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Ecologically-engineered seeds to enhance coccinellid and suppress aphid population in cabbage ecosystem

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ABSTRACT

Present investigations on field evaluation of ecologically-engineered seeds for coccinellids enhancement were conducted at Naraseepuram, Coimbatore, Tamil Nadu during March to June 2017 with 17 different treatments. Experiment was laid out in randomized block design with three replications. Seed germination ranged from 45.7 (T_{17}: Control) to 76.0 (T_9: Cabbage + CMC 5% + *B bassiana* 3 g + mycorrhizae 4 g + *P flouroscens*) per cent. The root length varied from 9.5 (T_{15}) to 18.1 (T_9) cm; shoot length varied from 9.5 to 18.1 cm with maximum 18.1 cm in T_9 which was at par with T_5, T_1 and T_2. Shoot length varied from 5.0 to 8.3 cm with maximum in case of T_9 and minimum 5.0 cm in control. The dry matter production lied in the range of 0.024 to 0.046 mg/10 seedlings with maximum in T_9. T_9 also recorded highest vigour index (1598.05). The maximum mean number of coccinelids/plant was recorded in T_9 (3.31) as compared to minimum in control (0.88). The minimum mean number of aphids/inch^2/leaf was recorded in T_9 (8.3) as compared to maximum in control (16.0).

Keywords: Aphids; coccinellids; cabbage; ecologically-engineered seeds

INTRODUCTION

Cabbage, *Brassica oleracea* var *capitata* L (Cruciferae) is an important temperate vegetable crop that grows well throughout the world. It is also a common vegetable grown in India throughout the year. It is used as salad, boiled and dehydrated vegetable as well as in cooked curries and pickles. It is rich in minerals and vitamins A, B1, B2 and C (Patra et al 2013). Indian cabbage ecosystem in general is a rich source of biodiversity of beneficial arthropods and insect pests. The major pests of cabbage in Naraseepuram region are diamondback moth, *Plutella xylostella* L, cutworm, *Spodoptera litura* Fab, cabbage looper, *Trichoplusia ni* Hübner and aphids, *Lipaphis erysimi* Kalt. Among the insect pests, aphids alone cause 9-96 per cent reduction in yield (Singh and Sharma 2012). The aphids are widely distributed throughout the world on all *Brassica* crops (Yue and Liu 2000).

Biological seed treatments are made up of renewable resources and contain naturally-occurring active ingredients targeting protection against soil-borne pathogens, crop pests, alleviate abiotic stress and increase plant growth (Schwinn 1994). Seed treatment with microbial antagonists or fungicides protects the seed from infection by seed borne and soil borne pathogens and enables the seed to germinate and establish as a healthy seedling (Chang and Kommedahl 1968, Henis and Chet 1975, Windels 1981). Application of beneficial microorganisms to seeds is an efficient mechanism for placement of microbial inoculates into soil where they are well positioned to colonize seedling roots or make contact with soil dwelling invertebrate pests that feed on plant roots (Graham and Vance 2003). Several entomopathogenic fungi can also colonize plant tissues as endophytes and affect pests systemically via the plant (Vega et al 2012). Seaweed extract is a natural organic fertilizer which promotes faster seed germination and is highly nutritious to plants. The seaweed extract contains growth regulators, plant growth hormones, carbohydrates, auxins, gibberellins and vitamins (Erulan et al 2009). It has its wide applications as soil amendment in pest control (Hong et al 2007). There is limited information on effect of ecologically-engineered seeds. The present study aims at knowing the significance of ecologically-engineered seed in biological control.

MATERIAL and METHODS

Preparation of ecologically-engineered seed with biological materials

Aqueous carboxymethyl cellulose (CMC) polymer (5%) was prepared and kept in magnetic stirrer overnight. CMC polymer and cabbage seeds were mixed at 3 ml per kg of seed. Then biological materials in varied concentrations were added and shade-dried for 12 h prior to evaluation. Each biological material was evaluated at three different concentrations. Treated seeds were evaluated for their performance in the laboratory for seed quality parameters such as germination percentage, root length, shoot length, dry matter content and vigour index (Anon 2014).

Freshly harvested cabbage seeds were treated with CMC polymer (5%) and further treated with best effective biological material and admixed with *Pseudomonas flouroscens*. These seeds were used in the field to study their sustainability in encouraging entomophages and pest suppression.

Treatments used were T_1 (Cabbage + carboxymethyl cellulose (CMC) + azadirachtin 1% + *Pseudomonas flouroscens* 10 g/kg of seed), T_2 (Cabbage + CMC 5% + mycorrhizae 4 g + *P flouroscens*), T_3: (Cabbage + CMC 5% + *Sargassum wightii* 7% + *P flouroscens*), T_4 (Cabbage + CMC 5% + *Kappaphycus alvarezii* 10% + *P flouroscens*), T_5 (Cabbage + CMC 5% + *Beauveria bassiana* 3 g + *P flouroscens*), T_6 (Cabbage + CMC 5% + humic acid 2 g + *P flouroscens*), T_7 (Cabbage + CMC 5% + gibberelic acid 2 g + *P flouroscens*), T_8 (Cabbage + CMC 5% + amino acid 3 g + *P flouroscens*), T_9 (Cabbage + CMC 5% + *B bassiana* 3 g + mycorrhizae 4 g + *P flouroscens*), T_{10} (Cabbage + CMC 5% + *B bassiana* 3 g + azadirachtin 1% + *P flouroscens*), T_{11} (Cabbage + CMC 5% + *B bassiana* 3 g + *S wightii* 7% + *P flouroscens*), T_{12} (Cabbage + CMC 5% + *B bassiana* 3 g + *K alvarezii* 10% + *P flouroscens*), T_{13} (Cabbage + CMC 5% + *B bassiana* 3 g + humic acid 2 g + *P flouroscens*), T_{14} (Cabbage + CMC 5% + *B bassiana* 3 g + amino acid 3 g + *P flouroscens*), T_{15} (Cabbage + CMC 5% + *B bassiana* 3 g + gibberelic acid 2 g + *P flouroscens*), T_{16} (Cabbage + CMC 5% + imidacloprid 1% + *P flouroscens*), T_{17} (Control: cabbage alone)

Effect of ecologically-engineered cabbage seeds on enhancing entomophages and pest management under field condition

Field experiment was laid out in farmers' fields at Narseepuram village, Thondamuthur block, Coimbatore, Tamil Nadu during March to June 2017. The experiment was laid out in randomized block design (RBD) with three replications in an area of 0.5 acre in well prepared soil. Seed rate used was 650 g per ha. Seedlings were sown at a spacing of 45 × 45 cm. The plot size for each treatment was 9 x 9 m^2. Standard good agronomic practices as per the recommendations of TNAU except pest management strategies were adopted to maintain healthy cabbage plants and the observations were recorded during crop growth till the harvest. No chemical pesticides were applied throughout the season.

In situ observations on the population of grubs and adults of various species of coccinellids (number/plant) and population of nymphs and adults of *Aphis gossypii* (number/$inch^2$/plant) on cabbage from 10 randomly selected plants from each replication were made. Standard taxonomic keys were used for the identification of coccinellid species observed during the study. Observations were taken during early morning hours at seven days interval from 15 days after transplanting (DAT) to 78 DAT.

Based on the observations occurrence ratio (OR) of coccinellids, preference ratio (PR) of aphids and pest defender ratio (PDR) were estimated by using the formulae as used by Muthukrishnan and Dhanasekaran (2014). Cost-benefit ratio was estimated as per Selvaraj and Sundara Babu (1994). The data from various laboratory and field experiments were analysed as per Gomez and Gomez (1984).

RESULTS and DISCUSSION

Effect of ecologically-engineered seed treatments on physiological attributes of cabbage (Table 1)

Seed germination ranged from 45.7 (T_{17}: Control) to 76.0 (T_9: Cabbage + CMC 5% + *B bassiana* 3 g + mycorrhizae 4 g + *P flouroscens*) per cent and

Table 1. Effect of ecologically-engineered seed on germination, seedling length, dry matter production and vigour index in cabbage

Treatment	Germination (%)	Root length (cm)	Shoot length (cm)	Dry matter production (mg/10 seedlings)	Vigour index value
T_1	64.0	16.7	6.7	0.033	1428.80
T_2	56.0	15.3	6.6	0.033	1187.20
T_3	60.0	12.0	6.0	0.030	1446.00
T_4	68.0	11.7	6.5	0.034	1497.60
T_5	73.0	17.0	7.2	0.039	1521.30
T_6	52.0	11.4	6.2	0.024	1275.20
T_7	65.3	12.3	5.9	0.034	1199.70
T_8	48.3	11.1	6.2	0.031	857.60
T_9	76.0	18.1	8.3	0.046	1598.05
T_{10}	72.0	12.3	6.2	0.032	1143.30
T_{11}	54.0	11.3	6.4	0.026	784.82
T_{12}	65.3	11.6	5.9	0.030	766.80
T_{13}	52.3	11.9	6.1	0.032	867.20
T_{14}	48.0	10.3	5.7	0.028	895.30
T_{15}	46.3	9.5	5.3	0.031	766.80
T_{16}	47.7	10.1	5.3	0.032	771.02
T_{17}	45.7	10.0	5.0	0.024	707.00
SEd	3.29	0.13	0.09	0.009	-
$CD_{0.05}$	8.05	4.68	0.45	0.0061	-

Data depict mean values of three replications, Data transformed appropriately and the original values given, OR: Occurrence ratio
T_1 (Cabbage + carboxymethyl cellulose (CMC) + azadirachtin 1% + *Pseudomonas flouroscens* 10 g/kg of seed), T_2 (Cabbage + CMC 5% + mycorrhizae 4 g + *P flouroscens*), T_3: (Cabbage + CMC 5% + *Sargassum wightii* 7% + *P flouroscens*), T_4 (Cabbage + CMC 5% + *Kappaphycus alvarezii* 10% + *P flouroscens*), T_5 (Cabbage + CMC 5% + *Beauveria bassiana* 3 g + *P flouroscens*), T_6 (Cabbage + CMC 5% + humic acid 2 g + *P flouroscens*), T_7 (Cabbage + CMC 5% + gibberelic acid 2 g + *P flouroscens*), T_8 (Cabbage + CMC 5% + amino acid 3 g + *P flouroscens*), T_9 (Cabbage + CMC 5% + *B bassiana* 3 g + mycorrhizae 4 g + *P flouroscens*), T_{10} (Cabbage + CMC 5% + *B bassiana* 3 g + azadirachtin 1% + *P flouroscens*), T_{11} (Cabbage + CMC 5% + *B bassiana* 3 g + *S wightii* 7% + *P flouroscens*), T_{12} (Cabbage + CMC 5% + *B bassiana* 3 g + *K alvarezii* 10% + *P flouroscens*), T_{13} (Cabbage + CMC 5% + *B bassiana* 3 g + humic acid 2 g + *P flouroscens*), T_{14} (Cabbage + CMC 5% + *B bassiana* 3 g + amino acid 3 g + *P flouroscens*), T_{15} (Cabbage + CMC 5% + *B bassiana* 3 g + gibberelic acid 2 g + *P flouroscens*), T_{16} (Cabbage + CMC 5% + imidacloprid 1% + *P flouroscens*), T_{17} (Control: cabbage alone)

the latter was statistically at par with T_4, T_5, T_9 and T_{10}. The variation in seed germination may be attributed to plant growth promotional effect of seed primers especially bioagents that produce growth regulatory substances upon seed imbibition (Patil 2010, Jin and Tylkowska 2005).

The root length varied from 9.5 to 18.1 cm with maximum 18.1 cm in T_9 which was at par with T_5, T_1 and T_2. Shoot length varied from 5.0 to 8.3 cm with maximum in case of T_9 and minimum 5.0 cm in control. The dry matter production lied in the range of 0.024 to 0.046 mg/10 seedlings with maximum in T_9 which was at par with T_5. Similar results were reported by Farooq et al (2006) in rice and also by Diniz et al (2009).

T_9 recorded highest vigour index (1598.05) followed by T_5 (1521.30). The lowest vigour index was found in control (707.00).

Effect of ecologically-engineered seed-based cabbage ecosystems on the population of coccinellids (in situ count) (Table 2)

The maximum mean number of coccinelids/plant was recorded in T_9 (3.31) as compared to minimum in control (0.88). Thus there was an increase of 73.58 per cent over control in the mean population of coccinelids in T_9 with occurrence ratio of 3.79.

Effect of ecologically-engineered seed-based cabbage ecosystems on the population of aphids (in situ count) (Table 3)

The minimum mean number of aphids/inch^2/leaf was recorded in T_9 (8.3) as compared to maximum in control (16.0). Thus there was an decrease of 48.1 per cent over control in the mean population of aphids in T_9 with preference ratio of 0.52. Fungal endophytes play an important role in protecting plants against herbivorous insects (Jallow et al 2004, 2008) and plant

Table 2. Effect of ecologically-engineered seed-based cabbage ecosystems on the population of coccinelids (in situ method)

Treatment	Number of coccinelids/plant on DAT											Increase over control (%)	OR
	15	22	29	36	43	50	57	64	71	78	Mean		
T_1	0	0.5	1.50	2.50	2.50	4.00	3.00	1.50	2.00	0	2.19	60.00	2.50
T_2	0	0.5	1.50	2.00	2.50	3.50	3.50	3.00	2.50	0	2.38	63.16	2.71
T_3	0	0.5	1.50	2.00	3.50	3.50	4.00	2.50	2.00	0	2.44	64.10	2.79
T_4	0	0.5	1.50	2.50	3.50	4.00	3.50	2.50	2.50	0	2.56	65.85	2.93
T_5	0	0.5	2.00	2.50	2.50	4.50	4.50	3.00	3.00	0	2.81	68.89	3.21
T_6	0	0.5	0.50	1.50	2.50	2.50	3.50	3.00	2.00	0	2.00	56.25	2.29
T_7	0	0.5	0.50	1.50	2.50	2.00	3.00	2.50	2.00	0	1.81	51.72	2.07
T_8	0	0.5	0.50	2.50	2.50	3.00	2.00	2.00	1.50	0	1.81	51.72	2.07
T_9	0	1.0	2.00	3.00	3.50	5.00	5.00	3.50	3.50	0	3.31	73.58	3.79
T_{10}	0	0.5	2.00	2.50	4.60	4.50	1.50	3.00	3.00	0	2.70	67.59	3.09
T_{11}	0	0.5	1.00	2.50	3.50	2.50	3.00	2.50	1.50	0	2.13	58.82	2.43
T_{12}	0	0.5	1.50	2.00	2.50	2.50	3.50	1.50	1.00	0	1.88	53.33	2.14
T_{13}	0	0.5	1.50	1.50	2.00	1.50	2.50	1.50	1.50	0	1.56	44.00	1.79
T_{14}	0	0.5	1.00	1.50	2.00	3.00	4.00	2.50	0.50	0	1.88	53.33	2.14
T_{15}	0	0.5	0.50	2.00	3.00	2.50	2.00	1.00	1.50	0	1.63	46.15	1.86
T_{16}	0	0.5	1.50	2.00	3.00	3.00	0.50	1.00	2.50	0	1.75	50.00	2.00
T_{17}	0	0.5	0.50	1.00	1.50	1.00	1.00	1.00	0.50	0	0.88	-	-
SEd	0	0.03	0.05	0.06	0.07	0.07	0.07	0.06	0.06	0	0.10	-	-
$CD_{0.05}$	0	0.06	0.10	0.12	0.15	0.14	0.15	0.12	0.11	0	0.21	-	-

Data mean values of three replications, Figures transformed by square root transformation and the original values given, OR: Occurrence ratio T_1 (Cabbage + carboxymethyl cellulose (CMC) + azadirachtin 1% + *Pseudomonas flouroscens* 10 g/kg of seed), T_2 (Cabbage + CMC 5% + mycorrhizae 4 g + *P flouroscens*), T_3: (Cabbage + CMC 5% + *Sargassum wightii* 7% + *P flouroscens*), T_4 (Cabbage + CMC 5% + *Kappaphycus alvarezii* 10% + *P flouroscens*), T_5 (Cabbage + CMC 5% + *Beauveria bassiana* 3 g + *P flouroscens*), T_6 (Cabbage + CMC 5% + humic acid 2 g + *P flouroscens*), T_7 (Cabbage + CMC 5% + gibberelic acid 2 g + *P flouroscens*), T_8 (Cabbage + CMC 5% + amino acid 3 g + *P flouroscens*), T_9 (Cabbage + CMC 5% + *B bassiana* 3 g + mycorrhizae 4 g + *P flouroscens*), T_{10} (Cabbage + CMC 5% + *B bassiana* 3 g + azadirachtin 1% + *P flouroscens*), T_{11} (Cabbage + CMC 5% + *B bassiana* 3 g + *S wightii* 7% + *P flouroscens*), T_{12} (Cabbage + CMC 5% + *B bassiana* 3 g + *K alvarezii* 10% + *P flouroscens*), T_{13} (Cabbage + CMC 5% + *B bassiana* 3 g + humic acid 2 g + *P flouroscens*), T_{14} (Cabbage + CMC 5% + *B bassiana* 3 g + amino acid 3 g + *P flouroscens*), T_{15} (Cabbage + CMC 5% + *B bassiana* 3 g + gibberelic acid 2 g + *P flouroscens*), T_{16} (Cabbage + CMC 5% + imidacloprid 1% + *P flouroscens*), T_{17} (Control: cabbage alone)

pathogens (Ownley et al 2008). *Beauveria bassiana* has been observed as an endophyte in a variety of plants including maize as reported by Wagner and Lewis (2000).

Bing and Lewis (1991) demonstrated that *B bassiana* was able to invade maize plants via the epidermis thereafter persisting in the plant though the entire growing season and reducing tunneling by *Ostrinia nubilalis* (Lepidoptera: Pyralidae).

Philippot et al (2013) in their study found that microbial inoculants applied as seed treatments delivered microorganisms directly to the plant rhizosphere the narrow zone of soil that surrounds the roots where plants interact directly with microorganisms.

CONCLUSION

Seed coating is a new technology that it is consolidating for great cultures due to advantages to the farmers. Ecologically-engineered designer seeds are environmentally acceptable alternatives to the existing insecticide-treated ones. Seed priming with fungicides and biocontrol agents plays vital role in increasing germination and results in proper plant stand and healthy seedlings. It applies a precise protection to the seed against diseases and insects; improves the sowing process allowing sowing of precision and establishment of an appropriate stand; uniformizes the format of the seeds and allows the adherence of the products necessary for the germination as the absorption of water and gases as well as of the hormones that help in germination and emergence.

Table 3. Effect of ecologically-engineered seed-based cabbage ecosystems on the population of aphid (in situ method)

Treatment	Number of aphids/inch²/leaf on DAT											Decrease over control (%)	PR
	15	22	29	36	43	50	57	64	71	78	Mean		
T_1	0	3.2	8.6	12.6	13.9	18.2	16.7	11.2	8.7	4.9	10.9	32.0	0.68
T_2	0	4.4	9.5	15.4	16.2	14.9	14.7	11.8	9.7	2.7	11.0	31.1	0.69
T_3	0	3.8	7.20	10.8	16.4	15.0	12.2	12.5	9.9	4.7	10.3	35.8	0.64
T_4	0	4.7	8.1	11.3	15.3	20.6	17.1	15.3	7.4	5.3	11.7	27.1	0.73
T_5	0	3.3	7.1	9.2	11.9	15.1	13.5	9.8	7.9	2.9	8.9	44.0	0.56
T_6	0	5.4	8.7	12.7	15.9	18.4	21.0	17.3	15.4	9.7	13.8	13.6	0.86
T_7	0	6.3	8.7	15.7	17.9	20.7	23.1	18.7	11.7	7.7	14.5	09.5	0.91
T_8	0	4.3	9.1	10.6	14.8	17.0	21.3	16.7	15.6	8.1	13.1	18.5	0.82
T_9	0	3.2	7.1	8.1	11.7	14.1	10.7	11.0	6.7	2.1	8.3	48.1	0.52
T_{10}	0	7.4	7.5	9.6	12.2	19.7	23.4	21.2	14.5	8.2	13.7	14.2	0.86
T_{11}	0	9.9	12.2	13.9	16.8	18.1	20.1	17.6	12.4	7.9	14.3	10.6	0.89
T_{12}	0	4.2	8.3	11.5	12.6	24.5	21.9	15.8	11.7	5.9	12.9	19.2	0.81
T_{13}	0	4.3	9.1	10.7	17.3	23.1	24.7	20.1	14.3	7.6	14.5	08.9	0.91
T_{14}	0	3.2	7.6	10.1	13.3	21.9	19.3	14.1	10.0	9.7	12.1	24.2	0.76
T_{15}	0	6.7	10.8	12.6	17.3	19.1	23.9	17.4	13.1	10.7	14.6	08.7	0.91
T_{16}	0	5.3	7.7	10.9	18.6	25.2	22.9	18.2	11.0	9.1	14.3	10.6	0.89
T_{17}	0	7.7	11.1	16.3	19.1	24.5	23.7	17.8	12.1	11.9	16.0	-	-
SEd	0	0.10	0.13	0.15	0.17	0.19	0.19	0.17	0.15	0.12	0.14	-	-
$CD_{0.05}$	0	0.20	0.26	0.30	0.34	0.40	0.39	0.35	0.29	0.24	0.27	-	-

Data mean values of three replications, Figures transformed by square root transformation and the original values given, PR: Preference ratio T_1 (Cabbage + carboxymethyl cellulose (CMC) + azadirachtin 1% + *Pseudomonas flouroscens* 10 g/kg of seed), T_2 (Cabbage + CMC 5% + mycorrhizae 4 g + *P flouroscens*), T_3: (Cabbage + CMC 5% + *Sargassum wightii* 7% + *P flouroscens*), T_4 (Cabbage + CMC 5% + *Kappaphycus alvarezii* 10% + *P flouroscens*), T_5 (Cabbage + CMC 5% + *Beauveria bassiana* 3 g + *P flouroscens*), T_6 (Cabbage + CMC 5% + humic acid 2 g + *P flouroscens*), T_7 (Cabbage + CMC 5% + gibberelic acid 2 g + *P flouroscens*), T_8 (Cabbage + CMC 5% + amino acid 3 g + *P flouroscens*), T_9 (Cabbage + CMC 5% + *B bassiana* 3 g + mycorrhizae 4 g + *P flouroscens*), T_{10} (Cabbage + CMC 5% + *B bassiana* 3 g + azadirachtin 1% + *P flouroscens*), T_{11} (Cabbage + CMC 5% + *B bassiana* 3 g + *S wightii* 7% + *P flouroscens*), T_{12} (Cabbage + CMC 5% + *B bassiana* 3 g + *K alvarezii* 10% + *P flouroscens*), T_{13} (Cabbage + CMC 5% + *B bassiana* 3 g + humic acid 2 g + *P flouroscens*), T_{14} (Cabbage + CMC 5% + *B bassiana* 3 g + amino acid 3 g + *P flouroscens*), T_{15} (Cabbage + CMC 5% + *B bassiana* 3 g + gibberelic acid 2 g + *P flouroscens*), T_{16} (Cabbage + CMC 5% + imidacloprid 1% + *P flouroscens*), T_{17} (Control: cabbage alone)

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