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UTILIZATION OF VERMIWASH AS BIOPESTICIDE IN THE MANAGEMENT OF POD BORER, *Helicoverpa armigera* (Hubner), IN CHICKPEA (*Cicer arietinum* L.)

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ABSTRACT

Natural products in insect pest management programs have gained recognition due to environmental pollution, pest resistance and resurgence caused by indiscriminate use of synthetic pesticides. An attempt was made to find out ecofriendly pest management strategies by utilizing locally available botanical and vermiwash extracts during *rabi*, 2015-16 at College of Agriculture Vijayapur (India), to assess compatibility between vermiwash and botanicals ant their effect on pod borer, *Helicoverpa armigera* (Hubner), in chickpea ecosystem. The botanical extracts, *viz. Parthenium hysterophorus* and *Vitex nigunda*, neem seed kernel extract (NSKE) and garlic-chilli kerosine extract (GCKE) were evaluated alone or in combination with vermiwash (10%.). The results revealed that the plots treated with vermiwash @ 10% + NSKE @ 5% or vermiwash @ 10% + GCKE @ 3% recorded less number of eggs and larva of *H. armigera*. Further, in these treatments less pod damage and high grain yields were observed. Vermiwash treatment alone recorded highest number of eggs, larvae and pod damage as compared to other treatment-combination but was superior in number of natural enemy, *Campoletis chloridae*. Further, grain yield in this treatment was inferior to botanical treatments but significantly superior over untreated control, followed by *Vitex nigunda* (5%).

Key words: Botanical extracts, chickpea, *Helicoverpa armigera*, vermiwash

INTRODUCTION

Chickpea (*Cicer arietinum* L.) is the only widely cultivated species of genus *Cicer* and belongs to the family Fabaceae. It is rich and readily available source of protein both for human and animals. Chickpea seed contains 20–30% protein, 35-40% carbohydrates and 3-6% oil (Gil *et al*., 1996). Chickpea grain is a rich source of minerals like calcium, magnesium, potassium, phosphorus, iron, zinc and manganese (Ibrikci *et al*., 2003). in India, chickpea crop is attacked by nearly 57 species of insects and other arthropods (Lal, 1992). Among them, pod borer, *Helicoverpa armigera* (Hubner) (Lepidoptera: Noctuidae) is most important and accounts for 90-95% of the damage caused by all the insect-pests (Sachan and Katti, 1994). It is a polyphagous, multivoltine, high reproductive rate, diapause and cosmopolitan pest so these attributes contribute to its serious pest-status (Sharma *et al*., 2005). The pest infests chickpea crop at seedling stage and continues to devour flowers, pods and developing seeds until crop maturity (Reed *et al.*,1987).

In recent years, due to the increase in awareness of health consciousness among the people, organic produces are gaining importance. Therefore, the use of botanical extracts seems a feasible alternative to chemicals for pod borer management of in chickpea. The botanicals are more toxic to pests and simultaneously eco-friendly, non-hazardous, safe to the natural enemies, less expensive and easily to prepare. Neem (*Azadirachta indica* A. Zuss) and garlic (*Allium sativum* L.) extracts have larvicidal, toxic, repellent, ovicidal, antifeedant and oviposition-deterrent effects on insect pests (Gundannavar and Giraddi, 2007; Hemavathy and Balaji, 2007).

Vermiwash is honey brown extract of vermi-composts and rich in macro- and micro-nutrients, enzyme, hormone and vitamins as well as contains enormous heterotrophic bacteria, fungi and actinomycetes including nitrogen fixers and phosphate solubilizers (Lozek and Fecenko, 1998). Vermiwash on translocation into the plant system possibly alters the physiological processes including enzyme activities thus leads to greater metabolite accumulation in plants which induce resistance against insect-pests (Bhawalkar and Bhawalkar, 1992; Bhinde, 1993). The present study was aimed to assess the impact of some botanicals in combination with vermiwash on pod borer {*Helicoverpa armigera* (Hubner)}in chickpea.

MATERIALS AND METHODS

An experiment was carried out to assess the efficacy of a combination of botanicals with vermiwash in the management of pod borer, *Helicoverpa armigera* (Hubner) in chickpea crop.

Preparation of vermiwash

One quintal capacity cement tank was first selected. Then a small 10 L capacity plastic bucket was placed upside down position in it. At bottom, 10 cm above the tank base and inside bucket an outlet pipe was inserted to remove the vermiwash extract collected in inner side bucket. In the tank, sand and stone gravels were filled up to height of inner side placed bucket and remaining space above the inner bucket was filled with fully decomposed FYM fallowed by watering. After 2 days, 5 kg earthworm (*Eudrillus euginae)* was released in the tank. Tank was daily watered with 4-5 L water along with a mixture of 100-150 g cow dung. After 7 days of earthworm release, vermiwash was collected through outlet and stored in amber coloured bottles in shade for field use.

Preparation of botanical extracts

For preparation of 5%neem seed kernel extract (NSKE), 5 kg neem seed was dried under shade conditions. The dried seeds were powdered and tied in muslin cloth. It was soaked overnight (12 h at room temperature) in 10 L water. Next day, extract decoction was collected by pressing the muslin cloth for 10-15 min and purified through a mesh/thin cloth. Finally, it the volume was made up to 100 L solution. Before spray, 100 g detergent powder was added to the final solution.

For preparation of garlic-chilli kerosene extract (GCKE), 1.5 kg garlic bulbs and 1.5 kg green chilli were grounded separately. Both the extracts were soaked overnight (8 h at room temperature) in 1.5 L kerosene. The extract was squeezed through muslin cloth. The filtered extract was made upto to 1000 mL. The extract was used @ 5 mL L^{-1} water. Just prior to spray, the solution was added with 1% soap powder.

For preparation of *Vitex negundo* leaf extract preparation, fresh leaves of *V. negundo* were collected and washed in tap water. The leaves were chopped into small pieces using knife. Then 50 g chopped material was grounded along with 100 mL water using mixer grinder. The contents were kept overnight (8 h) at room temperature. The contents were squeezed through a thin muslin cloth and volume made 500 mL by water. Further, the extract was diluted to obtain 5% solution. For the preparation of *Parthenium* leaf extract, similar procedure as followed for the preparation of *V. negunoi* was adopted.

Experimental details

The experiment was conducted during *rabi* 2015-2016 at the experimental area of College of Agriculture, Vijayapur, Karnataka (India). The chickpea (cv. JG 11) crop was sown on 27th September

2015 in a plot of 3×3 m^2 size. The experiment was laid out in a randomized complete block design with each treatment replicated three times. Recommended package of practices was followed to raise good crop, except plant protection measures (Anon, 2014). The experiment comprised of 11 treatments including one standard check (emamectin benzoate) and untreated control. The treatments were: i) vermiwash (10%) + neem seed kernel extract (NSKE) @ 5%; ii) **v**ermiwash (10%) + garlic-chilli kerosene extract (GCKE) @ 3%; iii) vermiwash (10%) + *Parthe-nium hysterophorus* leaf extract (5%); iv) vermiwash (10%) + *Vitex nigunda* leaf extract (5%); v) vermiwash (10%); vi) NSKE (5%); vii) GCKE (3%); viii) *P. hysterophorus* leaf extract (5%); ix) *V. nigunda* leaf extract (5%); x) emamectin benzoate 5% SG (standard check) @ 0.25 g L^{-1}; and xi) untreated control. The treatments were applied as foliar spray on crop based on economic thresh hold i.e. 2 eggs or 1 larvae m^{-2} row length. In each treatment egg count, larval population, the number of natural enemies, yield and yield related parameters were recorded.

Egg count, larval population and number of natural enemies

Observations on the number of eggs, larval population and natural enemies were made on five randomly selected m^{-1} row-length in each treatment at 5, 7 and 10 days interval after each foliar spray. The data obtained were subjected to square root transformation ($\sqrt{(x+0.5)}$ and analyzed by following the analysis of variance technique. The treatment means were compared as per DMRT (Gomez and Gomez, 1984). The per cent reduction of larvae over untreated control was worked out using the formula given by Henderson and Tilton (1955).

$$\text{Corrected\% reduction} = \frac{(1\text{-n in control before treatment x n in T after treatment) x 100}}{\text{n in control after treatment * n in T before treatment}}$$

Where: n = Insect population, T = treatment

Ten days after 3^{rd} spray, the number of natural enemy (*Campoletis chloridae*) m^{-1} row length was recorded in each treatment to know the safety of combination of vermiwash extract with botanicals.

Yield and yield parameters

The number of flowers at flowering stage were observed from five randomly selected plants in each treatment and then converted to per plant basis. At harvest, the total number of pods and damaged pods were recorded from five randomly selected tagged plants in each treatment and averaged on per plant basis. The parameter recorded were converted to percent basis using following formula:

$$\text{Per cent pod damage} = \frac{\text{No. of damaged pods x 100}}{\text{No. of total pods}}$$

The per cent data were subjected to arc sin transformation for statistical analysis purpose. The 100-seed weight and yield $plot^{-1}$ were also recorded and computed to hectare-basis to workout cost effectiveness of each treatment. All these observations were analyzed by following DMRT (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Prior to the treatment imposition, the number of *H. armigera* eggs and larvae m^{-1} row length was uniform amongst all the treatments. Reduction in egg load on crop was meager in all the treatments applied either alone or in combination with vermiwash at 5 days after 1^{st} spray. However, the efficacy was accelerated on 7 days onwards and in subsequent sprays (Table 1). Superiority of synergistic effect of vermiwash @ 10% + NSKE @ 5% proved to be no less than vermiwash @ 10% + GCKE @ 3% treatment. It caused 53.73, 56.18 and 53.30% reduction in egg load over untreated control after 5, 7 and 10 days of 1^{st} spray, respectively, as compared to 51.82, 53.87 and 49.38% in vermiwash @

Table 1: Combined effect of botanicals and vermiwash on egg and larval incidence of *H. armigera* in chickpea (after 1st spray)

Treat-ments	No. of eggs m^{-2} row length$^{\#}$				% Reduction in eggs over untreated control$^{\#\#}$			No. of larvae m^{-1} row length$^{\#}$				% Reduction in larva over untreated control$^{\#\#}$		
	Pre-treat	5 DAS	7 DAS	10 DAS	5 DAS	7 DAS	10 DAS	Pre-treat	5 DAS	7 DAS	10 DAS	5 DAS	7 DAS	10 DAS
T_1	6.73 (2.69)^{a}	3.13 (1.91)^{a}	3.00 (1.87)^{ab}	3.23 (1.93)^{a}	53.73 (47.14)^{a}	56.18 (48.55)^{a}	53.30 (46.89)^{a}	4.77 (2.30)^{a}	2.97 (1.86)^{a}	2.37 (1.69)^{ab}	2.53 (1.74)^{b}	45.57 (42.46)^{ab}	57.09 (49.07)^{b}	54.65 (47.67)^{b}
T_2	6.67 (2.68)^{a}	3.23 (1.93)^{a}	3.13 (1.91)^{ab}	3.47 (1.99)^{ab}	51.82 (46.05)^{ab}	53.87 (47.22)^{ab}	49.38 (44.64)^{ab}	5.40 (2.43)^{a}	3.73 (2.06)^{a}	3.00 (1.87)^{bc}	3.17 (1.92)^{bc}	39.62 (39.01)^{bc}	52.02 (46.16)^{bc}	49.81 (44.89)^{bc}
T_3	6.07 (2.56)^{a}	3.20 (1.92)^{a}	2.93 (1.85)^{ab}	3.17 (1.92)^{ab}	47.55 (43.60)^{abc}	52.55 (46.46)^{ab}	49.19 (44.53)^{ab}	4.67 (2.27)^{a}	3.53 (2.01)^{ab}	3.03 (1.88)^{bc}	3.40 (1.97)^{bc}	33.92 (35.62)^{cd}	43.96 (41.53)^{de}	37.75 (37.91)^{de}
T_4	6.00 (2.55)^{a}	3.57 (2.02)^{a}	3.43 (1.98)^{b}	3.87 (2.09)^{b}	40.81 (39.70)^{d}	43.81 (41.44)^{d}	37.24 (37.61)^{d}	4.57 (2.25)^{a}	3.77 (2.07)^{ab}	3.33 (1.96)^{bc}	3.80 (2.07)^{cd}	27.89 (31.88)^{efg}	37.06 (37.50)^{f}	28.91 (32.52)^{f}
T_5	5.77 (2.50)^{a}	5.53 (2.46)^{b}	5.70 (2.49)^{d}	5.73 (2.50)^{c}	4.66 (12.46)^{f}	2.90 (9.80)^{f}	3.37 (10.58)^{f}	4.97 (2.34)^{a}	4.87 (2.32)^{d}	4.83 (2.31)^{d}	4.87 (2.32)^{de}	14.35 (22.26)^{i}	16.06 (23.63)^{h}	16.22 (23.75)^{h}
T_6	5.60 (2.47)^{a}	3.00 (1.87)^{a}	2.80 (1.82)^{a}	3.40 (1.97)^{ab}	46.71 (43.11)^{bc}	50.85 (45.49)^{b}	40.92 (39.77)^{cd}	4.67 (2.27)^{a}	3.67 (2.04)^{ab}	2.87 (1.84)^{bc}	3.13 (1.91)^{bc}	31.30 (34.02)^{def}	46.92 (43.23)^{cd}	42.70 (40.80)^{d}
T_7	6.00 (2.55)^{a}	3.40 (1.97)^{a}	2.97 (1.86)^{ab}	3.37 (1.97)^{ab}	43.63 (41.34)^{c}	51.34 (45.77)^{b}	45.35 (42.33)^{bc}	4.97 (2.34)^{a}	3.87 (2.09)^{bc}	3.13 (1.91)^{bc}	3.47 (1.99)^{cd}	31.93 (34.41)^{de}	45.61 (42.48)^{de}	40.31 (39.41)^{de}
T_8	6.70 (2.68)^{a}	3.67 (2.04)^{a}	3.73 (2.06)^{c}	3.83 (2.08)^{ab}	45.51 (42.42)^{bcd}	45.28 (42.29)^{cd}	44.38 (41.77)^{bc}	6.03 (2.56)^{a}	5.07 (2.36)^{d}	4.73 (2.29)^{d}	5.07 (2.36)^{e}	26.50 (30.98)^{efgh}	32.25 (34.60)^{fg}	28.11 (32.02)^{f}
T_9	5.73 (2.50)^{a}	3.80 (2.07)^{a}	3.73 (2.06)^{c}	3.93 (2.10)^{b}	34.03 (35.68)^{e}	36.01 (36.88)^{e}	33.26 (35.22)^{e}	5.77 (2.50)^{a}	4.97 (2.34)^{d}	4.83 (2.31)^{d}	5.20 (2.39)^{e}	24.71 (29.81)^{ghi}	27.70 (31.76)^{g}	22.95 (28.62)^{g}
T_{10}	6.00 (2.55)^{a}	3.37 (1.97)^{a}	3.07 (1.89)^{ab}	3.67 (2.04)^{ab}	44.12 (41.63)^{cd}	49.70 (44.83)^{bc}	40.48 (39.51)^{cd}	5.47 (2.44)^{a}	3.07 (1.89)^{a}	1.87 (1.54)^{a}	1.37 (1.37)^{a}	50.94 (45.54)^{a}	70.47 (57.09)^{a}	78.59 (62.44)^{a}
T_{11}	5.77 (2.50)^{a}	5.80 (2.51)^{c}	5.87 (2.52)^{d}	5.93 (2.54)^{c}	0.00 (0.00)^{e}	0.00 (0.00)^{g}	0.00 (0.00)^{g}	5.07 (2.36)^{a}	5.80 (2.51)^{d}	5.87 (2.52)^{e}	5.93 (2.54)^{e}	0.00 (0.00)^{j}	0.00 (0.00)^{i}	0.00 (0.00)^{i}
S.Em.±	0.08	0.05	0.04	0.05	1.19	0.90	1.15	0.11	0.07	0.06	0.08	1.21	1.07	0.99
$CD_{0.05}$	ns	0.15	0.12	0.15	3.57	2.71	3.45	ns	0.21	0.18	0.24	3.63	3.21	2.97
CV (%)	13.11	11.81	9.25	12.07	13.14	10.02	11.67	10.33	11.56	16.88	13.35	11.32	10.25	16.53

T_1 = Vermiwash (10%) + NSKE (5%), T_2 = Vermiwash (10%) + garlic-chilli kerosene extract (3%); T_3 = Vermiwash (10%) + *Parthenium hysterophorus* leaf extract (5%); T_4 = Vermiwash (10%) + *Vitex nigunda* leaf extract (5%); T_5 = Vermiwash (10%); T_6 - NSKE (5%); T_7 = Garlic-chilli kerosene extract (3%); T_8 = *P. hysterophorus* leaf extract (5%); T_9 = *V. nigunda* leaf extract (5%); T_{10} = Emamectin benzoate 5% SG (standard check) @ 0.25g L^{-1}; T_{11} = Untreated control
$^{\#}$Values in the parentheses are $\sqrt{(x+0.5)}$ transformed values; **##:** Values in the parentheses are arc sine transformation; Means followed by same alphabet in a column do not differ significantly by DMRT.
DAS: Days after spraying.

10% + GCKE @ 3%. After 2nd spray, the reduction in egg population ranged from 41.94 (5 DAS) to 57.35% (10 DAS) in vermiwash @ 10% + NSKE @ 5 % which was at par with vermiwash @ 10% + GCKE @ 3%, as this treatment restricted egg population in the range of 39.39 (5 DAS) to 53.55 (10 DAS) (Table 2). Both the treatments were at par with chemical insecticide, emamectin benzoate 5% SG. At 7 days after 3rd pray, egg reduction in vermiwash @ 10% + NSKE @5%treatment was 71.73% which was comparable with vermiwash @ 10% + GCKE @ 3% (68.96%) and emamectin benzoate 5% SG (63.06%) treatments (Table 4). The reduction in egg load in NSKE treatments appeared due to the ovipositional deterrent properties in neem. The results are in conformity with Khuhro *et al.* (2016) who reported NSKE and pure compounds from NSKE effective in inducing diverse biological effects (antifeedant or repellent) on insects through oviposition deterrent. The ovicidal properties of neem and their derivatives have been observed by Hossain *et al.* (2010).

In present study, the addition of vermiwash @ 10% to GCKE @ 3% treatment was at par with vermiwash @ 10% + NSKE @ 5% in reducing egg load on chickpea. Garlic biopesticides have unique components like diallyl disulphide, diallyl trisulphide and diallyl sulfide which have repelling property and prevent the insects from feeding against economic pests like potato tuber moth (Chakra-varthy, 2009). Foliar spray of vermiwash provides mild resistance against pest to the growing plant for elongation, early flowering and fruiting phase and also bio-pesticide exhibits synergistic effect with vermiwash to control aphid population and for better productivity in pea (Mishra *et al.*, 2015). Larval reduction at ten days after 1st, 2nd and 3rd sprays was significantly higher in vermiwash @ 10% + NSKE @ 5% (54.65, 59.01 and 79.22%) and vermiwash @ 10% + GCKE @ 3% (49.81, 55.27 and

Table 2: Combined effect of botanicals and vermiwash on egg incidence of *H. armigera* in chickpea (after 2nd spray)

Treat-ments	No. of eggs m^{-1} row length#				% Reduction in eggs over untreated control##		
	Pre-treat	5 DAS	7 DAS	10 DAS	5 DAS	7 DAS	10 DAS
T_1	3.40 (1.97)	2.03 (1.59)^{b}	1.47 (1.40)^{a}	1.53 (1.42)^{b}	41.94 (40.36)^{ab}	58.16 (49.70)^{b}	57.35 (49.22)^{b}
T_2	3.53 (2.01)	2.20 (1.64)^{b}	1.60 (1.45)^{ab}	1.73 (1.49)^{bc}	39.39 (38.88)^{abc}	56.14 (48.52)^{bc}	53.55 (47.03)^{bc}
T_3	3.67 (2.04)	2.37 (1.69)^{b}	1.80 (1.52)^{ab}	1.87 (1.54)^{bc}	37.20 (37.58)^{bcd}	52.54 (46.45)^{cd}	51.70 (45.98)^{cd}
T_4	3.83 (2.08)	2.77 (1.81)^{cd}	1.97 (1.57)^{b}	2.27 (1.66)^{c}	29.67 (33.00)^{e}	50.22 (45.13)^{d}	43.82 (41.45)^{f}
T_5	4.93 (2.33)	4.40 (2.21)^{f}	4.27 (2.18)^{d}	4.13 (2.15)^{e}	13.21 (21.31)^{h}	16.18 (23.72)^{f}	20.59 (26.99)^{h}
T_6	3.60 (2.02)	2.47 (1.72)^{bc}	1.87 (1.54)^{a}	2.00 (1.58)^{bc}	33.28 (35.23)^{de}	49.73 (44.85)^{d}	47.34 (43.48)^{ef}
T_7	3.93 (2.10)	2.87 (1.84)^{cd}	2.00 (1.58)^{b}	2.13 (1.62)^{b}	28.98 (32.57)^{ef}	50.75 (45.43)^{d}	48.63 (44.21)^{de}
T_8	4.03 (2.13)	3.07 (1.89)^{de}	2.73 (1.80)^{c}	2.83 (1.82)^{d}	25.92 (30.61)^{f}	34.44 (35.94)^{e}	33.44 (35.33)^{g}
T_9	4.00 (2.12)	3.27 (1.94)^{e}	2.67 (1.78)^{c}	2.83 (1.82)^{d}	20.50 (26.92)^{g}	35.40 (36.51)^{e}	32.94 (35.02)^{g}
T_{10}	2.07 (1.60)	1.20 (1.30)^{a}	0.75 (1.12)^{a}	0.60 (1.05)^{a}	43.63 (41.34)^{a}	64.94 (53.69)^{a}	72.53 (58.39)^{a}
T_{11}	6.00 (2.55)	6.17 (2.58)^{g}	6.20 (2.59)^{e}	6.33 (2.61)^{f}	0.00 (0.00)^{i}	0.00 (0.00)^{g}	0.00 (0.00)^{i}
S.Em.±	0.04	0.04	0.05	0.04	1.01	0.92	0.80
$CD_{0.05}$	0.12	0.12	0.15	0.12	3.04	2.65	2.41
CV (%)	13.23	11.07	14.33	10.90	15.01	12.55	16.04

T_1 = Vermiwash (10%) + NSKE (5%), T_2 = Vermiwash (10%) + garlic-chilli kerosene extract (3%); T_3 = Vermiwash (10%) + *Parthenium hysterophorus* leaf extract (5%); T_4 = Vermiwash (10%) + *Vitex nigunda* leaf extract (5%); T_5 = Vermiwash (10%); T_6 - NSKE (5%); T_7 = Garlic-chilli kerosene extract (3%); T_8 = *P. hysterophorus* leaf extract (5%); T_9 = *V. nigunda* leaf extract (5%); T_{10} = Emamectin benzoate 5% SG (standard check) @ 0.25g L^{-1}; T_{11} = Untreated control
#Values in the parentheses are $\sqrt{(x+0.5)}$ transformed values; ##Values in the parentheses are arc sine transformation; Means followed by same alphabet in a column do not differ significantly by DMRT.
DAS: days after spraying.

62.26%) treatment combinations which were as effective as that of the recommended insecticide, emamectin benzoate 5% SG (79.22, 75.07 and 92.30%), respectively (Table 1, 3 and 4). The reduction of larval population in NSKE or GCKE with vermiwash treatment is due to fact that both plant products have ovipositonal deterrent, antifeedant and larvicidal properties. The present study was in conformity with Khuhro *et al*. (2016) who reported NSKE and pure compounds obtained from NSKE

Table 3: Combined effect of botanicals and vermiwash on larval incidence of *H. armigera* in chickpea (after 2nd spray)

Treat-ments	No. of eggs m^{-1} row length#				% Reduction in eggs over untreated control##		
	Pre-treat	5 DAS	7 DAS	10 DAS	5 DAS	7 DAS	10 DAS
T_1	2.67 (1.78)	1.40 (1.38)^{ab}	1.03 (1.24)^{ab}	1.13 (1.28)^{b}	47.82 (43.75)^{ab}	61.79 (51.82)^{b}	59.01 (50.19)^{b}
T_2	3.53 (2.01)	2.03 (1.59)^{b}	1.50 (1.41)^{bc}	1.63 (1.46)^{c}	42.77 (40.84)^{bc}	57.92 (49.55)^{bc}	55.27 (48.03)^{bc}
T_3	3.80 (2.07)	2.43 (1.71)^{cd}	2.03 (1.59)^{cd}	2.17 (1.63)^{cd}	36.36 (37.09)^{def}	47.09 (43.33)^{e}	44.69 (41.95)^{ef}
T_4	4.03 (2.13)	2.60 (1.76)^{cd}	2.27 (1.66)^{d}	2.47 (1.72)^{d}	35.80 (36.75)^{def}	44.21 (41.68)^{e}	40.63 (39.60)^{f}
T_5	4.67 (2.27)	4.17 (2.16)^{d}	4.07 (2.14)^{e}	3.97 (2.11)^{e}	11.14 (19.50)^{i}	13.69 (21.71)^{g}	17.66 (24.85)^{i}
T_6	3.47 (1.99)	2.17 (1.63)^{cd}	1.53 (1.42)^{bc}	1.73 (1.49)^{cd}	37.77 (37.92)^{cd}	56.33 (48.64)^{cd}	51.71 (45.98)^{cd}
T_7	3.73 (2.06)	2.37 (1.69)^{cd}	1.67 (1.47)^{c}	1.93 (1.56)^{cd}	36.77 (37.33)^{de}	55.66 (48.25)^{cd}	49.88 (44.93)^{d}
T_8	5.43 (2.44)	4.03 (2.13)^{d}	3.47 (1.99)^{e}	3.57 (2.02)^{e}	26.14 (30.75)^{g}	36.71 (37.29)^{f}	36.32 (37.06)^{g}
T_9	5.40 (2.43)	4.27 (2.18)^{d}	3.67 (2.04)^{e}	3.77 (2.07)^{e}	21.31 (27.49)^{h}	32.69 (34.87)^{f}	32.38 (34.68)^{h}
T_{10}	2.37 (1.69)	1.13 (1.28)^{a}	0.73 (1.11)^{a}	0.53 (1.01)^{a}	52.55 (46.46)^{a}	69.49 (56.47)^{a}	78.34 (62.26)^{a}
T_{11}	6.17 (2.58)	6.20 (2.59)^{e}	6.23 (2.59)^{f}	6.37 (2.62)^{f}	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
S.Em.±	0.09	0.08	0.06	0.05	1.04	0.90	0.79
$CD_{0.05}$	0.26	0.24	0.18	0.15	3.11	2.71	2.36
CV (%)	10.51	15.31	10.34	9.82	14.91	11.34	10.03

T_1 = Vermiwash (10%) + NSKE (5%), T_2 = Vermiwash (10%) + garlic-chilli kerosene extract (3%); T_3 = Vermiwash (10%) + *Parthenium hysterophorus* leaf extract (5%); T_4 = Vermiwash (10%) + *Vitex nigunda* leaf extract (5%); T_5 = Vermiwash (10%); T_6 - NSKE (5%); T_7 = Garlic-chilli kerosene extract (3%); T_8 = *P. hysterophorus* leaf extract (5%); T_9 = *V. nigunda* leaf extract (5%); T_{10} = Emamectin benzoate 5% SG (standard check) @ 0.25 g L^{-1}; T_{11} = Untreated control
#Values in the parentheses are $\sqrt{(x+0.5)}$ transformed values; ##Values in the parentheses are arc sine transformation; Means followed by same alphabet in a column do not differ significantly by DMRT.
DAS: days after spraying.

had been found to produce diverse biological effects (antifeedant or repellent) on insects through oviposition deterrent. Azadirachtin has major limonoid exerting antifeedant effect on *H. armigera* (Choudhury, 2016). Addition of vermiwash extract to these botanicals, help the plant consistently improved the early initiation of flowers, much more than could be possible from more conversion of mineral nutrients into more plant available forms, which it terms help the plant to recover the damage done by the larvae. Vermiwash of different wastes are rich source of enzymes, vitamins, plant growth hormones (such as IAA, gibberellins, cytokines, etc.) and also provide nutrients (such as phosphorus, potassium, calcium, etc.) [Gopal, *et al*., 2010; Nath and Singh, 2012]. The significant increase in the growth of gram plants was due to foliar spray of vermiwash and neem based biopesticides has been reported by Zambare *et al*. (2008). Nath *et al*. (2008) reported significant reduction in the population of *H. armigera* larvae after spray of vermiwash with neem-based pesticides on *Cajanus cajan* crop. The present investigation was in conformity with Gilani (2001) who reported that the effectiveness of NSKE may be due to antifeedant or repellent property while neem plant extracts deters insects from feeding. Mishra *et al.* (2013) reported that vermiwash combination of animal dung and municipal solid wastes with aqueous garlic extract caused significant reduction in the infestation rate of *H. armigera*.

Data on the effect of combined application of vermiwash and botanicals on the natural enemy (*Campletis chloridae*) in chickpea ecosystem indicated that combination of all botanicals with vermiwash were slightly effective on *Campletis chloridae* and were next best to sole vermiwash @

Table 4: Combined effect of different botanicals and vermiwash on larval incidence of *H. armigera* on chickpea (after 3rd spray)

Treatments	No. of eggs m^{-2} row length$^{\#}$				% Reduction in eggs over untreated control$^{\#\#}$			No. of larvae m^{-1} row length$^{\#}$				% Reduction in larva over untreated control$^{\#\#}$		
	Pre-treat	5 DAS	7 DAS	10 DAS	5 DAS	7 DAS	10 DAS	Pre-treat	5 DAS	7 DAS	10 DAS	5 DAS	7 DAS	10 DAS
T_1	1.07 (1.25)	0.47 (0.98)^{a}	0.33 (0.91)^{a}	0.40 (0.95)^{ab}	58.61 (49.96)^{a}	71.73 (57.88)^{a}	66.64 (54.72)^{b}	1.33 (1.35)	0.67 (1.08)^{a}	0.40 (0.95)^{ab}	0.27 (0.88)^{ab}	50.68 (45.39)^{b}	71.16 (57.52)^{b}	79.22 (62.88)^{b}
T_2	1.27 (1.33)	0.63 (1.06)^{a}	0.43 (0.96)^{ab}	0.60 (1.05)^{bc}	53.26 (46.87)^{b}	68.96 (56.14)^{ab}	57.83 (49.51)^{c}	1.93 (1.56)	1.03 (1.24)^{bc}	0.63 (1.06)^{bc}	0.47 (0.98)^{bc}	47.75 (43.71)^{b}	68.70 (55.98)^{b}	75.07 (60.05)^{b}
T_3	1.53 (1.42)	0.93 (1.20)^{b}	0.67 (1.08)^{bc}	0.80 (1.14)^{cd}	42.73 (40.82)^{cd}	59.86 (50.69)^{cd}	53.33 (46.91)^{cd}	2.27 (1.66)	1.33 (1.35)^{cd}	1.03 (1.24)^{cd}	0.73 (1.11)^{cd}	42.64 (40.77)^{c}	56.49 (48.73)^{cd}	67.08 (54.99)^{c}
T_4	1.80 (1.52)	1.20 (1.30)^{bc}	1.03 (1.24)^{cd}	1.33 (1.35)^{ef}	37.19 (37.58)^{de}	47.55 (43.59)^{fg}	34.05 (35.70)^{g}	2.87 (1.84)	1.87 (1.54)^{d}	1.67 (1.47)^{e}	1.07 (1.25)^{d}	36.21 (36.99)^{de}	44.20 (41.67)^{fg}	61.84 (51.85)^{d}
T_5	3.27 (1.94)	3.13 (1.91)^{e}	3.07 (1.89)^{f}	3.13 (1.91)^{g}	9.82 (18.26)^{g}	13.94 (21.92)^{g}	14.57 (22.44)^{h}	3.87 (2.09)	3.43 (1.98)^{f}	3.27 (1.94)^{g}	3.13 (1.91)^{f}	13.23 (21.33)^{g}	18.97 (25.82)^{h}	17.21 (24.51)^{g}
T_6	1.67 (1.47)	1.07 (1.25)^{b}	0.80 (1.14)^{c}	0.97 (1.21)^{cde}	39.63 (39.02)^{cde}	56.09 (48.50)^{de}	48.16 (43.95)^{de}	1.97 (1.57)	1.17 (1.29)^{c}	0.87 (1.17)^{cd}	0.73 (1.11)^{cd}	41.85 (40.31)^{c}	57.65 (49.40)^{c}	62.07 (51.98)^{d}
T_7	1.87 (1.54)	1.27 (1.33)^{bc}	1.00 (1.22)^{cd}	1.17 (1.29)^{d}	36.01 (36.88)^{e}	50.98 (45.56)^{ef}	44.16 (41.65)^{ef}	2.07 (1.60)	1.33 (1.35)^{cd}	1.00 (1.22)^{cd}	0.93 (1.20)^{d}	37.10 (37.52)^{d}	53.68 (47.11)^{cde}	54.01 (47.30)^{e}
T_8	2.03 (1.59)	1.53 (1.42)^{cd}	1.33 (1.35)^{de}	1.47 (1.40)^{f}	28.99 (32.58)^{f}	39.94 (39.20)^{gh}	35.37 (36.49)^{g}	3.73 (2.06)	2.47 (1.72)^{e}	2.00 (1.58)^{ef}	1.73 (1.49)^{e}	35.17 (36.37)^{de}	48.58 (44.19)^{ef}	52.52 (46.45)^{ef}
T_9	2.20 (1.64)	1.73 (1.49)^{d}	1.53 (1.42)^{e}	1.53 (1.42)^{f}	25.91 (30.60)^{f}	36.25 (37.02)^{h}	37.93 (38.02)^{fg}	3.87 (2.09)	2.77 (1.81)^{ef}	2.23 (1.65)^{f}	1.97 (1.57)^{e}	29.92 (33.16)^{f}	44.74 (41.98)^{fg}	47.89 (43.79)^{f}
T_{10}	0.67 (1.08)	0.40 (0.95)a	0.27 (0.88)a	0.17 (0.82)a	43.75 (41.41)^{c}	63.06 (52.57)^{bc}	77.35 (61.58)^{a}	0.93 (1.20)	0.33 (0.91)^{a}	0.13 (0.79)^{a}	0.07 (0.75)^{a}	65.26 (53.89)^{a}	86.60 (68.52)^{a}	92.30 (73.88)^{a}
T_{11}	4.40 (2.21)	4.67 (2.27)^{f}	4.80 (2.30)^{g}	4.93 (2.33)^{h}	0.00 (0.00)^{h}	0.00 (0.00)^{i}	0.00 (0.00)^{i}	6.07 (2.56)	6.20 (2.59)^{g}	6.33 (2.61)^{h}	5.93 (2.54)^{g}	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
S.Em.±	0.06	0.04	0.05	0.05	1.08	1.26	1.04	0.08	0.06	0.05	0.05	0.83	1.04	0.97
$CD_{0.05}$	0.18	0.12	0.15	0.15	3.24	3.77	3.12	0.23	0.18	0.15	0.15	2.48	3.12	2.91
CV (%)	13.76	10.01	16.55	11.89	18.05	14.33	13.29	13.33	10.67	16.03	11.40	12.33	9.39	13.65

T_1 = Vermiwash (10%) + NSKE (5%), T_2 = Vermiwash (10%) + garlic-chilli kerosene extract (3%); T_3 = Vermiwash (10%) + *Parthenium hysterophorus* leaf extract (5%); T_4 = Vermiwash (10%) + *Vitex nigunda* leaf extract (5%); T_5 = Vermiwash (10%); T_6 = NSKE (5%); T_7 = Garlic-chilli kerosene extract (3%); T_8 = *P. hysterophorus* leaf extract (5%); T_9 = *V. nigunda* leaf extract (5%); T_{10} = Emamectin benzoate 5% SG (standard check) @ 0.25g L^{-1}; T_{11} = Untreated control
$^{\#}$Values in the parentheses are $\sqrt{(x+0.5)}$ transformed values; $^{\#\#}$Values in the parentheses are arc sine transformation; Means followed by same alphabet in a column do not differ significantly by DMRT.
DAS: Days after spraying.

Table 5: Influence of various combination of botanicals and vermiwash on natural enemy (*Campoletis chloridae*) in chickpea ecosystem after 3rd treatment

Treatments	Number of *C. chlorideae* pupae m^{-1} row length#			
	Pre-treatment	5 DAS	7 DAS	10 DAS
Vermiwash (10%) + NSKE (5%)	2.00 (1.58)^{ab}	2.67 (1.77)^{abc}	3.33 (1.95)^{bc}	2.00 (1.58)^{b}
Vermiwash (10%) + GCKE (3%)	1.67 (1.46)^{ab}	2.00 (1.58)^{bcd}	2.67 (1.76)^{cd}	1.33 (1.34)^{bc}
Vermiwash (10%) + *P. hysterophorus* (5%)	1.67 (1.46)^{ab}	1.33 (1.34)^{d}	1.67 (1.46)^{e}	1.00 (1.22)^{c}
Vermiwash (10%) + *Vitex nigunda* (5%)	1.33 (1.34)^{ab}	3.00 (1.87)^{ab}	4.00 (2.12)^{ab}	1.67 (1.46)^{bc}
Vermiwash (10%)	4.00 (2.12)^{a}	3.67 (2.04)^{a}	4.33 (2.20)^{ab}	3.33 (1.95)^{a}
NSKE (5%)	1.00 (1.17)^{ab}	1.00 (1.17)^{d}	2.00 (1.58)^{de}	1.33 (1.34)^{bc}
GCKE (3%)	1.67 (1.46)^{ab}	1.33 (1.34)^{d}	1.33 (1.34)^{e}	1.00 (1.22)^{c}
P. hysterophorus (5%)	2.67 (1.76)^{ab}	1.67 (1.46)^{cd}	2.00 (1.58)^{de}	1.33 (1.34)^{bc}
Vitex nigunda (5%)	1.33 (1.34)^{ab}	1.00 (1.17)^{d}	1.67 (1.46)^{e}	2.00 (1.58)^{b}
Emamectin benzoate 5%SG @ 0.25 g L^{-1}	0.00 (0.71)^{b}	0.00 (0.71)^{e}	0.00 (0.71)^{f}	0.00 (0.71)^{d}
Untreated control	4.67 (2.27)^{a}	4.00 (2.12)^{a}	4.67 (2.27)^{a}	3.67 (2.04)^{a}
S.Em.±	0.34	0.13	0.09	0.08
$CD_{0.05}$	0.11	0.38	0.26	0.23
CV (%)	12.98	14.70	8.93	9.45

10% (3.33 m^{-1} row length) and untreated control (3.67 m^{-1} row length) treatments but superior to chemical insecticides i.e. emamectin benzoate 5% SC (Table 5). In a similar study Ranga Rao *et al.* (2013) found toxic effects of neem on soil-inhabiting and aerial natural enemies in chickpea to an extent of 41 and 29% population reduction, respectively, as compared to 63 and 51% by conventional insecticide (endosulfan). Neem spray registered 14.92% reduction in natural enemy population over control which was superior to chemical insecticide (Suganthy, 1999).

Vermiwash @ 10% + NSKE @ 5% and vermiwash @10% + GCKE @ 3% treatment combinations were most effective in reducing pod damage by 11.29 and 12.24%, respectively, and also increased the yield (24.35 and 23.68 q ha^{-1}) [Table 6]. Though the application of vermiwash alone induced plant to bear more number of flowers (24.47) and higher 100-seed weight (24.01 g), but failed to set pods due to higher pod borer incidence and resulted in higher pod damage (14.93%) and lower yield (10.06 q ha^{-1}) in this treatment. Our results are in conformity with Nath and Singh (2011) who observed significant higher productivity of soybean in all the combinations of vermiwash and vermiwash with neem plant part and neem-based pesticides. Based on our results, vermiwash

Table 6: Influence of various combinations of botanicals and vermiwash on yield and yield parameters

Treatments	No of flowers $plant^{-1}$	Pod damage (%)#	100-seed weight (g)	Yield (q ha^{-1})
Vermiwash (10%) + NSKE (5%)	28.67^{a}	11.29 (19.63)^{b}	24.35^{a}	14.53^{ab}
Vermiwash (10%) + GCKE (3%)	24.47^{b}	12.24 (20.46)^{bc}	23.68^{abc}	13.93^{abc}
Vermiwash (10%)+ *P. hysterophorus* (5%)	23.13^{bcde}	14.62 (22.48)^{cd}	23.44^{abc}	13.53^{bcd}
Vermiwash (10%)+*V. nigunda* (5%)	22.07^{cdef}	15.37 (23.08)^{de}	23.55^{abc}	11.83^{de}
Vermiwash (10%)	24.47^{b}	14.93 (22.72)^{d}	24.01^{abc}	10.06^{e}
NSKE (5%)	24.33^{bc}	13.68 (21.70)^{cd}	22.95^{abcd}	12.64c
GCKE (5%)	23.80^{bcd}	13.82 (21.82)^{cd}	22.79^{abcd}	12.58c
P. hysterophorus (5%)	21.73^{def}	15.80 (23.41)^{ef}	22.63^{abcd}	12.56^{c}
V. nigunda (5%)	17.07^{g}	17.60 (24.80)^{f}	21.70^{cd}	11.64^{e}
Emamectin benzoate 5%SG @ 0.25 g L^{-1}	27.73^{a}	7.10 (15.45)^{a}	24.02^{ab}	15.99^{a}
Untreated control	15.73^{g}	23.46 (28.97)^{g}	21.04^{d}	7.80^{f}
S.Em.±	0.80	0.51	0.74	0.60
$CD_{0.05}$	2.34	1.54	2.17	1.80
CV (%)	6.02	16.75	8.55	10.21

#: The values in parentheses are arc sine transformation used for statistical analysis.
Means followed by similar alphabets in the column do not differ significantly at 0.05% by DMRT

@ 10% can be successfully used in combination with NSKE @ 5% or GCKE @ 3% for better management of pod borer in chick pea ecosystem.

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