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Relative efficacy of seed protectants on storability of mungbean (*Vigna radiata* (L.) Wilczek) under ambient condition

Jitender Bhati, RB Singh, SC Vimal, Dheeraj Katiyar and Mohit Gupta

Abstract
Experiment was conducted to test the storability effect of newer molecules of insecticides and botanicals as seed protectants (*viz*. Emamectin benzoate @ 40.0 mg/kg^{1} seed, Spinetorum @ 8.5 mg/kg^{-1} seed, Sivanto prime @ 0.01 ml/kg^{-1} seed, Karanj oil@ 5ml/kg seed, Castor oil @5ml/kg seed, Sunflower oil @5ml/kg seed, Mustard oil @5ml/kg seed, Sesamum oil @5ml/kg seed, Neem oil @5ml/kg seed, Neemoz gold @ 5 ml/kg^{-1} seed, Coconut oil @5ml/kg seed, Neem leaf powder @5g/kg seed, Neem kernel powder @5g/kg seed and Gorakhmundi powder @5g/kg seed protectants along with Deltamethrin 2.8 EC@0.04ml/kg seed.) in mungbean against *Callosobruchus chinensis* Linnaeus under ambient condition at Seed Technology Laboratory of Acharya Narendra Deva University of Agriculture and Technology, Kumarganj, Ayodhya during 2019 and 2020. Among tested seed protectants, Emamectin benzoate @ 40.0 mg/kg^{1} seed followed by Sivanto prime @ 0.01 ml/kg^{-1} seed, Spinetorum @ 8.5 mg/kg^{-1} seed, Neemoz gold @ 5 ml/kg^{-1} seed and Karanj oil@ 5ml/kg seed was found most effective in respect to storability due to high percent seed germination, seedling length (cm),seedling dry weight, vigour index-i and vigour index-ii in respective seed protectants at 2, 4 and 6 months of ambient conditions of storage period.

Keywords: Storability, seed protectants, *Vigna radiata* (L.) Wilczek, *Callosobruchus chinensis* Linnaeus

Introduction
Mungbean (*Vigna radiata* L. Wilczek) is one of the most ancient and extensively grown leguminous crops in India. According to Vavilov (1926) [11] it is a native to India and Central Asia. Importance of this crop among other pulse crop is by virtue of its high nutritional value, short duration, adoptability to all seasons and suitability to various cropping system. Green gram is highly nutritious containing 24 per cent of high quality protein, 1.3 per cent fats, 56.6 per cent carbohydrates and 3 per cent dietary fibers. It is rich in mineral having 140 mg calcium, 8.4 mg iron and 280 mg phosphorus. In India, it is cultivated in Maharashtra, Andhra Pradesh, Rajasthan, Orissa and Karnataka. It can be grown under wide range of soils. These crops are mainly grown in *kharif* however, area under these crops are progressively increasing during rabi/spring seasons in Tamil Nadu and Karnataka. It is grown usually as rain fed crop and can also be grown as pre-monsoon crop. In India, it occupies 4.32 million ha area with a production of 2.17 million tonnes with the average yield 526 kg per ha Whereas, in Uttar Pradesh it occupies an area of about 109.0 lakh ha with a production of about 59.0 lakh tonnes with average productivity of 541 kg per ha (Anon., 2018) [2]. Though India has the distinction of being the world's largest producer of pulses, the average productivity is very low because of the abiotic and biotic stresses. Annually about 2.0 to 2.4 million tonnes of pulses with approximate monetary value of Rs. 6000 crores are lost due to the damage caused by insect pests (Reddy, 2009) [9].

According to an estimate, 60% of the whole production that produced is destroyed by insect pest in which storage insect-pest play an important role. The insects causing damage to stored grain is mainly Rice weevil (*Sitophilus oryzae*), khapra beetle *(Trogoderma gramarium)*, lesser grain borer (*Rhizopertha dominica*), Grain mite (*Acarus siro*) and Pulse beetle (*Callosobruchus chinensis* L.). Among these, the pulse beetle is most important insect-pest due to causing infestation to pulses both in field as well as in ambient storage. The bruchids are most degraded stored grain pest, causing loss of nearly 10-90% (Rathore and Sharma, 2002) [8].

Materials and Methods

The Experiment was conducted in CRD with Sixteen treatments included control with three replications in Seed Entomology Laboratory, Seed Science and Technology Section of Acharya Narendra Deva University of Agricultural and Technology, Kumarganj, Ayodhya during 2019-20. For this purpose, disinfested seed of mungbean seed cv. IPM-2-3 was used. From disinfested seed five hundred gram of seed was mix with required quantities of seed protectants after diluting in water @ 5 ml/kg seed as per technical programme taken for each replication in each treatment for proper seed coating. After mixing the protectants and drying in shade, seed was packed in 1kg capacity of gunny (Jute) bags. The packed bags were kept on racks under ambient conditions in the laboratory of seed entomology for observations. The observations were recorded at 2, 4 and 6 months of storage periods. Obtaining the germination percent of mung bean seed by (ISTA, 1976) given formula

$$\text{Percent Seed germination} = \frac{\text{Total number of germinated seed}}{\text{Total number of seed plated}} \times 100$$

At the end of germination test period after taken the randomly five normal seedlings were carefully removed from each replications. The distance between the collar and tip of the primary root as root length (cm) and between the collar and tip of shoot as the shoot length (cm) was measured. Total value of root and shoot length are called as seedling length.

Five normal seedlings in each treatment were randomly chosen for measurement of shoot length on the day of final count (7th day) and the average was calculated. Shoot length was measured on metric scale from base of primary leaf to the base of hypocotyls and mean shoot length was expressed in centimeters (cm).Earlier chosen five normal seedlings for measuring shoot and root lengths were used to determine seedling dry weight. The seedlings kept in butter paper bags were dried in hot air oven at 103 ± 1°C for 24 hours. After drying, they were cooled in a desiccators for 30 minutes and were weighed on an electronic balance. Their average weight was expressed in gram per seedling (g) for each treatment. The Seed vigor index was calculated as per method prescribed by Abdul-Baki and Anderson (1973) [1].

1. Seed vigor index (SVI) = Standard germination (%) x Total seedling length (cm).
2. Seed vigor index (SVI) = Standard germination (%) x Total seedling dry weight (g).

Results and Discussion

Per cent seed germination

The results revealed that (Table-1 and Fig.-1) significant differences in percent seed germination among different protectants were found at 2, 4 and 6 months of storage during 2019 and 2020.

At 2 months of storage, pooled mean of both years the percent seed germination was ranged from 83.99-93.83. The maximum percent seed germination was recorded in Emamectin benzoate @ 40.0 mg/kg^{-1} seed (93.83%) followed by Sivanto prime @ 0.01 ml/kg^{-1} seed (93.16%), Spinetorum @ 8.5 mg/kg^{-1} seed (92.49%), Neemoz gold @ 5 ml/kg^{-1} seed (92.00%) as compared to Deltamethrin 2.8 EC @ 0.04 ml kg^{-1} (92.83%). The minimum percent seed germination was recorded in Gorakhmundi powder @ 5g/kg^{-1} seed (86.99%) followed by castor oil @ 5ml/ kg^{-1} seed (87.66%), Sesamum oil @ 5 ml/kg^{-1} seed (87.99%) and Coconut oil @5ml/kg^{-1} seed (89.16%).

At 4 months of storage, pooled mean of both years the percent seed germination was ranged from 76.49-90.99. The maximum percent seed germination was recorded in Emamectin benzoate @ 40.0 mg/kg^{-1} seed (90.99%) followed by Sivanto prime @ 0.01 ml/kg^{-1} seed (90.50%), Spinetorum @ 8.5mg/kg^{-1} seed (89.49%), Neemoz gold @ 5ml/kg^{-1} seed (88.83%) and Karanj oil @ 5ml/kg^{-1} seed (87.99%) as compared to Deltamethrin 2.8 EC @ 0.04 mlkg-1 seed (89.83%).The minimum percent seed germination was recorded in Gorakhmundi powder @ 5g/kg^{-1} seed (82.83%) followed by Castor oil @ 5ml/kg^{-1} seed (83.83%), Sesamum oil @ 5ml/kg^{-1} seed (84.16%), Coconut oil @ 5ml/kg^{-1} seed (84.49%) and Neem kernel powder @ 5g/kg-1 seed (85.66%).

At 6 months of storage, pooled mean of both years the percent seed germination was ranged from 69.83-86.83. The maximum percent seed germination was recorded in Emamectin benzoate @ 40.0 mg/kg^{-1} seed (86.83%) followed by Sivanto prime @ 0.01 ml/kg^{-1} seed (85.66%), Spinetorum @ 8.5mg/kg^{-1} seed (84.66%), Neemoz gold @ 5ml/kg^{-1} seed (84.33%) and Karanj oil @ 5ml/kg^{-1} seed (82.83%) as compared to Deltamethrin 2.8 EC @ 0.04 mlkg-1 seed (85.16%). The minimum percent seed germination was recorded in Gorakhmundi powder @ 5g/kg^{-1} seed (77.66%) followed by Castor oil @ 5ml/kg^{-1} seed (78.66%), Sesamum oil @ 5ml/kg^{-1} seed (79.33%), Coconut oil @ 5ml/kg^{-1} seed (79.83%) and Neem kernel powder @ 5g/kg-1 seed (81.33%). These findings were also supported by Shaheen *et al.* (2016) [10] and Chitra and Sreeja (2013) [4] in mungbean.

Seedling length (cm)

The results revealed that (Table-2 and Fig.-2) seedling length (cm.) was influenced by the nature of seed protectants, storage durations and environmental conditions of storage (Table-4.4 Fig.4).

At 2 months of storage perusal of the result revealed that pooled mean of both years seedling length was ranged from 29.54-47.06 centimeter. The maximum seedling length 47.06 cm. was recorded in Emamectin benzoate @ 40.0 mg/kg^{-1} seed followed by Sivanto prime @ 0.01 ml/kg^{-1} seed (45.28 cm.), Spinetorum @ 8.5mg/kg^{-1} seed (43.43 cm.), Neemoz gold @ 5ml/kg^{-1} seed (42.63 cm.) and Karanj oil @ 5ml/kg^{-1} seed (42.10 cm.) as compared to Deltamethrin 2.8 EC @ 0.04 mlkg-1 seed (44.66 cm.). The minimum seedling length with 34.22 (cm.) was recorded in Gorakhmundi powder @ 5g/kg^{-1} seed followed by Castor oil @ 5ml/kg^{-1} seed (35.16 cm.), Sesamum oil @ 5ml/kg^{-1} seed (35.98 cm.), Coconut oil @ 5ml/kg^{-1} seed (36.91 cm.) and Neem kernel powder @ 5g/kg-1 seed (40.00 cm.).

At 4 months of storage pooled mean of both years seedling length ranged from 29.08-44.62 cm. The maximum seedling length (cm.) was recorded in Emamectin benzoate @ 40.0 mg/kg^{-1} seed (44.62 cm.) followed by Sivanto prime @ 0.01 ml/kg^{-1} seed (43.72 cm.), Spinetorum @ 8.5mg/kg^{-1} seed (41.02), Neemoz gold @ 5ml/kg^{-1} seed (39.59 cm.) and Karanj oil @ 5ml/kg^{-1} seed (38.55 cm.) as compared to Deltamethrin 2.8 EC @ 0.04 mlkg-1 seed (42.05 cm.). The minimum seedling length (cm.) was observed in Gorakhmundi powder @ 5g/kg^{-1} seed (29.70 cm.) followed by Castor oil @ 5ml/kg^{-1} seed (30.86 cm.), Sesamum oil @ 5ml/kg^{-1} seed (31.78 cm.), Coconut oil @ 5ml/kg^{-1} seed (32.50 cm.) and Neem kernel powder @ 5g/kg^{-1} seed (35.85

cm.).
At 6 months of storage, pooled mean of both years the seedling length (cm.) was ranged from 28.09-43.00 (cm.).The minimum seedling length (cm.) was recorded in Gorakhmundi powder @ 5g/kg^{-1} seed (29.25 cm.) followed by Castor oil @ 5ml/kg^{-1} seed (29.73 cm.), Sesamum oil @ 5ml/kg^{-1} seed (30.20 cm.), Coconut oil @ 5ml/kg^{-1} seed (30.61 cm.) and Neem kernel powder @ 5g/kg-1 seed (34.00 cm.). and maximum seedling length (cm.) was recorded in Emamectin benzoate @ 40.0 mg/kg^{-1} seed (43.00 cm.) followed by Sivanto prime @ 0.01 ml/kg^{-1} seed (42.33 cm.), Spinetorum @ 8.5mg/kg^{-1} seed (39.56), Neemoz gold @ 5ml/kg^{-1} seed (38.74 cm.) and Karanj oil @ 5ml/kg^{-1} seed (36.76 cm.) as compared to Deltamethrin 2.8 EC @ 0.04 ml/kg-1 seed (40.59 cm.). These results were also supported by Khantun *et al.* (2008) in lentil, whereas Chirag *et al.* (2016) [3] and Murtazal *et al.* (2018) [7] in mungbean.

Seedling dry weight (g)
The results showed (Table-3 and Fig.-3) the variation pooled mean of both years the seedling dry weight (g) in mungbean seed at different storage periods. All the seed protectants at 6 months were found significant over control.
At 2 months of storage pooled mean of both years the seedling dry weight (g) was ranged from 0.139 to 0.168 (g). The maximum seedling dry weight (g) was found in Emamectin benzoate @ 40.0 mg/kg^{-1} seed (0.168g.) followed by Sivanto prime @ 0.01 ml/kg^{-1} seed (0.167g.), Spinetorum @ 8.5mg/kg^{-1} seed (0.163g.), Neemoz gold @ 5ml/kg^{-1} seed (0.162g.) and Karanj oil @ 5ml/kg^{-1} seed (0.160g.) as compared to Deltamethrin 2.8 EC @ 0.04 mlkg-1 seed (0.165g.). The minimum seedling dry weight (g) was found in Gorakhmundi powder @ 5g/kg^{-1} seed (0.142g.) followed by Castor oil @ 5ml/kg^{-1} seed (0.144g.), Sesamum oil @ 5ml/kg^{-1} seed (0.146g.), Coconut oil @ 5ml/kg^{-1} seed (0.148g.) and Neem kernel powder @ 5g/kg-1 seed (0.155g.) respectively.
At 4 months of storage, pooled mean of both years the seedling dry weight (g) was ranged from 0.134 to 0.167 (g.). The minimum seedling dry weight (g) was found in Gorakhmundi powder @ 5g/kg^{-1} seed (0.137g.) followed by Castor oil @ 5ml/ kg^{-1} seed (0.140g.), Sesamum oil @ 5 ml/kg^{-1}seed (0.142g.) and Coconut oil @5ml/kg^{-1} seed (0.145g.). The maximum seedling dry weight was found in Emamectin benzoate @ 40.0 mg/kg^{-1} seed (0.167g.) followed by Sivanto prime @ 0.01 ml/kg^{-1} seed (0.166g.), Spinetorum @ 8.5 mg/kg^{-1} seed (0.161g.) and Neemoz gold @ 5 ml/kg^{-1} seed (0.158g.) as compared to Deltamethrin 2.8 EC @ 0.04 ml kg^{-1} (0.163g.) respectively.
At 6 months of storage, pooled mean of both years the seedling dry weight (g) was ranged from 0.130 to 0.166g. The maximum seedling dry weight (g) was found in Emamectin benzoate @ 40.0 mg/kg^{-1} seed (0.166g.) followed by Sivanto prime @ 0.01 ml/kg^{-1} seed (0.164g.), Spinetorum @ 8.5mg/kg^{-1} seed (0.160g.), Neemoz gold @ 5ml/kg^{-1} seed (0.155g.) and Karanj oil @ 5ml/kg^{-1} seed (0.153g.) as compared to Deltamethrin 2.8 EC @ 0.04 mlkg-1 seed (0.161g.). The minimum seedling dry weight (g) was found in Gorakhmundi powder @ 5g/kg^{-1} seed (0.132g.) followed by Castor oil @ 5ml/kg^{-1} seed (0.135g.), Sesamum oil @ 5ml/kg^{-1} seed (0.138g.), Coconut oil @ 5ml/kg^{-1} seed (0.140g.) and Neem kernel powder @ 5g/kg-1 seed (0.147g.).The seedling dry weight (g.) in control was 0.130g. Significantly higher than all treatments. These finding results was conformity with Chirag *et al.* (2016) [3] in mungbean, whereas, Murtazal *et al.* (2018) [7] in mungbean.

Seed vigour index-i
The significant differences results showed (Table-4 and Fig.-4) the percent seed germination among tested different seed protectants was found at 2, 4 and 6 months of storage during 2019 and 2020.
At 2 months of storage pooled mean of both years the seed vigour index-i was ranged from 2353.09-4329.82. The highest seed vigour index-i was found in Emamectin benzoate @ 40.0 mg/kg^{-1} seed (4329.82) followed by Sivanto prime @ 0.01 ml/kg^{-1} seed (4133.84), Spinetorum @ 8.5mg/kg^{-1} seed (3928.07), Neemoz gold @ 5ml/kg^{-1} seed (3834.74) and Karanj oil @ 5ml/kg^{-1} seed (3753.57) as compared to Deltamethrin 2.8 EC @ 0.04 ml/kg-1 seed (4054.42). The lowest seed vigour index-i was found in Gorakhmundi powder @ 5g/kg^{-1} seed (2875.27) followed by Castor oil @ 5ml/kg^{-1} seed (2986.20), Sesamum oil @ 5ml/kg^{-1} seed (3067.37), Coconut oil @ 5ml/kg^{-1} seed (3177.07) and Neem kernel powder @ 5g/kg-1 seed (3499.96).
At 4 months of storage pooled mean of both years the seed vigour index-i was ranged from 2225.13-4061.30. The highest seed vigour index-i was found in Emamectin benzoate @ 40.0 mg/kg^{-1} seed (4061.30) followed by Sivanto prime @ 0.01 ml/kg^{-1} seed (4024.60), Spinetorum @ 8.5mg/kg^{-1} seed (3747.82), Neemoz gold @ 5ml/kg^{-1} seed (3595.90) and Karanj oil @ 5ml/kg^{-1} seed (3490.72) as compared to Deltamethrin 2.8 EC @ 0.04 mlkg-1 seed (3857.49). The lowest seed vigour index-i was found in Gorakhmundi powder @ 5g/kg^{-1} seed (2545.45) followed by Castor oil @ 5ml/kg^{-1} seed (2669.23), Sesamum oil @ 5ml/kg^{-1} seed (2760.62), Coconut oil @ 5ml/kg^{-1} seed (2845.33) and Neem kernel powder @ 5g/kg-1 seed (3172.91).
At 6 months of storage pooled mean of both years the seed vigour index-i was ranged from 1961.48-3734.31. The highest seed vigour index-i was found in Emamectin benzoate @ 40.0 mg/kg^{-1} seed (3734.31) followed by Sivanto prime @ 0.01 ml/kg^{-1} seed (3626.68), Spinetorum @ 8.5mg/kg^{-1} seed (3350.04), Neemoz gold @ 5ml/kg^{-1} seed (3267.04) and Karanj oil @ 5ml/kg^{-1} seed (3043.55) as compared to Deltamethrin 2.8 EC @ 0.04 mlkg-1 seed (3457.13). The lowest seed vigour index-i was found in Gorakhmundi powder @ 5g/kg^{-1} seed (2272.29) followed by Castor oil @ 5ml/kg^{-1} seed (2338.23), Sesamum oil @ 5ml/kg^{-1} seed (2395.32), Coconut oil @ 5ml/kg^{-1} seed (2443.42) and Neem kernel powder @ 5g/kg-1 seed (2763.44). These findings were also supported by Khatun *et al.* (2008) [6] in lentil, whereas, Gawade *et al.* (2016) [5] in mungbean, Patil, A.K. (2000) [14], Manaddi. (2002) [12] and Manonmani, V. (2000) [13].

Seed vigour index-ii
The significant differences results (Table-4 and Fig.-4) showed the percent seed vigour index-ii among tested different seed protectants was found at 2, 4 and 6 months of storage during 2019 and 2020.
At 2 months of storage pooled mean of both years the seed vigour index-ii was ranged from 11.62-15.77. The highest seed vigour index-ii was found in Emamectin benzoate @ 40.0 mg/kg^{-1} seed (15.77) followed by Sivanto prime @ 0.01 ml/kg^{-1} seed (15.57), Spinetorum @ 8.5mg/kg^{-1} seed (14.98), Neemoz gold @ 5ml/kg^{-1} seed (14.83) and Karanj oil @ 5ml/kg^{-1} seed (14.41) as compared to Deltamethrin 2.8 EC @ 0.04 ml/kg-1 seed (15.42). The lowest seed vigour index-ii

was found in Gorakhmundi powder @ 5g/kg^{-1} seed (12.24) followed by Castor oil @ 5ml/kg^{-1} seed (12.56), Sesamum oil @ 5ml/kg^{-1} seed (12.82), Coconut oil @ 5ml/kg^{-1} seed (13.20) and Neem kernel powder @ 5g/kg-1 seed (13.75)

At 4 months of storage pooled mean of both years the seed vigour index-ii was ranged from 10.36-15.24. The highest seed vigour index-ii was found in Emamectin benzoate @ 40.0 mg/kg^{-1} seed (15.24) followed by Sivanto prime @ 0.01 ml/kg^{-1} seed (15.04), Spinetorum @ 8.5mg/kg^{-1} seed (14.51), Neemoz gold @ 5ml/kg^{-1} seed (14.37) and Karanj oil @ 5ml/kg^{-1} seed (14.11) as compared to Deltamethrin 2.8 EC @ 0.04 mlkg-1 seed (14.76). The lowest seed vigour index-ii was found in Gorakhmundi powder @ 5g/kg^{-1} seed (11.51) followed by Castor oil @ 5ml/kg^{-1} seed (11.82), Sesamum oil @ 5ml/kg^{-1} seed (12.06), Coconut oil @ 5ml/kg^{-1} seed (12.35) and Neem kernel powder @ 5g/kg-1 seed (13.17).

At 6 months of storage pooled mean of both years the seed vigour index-ii was ranged from 09.07-14.39. The highest seed vigour index-ii was found in Emamectin benzoate @ 40.0 mg/kg^{-1} seed (14.39) followed by Sivanto prime @ 0.01 ml/kg^{-1} seed (14.03), Spinetorum @ 8.5mg/kg^{-1} seed (13.54), Neemoz gold @ 5ml/kg^{-1} seed (13.11) and Karanj oil @ 5ml/kg^{-1} seed (12.73) as compared to Deltamethrin 2.8 EC @ 0.04 mlkg-1 seed (13.76). The lowest seed vigour index-ii was found in Gorakhmundi powder @ 5g/kg^{-1} seed (10.30) followed by Castor oil @ 5ml/kg^{-1} seed (10.68), Sesamum oil @ 5ml/kg^{-1} seed (10.97), Coconut oil @ 5ml/kg^{-1} seed (11.18) and Neem kernel powder @ 5g/kg-1 seed (11.99). These findings were also supported by Khatun *et al.* (2008) [6] in lentil, whereas, Gawade *et al.* (2016) [5], Sharma, K.R. and Kanwar, H.S. (2013) [15] and Chirag *et al.* (2016) [3] in mungbean.

Table 1: Effect of newer insecticides and botanicals against *Callosobruchus chinensis* as seed protectants on percent seed Germination in mungbean at 2, 4 and 6 months of ambient storage during 2019 and 2020.

	Treatment	Seed Germination (%)								
		2 months			4 months			6 months		
		2019	2020	P.M	2019	2020	P.M	2019	2020	P.M
T_1	Emamectin benzoate@40mg/kg	94.33(76.24)	93.33(75.01)	93.83	91.33(72.89)	90.66(72.18)	90.99	86.00(68.00)	87.66(69.41)	86.83
T_2	Spinotorum (11.7%SC@8.5mg/kg)	93.33(75.07)	91.66(73.23)	92.49	89.66(71.22)	89.33(70.91)	89.49	84.33(66.67)	85.00(67.19)	84.66
T_3	Sivanto (17.09%SL@0.01ml/kg)	94.00(75.82)	92.33(73.90)	93.16	91.00(72.53)	90.00(71.55)	90.50	85.00(67.19)	86.33(68.28)	85.66
T_4	Deltamethrin (Decis (2.8%EC@0.04ml/kg) Check	93.66(75.40)	92.00(73.56)	92.83	90.00(71.55)	89.66(71.22)	89.83	84.66(66.93)	85.66(67.74)	85.16
T_5	Karanj oil@5ml/kg	92.66(74.29)	89.66(71.22)	91.16	87.66(69.42)	88.33(70.00)	87.99	82.00(64.88)	83.66(66.14)	82.83
T_6	Castor oil@5ml/kg	89.33(70.96)	86.00(68.00)	87.66	84.00(66.40)	83.66(66.14)	83.83	78.00(62.00)	79.33(62.94)	78.66
T_7	Sunflower oil@5ml/kg	91.33(71.91)	88.33(70.00)	89.83	85.33(67.47)	85.00(67.19)	85.16	80.00(63.18)	81.66(64.63)	80.83
T_8	Mustard oil@5ml/kg	91.00(72.53)	88.00(69.71)	89.50	85.00(67.19)	84.66(66.92)	84.83	79.66(63.18)	81.33(64.38)	80.49
T_9	Sesamum oil@5ml/kg	89.66(71.28)	86.33(68.28)	87.99	84.33(66.66)	84.00(66.40)	84.16	78.66(62.47)	80.00(63.41)	79.33
T_{10}	Neem oil@5ml/kg	92.33(73.90)	89.33(70.91)	90.83	87.33(69.15)	86.33(68.28)	86.83	81.00(64.13)	83.00(65.63)	82.00
T_{11}	Neemoz gold@5ml/kg	93.00(74.65)	91.00(72.53)	92.00	89.00(70.61)	88.66(70.32)	88.83	84.00(66.40)	84.66(66.92)	84.33
T_{12}	Coconut oil@5ml/kg	90.66(72.20)	87.66(69.41)	89.16	84.66(66.93)	84.33(66.66)	84.49	79.00(62.70)	80.66(63.89)	79.83
T_{13}	Neem leaf powder@5g/kg	92.00(73.56)	89.00(70.61)	90.50	86.66(68.56)	86.00(68.00)	86.33	80.66(63.90)	82.66(65.38)	81.66
T_{14}	Neem kernel powder@5g/kg	91.66(73.23)	88.66(70.32)	90.16	86.00(68.00)	85.33(67.47)	85.66	80.33(63.66)	82.33(65.13)	81.33
T_{15}	Gorakhmundi powder@5g/kg	88.66(70.32)	85.33(67.45)	86.99	83.00(65.63)	82.66(65.37)	82.83	77.00(61.32)	78.33(62.23)	77.66
T_{16}	Untreated control	85.33(67.47)	82.66(65.38)	83.99	76.66(61.10)	76.33(60.87)	76.49	69.33(56.35)	70.33(56.98)	69.83
	S.Em±	0.80	0.55	0.67	0.55	0.56	0.55	0.74	0.63	0.68
	CD at 5%	2.32	1.60	1.96	1.60	1.67	1.63	2.16	1.84	2.00

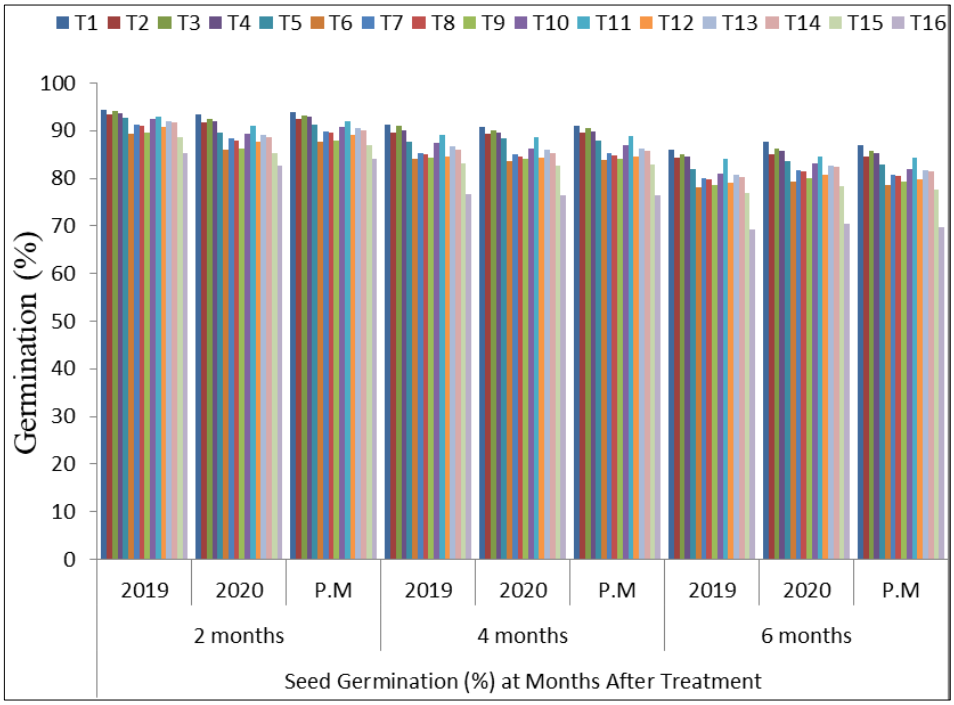

Fig 1: Effect of newer insecticides and botanicals against *Callosobruchus chinensis* as seed protectants on percent seed Germination in mungbean at 2, 4 and 6 months of ambient storage during 2019 and 2020

Table 2: Effect of newer insecticides and botanicals against *Callosobruchus chinensis* as seed protectants on seedling length (cm) in mungbean at 2, 4 and 6 months of ambient storage during 2019 and 2020

	Treatment	Seedling length (cm)								
		2 months			4 months			6 months		
		2019	2020	P.M	2019	2020	P.M	2019	2020	P.M
T_1	Emamectin benzoate@40mg/kg	47.17(43.36)	46.95(43.24)	47.06	45.95(42.66)	43.29(41.13)	44.62	43.19(41.07)	42.82(40.85)	43.00
T_2	Spinotorum (11.7%SC@8.5mg/kg)	46.19(42.80)	40.68(39.61)	43.43	41.45(40.06)	40.60(39.56)	41.02	39.21(38.75)	39.91(39.16)	39.56
T_3	Sivanto (17.09%SL@0.01ml/kg)	47.14(43.34)	43.42(41.20)	45.28	44.93(42.07)	42.51(40.67)	43.72	42.57(40.71)	42.09(40.43)	42.33
T_4	Deltamethrin (Decis (2.8%EC@0.04ml/kg) Check	46.63(43.05)	42.69(40.78)	44.66	43.32(41.14)	40.78(39.67)	42.05	41.10(39.85)	40.09(39.27)	40.59
T_5	Karanj oil@5ml/kg	44.09(41.58)	40.12(39.29)	42.10	39.17(38.73)	37.94(38.00)	38.55	37.30(37.63)	36.22(36.97)	36.76
T_6	Castor oil@5ml/kg	38.58(38.38)	31.74(34.27)	35.16	31.09(33.87)	30.63(33.58)	30.86	30.39(33.44)	29.07(32.61)	29.73
T_7	Sunflower oil@5ml/kg	41.54(40.11)	36.64(37.23)	39.09	34.72(36.09)	35.01(36.26)	34.86	33.85(35.56)	31.28(33.99)	32.56
T_8	Mustard oil@5ml/kg	40.32(39.40)	35.37(36.48)	37.84	33.87(35.57)	33.41(35.29)	33.64	31.98(34.42)	30.75(33.65)	31.36
T_9	Sesamum oil@5ml/kg	39.43(38.88)	32.53(34.75)	35.98	31.81(34.31)	31.76(34.29)	31.78	31.21(33.94)	29.19(32.68)	30.20
T_{10}	Neem oil@5ml/kg	44.04(41.56)	39.34(38.83)	41.69	38.51(38.34)	36.99(37.44)	37.75	36.53(37.17)	35.42(36.50)	35.97
T_{11}	Neemoz gold@5ml/kg	44.67(41.92)	40.59(39.56)	42.63	39.47(38.90)	39.71(39.04)	39.59	38.45(38.30)	39.03(38.65)	38.74
T_{12}	Coconut oil@5ml/kg	39.69(39.03)	34.14(35.74)	36.91	32.76(34.90)	32.25(34.59)	32.50	31.41(34.07)	29.81(33.08)	30.61
T_{13}	Neem leaf powder@5g/kg	43.04(40.98)	38.69(38.45)	40.86	37.40(37.68)	36.31(37.03)	36.85	36.12(36.93)	33.99(35.65)	35.05
T_{14}	Neem kernel powder@5g/kg	41.64(40.17)	38.37(38.26)	40.00	35.91(36.80)	35.79(36.73)	35.85	35.47(36.54)	32.53(34.75)	34.00
T_{15}	Gorakhmundi powder@5g/kg	38.37(38.26)	30.07(33.24)	34.22	30.07(33.24)	29.33(32.77)	29.70	29.49(32.87)	29.02(32.58)	29.25
T_{16}	Untreated control	29.58(32.93)	29.51(32.88)	29.54	29.28(32.75)	28.89(32.49)	29.08	28.70(32.38)	27.48(31.60)	28.09
	S.Em±	0.273	0.955	0.61	0.277	0.731	0.50	0.226	0.892	0.56
	CD at 5%	0.791	2.763	1.77	0.802	2.115	1.45	0.655	2.581	1.62

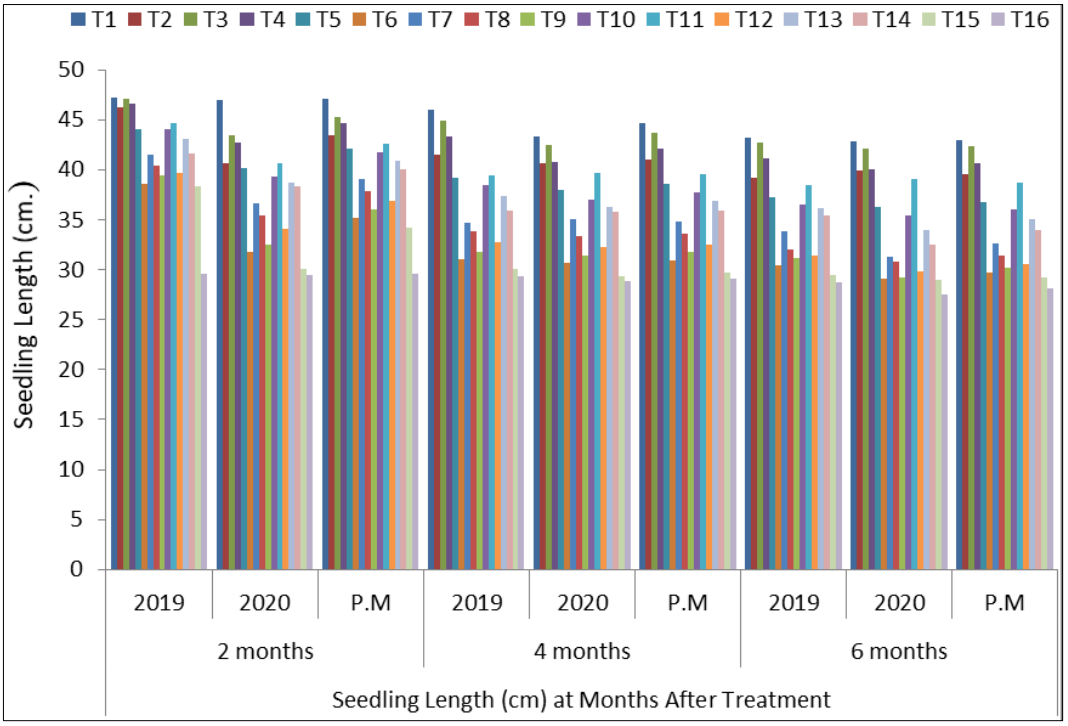

Fig 2: Effect of newer insecticides and botanicals against *Callosobruchus chinensis* as seed protectants on seedling length (cm) in mungbean at 2, 4 and 6 months of ambient storage during 2019 and 2020

Table 3: Effect of newer insecticides and botanicals against *Callosobruchus chinensis* as seed protectants on Seedling dry wt. (g) in mungbean at 2, 4 and 6 months of ambient storage during 2019 and 2020.

	Treatment	Seedling dry wt. (g)								
		2 months			4 months			6 months		
		2019	2020	P.M	2019	2020	P.M	2019	2020	P.M
T_1	Emamectin benzoate@40mg/kg	0.170(2.36)	0.167(2.34)	0.168	0.169(2.36)	0.166(2.33)	0.167	0.167(2.34)	0.165(2.32)	0.166
T_2	Spinotorum (11.7%SC@8.5mg/kg)	0.167(2.34)	0.160(2.29)	0.163	0.165(2.33)	0.157(2.27)	0.161	0.164(2.32)	0.156(2.26)	0.160
T_3	Sivanto (17.09%SL@0.01ml/kg)	0.169(2.35)	0.165(2.33)	0.167	0.168(2.35)	0.164(2.32)	0.166	0.166(2.33)	0.162(2.30)	0.164
T_4	Deltamethrin (Decis (2.8%EC@0.04ml/kg) Check	0.168(2.34)	0.162(2.30)	0.165	0.167(2.34)	0.160(2.29)	0.163	0.165(2.32)	0.158(2.28)	0.161
T_5	Karanj oil@5ml/kg	0.163(2.31)	0.158(2.27)	0.160	0.161(2.30)	0.152(2.23)	0.156	0.158(2.28)	0.149(2.21)	0.153
T_6	Castor oil@5ml/kg	0.149(2.20)	0.140(2.14)	0.144	0.142(2.15)	0.138(2.12)	0.140	0.138(2.13)	0.133(2.09)	0.135
T_7	Sunflower oil@5ml/kg	0.156(2.26)	0.149(2.21)	0.152	0.151(2.22)	0.146(2.19)	0.148	0.149(2.21)	0.142(2.15)	0.145
T_8	Mustard oil@5ml/kg	0.155(2.26)	0.146(2.19)	0.150	0.149(2.21)	0.145(2.18)	0.147	0.146(2.18)	0.139(2.13)	0.142
T_9	Sesamum oil@5ml/kg	0.151(2.22)	0.142(2.16)	0.146	0.144(2.17)	0.140(2.14)	0.142	0.142(2.15)	0.135(2.10)	0.138
T_{10}	Neem oil@5ml/kg	0.161(2.29)	0.156(2.26)	0.158	0.159(2.28)	0.151(2.23)	0.155	0.157(2.27)	0.147(2.19)	0.152
T_{11}	Neemoz gold@5ml/kg	0.166(2.33)	0.159(2.29)	0.162	0.164(2.32)	0.153(2.24)	0.158	0.161(2.29)	0.150(2.22)	0.155

T_{12}	Coconut oil@5ml/kg	0.153(2.24)	0.144(2.17)	0.148	0.148(2.20)	0.143(2.16)	0.145	0.143(2.17)	0.137(2.12)	0.140
T_{13}	Neem leaf powder@5g/kg	0.159(2.28)	0.154(2.25)	0.156	0.157(2.27)	0.150(2.22)	0.153	0.155(2.25)	0.145(2.18)	0.150
T_{14}	Neem kernel powder@5g/kg	0.157(2.27)	0.153(2.24)	0.155	0.154(2.25)	0.148(2.20)	0.151	0.151(2.22)	0.144(2.17)	0.147
T_{15}	Gorakhmundi powder@5g/kg	0.147(2.19)	0.138(2.13)	0.142	0.140(2.14)	0.134(2.10)	0.137	0.134(2.10)	0.131(2.07)	0.132
T_{16}	Untreated control	0.144(2.17)	0.134(2.10)	0.139	0.137(2.12)	0.132(2.08)	0.134	0.131(2.07)	0.129(2.06)	0.130
	S.Em±	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
	CD at 5%	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002

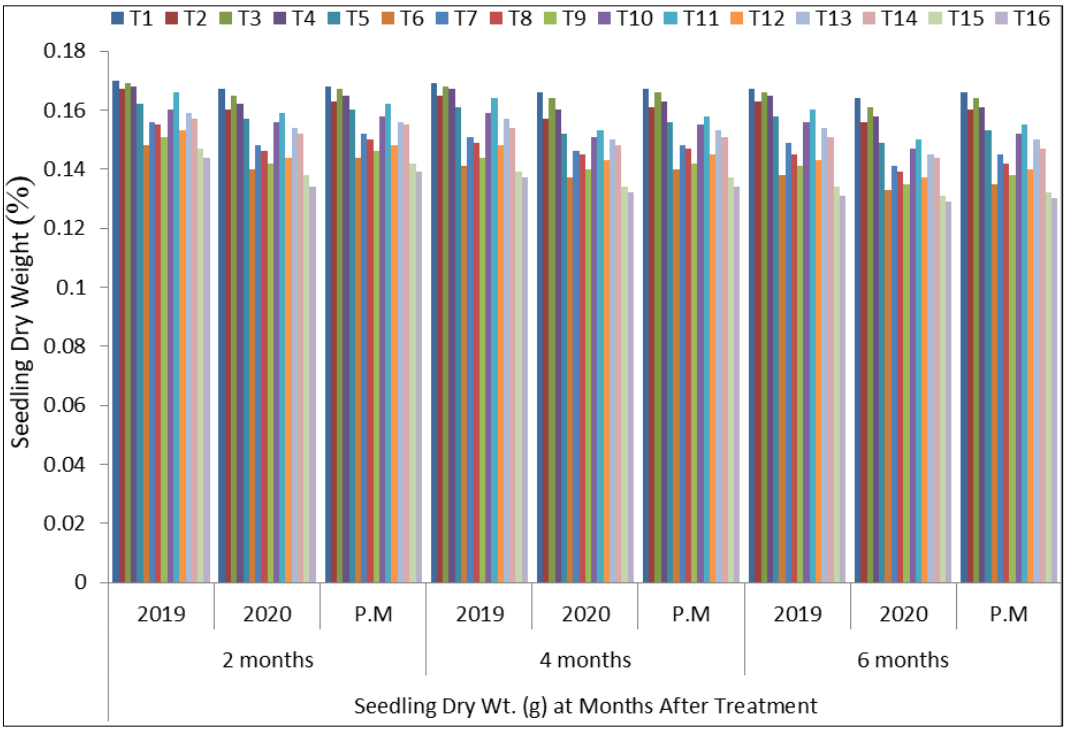

Fig 3: Effect of newer insecticides and botanicals against *Callosobruchus chinensis* as seed protectants on Seedling dry wt. (g) in mungbean at 2, 4 and 6 months of ambient storage during 2019 and 2020

Table 4: Effect of newer insecticides and botanicals against *Callosobruchus chinensis* as seed protectants on Vigor Index-i in mungbean at 2, 4 and 6 months of ambient storage during 2019 and 2020

	Treatment	Vigor Index-I								
		2 months			4 months			6 months		
		2019	2020	P.M	2019	2020	P.M	2019	2020	P.M
T_1	Emamectin benzoate@40mg/kg	4277.03	4382.61	4329.82	4197.07	3925.54	4061.30	3714.76	3812.52	3734.31
T_2	Spinotorum (11.7%SC@8.5mg/kg)	4126.51	3729.64	3928.07	3868.963	3626.69	3747.82	3307.03	3505.72	3350.04
T_3	Sivanto (17.09%SL@0.01ml/kg)	4258.33	4009.35	4133.84	4223.823	3825.37	4024.60	3618.98	3663.38	3626.68
T_4	Deltamethrin (Decis (2.8%EC@0.04ml/kg) Check	4181.57	3927.28	4054.42	4057.837	3657.16	3857.49	3479.79	3571.54	3457.13
T_5	Karanj oil@5ml/kg	3909.09	3598.05	3753.57	3630.62	3350.81	3490.72	3058.85	3028.25	3043.55
T_6	Castor oil@5ml/kg	3241.37	2731.03	2986.20	2776.727	2561.74	2669.23	2370.41	2306.06	2338.23
T_7	Sunflower oil@5ml/kg	3545.31	3236.02	3390.66	3137.67	2976.80	3057.23	2697.14	2554.47	2625.80
T_8	Mustard oil@5ml/kg	3427.47	3112.51	3259.99	3082.737	2828.82	2955.78	2548.57	2500.43	2524.50
T_9	Sesamum oil@5ml/kg	3325.38	2809.37	3067.37	2852.33	2668.92	2760.62	2454.93	2335.72	2395.32
T_{10}	Neem oil@5ml/kg	3861.33	3515.05	3688.19	3556.187	3193.81	3374.99	2959.84	2941.61	2950.72
T_{11}	Neemoz gold@5ml/kg	3976.39	3693.09	3834.74	3671.13	3520.68	3595.90	3229.71	3304.39	3267.04
T_{12}	Coconut oil@5ml/kg	3360.97	2993.17	3177.07	2970.853	2719.82	2845.33	2481.66	2405.18	2443.42
T_{13}	Neem leaf powder@5g/kg	3730.85	3444.30	3587.57	3441.267	3123.02	3382.14	2914.05	2809.43	2861.74
T_{14}	Neem kernel powder@5g/kg	3595.53	3404.39	3499.96	3292.15	3053.68	3172.91	2850.13	2676.76	2763.44
T_{15}	Gorakhmundi powder@5g/kg	3184.79	2565.74	2875.27	2666.553	2424.35	2545.45	2270.50	2274.18	2272.29
T_{16}	Untreated control	2268.53	2437.65	2353.09	2245.533	2204.72	2225.13	1989.89	1933.07	1961.48
	S.Em±	37.88	87.03	62.45	44.08	61.06	52.57	31.92	77.05	54.48
	CD at 5%	109.62	251.84	180.73	127.34	176.68	152.01	92.369	222.97	157.67

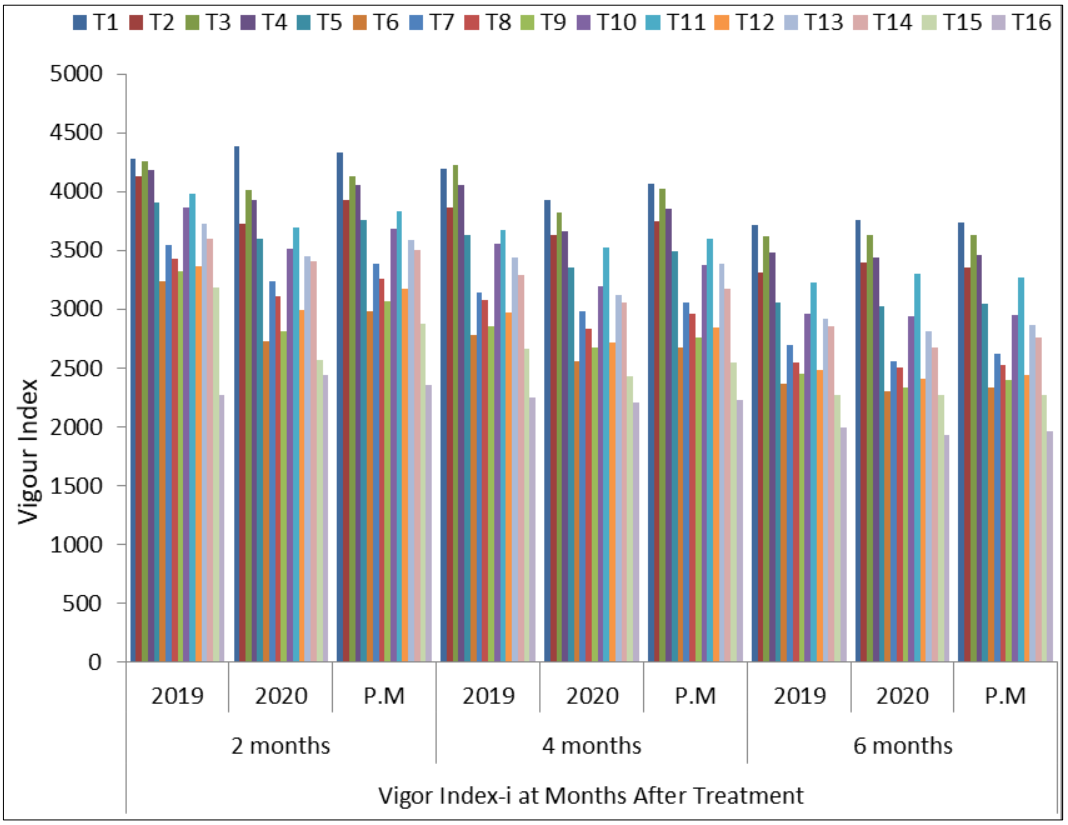

Fig 4: Effect of newer insecticides and botanicals against *Callosobruchus chinensis* as seed protectants on Vigor Index-i in mungbean at 2, 4 and 6 months of ambient storage during 2019 and 2020

Table 5: Effect of newer insecticides and botanicals against *Callosobruchus chinensis* as seed protectants on Vigor Index-ii in mungbean at 2, 4 and 6 months of ambient storage during 2019 and 2020.

	Treatment	vigor index-II								
		2 months			4 months			6 months		
		2019	2020	P.M	2019	2020	P.M	2019	2020	P.M
T_1	Emamectin benzoate@40mg/kg	16.03	15.52	15.77	15.35	15.14	15.24	14.36	14.43	14.39
T_2	Spinotorum (11.7%SC@8.5mg/kg)	15.58	14.39	14.98	14.74	14.29	14.51	13.80	13.29	13.54
T_3	Sivanto (17.09%SL@0.01ml/kg)	15.92	15.23	15.57	15.21	14.88	15.04	14.11	13.95	14.03
T_4	Deltamethrin (Decis (2.8%EC@0.04ml/kg) Check	15.73	15.12	15.42	15.00	14.52	14.76	13.97	13.56	13.76
T_5	Karanj oil@5ml/kg	15.07	13.75	14.41	14.30	13.92	14.11	12.98	12.49	12.73
T_6	Castor oil@5ml/kg	13.28	11.84	12.56	11.90	11.74	11.82	10.79	10.58	10.68
T_7	Sunflower oil@5ml/kg	14.12	12.89	13.50	12.91	12.64	12.77	11.90	11.57	11.73
T_8	Mustard oil@5ml/kg	14.16	12.76	13.46	12.69	12.36	12.52	11.60	11.31	11.45
T_9	Sesamum oil@5ml/kg	13.54	12.11	12.82	12.17	11.95	12.06	11.14	10.80	10.97
T_{10}	Neem oil@5ml/kg	14.83	13.52	14.17	13.94	13.47	13.70	12.69	12.20	12.44
T_{11}	Neemoz gold@5ml/kg	15.44	14.23	14.83	14.62	14.13	14.37	13.49	12.73	13.11
T_{12}	Coconut oil@5ml/kg	13.87	12.54	13.20	12.53	12.17	12.35	11.32	11.05	11.18
T_{13}	Neem leaf powder@5g/kg	14.63	13.35	13.99	13.64	13.27	13.45	12.47	12.01	12.24
T_{14}	Neem kernel powder@5g/kg	14.39	13.12	13.75	13.32	13.03	13.17	12.13	11.85	11.99
T_{15}	Gorakhmundi powder@5g/kg	13.03	11.46	12.24	11.59	11.44	11.51	10.34	10.26	10.30
T_{16}	Untreated control	12.31	10.94	11.62	10.50	10.23	10.36	9.08	9.07	9.07
	S.Em±	0.143	0.102	0.122	0.101	0.095	0.098	0.121	0.114	0.117
	CD at 5%	0.413	0.294	0.353	0.291	0.276	0.283	0.349	0.331	0.340

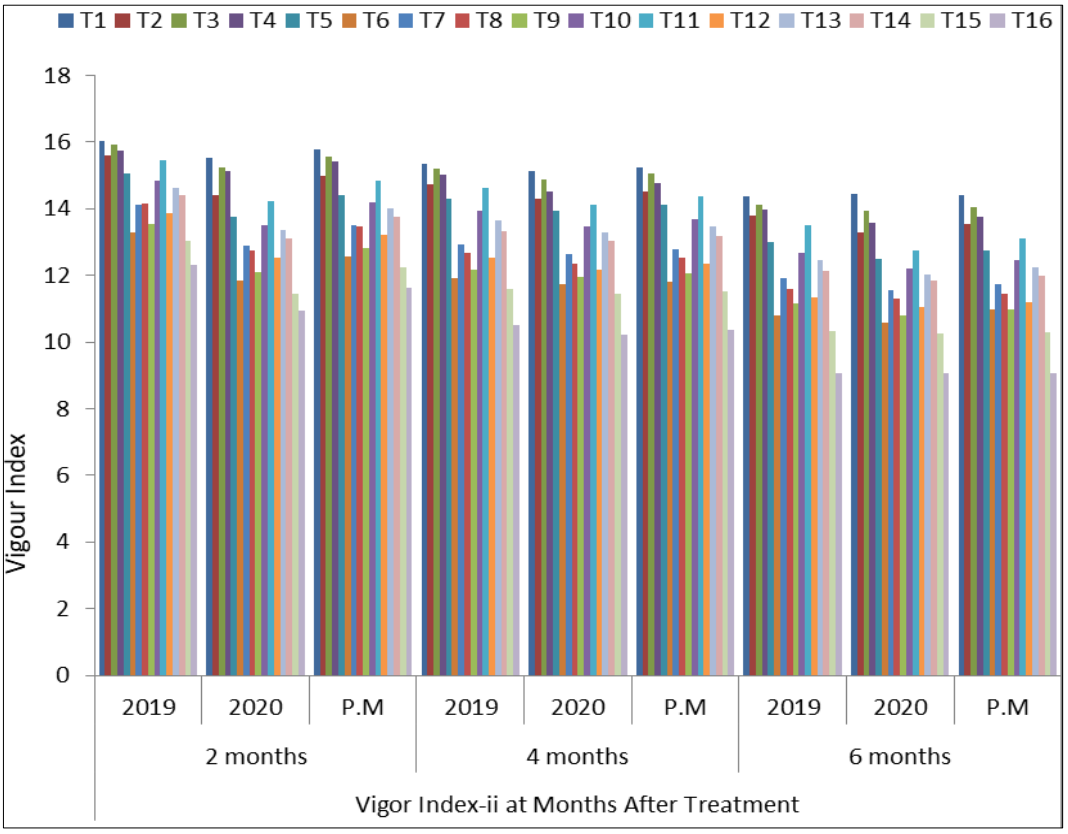

Fig 5: Effect of newer insecticides and botanicals against *Callosobruchus chinensis* as seed protectants on Vigor Index-ii in mungbean at 2, 4 and 6 months of ambient storage during 2019 and 2020.

Due to decreased in percent seed germination, seedling length (cm.) and seedling dry weight (g), vigour index-i and vigour index-ii of mungbean seed was inversely propionate to storage period but all seed protectants were able to maintained the IMSCS upto 6 months of storage. Thus, the present investigation advocated that Emamectin benzoate @ 40.0 mg/kg^{-1} seed, Sivanto prime @ 0.01 ml/kg^{-1} seed, Neemoz gold @ 5ml/kg^{-1} seed and karanj oil @ 5ml/kg seed may be utilize as seed protectants to store mungbean against pulse beetle *Callsobruchus chinensis* Linn for a long period of storage *i.e.* up to 6 month.

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