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Polymer film coating mediated delivery of pesticide enhances germination, vigour and shelf life of cowpea seeds under biotic stress and natural ageing

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Abstract
Cowpea seeds are highly susceptible to insect and pathogen in storage and in the field as well. Synthetic polymer based film coating was envisaged to provide external protection from natural stresses (abiotic and biotic) by holding plant protectants onto the seeds. Seeds were coated through a commercial seed coating machine with different combination of fungicide (F:bavistin @ 2 g/kg seed), insecticide (I:malathion @ 2 g/kg seed), synthetic polymer (@ 6 ml/kg seed) and neem seed kernel extract (NSKE @ 10 ml/kg seed). Chemical plant protectants and polymer, when used alone reduced the germination at initial germination test, which recovered afterwards. After seed storage for three, six and nine months, film coated plant protectants provided better protection to the seeds, in terms of germination and seed vigour. Induced feeding of seed to pulse beetle/ bruchid (*Callosobruchus chinensis*) was conducted to test the efficacy of film coating. Film coating with plant protectants exhibited better performance over control in terms of seed damage, oviposition and number of holes created by beetles on the seed surface, as well as with increase in vertical depth in seed container.

Keywords: Bruchid, Cowpea, Germination, Pulse beetle, Seed coating, Storability, Vigour

Introduction
Cowpea (*Vigna unguiculata*) is an ecologically and economically important leguminous plant and rich in protein (Goncalves *et al.*, 2016). It has been observed that the nutrient content of cowpea is similar to common bean, in addition to the high folic acid content and low flatulence producing factor. It is an annual herbaceous legume cultivated for its edible seeds and for fodder. Cowpea is called the 'hungry-season crop' in some parts of the world because it is the first harvested crop, before the cereal crops. Cowpea has great flexibility in use: farmers can choose to harvest it for grains or as forage for their livestock, depending on economic or climatic constraints (Gomez, 2004). Dual-purpose varieties have been developed to provide both grain and fodder while suiting the different cropping systems prevalent in Africa as well as in Asia (Tarawali *et al.*, 1997). Cowpea can produce good yields of high quality foliage and dry matter, if sown with seeds of high initial vigour resulted from value added seed treatment (Maity *et al.*, 2016a). Under dry land conditions, cowpea forage yield has ranged from 0.5 t DM/ha to over 4 t DM/ha under favourable conditions. Production per season is usually 2 to 3 t DM/ha. Yields of up to 8 t DM/ha have been recorded in irrigated areas (Mullen, 1999). Farmers may harvest up to 0.4 t/ha of cowpea leaves in a few cuts with no noticeable reduction in seed yield. A potential yield of 4 t/ha of hay can be achieved with good management from a pure stand of cowpea. However, the world average yield of cowpea fodder is 0.5 t/ha (air-dried leafy stems) (Madamba *et al.*, 2006). Cowpea pastures and cut-and-carry systems are well adapted in Asia and Australia. Quality of cowpea forage is considered at its best during summer and autumn (Tarawali *et al.*, 1997). When seasons are suitable, and it is sown comparatively early, the best forage types will regrow after grazing or cutting.

But, when we come to raising the crop with seed as the only propagule, cowpea seeds are highly susceptible to insect, pest and seed borne diseases during storage and also in field condition. Cowpea seeds lose viability within 3-4 months if the storage arrangement and the condition of seeds are not proper. High level of temperature, relative humidity and moisture in the storage environment appears to be main factor to hasten degenerating biochemical changes and insect-pathogen growth that eventually lead to deterioration in seed quality (Maity and Pramanik, 2013). Maintenance of seed quality during storage period is important not only for crop production in the following year but also for the maintenance of seeds because of their constant threat of genetic erosion due to severe effect of changing climate (Maity *et al.*, 2016b), as the seeds are stored mostly in uncontrolled condition. Besides, maintaining controlled microclimate in seed storage to maintain physiological quality of seed, usually seeds are mixed with insecticide and fungicide to protect it from insect pests. But only mixing or dry dressing of seeds with plant protectants leads to wastage of chemicals during handling because the dry powders do not remain adhered to the seed surface throughout the storage period. Thus they sometimes cannot provide continuous/ sustained protection to seeds. Hence, film coating of seed was envisaged in order to protect the seeds from pest attack and boost initial seedling vigour. Seed film coating is a management technique employed to strengthen physical property and physiological performance of seed under harsh field condition. It enables spread of accurate and even dose of chemicals, and reduces chemical wastage. It also provides resistance against mechanical damage during post-harvest handling and in the seed drill as well. Some of the common benefits of coating/ pelleting are uniformity in seed size, precision planting; uniform stands with reduced seed rate, more insect and disease resistance, better performance under stress conditions and additional nourishment to the seedlings (Peterhalmer, 2003). In addition, it is employed to also add some required substances to the individual seed so that the seeds fetch some extra benefits upon absorption of such substances when they get sufficient water, and enrich the rhizosphere region for sustained growth. Thus each and every seed gets sufficient nutrition supply without physiological modification of seed but by simple physical alterations in microclimate of the seed (Suma, 2005). In view of the above facts, the present study was undertaken to evaluate the effect of film coating, with different additives, on germination and seedling vigour of cowpea seed at field as well as in stored condition.

Materials and Methods

Materials for the experiment: Seed of cowpea variety EC 4216 was collected from Division of Seed Technology, ICAR-Indian Grassland and Fodder Research Institute (IGFRI), Jhansi and checked to confirm moisture content of 8%. Seed coating polymer from Incotec Private Ltd., India was taken as base for film coating. Fungicide (bavistin) and insecticide (malathion) were collected from standard private firm (Table 1).

Seed coating process: Seeds were film coated through a commercial seed coating machine (Lab Coater-LCM150, Reliance Automations Solutions, Hyderabad, India). Fungicide (F), insecticide (I) and synthetic polymer (P) were added sequentially onto the rotating seeds in the coating pan so that they made separate layers on the seed surface. During addition of F and I to the dry seed surface, water was added @ 3 ml/kg of seed so that the dry powders could adhere onto the seed surface. The seeds were air dried after each step of coating to eliminate the problem of additional moisture accumulation onto the seed. The seeds were then stored under ambient conditions in cloth bags.

Insect bioassay-forced and natural infestation: Bruchids (*Callosobruchus chinensis*) may or may not attack the treatments uniformly in open condition. To ensure uniform feeding by bruchids/ pulse beetles, during its peak multiplication time 12 no. of bruchids were placed per closed petridish containing 100 seeds. All petridishes with beetles were maintained under controlled laboratory conditions at 28°C and 55% (± 10%) RH with a 12 h: 12 h light: dark cycle. Bruchid had almost equivalent sex ratio (Chakraborty and Mondal, 2015). So 12 no. were placed in each petridish to ensure the presence of both male and female so that they can multiply within the closed petridish. After one month, the peak activity of beetles was over the seed infestation (percentage of seed damaged by bruchids) were recorded upto nine months at three months interval. The seeds damaged by more than 50% with the damaged embryo were considered as damaged seeds.

Table 1. Treatment details

Component	Name and supplier	Dose
Polymer (P)	Seed coating liquid (DISCO AGRO SP), Integrated Coating and Seed Technology India Private Ltd., Ahmedabad, India	6 ml/kg of seed
Neem seed kernel extract (NSKE)	Neem seed oil, Vyas Pharmaceuticals, Indore, India	10 ml/kg of seed
Fungicide (F)	Bavistin (carbendazim), SDS Ramcides Crop Science Private Ltd., Chennai, India	2 mg/kg of seed
Insecticide (I)	Malathion, Gujarat Pesticides Private Ltd., Gujarat, India	2 mg/kg of seed

Table 2. Germination and shoot length of cowpea seed in response to different coating treatment at three months interval

Treatment	Germination (%)				Shoot length (cm)			
	0 months	3 months	6 months	9 months	0 months	3 months	6 months	9 months
Control	94.7[a] (77.06)	91.3[bc] (72.87)	68.0[d] (55.55)	50.0[c] (44.98)	16.53[a]	14.87[c]	13.60[c]	12.53[d]
NSKE	92.0 [ab] (73.62)	93.3 [ab] (75.04)	89.3[ab] (70.98)	71.3[a] (57.65)	16.07[a]	16.87[b]	15.53[ab]	14.50[ab]
F	87.3[c] (69.18)	88.7[bc] (70.32)	86.7[bc] (68.64)	68.7[b] (55.98)	16.40[a]	13.17[d]	13.70[c]	13.03[cd]
I	88.0[c] (69.75)	94.0[ab] (75.92)	90.0[ab] (71.59)	72.0[ab] (58.04)	15.67[a]	14.27[cd]	15.37[bc]	14.17[bc]
F+I	89.3[bc] (70.98)	94.0[ab] (75.92)	84.7[bc] (66.99)	66.7[b] (54.73)	16.57[a]	14.59[c]	15.57[ab]	14.50[ab]
P	87.3[c] (69.14)	93.3[ab] (75.25)	88.0[bc] (69.87)	70.0[ab] (56.79)	16.43[a]	15.67[bc]	14.67[b]	13.53
P+F	88.7[b] (70.32)	87.3[c] (69.18)	88.7[abc] (70.49)	70.7[a] (57.23)	16.40[a]	16.43[b]	16.43[a]	14.53[ab]
P+I	89.3[bc] (70.93)	93.3[ab] (75.04)	92.0[ab] (73.76)	74.0[a] (59.35)	16.52[a]	16.83[b]	15.57[ab]	14.93[ab]
P+F+I	88.7[bc] (70.32)	96.0[a] (80.53)	93.3[ab] (75.25)	75.3[a] (60.22)	15.27[a]	18.45[a]	16.97[a]	15.80[a]
Mean	89.5	92.4	86.7	68.7	16.21	15.68	15.27	14.17

NSKE= Neem seed kernel extract @10 ml/kg of seed; F= Fungicide- Bavistin @ 2 g/kg of seed; I= Insecticide- Malathion @ 2 g/kg of seed; P= Polymer @ 6 ml/kg of seed

Another set of samples were kept in open beaker of 500 ml volume at ambient condition (mentioned above) to assess the depth up to which bruchides could attack the seeds. To quantify the depth of infestation, the beaker was vertically marked in three parts. Each part of seed was taken out carefully, observed, and kept aside separately until the lower one third parts was observed. Randomly selected twenty (20) seeds from each petridish were observed under magnifying glass to count the oviposition (number of eggs laid on seed surface) and number of holes generated on seed surface through natural infestation. Then each part of seed was put at its original position/ layer.

***Seed germination test*:** Seeds were tested for germination and seed vigour traits as per standard methods of ISTA (2008). Germination test was conducted by putting 400 seeds in four replicates of 100 seeds on top of the paper at 25°C in the germinator with alternation of 16 hours light and 8 hours dark. At the end of the test (8 days), germination and seedling parameters were measured.

Statistical analysis: The obtained data were statistically analysed using analysis of variance (ANOVA), and means were compared and grouped by using the Least Significant Difference test (LSD 0.05) with the SAS 9.1.3 programme (SAS Institute, 2004).

Results and Discussion

***Germination test*:** Film coated seed exhibited a decorated appearance and produced vigorous seedling at germination test, hence improved the marketability (Fig 1). Germination test indicated that polymer film coating, fungicide and insecticide, when applied separately or in combination, reduced germination of cowpea seed (88.7%) significantly as compared to control seed or uncoated seed (94.7%) when tested immediately after film coating (Table 2). But they maintained the quality of seed at higher level than uncoated seed for longer duration. Fungicide (87.3%) reduced the germination more than that by insecticide (88.0%) at initial stage. NSKE (92%) had no detrimental effect on seed germination immediately after treatment, but it proved to be a weaker quality maintainer than the film coated fungicide and insecticide after a storage duration of three months and thereafter. After three months of storage, uncoated seeds started losing germinability, whereas fungicide, insecticide and polymer film coating helped to maintain the viability. After nine months of storage, uncoated seed showed only 50% germination as compared to 70% (P) and 75.3% (P+F+I) in case of coated seed. The common practice of treating seeds with dry powders of insecticide and fungicide could protect the seeds in better way than in case of untreated seed, but when the materials were packed within film coating it could maintain the viability more efficiently. NSKE treated seed showed 92% germination immediately after treatment, which was at par with control, and maintained it at 71.3%, equal with the quality retained by P+F treated seeds, even after nine months of storage.

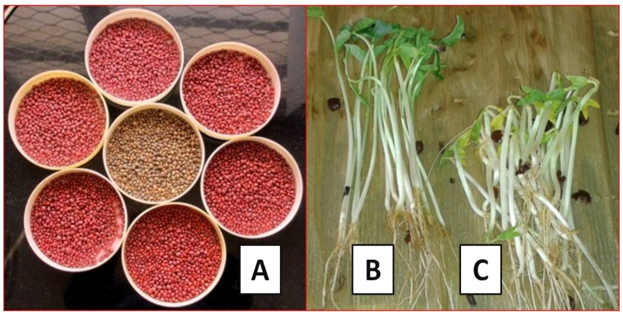

Fig 1. Coating experiment; A. Coated seed of cowpea, B. Seedling of coated and C. Seedling of uncoated seed at end of germination test

Film coating of seed reduced germination rates as compared to uncoated seeds when they were tested immediately after coating, which was confirmed by many reports and the germination rate depends strongly on the amount of coating material applied to the seed (Gorim and Yuya, 2014). And thereafter, during storage, the germination of coated seeds was maintained in better condition as compared to uncoated seed. The positive and significant response of polymer seed coating alone or in combination with insecticide/fungicide on germination, seedling vigour, growth and yield improvement were reported earlier by several workers (Rana *et al*., 2001; Ramya, 2003; Williams and Hopper, 1998). The promoting and protecting role of polymer on seed germination and vigour were explained and discussed by researchers in many ways. The polymers used generally for film coating are synthetic in chemical nature, hence there may be an initial antagonistic effect when the radicle comes out of the seed. The radicle which is the first part of a seedling to face the external world is the tender most part as well. It may be inferred that seeds take a little time to adjust with the foreign cover, hence the immediate germination test exhibited a detrimental effect. West *et al*. (1985) explained that dry seed gets injured by rapid uptake of water at imbibitions and film coating of polymer restricts the water entry in a humid environment, thus protecting the seed from loss of membrane integrity (Powell and Matthews, 1978; Bochicchio *et al*., 1991). A review of the results available did not yield a clear picture of the mode of effectiveness of film coating in promoting germination. Seed coats seem to interact with a variety of factors such as soil type, nutrient availability, cultivation methods as well as species and these interactions depend on the type, dose and composition of coating (Richardson and Hignight, 2010; Gorim *et al*., 2009; Peltonen-Sainio *et al*., 2006).

During storage, the seeds lose their germinability invariably and the present experiment is not an exception. Germination (mean of the treatments) was 89.5% immediately after coating, 92.4% after three months, 86.7% after six months and 68.9% after nine months of storage. The decline in germination percentage with the advancement in storage period may be attributed to ageing effect, leading to depletion of food reserves and decline in synthetic activity of embryo apart from loss of viability and storage condition (Kunkur *et al*., 2007). The film formed around seed acts as a physical barrier, which was reported to reduce leaching of inhibitors from the seed coverings and may restrict oxygen diffusion to the embryo (Duan and Burris, 1997). Sometimes, it is due to increase in the rate of imbibition where the fine particles in the coating act as moisture attracting material or perhaps to improve germination (Kunkur *et al*., 2007).

***Seed vigour*:** Seed vigour in terms of shoot-root length and seedling dry weight followed the same pattern as the seed germination (Table 2-3). With increase in storage period, decrease in the seedling dry weight, shoot and root length was noticed irrespective of seed treatments. Film coating and chemicals retarded seedling growth at initial germination test but it helped in maintaining the seed vigour for longer duration. Immediately after treatment, shoot length was 16.53 cm in untreated seed, whereas coated seed (P+F+I) had only 15.27 cm. Root length was shorter in fungicide and insecticide treated seed (13.80 cm in both cases) as compared to control (14.83 cm) at initial germination test. The rate of growth retardation by chemical protectants was more in root than shoot at initial germination test. Uncoated seeds lost its vigour drastically after six months of storage, but coated seed (P+F+I) maintained it sufficiently even after nine months of storage. At initial germination test, seedling dry weight was minimum in fungicide treated seed (2.78 mg) as compared to control (3.44 mg), but it enhanced at later points of storage. After three months, seedling dry weight was maximum (5.29 mg) in P+F+I treated seeds and decreased thereafter but remained higher (4.43 mg) than control (3.90 mg) even after nine months of storage. Neem seed kernel extract is a potential plant protectant as evidenced from our study. It has substantial efficiency of protecting and promoting the seed performance. In case of seedling traits also, it performed satisfactorily, but could not maintain over storage period.

The initial effect of coating on seed vigour may be due to the physical strength of the polymer that restricts the smooth protrusion of radicle and plumule from seed upon germination test. But then the seed could succeed in overcoming the barrier and exhibited better performance as compared to uncoated seed. The phenomenon was justified differently. When Ghebru *et al*. (2007) applied polymer as a seed coating material, it potentially buffered water deficits during germination and early seedling growth. Gorim and Yuya (2014) explained that seedlings growing from coated seeds showed accelerated early seedling growth which might be due to strongly reduced respiratory losses during the mobilization of endosperm reserves, combined with significantly increased mobilisation efficiency in cereals. Their analysis showed that the sucrose metabolism which makes glucose available as energy provider for growth varied strongly between coated and uncoated seeds. It was shown that seed film coating influenced the germination and also the seedling metabolism by inducing hypoxic conditions in embryonic tissue which shift the sugar metabolism to a more energy efficient pathway.

The fungicide and insecticide delivered through film coating and/or seed pelleting on seed was reported to exhibit different impact on seed germination and vigour (Maity *et al*., 2017). In the present experiment, fungicide (bavistin) and insecticide (malathion) delivered through film coating exhibited an initial retarding effect on seed germination and seedling growth. But after few months of storage, the negative effect of fungicide and insecticide was overtaken by their protecting and supporting role that facilitated better germination and seedling growth in film coated seed than in uncoated. The magnitude of seed germination, vigour and storability of seed film coated with pesticides depends on firm attachment of these chemicals to the seed coat during handling and planting (Williams and Hopper, 1998). Loss/shedding of these materials from the seed coat are called dust-off that may result in reduced crop performance and environmental contamination (Nuyttens *et al*., 2013). Besides it, Kunkur *et al*. (2007) reported that fungicide acted as protective agent against seed deterioration due to fungal invasion and physiological ageing, and malathion provided a phytotonic effect as a result of which the seed viability was maintained for comparatively longer period. These findings were in agreement with results obtained by Hunje *et al*. (1990) in cowpea. In addition, sometimes, excessive amounts of pesticides are applied to obtain the uniform coating and desired seed quality *i.e*. germination and vigour. Thus, the traditional practice of dry treatment of seeds with these chemicals has draw backs as it may contribute significantly to pesticide dust-off during handling and seeding. Film coating technique of seed with non-toxic polymer has contributed to reduce pesticide contents per seed and cost because of improved seed adherence (Brooker *et al*., 2007; Gevrek *et al*., 2012). However, critically there should be assurance that sufficient compatibility sustains between the polymer and seed germination, plant growth and timely delivery of the pesticides. NSKE in our experiment was proved to be satisfactory plant protect to certain extent, though it could not maintain the seed quality after few months of storage.

Table 3. Root length and seedling dry weight of cowpea seed in response to different coating treatment at three months interval

Treatment	Root length (cm)				Seedling dry weight (mg)			
	0 months	3 months	6 months	9 months	0 months	3 months	6 months	9 months
Control	14.83^{a}	15.10^{bc}	11.70^{c}	09.90^{c}	3.44^{a}	4.82^{bc}	3.80^{d}	3.90^{bc}
NSKE	14.95^{a}	14.38^{bc}	13.83^{ab}	13.03^{ab}	3.39^{a}	5.01^{ab}	4.46^{bc}	4.05^{ab}
F	13.83^{a}	14.87^{bc}	13.57^{b}	12.43^{b}	2.78^{a}	4.45^{c}	4.25^{c}	3.61^{c}
I	13.82^{a}	15.30^{ab}	13.90^{ab}	13.03^{ab}	3.16^{a}	4.88^{bc}	4.38^{c}	3.96^{bcd}
F+I	13.80^{a}	14.11^{c}	14.10^{ab}	13.20^{ab}	3.53^{a}	4.89^{bc}	4.31^{c}	4.02^{abc}
P	14.69^{a}	15.39^{ab}	13.70^{b}	12.67^{b}	3.40^{a}	4.83^{bc}	4.53^{bc}	3.91^{bc}
P+F	14.11^{a}	15.50^{ab}	13.77^{b}	13.10^{ab}	2.48^{a}	4.86^{bc}	4.86^{ab}	4.27^{ab}
P+I	14.23^{a}	14.40^{bc}	14.10^{ab}	13.33^{a}	3.06^{a}	4.94^{bc}	4.73^{ab}	4.33^{ab}
P+F+I	14.63^{a}	16.37^{a}	14.77^{a}	14.17^{a}	3.35^{a}	5.29^{a}	5.10^{a}	4.43^{a}
Mean	14.32	15.05	13.71	12.76	3.18	4.88	4.49	4.05

NSKE= Neem seed kernel extract @10 ml/kg of seed; F= Fungicide- Bavistin @ 2 g/kg of seed; I= Insecticide- Malathion @ 2 g/kg of seed; P= Polymer @ 6 ml/kg of seed

Bruchid infestation-natural and forced: In case of forced infestation, the uncoated seed were physically damaged by 35.7% only after three months and were damaged completely (100%) by bruchids after six months, whereas treated seeds were intact even after nine months (Fig 2). In the petridishes of uncoated seed, only seed and insect debris were the remainder after six months of infestation. All the protectants used in this experiment provided some protection to the seeds but the degree varied. Insecticide when applied with film coating, after three months, provided the highest protection (0.3% damage) than others (0.7-1.3% damage), but film coating with both fungicide and insecticide could provide the maximum protection after six (5.0% damage) and nine months (6.0% damage) of infestation. NSKE, fungicide and insecticide, when applied separately, could provide reasonable protection at three months (0.7-1.0% damage), but fell short after nine months of forced infestation (10.7-17.7% damage).

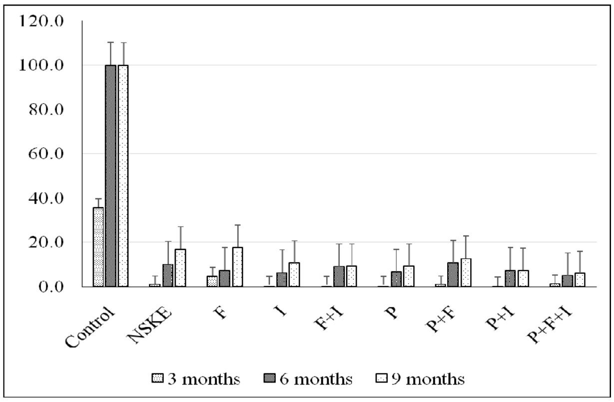

Fig 2. Percent seed damaged by bruchid under insect feeding trial

Oviposition or number of egg laid by bruchid on single seed surface varied among treatments in upper part (Table 4). The highest value was observed on uncoated seed (4.85/ seed) and minimum was on film coated fungicide-insecticide treated seed (1.60/ seed). Fungicide (4.35) and polymer (4.25) solely could not reduce egg laying as compared to control seed. But NSKE (1.65) and insecticide (3.20) individually had detrimental effect on the oviposition. After six months, when the bruchid's natural activity was increased, the oviposition also increased consequently, the uncoated seeds (8.65) attracted more oviposition than that by all other treatments (5.30-7.05) except fungicide (7.70). In middle and lower parts, though oviposition varied significantly after three months of storage, they didn't show any variation after six months. It was clear from the result that bruchids do not travel long downward direction. On the other hand, number of hole generated by bruchid on seed surface of upper part also varied among treatments (0.5-0.95/seed) (Table 4). After three months of ambient storage, highest number of hole was developed on uncoated seed (0.95) followed by F and P+F (0.85) and P (0.80), and least was observed on NSKE treated seed (0.45) followed by insecticide (0.55). But after six months of storage, number of holes were maximum on uncoated (1.45) and minimum on film coated seed (P+F+I) (0.95). At middle and lower parts, holes were more or less equal in number except at lower part after three months. It was evident that vertical movement of bruchids to lower side is unimportant while managing bruchid damage.

Table 4. Oviposition and holes/ seed created by bruchid in insect feeding trial at ambient storage at three months interval

Treatment	Oviposition (no. of eggs/seed)						Hole (no. of holes/seed)					
	Upper		Middle		Lower		Upper		Middle		Lower	
	3 months	6 months	3 months	6 months	3 months	6 months	3 months	6 months	3 months	6 months	3 months	6 months
Control	4.85^{a}	8.65^{a}	2.90^{abc}	7.00^{a}	0.60^{b}	1.00^{a}	0.95^{a}	1.45^{a}	0.60^{a}	1.20^{a}	0.45^{a}	0.70^{a}
NSKE	1.65^{c}	7.05^{b}	0.65^{d}	6.45^{a}	0.20^{b}	1.55^{a}	0.45^{b}	1.05^{a}	0.20^{a}	1.15^{a}	0.15^{bc}	0.60^{a}
F	4.35^{a}	7.70^{ab}	3.75^{a}	6.85^{a}	0.75^{b}	1.05^{a}	0.85^{a}	1.40^{a}	0.55^{a}	1.25^{a}	0.50^{a}	0.70^{a}
I	3.20^{b}	6.80^{bc}	2.95^{abc}	6.25^{a}	1.45^{a}	0.90^{a}	0.55^{b}	1.25^{a}	0.45^{a}	1.30^{a}	0.30^{ab}	0.45^{a}
F+I	3.50^{b}	5.85^{cd}	1.75^{cd}	5.90^{a}	0.40^{b}	0.95^{a}	0.70^{ab}	1.16^{a}	0.25^{a}	1.05^{a}	0.05^{c}	0.45^{a}
P	4.25^{a}	6.70^{bcd}	2.65^{bc}	5.35^{a}	0.45^{b}	0.65^{a}	0.80^{a}	1.10^{a}	0.30^{a}	1.00^{a}	0.35^{ab}	0.45^{a}
P+F	3.75^{ab}	6.25^{cd}	3.95^{a}	6.80^{a}	0.80^{b}	1.65^{a}	0.85^{a}	1.30^{a}	0.30^{a}	1.35^{a}	0.20^{bc}	0.50^{a}
P+I	2.95^{b}	5.95^{cd}	3.75^{a}	6.65^{a}	1.40^{a}	0.55^{a}	0.50^{b}	1.10^{a}	0.40^{a}	1.05^{a}	0.35^{ab}	0.35^{a}
P+F+I	1.60^{c}	5.30^{d}	2.00^{c}	5.55^{a}	0.50^{b}	0.60^{a}	0.50^{b}	0.95^{a}	0.15^{a}	1.00^{a}	0.00^{c}	0.30^{a}
Mean	3.34	6.69	2.71	6.31	0.73	0.99	0.68	1.20	0.33	1.18	0.26	0.50

NSKE= Neem seed kernel extract @10 ml/kg of seed; F= Fungicide- Bavistin @ 2 g/ kg of seed; I= Insecticide- Malathion @ 2 g/kg of seed; P= Polymer @ 6 ml/kg of seed

The protective role of film coating on seed from insect-pests in storage as well as in field was proved in many studies (Burris, 1992; Devay *et al*., 1991; McGee *et al*., 1994; Maity *et al*. 2015). The main disadvantage of traditional method of treating seeds with dry powders of pesticides is that large part of it gets wasted as dust off during handling and thus it cannot provide protection to seeds for longer duration. Film coating helps to hold the desired chemicals and plant protectants with seed to maintain its viability and vigour by avoiding pest and pathogen in the storage. In the present study, the film coated pesticides provided protection for longer duration by sustained use of the costly chemicals. While we are talking about precision farming in recent days, the controlled or sustainable release of plant protectants is very important and film coating holds a promising prospect at this point. Research also showed protecting effect of NSKE that repels the pest and pathogens from attacking the seeds. The adult emergence was inhibited completely by karanj and neem-oil, up to 100 days. No emergence of adults was occurred up to 66 days, with the caster-oil. Minimum grain loss was noticed, with castor, mustard and groundnut oils, at 1% level up to 100 days and no adverse effect was observed, on the seed germination. Patil and Tandale (1999) reported that neem oil at 0.5% concentration inhibited oviposition, adult emergence and seed infestation by *Callosobruchus chinensis* in green gram seeds that was stored healthy for only four months. Seck *et al*. (1991) reported that differentformulations of neem reduced fecundity and oviposition of *C. maculatus* in cowpea seed lot. Many researchers proved its efficacy in different crops, starting from mung bean (Rahman and Talukder, 2006) to cowpea (Patil and Tandale, 1999).

Conclusion

Cowpea is very much susceptible to disease and pests in storage and as well as field condition. Polymer film coating proved to provide better protection to seeds by holding the pesticides and additives onto the cowpea seed surface for longer duration. Neem oil is also a moderate option to preserve the cowpea seeds, besides film coating. The physiological processes in seed during storage get minimum exposure to external hazards due to barrier of coating hence deteriorative reactions lose pace and seed maintains vigour for longer period.

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