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Evaluation of some management options to manage insect-pests of Brinjal, *Solanum melongena* L. in Kalahandi, Odisha

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Abstract
The experiment was conducted at Krishi Vigyan Kendra, Instructional Farm, Bhawanipatna, Kalahandi, Odisha, India during the cropping season 2020-21. All the treatments T1 – Neem oil (Multi Neem) @5ml/litre at an interval of 7 days + clipping of infested plant parts as and when seen, T2 −Neem oil (Multi Neem) @ 5ml/litre + clipping of infested plant parts as and when seen + bagging of fruits, T3 – Neem oil @ 5ml/litre + clipping of infested plant parts as and when seen + bagging of fruits + emamectin benzoate (Commander) 5% SG @ 12g *a.i.*/ha (0.5g/litre) at an interval of 14 days in alternate sprays (need-based basis), were significantly superior to T4-untreated check but efficacy level varied between treatments. Among all treatments, T3 produced the best impact causing the lowest damage and the least number of insect pests/plant. It was followed by T2 and T1 in the order. However, T3 was significantly superior to T2 and T1. The highest number of natural enemies were recorded in T4 and T1 was at par safe with it. T2 and T3 were also apparently safe to predatory coccinellids and spiders but both were inferior to T1 and T4 in terms of safety to natural enemies. The incremental cost benefit (ICBR) was found to be the highest in T3 (1: 3.02) followed by T2 (1: 2.06). The ICBR of T1 was 1: 1.09 which was the lowest ratio among all. However, the modules were effective, cost-effective, and safe for natural enemies and pollinators, and the components effectively checked pest populations and their damages.

Keywords: IPM, Insect-pests, *Solanum melongena*, Western Odisha

Introduction
Brinjal, *Solanum melongena* L., known as king of vegetables, is the most popular and important vegetable crop in the world. It, belongs to the family Solanaceae, is native to Asia (De Candolle, 1986) [3]. India is one of the world's largest producers of brinjal, with an area of 0.71 million hectares and a production of 13.56 million ton (NHB, 2015) [14]. The major brinjal growing states in India are Andhra Pradesh, Karnataka, West-Bengal, Tamil Nadu, Maharashtra, Odisha, Uttar Pradesh, Bihar and Rajasthan. Brinjal fruits are high in various minerals calcium, phosphorus, iron, and vitamins (Gopalan *et al.* 2007) [5]. Pesticide abuse, such as the use of excessive rates and non-registered chemicals, as well as disregard for re-entry and harvest-delay intervals, has resulted in pesticide ineffectiveness as well as environmental and human health damage (Rashid *et al.* 2004). Chemical insecticides are used indiscriminately, resulting in negative effects on natural enemies, pest resistance, and secondary pest outbreaks, as well as health risks and pollution (Bhadauria *et al.* 1999) [1]. Synthetic pyrethroids, commonly used to control the brinjal shoot and fruit borer, and their indiscriminate use, has led to whitefly, aphid, and mite resurgence. Several insect and mite pests are severely limiting egg-plant production (Srinivasan, 2009) [19]. Organo-chlorine pesticides have remained persistent in the environment, contaminating ground and surface water, air, soil, and food products, all of which have an impact on human health through direct contact (Helweg, 2003) [7]. Excessive pesticide use raises production costs and has negative health and environmental consequences (Kouser and Qaim, 2013; Muriithi *et al.* 2016) [10, 13]. Pesticide use is also a major contributor to the decline of natural pollinator populations as well as harming the biodiversity (Hackenberg, 2007) [6].
Today's emphasis is not only on the use of environmentally friendly chemical groups, but also on the effective control of insect pest populations through novel modes of action. Pheromone traps, grafting, soil amendments, pest-resistant cultivars, bio-pesticides, and beneficial insects are examples of IPM technologies which can be used for the ecological balance in nature as well as in the prevailing environment (Mian *et al*. 2016) [12].

However, rising concerns about harmful residues in food, non-target organism effects, and insecticide resistance have necessitated the development of new, safer molecules as well as management practices which are sustainable in nature (Kodandaram *et al.* 2015) [9]. Hence, the present study was undertaken to evaluate some management options to manage insect-pests of *S. melongena* in Western Odisha.

Materials and Methods

The present investigation was carried out at K.V.K Instructional Farm of Bhawanipatna, Kalahandi, Western Odisha during the cropping season from November, 2020 to May, 2021. The experimental field was prepared by cross ploughing with a tractor drawn cultivator. It was followed by harrowing and planking to pulverise the soil. Weed and crop residues were also removed. Seeds of brinjal (*cv.* VNR-212) were sown in a green-house plugged chamber on November 25, 2020, and after 25 days, seedlings were transplanted in the main field with row to row spacing of 70 cm and plant to plant spacing of 45 cm. The crop received the recommended fertiliser dose of 120:80:60 kg N, P, and K per hectare. The N, P, and K were applied as a basal dose in furrows at the time of transplanting using Urea, Single Super Phosphate (SSP), and Muriate of Potash (MOP), respectively. Glyphosate was used as a non-selective herbicide and one manual hand weeding was done at 25 DAT to keep the experimental plots weed-free. After 131 days of sowing, harvesting was done manually *i.e.* from March 4, 2021 to April 29, 2021. A total of nine plucking were done until final harvest.

The experiment was conducted in randomized block design (RBD) with four treatments including untreated check and each with five replicates. The experimental unit consisted of solo cropping units of brinjal. The field with good tilth was divided into 4 blocks. Each block was sub-divided into 5 sub plots, each of which was of 3 m × 2 m maintaining 30 cm border. The details of treatments were:

T_1: Neem oil (Multi Neem) @5ml/litre at an interval of 7 days + clipping of infested plant parts as and when seen

T_2: Neem oil (Multi Neem) @ 5ml/litre + clipping of infested plant parts as and when seen + bagging of fruits

T_3: Neem oil @ 5ml/litre + clipping of infested plant parts as and when seen + bagging of fruits + emamectin benzoate (Commander) 5% SG @ 12g ai/ha (0.5g/litre) at an interval of 14 days in alternate sprays (need-based basis)

T_4: untreated check.

The data recorded on different parameters were calculated using the following formula:

% plant/shoot/fruit infestation = (Number of infested plant/shoot/fruit ÷ Total number of plant/shoot/fruit) x 100

% increase/decrease over control = [(Mean of treated plot–Mean of untreated plot) ÷Mean of untreated plot] x 100

ICB ratio (Incremental Cost Benefits Ratio) = Net profit gain÷Total cost

Results and Discussion

Insect Pest

Whitefly: A very high whitefly (*Bemisia* sp.) incidence (12.09/3 leaf) was recorded in untreated check (T4) which indicated that it was an important pest on the crop. Treatment T3 was the most effective treatment in combating the pest as the mean numbers of whiteflies recorded was the lowest *i.e.* 5.60 whitefly/3 leaf (Table-1). Safer treatment T2 was also equally effective against whitefly recording low damage that was 6.20 white fly/3 leaf, but significantly inferior to T3. Another safer treatment, T1 also performed well (8.82 whitefly/3 leaf) but significantly inferior to T3 and T2 in terms of performance.

The present investigation are in line with the findings of Sarangdevot *et al.* (2006) who recorded that two sprays of neem oil @ 10 ml per litre of water were efficacious against egg-plant sucking pests like aphids, leafhoppers and whiteflies.

Table 1: Effect of the treatments on the incidence and damage of the pests on brinjal during 2020-21

Treatment	Mean whitefly /3 leaf	Mean epilachna beetle/Plant	Mean jassid/Plant	Mean fruit borer holes/Fruit	Mean larvae /Fruit	Mean % infested shoot	Mean % infested fruit
T1	8.82 (3.05)*	4.84 (2.31)	13.42 (3.73)	2.26 (1.66)	1.30 (1.34)	5.70 (13.81)**	4.37 (12.07)
T2	6.20 (2.59)	4.66 (2.27)	12.19 (3.56)	2.10 (1.61)	1.06 (1.25)	5.10 (13.05)	3.38 (10.59)
T3	5.60 (2.47)	4.44 (2.22)	10.26 (3.28)	0.55 (1.02)	0.36 (0.93)	4.50 (12.25)	2.16 (8.45)
T4	12.09 (3.55)	8.43 (2.99)	15.51 (4.00)	2.53 (1.74)	1.61 (1.45)	7.30 (15.68)	4.48 (12.22)
S.Em (±)	0.21	0.04	0.08	0.06	0.06	0.25	0.10
CD at 5%	0.61	0.13	0.25	0.17	0.17	0.73	0.30

**Figures in parentheses are arcsine√p transformations

*Figures in parentheses are square root transformed *i. e.* √ (x + 0.5) values

Epilachna Beetle

Leaf damaging epilachna beetle *Henosepilachna vigintiotopunctata* was also recorded in few numbers but still was noticeable (Table 1). Among the treatments, T4 had high infestation *i.e.* 8.43/plant. The lowest population of 4.44/plant was registered by T3 and safer treatments T2 (4.66 beetle/plant) and T1 (4.84 beetle/plant) closely followed but inferior to T2. Safer treatments T2 and T1 were inferior to T3 in suppressing the population builds up of the coleopteran and the difference was statistically significant. Shanmugappriyan and Kingsly (2001) [18] reviewed the phagodeterrent consequence of Neem oil and Neem cake extract on *Henosepilachna vigintioctopunctata* grubs and adults.

Jassid

A very high jassid (*A. biguttula biguttula*) incidence (15.51/plant) was recorded in untreated check (T4) which indicated that it was an important pest on the crop. Treatment T3 recorded the mean 10.26 jassids/plant which was the most effective treatment in combating the pest (Table 1). Safer treatment T2 was also equally effective against jassid recording low damage that is 12.19 jassid/plant, but significantly inferior to T3. Another safer treatment, T1 also performed well (13.42/plant) but significantly inferior to T3 and T2 in terms of performance damage though incidence. Ghosh *et al.* (2002) [4] noticed that application of neem oil at a rate of 2.5 ml per litre that had effective control on whitefly and jassid (64.37 and 65.34%, respectively) in egg-plant.

Brinjal Fruit and Shoot Borer

In T4, it was observed that the brinjal fruit and shoot borer *Leucinodes orbonalis* caused significant damage to green fruits and quite high infestation of shoot (7.30%) and fruit (4.48%) damages with high larval population (1.61 larva/fruit) and high fruit borer holes, 1.61/fruit (Table 1). Treatment T3 had the lowest infestation (4.50% shoot damage, 2.16% fruit damage, 0.36 larva/plant and 0.55 holes/fruit). The treatments effectively suppressed the population build up and fruit and shoot damage by the borer and the least damage. T2 that had low infestation (5.10% shoot damage, 3.38% fruit damage, 1.60 larva/plant and 2.10 holes/fruit) was closely followed by T3 but mean fruit borer holes/ fruit in T2 and T1 were statistically at par. The safer treatment T1 (Neem oil (multineem)@ 5ml/litre) was also quite effective but inferior to T3 and T2 *i.e.* 5.70% shoot damage, 4.37% fruit damage, 1.30 larva/plant and 2.26 holes/fruit). T3 was the most effective treatment in combating the population build up and damage by the fruit and shoot borer.

A component of IPM was tested which include the removal of infested shoots and fruits by clipping or hand-picking, along with dusting ash to check the population of *L. orbonalis*. The inference derived was that the damaged fruit/plot were less in continuous hand-picking as compared to a single hand-picking one in India (Verma, 1986) [20]. It was found that as compared to the control, the treatment consisting of mechanical clipping and removal of infested shoots and fruits with young one concluded a good control of *L. orbonalis* (Sasikala *et al.* 1999) [17]. Application of Neem oil @ 30 ml/liter of water lowered down the BSFB infestation to 41.11% as compared to the control. Extract of Satyanashi leaves (0.1%), extract of Neem leaves (0.1%) and Neemguard (0 5%) resulted 76.18, 69.55 and 55.92% control, as compared to the untreated check (Khorsheduzzaman *et al.* 1998) [8]. Kumar and Devappa (2006) [11] noted that during 2002-03 and 2003-04, emamectin benzoate was examined against shoot and fruit borer of egg-plant. Bhemanna *et al.* (2005) [2] screened emamectin benzoate (Proclaim 5% SG), a newer insecticide group against okra fruit borers. Emamectin benzoate @ 8.50 g *a.i.*/ha measured lesser damage to the fruit borer and elevated fruit yield and was enticing in contrast to fruit borers of okra.

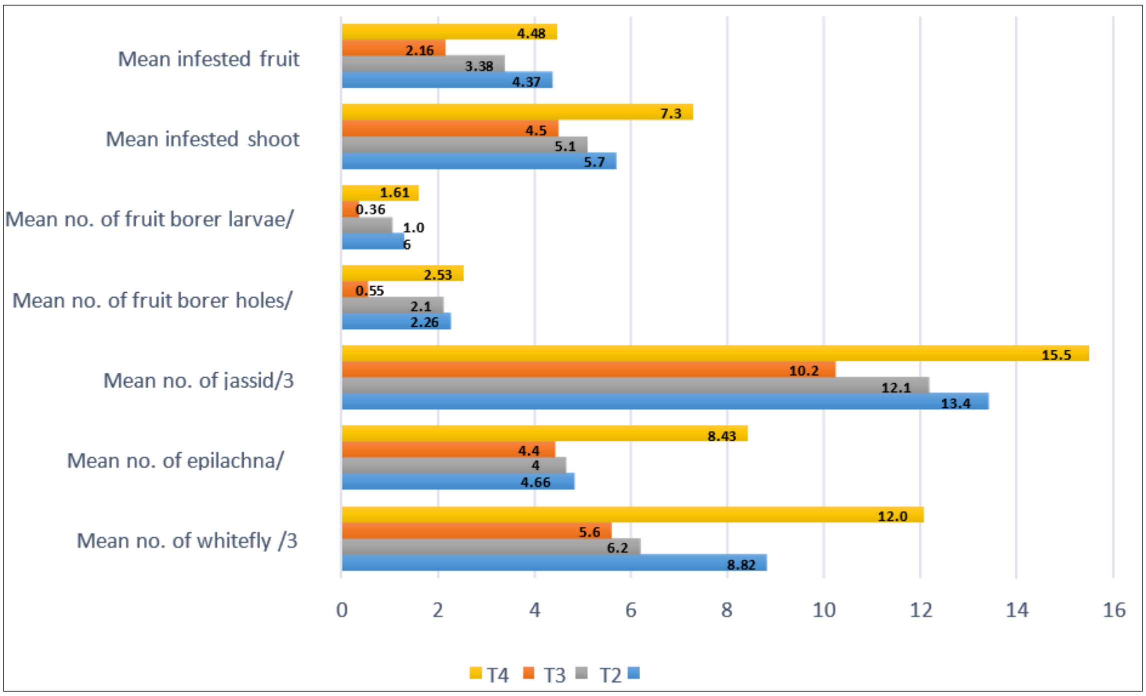

Fig 1: Effect of the treatments on the incidence and damage of the pests in Brinjal

Natural Enemies

Data on natural enemies in Table 2 showed that mostly generalist predators were found in brinjal ecosystem. Four species of coccinellids namely, *Cheilomenes sexmaculata* (Fab.), *Coccinella septempunctata* (L.), *Coccinella transversalis* (Fab.) and *Micraspis* sp.), three species of spiders namely, lynx (*Oxyopes* sp.), jumping (*Phiddipus* sp.) and wolf (*Marpissa* sp.), and one species of chrysopids, wood ant (*Tetraponera* sp.), damselfly were found in the plots.

Coccinellid: T4 showed highest number of coccinellids beetle (2.20 beetle/plant) closely followed by T1 (2.00 beetle/plant) (Table 2). In T2, coccinellids were 1.95 beetle/plant and it was statistically at par with T1 but inferior to T1. In T3, 1.51 beetle/plant were observed which was inferior to T2. The untreated control had the highest number of beetles followed by T1, T2 and T3. But, it was not statistically that much of difference somehow the insecticide had the detrimental effect on the coccinellids beetle.

Table 2: Effect of the treatments on populations of the pollinators along with the natural enemies found in brinjal during 2020-21

Treatment	Mean Number						
	Coccinellid/Plant	Spider/Plant	Chrysopids/Plot	Damselfly/Plot	Wood ant/Plant	Carpenter bee/Plot	Honey bee/Plot
T1	2.00 (1.58) *	3.95 (2.11)	0.35 (0.92)	0.10 (0.77)	2.50 (1.73)	0.35 (0.92)	1.15 (1.28)
T2	1.95 (1.57)	3.75 (2.06)	0.20 (0.84)	0.10 (0.77)	2.25 (1.66)	0.30 (0.89)	1.10 (1.26)
T3	1.51 (1.42)	3.75 (2.06)	0.20 (0.84)	0.08 (0.76)	2.25 (1.66)	0.25 (0.87)	1.09 (1.26)
T4	2.20 (1.64)	4.40 (2.21)	0.40 (0.95)	0.15 (0.81)	2.60 (1.76)	0.55 (1.02)	1.20 (1.30)
S.Em (±)	0.06	0.03	0.01	0.01	0.05	0.01	0.02
CD at 5%	0.18	0.09	0.04	0.03	0.15	0.03	0.06

*Figures in parentheses are square root transformed *i. e.* $\sqrt{(x + 0.5)}$ values

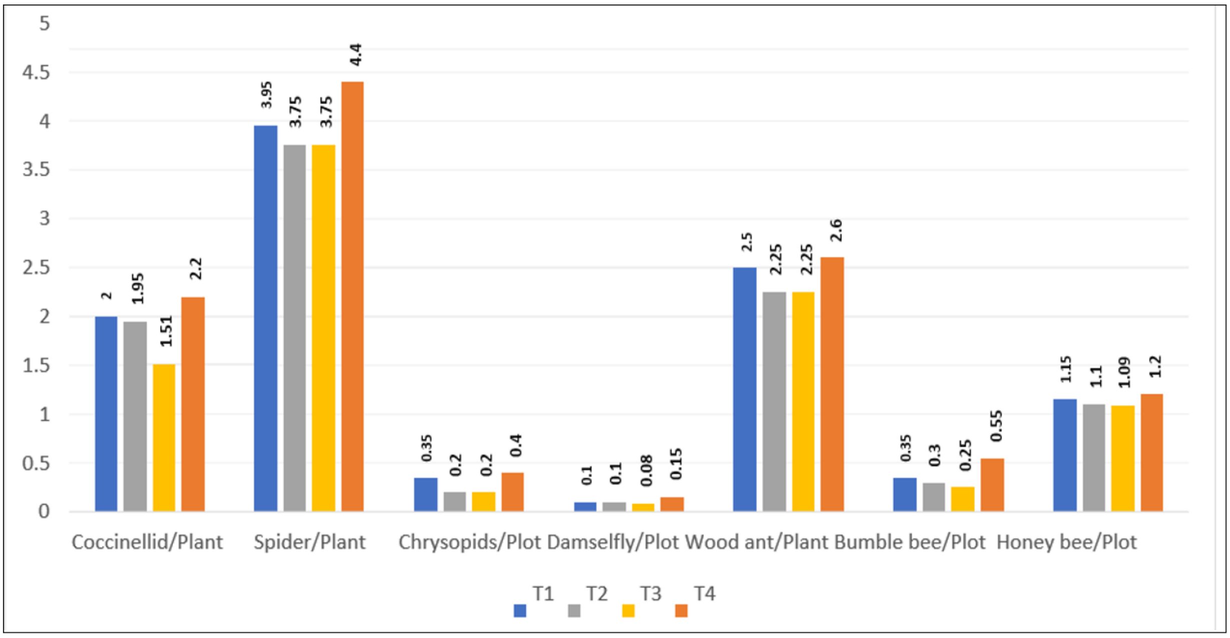

Fig 2: Effect of treatments on population of pollinators along with the natural enemies found in brinjal

Spider

The untreated check T4 showed highest number of coccinellids beetle (4.40 Spiders/plant). In T1, the number of spider was 3.95 Spiders/plant. T2 and T3 had the same number of spiders *i.e.* 3.75 Spiders/plant (Table 2). T1, T2 and T3 were statistically at par with each other. Untreated check was the superior among all treatments.

Wood ants

The untreated check T4 showed highest number of red ants (2.60 ants/plant) and closely followed by T1 (2.50 ants/plant) which was statistically at par with T4. T3 (2.25 ants/plant) was statistically at par with T2 (2.25 ants/plant) (Table 2).

Damselfly

T4 showed highest number of damselfly among all (0.15/plot) and closely followed by T1 (0.10 /plot) and T2 (0.10 /plot) (Table 2). T1 and T2 were statistically at par with each other. T3 (0.17/plot) was also statistically at par with T2 and T1. There was very less population of damselfly in the field.

Chrysopid

T4 showed highest number of chrysopid (0.4 /plot) closely followed by T1 (0.35 /plot) (Table 2). T2 and T3 had same number of chrysopids (0.20 beetle/plant) and also statistically at par with each other. The population of chrysopids was very low in field and among treatments there was no such differences.

Pollinators

Data on pollinators (Table 2) found in brinjal ecosystem showed that mostly common bees were visited. Three species of honey bees *A. mellifera*, *A. dorsata* and *A. cerena indica* and one species of carpenter bee *Xylocopa* sp. were observed. Generally, more number of bees were visiting in untreated check T4 (1.20 honey bee /plot) and (0.55 carpenter bees/plot). T1 had (1.15 honey bee /plot) and (0.35 carpenter bees/plot), and T2 had (1.10 honey bee /plot) and (0.30 carpenter bees/plot) and T3 had (1.09 honey bee /plot) and (0.25 carpenter bees/plot). The solanaceous crops are mainly self-pollinated and having nectarless flower so pollinator population was generally low.

Economics and Yield of Different Treatments

The highest yield of 28.04 t/ha was registered by the safer treatment T3 which was 68.81% higher yield over untreated check. In another safer treatment T2, we observed fairly good yield 23.43 t/ha or 41.06% higher yield (6.82 t/ha) over untreated check. In T1, yield was 19.52 t/ha or 17.52% higher yield (2.91 t/ha) over untreated check. Untreated check yield was 16.61 t/ha (Table 3).

Economics of different treatments revealed that maximum net realization (753270 Rs/ ha) was found with T3 (Neem oil (Multi neem) @ 5ml/litre + clipping of infested plant parts as and when seen + bagging of fruits + emamectin benzoate (Commander) 5% SG @ 12g *a.i.*/ha (0.5g/litre) at an interval of 14 days in alternate sprays (need-based basis)) followed by T2 (Neem oil (Multi neem) @ 5ml/litre + clipping of infested plant parts as and when seen + bagging of fruits) (632730 Rs/ha). And T1 (Neem oil (Multi neem) @ 5ml/litre) with (539010 Rs/ha). The incremental cost benefit ratio was found to be the highest in T3 (1: 3.02) followed by T2 (1: 2.06). The ICBR of T1 was 1: 1.09 which was the lowest ratio among all (Table 3). Thus, T3 was found to be the most effective and superior to all treatments.

Table 3: Economics of various treatments in Brinjal

Treat.	Cost of insecticide (Rs/ha)	Total cost (Rs/ha)	Yield (t/ha)	Extra yield over control (t/ha)	% of yield increase over control	Gross realization (Rs)	Net realization (Rs)	Net gain (Rs)	ICBR
T1	27000	46680	19.52	2.91	17.52	585690	539010	50970	1: 1.09
T2	28500	70020	23.43	6.82	41.06	702750	632730	144690	1: 2.06
T3	36450	87810	28.04	11.43	68.81	841080	753270	265230	1: 3.02
T4	0	10496	16.61	-	-	497880	488040		

*Labour charge – Rs 328/day
*Neem oil – 100ml – Rs 60/-
*Emamectin benzoate – 100gm – Rs 900/-

Conclusion

Among all treatments, T3 *i.e.* Neem oil @ 5ml/litre + clipping of infested plant parts as and when seen + bagging of fruits + emamectin benzoate (Commander) 5% SG @ 12g *a.i.*/ha (0.5g/litre) at an interval of 14 days in alternate sprays (need-based basis), produced the best impact causing the lowest damage and the least number of insect pests/plant. It was followed by T2 and T1 in the order. The highest number of natural enemies were recorded in untreated check and T1 was at par safe with it. T2 and T3 were also apparently safe to predatory coccinellids and spiders but both were inferior to T1 and T4 in terms of safety to natural enemies. Due to the high cost of insecticides and the dangers they pose to the environment, different integrated insect pest management strategies for the region had to be devised. Morphological characteristics of recommended brinjal varieties should be examined to determine available resistance mechanisms. Insecticide residual toxicity on brinjal fruit can be investigated. There is also need to compare the efficacy of newer insecticides and bio-rationalize insecticides against the brinjal pest complex.

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