EFFECT OF SEED PROTECTANTS AGAINST PULSE BEETLE ON VIABILITY, VIGOUR AND HEALTH OF COWPEA SEEDS

By

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THESIS

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DECLARATION

I, hereby declare that this thesis entitled '**Effect of seed protectants against pulse beetle on viability, vigour and health of cowpea seeds**' is a bonafide record of the research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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CERTIFICATE

Certified that this thesis entitled **'Effect of seed protectants against pulse beetle on viability, vigour and health of cowpea seeds'** is a bonafide record of the research work done independently by **Ms. A. Libi Antony** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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LIST OF ABBREVIATIONS

FAO	-Food and Agricultural Organisation
DES	-Directorate of Economics and Statistics
KAU	-Kerala Agricultural University
^0C	-degree Celsius
Mm	-millimetre
g	-gram
Kg	-kilogram
Cm	-centimetre
mg	-milligram
dSm^{-1}	-desi Siemens per metre

Introduction

1. INTRODUCTION

Pulses are the dry edible seeds of pod bearing plants belonging to the family Fabaceae. Food and Agriculture Organization (FAO) recognizes 11 types of pulses: dry beans, dry broad beans, dry peas, chickpeas, cowpeas, pigeon peas, lentils, bambara beans, vetches, lupins and pulses nes (minor pulses). Minor pulses include lablab, jack bean, sword bean, winged bean, velvet bean, cowitch and yam bean. Under the slogan 'nutritious seeds for a sustainable future,' the United Nations, has declared 2016 as the 'International Year of Pulses', to raise awareness about the protein power and health benefits of all kinds of dried beans and peas, to boost their production and trade, and to encourage new andsmarter uses of these throughout the food chain.

Cowpea(*Vignaunguiculata*(L.)Walp) is one of the major grain legumes cultivated throughout the tropics and subtropics. During 2006-2007 more than 11.8 million hectare of cowpea crop was grown worldwide, and the total grain production amounted to approximately 5.4 million tons (FAO, 2007). West and Central Africa isthe leading cowpea producing regions in the world, producing 64 per cent of the estimated threemillion tons of cowpea seed produced annually. Nigeria is the world's leading cowpea producing country and is followed by Brazil (FAO, 2012).

Pulses, especially cowpea,complement well with the cereal based Indian diet as they contain considerable amounts of amino acids particularly lysine. In addition, they are rich in protein (17-43g), carbohydrate (20-60g) and have high levels of minerals such as calcium (60-240mg), iron (2.5-10.5mg) and phosphorous (290-690mg)(Otitoju*et al.*, 2015).

Unlike in other parts of the country, cowpea is widely cultivated as a vegetable cropin Kerala. During 2014-2015 it was cultivated across an area of 1004 hectares out of 3601 hectare planted under pulses (DES, 2016). The crop is grown throughout the year with the peak growing season coinciding with the onset of monsoon in June. Farmers usually store seeds of cowpea throughout the year as a buffer for the next sowing season. As in case of all pulses, safe storage of cowpea seeds over long periods remain a great challenge owing to infestation by pulse beetle, *Callosobruchus*spp.(Bruchidae: Coleoptera). In India, 17 species of bruchids belonging to 11 genera have been recorded as infesting different pulses (Jat*et al.*, 2013), *C. maculatus, C. analis* and *C. chinensis* being the predominant species. The bruchid infestation results in loss of weight, nutritional value, physical quality and seed viability (Booker, 1967 and Okunola, 2003). Up to 100 per cent infestation of pulse grains can occur within three to six months of storage (Singh, 1978; Maina*et al.*, 2011).

Mechanical, biological and chemical means have been advocated to manage this pest. Pulse beetle, being an internal feeder, is difficult to control using insecticides. However, the use of insecticides to protect pulse beetle in storage is often resorted to. Such indiscriminate use of insecticides often results in the development of pesticide resistance, hazardous effects on non-target organisms and environmental contamination. In addition to the above, farmers sometimes use the stored seeds for consumption too. Under these circumstances, it is not prudent to treat cowpea seeds with insecticides. Though fumigation has been advocated, it is difficult and less practical as most farmers store the seeds at home. Hence, there is a need to develop cheaper and safer methods for management of pulse beetle in cowpea. Of late,the useof botanicals with less toxic effectis on the increase (Sadeghi*et al.*, 2006). Use of botanicals, essential oils, inert diatomaceous earth and less toxic insecticides like spinosad have been recommended. The pest controlling efficacy of many plant derivatives has already been proved against several storage pests (Rahman and Talukder 2004, Mahdi and Rahman 2008). The negative environmental impact of such protectants in terms of insecticidal hazards is almost non-existent and could therefore benefit our agricultural sector.

However, information on the effect of such seed treatments on seed longevity and seedling growth of cowpea is limited. Considering the above, the present study was formulated with the following objectives:

- To assess the effectiveness of seed protectants against cowpea pulse beetle *Callosobruchus*spp.(F.) (Coleoptera: Chrysomelidae).

- To study the effect of seed protectants on seed viability, seedling vigour and seed microflora.

Review of Literature

2. REVIEW OF LITERATURE

Over 70 insect pests have been identified to attack stored grains. In most cases, the infestation is carried forward to the storehouses from the infested field crops and spread rapidly (Upadhyay and Ahmad, 2011).

Protecting cowpea during storage from the cosmopolitan pest *Callosobruchus* spp. is a challenge for both seed growers and farmers. Literature on the nature of pest, the loss incurred, the various seed protectants used to combat this pest, their mode of action and the physiological changes that occur in the seed during storage are reviewed henceforth.

2.1 The pulse beetle, *Callosobruchus*spp.

At least 20 species of the genus *Callosobruchus*are found to infest stored grain legumes *viz.*, cowpea, gram, arhar, soybean, moong, urd and moth. These include *C. analis, C. chinensis, C. dolichosi, C. imitator, C. latealbus, C. maculatus, C. nigripennis, C. phaseoli, C. pulcher, C. rhodesianus, C. semigriseus, C. subinnotatus and C. theobromae*(Tuda*et al.*, 2006). *Callosobruchus*spp. belongs to the super family Chrysomeloidea, family Chrysomelidae and subfamily Bruchinae. Earlier it was grouped under the family Bruchidae (Lawrence and Britton, 1991).

Among the species, *Callosobruchusmaculatus*was the most dominant in infesting pulse seeds. *C. maculatus* adults are usually 2.0 to 3.5 mm long. Male and female beetles are easily distinguished by general appearance. The antennae of both sexes are slightly serrate (Mbata*et al.*, 1997). The most distinguishing characteristics isthe colouration on the plate covering the end of the abdomen. In the female, the plate is enlarged and is darkly colored on both sides. In the male, the plate is smaller and lack stripes. Generally, females are larger in size than males, but there is much variation. In some strains, females are black in colour and males are brown. In common with other species of *Callosobruchus*, *C.*

maculatus has a pair of distinct ridges (inner and outer) on the ventral side of each hind femur, and each ridge bears a tooth near the apical end. The inner tooth is triangular, and equal to (or slightly longer than) the outer tooth (Beck and Blumer, 2014).

The fecundity of pulse beetleis about 100- 135 eggs per female. Eggs are whitish elongate, domed structures with oval, flat bases (Radha and Susheela, 2014). When newly laid they are small, translucent grey and inconspicuous. Eggs hatch after 3-6 days of incubation. Upon hatching, the larva bites through the base of the egg, through the testa of the seed and into the cotyledons. Detritus produced during this period is packed into the empty egg as the insect hatches, turning the egg white and making it clearly visible to the naked eye. Total larval and pupal period may vary between 12 and 20 days (Howe and Currie, 1964; Radha and Susheela, 2014) When multiple conspecific eggs are laid on a single seed, larval competition may be evident (Horng, 1997). Completion of life cycle takes 4-5 weeks and there may be 6-7 overlapping generations in a year. According to Ghosh and Durbey (2003), the life cycle of pulse beetle was completed in 25-30 days during summer whereas it took 40-50 days in winter.

2.2Infestation by pulse beetle and loss incurred in cowpea and other pulses.

The infestation of cowpea by pulse beetle initially begins in the field, where female insect lays eggs on the green pods. Grubs feed on the pod epithelium and remain concealed inside the developing seeds. When such seeds are harvested and stored, the pest population increases rapidly and results in total destruction within a short duration of three to six months (Maina*et al.*, 2011, Sujatha*et al.*, 2015).

Female lay eggs on the seeds; and the newly hatched larva bore into the seeds and feed inside. The larva is accountable for most of the grain damage. The larvae rescind seeds by feeding inside partially or completely and make them unfit for human consumption (Atwal and Dhaliwal, 2005). According to Koona and

Koona (2006), the visible signs of seed damage are the presence of holes caused by the adult beetles on the seed.

Losses of upto 20- 60 per cent have been reported in stored legumes under pulse beetle infestation (Gujar and Yadav, 1978; Lawrence and Britton, 1991, Umeozor, 2005). At times, the loss could be complete (Adugna, 2007; Udo and Harry, 2013). Gujar and Yadav (1978) had observed loss in protein content which made the seeds to be unfit for planting as well as for human consumption. The loss in seed germination due to bruchid attack may reach 100 per cent for grains with four holes per seed (Santos, 1971). The loss in seed weight commonly reached 50 per cent after only 3 months of storage (Hussain*et al.*, 1982).

Ofuya (2001) reported that infestation caused by pulse beetle resulted in dry weight loss, reduction in nutritional value (denaturing of protein) or physical quality (disfigured with egg covers or riddled with adult exit holes) and poor seed germination ability. Significant weight loss, decreased germination potential and reduction in commercial value of the seed in pulse beetle infested seeds have also been reported by Okunola (2003). Venkatesham*et al.* (2015) reported that the mean seed damage and weight loss were 7.87 per cent and 4.19 per cent respectively, after 30 days of infestation which increased to 99.33 and 48.73 per cent respectively after 120 days.

The damage caused by pulse beetle was distinctive. Larvae fed and developed inside the seed and when adults emerge they left a neat circular exit hole. Each insect consumed approximately 25 per cent of the seed from which it developed. Heavy infestation caused the seed to heat up which resulted in loss of quality and mould growth (Asawalam and Anaeto, 2014). The larvae of this pest penetrated into the pulse grains and fed onendosperms, which leads to damage ofgrains as well as deterioration in nutritional value and germination capacity (Roy *et al.*, 2014).

2.3 Management strategies to combat pulse beetle infestation

According to Amrutaet *al.* (2015) the quality of seeds in storage is influenced by several factors like variety of seed, initial seed quality, storage condition, moisture content, insect pests, bacteria and fungi. The poor storage of pulse seeds is a problem owing to infestation by *Callasobruchusmaculatus*(F.) which causes qualitative and quantitative losses. Several management practices were followed for the control of pulse beetle.

Fumigation though an effective method, cannot be practiced in our villages because the storage structures are not airtight and these are commonly built inside the residential areas (Selvaraj*et al.*, 2012). Patel and Joshi (2014) stated that the amounts of fumigants absorbed are greatly increased by presence of fat in grain kernel and the exposure period. As the duration of exposure period increases, its residual effect on germination, vigour and other qualities of seeds gets deteriorated. In contrast, plant products, inert dusts and edible oils traditionally used against pulse beetle appear to be quite safe and promising. Several studies have reported the insecticidal action and growth inhibiting effects of plant products on pulse beetle and the treated seed viability. World over, as many as 2,400 plant species have been recorded that have potential pesticidal properties and biological activity against a wide range of pests (Grainge and Ahmed, 1988).

The seed potentiation, mainly achieved by treating the seeds with various chemicals and botanicals, can reduce the infestation and maintain the quality of the seed in terms of viability and vigour for longer period in storage (Duruigbo, 2010; Basavegowda and Arunkumar, 2013). The important management strategies adopted are reviewed below.

2.3.1 Bioefficacy of botanicals against pulse beetle

Botanicals play a much important role in maintaining seed quality parameters and protection against pulse beetle for their non-toxic effects and moderate efficacy without leaving any residues in the environment. Jacobson (1989) pointed out that the most promising botanical insect-control agents were in the plant families of Annonaceae, Asteraceae, Clamiaceae, Meliaceae and Rutaceae.

Among the botanicals, one of the most investigated is neem (*Azadirachtaindica*). Parts of neem such as leaves, seed kernel, oil, pulp and husk have been found to possess pesticidal properties. Neem products possess anti-feedant and repellent properties because of compounds like isoprenoids, glycerides, polysaccharides, flavonoids, aliphatic compounds *etc.* (Devakumar and Sukhdev, 1993). Among the chemical constitutents, azadirachtin is the most potent and abundant one having antifeedant and ecdysis inhibition properties on several major pests. However, the greatest concentrations of these substances are found in the seed. It reduces the level of the insect hormone ecdysone thereby disrupting the insect's molting process so that the immature larvae cannot develop into adults. After treatment with neem-based pesticides, insects become crippled with distorted wings. Or the immature larvae and nymphs remain in an immature stage and then die. Some soft-skinned insect larvae may be killed by direct contact with the spray. Adults are not killed by the growth regulating properties of azadirachtin but mating and sexual communication may be disrupted which results in reduced fecundity (Schmutter, 1990). Leaves and kernels of neem slightly increased the adult mortality of *C. maculatus*(Seck*et al.,* 1991).

The efficacy of sweet flag, goat weed(*Ageratum conyzoids),* *Lantanacamara*, Indian privet (*Vitexnegundo*), mug-wort (*Artimisia vulgaris*), chinaberry (*Meliaazederach*), rice husk ash, mustard (*Brassica* spp.) oil and neem oil were evaluated for their effects against pulse beetle (*C. maculatus*F.). Rhizome powder of sweet flag, rice husk ash and mustard oil exhibited a significant effect in killing the pulse beetle within a week at 0.5, 1 and 2 per cent concentrations. Neem oil was found very effective with 100 per cent mortality of the beetle within two days. Other tested materials also revealed insect killing properties but with comparatively lower efficacy than that of sweet flag rhizome powder, mustard oil, neem oil and rice husk ash (Paneru and Shivakoti, 2001).

Aslam*et al.* (2002) tried six spice powders against *C. chinensis*. The data were taken on days to 100 per cent mortality; days to adult emergence, number of adult emergence and grain weight loss. Among the six spice powders, clove and black pepper exhibited minimum days to 100 per cent mortality, minimum number of adult emergence and minimum per cent weight loss compared to other treatments and the control.

Studies were conducted by Dhakshinamoorthy and Selvanarayanan (2002) to evaluate the effect of some natural products against *C.maculatus*. The treatments comprised of leaf powders of neem, notchi (Indian privet), pungam, citrus and thulasi (*Ocimum* spp.); fly-ash, kitchen ash, castor oil, red earth, malathion (as standard control) and the untreated control. The results showed that the mortality of the beetle at 7 days after treatment was the highest (100%) in castor oil followed by neem leaf powder (91.66%).

Umrao and Verma (2002) conducted an experiment to study the efficacy of various plant products *viz.,* some leaf powders, oils of coconut, mustard, groundnut and neem products against pulse beetle *C.chinensis* on the basis of per cent grain damaged and per cent loss in weight. The mustard and groundnut oils were on par, registered less infestation having 8.86 and 11.35 per cent damage respectively. The coconut oil provided less infestation having 12.40 per cent grain damage. Oils of mustard, groundnut and coconut were not significantly different between them and these oils were superior to rest of the treatments and control.

Shaheen and Khaliq (2005) examined the management of pulse beetle, *C. chinensis*(L.) in chickpea using fly ash, cow dung ash, *Acacia* ash, red soil powder and turpentine oil. The results revealed that fly ash at 1.0 g per 50 g of grains recorded the lowest number of days (5.06) to 100 per cent mortality of released adults, minimum fecundity (0.86 eggs per grain), minimum holes (0.41 per grain), lowest number (3.14) of F_1 adults emerged, maximum inhibition (78.62%) of F_1 adults, minimum weight loss (9.63%) and the minimum of 2.86 days to 100 per cent mortality of F_1 adults. However, fly ash proved to be the best in managing pulse beetle infestation to lower levels followed by turpentine oil and cow-dung ash while red soil powder and kikar ash were less effective and were similar to the control at their lower application rates.

An experiment was conducted by Sharda*et al.* (2006) to assess the effect of neem leaf powder on infestation of the pulse beetle *C. chinensis*L. in stored pigeon pea. It was concluded that the general mixing of seeds with neem leaf powder has been the effective control measure of pest infestation.

Sathyaseelan*et al.* (2008) studied the efficacy of indigenous pesticidal plants *viz., Prosophis*sp.,*Nerium*sp., *Ocimum*sp., *Acalypha* sp., *Catheranthus*sp. and *Vitex*sp. against pulse beetle, *C. chinensis*(L.) in green gram. Five per cent leaf extract of *Vitex*sp. was most effective in inhibiting the oviposition (26.6eggs/ female) as that of 79.4eggs/ female in untreated control. It was concluded that *Vitex*sp. treated seeds at five per cent caused maximum reduction in adult emergence (85.0%) followed by *Catheranthus*spp.(83.7%), *Acalypha* spp.(73.3%),*Nerium*spp.(70.0%), *Ocimum*spp.(68.7%) and minimum reduction was reported in *Prosophis*spp.(60.0%).

An experiment was conducted to find out the efficacy of dodder vine (cuscuta)extract as seed protectant against pulse beetle, *C. chinensis* on chickpea seed. Dodder vine extract was found effective in checking oviposition, adult progeny development and severity of seed damage. Seeds treated with five per cent concentration of dodder vine extract recorded lesser oviposition, adult emergence and seed weight loss by *C. chinensis* and this concentration might be useful in protection of pulse seed (Rahman*et al.*, 2010).

Hossain and Haque (2010) conducted an experiment to evaluate the efficacy of some indigenous leaf and seed extracts against pulse beetle, *C. chinensis*L. on chickpea seeds. All the tested extracts except methi were found to significantly check the oviposition, adult emergence, seed infestation and weight loss as compared to control. The extracts of neem seed had no adverse effects on seed germination up to three months of storage.

A laboratory experiment was conducted to investigate the insecticidal activities of seven plant materials namely: citrus leaf powder (CLP), *Acacia* leaf powder (ALP), *Ocimum* leaf powder (OLP), mahogany bark powder (MBP), hot pepper powder (HPP), ginger powder (GP) and mahogany wood ash (MWA); and a synthetic insecticide, pirimiphos-methyl dust (PMD) as check in the suppression of *C. chinensis*. The results showed that MWA was more effective in causing mortality in adult *C.chinensis* while CLP was significantly ($P<0.05$) more effective in reducing adult emergence, per cent hatching inhibition rate and per cent holed cowpea seeds. Application of CLP at the rate of 50 g/kg of cowpea seeds was recommended for the control of *C. chinensis* development and damage to cowpea seeds while in storage (Singh, 2011).

Pradyumn and Jakhmola (2011) evaluated the efficacy of botanical extracts on biological activities of pulse beetle *C.maculatus*F. on green gram. Per cent reduction in adult emergence continuously decreased up to 90 days post treatment under all botanical treatments. One day after treatment, reduction in adult emergence varied from 25.50 to 65.10 per cent, whereas, it was 6.63 to 25.90 per cent at 90 days after treatment.

The effectiveness of 17 indigenous plant powders as grain protectants was assessed against *C. chinensis*(L.). Among all the tested plant materials, tobacco leaf powder had promising effects on inhibiting oviposition and reducing adult emergence, seed infestation, and weight loss by *C. chinensis*. Tobacco leaf powder at 20.0 g/kg seeds offered complete protection of chickpea seeds (Hossain*et al.* 2014).

Ramazeame*et al.* (2014) reported that neem kernel powder @ 5 g/kg seed can be recommended for the management of the pulse beetle in store house. Germination was on par with untreated check in all the treatments except neem kernel powder, sweet flag rhizome powder, activated clay and pongam oil, indicating that these treatments did not affect germination to a large extent.

The efficacy of different neem products like neem seed powder, neem cake, neem dry leaf powder, neem oil and commercially available neem formulations *viz.*, Econeem plus, Neemindia and Neemazal were evaluated in the laboratory for the control of pulse beetle, *C. chinensis* in stored black gram. All the neem formulations were found to be effective against *C. chinensis* up to 15 months of storage. Neem oil @ 5 ml/kg seed affected badly the germinability and seedling vigour of black gram seed under storage. The neem formulations *viz.*, Neemazal, Econeem plus and neem cake were on par with deltamethrin and were found to be very effective against pulse beetle and improved the storability and quality of black gram seed (Rajasri*et al.* 2014).

Valsala and Gokuldas (2015) conducted an experiment to study the repellent and oviposition deterrent effects of different concentrations (0.5, 2, 4 and 6%) of leaf extract of *Clerodendruminfortunatum* on the pulse beetle. Repellency was found to increase with an increase in concentration and decrease with exposure time. Dose dependent effects were observed in the case of oviposition deterrence and adult emergence of insects while treating with the extracts. Maximum oviposition deterrence and minimum adult emergence were exhibited in insects present in samples treated with 6 per cent concentration of leaf extract. Per cent reproduction control exhibited by the extract was 97.1.

2.3.2 Bioefficacy of oils against pulse beetle

Besides plant extracts, essential oils have been shown to exhibit insecticidal activity against field crop pests and storage pests. Many of these oils are also reported to have high oviposition and growth inhibitory activity

A laboratory experiment on pre-storage seed treatment of chickpea with the oils of aripple(*Lantana camara)*, karanj (*Millettiapinnata*), eucalyptus, neem, palas (*Buteamonosperma*), citronella (*Cymbopogon*sp.) and anona (*Annona*sp.) against *C.chinensis* was conducted by Biswas and Biswas (2005). Citronella and neem oil at 2.5 and 5.0 ml/kg of seed effectively controlled *C. chinensis*population by reducing oviposition rate, seed damage and weight loss due to pulse beetle infestation, as well as recording the highest percentage of gram seed germination.

The efficacy of seven edible oils *viz.,* sunflower, mustard, groundnut, sesame, soybean, olive and oil palm against *C. chinensis*was studied by Khalequzzaman*et al.* (2007). Groundnut oil at one per cent prevented adult emergence and achieved minimum grain loss upto 66 days after treatment.

Bajya*et al.* (2007) studied the efficacy of few vegetable oils against *C. chinensis*on cowpea seeds and reported that neem oil was most effective in causing adult mortality (96.0%) three days after treatment, followed by castor oil causing 84.0 per cent mortality of the pest both used at 1.2 ml/100 g seeds. Cowpea seeds treated with coconut oil recorded less bruchids damage (Swella and Mushobozy, 2007).

Sharanabasappa and Kulkarni (2008) conducted a laboratory experiment to study the effectiveness of neem, castor, karanj, mustard, sunflower, oil palm and coconut oil against the fecundity of *C. chinensis*in greengram. Neem oil, castor oil and karanj oil recorded the lowest number of eggs per 50 seeds at 30 days after treatment and a similar trend was observed at 60, 90 and 120 days after treatment.

No adverse influence on germination of seeds was reported at 60 and 120 days after treatment.

Ani (2010) investigated the effect of some oil extracts *viz.*, cashew nut oil, coconut oil and neem leaf oil in controlling stored black bean weevil (*C. chinensis*) and concluded that the treatment with coconut oil extract was more effective than the extracts of other oils.

The fumigant toxicity of essential oils against pulse beetle, *C. maculatus*F. (Coleoptera: Bruchidae) was examined by Sivakumar*et al.* (2010). The results stated that the lowest LD_{50} value was observed for eucalyptus oil (11.66 µll-1of air) and the LD_{50} value of geranium was the highest (25.11 µl l-1 of air).

Lal and Raj (2012) studied the efficacy of neem, eucalyptus, sunflower and castor oil at 1 ml and 3 ml/ kg of pigeon pea as grain protectant against *C.maculatus.* The doses *i.e.* 1 ml and 3 ml/ kg seed reduced the egg laying as well as adult emergence and delayed the developmental period. The infestation after 120 days of treatment with higher concentration (3ml/kg) of eucalyptus, castor and neem oilwas recorded in terms of reduction in weight loss of the grain, which gave 100 per cent control while 1ml/kg seed dose of these oils was also found effective (0.33, 0.46 and 0.55%).Out of two dosages applied, 3ml/kg seed was found most effective in minimizing the pest incidence. Seed treatment with different oils @ 1ml and 3ml/kg seed has no significant adverse effect on seed germination after 120 days of treatment.

The efficacy of seven vegetable oils *viz.*, mustard, neem, karanj, cedar wood, apricot and olive oil at 1, 3 and 5 per cent concentrations against pulse beetle infestation and germination of pea seeds were examined. Neem oil was the most effective treatment allowing only 0.11 per cent damage, followed by karanj(0.18%), cedar (0.29%), mustard (0.47%), olive (0.87%) and apricot (1.43%). Seed damage in untreated control was 9.72 per cent. No seed damage was recorded in neem oil at five per cent concentration and it was at par with its lower concentrations (3 and 1 %), karanj(5, 3 and 1%), cedar and mustard (5 and 3 %), olive and apricot (5%) (Bhardwaj and Verma, 2013).

Vishwamithra*et al.* (2014) tested the efficacy of vegetable oils and insecticides against pulse beetle in pigeon pea. The study indicated that all the four oils *viz.*, soybean, sesame, eucalyptus and karanj oil used at the rate of 3ml/kg seed significantly reduced the fecundity, adult emergence and seed infestation and were on par with the chemical protectants deltamethrin 2.8 EC (0.04ml/kg seed) and spinosad 45 SC (4 ppm). Theinsecticides caused 100 per cent mortality at 24 hours after treatment while all the oils, except karanj oil which recorded 82.67 per cent mortality at 24 hours after treatment, were slow in their action and caused less mortality of test insect even after seven days of treatment.

An experiment was conducted by Fatiha *et al.* (2014) to study the efficacy of oils of some medicinal plants namely wild sage (*Salvia verbenaca*L.), sea squill(*Scillamaritima*L.), and white wormwood (*Artemisia herba-alba*)against cowpea weevil, (*C. chinensis*L.). Their results showed that the tested plant oils have a real organic insecticide effect. The essential oil of *Artemisia* proved most effective as a biocide; achieving a mortality rate of 100 per cent. A significant reduction in longevity was observed under the effect of 30 µl of *S. maritima*(1.3 days) and *S. verbenaca*(2.8, 4.6 days), respectively, for males and females compared to 8 and 15 days for the control. For fecundity, an inhibition of oviposition was obtained using 30 µl of *Salvia* and *Scilla*essential oils. The test on the seed germination using different essential oils, showed no damage to the germinating seeds.

Ahmad *et al.* (2015) evaluated the effectiveness of four environment friendly treatments, *viz.*, sesame oil, neem seed powder, hot water and cold water for management of pulse beetle, *C.chinensis* infesting faba bean and cowpea.

They revealed that all the treatments significantly reduced the infestation of bruchid beetle from first month and fifth month. The most effective treatments were found to be sesame oil (5 drops), neem seed powder (10 g) and hot water (50 L) each in 250g grains.

2.3.3 Bioefficacy of spinosadagainst pulse beetle

Spinosad, a bio-insecticide is a promising substitute to other commercially available insecticides for the control of storage insects. It is a fermentation product of the actinomycetes bacterium *Saccharopolysporaspinosa,* discovered by Mertz and Yao during 1980's (Mertz and Yao, 1990). Spinosad is lethal to insects by ingestion or contact, and it acts on insect's nervous system at the nicotinic acetylcholine and gamma-aminobutyric acid (GABA) receptor sites (Salgado 1997, 1998).

The US Environmental Protection Agency has classified spinosad as a reduced risk insecticide due to its low effective use rate and safety to the environment and mammals. It is considered as natural product suitable for use in organic agriculture by numerous national and international certification bodies (Racke, 2007). It has been effectively used for the protection of more than 100 major crops worldwide against insect pests belonging to Lepidoptera, Coleoptera, Diptera, Thysanoptera and Orthoptera. Also it is reported that the insecticide spinosad will be used more widely in many countries for the management of storage pests (Vayias*et al.*, 2009). In addition to replacing synthetic pesticides, spinosad can be used to manage resistance to synthetic pesticides (Huang and Subramanyan, 2004).

Sanon*et al.* (2010) was the first to evaluate spinosad against *C.maculatus*revealed thatspinosad caused high mortality of adult *C. maculatus* and decreased the number of eggs. In on-farm experiments, it was effective in controlling *C. maculatus*. After six months of storage, number of insects emerging from cowpea seeds was reduced by more than 80 per cent in seeds coated with spinosad. On-farm trial confirmed that spinosad could be used for protecting cowpea grains from pulse beetle attack during post-harvest storage.

The effectiveness of spinosad dust formulation containing 0.125 per centspinosad, was evaluated against adults *C.maculatus*(F.) on four commodities *viz.,* chickpea, split pea, cowpea and lentil. Spinosad was applied at three dose rates: 0.1, 0.2 and 0.3 g/kg, corresponding to 0.125, 0.25 and 0.375 mg/kg of the active ingredient, respectively. The application of spinosad significantly reduced progeny production in four commodities tested in comparison with the untreated ones. High reduction in progeny production was recorded when spinosad was applied at the rate of 0.3 g/kg on split pea and cowpea (94.33 and 94.21%, respectively). The results revealed that spinosad dust could be successfully used as a grain protectant against *C. maculatus* (Khashaveh *et al.,* 2011).

Amrithakumari (2011) found that among the various seed protectants used against pulse beetle, spinosad at the rate of 70ppm was most effective with no adverse effect on seed viability upto one month after treatment.

Parsaeyan*et al.* (2012) evaluated the lethal and sublethal effects of diatomaceous earth and spinosad against *C. maculatus*. The results showed that the LC_{50} values at 24 and 48 h after treatment were 1.47 and 0.2 g/m^2 for diatomaceous earth and 102.9 and 68.8 mg ai/l for spinosad, respectively. Treatment with LC_{20} concentration of both diatomaceous earth and spinosad reduced the fecundity of the pest by 71.5 per cent and 17.2 per cent, the egg hatching rate by 57.5 per cent and 27.8 per cent, and adult longevity by 74.7 per cent and 17.1 per cent, respectively, compared to the control. Pupal period of the insect exposed to LC_{20} concentration of diatomaceous earth and spinosad increased by 4.8 per cent and 2.3 per cent, respectively, compared to the control. The sublethal effect study showed that both diatomaceous earth and spinosad negatively affected life parameters of cowpea beetle.

An experiment to study the efficacy of insecticides like fenvalerate, malathion, deltamethrin, spinosad, cypermethrin and dichlorvos was conducted by Rajput*et al.*(2013). They reported that spinosad was the most effective treatment against *S. oryzae*, *C. chinensis* and *C. maculatus* with LC_{50} value of 0.08 ppm, 0.24 ppm and 0.05 ppm, respectively. The next best treatment was deltamethrin with LC_{50} value of 0.66, 0.69 and 0.76 ppm against *S.oryzae* and *C. chinensis* and *C.maculatus* respectively.

Duraimurugan*et al.* (2014) determined the toxicity of Spinosad 45 SC against adults of pulse beetle, *C. chinensis*and its hymenopteran parasitoid, *Dinarmusbasalis* using dry film contact toxicity method under laboratory conditions. They revealed that spinosadhas contact toxicity against *C.chinensis*and the median lethal concentration (LC_{50}) values at 24, 48 and 72 h post-treatment were 51.05, 11.99 and 1.92 ppm respectively. Contact toxicity of spinosad to *D. basalis*was higher with LC_{50} values of 0.130, 0.062 and 0.015 ppm at 24, 48 and 72 h post-treatment respectively. Field evaluation of Spinosad 45SC in mungbean and urdbean showed that the insecticide was effective in reducing pod (82.9 to 84.9% reduction over control) and seed (76.5 to 78.1% reduction over control) damage due to the pulse beetle and was comparable with conventional insecticide dichlorvos 76EC (81.8 to 90.2% and 82.4 to 84.4% reduction in pod and seed damage respectively).They concluded that the biologically derived insecticide, spinosad, can be used for efficient pest management programs against pulse beetle (*C. chinensis*) infesting seeds of legumes under field and storage conditions.

Rashmi*et al.* (2014) studied the efficacy of insecticides, *viz.* emamectin benzoate, spinosad and deltamethrin against *C. chinensis*on stored pigeon pea seeds in HDPE bags. They found out that the infestation caused by pulse beetle was the lowest (2.33) in emamectin benzoate treated pigeon pea seeds after two months of storage in HDPE bag which was statistically at par with deltamethrin. Similar trend was observed after four and six months of storage withemamectin benzoate being superior (4.33 and 7.00, respectively) to spinosad and deltamethrin.

An experiment was conducted to study the effect of chemical treatment on seed storability of field pea. The seeds were treated with emamectin benzoate @ 40mg/kg, spinosad @4.4mg/kg, indoxacarb @ 13.8mg/kg, rynaxypr @9.9mg/kg, chlorfenapyr @ 0.2mg/kg, deltamethrin 2.8EC @0.04 ml/kg and stored in jute canvas bags under ambient storage conditions. The observations were recorded on germination, seedling length, seedling dry weight, seed vigour index, field emergence and insect infestation at trimonthly interval. Results showed that the highest germination and vigour parameters as well as field emergence with minimum insect infestation was maintained through the treatment withdeltamethrin 2.8 EC @ 0.04ml/kg or spinosadat the rate of 4.4 mg/kg stored in jute canvas bags under ambient conditions (Singh *et al.* 2015).

Laboratory studies were carried out to determine the efficacy of newer insecticides *viz.*, flubendiamide, emamectin benzoate, spinosad, thiodicarb, indoxacarb and lufenuron against the pulse beetle, *C.chinensis*in greengram. Among the insecticides evaluated, spinosad and emamectin benzoate recorded higher mortality (>90%) of adult beetles within seven days of treatment compared to the check deltamethrin (50%). After nine months of storage, spinosad, indoxacarb and emamectin benzoate were found to be most effective against *C. chinensis*with low insect damage of 0.5, 0.6 and 1.0 per cent respectively, compared to deltamethrin (23%) and untreated control (99%). The germination of greengram seed dropped to 20 per cent in untreated control within three months of storage, whereas, it was maintained above 90 per cent in all other treatments except flubendiamide (72.7%). Spinosad, indoxacarb and emamectin benzoate maintained high germination (> 90 %) up to nine months of storage compared to deltamethrin (28%) and untreated control (0%) (Mandali and Rani, 2015).

2.3.4 Bio-efficacy of entomopathogenic fungi against pulse beetle

Entomopathogenic fungi include those genera of fungi that associate with insects and some other arthropods like spiders and mites. They have the ability to attach and penetrate host cuticle and multiply within the host and ultimately result in the death of host insect (Easwaramoorthy, 2003). The ability of entomopathogenic fungi to control stored grain pests, particularly coleopterans has been studied by several instances (Adane*et al.*, 1996; Rice and Cogburn, 1999; Kassa*et al.,* 2002) a number of which have assessed fungal pathogens for the control of *C. maculatus* in cowpea.

An experiment was conducted by Lawrence and Khan (2002) for the comparison of the pathogenicity of the entomopathogenic fungi, *Beauveria bassiana, Metarhiziumanisopliae*and *Paecilomycesfumosoroseus*to adults of*C.maculatus.* They revealed that the *M. anisopliae*had the lowest LD_{50} value (2.33 x 10^6spores/ml). However, the lowest LD_{50} value was displayed by *B. bassiana* (4.14 days). There was no significant difference (p=0.05) between the LT_{50} values of *M.anisopliae*and *P. fumosoroseus*treated seeds.

Cherry *et al.*(2004) evaluated twelve indigenous and exotic isolates of *B. bassiana* and *M.anisopliae* for their virulence and their ability to suppress populations of *C.maculatus*F. in stored cowpea. They reported that *B. bassiana* 0362 was the most virulent isolate followed by *M. anisopliae*0351.

An experiment was conducted to test the suppressive efficacy of entomopathogenic fungus*Beauveria bassiana* against adults of *C.maculatus*and *Sitophilusgranarius*on stored grains in darkness. Probit analysis showed that the lowest LT_{50} values in suspensions with highest concentrations(2.3x10^7 conidia per ml) were 6.63 and 10.45 days for *C.maculatus*and *S. granarius,* respectively (Shams *et al.*2011).

Shiva *et al.* (2011) conducted a bioassay with five different concentrations of *B. bassiana* ($1x10^4$ to $1x10^8$ ml^{-1}) against pulse beetle, *C.maculatus*. The results revealed that the funguscaused oviposition reduction and 100 per cent adult mortality at higher concentrations. At higher concentrations ($1x10^8$ ml^{-1}), reduction in oviposition was 60.58 per cent, and adult mortality was 99.44 per cent respectively at 92 hours.

The efficacy of different formulation of two entomopathogenic fungi,*Metarhiziumanisopliae*(Deuteromycotina: Hyphomycetes) and *Beauveria bassiana* (Ascomycota: Hypocreales) against cowpea bruchid, *C. maculatus* was investigated by Radha (2012). The results showed that treatment with liquid formulation of *Baeuveria bassiana* resulted in adult mortality of 96 per cent at 5 $x10^6$ conidial concentrations, 96 h after treatment and that LT_{50} value was only 1.24 per cent. Comparison of LC_{50}, LT_{50} values and mortalities indicated that in both assays, *B. bassiana* was consistently more virulent to bruchids.

Francisco *et al.* (2012) conducted an experiment to investigate the pathogenicity of different isolates of *Beauveria bassiana* to control *Callosobruchusmaculatus*F. in adult phase under laboratory conditions. They found that mortality varied from 12.24 to 100 per cent in the course of nine days experiment. The isolates of *B. bassiana* were highly pathogenic as confirmed by mortality over 40 percent in the insects treated until fourth day. in all conidial concentrations tested. Among the isolates studied, URM 2921, URM 2923 and URM4544, were reported as the most virulent to the beetle.

2.3.5 Effectiveness of other inorganic and organic substances used against pulse beetle

Seed treatment with inert materials has been reported to be very effective in maintaining seed quality because it hinders the activities of storage pests and fungi (Gupta *et al.*, 1989). Ebeling (1971) stated that diatomaceous earth was composed of fossils of phytoplanktons (diatoms) which absorb the epicuticularlipids of the insect cuticle, causing death through desiccation. Diatomaceous earth derived from mineralized rocks is also known to be effective in the control of stored grain pest since they have silica in their composition which absorbs lipids from the waxy outer layer of insect's exoskeletons causing dehydration.

Subramanyam and Roesli (2000) reported that diatomite kills by disturbing the oily or waxy outer cuticular layer which protects insects from dehydration and when the thin waterproof layer of the epicuticle is lost, the insect loses water and dies from desiccation.

Apart from botanicals and oils, inert dusts like diatomaceous earth (DE) also play a major role in the management of pulse beetle. According to Remya (2007), ovipositing female of*Callosobruchus*spp. inspect seeds by palpating the seed coat before laying eggs, and this behaviour leads to the accumulation of a considerable amount of DE from the treated seeds on the ovipositor, antennae, palpi, mouthparts, and other delicate organs. Such accumulations of DE may suppress physico-chemical receptive sensillae on these organs leading to reduced activity or survival rate.

Mahdi and Khalequzzaman (2012) studied the efficacy of diatomaceous earth (DE) and other inert dusts (kaolin powder, paddy husk ash, coal ash, alluvial soil, china clay) and a dust formulation of the insecticide carbaryl against pulse beetles *C. chinensis*and *C.maculatus*. They reported that diatomaceous earth at the rates of 1600 ppm produced high mortality. Other dusts and clays used were inactive against both *C. chinensis*and *C. maculatus*but in combination with DE they also provided some sort of synergistic effects.

Inert materials like activated clay, kaolinite and diatomaceous earth have been found to be effective in controlling pulse beetle. Among theses, diatomaceous earth was found to cause high mortality rates in the adult populations of *C. maculatus*(Neda*et al.*, 2012).

An attempt was made by Arumugam*et al.* (2016) to use nano-silicas or abrasives used to coat pulseseeds against infestation by stored product pests. They observed that the physical characteristics of seeds play a significant role in limiting the coating or covering maximum surface area on the seeds by nanosilic. They found that nanosilica coating was not much influenced by the surface properties and the seeds were not protected from the infestation of *C. maculatus*. But, majority of the seeds were protected from the infestation of stored pest with the treatment of nanosilica showed their efficacy in stored product pest control.

Materials and Methods

3. MATERIALS AND METHODS

The study was carried out in the Department of Seed Science and Technology, College of Horticulture, Vellanikkara during the year 2014-2016, aiming to analyze the effect of seed protectants against pulse beetle on viability, vigour and health of seeds of cowpea varieties Lolaand Kanakamony. The details of materials and techniques used during the course of the study are described hereunder.

3.1 Location and climate

The study was conducted in the Department of Seed Science and Technology, College of Horticulture, Kerala Agricultural University (KAU), Vellanikkara P.O., Thrissur. Vellanikkara is located 40 m above MSL at 10^0 54' North latitude and 76^0 28' East longitudes and experiences humid tropical climate with relative humidity remaining above 75 per cent for most part of the year (Fig 1). The monthly mean maximum temperatures during the storage period varied between 30.3^{0}C (July 2016) and 36.3^{0}C (March 2016), while the mean minimum temperature ranged from 23^{0}C (February 2015) to 26.2^{0}C (April 2016). Highest rainfall during the experimental period was recorded in May 2015 (629.8mm) with the relative humidity reaching the maximum (85%) in June 2015.

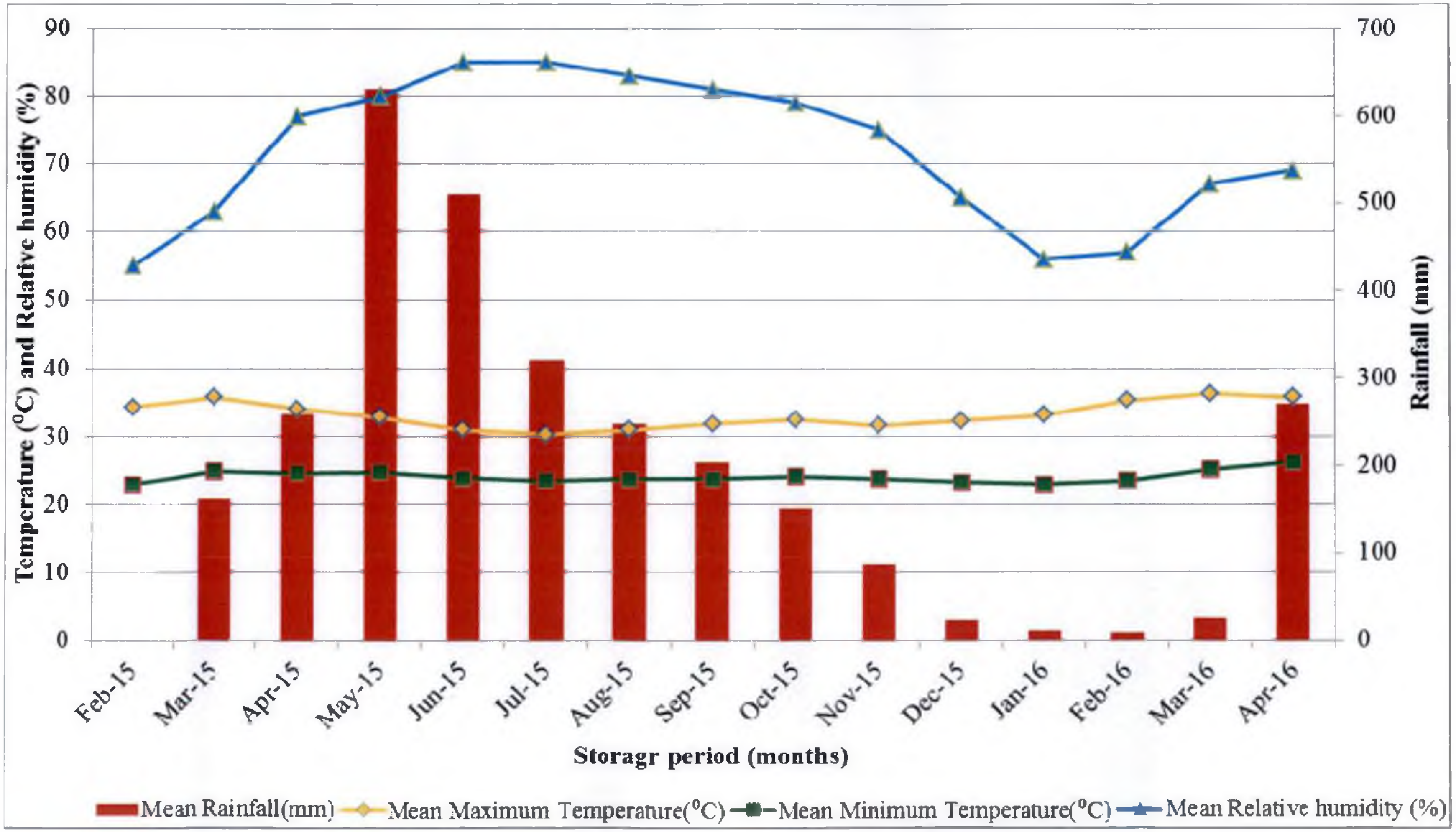
3.2 Experimental material

The study was conducted using the seeds of semi-trailing cowpea variety Kanakamony and the trailing variety Lola, released by KAU. Seeds of both the varieties Lola and Kanakamony were procured immediately after harvest from the Department of Olericulture, College of Horticulture and Plant Propagation and Nursery Management Unit, Vellanikkara respectively.

3.3 Experimental method

Separate experiments were conducted for both Lola and Kanakamony varieties following a completely randomized design (CRD) with thirteen treatments and three replications.

Fig 1. Mean maximum and mean minimum temperature (^{0}C), relative humidity (%) and rainfall (mm) during the storage periods of two varieties Lola: Feb 2015- Feb 2016 and Kanakamony : Apr 2015 – Apr 2016



3.3.1 Treatment details

The seed protectants were selected on the basis of their reported insecticidal and ovicidal activity against pulse beetles, *Callosobruchus*spp. Seeds of each variety were treated with seed protectants listed in Table 1 and compared to respective untreated seeds that served as control (Plate 1).

Table 1: Treatment details

Treatment	Common name	Dose/kg of seed
T_1	Neem oil	10 ml
T_2	Castor oil	10ml
T_3	Coconut oil	10ml
T_4	Sweet flag rhizome powder	10g
T_5	Neem leaf powder	10g
T_6	Paanal leaf powder	10g
T_7	Karinotchi leaf powder	10g
T_8	Neem kernel powder	10g
T_9	Rice husk ash	10g
T_{10}	Diatomaceous earth	10g
T_{11}	*Beauveria bassiana*	$1x10^8$ spores/ml
T_{12}	Spinosad	70ppm
T_{13}	Control (untreated seeds)	-

Neem: *Azadirachtaindica*
Coconut: *Cocosnucifera*
Paanal:*Glycosmispentaphylla*
Castor:*Ricinuscommunis*
Sweetflag:*Acoruscalamus*
Karinotchi :*Vitexnegundo*

Plate 1: Seed protectants used for seed

Neem oil

Castor oil

Coconut oil

Sweet flag rhizomepowder

Neem leaf powder

Paanal leaf powder

Karinotchi leaf powder

Neem kernel powder

Rice husk ash

Diatomaceous earth

Beauverria bassiana

Spinosad

3.3.2 Procurement and preparation of seed protectants

Fresh leaves of karinotchi, neem and paanal as well as neem seed kernels and rhizomes of sweet flag were collected and air-dried in shade. These were then ground to fine powder separately in an electric grinder. The resultant powder was passed through a 25-mesh sieve to obtain a fine dust to treat the seeds. Rice husk ash was obtained by burning paddy husk. Vegetable oils like neem oil, castor oil, coconut oil and commercial formulation of insecticide spinosad (Tracer 45 SC) wereprocured locally.. The entomopathogenic fungus *Beauveria bassiana* was obtained from All India Co-ordinated Research project on Biological Control of Crop Pests and Weeds (AICRP on BCCP & W), College of Horticulture, Vellanikkara. Diatomaceous earth was received from Agripower, Australia through the network project coordinated by Dr. N.B. Prakash, Professor, Department of Soil Science and Agricultural Chemistry, University of Agricultural Sciences, Bangalore.

3.3.3 Procedure of seed treatment and storage

Seeds of each variety dried to less than 10 per cent moisture were treated with the seed protectants given in Table 1 by mixing the required quantity of seeds with the protectants. Approximately 25g each of the seeds treated with seed protectants were then packed in polythene bags of 700 G thickness and heat sealed. Each replicate of a treatment comprised of 13 such packs, one each intended to be used for recording observations of a particular month over the storage period of 13 months. Both treated and untreated seeds were stored under ambient conditions for a period of 13 months. The storage period of variety Lola extended from February 2015 to February 2016 while it was from April 2015 to April 2016 in case of Kanakamony

3.3.4 Mass culturing of pulse beetle

Pulse beetles, *Callosobruchus* spp. were collected from previously infested cowpea seeds and maintained under ambient conditions (mean temperature 27 ± 1^0C and mean relative humidity 70 ± 5%). Approximately twenty freshly emerged beetles from the above culture were transferred to individual plastic containers of size 59 cm x 21 cm x 18 cm, containing 500 g of cowpea seeds. The plastic containers were then covered with muslin cloth and fastened with rubber bands to prevent escape of insects. The insects were allowed to mate and lay eggs for seven days. The beetles were then sieved out and the cowpea seeds along with beetle eggs were left undisturbed until the new adults emerged. They were raised in the aforesaid manner and the subsequent F_1 progenies were used for the experiment. The culture was maintained throughout the study period to ensure a constant supply of beetles as and when required (Plate 2).

3.3.5 Insect Bioassay

The efficacy of seed protectants against pulse beetle was evaluated separately in each treatment at monthly intervals by recording seed infestation, mortality, fecundity and egg hatchability in twenty five seeds drawn randomly from each replication.

Five pairs of three day old adult beetles were introduced into each jar containing twenty five seeds. The jars were then covered with muslin cloth and fastened with rubber bands. The beetles were allowed to mate and lay eggs for seven days, afterwards, the beetles were removed from containers (Plate 3).

3.4 Observations recorded

The quality parameters of seeds were assessed and recorded before and after treatment with seed protectants. Thereafter, samples of seeds stored were drawn at monthly intervals and tested for quality parameters following standard procedures. Observation on seed micro-flora was recorded only at the start and end of storage period.

3.4.1 Germination

The germination test was conducted at monthly intervals using sand substratum as prescribed by ISTA (1985). Four replicates of hundred seeds each were drawn from each replication of each treatment and sown in trays containing

Plate 2: Rearing for *Callosobruchus* spp.

Plate 3: Cowpea seeds with pulse beetle eggs

Variety: Lola

Variety: Kanakamony

sterilized sand. The test was conducted at room temperature and a germination period of eight days was adopted throughout the study. On 8^{th} day, the total number of normal seedlings were counted and expressed in per cent.

3.4.2 Speed of germination

Number of seedlings emerging daily were counted from the day of sowing the seeds in the medium and recorded up to the final count (8 days). The speed of germination was calculated employing the following formula suggested by Maguire (1962).

Speed of germination = $X_1/Y_1 + X_2\text{-}X_1/Y_2 + \ldots\ldots\ldots\ldots + X_n\text{-}X_{n-1}/Y_n$

Where,

X_n = per cent germination on nth day

Y_n = number of days from sowing to n^{th} count

3.4.4 Seedling shoots length

Five normal seedlings were selected randomly from each replication of a treatment at the end of germination test and the shoot length was measured from the base of primary leaf to collar region. The mean shoot length was expressed in centimetre.

3.4.5 Seedling root length

The five normal seedlings used for measuring the shoot length were used to measure the root length. The root length of each seedling was measured from collar region to the tip of primary root. The mean shoot length was expressed in centimetre.

3.4.6 Seedling dry weight

On measuring the shoot length and root length, the five normal seedlings were taken from each replication at the eighth day and air dried for first six hours and then in hot air oven maintained at 60^0 C for 48 h. The seedlings were then removed and allowed to cool in dessicators for 30 minutes before being weighed in digital balance and expressed in grams.

3.4.7 Vigour index I

The seedling vigour index I was recorded by adopting the formula suggested by Abdul – Baki and Anderson (1973) and expressed in whole number.

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

3.4.8 Vigour index II

The seedling vigour index II was computed by adopting the formula suggested by Abdul – Baki and Anderson (1973) and expressed in whole number.

Vigour index II = Germination (%) x Seedling dry weight (g)

3.4.9 Seed moisture content

Two replicates of five gram each both of treated and untreated cowpea seeds were taken for determining the moisture content through low constant temperature method as per procedure advocated by ISTA (1993). The cowpea seeds were ground to coarse powder using grinding mill. The powdered seed material was placed in a weighed airtight aluminium cup with lid. After removing the lid, the seed material was placed in hot air oven maintained at 103 ± 2^{0}C and allowed to dry for 17± 1 h. After the drying period, the lid was replaced and the contents cooled in a dessicator for 30 minutes before being weighed onan electronic balance. The moisture content was worked out using the following formula and expressed as percent (ISTA, 1999).

$$\text{Moisture content (\%)} = \frac{M2-M3}{M2-M1} \times 100$$

Where, M1 = Weight of aluminium cup with lid alone

M2 = Weight of aluminium cup with lid + sample before drying

M3 = Weight of aluminium cup with lid + sample after drying

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

A sample of 5 gram was drawn from each replication of a treatment, weighed and surface sterilized with 0.1 per cent mercuric chloride solution for 5-10 min. The sample was washed thoroughly in distilled water. The clean seeds were immersed in 25 ml of distilled water at 25 ±10°C temperature. After 24 h of soaking, the seeds were removed with a clean forceps. The steep water left was decanted and the volume made up to 25 ml using distilled water. The electrical conductivity was recorded using the digital conductivity meter (Model- Eutech-CON 510) and expressed in decisiemens per metre (dSm^{-1}) (ISTA, 1999).

3.4.11 Mortality of adults

Seven days after the release of beetle, the number of dead beetles was recorded to calculate the per cent mortality as follows,

$$\text{Per cent mortality} = \frac{\text{Total number of dead pulse beetle}}{\text{Total number of pulse beetle released}} \times 100$$

3.4.12 Number of eggs and egg hatchability

Following the removal of beetles after seven days, each lot of seeds were carefully examined using a hand lens to record the total number of eggs laid. The number of eggs hatched in each treatment was recorded for five days at every 24 hours.

3.4.13 Seed infestation

The seeds containing eggs were kept at room temperature for 30 days without any disturbance. After 30 days, the dead beetles and other debris were removed. The number of infested seeds, as indicated by presence of holes from each treatment was counted and the percent seed infestation calculated as per Adams and Schulden (1978).

$$\text{Seed infestation (\%)} = \frac{\text{Number of holed seeds}}{\text{Total number of seeds}} \times 100$$

3.4.14 Seed infection

The seed microflora was detected by using standard moist blotter paper method and agar plate method as recommended by ISTA (1996) and Paul (1973).

3.4.14.1 Standard blotter paper method

In moist blotter paper method, a pair of white blotter papers was jointly soaked in sterile distilled water and placed in pre-sterilized glass petriplates. Ten seeds from each treatment and control were placed at equal distance aseptically on the moist blotter paper. For detecting internal seed microflora ten seeds from each treatment and control were taken and seeds were treated with 0.1per cent Mercuric chloridesolution for five minutes and then washed thoroughly with sterile distilled water. The seeds were then placed at equal distance on the moistened blotter paper in pre-sterilized petriplates. Each treatment comprised of three petriplates. The petriplates were incubated 25 ± 2^{0}C under diurnal condition for eight days. On the eighth day, the seeds were examined under microscope for the determination of seed microflora.

3.4.14.2 Agar plate method

In this method 15 ml of autoclaved potato dextrose agar medium (PDA) were poured intopre- sterilized petriplates. PDA used was amended with 1 per cent streptomycinesulphate to suppress bacterial growth. On cooling of the medium treated and untreated seeds were placed at equal distance aseptically, on the poured media. A set of 10 seeds of the samples of cowpea with three replicates were used per treatment. All the petriplates were incubated at 25 ± 2^{0}C under diurnal condition for eight days. On the eighth day the seeds were examined under microscope for the determination of seed microflora. The number of infected seeds were counted and expressed in per cent.

3.5 Statistical analysis

Statistical analysis of the data on various seed quality parameters was performed using Web AgriStat Package (WASP) developed by Indian Council of Agricultural Research for completely randomized design. The treatment efficacy criteria were expressed as per cent and the numbers having low counts and zero values were transformed to square root of (x + 0.5) before analysis of variance (ANOVA). Data obtained were subjected to analysis of variance (ANOVA) procedureand test of significance was carried out by Duncan's Multiple Range Test (DMRT).

Results

4. RESULTS

Experiments to assess the effectiveness of seed protectants against cowpea pulse beetle *Callosobruchus* spp.(Coleoptera: Chrysomelidae) and their impact on seed quality and seedling vigour of cowpea varieties Lola and Kanakamony was conducted in Kerala Agricultural University (KAU) during the year 2014-2016. The impact of the treatments on the seeds was assessed for a period of thirteen months. The results obtained are enumerated below.

4.1 Seed quality parameters of cowpea variety Lola

The result obtained pertaining to seeds of cowpea variety Lola before and after treatment with various seed protectants against pulse beetle is detailed below.

4.1.1 Quality of seed before treatment

The quality parameters of the seed before treatment with seed protectants are furnished in Table 2.

A fresh seed lot with a germination of 95.5 per cent was used for seed treatment. The seedling shoot length, seedling root length, seedling dry weight, vigour index I, vigour index II, microflora infection and electrical conductivity of seed leachate of the seeds were27.03 cm, 11.27 cm, 0.087 g, 3657.65, 8.30, 13.3 per cent and 0.259 dSm^{-1} respectively. The seeds were found to be totally free from pulse beetle infestation

4.1.2 Seed quality parameters after seed treatment

4.1.2.1 Analysis of variance

The analysis of variance revealed that there existed significant differences in the impact of various seed treatments on seed quality parameters like germination per

Table 2. Seed quality parameters of cowpea (Lola) before storage

Parameter	Details
Moisture content (%)	9.00
Germination (%)	95.50
Seedling shoot length(cm)	27.03
Seedling root length(cm)	11.27
Seedling dry weight(g)	0.087
Vigour index I	3657.65
Vigour index II	8.30
EC of seed leachate(dSm^{-1})	0.259
Seed microflora infection (%)	13.30
Pulse beetle infested seed (%)	0.00

cent, speed of germination, seedling shoot and root length, seedling dry weight, seedling vigour index I and II, electrical conductivity of seed leachate and seed microflora over the storage period. Significant differences among treatments were also evident with respect to the effectiveness against pulse beetle infestation as assessed by number of eggs, hatchability and pulse beetle infested seed per cent during storage.

4.1.2.1.1 Germination

The impact of various seed treatments on germination during storage period is furnished in Table 3.

Irrespective of the seed protectants used for seed treatment, germination declined progressively over the period of storage. Germination was found to be above the minimum seed certification standards (MSCS) of 75 per cent for nine months in all seeds treated with seed protectants. However, in untreated seeds germination was retained above 75 per cent for eight months only.

Germination in all the seed protectant treatments was found to be significantly superior to untreated seeds (T13: Control) during storage. Over the storage period, higher germination was observed in seeds treated with neem based product *viz.*, kernel powder followed by leaf powder (T5) and oil (T1). Among these, germination was the highest in seeds treated with neem kernel powder (T8) the exceptions being at 5 and 12 months.

Germination in seeds treated with neem kernel powder was the highest (79.00 % and 53.70 % respectively) at ninth month and thirteenth month of storage (end of storage period). At ninth month, germination in T8 was found to be on par with seeds treated with neem leaf powder (T5: 78.00%) and neem oil (T1: 78.70%). Seeds treated with spinosad (T12: 77.00%), castor oil (T2: 77.00%), coconut oil

Table 3.Effect of seed treatments on germination in cowpea (Lola)during storage

Treatment	Germination(%)													
	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	Mean
T1	94.70 (9.76)	94.00^{ab} (9.72)	91.00^{bc} (9.57)	88.70^{b} (9.44)	87.00^{cde} (9.35)	83.70^{ab} (9.17)	81.00^{b} (9.03)	78.30^{bc} (8.88)	78.70^{a} (8.90)	71.00^{abc} (8.46)	68.00^{ab} (8.28)	60.70^{c} (7.82)	52.30^{ab} (7.27)	79.16 (8.90)
T2	94.00 (9.72)	93.00^{abc} (9.67)	91.00^{bc} (9.57)	88.00^{bc} (9.41)	85.70^{defg} (9.28)	83.00^{b} (9.14)	80.00^{b} (8.97)	77.30^{cd} (8.82)	77.00^{bc} (8.80)	70.00^{bc} (8.40)	67.00^{bc} (8.22)	60.00^{b} (7.78)	52.00^{ab} (7.25)	78.31 (8.85)
T3	93.70 (9.70)	93.00^{abc} (9.67)	92.00^{ab} (9.62)	88.00^{bc} (9.41)	86.30^{def} (9.32)	83.00^{b} (9.14)	79.00^{bc} (8.92)	77.00^{de} (8.80)	77.00^{bc} (8.80)	70.00^{bc} (8.40)	67.00^{bc} (8.22)	60.00^{b} (7.78)	51.70^{abc} (7.22)	78.28 (8.85)
T4	93.00 (9.67)	92.00^{bc} (9.62)	88.70^{c} (9.44)	87.00^{cd} (9.35)	84.70^{efg} (9.23)	83.70^{ab} (9.17)	78.70^{bc} (8.90)	76.30^{def} (8.77)	77.00^{bc} (8.80)	70.30^{abc} (8.42)	66.00^{cd} (8.15)	60.30^{b} (7.80)	49.70^{cd} (7.08)	77.49 (8.80)
T5	95.00 (9.77)	95.00^{a} (9.77)	91.30^{bc} (9.58)	89.30^{b} (9.48)	89.70^{ab} (9.50)	86.00^{a} (9.30)	75.70^{d} (8.73)	79.00^{b} (8.92)	78.00^{ab} (8.86)	72.30^{ab} (8.53)	68.00^{ab} (8.28)	62.70^{a} (7.95)	53.00^{ab} (7.31)	79.62 (8.92)
T6	94.00 (9.72)	95.00^{a} (9.77)	90.30^{cd} (9.53)	86.00^{de} (9.30)	84.30^{fg} (9.21)	83.00^{b} (9.14)	80.00^{b} (8.97)	76.00^{ef} (8.75)	76.00^{cd} (8.75)	69.00^{c} (8.34)	65.00^{d} (8.09)	60.00^{b} (7.78)	48.00^{de} (6.96)	77.43 (8.79)
T7	94.30 (9.74)	93.00^{abc} (9.67)	89.00^{de} (9.46)	85.70^{de} (9.28)	83.70^{g} (9.17)	83.70^{ab} (9.17)	80.00^{b} (8.97)	76.00^{ef} (8.75)	75.70^{cd} (8.73)	71.00^{abc} (8.46)	65.70^{cd} (8.13)	59.70^{b} (7.76)	45.70^{f} (6.79)	77.17 (8.78)
T8	96.00 (9.82)	95.00^{a} (9.77)	93.00^{a} (9.67)	91.30^{a} (9.58)	89.30^{bc} (9.48)	86.00^{a} (9.30)	84.30^{a} (9.21)	82.00^{a} (9.08)	79.00^{a} (8.92)	72.70^{a} (8.55)	69.00^{a} (8.34)	60.70^{ab} (7.82)	53.70^{a} (7.36)	80.92 (8.99)
T9	94.30 (9.74)	94.00^{ab} (9.72)	89.30^{de} (9.48)	87.00^{cd} (9.35)	84.70^{efg} (9.23)	82.70^{b} (9.12)	78.00^{bcd} (8.86)	76.00^{ef} (8.75)	75.70^{cd} (8.73)	70.70^{abc} (8.44)	65.70^{cd} (8.13)	60.00^{b} (7.78)	47.00^{ef} (6.89)	77.32 (8.79)
T10	95.00 (9.77)	95.00^{a} (9.77)	92.00^{ab} (9.62)	89.00^{b} (9.46)	87.30^{bcd} (9.37)	84.00^{ab} (9.19)	78.00^{bcd} (8.86)	76.30^{def} (8.77)	76.00^{cd} (8.75)	71.70^{ab} (8.49)	65.30^{d} (8.11)	60.30^{b} (7.80)	47.00^{ef} (6.89)	78.22 (8.84)
T11	93.50 (9.70)	93.50^{ab} (9.70)	90.00^{cde} (9.51)	85.00^{e} (9.25)	92.00^{a} (9.62)	80.00^{c} (8.97)	76.30^{cd} (8.76)	76.00^{ef} (8.75)	75.00^{de} (8.69)	71.00^{abc} (8.46)	65.00^{d} (8.09)	59.70^{b} (7.76)	45.70^{f} (6.79)	77.13 (8.77)
T12	93.00 (9.67)	93.00^{abc} (9.67)	92.00^{ab} (9.62)	86.30^{de} (9.32)	86.00^{defg} (9.30)	83.70^{ab} (9.17)	80.00^{b} (8.97)	77.00^{de} (8.80)	77.00^{bc} (8.80)	71.00^{abc} (8.45)	66.00^{cd} (8.150	60.70^{ab} (7.82)	51.30^{bc} (7.20)	78.23 (8.84)
T13	95.70 (9.81)	91.00^{c} (9.57)	90.00^{cde} (9.51)	85.70^{de} (9.28)	84.30^{fg} (9.21)	79.30^{c} (8.93)	78.70^{bc} (8.90)	75.70^{f} (8.73)	74.00^{e} (8.63)	66.00^{d} (8.15)	62.00^{e} (7.90)	51.00^{c} (7.18)	40.30^{g} (6.39)	74.90 (8.63)
Mean	94.32	93.58	90.74	87.46	86.54	83.22	79.21	77.15	76.62	70.52	66.13	59.68	49.03	
SEm±	0.012	0.014	0.012	0.016	0.023	0.019	0.023	0.016	0.014	0.019	0.019	0.030	0.045	
CD(0.05)	NS	0.120	0.078	0.086	0.134	0.136	0.227	0.063	0.083	0.142	0.097	0.133	0.151	

M: Month of storage

Means in each column with at least one letter in common are not significantly different at 5% level of probability

Values in parentheses are square root transformed values

(T3:77.00%) and sweet flag powder (T4: 77.00%) were the next best. These were found to be on par with T5 (Plate 4).

However, at the end of storage period (M13), germination in all the above mentioned treatments were on par with each other except in case of seeds treated with spinosad (T12: 51.30 %) and T4 (sweet flag rhizome powder: 49.70%) (Plate 5).

4.1.2.1.2 Speed of germination

The impact of various seed treatments on speed of germination during storage period is furnished in Table 4.

Speed of germination declined progressively over the period of storage irrespective of the seed protectants used. No significant difference in speed of germination was observed at 1, 2, 6 and 10th month of storage. Higher speed of germination over storage was observed in seeds treated with neem based products and oils *viz.*, neem kernel powder (T8: 22.09), neem leaf powder (T5: 21.84), neem oil (T1:21.74) followed by coconut oil (T3: 21.72), castor oil (T2: 21.62).

AtM9, speed of germination was highest in seeds treated with castor oil (T2: 21.47) followed by neem oil (T1: 21.06) and coconut oil (T3:20.97).These treatments were found to be on par with sweet flag rhizome powder (T4: 20.03), neem leaf powder (T5: 20.13), diatomaceous earth (T9: 19.99) and spinosad (T12: 19.94). Seeds treated with neem kernel powder (T8:19.72) was the next best. Howeverat thirteenth month, speed of germination was highest in neem kernel powder (T8:15.25). It was found to be on par with seeds treated with castor oil (T2:15.10), coconut oil (T3:15.06), spinosad (T12:14.96), neem oil (T1:14.87), sweet flag rhizome powder (T4:14.80), diatomaceous earth (T9: 14.43). Untreated seed (T13) was inferior to all other treatments both at ninth and thirteenth month of storage.

Plate 4: Germination at the start of storage

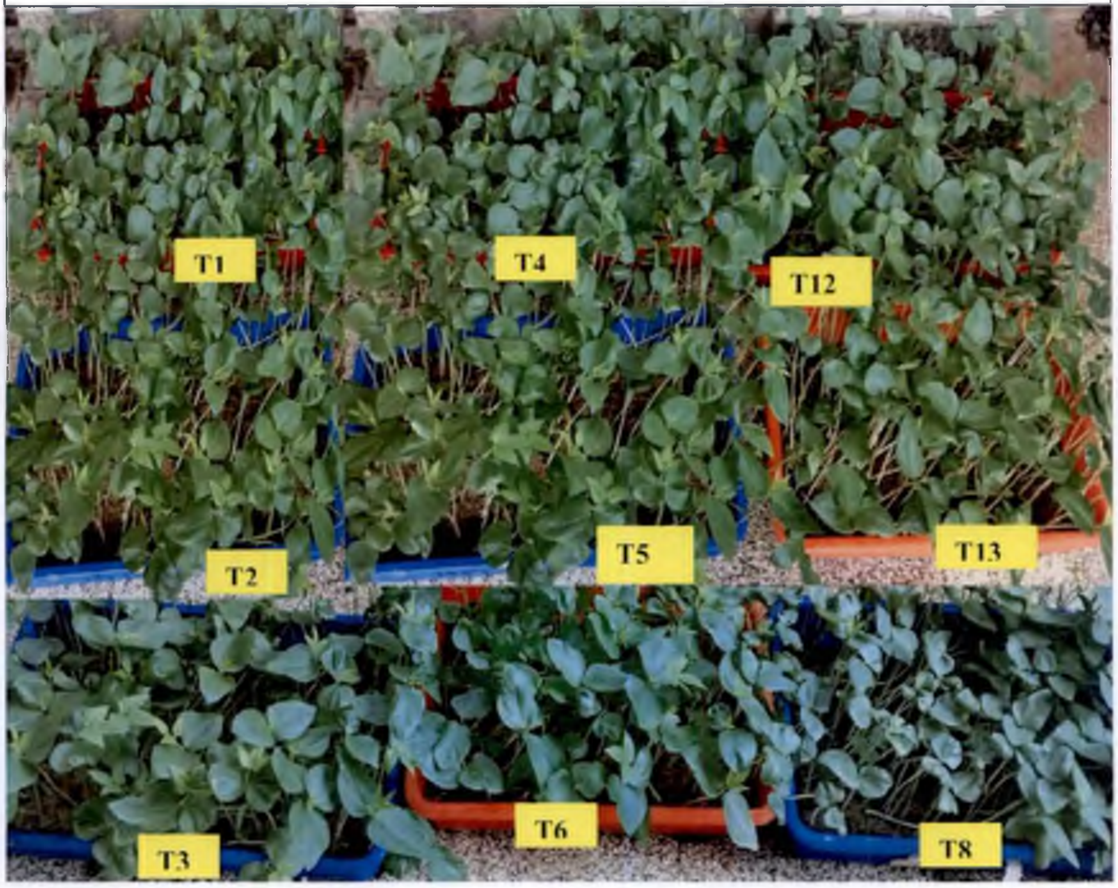


Plate 5: Germination at the end of storage

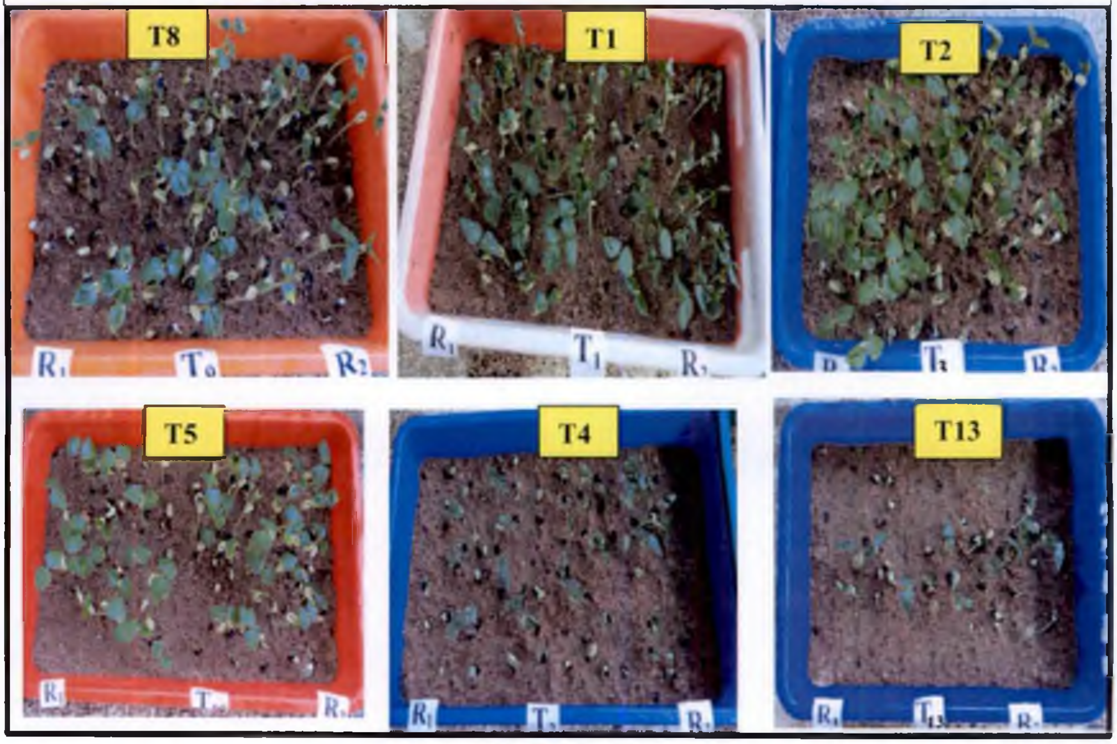


Table 4.Effect of seed treatments on speed of germination in cowpea (Lola) during storage

Treatment	Speed of germination													
	M1	**M2**	**M3**	**M4**	**M5**	**M6**	**M7**	**M8**	**M9**	**M10**	**M11**	**M12**	**M13**	**Mean**
T1	26.77	27.00	25.91^{abc}	24.14^{abc}	24.71^{abc}	22.91	21.19^{bcd}	21.02^{a}	21.06^{ab}	19.25	17.43^{ab}	16.36^{a}	14.87^{abcd}	21.74
T2	26.87	27.00	25.65^{bcd}	24.68^{ab}	24.45^{bc}	22.80	21.24^{bcd}	19.50^{bcde}	21.47^{a}	18.87	17.13^{ab}	16.34^{a}	15.10^{ab}	21.62
T3	26.80	26.97	26.30^{ab}	24.75^{ab}	24.58^{abc}	23.58	19.68^{de}	20.42^{abc}	20.97^{ab}	19.66	17.27^{ab}	16.37^{a}	15.06^{ab}	21.72
T4	27.28	26.73	24.14^{de}	23.80^{bc}	24.21^{bcd}	22.81	20.84^{bcde}	19.66^{bcd}	20.03^{abc}	19.11	16.88^{bc}	16.14^{a}	14.80^{abcd}	21.26
T5	25.91	27.27	25.92^{abc}	24.83^{ab}	25.44^{ab}	24.30	20.60^{bcde}	20.54^{ab}	20.13^{abc}	20.19	17.14^{ab}	16.45^{a}	15.16^{a}	21.84
T6	25.33	26.51	26.15^{abc}	24.52^{ab}	24.26^{bcd}	23.15	20.04^{de}	19.44^{bcde}	19.19^{cd}	18.98	16.20^{c}	15.99^{a}	14.09^{e}	21.07
T7	26.74	27.54	24.21^{de}	23.84^{bc}	24.20^{bcd}	22.91	20.36^{cde}	19.34^{cde}	19.11^{cd}	19.86	16.23^{c}	15.80^{a}	14.32^{cde}	21.11
T8	27.84	27.37	27.22^{a}	24.72^{ab}	24.87^{abc}	23.66	23.15^{a}	19.88^{abcd}	19.72^{bc}	19.94	17.17^{ab}	16.40^{a}	15.25^{a}	22.09
T9	27.53	27.35	24.87^{bcde}	25.13^{a}	24.11^{cd}	22.65	20.12^{de}	19.00^{def}	19.99^{abc}	19.62	17.20^{ab}	16.07^{a}	14.43^{bcde}	21.39
T10	28.31	28.04	24.67^{cde}	24.51^{ab}	24.07^{cd}	21.20	19.37e	18.45^{ef}	18.91^{cde}	19.41	17.14^{ab}	15.99^{a}	14.35^{cde}	21.11
T11	28.05	26.71	23.50^{e}	22.96^{c}	25.79^{a}	22.12	19.50^{e}	18.13^{f}	17.90^{de}	19.91	17.65^{a}	15.86^{a}	14.26^{de}	20.95
T12	27.66	27.96	23.92^{e}	23.93^{abc}	23.77^{cd}	22.66	21.90^{abc}	19.00^{def}	19.94^{abc}	20.29	17.73^{a}	15.88^{a}	14.96^{abc}	21.51
T13	27.94	26.98	25.56^{bcd}	23.27^{c}	23.19^{d}	22.02	22.00^{ab}	18.40^{ef}	17.41^{e}	18.64	16.73^{bc}	15.01^{b}	13.15^{f}	20.79
SEm±	0.193	0.162	0.211	0.139	0.145	0.187	0.214	0.165	0.223	0.142	0.092	0.081	0.105	
CD(0.05)	NS	NS	1.542	1.214	1.258	NS	1.592	1.194	1.592	NS	0.725	0.696	0.672	

M: Month of storage

Means in each column with at least one letter in common are not significantly different at 5% level of probability

4.1.2.1.3 Seedling shoot length

The impact of various seed treatment on seedling shoot length during storage period is furnished inAppendix I.

Seedling shoot length was observed to decrease with increase in storage period. Higher shoot length over storage was observed in seeds treated with neem based products *viz.*, kernel powder (T8: 22.32 cm) followed by leaf powder (T5: 21.95 cm) and oil (T1:21.75 cm).

At M9, shoot length was the highest in seeds treated with castor oil (T2: 23 cm) which weresignificantly superior to all other treatments. It was followed byT3 (Coconut oil: 21 cm), T5 (neem leaf powder: 20.83 cm), T4 (sweet flag rhizome powder: 20.50 cm), T1 (neem oil: 20.23 cm), T6 (paanal leaf powder: 19.84 cm) and T12 (spinosad: 19.97 cm) which were on par with each other

Atthe end of storage period (M13), shoot length was highest in seeds treated with neem kernel powder (T8: 16.65 cm). It was found to be on par with thosetreated with neem leaf powder (T5; 16.50 cm) and coconut oil (T3: 16.00 cm). Treatment T5 (neem leaf powder) was also found to be on par with that treated with coconut oil (T3:16.00 cm). Untreated seeds (T13) recorded the least shoot length (13.45 cm) and differed significantly from other treatments.

4.1.2.1.4 Seedling root length

The impact of various seed treatments on seedling root length during storage period is furnished in Appendix II.

Seedling root length decreased over the period of storage.Higher root length over storage was observed in seeds treated with neem based product *viz.*, neem kernel powder (T8: 9.06 cm), followed by neem leaf powder (T5: 8.90 cm) and neem oil

(T1: 8.89 cm) while it was the least in treatment with *Beauveria bassiana* (T11: 8.18 cm).

At M9, root length was the highest in seeds treated with neem leaf powder (T5: 9.85 cm). This was found to be on par with seeds treated with neem kernel powder (T8: 9.8 cm), neem oil (T1: 9.75 cm), castor oil (T2: 9.73 cm) and coconut oil (T3: 9.35 cm). The above treatments were significantly superior to all other seed treatments. However, at the end of storage period (M13), treatments T8, followed by neem leaf powder (T5: 6.5 cm) and spinosad (T12: 6.25 cm) registered higher root length and were found to be on par with each other. Lower root length at both ninth and thirteenth month was observed in seeds treated with *Beauveria bassiana* (T11) and untreated seeds (T13)

4.1.2.1.5 Seedling dry weight

The impact of various seed treatments on seedling dry weight during storage period is furnished in Appendix III.

Irrespective of the seed protectants used for seed treatment, seedling dry weight decreased over the period of storage. Throughout the storage period, seeds treated with neem kernel powder (T8) had recorded the highest seedling dry weight, except at 5^{th}, 6^{th} and 11^{th} month of storage. At the end storage period (M13), seedling dry weight varied between 0.055 g (T8 and T5) and 0.038 g (T13). Treatments T8 and T5 was found to be on par with T1 (0.050 g), T3 (0.050 g) and T2 (0.049 g) at the end of storage while T8 was significantly superior to all the other treatments at M9. Treatment T13 recorded the least dry weight at both ninth month (0.064 g) and thirteenth month of storage (0.038 g).

4.1.2.1.6 Seedling vigour index I

The impact of various seed treatments on seedling vigour index I during storage period is furnished in Table 5.

Irrespective of the seed protectants used for seed treatment, vigour index I declined progressively over the period of storage. Higherseedling vigour index I over storage was observed in seeds treated with neem based product *viz.*, kernel powder (T8:2589.65) followed by leaf powder (T5:2509.37) and oil (T1:2477.09), while it was the least in untreated seeds (T13: 2197.59).

At ninth month, seedling vigour index I of seeds treated with castor oil (T2: 2520.30) was found to be on par with that of seeds treated with neem kernel powder (T8: 2433.70). Treatment T8 was also found to be on par with those treated with neem leaf powder (T5: 2392.80), coconut oil (T3:2337.00) and neem oil (T1: 2358.30). However, at the end storage period (M13), vigour index I of seeds treated with neem kernel powder (T8: 1248.60) was found to be on par with seeds treated with neem leaf powder (T5:1219.00). Treatments with neem oil (T1:1149.50), castor oil (T2:1139.10) and coconut oil (T3:1139.40) were found to be on par with each other and next best to T8 and T5.

Seedling vigour index I in untreated seeds (T13) and those treated with protectant treatments *Beauveria bassiana* (T11: 2065.00 and 914.30 respectively), diatomaceous earth (T9: 2054.30 and 975.10 respectively) and rice husk ash (T10: 2048.20 and 972.70 respectively), were low at both ninth month and thirteenth month of storage.

4.1.2.1.7 Seedling vigour index II

The impact of various seed treatments on seedling vigour index II during storage period is furnished in Table 6.

Table 5.Effect of seed treatments on seedling vigour index I in cowpea (Lola) during storage

Treatment	Seedling vigour index I													
	M1	**M2**	**M3**	**M4**	**M5**	**M6**	**M7**	**M8**	**M9**	**M10**	**M11**	**M12**	**M13**	**Mean**
T1	3906.1^{a}	3202.1^{a}	2884.4^{bc}	3019.2^{b}	2973.4^{d}	2662.2^{cde}	2380.5^{de}	2346.3^{bc}	2358.3^{bcd}	1994.9^{abc}	1855.5^{ab}	1469.7^{bc}	1149.5^{b}	2477.09
T2	3615.9^{bcd}	2937.1^{de}	2794.3^{cd}	2681.7^{g}	2855.5^{de}	2400.9^{f}	2498.0^{bcd}	2417.9^{abc}	2520.3^{a}	2100.0^{a}	1859.3^{ab}	1455.0^{cd}	1139.1^{b}	2405.76
T3	3561.6^{cde}	2952.5^{de}	2611.9^{fg}	2781.7^{f}	2757.4^{e}	2615.5^{de}	2394.2^{cde}	2417.0^{abc}	2337.0^{bcd}	2040.4^{ab}	1885.7^{a}	1449.0^{cd}	1139.4^{b}	2380.23
T4	3356.2^{f}	2930.7^{de}	2548.5^{fg}	2913.1^{cde}	2831.3^{de}	2576.6^{e}	2334.2^{e}	2349.8^{bc}	2283.1^{cde}	1966.0^{bcd}	1815.0^{b}	1395.9^{d}	1028.1^{cd}	2332.96
T5	3592.4^{cd}	3101.0^{b}	2734.0^{fg}	3012.1^{b}	3506.7^{a}	2779.8^{ab}	2386.8^{cde}	2473.9^{ab}	2392.8^{bc}	2010.2^{abc}	1849.6^{ab}	1563.5^{a}	1219.0^{a}	2509.37
T6	3430.1^{ef}	3064.2^{bc}	2517.5^{g}	2795.1^{f}	3315.6^{b}	2602.7^{de}	2663.5^{a}	2251.9^{bcd}	2176.4^{efg}	1861.4^{de}	1662.5^{d}	1401.3^{cd}	1010.1^{d}	2365.56
T7	3492.1^{de}	2907.9^{de}	2646.7^{ef}	2835.2^{ef}	3266.9^{bc}	2582.1^{de}	2401.4^{cde}	2308.1^{bcd}	2141.3^{fgh}	1902.9^{cde}	1677.7^{d}	1389.3^{de}	945.5^{e}	2345.93
T8	3739.0^{b}	3083.3^{bc}	3081.7^{a}	3327.5^{a}	3155.8^{c}	2757.0^{abc}	2748.3^{a}	2612.9^{a}	2433.7^{ab}	2047.5^{ab}	1904.4^{a}	1525.9^{ab}	1248.6^{a}	2589.65
T9	3610.0^{bcd}	2995.9^{cd}	2616.4^{fg}	2940.6^{bcd}	3276.8^{bc}	2805.1^{a}	2476.4^{cd}	2237.3^{cd}	2054.3^{h}	1862.0^{de}	1746.8^{c}	1410.7^{cd}	975.1^{de}	2385.18
T10	3646.7^{bc}	2888.1^{e}	2885.9^{bc}	3010.6^{bc}	3143.1^{c}	2664.9^{cde}	2618.4^{ab}	2417.3^{abc}	2048.2^{h}	1909.7^{cde}	1672.5^{d}	1396.7^{d}	972.7^{de}	2405.75
T11	3520.8^{cde}	2725.1^{f}	2934.3^{b}	2856.0^{def}	3302.3^{b}	2600.4^{de}	2320.3^{e}	2080.1^{d}	2065.0^{h}	1856.7^{e}	1647.8^{d}	1324.6^{e}	914.3^{e}	2319.05
T12	3540.1^{cde}	2952.6^{de}	2920.7^{b}	2927.3^{bcde}	2913.0^{d}	2686.9^{bcd}	2401.1^{bcd}	2393.9^{abc}	2249.3^{def}	1970.4^{bc}	1692.9^{cd}	1422.7^{cd}	1072.6^{c}	2395.65
T13	3547.0^{cde}	2721.9^{f}	2606.7^{fg}	2551.6^{h}	2754.8^{e}	2337.1^{f}	2521.6^{bc}	2254.0^{bcd}	2089.5^{gh}	1726.9^{f}	1580.0^{e}	1127.2^{f}	750.4^{f}	2197.59
SEm±	23.88	22.67	28.99	30.32	40.09	22.77	23.49	27.53	26.24	17.95	17.61	17.27	21.96	
CD(0.05)	135.420	93.427	115.180	98.538	142.298	110.035	141.043	233.990	109.867	107.575	65.014	69.521	61.589	

M: Month of storage

Means in each column with at least one letter in common are not significantly different at 5% level of probability

Table 6.Effect of seed treatments on seedling vigour index II in cowpea (Lola) during storage

Treatment	Seedling vigour index II													
	M1	**M2**	**M3**	**M4**	**M5**	**M6**	**M7**	**M8**	**M9**	**M10**	**M11**	**M12**	**M13**	**Mean**
T1	9.04^{a}	7.24^{a}	6.58^{ef}	7.39^{b}	7.77^{bcd}	6.63^{cd}	6.45^{c}	5.80^{bcd}	5.77^{bc}	5.06^{bcd}	4.62^{b}	3.42^{abc}	2.63^{bc}	6.031
T2	8.12^{bcd}	6.60^{fg}	6.37^{f}	6.89^{cd}	6.71^{g}	6.23^{ef}	6.13^{de}	5.67^{bcde}	5.49^{de}	4.83^{cde}	4.42^{bcd}	3.36^{abcd}	2.57^{c}	5.646
T3	8.18^{bcd}	6.93^{cde}	6.72^{cde}	7.04^{c}	7.19^{ef}	6.17^{fg}	6.06^{de}	5.54^{cde}	5.49^{de}	4.76^{cde}	4.42^{bcd}	3.42^{abc}	2.60^{c}	5.732
T4	8.00^{cd}	6.86^{de}	6.38f	7.05^{c}	7.54^{cde}	6.55^{cde}	6.06^{de}	5.34^{cde}	5.40^{defg}	4.64^{de}	4.18^{def}	2.84^{def}	2.20^{d}	5.618
T5	8.49^{bc}	7.27^{a}	6.79cde	7.44^{b}	8.52^{a}	7.48^{a}	6.28^{cd}	6.11^{b}	5.93^{b}	5.38^{ab}	4.99^{a}	3.63^{a}	2.92^{ab}	6.248
T6	7.93^{d}	7.12^{abc}	6.59^{def}	7.00^{c}	7.95^{bc}	6.31^{def}	6.85^{b}	5.35^{cde}	5.36^{efg}	4.58^{ef}	4.25^{cdef}	3.01^{cdef}	2.23^{d}	5.733
T7	8.07^{cd}	6.73^{efg}	6.35^{f}	6.71^{de}	7.03^{fg}	6.47^{def}	6.05^{de}	5.35^{cde}	5.17^{g}	4.64^{de}	4.03^{fg}	2.51^{fg}	1.89^{e}	5.459
T8	9.12^{a}	7.35^{a}	7.44^{a}	7.70^{a}	7.98^{b}	7.08^{b}	7.31^{a}	6.89^{a}	6.27^{a}	5.55^{a}	5.04^{a}	3.61^{ab}	2.97^{a}	6.485
T9	8.62^{ab}	6.99^{bcd}	6.73^{cde}	7.08^{c}	7.73^{bcd}	6.89^{bc}	6.06^{de}	5.31^{de}	5.25^{efg}	5.01^{bcde}	4.53^{bc}	2.78^{ef}	2.08^{de}	5.774
T10	8.65^{ab}	7.22^{ab}	7.18^{b}	7.33^{b}	7.73^{bcd}	6.47^{def}	5.98^{e}	5.34^{cde}	5.19^{fg}	4.68^{de}	4.07^{efg}	2.90^{cdef}	2.12^{de}	5.758
T11	7.87^{d}	6.83^{def}	6.87^{c}	6.89^{cd}	8.03^{b}	6.24^{ef}	5.54^{f}	5.62^{bcde}	5.43^{def}	4.97^{bcde}	4.36^{bcde}	2.53^{fg}	1.89^{e}	5.620
T12	8.00^{cd}	6.93^{cde}	6.84^{cd}	6.94^{c}	7.42^{def}	6.55^{cde}	6.16^{de}	5.85^{bc}	5.62^{cd}	5.19^{abc}	4.44^{bcd}	3.10^{bcde}	2.38^{cd}	5.801
T13	7.97^{cd}	6.52^{g}	6.03^{g}	6.63^{c}	7.35^{def}	5.82^{g}	5.64^{f}	5.22^{e}	4.74^{h}	4.18^{f}	3.78^{g}	2.11^{g}	1.53^{f}	5.193
SEm±	0.079	0.045	0.061	0.051	0.082	0.073	0.076	0.082	0.063	0.067	0.061	0.084	0.070	
CD(0.05)	0.551	0.249	0.254	0.224	0.438	0.357	0.274	0.513	0.257	0.450	0.318	0.524	0.305	

M: Month of storage

Means in each column with at least one letter in common are not significantly different at 5% level of probability

Irrespective of the seed protectants used for seed treatment, seedling vigour index II declined progressively over the period of storage. Seedling vigour index II in all the seed protectant treatments was found to be superior to untreated seeds (T13) for most part of storage. Throughout the storage period of 13 months, seeds treated with neem kernel powder (T8) had recorded the highest seedling vigour index II, except at M5, M6 and M12. Highervigour index II over storage was observed in seeds treated with neem based products *viz.*, neem kernel powder (T8) followed by neem leaf powder (T5) and neem oil (T1). Lower values were recorded in untreated control (T13) and those treated with sweet flag rhizome powder (T4), karinotchi leaf powder (T7) and *Beauveria bassiana* (T11).

Vigor index II of seeds treated with neem kernel powder was the highest at ninth month as well as thirteenth month of storage (6.27 and 2.97, respectively). It was followed by treatment with neem leaf powder (T5: 5.93 and 2.92, respectively) and neem oil (T1: 5.77 and 2.63, respectively). Treatment T1 was also found to be on par with seeds treated with spinosad (T12) at ninth month (5.62) and thirteenth month (2.38).

4.1.2.1.8 Seed moisture content

The impact of various seed treatments on moisture content during storage period is furnished in Table 7.

Throughout storage, no significant difference was observed in moisture content of seeds between treatments.

4.1.2.1.9 Electrical conductivity of seed leachate

The impact of various seed treatments on electrical conductivity of seed leachate during storage period is furnished in Table 8.

Table 7.Effect of seed treatments on moisture content in cowpea (Lola) during storage

Treatment	Moisture content (%)													
	M1	**M2**	**M3**	**M4**	**M5**	**M6**	**M7**	**M8**	**M9**	**M10**	**M11**	**M12**	**M13**	**Mean**
T1	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.03	9.03	9.03	9.03	9.03	9.01
T2	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.03	9.03	9.03	9.03	9.03	9.01
T3	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.03	9.03	9.03	9.00	9.03	9.01
T4	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.07	9.03	9.07	9.03	9.07	9.02
T5	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.07	9.01	9.03	9.07	9.01
T6	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.07	9.00	9.10	9.01
T7	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.03	9.03	9.03	9.00	9.10	9.02
T8	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.07	9.03	9.03	9.07	9.02
T9	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.03	9.07	9.07	9.01
T10	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.03	9.00	9.03	9.03	9.07	9.01
T11	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.03	9.03	9.00	9.07	9.01
T12	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.03	9.03	9.00	9.00	9.03	9.01
T13	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.03	9.07	9.07	9.10	9.10	9.03

M: Month of storage

Statistical analysis was not done since the range is too small

Table 8.Effect of seed treatments on electrical conductivity of seed leachate in cowpea (Lola) during storage

Treatment	Electrical conductivity of seed leachate (dSm^{-1})													
	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	Mean
T1	0.205	0.220^{cd}	0.235^{f}	0.242^{ef}	0.299	0.365^{d}	0.374^{fg}	0.400^{de}	0.431	0.464^{cde}	0.477^{de}	0.482^{de}	0.486^{ef}	0.360
T2	0.248	0.225^{abc}	0.239^{ef}	0.248^{bcdef}	0.322	0.368^{cd}	0.372^{g}	0.403^{de}	0.432	0.461^{e}	0.478^{de}	0.482^{de}	0.487^{ef}	0.366
T3	0.246	0.210^{d}	0.241^{def}	0.250^{bcde}	0.326	0.355^{e}	0.378^{defg}	0.405^{de}	0.430	0.462^{de}	0.476^{de}	0.484^{cde}	0.488^{ef}	0.365
T4	0.224	0.235^{ab}	0.249^{abc}	0.256^{ab}	0.320	0.367^{cd}	0.387^{bc}	0.424^{abcd}	0.449	0.468^{bcde}	0.481^{cd}	0.488^{bcd}	0.491^{def}	0.372
T5	0.231	0.219^{cd}	0.241^{def}	0.241^{f}	0.295	0.365^{d}	0.379^{cdefg}	0.410^{cde}	0.436	0.464^{cde}	0.478^{de}	0.480^{e}	0.483^{ef}	0.363
T6	0.232	0.223^{bc}	0.251^{ab}	0.255^{abc}	0.294	0.373^{abcd}	0.384^{cde}	0.423^{abcd}	0.440	0.473^{bcd}	0.486^{bc}	0.490^{bc}	0.505^{bcde}	0.371
T7	0.234	0.231^{abc}	0.246^{abcde}	0.252^{abcd}	0.298	0.377^{ab}	0.382^{cdef}	0.423^{abcd}	0.437	0.472^{bcd}	0.484^{bc}	0.492^{b}	0.518^{bc}	0.373
T8	0.214	0.218^{cd}	0.236^{f}	0.246^{cdef}	0.299	0.368^{cd}	0.376^{efg}	0.394^{e}	0.428	0.467^{bcde}	0.474^{e}	0.481^{de}	0.482^{f}	0.360
T9	0.216	0.230^{abc}	0.247^{abcd}	0.245^{def}	0.297	0.371^{bcd}	0.384^{cde}	0.437^{ab}	0.457	0.473^{bc}	0.485^{bc}	0.486^{bcde}	0.500^{cdef}	0.371
T10	0.211	0.237^{a}	0.244^{bcde}	0.245^{def}	0.301	0.373^{abc}	0.385^{cd}	0.433^{abc}	0.461	0.472^{bcd}	0.485^{bc}	0.489^{bcd}	0.511^{bcd}	0.373
T11	0.226	0.238^{a}	0.247^{abcd}	0.250^{bcde}	0.311	0.371^{bcd}	0.398^{a}	0.443^{a}	0.464	0.478^{ab}	0.486^{b}	0.491^{bc}	0.524^{b}	0.379
T12	0.217	0.218^{cd}	0.242^{cdef}	0.251^{bcd}	0.303	0.371^{bcd}	0.383^{cde}	0.415^{bcde}	0.440	0.465^{cde}	0.478^{de}	0.482^{de}	0.490^{def}	0.366
T13	0.224	0.234^{ab}	0.253^{a}	0.260^{a}	0.351	0.380^{a}	0.394^{ab}	0.431^{abc}	0.487	0.489^{a}	0.501^{a}	0.504^{a}	0.551^{a}	0.389
SEm±	0.003	0.002	0.001	0.001	0.004	0.001	0.001	0.003	0.004	0.001	0.001	0.001	0.004	
CD(0:05)	NS	0.013	0.008	0.009	NS	0.008	0.008	0.024	NS	0.011	0.005	0.008	0.022	

M: Month of storage

Means in each column with at least one letter in common are not significantly different at 5% level of probability

Irrespective of the seed protectants used for seed treatment, electrical conductivity of seed leachate increased progressively over the period of storage.

At ninth month the treatments did not differ significantly from each other with respect to electrical conductivity of seed leachate. However, at the end storage period (M13), electrical conductivity of seed leachate varied between 0.482dSm^{-1}(T8: neem kernel powder) and 0.551dSm^{-1}(T13: control). Treatment with neem kernel powder (T8: 0.482dSm^{-1}) with the least value recorded was significantly different from all other treatments. Next to T8, EC of seed leachate was low in treatments with neem leaf powder (T5: 0.483dSm^{-1}), neem oil (T1: 0.486dSm^{-1}), castor oil (T2: 0.487dSm^{-1}) and coconut oil (T3: 0.488dSm^{-1}).These were also found to be on par with each other. EC of seeds treated with sweet flag powder (T4: 0.491 dSm^{-1}) was found to be on par with that treated with spinosad (T12: 0.490 dSm^{-1}).

4.1.2.1.10 Mortality of adults

The results of the experiment on the impact of different seed protectants on mortality of adults are presented in Table 9.

All the seed protectants used had induced hundred per cent mortality of the adult beetles exposed, for the first three months of storage. Seeds treated with neem oil, castor oil, coconut oil, neem leaf powder, neem kernel powder, diatomaceous earth and ash caused hundred per cent mortality for up to five months of storage, while spinosad registered hundred per cent kill for up to seven months of storage. Sweet flag rhizome powder, pannal leaf powder, karinotchi leaf powder and *Beauveria bassiana* consistently recorded lower values for mortality. However, all the seed protectants were significantly superior to control and were on par with each other for up to ninth month of storage. Spinosad remained significantly superior to all other treatments from tenthmonth onwards with mortality ranging from cent per cent (7th month)to 33.3 per cent in thirteenth month.

Table 9.Effect of seed treatments on mortality of adults pulse beetles in cowpea (Lola) during storage

Treatment	Mortality of adult beetles (%)									
	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13
T1	100.00^{a} (10.02)	100.00^{a} (10.02)	83.30^{ab} (9.15)	83.30^{b} (9.15)	80.00^{ab} (8.97)	66.70^{b} (8.19)	60.00^{b} (7.78)	43.30^{b} (6.61)	40.00^{b} (6.36)	26.70 (5.19)
T2	100.00^{a} (10.02)	100.00^{a} (10.02)	83.30^{ab} (9.15)	76.70^{bc} (8.78)	70.00^{bc} (8.40)	70.00^{ab} (8.40)	56.70^{bc} (7.55)	43.30^{b} (6.61)	40.00^{b} (6.36)	23.30 (4.86)
T3	100.00^{a} (10.02)	100.00^{a} (10.02)	80.00^{b} (8.97)	76.70^{bc} (8.78)	73.30^{abc} (8.59)	63.30^{bc} (7.98)	53.30^{bc} (7.33)	40.00^{b} (6.36)	40.00^{b} (6.36)	23.30 (4.86)
T4	90.00^{a} (9.51)	96.70^{ab} (9.85)	73.30^{b} (8.59)	66.70^{cd} (8.19)	63.30^{bc} (7.98)	53.30^{cd} (7.33)	46.70^{c} (6.86)	26.70^{cd} (5.19)	26.70^{d} (5.19)	13.30 (3.25)
T5	100.00^{a} (10.02)	100.00^{a} (10.02)	80.00^{b} (8.97)	76.70^{bc} (8.78)	70.00^{bc} (8.40)	66.70^{b} (8.19)	53.30^{bc} (7.33)	36.70^{b} (6.08)	36.70^{bc} (6.08)	20.00 (4.53)
T6	90.00^{a} (9.50)	100.00^{a} (10.02)	73.30^{b} (8.59)	63.30^{cd} (7.98)	63.30^{bc} (7.98)	56.70^{bcd} (7.55)	50.00^{bc} (7.11)	26.70^{cd} (5.19)	30.00^{cd} (5.52)	20.00 (4.53)
T7	90.00^{a} (9.50)	96.70^{ab} (9.85)	73.30^{b} (8.59)	63.30^{cd} (7.98)	66.70^{bc} (8.16)	53.30^{cd} (7.33)	56.70^{bc} (7.55)	33.30^{bc} (5.80)	33.30^{bcd} (5.80)	16.70 (4.10)
T8	100.00^{a} (10.02)	100.00^{a} (10.02)	83.30^{ab} (9.15)	76.70^{bc} (8.78)	73.30^{abc} (8.59)	66.70^{b} (8.19)	53.30^{bc} (7.33)	36.70^{b} (6.08)	36.70^{bc} (6.08)	20.00 (4.53)
T9	100.00^{a} (10.02)	100.00^{a} (10.02)	83.30^{ab} (9.15)	63.30^{cd} (7.98)	66.70^{bc} (8.19)	50.00^{d} (7.11)	53.30^{bc} (7.33)	26.70^{cd} (5.19)	30.00^{cd} (5.52)	16.70 (4.10)
T10	100.00^{a} (10.02)	100.00^{a} (10.02)	83.30^{ab} (9.15)	63.30^{cd} (7.98)	63.30^{bc} (7.95)	53.30^{cd} (7.33)	53.30^{bc} (7.33)	26.70^{cd} (5.19)	26.70^{d} (5.19)	16.70 (4.10)
T11	96.70^{a} (9.85)	90.00^{b} (9.50)	80.00^{b} (8.97)	60.00^{d} (7.78)	56.70^{c} (7.55)	50.00^{d} (7.11)	46.70^{c} (6.86)	23.30^{d} (4.86)	26.70^{d} (5.19)	16.70 (4.10)
T12	100.00^{a} (10.02)	100.00^{a} (10.02)	100.00^{a} (10.02)	100.00^{a} (10.020	90.00^{a} (9.50)	83.30^{a} (9.15)	80.00^{a} (8.97)	66.70^{a} (8.19)	46.70^{a} (7.11)	33.30 (6.08)
T13	3.30^{b} (1.55)	13.30^{c} (3.67)	10.00^{c} (2.83)	6.70^{e} (2.40)	6.70^{d} (2.40)	3.30^{e} (9.15)	6.70^{d} (2.40)	0.00	0.00	0.00
SEm±	0.367	0.275	0.286	0.290	0.281	0.295	0.243	0.166	0.110	0.162
CD(0.05)	0.776	0.467	0.998	0.848	1.039	0.852	0.878	0.822	0.634	NS

M: Month of storage

Means in each column with at least one letter in common are not significantly different at 5% level of probability

Values in parentheses are square root transformed values

Statistical analysis was not done for M1,M2 and M3 since the range is too small

The mortality of adults decreased progressively over the period of study, for all the treatments evaluated. However, spinosad consistently registered highest mortality of adults throughout the storage period. Spinosad was followed by neem oil treated seeds with mortality ranging from 100 per cent in first three months to 26.7 per cent in the thirteenth month of storage. However, neem oil was on par with castor oil, coconut oil, neem leaf powder and neem kernel powder during the course of evaluation. Sweet flag rhizome powder and *Beauveria bassiana* registered the lowest mortality of adult beetles during the period of study.

No significant difference was observed in terms of mortality of beetles was observed at the end storage period (M13). However, the highest mortality (33.3 %) of adults was observed in spinosad treated seeds.

4.1.2.1.11 Number of eggs

The effect of different seed protectants on number of eggs laid by beetle during the storage period is furnished in Table 10.

The results indicated that all the treatments were significantly superior to control in inhibiting egg laying by the female beetle. No eggs were laid in seeds treated with protectants and stored for up to one month. However, oviposition was observed in all the treatments from second month of storage onwards. The number of eggs laid increased progressively over the period of study. In contrast, no eggs were laid in seeds treated with spinosad for up to five months of storage.

Least number of eggs werelaid in spinosad treated seeds with the number of eggs ranging from zero in second month to 96.67 in the thirteenth month of storage. It was followed by neem oil with number of eggs ranging from 0 - 99 eggs during the period of storage. Neem oil was on par with castor oil and coconut oil treated seeds with the number of eggs ranging from 0-100.67 throughout the study period. Similarly, neem leaf powder and neem kernel powder were found to be on par with

Table 10.Effect of seed treatments on number of eggs laid by beetle in cowpea (Lola) during storage

Treatment	Number of eggs laid											
	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13
T1	9.00^{e} (3.08)	14.67^{c} (3.89)	16.67^{f} (4.14)	14.67^{c} (3.89)	26.67^{g} (5.21)	35.00^{d} (5.95)	49.67^{f} (7.08)	56.67^{f} (7.56)	77.00^{f} (8.80)	84.67^{e} (9.23)	93.00^{cd} (9.67)	99.00^{cd} (9.97)
T2	10.50^{cde} (3.32)	14.67^{c} (3.89)	17.67^{ef} (4.26)	15.00^{c} (3.94)	27.00^{fg} (5.24)	35.00^{d} (5.96)	53.67^{def} (7.36)	59.67^{def} (7.75)	82.67^{def} (9.12)	90.67^{cde} (9.55)	94.67^{c} (9.76)	100.67^{c} (10.06)
T3	10.00^{cde} (3.24)	14.67^{c} (3.89)	18.33^{ef} (4.34)	14.67^{c} (3.89)	29.67^{efg} (5.49)	35.00^{d} (5.95)	53.00^{ef} (7.31)	59.67^{def} (7.76)	81.00^{ef} (9.03)	90.67^{cde} (9.55)	95.00^{c} (9.77)	100.67^{c} (10.06)
T4	11.50^{bcd} (3.46)	19.00^{b} (4.41)	25.00^{d} (5.05)	28.33^{b} (5.37)	33.00^{defg} (5.77)	44.67^{b} (6.72)	58.00^{cd} (7.65)	66.00^{bc} (8.15)	94.00^{b} (9.72)	97.67^{bc} (9.91)	102.67^{b} (10.16)	108.67^{b} (10.45)
T5	10.00^{cde} (3.23)	16.00^{bc} (4.06)	18.67^{ef} (4.36)	18.67^{c} (4.38)	29.00^{fg} (5.43)	36.00^{cd} (6.04)	53.00^{ef} (7.31)	62.00^{cde} (7.90)	86.00^{cde} (9.30)	90.67^{cde} (9.55)	95.00^{c} (9.77)	102.67^{c} (10.12)
T6	12.50^{bc} (3.59)	17.67^{bc} (4.25)	32.67^{b} (5.76)	28.67^{b} (5.38)	37.67^{bcd} (6.18)	48.00^{b} (6.96)	59.67^{bc} (7.75)	66.00^{bc} (8.15)	90.67^{bc} (9.55)	99.00^{b} (9.97)	102.67^{b} (10.16)	110.67^{b} (10.54)
T7	13.50^{b} (3.74)	18.00^{bc} (4.29)	31.00^{bc} (5.61)	35.00^{b} (5.95)	44.67^{b} (6.72)	44.00^{bc} (6.64)	61.00^{bc} (7.84)	64.67^{bc} (8.07)	88.00^{bcd} (9.41)	100.00^{b} (10.02)	101.67^{b} (10.11)	108.67^{b} (10.45)
T8	9.50^{de} (3.16)	14.50^{c} (3.87)	18.00^{ef} (4.30)	14.67^{c} (3.89)	27.00^{fg} (5.24)	35.67^{cd} (6.01)	52.00^{ef} (7.24)	59.00^{ef} (7.71)	81.67^{ef} (9.06)	89.67^{de} (9.50)	94.67 (9.76)	101.67^{c} (10.11)
T9	10.50^{cde} (3.30)	16.50^{bc} (4.12)	23.67^{d} (4.91)	19.67^{c} (4.49)	33.67^{def} (5.84)	40.67^{bcd} (6.42)	53.00^{ef} (7.31)	65.00^{bc} (8.09)	87.67^{cd} (9.39)	96.67^{bcd} (9.85)	100.67^{b} (10.06)	106.67 (10.35)
T10	11.50^{bcd} (3.46)	16,50^{bc} (4.12)	21.67^{de} (4.71)	17.00^{c} (4.18)	36.00^{cde} (6.04)	40.67^{bcd} (6.42)	54.67^{de} (7.42)	63.67^{cd} (8.01)	88.67^{bc} (9.44)	93.67^{bcd} (9.70)	100.67^{b} (10.06)	107.00^{b} (10.37)
T11	11.50^{bcd} (3.46)	18.00^{bc} (4.29)	26.00^{cd} (5.15)	30.67^{b} (5.58)	42.00^{bc} (6.52)	47.00^{b} (6.89)	64.67^{b} (8.07)	68.67^{b} (8.32)	90.67^{bc} (9.55)	99.67^{b} (10.01)	101.67^{b} (10.11)	109.00^{b} (10.46)
T12	0.00	0.67^{d} (1.00)	0.00	4.00^{d} (2.11)	4.00^{h} (2.08)	11.00^{e} (3.38)	22.67^{g} (4.81)	34.33^{g} (5.90)	47.33^{g} (6.92)	61.00^{f} (7.84)	89.67^{d} (9.49)	96.67^{d} (9.86)
T13	114.00^{a} (10.70)	117.50^{a} (10.86)	141.67^{a} (11.92)	111.00^{a} (10.51)	122.67^{a} (11.07)	126.00^{a} (11.23)	136.00^{a} (11.68)	102.00^{a} (10.12)	131.00^{a} (11.46)	143.67^{a} (12.01)	154.00^{a} (12.43)	151.30^{a} (12.32)
SEm±	0.345	0.335	0.347	0.311	0.303	0.266	0.229	0.140	0.152	0.141	0.116	0.098
CD(0.05)	0.371	0.488	0.476	0.693	0.606	0.632	0.320	0.281	0.322	0.373	0.253	0.198

M: Month of storage
Means in each column with at least one letter in common are not significantly different at 5% level of probability
Values in parentheses are square root transformed values
Statistical analysis was not done for M1 since the range is too smal

each other. Highest number of eggs was observed in control, which varied from 111.00 in fifth months to 154.00 in the twelfth month of storage.

At the end of storage period (M13), number of eggs laid by pulse beetles varied from 96.67 (spinosad) to 151.30 (control). Spinosad was followed by the vegetable oils namely neem oil (99.00), castor oil (100.67) and coconut oil (100.67) as well as neem kernel powder (101.67) and neem leaf powder (102.67), all of which were significantly superior to the remaining treatments. Paanal leaf powder (T6) and *Beauveria bassiana* (T12) registered the highest number of eggs among the different seed protectants evaluated (108.67 and 109.00 respectively), but were superior to control (151.30).

4.1.2.1.12 Egg hatchability

The results of influence of different seed protectants on egg hatchability during storage period are presented in Table 11.

All the seed protectant treatments used wassignificantly superior to control in suppressing the hatching of beetle eggs. Highest number of eggs hatched in untreated seeds throughout the study period, with values ranging from 47.64 per cent in fifth month of storage to 60.45 per cent in the fourth month. No eggs hatched out in treatments involving neem oil, castor oil, neem leaf powder and neem kernel powder for up to three months of storage. No egg hatched in coconut oil for up to six months of storage, but for a negligible variation at the fourth month of storage. Treatment with spinosad prevented eggs from hatching for up to seven months. Egg hatchability increased progressively throughout the storage period irrespective of the seed protectants used.

Spinosad consistently recorded the lowest egg hatchability (10.12 % at M8 to 26.20 % at M13) and was significantly superior to all other treatments. At the end of storage, egg hatchability varied from 26.20 per cent (spinosad) to 55.73 per cent

Table 11.Effect of seed treatments on egg hatchability of pulse beetle in cowpea (Lola) during storage

Treatment	Egg hatchability of pulse beetle (%)										
	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13
T1	0.00	5.88^{d} (2.24)	0.00	8.78^{c} (3.03)	16.02^{de} (4.05)	18.11^{de} (4.31)	21.16^{e} (4.65)	25.90^{d} (5.12)	27.96^{cd} (5.33)	28.67^{c} (5.40)	28.28^{d} (5.36)
T2	0.00	7.04^{d} (2.45)	0.00	8.70^{c} (3.02)	18.21^{cd} (4.28)	19.86^{cde} (4.51)	21.80^{e} (4.72)	24.54^{de} (5.00)	27.58^{cd} (5.30)	29.58^{c} (5.48)	30.13^{d} (5.53)
T3	0.00	1.67^{d} (1.25)	0.00	0.00	10.48^{e} (3.31)	16.35^{e} (4.10)	19.56^{e} (4.48)	21.40^{ef} (4.67)	25.43^{d} (5.09)	28.06^{c} (5.34)	29.14^{d} (5.44)
T4	8.60^{b} (2.66)	18.75^{b} (4.38)	14.14 (3.83)	19.45^{b} (4.46)	25.34^{b} (5.08)	25.16^{bc} (5.05)	28.25^{bcd} (5.36)	32.64^{b} (5.76)	33.80^{b} (5.86)	34.09^{b} (5.88)	36.20^{b} (6.06)
T5	0.00	7.03^{cd} (2.73)	6.84 (2.42)	10.14^{c} (3.20)	20.02^{bcd} (4.47)	20.75^{bcde} (4.61)	23.18^{cde} (4.86)	28.29^{bcd} (5.36)	29.04^{c} (5.43)	30.17^{c} (5.54)	32.37^{c} (5.73)
T6	8.68^{b} (2.68)	18.24^{b} (4.30)	12.54 (3.09)	17.61^{b} (4.24)	24.20^{bc} (4.96)	24.58^{bc} (5.01)	28.29^{bcd} (5.36)	31.26^{bc} (5.63)	34.69^{b} (5.93)	34.76^{b} (5.94)	37.65^{b} (6.18)
T7	6.88^{b} (2.43)	17.08^{bc} (4.14)	15.99 (4.05)	21.62^{b} (4.69)	23.62^{bc} (4.89)	22.39^{bcd} (4.78)	29.38^{bc} (5.47)	30.69^{bc} (5.58)	35.67^{b} (6.01)	34.44^{b} (5.91)	36.89^{b} (6.11)
T8	0.00	7.04^{d} (2.45)	5.56 (1.85)	9.88^{c} (3.18)	20.58^{bcd} (4.58)	20.52^{bcde} (4.58)	23.21^{de} (4.85)	26.94^{cd} (5.24)	29.00^{c} (5.43)	30.28^{c} (5.55)	32.79^{c} (5.77)
T9	5.72^{b} (2.23)	18.40^{b} (4.34)	15.00 (3.39)	18.82^{b} (4.39)	21.30^{bcd} (4.66)	24.58^{bc} (5.01)	28.90^{bcd} (5.40)	30.79^{bc} (5.59)	32.55^{b} (5.75)	34.78^{b} (5.94)	35.96^{b} (6.04)
T10	5.53^{b} (2.20)	19.99^{b} (4.52)	16.99 (3.59)	18.45^{b} (4.35)	23.78^{bc} (4.93)	25.74^{b} (5.11)	28.79^{bcd} (5.41)	31.95^{b} (5.69)	34.34^{b} (5.90)	34.44^{b} (5.91)	36.46^{b} (6.08)
T11	9.10^{b} (3.08)	21.79^{b} (4.69)	19.35 (3.86)	22.25^{b} (4.77)	26.86^{b} (5.22)	25.75^{b} (5.12)	29.61^{b} (5.49)	31.97^{b} (5.69)	36.13^{b} (6.05)	35.08^{b} (5.96)	37.32^{b} (6.15)
T12	0.00	0.00	0.00	0.00	0.00	10.12^{f} (3.17)	14.41^{f} (3.83)	20.43 (4.57)	21.27^{e} (4.66)	24.16^{d} (4.97)	26.20^{e} (5.17)
T13	53.28^{a} (7.33)	60.45^{a} (7.80)	47.64 (6.92)	52.73^{a} (7.29)	47.85^{a} (6.95)	54.16^{a} (7.39)	52.43^{a} (7.25)	50.85^{a} (7.16)	53.38^{a} (7.34)	55.08^{a} (7.45)	55.73^{a} (7.50)
SEm±	0.449	0.302	0.400	0.215	0.153	0.154	0.133	0.105	0.103	0.093	0.091
CD(0.05)	2.308	1.483	NS	0.688	0.765	0.580	0.605	0.424	0.305	0.224	0.191

M: Month of storage

Means in each column with at least one letter in common are not significantly different at 5% level of probability

Values in parentheses are square root transformed values

Statistical analysis was not done for M1and M2 since the range is too small

(control). Spinosad was followed by the three vegetable oils, namely, neem oil (28.28%), coconut oil (29.14 %) and castor oil (30.13%), which registered low hatchability and were on par with each other. Similarly, neem leaf powder (32.37 %) and neem kernel powder (32.79%) were found to be on par with each other. All the other treatments were found to be on par with each other and weresignificantly superior to control.

4.1.2.1.13 Seed infestation

The results of influence of different seed protectants on seed infestation during storage period are presented in Table 12.

All the seed protectant treatments used weresignificantly superior to control in reducing infestation of cowpea seeds in storage. Seed infestation was not observed in treatments involving neem oil, castor oil, neem leaf powder and neem kernel powder for up to four months of storage and that of coconut oil treated seeds for up to six months of storage. No seed infestation was observed in spinosad treated seeds for up to seven months of storage. Seed infestation increased progressively throughout the storage period, irrespective of the seed protectants used.

Spinosad consistently recorded the lowest seed infestation (12.00 % at M8 to 36.00 % at M13) and was significantly superior to all other treatments. Spinosad was followed by the three vegetable oils, namely, neem oil, castor oil and coconut oil, which registered low seed infestation. Next to oils, neem leaf powder and neem kernel powder recorded the least seed infestation.

At the end of the storage period, treatment with neem oil (32.00%) recorded the lowest seed infestation and was followed by castor oil (34.70%), spinosad (36.00%) and coconut oil (37.30%).All the other treatments were found to be on par with each other. The highest seed infestation was recorded in control (60.00%).

Table 12.Effect of seed treatments on seed infestation in cowpea (Lola) during storage

Treatment	Per cent seed infestation with pulse beetle									
	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13
T1	0.0	0.0	9.3^{d} (3.12)	12.0^{cde} (3.54)	17.3^{de} (4.22)	22.7^{d} (4.81)	26.7^{ef} (5.21)	29.3^{c} (5.46)	33.3^{d} (5.81)	32.0^{d} (5.70)
T2	0.0	0.0	9.3^{d} (3.12)	10.7^{de} (3.33)	20.0^{cde} (4.53)	24.0^{cd} (4.91)	28.0^{def} (5.33)	30.7^{c} (5.58)	34.7^{d} (5.93)	34.7^{cd} (5.93)
T3	0.0	0.0	0.0	8.0^{e} (2.92)	16.0^{e} (4.06)	25.3^{bcd} (5.08)	33.3^{bcd} (5.81)	30.7^{c} (5.58)	34.7^{d} (5.93)	37.3^{c} (6.14)
T4	17.3^{b} (4.18)	10.7^{b} (3.33)	14.7^{c} (3.89)	22.7^{b} (4.81)	25.3^{bc} (5.06)	30.7^{b} (5.58)	38.7^{b} (6.25)	38.7^{b} (6.25)	45.3^{bc} (6.76)	45.3^{b} (6.76)
T5	0.0	6.7^{b} (2.39)	12.0^{cd} (3.50)	17.3^{bc} (4.20)	21.3^{bcd} (4.67)	26.7^{bcd} (5.21)	33.3^{bcd} (5.81)	36.0^{b} (6.04)	36.0^{d} (6.04)	44.0^{b} (6.67)
T6	18.7^{b} (4.23)	13.3^{b} (3.24)	20.0^{b} (4.51)	24.0^{b} (4.94)	25.3^{b} (5.08)	30.7^{b} (5.58)	38.7^{b} (6.25)	41.3^{b} (6.47)	44.0^{bc} (6.67)	45.3^{b} (6.77)
T7	16.0^{b} (3.84)	13.3^{b} (3.71)	21.3^{b} (4.67)	22.7^{b} (4.78)	25.3^{b} (5.08)	32.0^{b} (5.70)	38.7^{b} (6.26)	41.3^{b} (6.47)	45.3^{bc} (6.77)	45.3^{b} (6.77)
T8	0.0	4.0^{b} (1.65)	12.0^{cd} (3.54)	16.0^{cd} (3.99)	22.7^{bc} (4.81)	26.7^{bcd} (5.19)	32.0^{cde} (5.68)	36.0^{b} (6.04)	36.0^{d} (6.04)	44.0^{b} (6.67)
T9	18.7^{b} (4.37)	12.0^{b} (3.06)	20.0^{b} (4.53)	22.7^{b} (4.81)	24.0^{bc} (4.94)	29.3^{bc} (5.46)	36.0^{bc} (6.02)	40.0^{b} (6.36)	42.7^{c} (6.56)	44.0^{b} (6.67)
T10	20.0^{b} (4.53)	12.0^{b} (3.06)	20.0^{b} (4.53)	22.7^{b} (4.81)	24.0^{bc} (4.94)	30.7^{b} (5.58)	37.3^{bc} (6.15)	41.3^{b} (6.46)	44.0^{bc} (6.67)	44.0^{b} (6.67)
T11	21.3^{b} (4.65)	10.7^{b} (2.94)	20.0^{b} (4.53)	24.0^{b} (4.94)	24.0^{bc} (4.95)	32.0^{b} (5.70)	40.0^{b} (6.36)	41.3^{b} (6.47)	48.0^{ab} (6.96)	44.0^{b} (6.67)
T12	0.0	0.0	0.0	0.0	12.0^{f} (3.50)	14.7^{e} (3.84)	24.0^{f} (4.95)	26.7^{c} (5.21)	28.0^{e} (5.34)	36.0^{c} (6.04)
T13	61.3^{a} (7.86)	56.0^{a} (7.51)	62.7^{a} (7.95)	65.3^{a} (8.11)	62.7^{a} (7.94)	65.3^{a} (8.11)	65.3^{a} (8.11)	61.3^{a} (7.86)	53.3^{a} (7.33)	60.0^{a} (7.78)
SEm±	0.327	0.398	0.229	0.220	0.166	0.157	0.128	0.110	0.092	0.085
CD(0.05)	1.556	2.756	0.498	0.752	0.547	0.649	0.560	0.447	0.374	0.303

M: Month of storage

Means in each column with at least one letter in common are not significantly different at 5% level of probability

Values in parentheses are square root transformed values

Statistical analysis was not done for M1and M2 since the range is too small

4.1.2.1.14 Seed microflora infection

The result of seed infection per cent as influenced by seed protectant treatments during the storage period are presented in Table 13.

Seed microflora infection was examined by blotter and agar plate method. In blotter method, the seed microflora infection (%) varied from 30.00 per cent in T1, T2, T3, T5 and T8 to 50.00 per cent in T13 at the end of storage period. The lowest seed microflora infection was recorded in seeds treated with oils and neem based products *viz.*,neem oil, castor oil, coconut oil, leaf powder and kernel powder (30.00%) followed by spinosad and diatomaceous earth (33.33%).T10 (ash; 36.67 %) was found to be on par with the above mentioned treatments. The highest seed microflora infection was recorded in T13 (control; 50.00 %) at the end of storage period. Before storage, the initial seed microflora infection recorded was 13.33 per cent.

In agar plate method, the seed microflora infection (%) varied from 40.00 per cent in T1, T2, T3, T5 and T8 to 60.00 per cent in T13 at the end of storage period. The lowest seed microflora infection was recorded in seeds treated with oils and neem based products *viz.*,neem oil, castor oil, coconut oil, leaf powder and kernel powder (40.00%) followed by spinosad and diatomaceous earth (43.33%). T10 (ash; 46.67 %) was found to be on par with the above mentioned treatments. The highest seed microflora infection was recorded in T13 (control; 60.00 %) at the end of storage period. In both methods, seed microflora observed was*Aspergillus niger* and *Aspergillus flavus.*

4.2 Seed quality parameters of cowpea variety Kanakamony

The result obtained pertaining to seeds of cowpea variety Kanakamony before and after treatment with various seed protectants against pulse beetle is detailed below.

Table 13. Effect of seed treatments on seed infection in cowpea (Lola) at the end of storage

Treatment	Seed infection %	
	Blotter method	Agar plate method
T1	30.00[c] (5.52)	40.00[d] (6.36)
T2	30.00[c] (5.52)	40.00[d] (6.36)
T3	30.00[c] (5.52)	40.00[d] (6.36)
T4	43.33[ab] (6.61)	53.33[abc] (7.33)
T5	30.00[c] (5.52)	40.00[d] (6.36)
T6	43.33[ab] (6.61)	53.33[abc] (7.33)
T7	46.67[a] (6.86)	56.67[ab] (7.54)
T8	30.00[c] (5.52)	40.00[d] (6.36)
T9	33.33[c] (5.80)	43.33[cd] (6.61)
T10	36.67[bc] (6.08)	46.67[bcd] (6.86)
T11	46.67[a] (6.86)	56.67[ab] (7.51)
T12	33.33[c] (5.80)	43.33[cd] (6.61)
T13	50.00[a] (7.08)	60.00[a] (7.76)
SEm±	0.108	0.105
CD(0.05)	0.649	0.794

Means in each column with at least one letter in common are not significantly different at 5% level of probability

Values in parentheses are square root transformed values

4.2.1 Quality of seed before treatment

The quality parameters of the seed before treatment with seed protectants are furnished in Table 14.

A fresh seed lot with a germination of 100 per cent was used for seed treatment (T1 to T13).The seedling shoot length, seedling root length, seedling dry weight, vigour index I, vigour index II, microflora infection and electrical conductivity of seed leachate of the seeds were29.42 cm, 12.01 cm, 0.049 g, 4143, 4.9, 10 per cent and 0.265 dSm^{-1} respectively. The seeds were found to be totally free from pulse beetle infestation

4.2.2 Seed quality parameters after seed treatment

4.2.2.1 Analysis of variance

The analysis of variance revealed that, there existed significant differences in the impact of various seed treatments on seed quality parameters like germination per cent, speed of germination, seedling shoot and root length, seedling dry weight, seedling vigour index I and II, electrical conductivity of seed leachate and seed microflora over the storage period. Significant differences among treatments were also evident with respect to the effectiveness against pulse beetle infestation as assessed by number of eggs, hatchability and pulse beetle infested seed per cent during storage.

4.2.2.1.1 Germination

The impact of various seed treatments on germination during storage period is furnished in Table 15.

Irrespective of the seed protectants used for seed treatment, germination declined progressively over the period of storage. Germination was found to be above

Table 14. Seed quality parameters of cowpea (Kanakamony) before storage

Parameter	Details
Moisture content (%)	9.00
Germination (%)	100.00
Seedling shoot length(cm)	29.42
Seedling root length(cm)	12.01
Seedling dry weight (g)	0.049
Vigour index I	4143.00
Vigour index II	4.90
EC of seed leachate (dSm^{-1})	0.265
Seed microflora infection (%)	10.00
Pulse beetle infested seed (%)	0.00

Table 15.Effect of seed treatments on germination in cowpea (Kanakamony) during storage

Treatment	Germination (%)													
	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	Mean
T1	99.67 (10.01)	98.00 (9.92)	99.00^{a} (9.97)	93.33^{ab} (9.69)	86.67 (9.34)	87.00^{ab} (9.35)	86.00^{b} (9.30)	82.33^{cd} (9.10)	80.33^{bc} (8.99)	73.33^{abc} (8.59)	68.67^{abc} (8.32)	62.33^{a} (7.93)	54.33^{a} (7.40)	82.38 (9.07)
T2	99.67 (10.01)	98.00 (9.92)	96.00^{cd} (9.82)	93.00^{ab} (9.67)	84.00 (9.19)	85.33^{ab} (9.26)	85.33^{bc} (9.26)	83.00^{bc} (9.14)	80.00^{bcd} (8.97)	73.67^{ab} (8.61)	68.00^{abc} (8.28)	62.00^{a} (7.90)	52.67^{a} (7.29)	81.59 (9.03)
T3	99.67 (10.01)	98.33 (9.94)	96.00^{cd} (9.82)	94.00^{a} (9.72)	85.67 (9.28)	86.33^{ab} (9.32)	86.00^{b} (9.30)	82.33^{cd} (9.10)	81.33^{ab} (9.05)	73.33^{abc} (8.59)	68.67^{abc} (8.32)	61.33^{a} (7.86)	54.00^{a} (7.38)	82.08 (9.05)
T4	100.00 (10.02)	98.00 (9.92)	96.00^{cd} (9.82)	93.00^{ab} (9.67)	85.00 (9.25)	84.33^{b} (9.21)	84.00^{de} (9.19)	80.33^{ef} (8.99)	78.00^{de} (8.86)	72.33^{abcd} (8.53)	67.00^{abcd} (8.22)	59.33^{ab} (7.73)	48.00^{bc} (6.96)	80.41 (8.95)
T5	100.00 (10.02)	98.67 (9.96)	99.00^{a} (9.97)	94.00^{a} (9.72)	88.00 (9.41)	87.33^{ab} (9.37)	86.33^{b} (9.32)	84.33^{ab} (9.21)	81.33^{ab} (9.05)	74.00^{a} (8.63)	69.00^{ab} (8.34)	63.00^{a} (7.97)	52.00^{a} (7.24)	82.85 (9.09)
T6	99.00 (9.97)	99.00 (9.97)	96.00^{cd} (9.82)	91.00^{bc} (9.57)	84.00 (9.19)	84.00^{bc} (9.19)	83.00^{e} (9.14)	81.00^{de} (9.03)	79.33^{bcd} (8.93)	69.33^{de} (8.36)	66.33^{cd} (8.18)	60.00^{ab} (7.77)	46.67^{c} (6.86)	79.90 (8.92)
T7	99.33 (9.99)	98.33 (9.94)	95.33^{cd} (9.79)	90.00^{c} (9.51)	84.00 (9.19)	84.00^{bc} (9.19)	83.33^{de} (9.16)	81.03^{de} (9.03)	78.00^{de} (8.86)	70.33^{bcde} (8.42)	66.67^{bcd} (8.19)	59.33^{ab} (7.73)	46.67^{c} (6.87)	79.72 (8.91)
T8	100.00 (10.02)	99.00 (9.97)	98.00^{bc} (9.92)	94.00^{a} (9.72)	89.00 (9.46)	88.33^{a} (9.42)	88.00^{a} (9.41)	85.00^{a} (9.25)	83.00^{a} (9.14)	74.00^{a} (8.63)	69.33^{a} (8.36)	62.33^{a} (7.93)	52.00^{a} (7.25)	83.23 (9.11)
T9	100.00 (10.02)	99.00 (9.97)	97.00^{bc} (9.87)	90.00^{c} (9.51)	85.00 (9.25)	85.00^{ab} (9.25)	84.33^{cd} (9.21)	82.33^{cd} (9.10)	78.00^{de} (8.86)	70.00^{cde} (8.40)	66.67^{bcd} (8.20)	59.33^{ab} (7.73)	47.00^{c} (6.89)	80.28 (8.94)
T10	100.00 (10.02)	99.00 (9.97)	95.00^{d} (9.77)	91.00^{bc} (9.57)	84.00 (9.19)	84.33^{b} (9.21)	83.33^{de} (9.16)	82.33^{cd} (9.10)	78.33^{cde} (8.88)	70.33^{bcde} (8.42)	66.67^{bcd} (8.19)	59.3^{ab} (7.73)	47.67^{bc} (6.94)	80.10 (8.94)
T11	99.33 (9.99)	97.67 (9.91)	94.67^{d} (9.76)	87.00^{d} (9.35)	86.00 (9.30)	84.00^{bc} (9.19)	83.00^{e} (9.14)	78.00^{g} (8.86)	77.00^{e} (8.80)	68.67^{e} (8.32)	64.67^{d} (8.07)	56.00^{bc} (7.52)	46.33^{c} (6.84)	78.64 (8.85)
T12	99.67 (10.01)	98.33 (9.94)	96.00^{cd} (9.82)	90.00^{c} (9.51)	84.67 (9.23)	85.33^{ab} (9.26)	83.00^{e} (9.14)	80.33^{ef} (8.99)	79.67^{bcd} (8.95)	70.67^{abcde} (8.43)	67.67^{abc} (8.26)	62.00^{a} (7.91)	51.00^{ab} (7.18)	80.64 (8.97)
T13	100.00 (10.02)	98.67 (9.96)	94.33^{d} (9.74)	86.33^{d} (9.32)	83.33 (9.16)	80.67^{c} (9.01)	81.00^{f} (9.03)	79.00^{fg} (8.92)	74.00^{f} (8.63)	64.67^{f} (8.07)	62.00^{e} (7.91)	53.67^{c} (7.36)	40.67^{d} (6.41)	76.79 (8.73)
Mean	99.72	98.46	96.33	91.28	85.33	85.08	84.36	81.64	79.10	71.13	67.03	60.00	49.15	
SEm±	0.004	0.006	0.014	0.024	0.023	0.023	0.016	0.018	0.022	0.029	0.022	0.036	0.048	
CD(0.05)	NS	NS	0.092	0.149	NS	0.198	0.065	0.108	0.117	0.202	0.158	0.308	0.279	

M: Month of storage

Means in each column with atleast one letter in common are not significantly different at 5% level of probability

Values in parentheses are square root transformed values

the minimum seed certification standards (MSCS) of 75 per cent for nine MAS in all the treatments except in untreated seeds (T13: control). In T13, germination was retained above 75 per cent for up to eighth month of storage only.

Germination in all the seed protectant treatments were found to be significantly superior to untreated seeds (T13: control) during storage. Mean germination over the storage period ranged from 76.79 per cent (control) to 80.92 per cent (neem kernel powder). Highermean germination was observed in seeds treated with neem based product *viz.*, kernel powder (T8) followed by leaf powder (T5) and oil (T1).

No significant difference in germination was observed for 1st, 2nd and 5th month of storage. However, Germination in all the seed protectant treatments was found to be significantly superior to untreated seeds (T13: control) during storage. Throughout the storage period of 13 MAS, treatment T8 had recorded the highest germination, the exception being at M3.

Germination in seeds treated with neem kernel powder (T8) was the highest (83.00 % and 52.00% respectively) at ninth and thirteenth month of storage (end of storage period). At ninth month, germination in T8was found to be on par with seeds treated with neem leaf powder (T5: 81.33%) and coconut oil (T3: 81.33%). Seeds treated with neem oil (T1: 80.33 %), castor oil (T2: 80.00%), spinosad (T12: 79.67%), and paanal leaf powder (T6: 79.33%) were the next best.

At the end storage period (M13), neem oil (T1: 54.33 %) recorded the highest germination per cent. Treatments T1 (neem oil: 54.33 %), T2 (castor oil: 52.67 %), T3 (coconut oil: 54.00%), T5 (neem leaf powder: 52.00%) and T8 (neem kernel powder: 52.00 %) were found to be on par with each other. T12 (spinosad: 51.00%) was found to be on par with all the above treatments.

4.2.2.1.2 Speed of germination

The impact of various seed treatment on speed of germination during storage period is furnished in Table 16.

Speed of germination declined progressively over the period of storage irrespective of the seed protectants used. No significant difference in speed of germination was observed at 1, 2, 4, 6 and 9 month of storage. Highermean speed of germination over storage was observed in neem kernel powder (T8: 24.03), neem leaf powder (T5:23.88)and neem oil (T1:23.83) followed by coconut oil (T3: 23.81) and castor oil (T2: 23.60).

Unlike this, at thirteenth month, speed of germination was highest in neem oil (T1:15.45). Seeds treated with coconut oil (T3:15.38), castor oil (T2:15.11) and neem leaf powder (T5: 14.65) were found to be the next best. Untreated seed (T13) was inferior to all other treatments both at 9 and 13 month of storage.

4.2.2.1.3 Seedling shoot length

The impact of various seed treatments on seedling shoot length during storage period is furnished in Appendix IV.

Seedling shoot length was observed to decrease with increase in storage period. Highermean shoot length over storage was observed in seeds treated with neem based product *viz.*, kernel powder (T8: 21.64 cm) followed by leaf powder (T5:21.64 cm) and oil (T1:21.10 cm). No significant difference in shoot length was observed at 9, 10, 11 and 13 month of storage.

After twelve months of storage, highest shoot length was recorded in neem leaf powder (T5: 13.00 cm). Neem kernel powder (T8:12.00 cm) and castor oil (T2: 12.00 cm) were found to be on par with each other. T1 (neem oil: 12.33 cm) and T3

Table 16.Effect of seed treatments on speed of germination in cowpea (Kanakamony) during storage

Treatment	Speed of germination													
	M1	**M2**	**M3**	**M4**	**M5**	**M6**	**M7**	**M8**	**M9**	**M10**	**M11**	**M12**	**M13**	**Mean**
T1	30.98	29.74	30.39^{a}	26.36	25.54^{ab}	25.50	24.88^{bcd}	22.70^{cd}	22.20	21.47^{ab}	18.48^{ab}	16.13^{a}	15.45^{a}	23.83
T2	30.94	29.74	28.48^{abc}	25.48	25.52^{ab}	25.31	25.44^{ab}	22.77^{cd}	22.28	21.30^{ab}	18.24^{ab}	16.12^{a}	15.11^{a}	23.60
T3	30.97	29.96	28.11^{bc}	26.65	25.52^{ab}	25.34	25.87^{ab}	22.87^{cd}	22.83	21.60^{ab}	18.39^{ab}	16.03^{a}	15.38^{a}	23.81
T4	31.28	30.11	28.10^{bc}	24.71	24.72^{abc}	24.88	24.24^{cde}	22.47^{d}	22.10	21.21^{ab}	18.40^{ab}	15.53^{a}	13.55^{b}	23.18
T5	31.35	30.08	30.48^{a}	25.40	25.43^{ab}	25.63	25.20^{bc}	23.73^{ab}	22.67	21.67^{ab}	18.36^{ab}	15.80^{a}	14.65^{a}	23.88
T6	30.55	30.67	28.19^{bc}	24.63	24.15^{bc}	24.40	23.10^{fgh}	22.57^{d}	22.45	21.41^{ab}	17.99^{abc}	15.66^{a}	12.97^{b}	22.98
T7	30.58	30.95	27.19^{c}	27.03	24.39^{bc}	24.67	23.80^{efg}	22.47^{d}	22.00	21.06^{b}	18.08^{abc}	15.53^{a}	13.22^{b}	23.15
T8	31.31	31.13	29.96^{ab}	26.55	26.02^{a}	25.67	26.42^{a}	23.93^{a}	23.23	22.20^{a}	18.53^{a}	16.11^{a}	11.29^{cd}	24.03
T9	31.31	30.94	29.60^{ab}	26.20	24.37^{bc}	25.27	24.03^{def}	22.50^{d}	22.10	21.35^{ab}	18.00^{abc}	15.51^{a}	11.59^{cd}	23.29
T10	31.28	30.87	28.19^{bc}	25.72	23.40^{c}	23.67	23.37^{efgh}	23.47^{abc}	22.16	21.76^{ab}	17.91^{bc}	15.51^{a}	11.40^{cd}	22.98
T11	30.89	30.00	27.17^{c}	24.06	23.47^{c}	23.67	22.87^{gh}	22.73^{cd}	22.56	21.41^{ab}	17.51^{c}	15.19^{a}	12.74^{b}	22.63
T12	31.25	31.09	29.80^{ab}	25.67	24.36^{bc}	23.60	24.33^{cde}	23.27^{abcd}	22.80	21.79^{ab}	18.28^{ab}	16.37^{a}	13.20^{b}	23.52
T13	31.33	31.33	28.45^{abc}	25.34	24.27^{bc}	23.11	22.63^{h}	22.89^{bcd}	21.92	19.44^{c}	16.44^{d}	13.08^{b}	10.44^{d}	22.36
SEm±	0.074	0.146	0.246	0.202	0.181	0.230	0.203	0.102	0.088	0.132	0.098	0.166	0.271	
CD(0.05)	NS	NS	2.151	NS	1.591	NS	1.054	0.847	NS	1.077	0.572	1.326	1.039	

M: Month of storage

Means in each column with at least one letter in common are not significantly different at 5% level of probability

(castor oil: 12.33 cm) too werefound to be on par with each other. Untreated seeds recorded the least shoot length (7.67 cm) and differed significantly from other treatments.

4.2.2.1.4 Seedling root length

The impact of various seed treatments on seedling root length during storage period is furnished in Appendix V.

Seedling root length decreased over the period of storage. Highermean root length over storage was observed in seeds treated with neem based product *viz.*, neem kernel powder (T8: 8.91 cm), followed by neem leaf powder (T5: 8.43 cm) and neem oil (8.81 cm) while it was the least in control (T13: 8.09 cm).No significant difference in root length was observed at ninth month of storage.

Similar trend was observed at the end storage period (M13).Neem leaf powder (T5: 6.87 cm) followed by neem kernel powder (T8: 6.80 cm) and neem oil (6.77 cm) registered higher root length. Castor oil (6.57) and coconut oil (6.50) werefound to be on par with the above mentioned treatments. The lowest root length was recorded in T13 (5.87 cm) and differed significantly from other treatments.

4.2.2.1.5 Seedling dry weight

The impact of various seed treatments on seedling dry weight during storage period is furnished in Appendix VII.

Seedling dry weightdecreased over the period of storage, irrespective of the seed protectants used.Highermean seedling dry weight over storage observed in neem kernel powder (T8: 0.042 g) and neem leaf powder (T5: 0.042 g), followed by neem oil (T1:0.042 g). At the end storage period (13MAS), seedling dry weight varied between 0.029 g (T8 and T5) and 0.024 g (T13). Treatments T8 and T5 was found to be on par with T1 (0.028 g). Treatment 13 recorded the least dry weight at both ninth month (0.043 g) and thirteenth month (0.024 g) of storage.

4.2.2.1.6 Seedling vigour index I

The impact of various seed treatments on seedling vigour index I during storage period is furnished in Table 17.

Irrespective of the seed protectants used for seed treatment, vigour index I declined progressively over the period of storage. Highermean seedling vigour index I over storage was observed in seeds treated with neem based products *viz.*, kernel powder (T8: 2621.36), leaf powder (T5:2605.83) and oil (T1:2540.00), while it was the least in untreated seeds (T13: 2131.92). Throughout the storage period of M13, treatment T8 had recorded the highest seedling vigour index I, the exception being at 2, 4 and 13 month of storage.

At M9, seedling vigour index I of seeds treated with protectant neem kernel powder (T8: 2714.10) was found to be on par with that treated with neem leaf powder (T5: 2482.67). Treatment T8 was also found to be on par with those treated with castor oil (T2: 2482.67), neem oil (T1: 2460.83) and coconut oil (T3: 2448.13). However, at the end storage period (M13), seeds treated with neem oil (T1: 1001.43) recorded the highest vigour index I and was found to be on par with neem leaf powder (T5: 963.93), neem kernel powder (T8: 960.27), coconut oil (T3: 948.60) and castor oil (T2: 903.93) treated seeds. Seeds treated with spinosad (867.40) were found to be on par with the above treatments. The lowest seedling vigour index I was recorded in T13 (589.67).

4.2.2.1.7 Seedling vigour index II

The impact of various seed treatments on seedling vigour index II during storage period is furnished in Table 18.

Table 17.Effect of seed treatments on seedling vigour index I in cowpea (Kanakamony) during storage

Treatment	Seedling vigour index I												
	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	Mean
T1	3647.9^{bc}	3525.9^{bc}	3402.2^{ab}	3149.9^{a}	2793.1^{b}	2863.1^{ab}	2717.6^{b}	2601.6^{abc}	2460.8^{abc}	1985.5^{abc}	1653.5^{abc}	1217.5^{a}	1001.4^{a}	2540.0
T2	3596.1^{bcd}	3324.8^{ef}	3183.4^{ef}	2707.4^{e}	2472.6^{ef}	2787.6^{abc}	2682.5^{bc}	2548.1^{bcd}	2482.7^{abc}	1934.9^{abcd}	1706.4^{ab}	1184.2^{ab}	903.9^{ab}	2424.2
T3	3605.4^{bcd}	3389.2^{de}	3045.4^{g}	2720.2^{e}	2633.7^{cd}	2820.1^{abc}	2683.2^{bc}	2520.5^{bcde}	2448.1^{bc}	1906.0^{abcde}	1626.0^{abcd}	1193.9^{ab}	948.6^{ab}	2426.1
T4	3385.0^{e}	3511.8^{bc}	3091.5^{fg}	2741.4^{e}	2722.3^{bc}	2619.8^{d}	2430.8^{ef}	2249.5^{fg}	2249.0^{cde}	1839.0^{abcde}	1476.2^{cdef}	1002.7^{cde}	747.7^{cd}	2312.8
T5	3810.6^{a}	3656.8^{a}	3327.0^{bc}	3012.2^{bc}	2932.6^{a}	2896.7^{a}	2844.6^{a}	2752.1^{ab}	2613.5^{ab}	2029.3^{ab}	1753.2^{a}	1283.2^{a}	963.9^{ab}	2605.8
T6	3521.4^{d}	3438.5^{cd}	3281.0^{cd}	2945.7^{cd}	2755.8^{b}	2562.9^{d}	2401.5^{f}	2303.3^{efg}	2332.3^{cde}	1713.9^{def}	1547.3^{bcde}	1013.6^{cde}	772.1^{cd}	2353.1
T7	3699.9^{b}	3198.7^{g}	3204.9^{de}	2832.5^{de}	2724.2^{bc}	2566.8^{d}	2444.4^{ef}	2293.2^{efg}	2249.0^{cde}	1731.5^{cdef}	1523.3^{bcde}	978.5^{de}	720.1^{de}	2320.5
T8	3821.5^{a}	3409.3^{de}	3487.5^{a}	3069.0^{abc}	2963.7^{a}	2934.5^{a}	2886.3^{a}	2822.0^{a}	2714.1^{a}	2052.3^{a}	1748.9^{a}	1208.3^{a}	960.3^{ab}	2621.3
T9	3563.7^{cd}	3295.0^{f}	3359.4^{bc}	3174.3^{a}	2462.1^{ef}	2620.8^{d}	2530.1^{de}	2337.9^{defg}	2295.8^{cde}	1774.6^{bcdef}	1491.3^{cdef}	1004.7^{cde}	741.8^{cd}	2357.8
T10	3834.7^{a}	3596.0^{ab}	3324.1^{bc}	3128.9^{ab}	2415.0^{f}	2673.4^{cd}	2582.5^{cd}	2474.6^{cdef}	2336.9^{cde}	1764.9^{cdef}	1453.9^{def}	1039.9^{bcd}	757.9^{cd}	2414.1
T11	3568.73^{cd}	3383.1^{de}	3154.1^{ef}	2708.8^{e}	2487.5^{ef}	2671.0^{cd}	2351.8^{fg}	2215.1^{g}	2183.5^{de}	1649.9^{ef}	1408.3^{ef}	882.9^{ef}	709.6^{de}	2259.6
T12	3549.2^{cd}	3257.9^{fg}	3094.7^{fg}	2762.3^{e}	2575.3^{de}	2707.9^{bcd}	2526.3^{de}	2401.8^{cdefg}	2421.4^{bcd}	1884.7^{abcde}	1561.9^{bcde}	1134.6^{abc}	867.4^{bc}	2365.0
T13	3524.2^{d}	3261.9^{fg}	3019.8^{g}	2446.8^{f}	2370.2^{f}	2297.5^{e}	2246.0^{g}	2230.5^{g}	2147.9^{e}	1523.7^{f}	1309.5^{f}	747.3^{f}	589.7^{e}	2131.9
SEm±	22.47	22.70	24.06	35.93	31.63	29.72	31.39	36.36	33.00	31.71	25.56	26.70	22.24	
CD(0.05)	104.76	87.38	95.58	129.08	117.79	162.98	120.43	240.41	261.62	259.29	184.83	154.05	130.66	

M: Month of storage

Means in each column with at least one letter in common are not significantly different at 5% level of probability

Table 18.Effect of seed treatments on seedling vigour index II in cowpea (Kanakamony) during storage

Treatment	Seedling vigour index II													
	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	Mean
T1	4.88^{bc}	4.66^{b}	4.55^{ab}	4.26^{abc}	3.76^{b}	3.76^{bc}	3.81^{a}	3.62^{ab}	3.49^{bc}	2.96^{ab}	2.47^{abc}	1.91^{a}	1.50^{a}	3.51
T2	4.62^{efg}	4.44^{def}	4.32^{defg}	3.81^{d}	3.22^{d}	3.68^{bcd}	3.79^{a}	3.67^{a}	3.55^{b}	2.87^{abc}	2.54^{ab}	1.88^{a}	1.40^{a}	3.37
T3	4.52^{gh}	4.46^{def}	4.22^{fgh}	3.70^{d}	3.37^{cd}	3.76^{bc}	3.80^{a}	3.42^{bcde}	3.44^{bcd}	2.83^{abcd}	2.43^{abcd}	1.84^{ab}	1.46^{a}	3.33
T4	4.33^{i}	4.64^{bc}	4.26^{efgh}	3.72^{d}	3.65^{b}	3.56^{d}	3.50^{bc}	3.31^{def}	3.23^{de}	2.58^{cde}	2.17^{e}	1.58^{de}	1.22^{c}	3.21
T5	4.93^{b}	4.87^{a}	4.65^{a}	4.33^{ab}	3.99^{a}	3.81^{b}	3.67^{ab}	3.55^{abc}	3.50^{bc}	3.09^{a}	2.58^{a}	1.97^{a}	1.49^{a}	3.57
T6	4.65^{efg}	4.49^{cde}	4.45^{bcd}	4.09^{c}	3.72^{b}	3.56^{d}	3.25^{cde}	3.27^{def}	2.66^{h}	2.68^{bcde}	2.23^{cde}	1.62^{cd}	1.23^{bc}	3.22
T7	4.70^{def}	4.26^{gh}	4.13^{hi}	4.14^{c}	3.64^{b}	3.56^{d}	3.21^{de}	3.43^{bcde}	2.98^{g}	2.49^{def}	2.15^{e}	1.55^{de}	1.18^{c}	3.19
T8	5.10^{a}	4.55^{bcd}	4.54^{abc}	4.42^{a}	4.03^{a}	3.97^{a}	3.30^{cde}	3.62^{ab}	3.78^{a}	3.06^{a}	2.54^{ab}	1.93^{a}	1.49^{a}	3.56
T9	4.73^{cde}	4.19^{h}	4.40^{cde}	4.14^{c}	3.74^{b}	3.66^{bcd}	3.48^{bcd}	3.26^{ef}	3.24^{de}	2.61^{bcde}	2.20^{de}	1.60^{de}	1.22^{c}	3.27
T10	4.83^{bcd}	4.39^{efg}	4.37^{def}	4.19^{bc}	3.70^{b}	3.57^{d}	3.68^{ab}	3.50^{abcd}	3.22^{ef}	2.60^{bcde}	2.11^{ef}	1.66^{bcd}	1.22^{c}	3.31
T11	4.57^{fg}	4.33^{fgh}	4.20^{ghi}	3.68^{d}	3.70^{b}	3.63^{cd}	3.25^{cde}	3.15^{f}	3.02^{fg}	2.36^{ef}	2.09^{ef}	1.42^{ef}	1.17^{c}	3.12
T12	4.62^{efg}	4.26^{gh}	4.13^{hi}	3.69^{d}	3.67^{b}	3.70^{bcd}	3.20^{de}	3.24^{ef}	3.31^{cde}	2.80^{abcd}	2.30^{bcde}	1.80^{abc}	1.38^{ab}	3.24
T13	4.40^{hi}	4.28^{gh}	4.06^{i}	3.37^{e}	3.44^{c}	3.34^{e}	3.17^{e}	3.36^{cdef}	3.15^{efg}	2.18^{f}	1.88^{f}	1.29^{f}	0.98^{d}	2.99
SEm±	0.036	0.033	0.031	0.052	0.037	0.027	0.045	0.032	0.048	0.051	0.038	0.036	0.028	
CD(0.05)	0.159	0.153	0.149	0.181	0.156	0.210	0.278	0.230	0.214	0.368	0.241	0.182	0.149	

M: Month of storage

Means in each column with at least one letter in common are not significantly different at 5% level of probability

Irrespective of the seed protectants used for seed treatment, seedling vigour index II declined progressively over the period of storage. Seedling vigour index II in all the seed protectant treatments was found to be superior to untreated seeds (T13) for most part of storage. Highermean vigour index II over storage was observed in seeds treated with neem based products *viz.*, neem leaf powder (T5: 3.57) followed by neem kernel powder (T8: 3.56) and neem oil (T1: 3.51).The lowest mean seedling vigour index II was recorded in T13 (2.99).

At ninth month, seeds treated with neem kernel powder (T8: 3.78) recorded the highest seedling vigour index II followed by castor oil (T2: 3.55). Treatment T2 was found to be on par with those treated with neem leaf powder (T5: 3.50), neem oil (T1: 3.49) and coconut oil (T3: 3.44). However, at the end storage period (M13), seeds treated with neem oil (T1: 1.50) recorded the highest vigour index II and was found to be on par with neem leaf powder (T5: 1.49), neem kernel powder (T8: 1.49), coconut oil (T3: 1.46) and castor oil (T2: 1.40) treated seeds. Seeds treated with spinosad (1.38) were found to be on par with the above treatments. The lowest seedling vigour index I was recorded in T13 (0.98).

4.2.2.1.8 Seed moisture content

The impact of various seed treatments on moisture content during storage period is furnished in Table 19.

Throughout storage, no significant difference was observed in moisture content of seed between treatments.

4.2.2.1.9 Electrical conductivity of seed leachate

The impact of various seed treatments on electrical conductivity of seed leachate (dSm^{-1}) during storage period is furnished in Table 20.

Table 19.Effect of seed treatments on seed moisture content in cowpea (Kanakamony) during storage

Treatment	Moisture content (%)												
	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	Mean
T1	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.03	9.03	9.03	9.03	9.03	9.01
T2	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.03	9.03	9.03	9.03	9.03	9.01
T3	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.03	9.03	9.03	9.00	9.03	9.01
T4	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.03	9.03	9.07	9.03	9.07	9.02
T5	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.07	9.01	9.03	9.07	9.01
T6	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.07	9.00	9.07	9.01
T7	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.03	9.03	9.03	9.00	9.07	9.01
T8	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.07	9.03	9.03	9.07	9.02
T9	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.03	9.07	9.07	9.01
T10	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.03	9.00	9.03	9.03	9.07	9.01
T11	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.03	9.03	9.00	9.07	9.01
T12	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.03	9.03	9.00	9.00	9.03	9.01
T13	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.03	9.07	9.07	9.10	9.10	9.03

M: Month of storage

Statistical analysis was not done since the range is too small

Table 20. Effect of seed treatments on electrical conductivity of seed leachate in cowpea (Kanakamony) during storage

Treatment	Electrical conductivity of seed leachate (dSm^{-1})													
	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	Mean
T1	0.275^{cd}	0.280	0.280^{e}	0.272^{d}	0.291^{e}	0.310^{d}	0.355^{g}	0.392^{d}	0.425^{e}	0.473^{c}	0.485^{c}	0.497^{g}	0.541^{d}	0.375
T2	0.282^{bcd}	0.290	0.289^{bcde}	0.273^{d}	0.293^{de}	0.323^{c}	0.359^{fg}	0.402^{cd}	0.429^{de}	0.474^{c}	0.484^{c}	0.502^{fg}	0.560^{bcd}	0.382
T3	0.281^{bcd}	0.285	0.291^{bcde}	0.278^{d}	0.299^{cde}	0.314^{cd}	0.355^{g}	0.399^{cd}	0.428^{de}	0.476^{c}	0.484^{c}	0.502^{fg}	0.551^{bcd}	0.380
T4	0.284^{bc}	0.299	0.308^{abcd}	0.316^{bc}	0.332^{b}	0.345^{b}	0.397^{bc}	0.434^{b}	0.476^{ab}	0.481^{b}	0.496^{b}	0.526^{cde}	0.568^{b}	0.405
T5	0.278^{bcd}	0.295	0.282^{de}	0.278^{d}	0.299^{cde}	0.312^{d}	0.360^{fg}	0.391^{d}	0.423^{e}	0.474^{c}	0.483^{c}	0.498^{g}	0.546^{cd}	0.378
T6	0.288^{ab}	0.300	0.313^{ab}	0.305^{c}	0.312^{cd}	0.349^{b}	0.392^{bc}	0.418^{bc}	0.444^{cde}	0.481^{b}	0.493^{b}	0.541^{bcd}	0.571^{b}	0.401
T7	0.271^{d}	0.293	0.308^{abcd}	0.306^{bc}	0.316^{bc}	0.347^{b}	0.390^{cd}	0.429^{d}	0.452^{bcd}	0.482^{b}	0.493^{b}	0.545^{abc}	0.571^{b}	0.400
T8	0.279^{bcd}	0.242	0.283^{cde}	0.277^{d}	0.293^{de}	0.312^{d}	0.366^{ef}	0.391^{b}	0.426^{e}	0.473^{c}	0.484^{c}	0.503^{fg}	0.542^{d}	0.375
T9	0.284^{bc}	0.277	0.309^{abc}	0.317^{bc}	0.303^{cde}	0.343^{b}	0.390^{c}	0.426^{b}	0.444^{cde}	0.480^{b}	0.492^{b}	0.522^{def}	0.569^{b}	0.397
T10	0.283^{bcd}	0.294	0.309^{abcd}	0.313^{bc}	0.310^{cde}	0.350^{b}	0.382^{d}	0.416^{bc}	0.440^{cde}	0.482^{b}	0.493^{b}	0.519^{ef}	0.567^{bc}	0.397
T11	0.284^{bc}	0.290	0.315^{ab}	0.323^{ab}	0.309^{cde}	0.344^{b}	0.399^{b}	0.428^{b}	0.457^{bc}	0.483^{b}	0.496^{b}	0.552^{ab}	0.568^{b}	0.404
T12	0.281^{bcd}	0.283	0.289^{bcde}	0.276^{d}	0.311^{cd}	0.316^{cd}	0.370^{e}	0.325^{e}	0.428^{de}	0.474^{c}	0.486^{c}	0.504^{fg}	0.559^{bcd}	0.377
T13	0.298^{a}	0.298	0.328^{a}	0.338^{a}	0.358^{a}	0.401^{a}	0.411^{a}	0.477^{a}	0.494^{a}	0.496^{a}	0.503^{a}	0.564^{a}	0.626^{a}	0.430
SEm±	0.001	0.004	0.003	0.004	0.003	0.004	0.003	0.006	0.004	0.001	0.001	0.004	0.004	
CD(0.05)	0.012	NS	0.027	0.017	0.020	0.009	0.008	0.020	0.025	0.004	0.006	0.021	0.022	

M: Month of storage

Means in each column with at least one letter in common are not significantly different at 5% level of probability

Irrespective of the seed protectants used for seed treatment, electrical conductivity of seed leachate increased progressively over the period of storage. Lower mean electrical conductivity over storage was observed in seeds treated with T8 and T1 (0.375 dSm^{-1}), followed by T5 (0.378 dSm^{-1}).The highest mean electrical conductivity of seed leachate over storage was recorded in control (0.430 dSm^{-1}) followed by *Beauveria bassiana* (0.404 dSm^{-1}).

At ninth month, seeds treated with neem based products *viz.* leaf powder (T5: 0.423dSm^{-1}), oil (T1: 0.425 dSm^{-1}) and kernel powder (T8: 0.426 dSm^{-1}) recorded the lowest electrical conductivity of seed leachate. However, at the end storage period (M13), electrical conductivity of seed leachate varied between 0.541dSm^{-1}(T1: neem oil) and 0.626 dSm^{-1}(T13: control). EC of seed leachate was low in treatments with neem oil (T1:0.541dSm^{-1}) followed by neem kernel powder (T8: 0.542dSm^{-1}). Treatments T5 (0.546dSm^{-1}) was found to be on par with castor oil (T2: 0.560dSm^{-1}), coconut oil (T3: 0.551dSm^{-1}) and spinosad (T12: 0.559dSm^{-1}). The highest electrical conductivity of seed leachate was recorded in control (0.626 dSm^{-1}).

4.2.2.1.10 Mortality of adults

The result of the experimenton the impact of different seed protectants on mortality of adults are presented in Table 21.

Maximum mortality (100 %) of the all beetles exposed was observed in all the seed protectants for the first three months of storage. Seeds treated with neem oil, castor oil, coconut oil, neem leaf powder, neem kernel powder, diatomaceous earth, and ash recorded hundred per cent mortality up to five months, while spinosad registered hundred per cent kill for up to seven months of storage. Among the treatments, sweet flag rhizome powder, pannal leaf powder, karinotchi leaf powder and *Beauveria bassiana* recorded consistently lower value for mortality. All treatments were significantly superior to control and were on par with each

Table 21. Effect of seed treatments on mortality of adult pulsebeetles in cowpea (Kanakamony) during storage

Treatment	Mortality of adult beetles (%)									
	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13
T1	100.00^{a} (10.02)	100.00^{a} (10.02)	86.70^{ab} (9.32)	86.70^{b} (9.33)	80.00^{ab} (8.97)	70.00^{ab} (8.40)	60.00^{b} (7.98)	46.70^{b} (6.86)	40.00^{ab} (6.36)	26.70^{ab} (5.19)
T2	100.00^{a} (10.02)	100.00^{a} (10.02)	86.70^{ab} (9.32)	83.30^{b} (9.15)	73.30^{bc} (8.59)	70.00^{ab} (8.40)	56.70^{bc} (7.55)	43.30^{bc} (6.61)	40.00^{ab} (6.36)	26.70^{ab} (5.19)
T3	100.00^{a} (10.02)	100.00^{a} (10.02)	80.00^{b} (8.97)	80.00^{bc} (8.96)	73.30^{bc} (8.59)	63.30^{bc} (7.98)	56.70^{bc} (7.55)	40.00^{bc} (6.36)	40.00^{ab} (6.36)	23.30^{abc} (4.86)
T4	96.70^{a} (9.85)	93.30^{a} (9.68)	73.30^{b} (8.59)	66.70^{def} (8.19)	66.70^{bcd} (8.19)	50.00^{d} (7.11)	46.70^{c} (6.86)	26.70^{de} (5.19)	26.70^{de} (5.19)	16.70^{cd} (4.10)
T5	100.00^{a} (10.02)	100.00^{a} (10.02)	80.00^{b} (8.97)	76.70^{bcd} (8.78)	70.00^{bcd} (8.40)	66.70^{b} (8.19)	53.30^{bc} (7.33)	36.70^{bc} (6.08)	36.70^{bc} (6.08)	20.00^{bcd} (4.53)
T6	90.00^{a} (9.50)	93.30^{a} (9.67)	73.30^{b} (8.59)	70.00^{cde} (8.40)	63.30^{bcd} (7.98)	53.30^{cd} (7.33)	50.00^{bc} (7.11)	26.70^{de} (5.19)	23.30^{e} (4.86)	20.00^{bcd} (4.53)
T7	93.30^{a} (9.68)	93.30^{a} (9.68)	73.30^{b} (8.59)	63.30^{ef} (7.98)	66.70^{bcd} (8.16)	53.30^{cd} (7.33)	56.70^{bc} (7.55)	33.30^{cd} (5.80)	26.70^{de} (5.19)	16.70^{cd} (4.10)
T8	100.00^{a} (10.02)	100.00^{a} (10.02)	83.30^{ab} (9.15)	76.70^{bcd} (8.78)	70.00^{bcd} (8.40)	66.70^{b} (8.19)	53.30^{bc} (7.33)	36.70^{bc} (6.08)	33.30^{bcd} (5.80)	20.00^{bcd} (4.53)
T9	100.00^{a} (10.02)	93.30^{a} (10.67)	76.70^{b} (8.77)	66.70^{def} (8.19)	63.30^{bcd} (7.98)	50.00^{d} (7.11)	50.00^{bc} (7.11)	26.70^{de} (5.19)	30.00^{cde} (5.52)	16.70^{cd} (4.10)
T10	100.00^{a} (10.02)	96.70^{a} (9.85)	80.00^{b} (8.96)	66.70^{def} (8.19)	63.30^{cd} (7.95)	53.30^{cd} (7.33)	50.00^{bc} (7.11)	26.70^{de} (5.19)	23.30^{e} (4.86)	13.30^{d} (3.67)
T11	96.70^{a} (9.85)	96.70^{a} (9.85)	83.30^{ab} (9.15)	60.00^{f} (7.78)	56.70^{d} (7.55)	50.00^{d} (7.11)	46.70^{c} (6.86)	23.30^{e} (4.86)	23.30^{e} (4.86)	13.30^{d} (3.67)
T12	100.00^{a} (10.02)	100.00^{a} (10.02)	100.00^{a} (10.02)	100.00^{a} (10.02)	93.30^{a} (9.68)	83.30^{a} (9.15)	76.70^{a} (8.78)	66.70^{a} (8.19)	46.60^{a} 6.86)	33.30^{a} (5.80)
T13	6.70^{b} (2.40)	10.00^{b} (3.24)	6.70^{c} (2.40)	16.30^{g} (4.06)	6.70^{e} (2.40)	6.70^{e} (2.40)	3.30^{d} (1.55)	0.00	0.00	0.00
SEm±	0.332	0.291	0.303	0.226	0.283	0.262	0.273	0.168	0.129	0.132
CD(0.05)	0.762	0.486	0.946	0.615	1.019	0.816	0.855	0.822	0.739	0.972

M: Month of storage

Means in each column with at least one letter in common are not significantly different at 5% level of probability

Values in parentheses are square root transformed values

Statistical analysis was not done for M,M2 and M3 since the range is too small otherexcept for spinosad. Spinosad remained significantly superior to all other treatments from tenth month onwards with mortality ranging from cent per cent (7^{th} month)to 33.3 per cent in thirteenth month.

The mortality of adults decreased with increase in storage period, for all the treatments evaluated. However, Spinosad consistently registered highest mortality of adults throughout the storage period. Spinosad was followed by neem oil (T1), which induced mortality ranging from 100 per cent initially to 26.7 per cent in thirteenth month of storage. T1 (neem oil) was on par with castor oil, coconut oil, neem leaf powder and neem kernel powder during the course of evaluation. Sweet flag rhizome powder (T4), Ash (T10) and *Beauveria bassiana* (T12) recorded the lowest mortality of adult beetles during the period of study.

At the end of storage, the highest mortality (33.30 %) of adults was observed in spinosad treated seeds. It was followed by the seeds treated with neem oil (T1: 26.70%) and castor oil (T2:26.70%) and was on par with spinosad treated seeds. Coconut oil (T3: 23.30 %) was found to be on par with the above treatments. Among the seed protectants, lowest mortality was recorded in seeds treated with *Beauveria bassiana* (T11:13.3%) and ash (T10:13.30%) trough both weresignificantly superior tocontrol.

4.2.2.1.11 Number of eggs

The effect of different seed protectants on the fecundity of pulse beetles during the storage period is furnished in Table 22.

All the treatments were significantly superior to control (T13) during the storage period. No eggs were laid in seeds treated with seed protectants for up to one month after storage. However, oviposition was observed in all the treatments from second month of storage onwards. In contrast, no eggs were laid in seeds treated with

Table 22. Effect of seed treatments on number of eggs laid pulse beetle in cowpea (Kanakamony) during storage

Treatment	Number of eggs laid											
	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13
T1	8.00^{c} (2.90)	10.33^{e} (3.29)	17.33^{cd} (4.22)	19.00^{e} (4.41)	26.33^{ef} (5.17)	35.33^{c} (5.99)	50.33^{d} (7.13)	55.33^{d} (7.47)	74.00^{d} (8.63)	86.00^{c} (9.30)	91.00^{fg} (9.57)	98.00^{ef} (9.92)
T2	9.00^{de} (3.08)	12.00^{cde} (3.52)	16.33^{d} (4.10)	21.33^{de} (4.67)	28.33^{def} (5.37)	35.00^{c} (5.95)	49.00^{d} (7.04)	59.33^{cd} (7.72)	80.00^{cd} (8.97)	87.33^{c} (9.37)	94.00^{efg} (9.72)	99.00^{ef} (9.97)
T3	9.33^{cde} (3.13)	11.33^{de} (3.44)	17.33^{cd} (4.21)	20.00^{e} (4.53)	28.33^{def} (5.37)	35.00^{c} (5.96)	52.33^{cd} (7.27)	61.33^{bcd} (7.86)	79.00^{cd} (8.92)	85.33^{c} (9.26)	95.00^{def} (9.77)	99.00^{ef} (9.97)
T4	16.00^{b} (4.06)	13.00^{bcde} (3.67)	21.33^{bc} (4.66)	24.00^{cde} (4.94)	28.33^{def} (5.35)	43.33^{b} (6.62)	58.00^{bc} (7.65)	69.00^{b} (8.33)	95.33^{b} (9.79)	96.00^{b} (9.82)	104.33^{bc} (10.24)	107.33^{bcd} (10.38)
T5	10.00^{cde} (3.23)	13.33^{bcde} (3.71)	16.33^{d} (4.10)	20.00^{e} (4.53)	27.00^{def} (5.24)	34.33^{c} (5.89)	53.00^{cd} (7.31)	66.00^{bc} (8.15)	80.33^{cd} (8.98)	87.33^{c} (9.37)	96.00^{def} (9.82)	100.00^{e} (10.02)
T6	13.00^{bc} (3.67)	14.00^{bcde} (3.78)	19.00^{bcd} (4.41)	28.00^{bcd} (5.32)	36.00^{bc} (6.04)	43.33^{b} (6.62)	63.00^{b} (7.97)	61.00^{bcd} (7.84)	88.00^{bc} (9.41)	98.33^{b} (9.94)	106.00^{b} (10.32)	111.00^{b} (10.56)
T7	12.33^{bcd} (3.56)	15.33^{bc} (3.97)	18.33^{bcd} (4.34)	34.00^{b} (5.87)	37.33^{bc} (6.14)	36.00^{c} (6.04)	58.00^{bc} (7.65)	64.33^{bc} (8.05)	88.00^{bc} (9.41)	97.00^{b} (9.87)	101.00^{bcd} (10.07)	109.33^{bc} (10.48)
T8	7.00^{e} (2.72)	13.00^{bcde} (3.67)	19.33^{bcd} (4.45)	19.00^{e} (4.41)	24.33^{f} (4.98)	38.33^{bc} (6.23)	52.00^{d} (7.24)	58.33^{cd} (7.67)	79.00^{cd} (8.91)	87.00^{c} (9.35)	92.33^{efg} (9.63)	100.00^{e} (10.02)
T9	12.33^{bcd} (3.54)	13.33^{bcde} (3.72)	21.00^{bc} (4.62)	19.00^{e} (4.40)	32.00^{cde} (5.70)	40.33^{bc} (6.39)	59.00^{b} (7.71)	61.33^{bcd} (7.86)	91.33^{b} (9.58)	97.00^{b} (9.87)	99.00^{cde} (9.97)	106.00^{cd} (10.32)
T10	9.00^{de} (3.08)	15.00^{bcd} (3.93)	19.33^{bcd} (4.43)	19.33^{e} (4.45)	33.33^{cd} (5.81)	37.33^{bc} (6.15)	61.33^{b} (7.86)	63.33^{bcd} (7.99)	88.00^{bc} (9.41)	95.00^{b} (9.77)	99.00^{bcde} (9.97)	105.33^{d} (10.29)
T11	10.00^{cde} (3.23)	16.00^{b} (4.06)	23.00^{b} (4.84)	29.00^{bc} (5.43)	42.00^{b} (6.52)	43.33^{b} (6.62)	61.33^{b} (7.86)	66.00^{bc} (8.15)	92.00^{b} (9.62)	97.00^{b} (9.87)	105.33^{bc} (10.28)	106.33^{cd} (10.34)
T12	0.00	0.00	0.00	0.00	4.33^{g} (2.20)	12.33^{d} (3.57)	20.00^{e} (4.52)	31.00^{e} (5.58)	44.67^{e} (6.72)	58.33^{d} (7.66)	88.00^{g} (9.41)	95.33^{f} (9.79)
T13	107.33^{a} (10.38)	110.33^{a} (10.50)	139.00^{a} (11.81)	119.33^{a} (10.91)	119.33^{a} (10.92)	119.33^{a} (10.92)	134.00^{a} (11.59)	108.00^{a} (10.42)	136.33^{a} (11.67)	145.00^{a} (12.06)	175.33^{a} (12.29)	174.00^{a} (12.21)
SEm ±	0.340	0.323	0.351	0.301	0.295	0.249	0.234	0.164	0.173	0.148	0.116	0.097
CD(0.05)	0.550	0.527	0.511	0.738	0.629	0.553	0.384	0.572	0.597	0.319	0.345	0.188

M: Month of storage

Means in each column with at least one letter in common are not significantly different at 5% level of probability

Values in parentheses are square root transformed values

Statistical analysis was not done for M1 since the range is too small spinosad, for up to five months after storage. The number of eggs laid increased with duration of storage.

Seeds treated with spinosad had the lowest number of eggs ranging from zero in second month to 95.33 in the thirteen month of storage. It was followed by neem oil (T1) with number of eggs ranging from 0 - 98 during storage. Neem oil (T1) was on par with castor oil (T2) and coconut oil (T3) throughout the study period. Similarly, neem leaf powder and neem kernel powder were found to be on par with each other. Highest number of eggs was observed in control, which varied from 100.33 in first month to 150.67 in the twelfth month of storage.

At the end storage period (M13), number of eggs laid by pulse beetles varied from 95.33 (spinosad) to 148.67 (control). Spinosad was followed by the vegetable oils namely neem oil (98.00), castor oil (99.00) and coconut oil (99.00) as well as neem kernel powder (100.00) followed by neem leaf powder (100.00), which were significantly superior to other treatments. Pannal leaf powder (T6: 111.00) and karinotchi leaf powder (T7: 109.33) registered the highest number of eggs among the different seed protectants evaluated, but weresuperior to control with 148.67 numbers of eggs.

4.2.2.1.12 Egg hatchability

The results of influence of different seed protectants on egg hatchability during storage period are presented in Table 23.

All the seed protectants evaluated were significantly superior to control in suppressing the hatching of beetle eggs. Highest number of eggs hatched in control throughout the study period, with values ranging from 43.74 per cent in first month l to 60.68 in the eleventh month of storage. No eggs hatched out in treatments involving neem oil, castor oil, neem leaf powder and neem kernel powder for up to four months after storage. No egg hatched in coconut oil for up to five month of

Table 23.Effect of seed treatments on egg hatchability of pulse beetle in cowpea (Kanakamony) during storage

Treatment	Egg hatchability of pulse beetle (%)										
	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13
T1	0.00	0.00	1.67^{e} (1.25)	8.82^{d} (3.05)	16.98^{f} (4.18)	17.19^{cd} (4.20)	22.01^{bcd} (4.69)	26.08^{efg} (5.15)	28.89^{de} (5.40)	29.30^{de} (5.46)	29.57^{f} (5.48)
T2	0.00	0.00	3.04^{e} (1.73)	8.21^{d} (2.94)	17.26^{ef} (4.21)	19.75^{bcd} (4.50)	21.44^{cd} (4.68)	25.42^{fg} (5.09)	28.67^{de} (5.39)	30.50^{cd} (5.57)	31.99^{def} (5.70)
T3	0.00	0.00	0.00	3.55^{e} (2.01)	9.50^{g} (3.16)	16.49^{d} (4.11)	20.47^{de} (4.57)	21.88^{gh} (4.72)	26.57^{e} (5.20)	29.11^{de} (5.44)	29.96^{ef} (5.52)
T4	7.33^{b} (2.47)	6.62^{b} (2.61)	11.98^{bcd} (3.44)	18.40^{b} (4.33)	23.85^{bcd} (4.93)	25.23^{b} (5.06)	27.86^{bcd} (5.32)	33.94^{b} (5.87)	34.04^{bc} (5.88)	33.24^{bcd} (5.81)	34.77^{bc} (5.94)
T5	0.00	1.85^{e} (1.29)	6.43^{cde} (2.30)	10.93^{cd} (3.37)	19.26^{ef} (4.44)	20.58^{bcd} (4.57)	22.08^{bcd} (4.71)	28.18^{cdef} (5.34)	29.78^{cde} (5.50)	31.30^{bcd} (5.64)	32.00^{def} (5.70)
T6	6.08^{b} (2.29)	6.89^{b} (2.70)	13.59^{bc} (3.72)	18.45^{b} (4.33)	25.37^{bc} (5.08)	24.37^{b} (4.99)	28.95^{bc} (5.42)	30.98^{bcde} (5.61)	34.24^{bc} (5.89)	35.55^{bc} (5.97)	34.54^{bcd} (5.92)
T7	5.93^{b} (2.26)	5.48^{b} (2.44)	14.61^{b} (3.88)	21.21^{b} (4.65)	24.28^{bcd} (4.97)	23.48^{bc} (4.89)	28.56^{bc} (5.39)	31.83^{bc} (5.68)	35.03^{b} (5.96)	34.75^{bc} (5.94)	34.14^{bcd} (5.89)
T8	0.00	0.00	4.93^{de} (2.09)	10.94^{cd} (3.37)	20.85^{de} (4.62)	19.87^{bcd} (4.51)	23.26^{bcd} (4.83)	26.59^{def} (5.20)	29.11^{de} (5.44)	31.03^{bcd} (5.61)	32.40^{cde} (5.73)
T9	2.38^{b} (1.39)	4.88^{b} (2.31)	15.97^{b} (4.03)	17.08^{bc} (4.10)	23.25^{cd} (4.87)	23.22^{bc} (4.86)	27.14^{bcd} (5.25)	29.66^{bcdef} (5.48)	32.99^{bcd} (5.79)	33.32^{bcd} (5.82)	33.34^{bcd} (5.82)
T10	3.92^{b} (1.64)	5.37^{b} (2.41)	17.00^{b} (4.16)	17.23^{bc} (4.17)	23.23^{cd} (4.87)	23.18^{bcd} (4.82)	27.72^{bcd} (5.28)	30.72^{bcde} (5.59)	35.13^{b} (5.97)	34.01^{bcd} (5.87)	34.17^{bcd} (5.89)
T11	7.87^{b} (2.57)	7.13^{b} (2.75)	18.41^{b} (4.35)	23.82^{b} (4.93)	27.63^{b} (5.30)	24.93^{b} (5.04)	29.75^{b} (5.50)	31.53^{bcd} (5.66)	35.39^{b} (5.99)	36.07^{b} (6.05)	35.10^{b} (5.96)
T12	0.00	0.00	0.00	0.00	0.00	9.88^{e} (3.16)	13.94^{e} (3.80)	19.38^{h} (4.45)	19.49^{f} (4.47)	25.03^{e} (5.05)	25.17^{g} (5.07)
T13	45.29^{a} (6.77)	47.24^{a} (6.91)	47.03^{a} (6.89)	50.19^{a} (7.10)	55.86^{a} (7.50)	52.83^{a} (7.28)	53.05^{a} (7.31)	52.77^{a} (7.29)	60.68^{a} (7.82)	58.62^{a} (7.69)	59.25^{a} (7.73)
SEm±	0.452	0.337	0.292	0.218	0.167	0.155	0.142	0.112	0.122	0.103	0.097
CD(0.05)	2.405	0.852	1.436	0.855	0.426	0.753	0.810	0.462	0.413	0.451	0.229

M: Month of storage

Means in each column with at least one letter in common are not significantly different at 5% level of probability

Values in parentheses are square root transformed values

Statistical analysis was not done for M1and M2 since the range is too small

storage. Treatment with spinosad prevented eggs from hatching for up to seven month of storage. Egg hatchability increased progressively throughout the storage period for all the seed protectants used.

Spinosad consistently recorded the lowest egg hatchability (9.88 % at M8 to 25.17 % at M13) and was significantly superior to all other treatments. Spinosad was followed by the three vegetable oils, namely, neem oil, castor oil and coconut oil, which registered low hatchability and were on par with each other. All the other treatments were found to be on par with each other. Highest egg hatchability was recorded in control, ranging from 43.74 per cent at start of storage to 60.68 per cent at the eleventh month.

4.2.2.1.13 Seed infestation

The results of influence of different seed protectants on seed infestation during storage period are presented in Table 24.

All the seed protectants evaluated were significantly superior to control in reducing infestation of seeds. No seed infestation was observed in treatments involving neem oil, castor oil, coconut oil and neem kernel powder for up to five months of storage. Treatment with spinosad prevented seed infestation for up to seven months of storage. Seed infestation increased progressively throughout the storage period for all the seed protectants used.

Spinosad consistently recorded the lowest seed infestation (14.67 % at M8 to 30.67% at M13) and was significantly superior to all other treatments. Spinosad was followed by the three vegetable oils, namely, neem oil, castor oil and coconut oil, which registered low seed infestation and were on par with each other. All the other treatments were found to be on par with each other.

Table 24.Effect of seed treatments on seed infestation in cowpea (Kanakamony) during storage

Treatment	Per cent seed infestation with pulse beetle									
	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13
T1	0.00	0.00	6.67^{d} (2.65)	12.00^{de} (3.54)	17.33^{de} (4.22)	24.00^{bc} (4.94)	26.67^{de} (5.21)	29.33^{de} (5.41)	33.33^{ef} (5.80)	33.33^{d} (5.81)
T2	0.00	0.00	5.33^{d} (2.39)	13.33^{d} (3.66)	18.67^{cde} (4.37)	25.33^{bc} (5.08)	28.00^{de} (5.34)	29.33^{de} (5.46)	33.33^{def} (5.81)	33.33^{d} (5.81)
T3	0.00	0.00	4.00^{d} (2.12)	6.67^{e} (2.59)	20.00^{bcde} (4.48)	25.33^{bc} (5.07)	28.00^{de} (5.33)	33.33^{cd} (5.81)	34.67^{cdef} (5.92)	36.00^{d} (6.02)
T4	10.67^{b} (3.30)	16.00^{c} (4.04)	21.33^{b} (4.67)	21.33^{bc} (4.67)	25.33^{bc} (5.08)	30.67^{b} (5.53)	37.33^{bc} (6.15)	41.33^{bc} (6.47)	48.00^{b} (6.96)	42.67^{bc} (6.57)
T5	1.33^{d} (1.18)	0.00	14.67^{c} (3.89)	17.33^{bcd} (4.20)	21.33^{bcd} (4.67)	26.67^{bc} (5.21)	32.00^{bcd} (5.68)	37.33^{bcd} (6.12)	34.67^{cdef} (5.93)	41.33^{bc} (6.46)
T6	9.33^{bc} (3.12)	18.67^{bc} (4.34)	20.00^{bc} (4.51)	24.00^{bc} (4.95)	25.33^{bc} (5.08)	30.67^{b} (5.57)	40.00^{b} (6.34)	40.00^{bc} (6.36)	44.00^{bc} (6.62)	42.67^{bc} (6.57)
T7	8.00^{bc} (2.92)	21.33^{bc} (4.64)	20.00^{bc} (4.47)	24.00^{bc} (4.94)	24.00^{bcd} (4.94)	30.67^{b} (5.57)	40.00^{b} (6.36)	42.67^{b} (6.57)	44.00^{bc} (6.66)	44.00^{b} (6.67)
T8	0.00	0.00	14.67^{c} (3.89)	16.00^{cd} (4.04)	20.00^{bcde} (4.53)	24.00^{bc} (4.92)	29.33^{cde} (5.46)	36.00^{bcd} (6.02)	37.33^{cde} (6.12)	41.33^{bc} (6.45)
T9	5.33^{c} (2.39)	29.33^{b} (5.42)	22.67^{b} (4.81)	22.67^{bc} (4.78)	24.00^{bcd} (4.94)	28.00^{bc} (5.31)	33.33^{bcd} (5.79)	36.00^{bcd} (6.04)	40.00^{bcde} (6.35)	44.00^{b} (6.67)
T10	8.00^{bc} (2.86)	21.33^{bc} (4.59)	20.00^{bc} (4.51)	25.33^{b} (5.07)	24.00^{bcd} (4.94)	30.67^{b} (5.53)	33.33^{bcd} (5.81)	37.33^{bcd} (6.14)	42.67^{bcd} (6.57)	45.33^{b} (6.77)
T11	10.67^{b} (3.33)	24.00^{bc} (4.91)	20.00^{bc} (4.51)	25.33^{b} (5.08)	26.67^{b} (5.17)	32.00^{b} (5.69)	37.33^{bc} (6.12)	44.00^{b} (6.67)	41.33^{bcde} (6.47)	42.67^{bc} (6.56)
T12	0.00	0.00	0.00	0.00	14.67^{c} (3.84)	18.67^{c} (4.37)	22.67^{e} (4.80)	24.00^{e} (4.95)	28.00^{f} (5.34)	30.67^{d} (5.58)
T13	54.67^{a} (7.42)	66.67^{a} (8.19)	62.67^{a} (7.94)	56.00^{a} (7.47)	61.33^{a} (7.86)	57.33^{a} (7.58)	68.00^{a} (8.28)	65.33^{a} (8.10)	69.33^{a} (8.36)	68.00^{a} (8.27)
SEm±	0.362	0.319	0.252	0.207	0.163	0.139	0.145	0.133	0.130	0.113
CD(0.05)	0.901	1.268	0.724	0.951	0.793	0.961	0.721	0.753	0.755	0.567

M: Month of storage

Means in each column with at least one letter in common are not significantly different at 5% level of probability

Values in parentheses are square root transformed values

Statistical analysis was not done for M1,M2and M3 since the range is too small

At the end of the storage period, the lowest seed infestation was recorded in spinosad (30.67%) whichwas on par with neem oil (33.33%), castor oil (33.33%) and coconut oil (36%). Treatment with neem leaf powder (41.33%), neem kernel powder (41.33%), sweet flag rhizome powder (42.67%), paanal leaf powder (42.67%) and *Beauveria bassiana* (42.67%) were found to be on par with each other.

4.2.2.1.14 Seed microflora infection

The result of seed infection per cent as influenced by seed protectant treatments during the storage period are presented in Table 25.

Seed microflora infection was examined by blotter and agar plate method. In blotter method, the seed microflora infection (%) varied from 26.67 per cent in T1, T3 and T8 to 50.00 per cent in T13 at the end of storage period. The lowest seed microflora infection was recorded in seeds treated neem oil, coconut oil and kernel powder (26.67 %) followed by spinosad, castor oil and neem leaf powder (30.00 %). T10 (ash; 36.67 %) and T9 (diatomaceous earth; 36.67 %) were found to be on par with the above mentioned treatments. The highest seed microflora infection was recorded in T13 (control; 50.00 %) at the end of storage period. Before storage, the initial seed microflora infection recorded was 10.00 per cent.

In agar plate method, the seed microflora infection (%) varied from 36.67 per cent in T1, T3 and T8 to 60.00 per cent in T13 at the end of storage period. The lowest seed microflora infection was recorded in seeds treated with neem oil, coconut oil and kernel powder (36.67 %) followed by spinosad, castor oil and neem leaf powder (40.00 %). Diatomaceous earth and ash (46.67 %) were found to be on par with the above mentioned treatments. The highest seed microflora infection was recorded in T13 (control; 60.00 %) at the end of storage period. In both methods, seed microflora observed was*Aspergillus niger* and *Aspergillus flavus*.

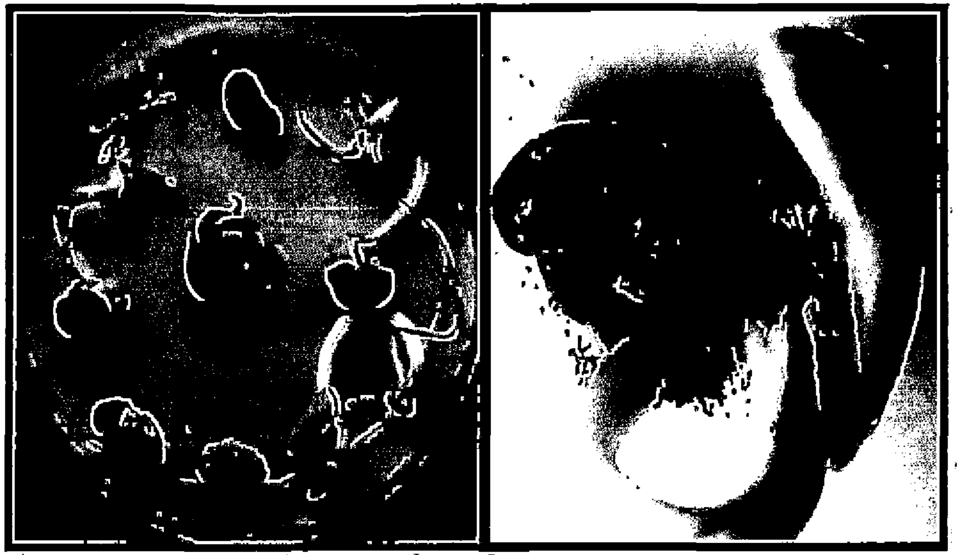
Table 25. Effect of seed treatments on seed infection in cowpea (Kanakamony) at the end of storage

Treatment	Seed infection %	
	Blotter method	Agar plate method
T1	26.67[d] (5.19)	36.67[d] (6.08)
T2	30.00[cd] (5.52)	40.00[cd] (6.36)
T3	26.67[d] (5.19)	36.67[d] (6.08)
T4	40.00[ab] (6.36)	50.00[abc] (7.11)
T5	30.00[cd] (5.52)	40.00[cd] (6.36)
T6	40.00[ab] (6.36)	50.00[abc] (7.11)
T7	43.33[ab] (6.61)	53.33[ab] (7.31)
T8	26.67[d] (5.19)	36.67[d] (6.08)
T9	36.67[bc] (6.08)	46.67[bcd] (6.84)
T10	36.67[bc] (6.08)	46.67[bcd] (6.86)
T11	43.33[ab] (6.61)	53.33[ab] (7.33)
T12	30.00[cd] (5.47)	40.00[cd] (6.33)
T13	50.00[a] (7.11)	60.00[a] (7.76)
SEm±	0.116	0.110
CD(0.05)	0.761	0.861

Means in each column with at least one letter in common are not significantly different at 5% level of probability
Values in parentheses are square root transformed values

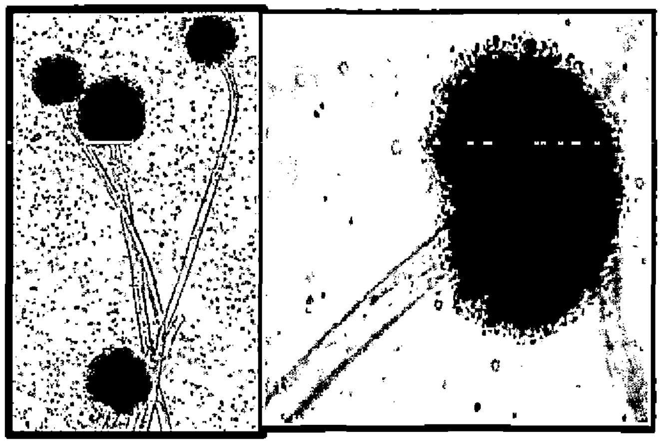
Plate 6: Detection of seed microflora

Blotter method

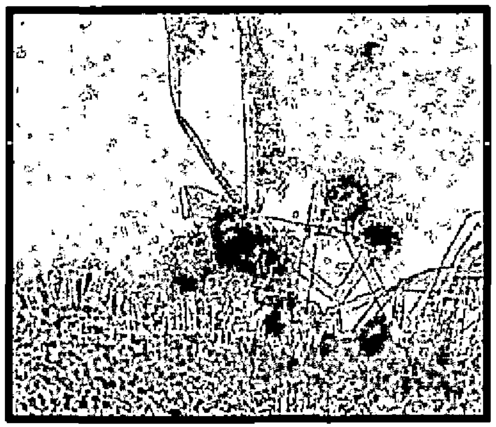


Agar plate method

Seed microflora identified at the end of storage period



Aspergillusniger

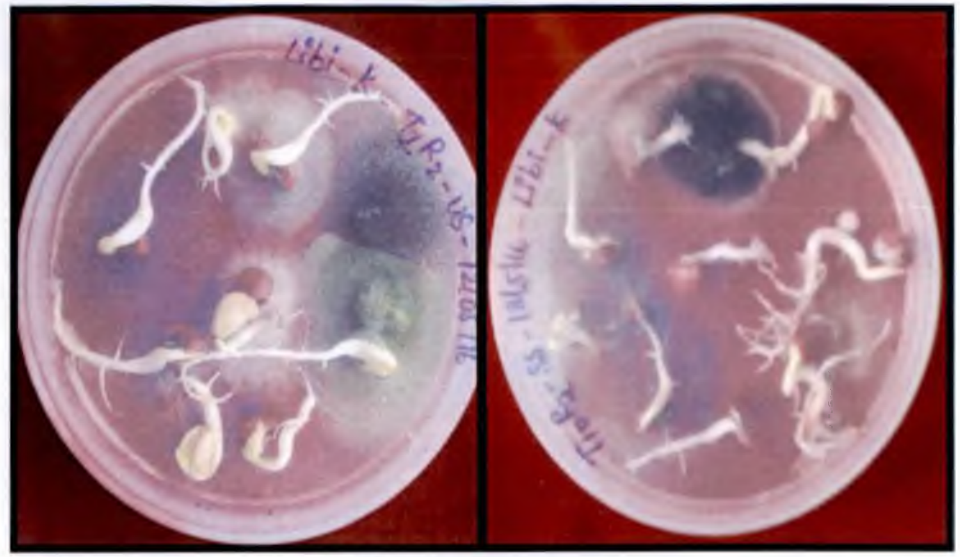


Aspergillusflavus

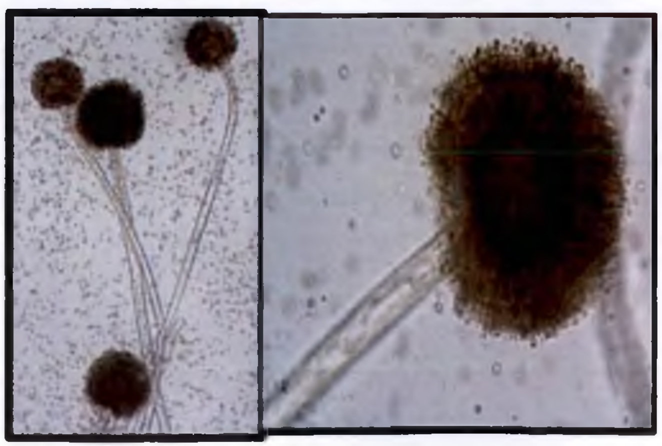
Plate 6: Detection of seed microflora

Blotter method

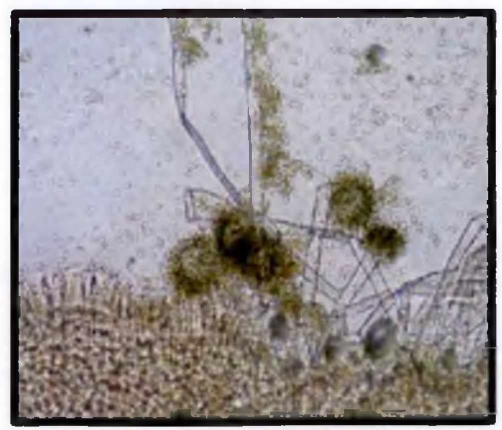
Agar plate method



Seed microflora identified at the end of storage period



Aspergillusniger



Aspergillusflavus

Discussion

5. DISCUSSION

Optimum quantity of good quality seed is a basic pre-requisite for obtaining higher yields in agriculture. Irrespective of the crop, seed quality basically affects the growth, development and yield. Therefore, production of quality seed is crucial for sustainable crop husbandry. Seed deterioration is an inevitable phenomenon that starts immediately after attaining physiological maturity. Several factors such as kind and variety, initial seed quality, storage conditions, moisture content, seed drying temperature and relative humidity, insects, pests, bacteria and fungi during storage influence the deterioration of seeds.

Small and marginal farmers of tropics and subtropics generally store pulses throughout the year for consumption and as seed material for the next year. Thus proper storage of pulses is a matter of great concern. Pulse beetle, *Callosobruchus*spp. is one of the most important storage pests, causing substantial losses to the pulses during storage. It causes weight loss, decreased germination potential and reduction in commercial value of the seed.

In order to prevent the quantitative and qualitative losses due to pulse beetle during storage, several control measures are being adopted. Use of insecticides for instance, for management of the pulse beetle is perhaps the most common. But the chemical means of pest management are not advisable as the stored pulse seeds are often used as food or feed. Under such circumstances, the ingested residues of the pesticides could lead to health hazards. In addition, their effect on seed quality and viability is hardly known. An alternative for pest control under storage is the use of plant products which are cheap, easily available, target specific and safe to environment and human beings. It has been proved that, great losses caused by storage insects can be avoided if botanicals and vegetable oils are smeared on seeds.

In view of the above facts, an attempt was made to evaluate the insecticidal efficacy of botanicals, essential oils, inert diatomaceous earth, entomopathogenic fungi and a novel insecticide spinosadagainst pulse beetle and their effect on seed viability, seedling vigour and seed microflora. The effect of seed protectants on seed quality and storage of cowpea seeds observed in the present study is discussed hereunder.

The germination and other parameters of both treated and untreated seed decreased progressively over storage period. Such decrease in germination with increase in ageing period is inevitable in cereals (Mandal and Basu, 1986), maize (Dharmalingam, 1995;Hussaini*et al.*, 1998 and Ramamoorthy*et al.*,1989),pea (Kumar *et al.*, 1997), chilli seeds (Manoharan, 1999), maize, soybean and sunflower seeds (Simic*et al.*, 2007), sunflower seeds (Shakuntala, 2009), barley seeds (Tabatabaei, 2013) and in cowpea seeds (Aswathi, 2015).

The results revealed that irrespective of the variety, the seed protectants significantly enhanced the viability and quality of treated seeds. The quality of treated seeds was higher than that of untreated seeds for most part of the storage period. The germination in untreated seeds was retained above 75 per cent (the minimum seed certification standards (MSCS) required for cowpea) for eight months while it was retained for nine months in all the treated seeds (Fig. 2).The present findings are in agreement with that of Rana*et al.* (2014) who reported that seed germination increased in treated pea seeds as compared to the untreated seeds.

However, it was evident that the rate of decrease in seed germination and quality was slower in the semi-trailing variety Kanakamony as compared to trailing variety Lola (Fig.3). Irrespective of seed treatment, the germination in variety Kanakamony decreased from 99.71 per cent at one month after storage to 49.15 per cent at end of storage period while it ranged from 94.32 to 49.03 per cent in variety Lola. Such genotype based variations in seed quality and storability has been reported earlier by Delouche (1973), Chauhan*et al.* (1984), Singh and

Gill (1994) and Aswathi (2015) in cowpea, Vanangamudi (1988) in soybean, Ramaiah (1994) in sunflower, Kharb*et al.*(1998) in soybean, Kurdikeri*et al.*(2003) in groundnut and Kavitha (2007) in chilli.

Throughout the storage period, seed quality of cowpea varieties were significantly influenced by the seed protectants used. Germination, for example at nine months after treatment varied from 83.00 per cent in seeds treated with neem kernel powder to 77.00 per cent in seeds treated with *Beauveria bassiana*in case of variety Kanakamony,compared to the untreated seeds (74.00). Similarly at the end of storage period, germination of untreated seeds was 40.67 per cent while incase of treated seeds, it varied between 54.33 percent in seeds treated with neem oil and 46.67 per cent in seeds treated withkarinotchi leaf powder. On nine months of storage,treated seeds of variety Lola had exhibited a germination ranging from 75.00 per cent in seeds treated with *Beauveria bassiana* to 79.00 per cent in in seeds treated with neem kernel powder,as against 74.00 per cent observed in the untreated seeds. Germination at the end of storage period (M13) ranged between 45.70 per cent in *Beauveria bassiana* treated seeds and 53.70 per cent in neem oil treated seeds compared to 40.30 per cent in untreated control.

It was evident that seed treatment with botanicals was superior in enhancing germination and seed quality parameters. Babu and Ravi (2008) had also reported that soybean seeds treated with botanicals exhibited higher germination, more seeding length and seedling dry weight.

Germination, speed of germination and seedling growth were consistently high in treatments with neem based seed protectants as well vegetable oil (Fig. 4).Seed vigour is the sum total of all those properties of seeds which determine the potential for rapid, uniform emergence and development of normal seedlings under a wide range of field conditions. Increase in seedling shoot length, root length and dry matter production during storage in neem based products *viz.,* kernel powder, leaf powder and oil was reflected in higher seed vigour indices (VI I and VI II). It was observed that all the seed protectant treatments were found to

Fig.2. Effect of seed treatments on germination in cowpea at the ninth month of storage

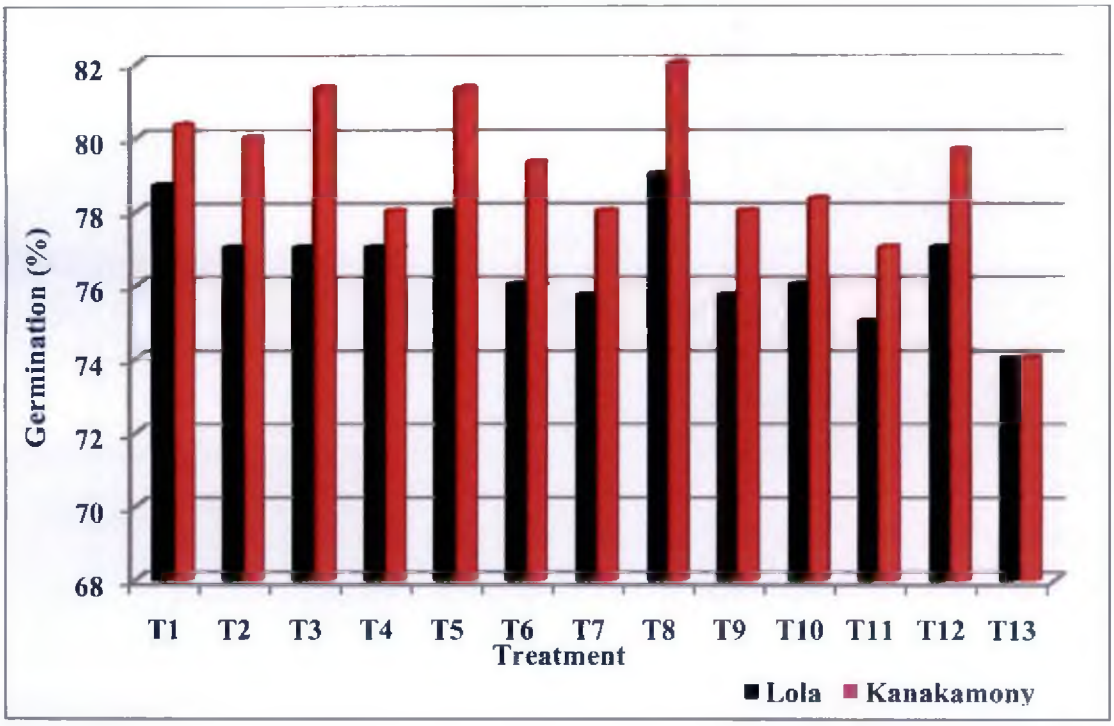
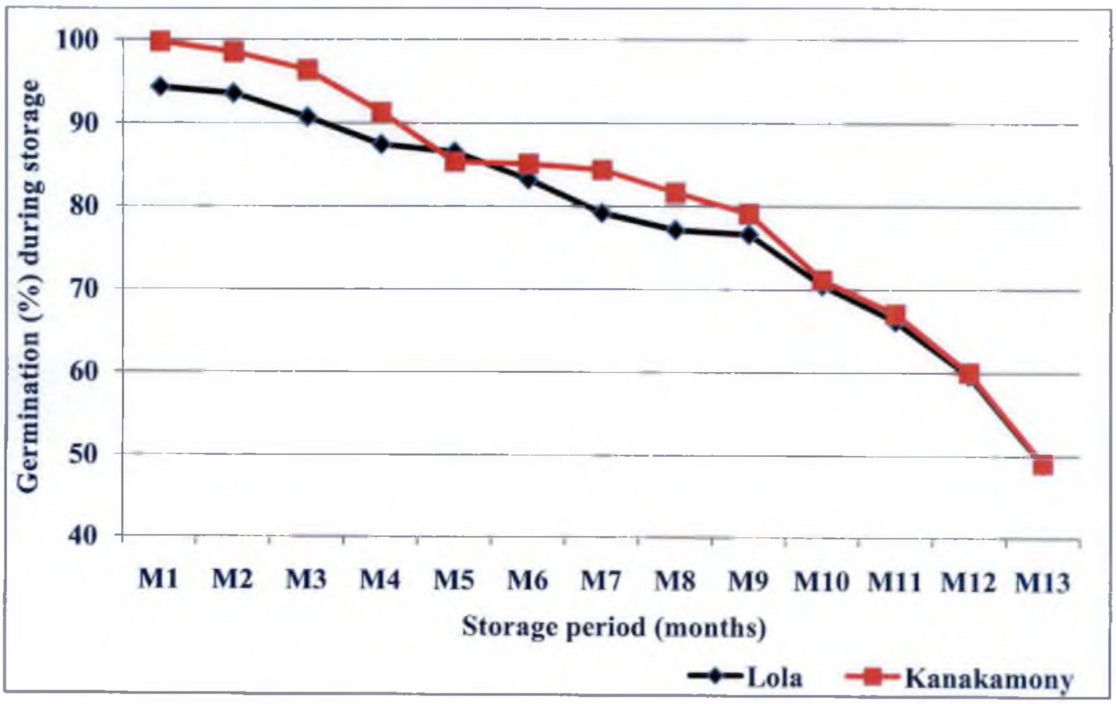


Fig.3. Germination in cowpea varieties Lola and Kanakamony over storage



be significantly superior to untreated seeds (Fig. 5 and Fig. 6). Similar impact on viability and vigour maintenance by seed treatment with plant oils and botanicals and insect control has been proven in pulses by several workers (Lele and Mustapha, 2000; Songa and Rono, 2010; Yusuf *et al*., 2011; Raja *et al*., 2013; Asawalam and Anaeto, 2014; ;Wahedi*et al*., 2015).

Among the neem based botanicals used, seed treatment with neem kernel powder maintained higher germination and other seed quality parameters during storage. Similar to the study, Kumbar (1999) and Merwade (2000) in chickpea seeds, Deshpande*et al.* (2010) in soybean seeds, Bhuiyan*et al.* (2010) in lentils, Sandeep*et al.* (2013) in sweet corn seeds and Asawalam and Anaeto (2014) in cowpea seeds also had reported the effectiveness of neem kernel powder, neem leaf powder and neem oil in obtaining higher seedling shoot length, root length and dry matter production during storage.

Maraddi (2002), Duruigbo (2010) and Kamara (2014) had observed that cowpea seeds treated with neem leaf powder recorded higher germination and vigour index compared to untreated control. Patil and Tandale (1999) as well as Sreeramaiah and Bommegouda (1992) had reported the beneficial effect of neem oil (0.5%) in maintaining higher germination and seed vigor during storage in case of green gram and cowpea respectively.

Improved germination and seedling vigour from seed treatment with neem kernel powder and neem leaf powder have been reported in case of wheat (Pal and Basu, 1995), bengalgram(Arati, 2000), cowpea (Maraddi, 2002), lentil seeds (Khatun*et al*., 2011) and sesame (Oyekale, 2012).

Electrical conductivity of seed leachate was found to increase with increase in storage period in the study has already been reported in chickpea (Kumbar,1999),cotton (Sandyarani, 2002), soybean (Saha and Sultana, 2008) and in sunflower(Divyashree, 2006 and Nataraj*et al.* 2011). The mean electrical conductivity of seeds treated with neem kernel powder, neem leaf powder, neem

Fig.4. Effect of seed treatments on speed of germination in cowpea at the ninth month of storage

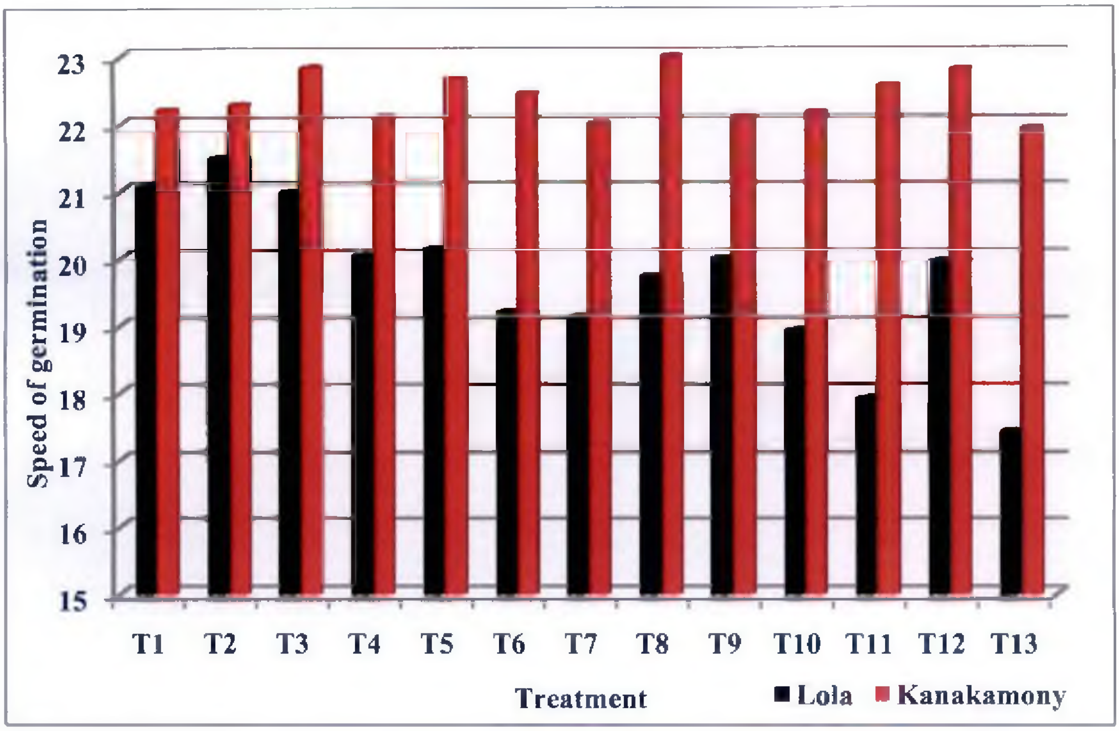
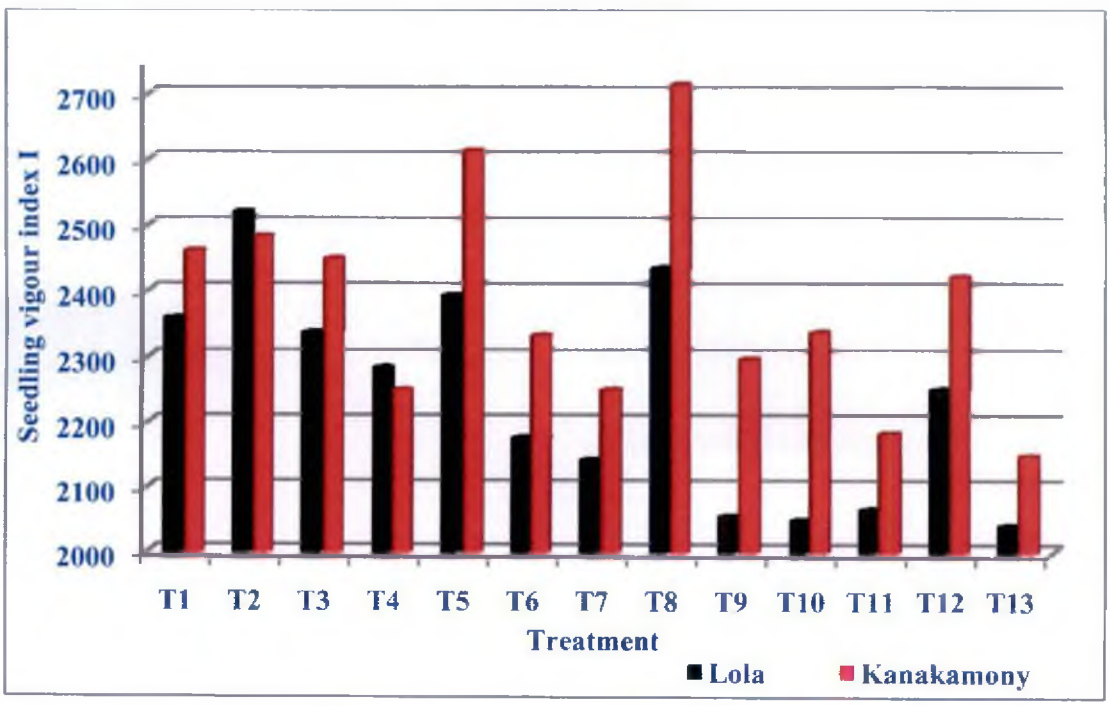


Fig.5. Effect of seed treatments on seedling vigour index I in cowpea at the ninth month of storage



oil, castor oil and coconut oil was lower when compared to control. Lower electrical conductivity of seed leachate was also observed in seeds treated with the other botanicals (Fig. 7). This may be due to the reduced seed membrane permeability in the treated seeds. The nature and extent of membrane protection offered may not be same for all treatments, resulting in differential EC values among seed protectant treatments (Kurdikeri, 1991). According to Patil (2000), botanicals serve as antifeedants and make seeds unpalatable to insects, thus reducing the cracks and aberrations of seed coat and minimizing the leaching of the electrolytes.

As the seeds in the present study were packed in polyethylene bag (700G), variation in moisture content over the storage period of 13 months was absent or neglible. According to Nagaveni (2005), moisture-proof sealed containers provide suitable environment for storage, offer protection against contamination and also acts as a barrier against the escape of seed treatment chemicals than in moisture pervious containers (Nagarajan and Karivaratharaju, 1976). These bags not only help in maintaining seed viability but also protect the seeds from pulse beetle damage. According to Amruta*et al.* (2015), treated seeds, when stored in polylined cloth bag exhibited higher quality parameters *i.e.* increased germination, vigour and lower EC value due to decrease in seed quantitative losses.

During storage it was observed that, the seed infection per cent increased towards the end of storage (Fig. 8 and Fig. 9). Similar findings have been reported earlier as well (Christensen and Kauffmann, 1969 and Krishnamurthy and Raveesha, 1996). The seed microflora observed in Lola and Kanakamony varieties of cowpea seeds were *Aspergillusniger* and *Aspergillusflavus*. It was observed that, the infection by fungi was highest in untreated seeds followed by seeds treated with sweet flag powder, karinotchi leaf powder, paanal leaf powder and the entomopathogenic fungi *Beauveria bassiana*. The incidence was consistently low in seeds treated with neem oil, coconut oil, neem kernel powder, castor oil and neem leaf powder and spinosad. The beneficial effects of these

Fig. 6. Effect of seed treatments on seedling vigour index II in cowpea at the ninth month of storage

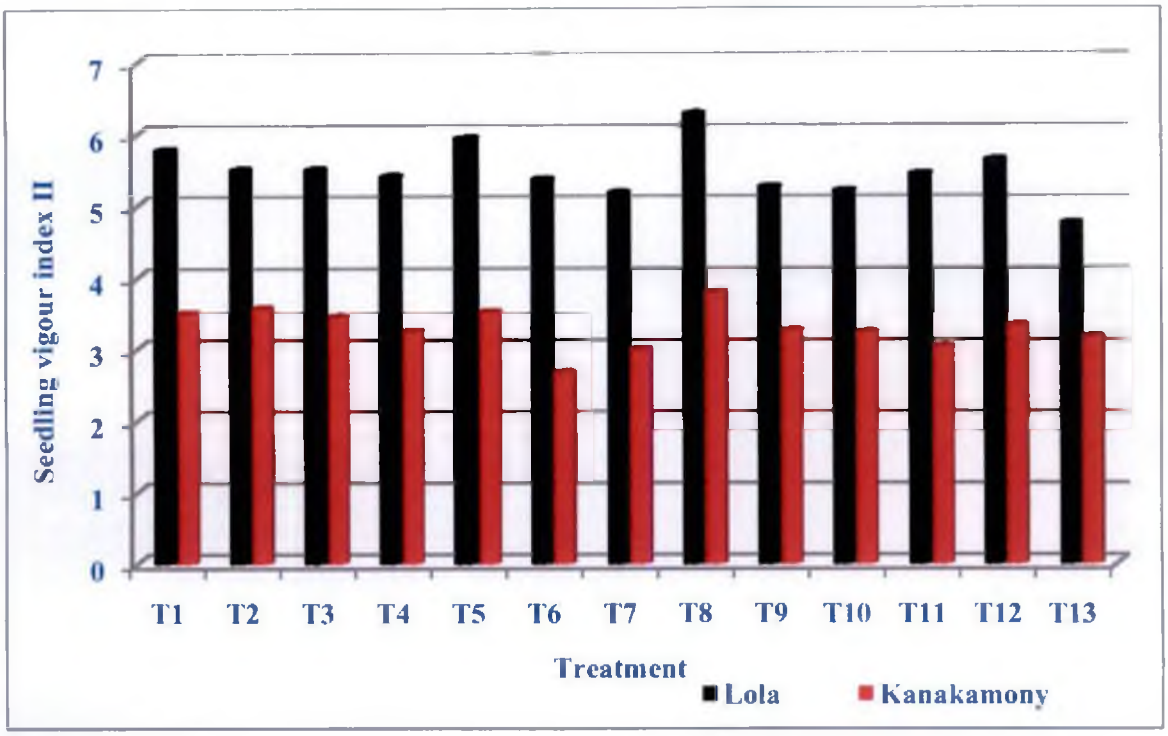
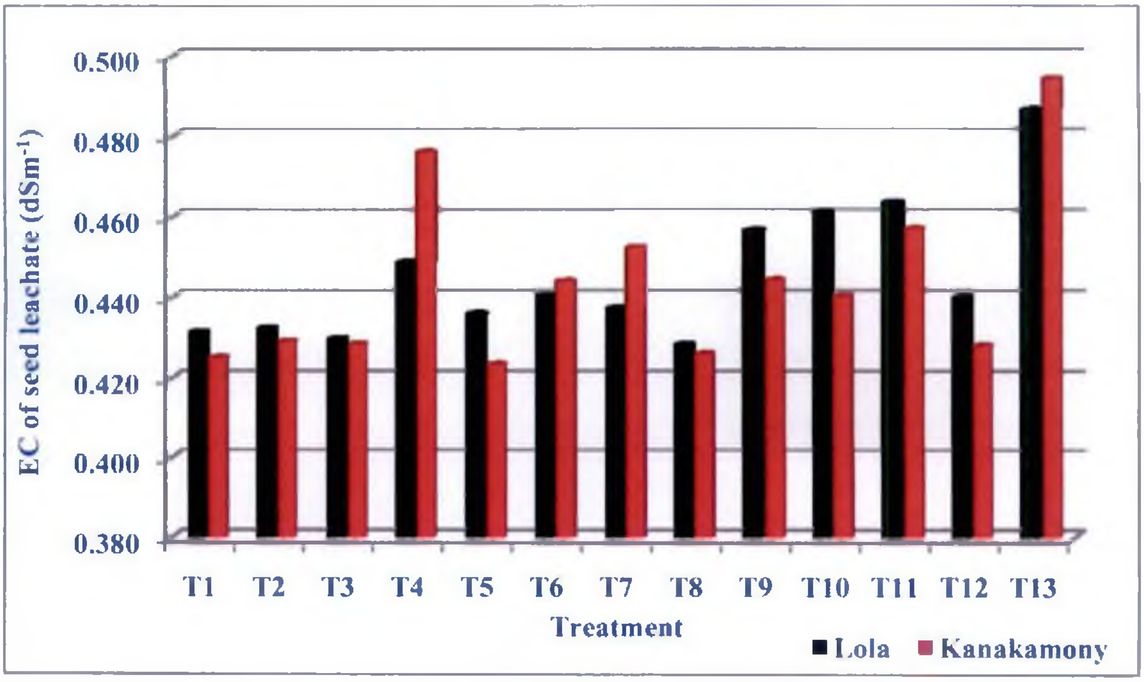


Fig. 7. Effect of seed treatments on electrical conductivity of seed leachate in cowpea at the ninth month of storage



botanicals and spinosad on germination and growth of seedlings have been discussed earlier. A consistency between seed germination, vigour parameters with seed infection per cent was evident in the study. Loss of viability and vigour of stored seeds was attributed to storage fungi by Roberts (1972). Hassan *et al.* (2015) studied the efficacy of neem seed powder against fungal pathogens and found that it was effective in controlling *Aspergillusniger, Aspergillusflavus and Rhizopus species.*

The results clearly pointed out that use of oils as seed protectants did not affect the viability and other quality parameters of the seed. This is in consonance with the findings of Mummigatti and Ragunathan (1977), Singh *et al.* (1978), Varma and Pandey (1978), Adu (1986), Obeng-Ofori (1995), Sharanabasappa and Kulkarni (2008) and Laxmareddy and Benarjee (2013). On the contrary, Yun-tai and Burkholder (1981), and Tembo and Murfitt (1995) had reported the detrimental effect of oils on seed viability.

Spinosad was found next best to the neem based products and other oils (coconut oil and castor oil), in maintaining higher seed and seedling qualities. Amrithakumari (2011) found that among the various seed protectants used against pulse beetle, spinosad at the rate of 70ppm was most effective with no adverse effect on seed viability up to one month after treatment.

Results discussed above indicated that although seed germination above MSCS was extended by one month in all the treated seeds as compared to control. However, the effect of *Beauveria bassiana*, inert diatomaceous earth, ash and botanicals were less effective in enhancing seed germination and seedling performance compared to neem based products, other oils and spinosad. Higher seed quality and seedling performance can be achieved on treating the seeds with seed protectants *viz.*, spinosad, neem based products and vegetable oils evaluated. Similarly, seed potentiation upon treating the seeds with botanicals, which significantly reduced the infestation and helped to maintain the viability and

Fig. 8.Effect of seed treatments on seed microflora infection in cowpea (Lola) at the end of storage

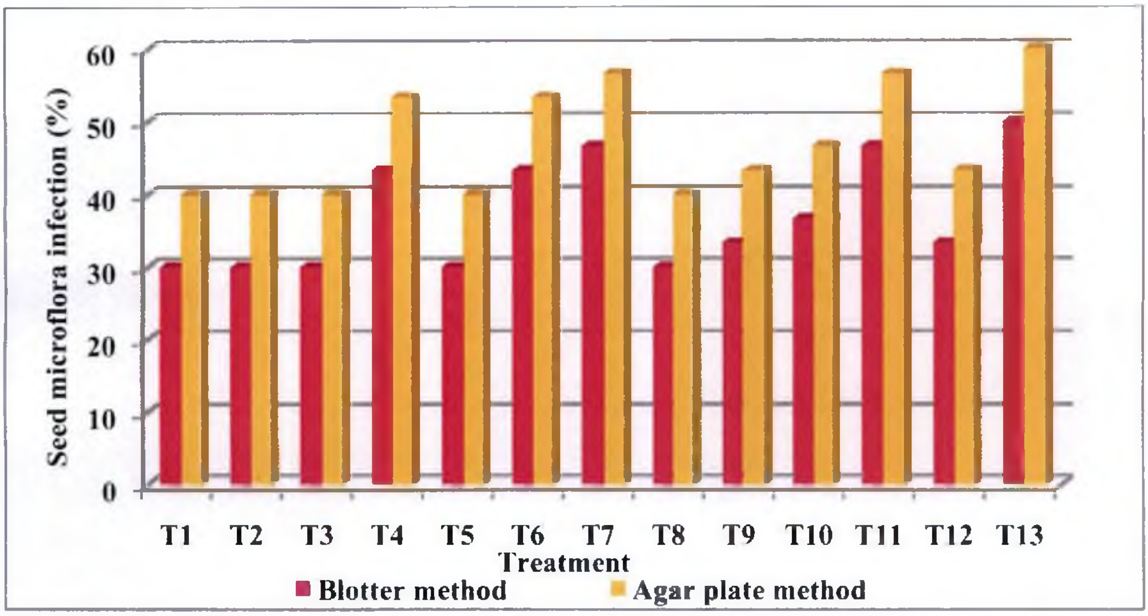
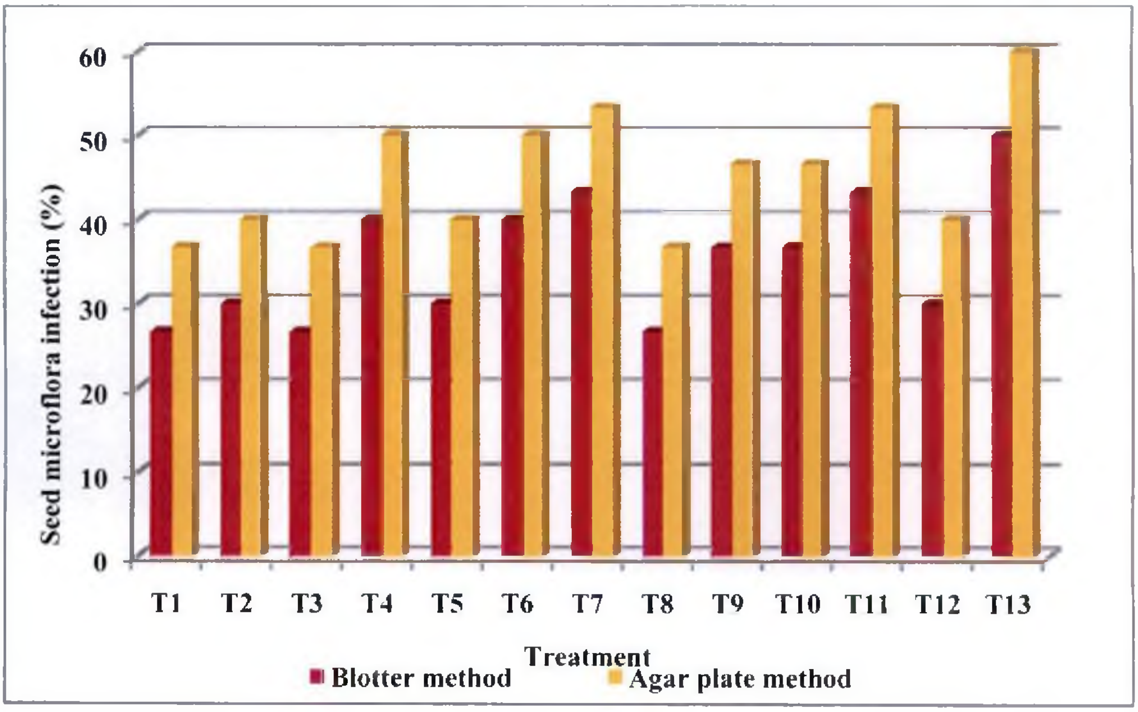


Fig. 9. Effect of seed treatments on seed microflora infection in cowpea (Kanakamony) at the end of storage



vigour for longer period in storage was also reported by Duruigbo (2010) as well as Basavegowda and Arunkumar (2013).

The effectiveness of different seed protectants on mortality of adult pulse beetles, fecundity, egg hatchability and infestation caused by beetle were studied in two varieties of cowpea, namely, Lola and Kanakamony. The results revealed that all the seed protectants used were effective against pulse beetle during the initial period of storage and were significantly superior to control over the period of storage.

Cent per cent mortality was recorded by all the seed protectants for first three months of storage. Seeds treated with neem oil, castor oil and coconut oil recorded maximum mortality (100 %) of adults for up to five months of storage in both varieties, whereas, diatomaceous earth and ash recorded cent per cent mortality for up to five months of storage in Lola and four months in Kanakamony. Seeds treated with spinosad registered cent per cent mortality for up to seven months of storage for both varieties. The mortality of adults showed a decrease with increase in storage. Throughout the storage period, spinosad recorded the highest mortality of adults (Fig. 10 and Fig.11).

Results indicated that among different treatments, spinosad offered protection against pulse beetle for the longest duration. Spinosad was followed by the neem oil and other vegetable oils and botanicals such as castor oil, coconut oil, neem kernel powder and neem leaf powder. These findings derive support from Sadat and Asghar (2006) who reported 75 to 100 per cent mortality of adult pulse beetles in spinosad treated seeds. Antoine *et al.* (2010) reported that spinosad significantly increased the mortality of adult pulse beetles when exposed to seeds immediately after treatment and also offered protection for up to five months of storage. The seeds treated with spinosad recorded higher mortality of above 90 per cent of adult beetles within seven days of treatment as compared to 50 per cent mortality in case of deltamethrin were reported by Mandali and Rani (2015).

Huang *et al.*(2007) and Khashaveh*et al.*, (2011) also observed similar results. Next to spinosad, lowest mortality of adults was recorded in vegetable oils like neem oil, castor oil and coconut oil as well as neem kernel powder and neem leaf powder. Dhakshinamoorthy and Selvanarayanan (2002) evaluated the effect of natural products like leaf powders of neem, notchi, pungam, citrus and thulsi along with materials such as fly-ash, kitchen ash, castor oil and red earth against *C. maculatus*. Mortality of the beetles at seven days after treatment was the highest (100%) in castor oil, followed by neem leaf powder (91.66%). Bajya*et al.* (2007) also studied the efficacy of some vegetable oils against *C. chinensis*on cowpea seeds and reported that neem oil was the most effective with an adult mortality of 96.0 per cent three days after treatment. It was followed by castor oil with 84.0 per cent mortality, both at a dose of 1.2 ml/100 g seeds. Bhardwaj and Verma (2013) also evaluated the efficacy of vegetable oils (neem, karanj, cedar, apricot, olive and mustard) against pulse beetle, *C. chinensis* infesting pea seeds. They found that mortality in the control increased substantially to 61.11 per cent and all treatments were superior to the control. Highest mortality of the pulse beetle was observed in seeds coated with neem oil at 5 per cent concentration (100.0%). The same was at par with neem oil (both 1 and 3 per cent) 15 days after treatment. A similar result on bioefficacy of neem oil was observed by Zahid*et al.* (2000) against pulse beetle.

Irrespective of the variety, female beetles laid significantly fewer eggs on the cowpea seeds treated with seed protectants compared to untreated seeds. Among the different seed protectants used, spinosad was found to be superior without any egg layingfor up to five months of storage, whereas, oviposition was observed from second month of storage in all other treatments. All the seed protectants used were significantly superior to control in terms of number of eggs laid. It was observed that the number of eggs increased with increase in storage period. Lowest number of eggs was recorded in seeds treated with spinosad, followed by neem oil, castor oil and coconut oil (Fig. 12 and Fig. 13).

Fig. 10.Effect of seed treatments on mortality of adults pulse beetles in cowpea (Lola) during storage

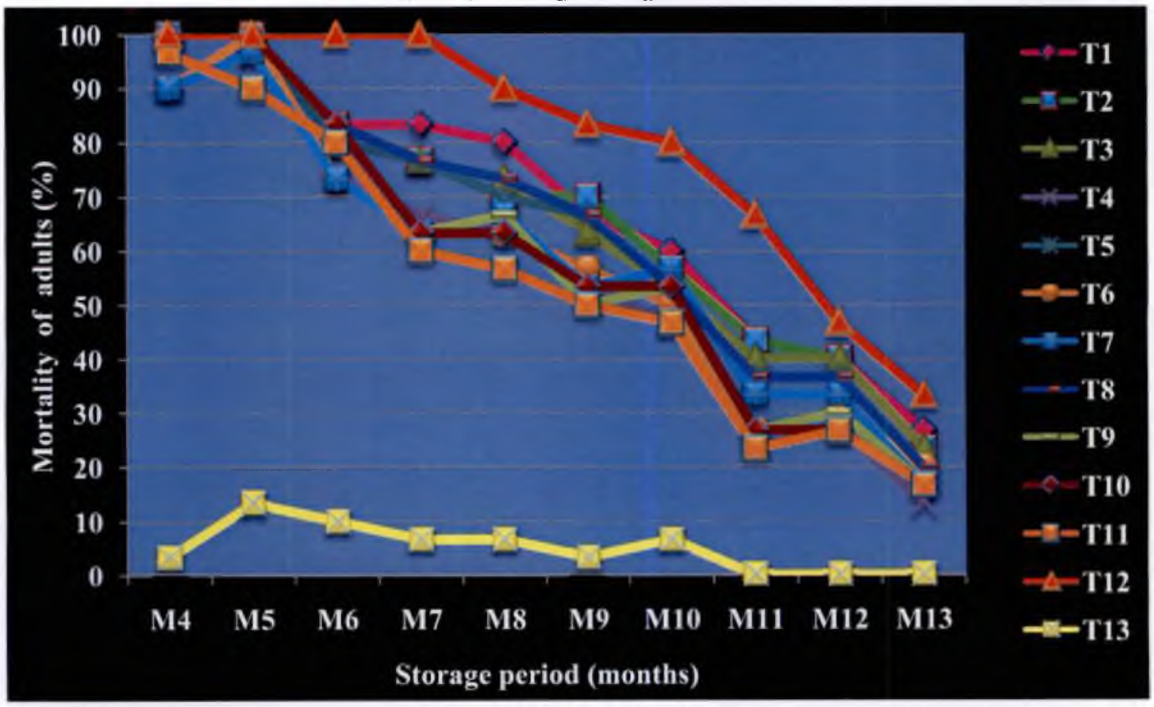
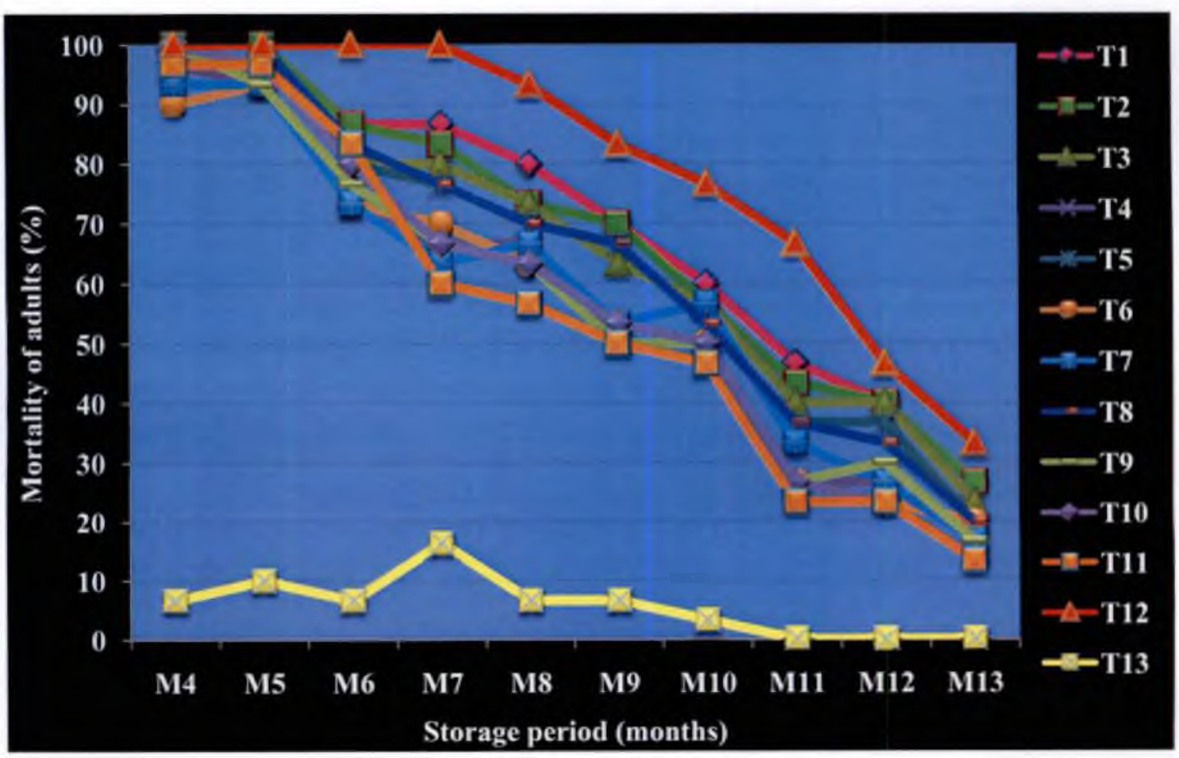


Fig. 11.Effect of seed treatments on mortality of adults pulse beetles in cowpea (Kanakamony) during storage



Results of this study are consistent with those of former studies reporting the ovicidal effect of spinosad on pulse beetle. Sanon*et al.* (2010) reported that the number of eggs laid by *C. maculatus*decreased signifcantly (F =30; df =7; P < 0.001) as the dose of spinosad increased. The present findings indicated that the least number of eggs was laid in spinosad treated seeds followed by vegetable oils, namely, neem oil, castor oil and coconut oil. Ovicidal action of neem oil against pulse beetle was reported by Khaire*et al.* (1993), Vir (1994) and Raghuraman and Singh (1997). Bhuiyah*et al.* (2003) found that neem, castor and bishkatali extracts (*Polygonumhydropiper*L.) were effective in preventing the egg laying of *C. chinensis*on chickpea seeds. AL-Lawati*et al.* (2002) and Mollah and Islam (2002) reported that the ovipositionby pulse beetle was markedly reduced when stored seeds were treated with different botanical extracts like neem, jatropha, sweetsop and bishkatali. Akter*et al.* (2007) also stated that neem extract reduced the oviposition by pulse beetle in stored blackgram. Pandey*et al.* (1986) observed that extracts of neem leaves and twigs had a repellent action against *C. chinensis.* Hossain and Haque (2010) also evaluated the efficacy of some indigenous plant extracts as grain protectants against pulse beetle and found that the highest numbers of eggs were laid in control (94.33) and the lowest in neem treated seeds (31.89). On the effect of oils on oviposition, the present results also agree with those reported by Singh *et al.* (1978), Messina and Renwich (1983), Sujatha and Punnaiah (1985),Yadav (1985), Babu*et al.* (1989), Pacheco *et al.* (1995), Raghvani and Kapadia (2003) and Jagjeet*et al.* (2005).

The influence of different seed protectants on egg hatchability was studied. In both varieties, it was revealed that all the treatments were significantly superior to control in suppressing the hatching of beetle eggs. Egg hatchability increased progressively over the period of study. Among the seed treatments, lowest egg hatchability was recorded in seeds treated with spinosad and it prevented eggs from hatching for up to seven months of storage. It was followed by coconut oil, neem oil and castor oil. Throughout the storage period of thirteen months, highest number of egg hatched in control (Fig. 14 and Fig. 15).

Fig. 12.Effect of seed treatments on number of eggs laid by beetles in cowpea (Lola) during storage

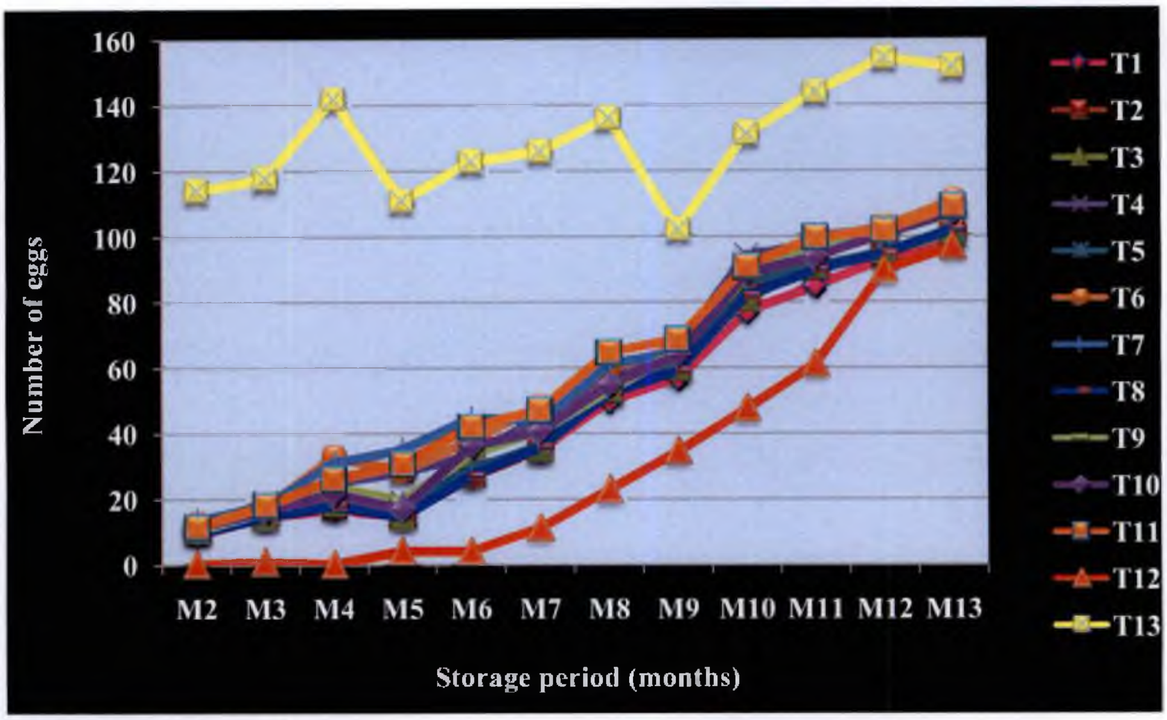
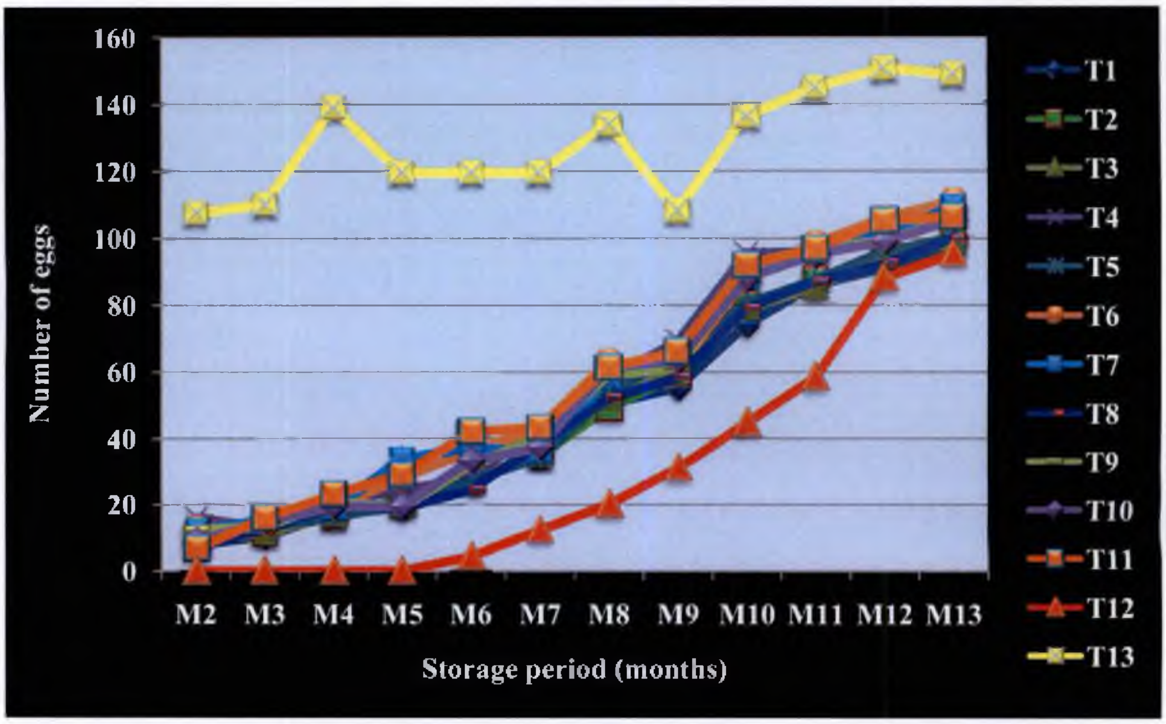


Fig.13.Effect of seed treatments on number of eggs laid by beetles in cowpea (Kanakamony) during storage



Seed protectants significantly reduced the egg hatchability over the period of storage compared to control. The lowest egg hatchability recorded in spinosad treated seed is in line with the findings of Sanon*et al.* (2010), who reported that spinosadsignifcantly reduced egg hatching compared with the untreated control ($F = 23$; df = 7; $P = 0.001$) and a dose of 2.5 mg spinosadper kilogram of seed caused a reduction similar to that caused by deltamethrin. These results are also in line with the earlier findings of persistent insecticidal activity of spinosad for 12 months against insect pests in stored corn (Liang *et al.*, 2002), corn and sunflower seeds (Huang and Subrahmanyam, 2004) as well as stored wheat (Flinn*et al.*, 2004). In a previous study at Kerala Agricultural University, Amrithakumari (2011) reported that no eggs hatched out in seeds treated with coconut oil. The present study also has confirmed the above findings, with zero hatchability in seeds treated with coconut oil for up to six months of storage. Previous works of Tripathy*et al.* (2001), Singh and Yadav (2003), Allotey (2004) and Tandon*et al.* (2004) also support the present findings that the active compounds present in the botanicals and oils possess ovicidal and repellent activity which protect the pulse seeds treated with them.

Extent of infestation is a measure of damage caused by insect. Seeds treated with protectants recorded significantly lower seed infestation compared to the control. No seed infestation was recorded in treated seeds for up to three months of storage. Thereafter, no seed infestation was recorded in seeds treated with spinosad for up to seven months of storage. Spinosad treated seeds also recorded lowest seed infestation among the different treatments throughout the study period. It was followed by neem oil, castor oil and coconut oil where no seed infestation was observed for up to five months of storage. Once initiated, infestation of seeds increased progressively over the period of storage. Throughout the storage period, lowest seed infestation was recorded in spinosad treated seeds followed by neem oil, coconut oil and castor oil. Next to oils, least seed infestation was recorded in neem leaf powder and neem kernel powder (Fig.16 and Fig. 17).

Fig.14.Effect of seed treatments on egg hatchability in cowpea (Lola) during storage

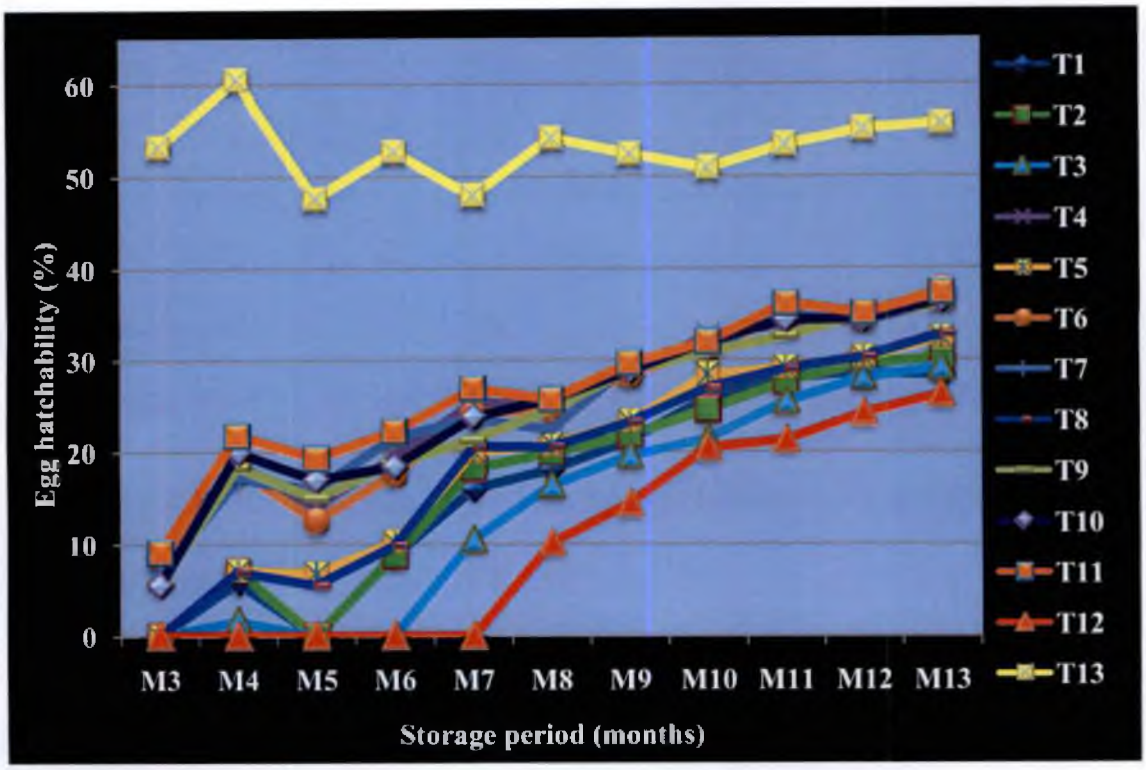
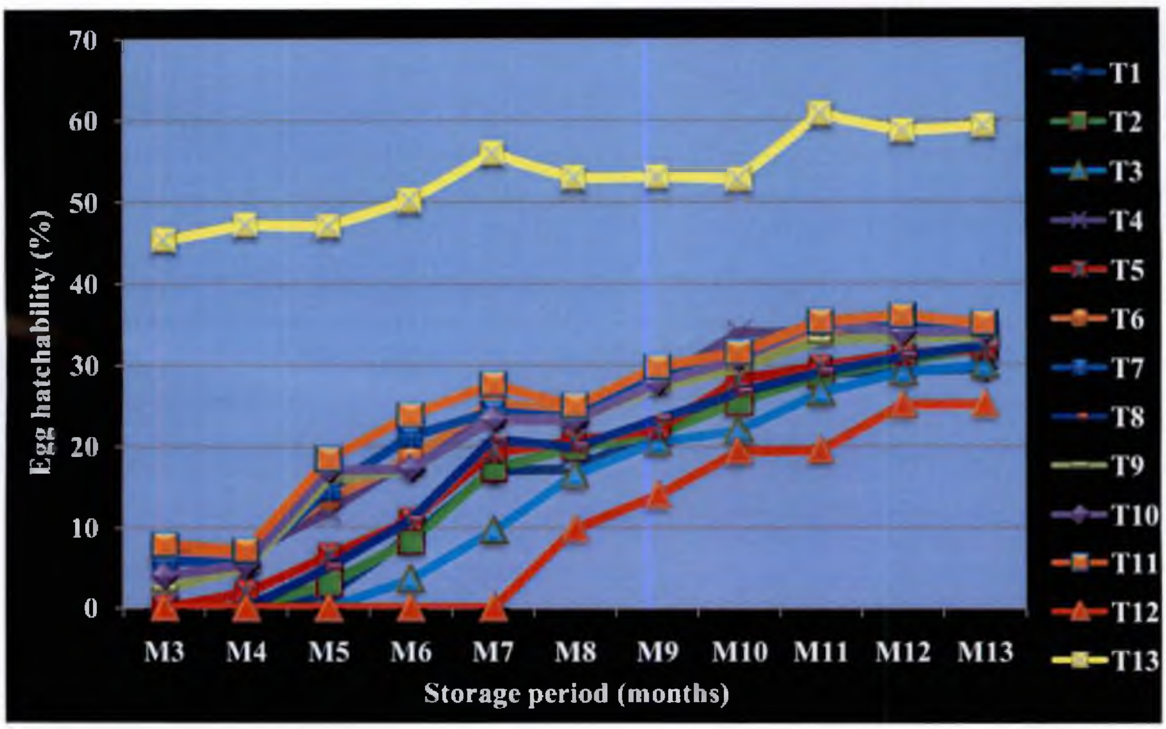


Fig.15.Effect of seed treatments on egg hatchability in cowpea (Kanakamony) during storage



The present findings showed that all seed protectants were highly effective in curbing development of the insect in the treated seeds and thereby reducing seed infestation. However, an increasing trend of infestation was discurbable due to reduction in efficacy of seed protectants which could be observed over a period of thirteen months. However, the treatments remained significantly superior to control, which could be evinced from the population reduction of beetle in treated pulse seeds. Among the seed protectants, lowest seed infestation was observed in spinosad followed by neem oil, castor oil and coconut oil as well as neem leaf powder and neem kernel powder. The present research findings are in agreement with that of earlier researchers who reported the efficacy of spinosad against stored pests (Huang and Subramanyam (2007), Khashaveh*et al.* (2009), Vayias*et al.* (2009), Mollaie*et al.* (2011) and Mirmoayedi*et al.* (2011)). Sanon*et al.* (2010) also observed that the percentage of grains with perforations was lower in spinosad treatment (15%) compared to deltamethrin treatment (29%) and control (65%). According to Mandali and Rani (2015), seeds treated with spinosad recorded 0.5 per cent seed damage after nine months of storage compared to hundred per cent damage in untreated seeds. Similarly Rashmi*et al.* (2014) reported that seeds treated with neem oil at 5 ml/kg were superior to all the botanicals (mentha oil and castor oil) with lowest pulse beetle infestation (9.0 %) after six months of storage, but was statistically at par with castor oil @ 5 ml/kg of treated seeds. Khaire*et al.* (1992) also reported the efficacy of neem oil against *C. chinensis* in storage. Okunola (2003) and Khalequzzaman*et al.* (2007) reported that vegetable oils protected the seeds from bruchids infestation. Malaker and Ahmed (2006) and Alice *et al.* (2007) mentioned that neem seed kernel extracts reduced the seed infestation against *C. chinensis*. Sujatha*et al.* (2015) also reported that the per cent hatchability and damage was higher in control (97.8% and 98.5%) while there was no sign of bruchid infection in case of seeds treated with leaf powders of neem and nochi up to 6 months of storage. Kamruzzaman*et al.* (2004) reported that the reduction of seed damage and weight loss might be due to antifeedant action of neem seed extract. Rao, *et al.* (1993) and Xie*et al.* (1995) also reported the antifeedant effect of neem leaf extract. The present study

Fig.16.Effect of seed treatments on seed infestation in cowpea (Lola) during storage

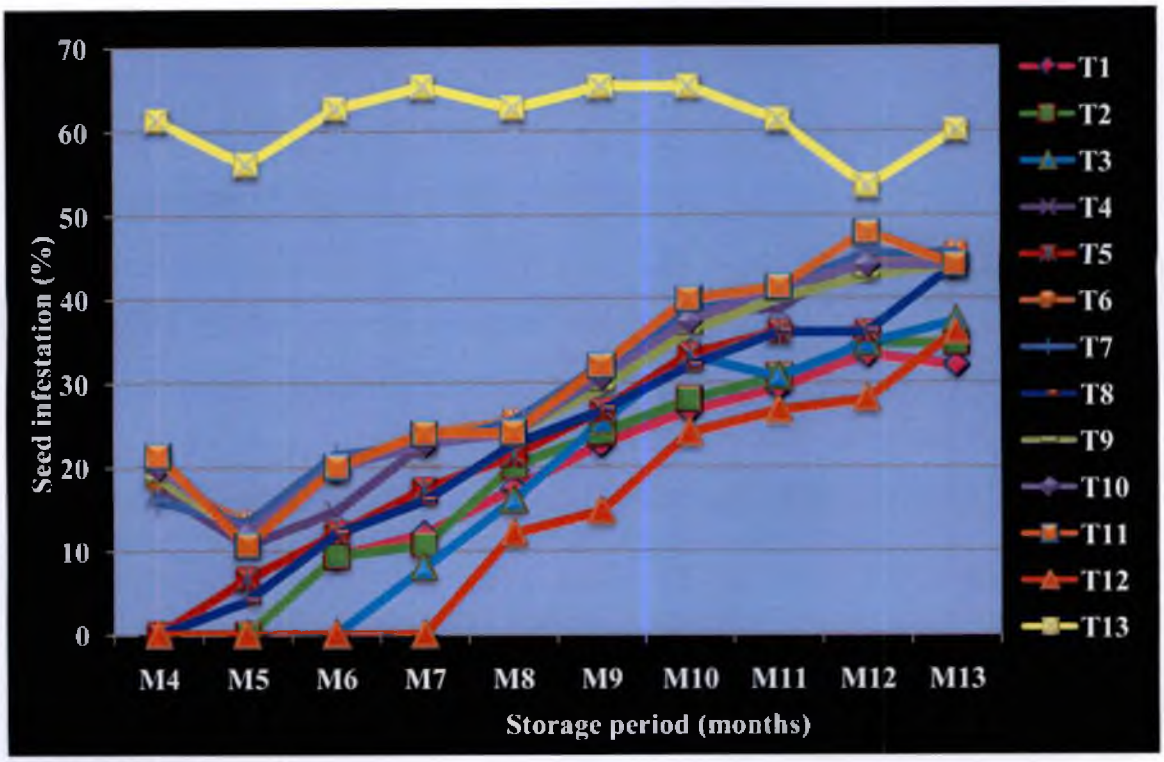
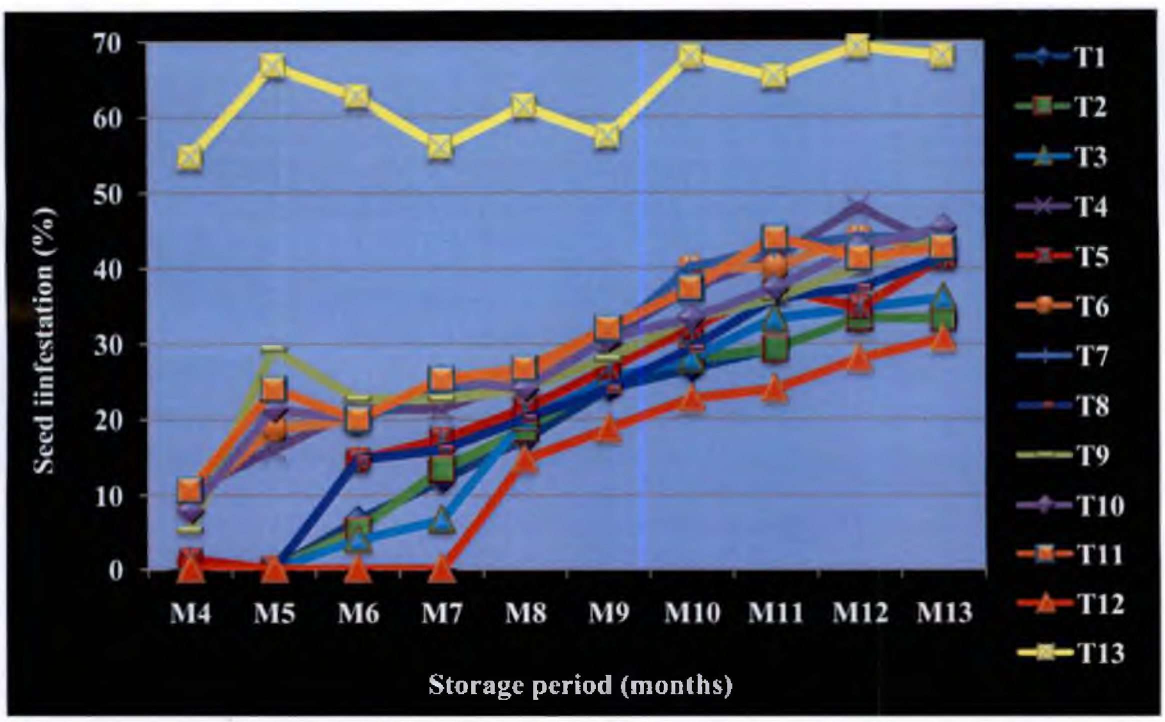


Fig.17.Effect of seed treatments on seed infestation in cowpea (Kanakamony) during storage



with various botanicals are in conformity with the results of Dwivedi and Kumari (2000), Dwivedi and Venugopalan (2001), Jangamashetti*et al.* (2008), Srinivasan (2008), Nayanathara*et al.* (2010), Devi *et al.* (2011), Patole (2011), Sreekanth*et al.* (2011) and Bharti (2012).

Better control of pulse beetle on using spinosad, oils and neem based products may be due to the antifeedent and repellent properties present in spinosad, oils and other neem based products. Salgado (1998) reported that spinosad is lethal to insects by ingestion or contact, and it acts on an insect's nervous system at the nicotinic acetylcholine and gamma - aminobutyric acid (GABA) receptor sites. Credland (1992) proposed that application of oil to *Callosobruchus* eggs might occlude the funnel, and thus lead to the death of the developing insect by asphyxiation. Neem products possess anti-feedant and repellent properties because of compounds like isoprenoids, glycerides, polysaccharides, flavonoids, aliphatic compounds *etc.* (Devakumar and Sukhdev, 1993). Among the chemical constitutents, Azadirachtin is the most potent and abundant one having antifeedant and ecdysis inhibition properties against several major pests.

For the selection of seed treatment best suited to maintain higher seed quality and also provide better protection against pulse beetle during storage, ranking of treatments in both varieties was done.All the seed quality parameters (germination, speed of germination, seedling vigour indices, electrical conductivity of seed leachate, mortality of adult pulse beetles, number of eggs laid by beetle, egg hatchability, seed infestation and microflora infection) at 9 months of storage were considered.The method suggested by Arunachalam and Bandopadhyay (1984) was followed with slight modification. Each treatment was ranked in serratum based on the magnitude of parameter considering the DMRT test values. Annotation 'a' was assigned rank 1, 2 for treatment with DMRT annotation 'ab', 3 for 'abc' and so on. Hence, higher the germination, speed of germination, seedling vigour indices, mortality of adult beetles of the treatment, lower would be the numerical value of the rank.

EC of leachate and other parameters (EC of seed leachate, number of eggs laid by beetle, egg hatchability, seed infestation and microflora infection per cent) which were found to be negatively affecting seed quality were ranked in the reverse format *i.e.*, these treatments were ranked in descending order of magnitude. Treatment with least value based on DMRT was assigned rank 1, the next 2 and so on. Therefore, treatment with the least EC of seed leachate, number of eggs laid by beetle, egg hatchability, seed infestation and microflora infection per cent were ranked 1, 2 and so on.

Final ranking of treatments were done considering the summation of score obtained by the treatments for each of the above criterion (EC of seed leachate, number of eggs laid by beetle, egg hatchability, seed infestation and microflora infection). The summation of ranking of each treatment for individual parameters was then arrived at. Treatment with the least total score was assigned final rank 1. The lower rank of a treatment thus indicated that it helped to maintain higher seed quality and offered greater protection against pulse beetle during storage.

In case of variety Lola, seeds treated with neem oil secured rank 1 followed by spinosad (rank 2) and neem kernel powder (rank 3).Castor oil as well as neem leaf powder had ranked fourth and coconut oil ranked fifth (Table 26). However, in varietyKanakamony, seeds treated with neem kernel powder andspinosad ranked first and second respectively.Coconut oil as well as neem oil had ranked third and castor oil as well as neem leaf powder had ranked fourth (Table 27).

Hence, it can be concluded that higher seed quality and seedling performance and enhancement of seed viability can be achieved by seed treatment with seed protectants *viz.*, spinosad, neem based products (neem kernel powder, neem leaf powder and neem oil) and vegetable oils (castor oil and coconut

Table 26.Ranking of seed treatments based on seed quality parameters and effectiveness against pulse beetle infestation of cowpea seedsat the 9th month of storage (Lola)

Treatment	Germination	Speed of germination	SV I	SV II	EC	Mortality	No. of eggs	Egg hatchability	Seed infestation	Total score	Rank
T1	1	2	5	3	2	3	2	2	2	22	1
T2	3	1	1	5	6	2	4	2	3	27	4
T3	3	2	4	5	5	4	4	2	4	33	5
T4	3	3	5	7	12	6	6	5	5	52	6
T5	2	3	3	2	1	3	5	4	4	27	4
T6	4	4	7	8	8	5	7	5	5	53	7
T7	4	4	8	10	10	6	7	6	5	60	10
T8	1	8	2	1	2	3	3	3	3	26	3
T9	4	3	10	8	9	7	5	5	5	56	8
T10	4	5	10	9	7	6	6	5	6	58	9
T11	5	6	10	6	11	7	5	7	6	63	11
T12	3	3	6	4	4	1	1	1	1	24	2
T13	6	7	9	11	13	8	8	8	7	77	12

Table 27.Ranking of seed treatments based on seed quality parameters and effectivenessagainst pulse beetle infestation of cowpea seedsat the 9th month of storage (Kanakamony)

Treatment	Germination	Speed of germination	SV I	SV II	EC	Mortality	No. of eggs	Egg hatchability	Seed infestation	Total score	Rank
T1	3	8	2	2	1	2	2	3	2	25	3
T2	4	7	3	2	1	2	3	3	2	27	4
T3	2	2	4	4	1	4	4	2	2	25	3
T4	6	10	6	6	2	6	6	4	3	49	7
T5	2	4	2	3	1	3	5	4	2	27	4
T6	4	6	6	10	2	5	4	5	3	45	5
T7	6	12	6	9	2	5	5	5	3	53	8
T8	1	1	1	1	1	3	3	4	2	17	1
T9	6	11	6	6	2	6	4	4	2	47	6
T10	5	9	6	7	2	5	4	4	3	45	5
T11	7	5	7	8	2	6	5	5	3	48	7
T12	4	3	5	5	1	1	1	1	1	22	2
T13	8	13	8	7	3	7	7	5	4	62	9

oil).Similarly, highest mortality of adult beetles, lowest fecundity, egg hatchability and seed infestation were recorded in seeds treated with spinosad followed by oils *viz.*, neem oil, coconut oil and castor oil as well as other neem based botanicals *viz.*, neem kernel powder and neem leaf powder. However in case the stored pulse seeds are meant for food, feed and seed purpose, treatment with coconut oil could be recommended in place of neem based products or spinosad. Neem oil, neem leaf powder and neem kernel powder are reported to cause sterility in humans and animals as observed in the insects (Gupta *et al.*, 2010).

Considering that spinosad offered protection against pulse beetle for the longest duration (7 months of storage) and viability of the treated seeds was retained for nine months of storage as in the case of seeds treated with other seed protectants, spinosad can be recommended as the best seed treatment for cowpea if it can ensured that the treated seeds would be used only for seed purpose.

Summary

6. SUMMARY

The present study 'Effect of seed protectants against pulse beetle on viability, vigour and health of cowpea seeds,' was carried out at Kerala Agricultural University (KAU), Vellanikkara during 2014-2016. Seeds of semi-trailing cowpea variety Kanakamony and that of trailing variety Lola were treated with various seed protectants against pulse beetle (*Callosobruchus* spp.). The seed protectants used included neem based products (neem oil, neem leaf powder and neem kernel powder), vegetable oils (castor oil and coconut oil), inert matter (diatomaceous earth and rice husk ash), powdered botanicals (sweet flag rhizome powder, paanal leaf powder and karinotchi leaf powder), entomopathogenic fungus*Beauveria bassiana* and insecticide spinosad. The performance of treated seeds was evaluated against untreated seeds for a period of 13 months. Both treated and untreated seeds, dried to nine per cent moisture content were stored under ambient conditions during this period.

The study was envisaged to analyze the effect of seed protectants against pulse beetle on viability, vigor and health of seeds of cowpea varieties.The results obtained are summarized below.

I. Effect of seed protectants on seed quality and viability of cowpea during storage (Lola and Kanakamony)

1. Irrespective of the seed protectants used, seed quality parameters like germination per cent, speed of germination, seedling shoot length, root length and vigour indices decreased with increase in storage period.
2. The rate of decrease in seed germination and seedling performance was slower in semi-trailing variety Kanakamony compared to trailing variety Lola.
3. Irrespective of the variety, seed protectants significantly enhanced seed viability. The germination in all treated seeds was retained above 75 per cent (the minimum seed certification standards (MSCS) required for

cowpea) for nine months compared to eight months in case of untreated seeds.

4. Treatment with seed protectants also ensured higher seed quality, seedling performance and provided better protection to the seeds from pulse beetle for most part of the storage period.
5. Seed germination, speed of germination, seedling growth parameters and vigour indices were consistently high in case of treatment with neem based seed protectants (neem kernel powder, neem leaf powder and neem oil) as well as oils (coconut oil and castor oil).
6. During storage, among the neem based botanicals used, higher germination and seedling performance *viz.,* seedling shoot length, seedling root length, seedling dry weight and seedling vigour index I and II was observed in seeds treated with neem kernel powder .
7. Seed treatment with neem kernel powder had also resulted in lower electrical conductivity of seed leachate and seed infection per cent at the end of storage.
8. Seeds treated with spinosad was found next best to the neem based products and other oils (coconut and castor oil), in maintaining higher seed and seedling qualities.

II. Effect of seed protectants against pulse beetle infestation in cowpea

1. All the seed protectants used were effective against pulse beetle during the initial period of storage and were significantly superior to control over the period of storage.
2. Among the seed protectants evaluated, highest mortality of adult beetles, lowest number of eggs laid by beetle, lowest egg hatchability and seed infestation were recorded in seeds treated with spinosad followed by oils *viz.,* neem oil, coconut oil and castor oil as well as other neem based botanicals *viz.,* neem kernel powder and neem leaf powder.
3. Seed treatment with spinosad offered protection against pulse beetle for up to seven months of storage as evident from the cent per cent mortality of

adult beetles, complete suppression of egg hatchability as well as low seed infestation in both varieties.

4. Seeds treated with neem oil, castor oil, coconut oil, neem kernel powder and neem leaf powder recorded cent per cent mortality of adult beetles for up to five months of storage in both varieties.
5. No seed infestation was recorded in seeds treated with neem oil, castor oil and coconut oil for up to five months of storage while a similar protection was offered by neem leaf powder and neem kernel powder for up to four months of storage.
6. Spinosad was found to be the most effective in controlling pulse beetle infestation throughout the storage period.
7. Pulse beetle infestation was not observed in both treated and untreated seeds of the two varieties packed in polyethylene bag (700G), stored under ambient conditions for up to thirteen months of storage.

III. Evaluation of seed protectants based on their combined impact on seed viability, seedling performance and seed health in cowpea

1. Enhancement of seed viability (by a period of one month over control), higher seed quality and seedling performance and better protection against pulse beetle infestation and infection by microflora in cowpea can be achieved by seed treatment with seed protectants *viz.*, spinosad, neem based products (neem kernel powder, neem leaf powder and neem oil) as well as oils (coconut oil and castor oil).
2. Although seed germination above MSCS was extended by one month in all the treated seeds compared to control, entomopathogenic fungus *Beauveria bassiana*, inert matter *viz.*, earth and rice husk ash, and powdered botanicals *viz.*, paanal leaf powder, karinotchi leaf powder and sweet flag rhizome powder as seed protectants were less effective in enhancing seed germination and seedling performance over storage period compared to neem based products, other oils and spinosad.

3. In case the stored pulse seeds are meant for use as food, feed and seed, treatment with coconut oil could be recommended in place of neem based products or insecticide spinosad. Neem oil, neem leaf powder and neem kernel powder are reported to cause sterility in humans and animals as observed in the insects.
4. If it can ensured that the treated seeds would be used only for seed purpose spinosad can be recommended as the best seed treatment for cowpea. Spinosad had offered protection against pulse beetle for the longest duration (7 months of storage) and retained seed viability for nine months of storage.

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Appendices

Appendix I.Effect of seed treatments on seedling shoot length in cowpea (Lola)during storage

Treatment	Seedling shoot length (cm)													
	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	Mean
T1	28.95^{ab}	25.44^{a}	23.83^{bc}	24.77^{c}	26.02^{de}	21.86^{de}	19.90^{f}	20.27	20.23^{bcde}	19.50^{bc}	18.53^{bc}	17.48^{ab}	15.95^{c}	21.75
T2	27.01^{g}	23.25^{de}	20.85^{h}	22.19^{de}	25.30^{e}	20.78^{f}	22.00^{ab}	21.5	23.00^{a}	21.10^{a}	19.00^{ab}	17.15^{abc}	15.80^{c}	21.46
T3	27.84^{defg}	23.45^{cde}	21.48^{gh}	22.62^{d}	23.54^{fg}	22.45^{cd}	20.40^{ef}	21.39	21.00^{b}	20.25^{ab}	19.40^{a}	17.05^{abcd}	16.00^{bc}	21.30
T4	27.12^{fg}	23.94^{bc}	21.57^{fgh}	25.71^{abc}	23.25^{g}	21.94^{de}	19.04^{g}	21.34	20.50^{bcd}	19.50^{bc}	19.00^{ab}	16.50^{cdef}	14.75^{def}	21.09
T5	28.05^{bcde}	24.00^{bcd}	23.00^{cd}	25.54^{abc}	26.39^{cd}	23.33^{ab}	21.38^{bcd}	21.28	20.83^{bc}	19.04^{cd}	18.50^{bc}	17.50^{ab}	16.50^{ab}	21.95
T6	27.23^{efg}	23.85^{bcd}	20.69^{h}	25.04^{bc}	28.54^{a}	23.61^{a}	22.39^{a}	19.78	19.84^{bcde}	18.53^{cdef}	17.23^{de}	16.50^{cdef}	15.20^{d}	21.42
T7	27.93^{cdef}	24.14^{bc}	22.44^{def}	23.13^{d}	27.53^{b}	22.63^{bcd}	20.76^{de}	20.67	19.40^{de}	18.56^{cdef}	17.20^{de}	16.95^{abcd}	15.00^{de}	21.26
T8	28.64^{abcd}	25.33^{a}	24.71^{ab}	26.25^{a}	25.71^{de}	23.06^{abc}	21.53^{bc}	21.54	21.00^{b}	19.23^{bc}	18.75^{abc}	17.75^{a}	16.65^{a}	22.32
T9	29.10^{a}	23.64^{cde}	21.92^{efg}	26.04^{ab}	27.12^{bc}	23.58^{a}	20.88^{cde}	19.94	18.00^{f}	18.00^{def}	17.95^{cd}	16.75^{bcde}	15.15^{de}	21.39
T10	28.76^{abc}	22.90^{e}	22.68^{de}	26.12^{a}	25.25^{e}	22.99^{abc}	22.08^{ab}	21.5	18.00^{f}	18.00^{def}	17.00^{e}	16.90^{bcd}	14.95^{def}	21.32
T11	28.43^{abcd}	21.94^{f}	25.29^{a}	25.23^{abc}	25.66^{de}	22.98^{abc}	21.38^{bcd}	18.39	19.00^{ef}	17.80^{f}	16.90^{e}	15.95^{ef}	14.45^{f}	21.03
T12	28.50^{abcd}	24.50^{b}	24.62^{ab}	24.89^{c}	23.56^{fg}	23.45^{a}	20.80^{cde}	21.02	19.97^{bcde}	18.95^{cde}	17.00^{e}	16.25^{def}	14.65^{ef}	21.40
T13	28.06^{bcde}	21.87^{f}	22.19^{gh}	21.22^{e}	24.19^{f}	21.19^{ef}	21.69^{ab}	20.04	19.54^{cde}	17.92^{ef}	17.25^{e}	15.90^{f}	13.45^{g}	20.35
SEm±	0.130	0.181	0.250	0.272	0.261	0.156	0.157	0.285	0.236	0.175	0.158	0.112	0.145	
CD(0.05)	0.917	0.802	0.889	1.045	0.811	0.796	0.742	NS	1.382	1.112	0.857	0.827	0.541	

M: Month of storage
Means in each column with at least one letter in common are not significantly different at 5% level of probability

Appendix II. Effect of seed treatments on seedling root length in cowpea (Lola) during storage

Treatment	Seedling root length (cm)													
	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	Mean
T1	12.32^{a}	8.63^{a}	7.88^{cd}	9.29^{bc}	8.16^{e}	9.98^{ab}	9.49^{fg}	9.68^{def}	9.75^{a}	8.85^{ab}	8.76^{ab}	6.75^{cde}	6.01^{bcde}	8.89
T2	11.47^{b}	8.34^{ab}	9.86^{a}	8.28^{def}	8.04^{e}	8.15^{fg}	9.23^{fg}	9.77^{cdef}	9.73^{a}	8.9^{a}	8.75^{ab}	7.10^{abc}	6.1^{bcd}	8.75
T3	10.19^{cd}	8.30^{ab}	6.92^{e}	8.99^{cd}	8.40^{e}	9.06^{cd}	9.91^{def}	10.00^{abcd}	9.35^{a}	8.89^{ab}	8.74^{ab}	7.10^{abc}	6.05^{bcde}	8.61
T4	8.97^{h}	7.73^{cd}	7.18^{de}	7.77^{ef}	10.19^{cd}	8.87^{d}	10.64^{bcd}	9.45^{f}	9.15^{bcd}	8.45^{cd}	8.5^{cde}	6.65^{cde}	5.95^{cde}	8.42
T5	9.77^{de}	8.64^{a}	6.94^{e}	8.18^{def}	12.72^{a}	8.01^{cd}	10.17^{cde}	10.05^{abcd}	9.85^{a}	8.75^{ab}	8.7^{abc}	7.45^{a}	6.5^{ab}	8.90
T6	9.26^{efgh}	8.41^{ab}	7.18^{de}	7.48^{f}	10.79^{c}	7.75^{g}	10.91^{abc}	9.85^{bcde}	8.8^{ef}	8.45^{cd}	8.35^{ef}	6.85^{bcd}	5.85^{cde}	8.46
T7	9.09^{gh}	7.13^{e}	7.30^{de}	9.96^{ab}	11.52^{b}	8.23^{efg}	9.25^{fg}	9.70^{cdef}	8.9^{de}	8.25^{d}	8.35^{ef}	6.35^{de}	5.7^{de}	8.44
T8	10.31^{c}	7.14^{e}	8.42^{bc}	10.20^{a}	9.61^{d}	9.01^{cd}	11.06^{ab}	10.33^{a}	9.8^{a}	8.95^{a}	8.85^{a}	7.4^{ab}	6.65^{a}	9.06
T9	9.17^{fgh}	8.23^{b}	7.37^{de}	7.77^{ef}	11.58^{b}	10.45^{a}	10.87^{abc}	9.51^{ef}	9.15^{bcd}	8.35^{d}	8.65^{abcd}	6.75^{cde}	5.6^{def}	8.73
T10	9.63^{ef}	7.50^{de}	8.69^{b}	7.71^{ef}	10.74^{c}	8.74^{de}	11.49^{a}	10.17^{ab}	8.95^{cde}	8.65^{bc}	8.6^{bcd}	6.25^{e}	5.75^{cde}	8.68
T11	9.15^{fgh}	7.21^{e}	7.32^{de}	8.37^{de}	10.24^{cd}	9.53^{bc}	8.44^{g}	8.98^{g}	8.55^{f}	8.35^{d}	8.45^{def}	6.25^{e}	5.55^{ef}	8.18
T12	9.56^{efg}	7.25^{e}	7.13^{de}	9.02^{cd}	10.31^{cd}	8.67^{def}	9.05^{fg}	10.08^{abc}	9.25^{bc}	8.8^{ab}	8.65^{abcd}	7.2^{abc}	6.25^{abc}	8.56
T13	9.02^{h}	8.04^{bc}	7.62^{de}	8.56^{cde}	8.49^{e}	8.27^{efg}	10.36^{bcd}	9.75^{cdef}	8.7^{ef}	8.25^{d}	8.25^{f}	6.215^{e}	5.15^{f}	8.21
SEm±	0.164	0.096	0.146	0.151	0.236	0.123	0.143	0.063	0.074	0.046	0.034	0.082	0.075	
CD(0.05)	0.520	0.400	0.779	0.854	0.727	0.550	0.752	0.381	0.340	0.249	0.231	0.565	0.511	

M: Month of storage

Means in each column with at least one letter in common are not significantly different at 5% level of probability

Appendix III.Effect of seed treatments on seedling dry weight in cowpea (Lola) during storage

Treatment	Seedling dry weight (g)													
	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	Mean
T1	0.096^{a}	0.077^{a}	0.073^{ef}	0.084^{ab}	0.090^{bc}	0.080^{bcd}	0.080^{c}	0.074^{bc}	0.074^{bc}	0.072^{abcd}	0.068^{bcd}	0.057^{ab}	0.0505^{ab}	0.075
T2	0.087^{cde}	0.071^{e}	0.071^{f}	0.079^{ef}	0.079^{f}	0.075^{def}	0.077^{d}	0.074^{bc}	0.072^{cdef}	0.069^{bcde}	0.066^{cdef}	0.056^{abc}	0.0495^{abc}	0.071
T3	0.088^{bcde}	0.075^{cd}	0.073^{def}	0.080^{de}	0.084^{e}	0.075^{ef}	0.077^{d}	0.072^{bc}	0.072^{cdef}	0.068^{cde}	0.066^{cdef}	0.057^{ab}	0.0505^{ab}	0.072
T4	0.086^{de}	0.075^{cd}	0.072^{ef}	0.081^{cd}	0.089^{bc}	0.079^{cde}	0.077^{cd}	0.070^{c}	0.070^{defg}	0.066^{de}	0.064^{defg}	0.047^{def}	0.0445^{cd}	0.071
T5	0.090^{bcd}	0.077^{ab}	0.075^{cde}	0.084^{ab}	0.095^{a}	0.087^{a}	0.083^{b}	0.078^{ab}	0.076^{b}	0.075^{ab}	0.074^{a}	0.058^{ab}	0.055^{a}	0.077
T6	0.085^{e}	0.075^{bc}	0.073^{def}	0.082^{cd}	0.095^{a}	0.076^{def}	0.086^{ab}	0.071^{c}	0.071^{cdefg}	0.066^{de}	0.066^{cdefg}	0.050^{bcde}	0.0465^{bcd}	0.072
T7	0.086^{de}	0.072^{e}	0.072^{f}	0.079^{ef}	0.084^{de}	0.078^{def}	0.076^{d}	0.071^{c}	0.068^{g}	0.066^{de}	0.062^{fg}	0.042^{f}	0.0415^{de}	0.069
T8	0.095^{a}	0.078^{a}	0.080^{a}	0.085^{a}	0.090^{bc}	0.083^{abc}	0.087^{a}	0.084^{a}	0.080^{a}	0.077^{a}	0.073^{ab}	0.059^{a}	0.0555^{a}	0.079
T9	0.092^{ab}	0.075^{cd}	0.076^{bcd}	0.082^{cd}	0.092^{ab}	0.084^{ab}	0.078^{cd}	0.070^{c}	0.070^{efg}	0.071^{abcd}	0.069^{abc}	0.0465^{def}	0.0445^{cd}	0.073
T10	0.091^{abc}	0.076^{abc}	0.078^{ab}	0.083^{bc}	0.089^{bc}	0.077^{def}	0.077^{d}	0.071^{c}	0.069^{fg}	0.066^{de}	0.063^{efg}	0.048^{cdef}	0.045^{bcd}	0.071
T11	0.084^{e}	0.073^{de}	0.077^{bc}	0.081^{cd}	0.088^{cd}	0.078^{cdef}	0.073^{e}	0.074^{bc}	0.073^{cde}	0.070^{bcd}	0.067^{cde}	0.0425^{ef}	0.0415^{de}	0.071
T12	0.086^{de}	0.075^{cd}	0.075^{cde}	0.081^{d}	0.087^{cde}	0.079^{cde}	0.077^{cd}	0.076^{bc}	0.073^{cd}	0.073^{abc}	0.068^{cd}	0.051^{bcd}	0.0465^{bcd}	0.073
T13	0.084^{e}	0.072^{e}	0.067^{g}	0.078^{f}	0.087^{cde}	0.074^{f}	0.072^{e}	0.069^{c}	0.064^{h}	0.064^{e}	0.061^{g}	0.0415^{f}	0.038^{e}	0.067
SEm±	0.0007	0.0004	0.0006	0.0004	0.0008	0.0007	0.0007	0.0008	0.0006	0.0008	0.0007	0.0012	0.0009	
CD(0.05)	0.005	0.002	0.003	0.002	0.004	0.005	0.003	0.007	0.003	0.006	0.005	0.008	0.006	

M: Month of storage

Means in each column with at least one letter in common are not significantly different at 5% level of probability

Appendix IV.Effect of seed treatments on seedling shoot length in cowpea (Kanakamony) during storage

Treatment	Seedling shoot length (cm)													
	M1	**M2**	**M3**	**M4**	**M5**	**M6**	**M7**	**M8**	**M9**	**M10**	**M11**	**M12**	**M13**	**Mean**
T1	25.31^{de}	25.56^{bc}	24.56^{de}	24.35^{c}	23.50^{b}	24.20^{ab}	23.00^{abc}	23.00^{ab}	22.00	18.85	16.00	12.33^{ab}	11.67	21.10
T2	25.30^{de}	24.33^{de}	24.10^{ef}	20.42^{hi}	20.90^{d}	23.73^{abc}	22.73^{bcd}	22.00^{abc}	22.50	18.17	17.00	12.00^{abc}	10.67	20.30
T3	25.69^{cd}	24.97^{cd}	22.25^{i}	20.04^{i}	22.21^{c}	23.93^{ab}	22.50^{cd}	22.00^{abc}	21.50	18.00	15.67	12.33^{ab}	11.00	20.16
T4	23.26^{g}	25.51^{bc}	23.14^{h}	20.85^{h}	23.44^{b}	22.73^{bcd}	20.50^{fgh}	19.50^{c}	20.50	17.67	14.67	10.00^{de}	9.33	19.32
T5	27.04^{a}	26.64^{a}	23.52^{gh}	22.70^{ef}	24.49^{a}	24.23^{a}	24.25^{a}	24.00^{ab}	23.50	19.00	17.33	13.00^{a}	11.67	21.64
T6	24.54^{f}	23.99^{ef}	25.02^{cd}	23.54^{d}	24.48^{a}	22.06^{d}	20.50^{fgh}	20.00^{c}	21.00	17.33	16.00	10.00^{de}	10.33	19.91
T7	26.25^{bc}	22.31^{h}	24.88^{cd}	22.84^{def}	24.05^{ab}	22.23^{d}	21.00^{efg}	20.00^{c}	20.50	17.00	15.33	9.67^{de}	9.33	19.65
T8	26.25^{bc}	24.50^{de}	25.97^{a}	23.21^{de}	24.42^{a}	24.23^{a}	24.00^{ab}	24.50^{a}	24.00	19.33	17.10	12.00^{abc}	11.67	21.64
T9	24.76^{ef}	22.93^{gh}	25.21^{bc}	26.34^{a}	20.13^{d}	22.33^{cd}	21.50^{def}	20.00^{c}	21.00	17.67	14.77	10.33^{cde}	9.67	19.74
T10	26.44^{ab}	26.29^{ab}	25.68^{ab}	25.25^{b}	20.12^{d}	23.20^{abcd}	22.50^{cd}	21.50^{bc}	21.50	17.60	14.33	10.67^{bcde}	9.67	20.36
T11	25.52^{d}	24.90^{cd}	23.98^{fg}	22.33^{fg}	20.49^{d}	23.35^{abcd}	20.00^{gh}	20.00^{c}	20.00	16.67	14.00	9.00^{ef}	9.33	19.20
T12	25.24^{def}	23.29^{fg}	23.02^{h}	21.85^{g}	21.88^{c}	23.00^{abcd}	22.00^{cde}	21.50^{bc}	22.00	18.67	15.00	11.00^{bcd}	10.67	19.93
T13	25.05^{def}	23.36^{fg}	23.20^{h}	19.84^{i}	20.12^{d}	20.25^{e}	19.50^{h}	20.00^{c}	21.00	16.33	13.67	7.67^{f}	8.67	18.36
SEm±	0.161	0.216	0.182	0.317	0.290	0.212	0.258	0.334	0.308	0.293	0.277	0.286	0.257	
CD(0.05)	0.718	0.908	0.558	0.709	0.808	1.473	1.407	2.675	NS	NS	NS	1.975	NS	

M: Month of storage
Means in each column with at least one letter in common are not significantly different at 5% level of probability

Appendix V.Effect of seed treatments on seedling root length in cowpea (Kanakamony) during storage

Treatment	Seedling root length (cm)													
	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	Mean
T1	11.29^{b}	10.42^{ab}	9.80^{b}	9.40^{a}	8.73^{abc}	8.73^{bc}	8.60^{abc}	8.60^{abc}	8.63	8.23^{ab}	8.10^{a}	7.20^{abc}	6.77^{a}	8.81
T2	10.78^{cde}	9.60^{fg}	9.06^{g}	8.70^{cd}	8.53^{bcd}	8.93^{bc}	8.70^{ab}	8.70^{a}	8.53	8.10^{abc}	8.07^{a}	7.10^{abcd}	6.50^{ab}	8.56
T3	10.48^{efg}	9.50^{g}	9.47^{cd}	8.90^{bc}	8.53^{bcd}	8.73^{bc}	8.70^{ab}	8.60^{abc}	8.60	8.0^{abcd}	8.01^{ab}	7.13^{abc}	6.57^{ab}	8.56
T4	10.59^{def}	10.33^{bc}	9.06^{g}	8.62^{cd}	8.60^{abcd}	8.33^{de}	8.43^{cde}	8.50^{bcd}	8.33	7.73^{bcde}	7.3^{d}	6.90^{bcd}	6.20^{bcd}	8.38
T5	11.07^{bc}	10.43^{ab}	10.09^{a}	9.33^{a}	8.83^{ab}	8.93^{ab}	8.70^{ab}	8.63^{ab}	8.63	8.37^{a}	8.07^{a}	7.37^{ab}	6.87^{a}	8.87
T6	11.03^{bc}	10.75^{a}	9.16^{fg}	8.83^{bcd}	8.33^{d}	8.43^{de}	8.43^{cde}	8.43^{cde}	8.40	7.37^{e}	7.33^{d}	6.90^{bcd}	6.23^{bcd}	8.43
T7	10.99^{bc}	10.22^{bcd}	8.74^{h}	8.63^{cd}	8.40^{cd}	8.33^{de}	8.33^{de}	8.30^{ef}	8.33	7.57^{cde}	7.53^{cd}	6.73^{cde}	6.10^{cd}	8.32
T8	11.97^{a}	9.93^{def}	9.61^{bc}	9.43^{a}	8.90^{a}	9.00^{a}	8.80^{a}	8.70^{a}	8.70	8.40^{a}	8.13^{a}	7.43^{a}	6.80^{a}	8.91
T9	10.88^{cd}	10.35^{bc}	9.43^{cde}	8.93^{bc}	8.83^{ab}	8.50^{cd}	8.50^{bcd}	8.40^{def}	8.43	7.70^{bcde}	7.60^{cd}	6.60^{de}	6.10^{cd}	8.48
T10	11.91^{a}	10.03^{cde}	9.31^{def}	9.13^{ab}	8.63^{abcd}	8.50^{cd}	8.50^{bcd}	8.53^{abcd}	8.33	7.53^{de}	7.50^{cd}	6.90^{bcd}	6.23^{bcd}	8.54
T11	10.41^{fg}	9.74^{efg}	9.34^{def}	8.80^{bcd}	8.43^{cd}	8.45^{de}	8.33^{de}	8.40^{def}	8.33	7.37^{e}	7.77^{bc}	6.77^{cde}	6.03^{cd}	8.32
T12	10.38^{fg}	9.84^{efg}	9.22^{efg}	8.84^{bcd}	8.53^{bcd}	8.73^{bc}	8.43^{cde}	8.40^{def}	8.40	8.00^{abcd}	8.07^{a}	7.30^{ab}	6.37^{bc}	8.50
T13	10.19^{g}	9.70^{efg}	8.81^{h}	8.50^{d}	8.33^{d}	8.23^{e}	8.23^{e}	8.23^{f}	8.03	7.23^{e}	7.47^{cd}	6.27^{e}	5.87^{d}	8.09
SEm±	0.090	0.066	0.061	0.055	0.040	0.044	0.034	0.027	0.042	0.075	0.054	0.066	0.058	
CD(0.05)	0.320	0.355	0.211	0.344	0.340	0.247	0.262	0.170	NS	0.546	0.297	0.514	0.372	

M: Month of storage

Means in each column with at least one letter in common are not significantly different at 5% level of probability

Appendix VI. Effect of seed treatments on seedling dry weight in cowpea (Kanakamony) during storage

Treatment	Seedling dry weight (g)													
	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	Mean
T1	0.049^{bc}	0.048^{ab}	0.046^{bc}	0.046^{bc}	0.043^{cd}	0.043^{ab}	0.044^{ab}	0.044^{ab}	0.043^{bc}	0.040^{abc}	0.036^{abc}	0.031^{ab}	0.028^{ab}	0.042
T2	0.046^{ef}	0.045^{c}	0.045^{de}	0.041^{e}	0.038^{g}	0.043^{ab}	0.044^{a}	0.044^{a}	0.044^{ab}	0.039^{abcde}	0.037^{a}	0.030^{ab}	0.027^{abc}	0.040
T3	0.045^{g}	0.045^{c}	0.044^{fg}	0.039^{fg}	0.039^{f}	0.044^{ab}	0.044^{ab}	0.042^{bcd}	0.042^{cde}	0.039^{abcde}	0.035^{abcd}	0.030^{abc}	0.027^{abc}	0.040
T4	0.043^{h}	0.047^{b}	0.044^{ef}	0.040^{f}	0.043^{d}	0.042^{bc}	0.042^{bcd}	0.041^{cd}	0.041^{de}	0.036^{def}	0.032^{ef}	0.027^{def}	0.025^{bc}	0.039
T5	0.049^{b}	0.049^{a}	0.047^{a}	0.046^{b}	0.045^{a}	0.044^{ab}	0.042^{abc}	0.042^{abcd}	0.043^{bcd}	0.042^{a}	0.037^{a}	0.031^{a}	0.029^{a}	0.042
T6	0.047^{de}	0.045^{c}	0.046^{ab}	0.045^{c}	0.044^{b}	0.042^{bc}	0.039^{def}	0.040^{cd}	0.034^{h}	0.039^{abcde}	0.034^{cde}	0.027^{cdef}	0.026^{abc}	0.039
T7	0.047^{d}	0.043^{de}	0.043^{gh}	0.046^{b}	0.043^{cd}	0.042^{bc}	0.039^{ef}	0.042^{abcd}	0.038^{g}	0.035^{ef}	0.032^{ef}	0.026^{def}	0.025^{bc}	0.039
T8	0.051^{a}	0.046^{bc}	0.046^{ab}	0.047^{a}	0.045^{a}	0.045^{a}	0.038^{f}	0.043^{abc}	0.046^{a}	0.041^{ab}	0.037^{ab}	0.031^{a}	0.029^{a}	0.042
T9	0.047^{d}	0.042^{e}	0.045^{cd}	0.046^{b}	0.044^{bc}	0.043^{bc}	0.041^{cde}	0.040^{d}	0.042^{cde}	0.037^{bcdef}	0.033^{def}	0.027^{cdef}	0.026^{abc}	0.040
T10	0.048^{c}	0.044^{cd}	0.046^{bc}	0.046^{b}	0.044^{bc}	0.042^{bc}	0.044^{abc}	0.043^{abc}	0.041^{ef}	0.037^{cdef}	0.032^{ef}	0.028^{bcde}	0.026^{bc}	0.040
T11	0.046^{fg}	0.044^{cd}	0.044^{ef}	0.042^{d}	0.043^{d}	0.043^{ab}	0.039^{def}	0.040^{cd}	0.039^{fg}	0.034^{f}	0.032^{ef}	0.025^{ef}	0.025^{bc}	0.038
T12	0.046^{ef}	0.043^{de}	0.043^{h}	0.041^{e}	0.043^{cd}	0.043^{ab}	0.039^{ef}	0.040^{cd}	0.042^{de}	0.040^{abcd}	0.034^{bcde}	0.029^{abcd}	0.027^{abc}	0.039
T13	0.044^{h}	0.043^{de}	0.043^{h}	0.039^{g}	0.041^{e}	0.041^{c}	0.039^{def}	0.043^{abc}	0.043^{cde}	0.034^{f}	0.030^{f}	0.024^{f}	0.024^{c}	0.038
SEm±	0.0003	0.0003	0.0002	0.0005	0.0003	0.0002	0.0005	0.0003	0.0005	0.0005	0.0004	0.0004	0.0003	
CD(0.05)	0.001	0.002	0.001	0.001	0.001	0.002	0.003	0.003	0.002	0.004	0.003	0.003	0.003	

M: Month of storage

Means in each column with at least one letter in common are not significantly different at 5% level of probability

EFFECT OF SEED PROTECTANTS AGAINST PULSE BEETLE ON VIABILITY, VIGOUR AND HEALTH OF COWPEA SEEDS

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ABSTRACT OF THE THESIS

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Abstract

Experiments to assess the effectiveness of seed protectants against cowpea pulse beetle (*Callosobruchus* spp.)and their impact on seed quality and seedling vigour of selected cowpea varieties were conducted at College of Horticulture, Vellanikkara during 2014-2016. Separate experiments were conducted for both Lola and Kanakamony varieties following a completely randomized design with 13 treatments and three replications. Seeds were treated with seed protectants *viz.* neem oil, castor oil, coconut oil, sweet flag rhizome powder, neem leaf powder, paanal leaf powder, karinotchi leaf powder, neem kernel powder, diatomaceous earth, rice husk ash, *Beauveria bassiana* and spinosad. Untreated seeds served as control. Both treated and untreated seeds were dried to nine per cent moisture content were stored under ambient conditions for a period of 13 months. The seed quality parameters like germination, speed of germination, seedling vigour indices, electrical conductivity of seed leachate, mortality of adult pulse beetles, number of eggs laid by beetle, egg hatchability and seed infestation were recorded at monthly intervals. Seed microflora infection per cent were recorded at start and end of storage period.

The results revealed that germination and other seed quality parameters in both treated and untreated seeds decreased progressively over the storage period. However, irrespective of the variety, the seed protectants significantly enhanced the viability and quality of treated seeds. The quality of treated seeds was higher than that of untreated seeds for most part of the storage period. The germination in untreated seeds was retained above 75 per cent (the minimum seed certification standards (MSCS) required for cowpea) for eight months while it was retained for nine months in all treated seeds.

The rate of decrease in seed germination and quality was slower in semi-trailing variety Kanakamony compared to trailing variety Lola. In both the varieties, the germination was lower in untreated seeds in comparison to the treated seeds. Germination, speed of germination, seedling growth parameters and vigour indices

were invariably high in seeds treated with neem based seed protectants *viz.*, neem kernel powder, neem leaf powder and neem oil. Among the neem based botanicals used, seed treatment with neem kernel powder maintained higher germination and seed quality parameters *viz.*, seedling shoot length, seedling root length, seedling dry weight and seedling vigour index I and II during storage. Similarly, the electrical conductivity of seed leachate and per cent infection by seed microflora was found to be consistently low in seeds treated with neem based botanicals, vegetable oils and spinosad.

The efficacy of seed protectants against pulse beetle was evaluated at monthly intervals by recording weight of infested seed, seed infestation, mortality, fecundity and egg hatchability in twenty five seeds drawn randomly from each replication. The results revealed that all the seed protectants used were effective against pulse beetle during the initial period of storage and were significantly superior to control over the period of storage.

Among the seed protectants evaluated, highest mortality of adult beetles, lowest fecundity, egg hatchability and seed infestation were recorded in seeds treated with spinosad followed by oils *viz.*, neem oil, coconut oil and castor oil as well as other neem based botanicals. Seed treated with spinosad offered protection against pulse beetle for up to seven months of storage as evident from the cent per cent mortality of adult beetles, complete suppression of egg hatchability as well as low seed infestation in both varieties. Seeds treated with neem oil, castor oil, coconut oil, neem kernel powder and neem leaf powder recorded cent per cent mortality of adult beetles for five months of storage in both varieties. No seed infestation was recorded in seeds treated with neem oil, castor oil and coconut oil for up to five months of storage while a similar protection was offered by neem leaf powder and neem kernel powder for up to four months of storage. Spinosad was found to be the most effective in controlling pulse beetle infestation throughout the storage period.

Based on the impact of seed protectants on seed viability, seedling performance as well as protection against pulse beetle infestation in cowpea, seed treatment with seed protectants *viz.*, spinosad or neem based products (neem kernel powder, neem leaf powder and neem oil) or as oils (coconut oil and castor oil) can be recommended to be most effective in enhancing seed viability (by a period of one month over control), higher seed and seedling performance and protection from pulse beetle infestation and infection by microflora in cowpea. Among the above Spinosad can be recommended as the best seed treatment for cowpea if it can ensured that the treated seeds would be used only for seed purpose. However, in case the stored pulse seeds are meant for use as food, feed and seed, treatment with coconut oil could be recommended in place of neem based products since neem based botanicals are reported to cause sterility in humans and animals.