months) of storage period are presented in Table 4.1.9.

The moisture content (%) increased and decreased gradually during storage period as per fluctuations in the prevalent temperature and relative humidity. On an average, the moisture content recorded at the beginning (February 2018) and at the end of storage period (December 2018) was 11.25 and 11.22 per cent, respectively.

After 26 months of storage, significantly lowest moisture content (%) was recorded in T_{10} - polymer + flowable thiram @ 2.4 ml/kg of seed + imidacloprid @ 4 ml/kg of seed (11.03%), which was at par with T_9 - polymer + vitavax 200 @ 2 g/kg of seed + imidacloprid @ 4 ml/kg of seed (11.07%), T_6 - polymer + vitavax 200 @ 2 g/kg of seed (11.10%), T_5 - vitavax 200 @ 2 g/kg of seed (11.13%), followed by T_4 - polymer + flowable thiram @ 2.4 ml/kg of seed (11.17%), T_3 - flowable thiram @ 2.4 ml/kg of seed (11.20%), T_7 - imidacloprid @ 4 ml/kg of seed (11.30%), T_8 - polymer + imidacloprid @ 4 ml/kg of seed (11.40%), and T_2 - polykote @ 3 ml/kg of seed (11.47%), while the highest moisture content (%) was recorded in T_1- untreated control (11.63%). At the end of storage period, the lowest moisture content (%) was recorded in T_{10} - polymer + vitavax 200 @ 2 g/kg of seed + imidacloprid @ 4 ml/kg of seed (11.10%), which was at par with T_9 - polymer + flowable thiram @ 2.4 ml/kg of seed + imidacloprid @ 4 ml/kg of seed (11.13%), T_6 - polymer + vitavax 200 @ 2 g/kg of seed (11.17%), while the highest moisture content was recorded in T_1 - untreated control (11.70%).

With the advancement of storage period, moisture content (%) of the seed fluctuated. Under storage conditions especially at night, relative humidity fluctuates and the seed also fluctuates in its moisture content equilibrium with atmospheric moisture content.

Table 4.1.9 Effect of seed coating treatments on moisture content (%) during storage in paddy

Treatment	Months after storage					
	26	28	30	32	34	36
T_1	11.63	11.53	12.47	13.63	12.87	11.70
T_2	11.47	11.33	12.33	13.50	12.70	11.57
T_3	11.20	11.00	11.93	13.13	12.33	11.33
T_4	11.17	10.97	11.90	13.10	12.30	11.27
T_5	11.13	10.93	11.87	13.07	12.27	11.23
T_6	11.10	10.90	11.83	13.03	12.23	11.17
T_7	11.30	11.10	12.07	13.27	12.47	11.43
T_8	11.40	11.20	12.27	13.47	12.67	11.53
T_9	11.07	10.87	11.80	13.00	12.20	11.13
T_{10}	11.03	10.83	11.77	12.97	12.17	11.10
Mean	11.25	11.07	12.02	13.22	12.42	11.35
SE(m±)	0.045	0.045	0.043	0.042	0.056	0.042
CD (5%)	0.13	0.13	0.13	0.12	0.16	0.12

T_1 - control (untreated seeds)
T_2 - polymer coating (polykote @ 3 ml/kg of seed, diluted with 5 ml of water)
T_3 - flowable thiram (Royal flow 40 SC) @ 2.4 ml/kg seed
T_4 - polymer + flowable thiram (Royal flow 40 SC) @ 2.4 ml/kg seed
T_5 - vitavax 200 (containing thiram 37.5% and carboxil 37.5%) @ 2 g/kg seed
T_6 - polymer + vitavax 200 (containing thiram 37.5% and carboxil 37.5%) @ 2 g/kg of seed
T_7 - imidacloprid (Gaucho) @ 4 ml/kg seed
T_8 - polymer + imidacloprid (Gaucho) @ 4 ml/kg seed
T_9 - polymer + flowable thiram (Royal flow 40 SC) @ 2.4 ml/kg seed + imidacloprid @ 4 ml/kg seed
T_{10} - polymer + vitavax 200 (containing thiram 37.5% and carboxil 37.5%) @ 2 g/kg of seed + imidacloprid (Gaucho) 4 ml/kg seed

Seeds coated with synthetic polymer and seed treatment chemicals will cover the pores in the seed coat and prevent the entry of both water and fungal mycelia and provide protection from physical damage.

Similar results were reported by Patil et al. (2014) who observed that pigeonpea seeds treated with thiram @ 3 g/kg of seed + spinosad @ 0.04 ml/kg resulted in lowest seed moisture content at the end of 6 months of storage period. Udabal et al. (2014) recorded that sunflower seed treated with vitavax @ 3 g/kg resulted in significantly lower seed moisture content over untreated seed at the end of eleven months of seed storage period. Thakur and Dhiman (2016) in soybean seeds observed that seeds treated with imidacloprid @ 6 ml/kg seed showed significantly lower moisture content over untreated control at the end of one year of storage. Sharma (2017) reported that paddy seeds treated with polymer + Vitavax 200 @ 2 g/kg of seed + Imidachloprid @ 6 ml/kg of seed, resulted in significantly lowest moisture content over untreated seeds at the end of one year of storage period.

In the present study, moisture content of the seed decreased after 28 months of storage as the ambient RH was low during that period of storage, however, moisture content of the seed started increasing after 30 months of storage till 32 months of storage as the ambient RH was high during that storage period and thereafter seed moisture content started to decrease with the decrease in RH till the end of storage period.

4.1.10 Electrical conductivity (m mho/cm/g)

The results recorded on electrical conductivity as influenced by seed coating treatments during twelve months (25^{th} to 36^{th} months) of storage period are presented in table 4.1.10.

Irrespective of seed coating treatments, the electrical conductivity continued to increase after 26 months to the end of 36 months of the storage period. On an average the electrical conductivity in the beginning and end of storage period was 0.239 m mho/cm/g and 0.278 m mho/cm/g, respectively.

Table 4.1.10 Effect of seed coating treatments on electrical conductivity (m mho/cm/g) during storage in paddy

Treatment	Months after storage					
	26	28	30	32	34	36
T_1	0.250	0.256	0.261	0.269	0.278	0.289
T_2	0.248	0.254	0.259	0.266	0.276	0.287
T_3	0.236	0.241	0.247	0.254	0.264	0.276
T_4	0.232	0.237	0.243	0.250	0.260	0.265
T_5	0.236	0.241	0.247	0.254	0.264	0.276
T_6	0.229	0.234	0.240	0.247	0.257	0.266
T_7	0.246	0.251	0.257	0.264	0.274	0.286
T_8	0.243	0.248	0.254	0.261	0.271	0.283
T_9	0.240	0.245	0.251	0.258	0.268	0.280
T_{10}	0.234	0.239	0.245	0.252	0.262	0.274
Mean	0.239	0.245	0.250	0.257	0.268	0.278
SE(m±)	0.0005	0.0004	0.0005	0.0004	0.0005	0.0004
CD (5%)	0.0014	0.0012	0.0014	0.0012	0.0015	0.0013

T_1 - control (untreated seeds)
T_2 - polymer coating (polykote @ 3 ml/kg of seed, diluted with 5 ml of water)
T_3 - flowable thiram (Royal flow 40 SC) @ 2.4 ml/kg seed
T_4 - polymer + flowable thiram (Royal flow 40 SC) @ 2.4 ml/kg seed
T_5 - vitavax 200 (containing thiram 37.5% and carboxil 37.5%) @ 2 g/kg seed
T_6 - polymer + vitavax 200 (containing thiram 37.5% and carboxil 37.5%) @ 2 g/kg of seed
T_7 - imidacloprid (Gaucho) @ 4 ml/kg seed
T_8 - polymer + imidacloprid (Gaucho) @ 4 ml/kg seed
T_9 - polymer + flowable thiram (Royal flow 40 SC) @ 2.4 ml/kg seed + imidacloprid @ 4 ml/kg seed
T_{10} - polymer + vitavax 200 (containing thiram 37.5% and carboxil 37.5%) @ 2 g/kg of seed + imidacloprid (Gaucho) 4 ml/kg seed

The electrical conductivity varied significantly throughout the storage period. After 26 months of storage, significantly less electrical conductivity was recorded in treatment T_6 - polymer + vitavax 200 @ 2 g/kg of seed (0.229 m mho/cm/g), which was followed by T_4 - polymer + flowable thiram @ 2.4 ml/kg of seed (0.232 m mho/cm/g), T_5 - vitavax 200@ 2g/kg of seed (0.236 m mho/cm/g), T_{10} - polymer + vitavax 200 @ 2 g/kg of seed + imidacloprid (Gaucho) @ 4 ml/kg of seed (0.234 m mho/cm/g), T_3 - flowable thiram @ 2.4 ml/kg of seed (0.236 m mho/cm/g), T_9 - polymer + flowable thiram @ 2.4 ml/kg of seed + imidacloprid (Gaucho) @ 4 ml/kg of seed (0.240 m mho/cm/g), T_8 - polymer + imidacloprid (Gaucho) @ 4 ml/kg of seed (0.243 m mho/cm/g) and T_7 - imidachloprid (Gaucho) @ 4 ml/kg of seed (0.246m mho/cm/g) as compared to T_1 - untreated control (0.250m mho/cm/g).

The same pattern was recorded till the end of the storage period and significantly lower electrical conductivity was recorded in T_6 - polymer + vitavax 200 @ 2 g/kg of seed (0.266 m mho/cm/g), followed by T_4 - polymer + flowable thiram @ 2.4 ml/kg of seed (0.265 m mho/cm/g) over T_1 - untreated control (0.289 m mho/cm/g).

Electrical conductivity increased with the advancing storage period. The electrical conductivity of seed leachates is used to assess the seed deterioration. Increase in electrical conductivity may be attributed to higher incidence of fungi that caused loss of membrane integrity. However, the polymer coating holds the seeds intact and covers the cracks and aberrations of the seed coat and thus reduces the leaching of electrolytes.

The result are in conformity with the results of Sushma (2013) who observed that chickpea seeds treated with polymer @ 10 ml/kg along with Deltamethrin 2.8 EC @ 0.4 ml/kg of seed + Vitavax power @ 2 g/kg of seed recorded significantly lower electrical conductivity as compared to untreated control at the end of four months of storage period. Udbal et al. (2014) recorded that sunflower seeds treated with Vitavax @ 3 g/kg resulted in significantly lower electrical conductivity over untreated control at the end of eleven months of storage period. Manoharapaladagu et al. (2017) observed that chilly seeds treated with polymer @ 7 ml/kg + thiram @ 2 g/kg of seeds resulted in significantly lower electrical conductivity over untreated seeds at the end of six months of storage period. Sharma and Dhiman (2017) in paddy reported that seed treated with polymer @ 3 ml/kg + vitavax 200 @ 2 g/kg resulted in significantly lower electrical conductivity over untreated seeds at the end of one year of storage period.

4.1.11 Fungal infection (%)

The results recorded on fungal infection (%) as influenced by seed coating treatments during twelve months (25^{th} to 36^{th} months) of storage period are presented in Table 4.1.11 and depicted in Fig. 4.5.

The storage fungi, infecting seeds were identified as *Fusarium* spp. and *Rhizophous* spp. Among these, *Fusarium* spp. was predominant.

The fungal infection (%) increased throughout the storage period, irrespective of seed coating treatments. After 26 months of storage, significantly lowest fungal infection over T_1 - untreated control (9.33%) was recorded in treatment T_6 - polymer + vitavax 200 @ 2 g/kg of seed (5.00%), which was at par with T_4 - polymer + flowable thiram @ 2.4 ml/kg of seed (5.33%), T_5 - vitavax 200 @ 2 g/kg of seed (5.67%), followed by T_{10} - polymer + vitavax 200 @ 2 g/kg of seed + imidacloprid (Gaucho) @ 4 ml/kg of seed (6.33%), T_3 - flowable thiram @ 2.4 ml/kg of seed (6.67%), T_9 - polymer + flowable thiram @ 2.4 ml/kg of seed + imidacloprid (Gaucho) @4 ml/kg of seed (7.00%), T_8 - polymer + imidacloprid (Gaucho) @ 4 ml/kg of seed (7.67%) and T_7 - imidacloprid (Gaucho) @ 4 ml/kg of seed (8.33%). However T_1 - untreated control (9.33%) recorded highest fungal infection. Similar trend was followed till the end of the storage and significantly lower fungal infection was recorded in T_6 - polymer + vitavax 200 @ 2 g/kg of seed (7.33%) which was at par with T_4 - polymer + flowable thiram @ 2.4 ml/kg of seed (7.67%), T_5 - vitavax 200 @ 2 g/kg of seed (8.33%), followed by T_{10} - polymer + vitavax 200 @ 2 g/kg of seed + imidacloprid (Gaucho) @ 4 ml/kg of seed (9.33%), as compared to T_1 - untreated control (14.33%). The percent total fungal colonies gradually increased with the period of seed storage in different seed treatments. Seed microflora is mainly responsible for the degradation of protein and other food reserves resulting in reduction of vigour and germination. Seed treated with polymer and vitavax exerted a significant influence on total fungal colonies of paddy seeds when stored for a period

Table 4.1.11 Effect of seed coating treatments on fungal infection (%) during storage in paddy

Treatment	Months after storage					
	26	28	30	32	34	36
T_1	9.33	9.67	10.33	11.67	13.00	14.33
	(3.21)	(3.27)	(3.37)	(3.56)	(3.74)	(3.92)
T_2	9.00	9.33	10.00	11.00	11.67	12.67
	(3.16)	(3.21)	(3.31)	(3.46)	(3.56)	(3.70)
T_3	6.67	7.33	8.00	8.67	9.33	10.00
	(2.77)	(2.89)	(3.00)	(3.11)	(3.21)	(3.31)
T_4	5.33	6.00	6.33	6.67	7.00	7.67
	(2.51)	(2.64)	(2.71)	(2.76)	(2.82)	(2.94)
T_5	5.67	6.33	7.00	7.33	7.67	8.33
	(2.58)	(2.71)	(2.82)	(2.89)	(2.94)	(3.05)
T_6	5.00	5.67	6.00	6.33	6.67	7.33
	(2.44)	(2.58)	(2.64)	(2.71)	(2.77)	(2.89)
T_7	8.33	9.33	9.67	10.33	11.00	12.33
	(3.05)	(3.21)	(3.27)	(3.37)	(3.46)	(3.65)
T_8	7.67	8.33	9.00	9.67	10.33	11.33
	(2.94)	(3.05)	(3.16)	(3.27)	(3.37)	(3.51)
T_9	7.00	7.67	8.67	9.33	10.00	10.67
	(2.82)	(2.94)	(3.11)	(3.21)	(3.31)	(3.41)
T_{10}	6.33	7.00	7.67	8.00	8.67	9.33
	(2.71)	(2.82)	(2.94)	(3.00)	(3.11)	(3.21)
Mean	7.03	7.67	8.20	8.93	9.53	10.40
	(2.82)	(2.93)	(3.03)	(3.14)	(3.23)	(3.36)
SE(m±)	0.076	0.075	0.079	0.071	0.069	0.055
CD (5%)	0.22	0.22	0.23	0.21	0.20	0.16

Figures in parentheses indicate square root values

T_1 - control (untreated seeds)
T_2 - polymer coating (polykote @ 3 ml/kg of seed, diluted with 5 ml of water)
T_3 - flowable thiram (Royal flow 40 SC) @ 2.4 ml/kg seed
T_4 - polymer + flowable thiram (Royal flow 40 SC) @ 2.4 ml/kg seed
T_5 - vitavax 200 (containing thiram 37.5% and carboxil 37.5%) @ 2 g/kg seed
T_6 - polymer + vitavax 200 (containing thiram 37.5% and carboxil 37.5%) @ 2 g/kg of seed
T_7 - imidacloprid (Gaucho) @ 4 ml/kg seed
T_8 - polymer + imidacloprid (Gaucho) @ 4 ml/kg seed
T_9 - polymer + flowable thiram (Royal flow 40 SC) @ 2.4 ml/kg seed + imidacloprid @ 4 ml/kg seed
T_{10} - polymer + vitavax 200 (containing thiram 37.5% and carboxil 37.5%) @ 2 g/kg of seed + imidacloprid (Gaucho) 4 ml/kg seed

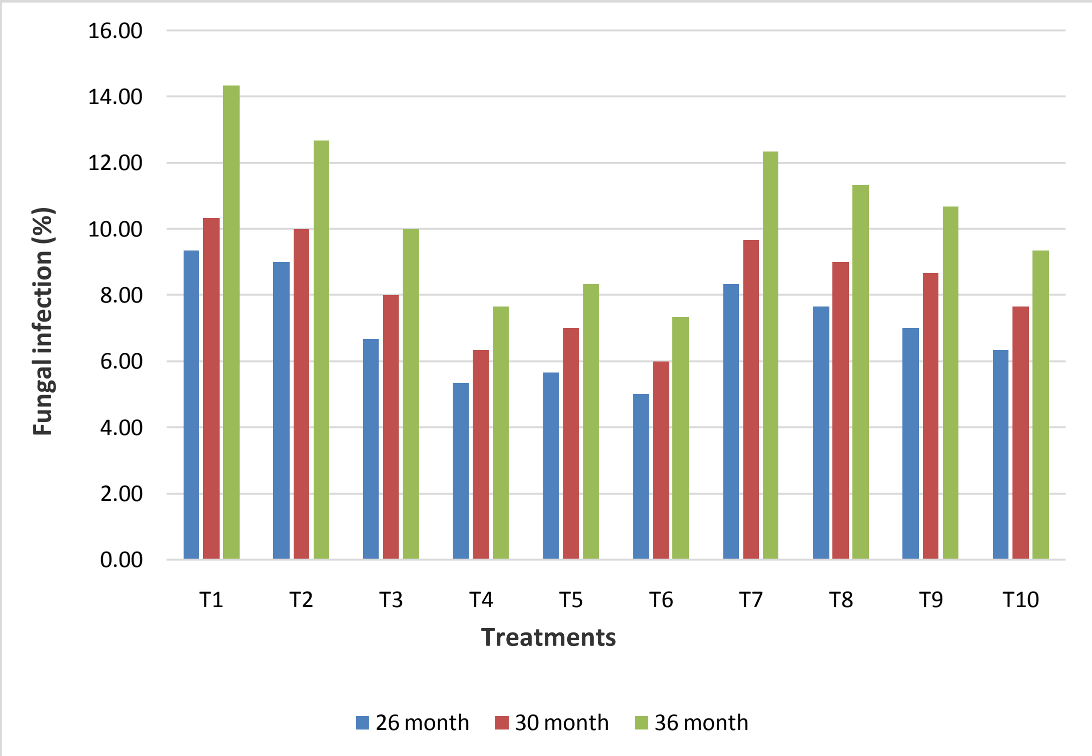

Fig. 4.5 Effect of seed coating treatments on fungal infection (%) in paddy

of twelve months (25^{th} to 36^{th} months). The polymer + fungicide seed coating enhances the efficiency of fungicide till the end of storage period. It forms a flexible film that adheres and protects the fungicide on the seed and preventing dusting off and loss of fungicide during storage.

Similar finding was reported by Rathinavel (2015) who observed that cotton seeds coated with polymer @ 3 ml/kg + Thiram @ 2.5 g/kg + Super red @ 5 ml/kg + Cruiser @ 5 g/kg of seeds resulted in significantly lesser seed infection as compared to untreated control at the end of 26 months of storage period. Desai et al. (2015) reported that soybean seeds treated with polymer and vitavax resulted in significantly lesser fungal infection over untreated seeds at the end 270 days of storage period. Vimal et al. (2011) observed that rice seeds treated with polykote + thiram + imidacloprid resulted in significantly lesser fungal infection as compared to untreated control. Thakur and Dhiman (2016) in soybean seeds observed that seeds treated with polymer of seed and flowable thiram @ 2.4 ml/kg of seed shows significantly lower fungal infection over untreated control at the end of one year of storage, Sharma et al. (2017) in maize observed that seeds treated with polymer + vitavax 200 @ 2 g/kg of seed resulted in significantly lower fungal infection over untreated control at the end of one year of storage and Sharma and Dhiman (2017) in paddy reported that seed treated with polymer + vitavax 200 @ 2 g/kg resulted in significantly lower fungal infection over untreated seeds at the end of one year of storage period.

4.1.12 Insect infestation (%)

No insect infestation was found in any of the treatment including untreated control till the end of storage period (36 months). Similar findings were reported by Sharma et al. (2017) who reported no insect infestation in maize seeds treated with polymer + vitavax 200 @ 2 g/kg of seed at the end of one year of storage period and Sharma and Dhiman (2017) also reported no insect infestation in paddy seeds treated with polymer + vitavax 200 @ 2 g/kg of seeds at the end of one year of storage period.

5. SUMMARY AND CONCLUSIONS

The present study entitled **"Effect of seed coating on seed longevity in rice (*Oryza sativa* L.)"** was undertaken to evaluate the effect of seed coating treatments for seed longevity and to identify the effective seed coating treatment for enhancing seed longevity of rice. Keeping in view these objectives, the storage experiment was carried out in the Seed Technology Laboratory (January 2018 - December 2018) of Department of Seed Science and Technology, CSK HPKV, Palampur using HPR-1068 variety of paddy. The results of experiment are summarized here under:

The seeds treated with polymer and fungicides recorded significant superiority for the seed quality parameters during storage. Significantly higher germination percentage (final count) was recorded for treatment T_6 - polymer + vitavax 200 @ 2 g/kg of seed (75.33%) which was at par with T_4 - polymer + flowable thiram @ 2.4 ml/kg of seed (75.00%), while the lowest germination was recorded for treatment T_1 - untreated control (67.33%) at the end of storage (36 months). Similarly significantly higher speed of germination was recorded in T_6 - polymer + vitavax 200 @ 2 g/kg of seed (9.00), followed by T_4 - polymer + flowable thiram @ 2.4 ml/kg of seed (8.83) over T_1 - untreated control (6.87) at the end of 36 months of storage.

Significantly higher seedling length (cm) as compared to T_1 - untreated control (6.50 cm) was recorded in treatment T_6 - polymer + vitavax 200 @ 2 g/kg of seed (8.07 cm), followed by T_4 - polymer + flowable thiram @ 2.4 ml/kg of seed (7.83 cm) at the end of storage (36 months). Similarly higher seedling dry weight (g) was recorded in T_6 - polymer + vitavax 200 @ 2 g/kg of seed (0.048 g), which was at par with T_4 - polymer + flowable thiram @ 2.4 ml/kg of seed (0.047 g) over T_1 - untreated control (0.035 g) at the end of 36 months of storage.

Higher seedling vigour index - I was recorded in T_6 - polymer + vitavax 200 @ 2 g/kg of seed (608), followed by T_4 - polymer + flowable thiram @ 2.4 ml/kg of seed (588) over T_1 - untreated control (438) at the end of storage period of 36 months. Similarly significantly higher vigour index - II was recorded in T_6 - polymer + vitavax 200 @ 2 g/kg of seed (3.59), which was at par with T_4 - polymer + flowable thiram @

2.4 ml/kg of seed (3.49) as compared to T_1 - untreated control (2.36) at the end of the storage period (36 months).

Significantly higher field emergence (%) was recorded in T_6 - polymer + vitavax 200 @ 2.4 ml/kg of seed (66.00%), which was at par with T_4 - polymer + flowable thiram @ 2.4 ml/kg of seed (65.33%) as compared to T_1 - untreated control (56.67%) at the end of storage (36 months).

Significantly highest test weight was recorded for T_{10} - polymer + vitavax 200 @ 2 g/kg of seed + imidacloprid @ 6 ml/kg of seed (28.07 g), which was at par with T_9 - polymer + flowable thiram @ 2.4 ml/kg of seed + imidacloprid (Gaucho) @ 4 ml/kg of seed (27.97 g), followed by T_6 - polymer + vitavax 200 @ 2 g/kg of seed (27.83 g), and T_5 - vitavax 200 @ 2 g/kg of seed (27.73 g) at the end of storage period (36 months).

The lowest moisture content (%) was recorded in T_{10} - polymer + vitavax 200 @ 2 g/kg of seed + imidacloprid @ 4 ml/kg of seed (11.10%), which was at par with T_9 - polymer + flowable thiram @ 2.4 ml/kg of seed + imidacloprid @ 4 ml/kg of seed (11.13%), T_6 - polymer + vitavax 200 @ 2 g/kg of seed (11.17%), and T_5 - vitavax 200 @ 2 g/kg of seed (11.23%), while the highest moisture content was recorded in T_1 - untreated control (11.70%) at the end of storage period (36 months).

Significantly lower electrical conductivity was recorded in T_6 - polymer + vitavax 200 @ 2 g/kg of seed (0.266 m mho/cm/g), followed by T_4 - polymer + flowable Thiram @ 2.4 ml/kg of seed (0.265 m mho/cm/g) over T_1 - untreated control (0.289 m mho/cm/g) at the end of storage (36 months).

Significantly lower fungal infection was recorded in T_6 - polymer + vitavax 200 @ 2 g/kg of seed (7.33%), which was at par with T_4 - polymer + flowable thiram @ 2.4 ml/kg of seed (7.67%), and T_5 - vitavax 200 @ 2 g/kg of seed (8.33%), as compared to T_1 - untreated control (14.33%) at the end of storage (36 months). No insect infestation was found in any of the treatment including untreated control throughout the storage period.

Conclusions

- The seed quality parameters declined progressively with the increase in storage period, irrespective of seed coating treatments.
- The results have shown that seeds treated with polymer + vitavax 200 @ 2 g/kg of seed (T_6) recorded significant superiority for most of the seed quality parameters during storage, followed by polymer + flowable thiram @ 2.4 ml/kg of seed (T_4) over untreated control (T_1).
- It can be concluded that for enhancing longevity and to maintain seed quality during storage, the seeds of paddy can either be treated with polymer coating @ 3 ml/kg of seed + vitavax 200 @ 2 g/kg of seed or polymer coating @ 3 ml/kg of seed + flowable thiram @ 2.4 ml/kg of seed.
- Though, two treatments viz. polymer coating @ 3 ml/kg of seed + vitavax 200 @ 2 g/kg of seed and polymer coating @ 3 ml/kg of seed + flowable thiram @ 2.4 ml/kg of seed resulted to maintain the germination percentage above Indian Minimum Seed Certification Standards (IMSCS) upto 32 months of storage, yet is not advisable to use the seed after 24 months of storage as all the quality parameters of seed performed very poor.

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APPENDICES

Appendix – I

AMBIENT TEMPERATURE AND RELATIVE HUMIDITY FROM JANUARY 2018 TO DECEMBER 2018

Months	Temperature (°C)		RH (%)
	Mean Max.	Mean Min.	
January 2018	13.92	12.39	38.45
February 2018	15.69	14.30	42.75
March 2018	19.17	17.72	38.83
April 2018	22.88	21.28	41.37
May 2018	25.21	23.95	31.98
June 2018	27.05	24.45	50.56
July 2018	24.53	23.24	75.53
August 2018	23.98	23.01	82.32
September 2018	28.94	22.34	76.83
October 2018	22.14	21.08	50.49
November 2018	18.42	16.98	46.97
December 2018	14.91	10.39	42.73

Source: Seed Technology Laboratory of Department of Seed Science and Technology, College of Agriculture, CSK HPKV, Palampur (H.P)

Appendix – II

***Mean performance of effects of seed coating on seed quality parameters at initial month of storage (December 2015)**

S. No.	Treatments	Moisture content (%)	Germination (%)		Seedling length (cm)	Seed dry weight (g/10 seedlings)	Vigour index- I	Vigour index- II	Field emergence (%)	Elect ricalcond uc tivity	Speed of germ ination	Fungal infection (%)
			First count (%)	Final count (%)								
1	**T_1**	10.80	75.33	91.33	18.36	0.094	1678	8.58	82.00	0.146	15.13	2.00
2	**T_2**	10.80	76.00	92.00	18.56	0.095	1708	8.73	83.00	0.144	15.20	1.83
3	**T_3**	10.80	79.00	95.00	19.23	0.100	1827	9.49	86.00	0.138	16.86	1.16
4	**T_4**	10.76	81.33	97.00	21.53	0.103	2089	9.99	88.33	0.134	18.56	0.50
5	**T_5**	10.73	80.33	96.66	20.86	0.102	2017	9.86	87.33	0.136	17.76	0.66
6	**T_6**	10.73	82.00	97.66	22.20	0.104	2168	10.15	89.33	0.133	18.83	0.33
7	**T_7**	10.80	76.00	93.00	18.66	0.097	1736	9.02	84.00	0.143	15.33	1.66
8	**T_8**	10.80	76.33	93.33	18.95	0.098	1769	9.14	84.00	0.142	15.46	1.66
9	**T_9**	10.73	77.66	94.00	19.20	0.099	1805	9.30	85.00	0.140	16.50	1.50
10	**T_{10}**	10.80	79.66	96.00	19.33	0.101	1856	9.69	87.00	0.137	17.53	0.66
	SE (m±)	0.02	0.28	0.61	0.40	0.0005	10.06	0.04	0.39	0.0005	0.039	0.04
	CD (5%)	NS	0.83	1.80	0.12	0.0016	29.73	0.16	1.15	0.0016	0.11	0.14

***Source:** (Sharma 2017)

Appendix – III

Mean performance of effects of seed coating on seed quality parameters after 36 months

S. No.	Treatments	Moisture content (%)	Germination (%)		Seedling length (cm)	Seed dry weight (g/10 seedlings)	Vigour index- I	Vigour index- II	Field emergence (%)	Elect ricalcond uc tivity	Speed of germ ination	Fungal infection (%)
			First count (%)	Final count (%)								
1	**T_1**	11.70	65.67	67.33	6.50	0.035	438	2.36	56.67	0.289	6.87	14.33
2	**T_2**	11.57	67.33	68.67	6.77	0.037	465	2.52	58.33	0.287	7.13	12.67
3	**T_3**	11.33	70.00	73.00	7.47	0.042	545	3.04	61.33	0.276	8.10	10.00
4	**T_4**	11.27	73.00	75.00	7.83	0.046	588	3.45	65.33	0.265	8.83	7.67
5	**T_5**	11.23	71.67	73.67	7.77	0.045	572	3.29	64.00	0.276	8.60	8.33
6	**T_6**	11.17	73.33	75.33	8.07	0.048	608	3.59	66.00	0.266	9.00	7.33
7	**T_7**	11.43	68.00	71.33	6.90	0.039	492	2.78	59.33	0.286	7.33	12.33
8	**T_8**	11.53	68.67	72.00	7.07	0.040	509	2.86	60.00	0.283	7.50	11.33
9	**T_9**	11.13	69.00	72.67	7.30	0.041	530	2.98	60.67	0.280	7.70	10.67
10	**T_{10}**	11.10	70.67	73.33	7.60	0.044	557	3.23	62.67	0.274	8.40	9.33
	SE (m±)	0.04	0.48	0.42	0.05	0.0005	4.45	0.04	0.49	0.0004	0.05	0.37
	CD (5%)	0.12	1.42	1.24	0.14	0.001	13	0.10	1.46	0.001	0.15	1.08

Appendix – IV (a) Analysis of variance for germination (%) –first count

Mean sum of squares							
Germination first count (%)							
Months after storage		**26**	**28**	**30**	**32**	**34**	**36**
Source	d.f.						
Treatment	9	7.73*	9.63*	7.15*	8.47*	7.71*	7.19*
Error	20	0.22	0.30	0.26	0.26	0.28	0.28

*Significant at 5% level of significance

Appendix – IV (b) Analysis of variance for germination (%) – final count

Mean sum of squares							
Germination final count (%)							
Months after storage		**26**	**28**	**30**	**32**	**34**	**36**
Source	d.f.						
Treatment	9	10.68*	10.54*	9.75*	8.85*	9.35*	7.91*
Error	20	0.25	0.36	0.26	0.25	0.29	0.22

*Significant at 5% level of significance

Appendix – IV (c) Analysis of variance for seedling length (cm)

Mean sum of squares							
Seedling length (cm)							
Months after storage		**26**	**28**	**30**	**32**	**34**	**36**
Source	d.f.						
Treatment	9	0.245*	0.319*	0.427*	0.617*	0.814*	0.780*
Error	20	0.005	0.006	0.006	0.007	0.007	0.007

*Significant at 5% level of significance

Appendix – IV (d) Analysis of variance for dry weight (g)

Mean sum of squares							
Dry weight of 10 seedlings (g)							
Months after storage		**26**	**28**	**30**	**32**	**34**	**36**
Source	d.f.						
Treatment	9	0.000044*	0.000042*	0.000039*	0.000052*	0.000046*	0.000049*
Error	20	0.000001	0.000001	0.000001	0.000001	0.000001	0.000001

*Significant at 5% level of significance

Appendix – IV (e) Analysis of variance for field emergence (%)

Mean sum of squares							
Field emergence (%)							
Months after storage		**26**	**28**	**30**	**32**	**34**	**36**
Source	d.f.						
Treatment	9	10.68*	9.17*	8.95*	8.93*	10.31*	9.69*
Error	20	0.29	0.26	0.24	0.25	0.16	0.26

*Significant at 5% level of significance

Appendix – IV (f) Analysis of variance for electrical conductivity

Mean sum of squares							
Electrical conductivity							
Months after storage		**26**	**28**	**30**	**32**	**34**	**36**
Source	d.f.						
Treatment	9	0.00014*	0.00017*	0.00015*	0.00016*	0.00015*	0.00021*
Error	20	0.000001	0.0000005	0.000001	0.000001	0.000001	0.000001

*Significant at 5% level of significance

Appendix – IV (g) Analysis of variance for moisture content (%)

Mean sum of squares							
Moisture content (%)							
Months after storage		**26**	**28**	**30**	**32**	**34**	**36**
Source	d.f.						
Treatment	9	0.115*	0.154*	0.184*	0.168*	0.178*	0.125*
Error	20	0.006	0.005	0.006	0.005	0.009	0.005

*Significant at 5% level of significance

Appendix – IV (h) Analysis of variance for test wt. (g)

Mean sum of squares							
Test wt. (g)							
Months after storage		**26**	**28**	**30**	**32**	**34**	**36**
Source	d.f.						
Treatment	9	0.171*	0.131*	0.347*	0.383*	0.342*	0.288*
Error	20	0.007	0.006	0.009	0.007	0.005	0.004

*Significant at 5% level of significance

Appendix – IV (i) Analysis of variance for Seedling vigour index -I

Mean sum of squares							
Seed vigour index –I							
Months after storage		**26**	**28**	**30**	**32**	**34**	**36**
Source	d.f.						
Treatment	9	6084.68*	6986.82*	8276.49*	9467.35*	10358.73*	8763.98*
Error	20	48.25	91.29	69.08	95.91	119.50	61.01

*Significant at 5% level of significance

Appendix – IV (j) Analysis of variance for Seedling vigour index- II

Mean sum of squares							
Seed vigour index- II							
Months after storage		**26**	**28**	**30**	**32**	**34**	**36**
Source	d.f.						
Treatment	9	0.580*	0.578*	0.521*	0.589*	0.5048*	0.462*
Error	20	0.006	0.005	0.004	0.006	0.007	0.004

*Significant at 5% level of significance

Appendix – IV (k) Analysis of variance for fungal infection (%)

Mean sum of squares							
Fungal infection (%)							
Months after storage		**26**	**28**	**30**	**32**	**34**	**36**
Source	d.f.						
Treatment	9	0.216*	0.185*	0.193*	0.247*	0.308*	0.349*
Error	20	0.017	0.016	0.019	0.015	0.014	0.009

*Significant at 5% level of significance

Appendix – IV (l) Analysis of variance for speed of germination

Mean sum of squares							
Speed of germination							
Months after storage		**26**	**28**	**30**	**32**	**34**	**36**
Source	d.f.						
Treatment	9	1.068*	1.000*	1.153*	1.119*	1.362*	1.672*
Error	20	0.009	0.007	0.010	0.007	0.006	0.007

*Significant at 5% level of significance

Brief Biodata of student

Name : Amandeep Singh

Father's Name : S. Raghbir Singh

Mother's Name : Smt. Gurwinder Kaur

Date of Birth : March 27, 1993

Permanent Address : V.P.O Doda Distt. Shri Muktsar Sahib (Punjab)
Pin code: 152031

Academic Qualifications:

Qualification	**Month**	**Year of passing**	**School/ Board/ University**	**Marks (%)**	**Division**
10^{th} Class	March	2010	KJM Regional Convent School Rupana Muktsar.(P.B.)	68.0	First
12^{th} Class	March	2012	Police Public School Bathinda. (P.B.)	50.0	Second
B.Sc. (Hons.) Agriculture	June	2017	Punjab Agricultural University, Ludhiana.(P.B.)	63.5	First
M.Sc. (Seed Science and Technology)	July	2019	CSK HPKV, Palampur, Kangra (H.P.)	67.0	First