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EVALUATION OF WHORL APPLICATION OF INSECTICIDES MIXED WITH SAND AGAINST FALL ARMY WORM *SPODOPTERA FRUGIPERDA* IN MAIZE

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ABSTRACT

The fall army worm (FAW) *Spodoptera frugiperda* is now spread all over India and at present, spraying insecticides is the primary method of control. Considering its presence in whorl and negative impact of insecticidal spray on the natural enemies, there is a need of evolving alternate techniques. In the present study, whorl application of insecticides mixed in river sand was evaluated for its efficacy. Sand mixed with chlorantraniliprole 18.5SC @0.4 ml/ kg, emamectin benzoate 5SG@ 0.4 g/ kg and spinosad 45SC @ 0.4 ml/ kg sand were found to be effective, with significant reduction in leaf damage. The quantity of insecticide required/ unit area was 50% less than the spray while maximum grain yield/ cost benefit ratio was obtained.

Key words: *Spodoptera frugiperda*, maize, chlorantraniliprole, emamectin benzoate, spinosad, sand, whorl application, grain yield, C: B ratio

Maize (*Zea mays* L.) is one of important crops having wider adaptability under varied agroclimatic conditions, and it has a good yield potential among the cereals (Singh and Jaglan, 2018). In India, it has a productivity of 2.69 mt/ ha (Anonymous, 2019), and insect pests are the reasons for the reduced productivity. As many as 141 insect pests cause a varying degree of damage from sowing to till harvest (Reddy and Trivedi, 2008). Fall army worm, *Spodoptera frugiperda* (J E Smith) is a recent invasive pest in India (Sharanabasappa et al., 2018; Mahadevaswamy et al., 2018; Shylesha et al., 2018). The pest being native to America, was reported for the first time in Africa (Goergen et al., 2016) and then in Asian countries (Sharanabasappa et al., 2018; Wu et al., 2019; CABI, 2020). It causes significant loss to maize (Deshmukh et al., 2020), strategies are essential to make the insecticides reach the leaf whorl. The whorl application of sand, soil and ash against *S. frugiperda* is a traditional management practice adopted by farmers in Africa (Kumela et al., 2019; Abate et al., 2000) and America (Wyckhuys and Oneil, 2007) but their efficacy has not been documented in India. Babendreier et al. (2020) found that whorl application of construction sand might be useful. Similarly, diatomaceous earth (DE) has long been used for insect control, especially for stored grain pests (Korunic, 2013) and many commercial products are available (Ebeling, 1971). Constanski et al. (2016) studied the effects of several inert powders, including DE and bentonite, and bentonite was found to cause 93% and DE 47% mortality. As abrasive material, sand physically damages the insects. Sand entrapment provides the plant with herbivore resistance (Neinhuis et al., 1996; Lopresti et al., 2018). In India, most of the research is concentrated on spray formulations (Deshmukh et al., 2020). As the pest hides and feed inside the whorl alternative technique need to be developed. Considering good canopy of maize plant, insecticidal spray has negative effect on the natural enemies and wastage of insecticide generally occurs. Therefore, this study to evaluate whorl application of insecticides mixed with river sand against *S. frugiperda*.

MATERIALS AND METHODS

A field experiment was conducted during kharif 2019-20 at two locations- (i) Agricultural and Horticultural Research Station, Bhavikere (13°.14'.679"N, 75°.43'.525"E, 567 masl) and (ii) College of Agriculture, Navile, Shivamogga, (13°.58'.540"N75°, 34'.754"E, 526 masl) University of Agricultural and Horticultural Sciences, Shivamogga, Karnataka, India. The experiment was laid out in a randomized complete block design (RCBD) with ten treatments in three replications. The plot size followed was 5x 4 m with 1 m replication border and 0.5 m treatment border between the plots. Experimental plots were separated by raised bunds of about 10 cm height

Table 1. Evaluation of insecticides mixed with sand against *S. frugiperda*- kharif 2019-20

T. No.	Treatments	Dose/ kg of sand	DBT	Mean no. of larvae/ plant# I Treatment (20 DAS) 7 DAT	I Treatment (20 DAS) 14 DAT	II Treatment (35 DAS) 7 DAT	II Treatment (35 DAS) 14 DAT	Mean	% reduction over control
AHRS, Bhavikere (Location 1)									
T1	Chlorpyriphos 20EC	2 ml	1.63 (1.45)	0.87 (1.17)^{cd}	1.20 (1.30)^{bc}	0.67 (1.07)^{bcd}	0.60 (1.05)^{bcd}	0.83 (1.15)^{cd}	53.92
T2	Thiodicarb 75WP	0.6 g	2.00 (1.58)	0.50 (0.96)^{def}	0.83 (1.15)^{cde}	0.40 (0.95)^{cde}	0.30 (0.89)^{def}	0.51 (1.00)^{ef}	71.89
T3	Chlorantraniliprole 18.5 SC	0.4 ml	2.07 (1.60)	0.13 (0.75)^{g}	0.27 (0.87)^{f}	0.00 (0.71)^{f}	0.00 (0.71)^{g}	0.10 (0.77)^{h}	94.47
T4	Malathion 50EC	2 ml	1.67 (1.47)	0.97 (1.21)^{bc}	1.30 (1.34)^{bc}	0.73 (1.11)^{bc}	0.67 (1.08)^{bc}	0.92 (1.19)^{c}	49.31
T5	Spinosad 45SC	0.4 ml	1.60 (1.44)	0.33 (0.87)^{efg}	0.70 (1.09)^{de}	0.30 (0.89)^{def}	0.10 (0.77)^{efg}	0.36 (0.93)^{fg}	80.18
T6	Emamectin benzoate 5SG	0.4 g	2.03 (1.59)	0.27 (0.84)^{fg}	0.57 (1.03)^{ef}	0.17 (0.81)^{ef}	0.07 (0.75)^{fg}	0.27 (0.87)^{gh}	85.25
T7	Neem soap 10%	10 ml	1.93 (1.54)	0.57 (1.03)^{cdef}	1.03 (1.23)^{cde}	0.43 (0.96)^{cde}	0.33 (0.91)^{cdef}	0.59 (1.04)^{def}	67.28
T8	Diatomaceous earth	200 g	1.70 (1.48)	0.70 (1.09)^{cde}	1.10 (1.26)^{cd}	0.50 (1.00)^{cde}	0.40 (0.95)^{cde}	0.68 (1.08)^{cde}	62.67
T9	Sand	5 g/ plant	2.03 (1.59)	1.37 (1.36)^{b}	1.77 (1.50)^{ab}	1.00 (1.22)^{ab}	0.90 (1.18)^{ab}	1.26 (1.33)^{b}	30.41
T10	Untreated check	-	2.10 (1.61)	2.23 (1.65)^{a}	2.27 (1.66)^{a}	1.50 (1.41)^{a}	1.23 (1.31)^{a}	1.81 (1.52)^{a}	-
	SEM ±	-	-	0.065	0.069	0.070	0.060	0.042	-
	CD (p=0.05)	-	NS	0.193	0.205	0.209	0.179	0.123	-
	CV (%)	-	8.95	10.17	9.62	12.04	10.90	6.61	-
UAHS, Shivamogga (Location 2)									
T1	Chlorpyriphos 20EC	2 ml	1.80 (1.52)	0.57 (1.02)^{bcd}	1.10 (1.26)^{bc}	0.60 (1.05)^{bcd}	0.53 (1.01)^{bcd}	0.70 (1.10)^{cd}	53.33
T2	Thiodicarb 75WP	0.6 g	1.93 (1.55)	0.37 (0.93)^{cdef}	0.73 (1.11)^{cde}	0.30 (0.89)^{de}	0.23 (0.85)^{def}	0.41 (0.95)^{ef}	72.78
T3	Chlorantraniliprole 18.5SC	0.4 ml	1.53 (1.41)	0.10 (0.77)^{f}	0.33 (0.91)^{f}	0.00 (0.71)^{f}	0.00 (0.71)^{f}	0.11 (0.78)^{h}	92.78
T4	Malathion 50EC	2 ml	2.13 (1.62)	0.70 (1.09)^{bc}	1.17 (1.29)^{bc}	0.67 (1.08)^{bc}	0.63 (1.06)^{bc}	0.79 (1.14)^{c}	47.22
T5	Spinosad 45SC	0.4 ml	1.97 (1.57)	0.23 (0.85)^{def}	0.63 (1.06)^{def}	0.17 (0.81)^{ef}	0.10 (0.77)^{ef}	0.28 (0.89)^{fg}	81.11
T6	Emamectin benzoate 5SG	0.4 g	1.90 (1.55)	0.17 (0.81)^{ef}	0.50 (0.99)^{ef}	0.10 (0.77)^{ef}	0.03 (0.73)^{f}	0.20 (0.84)^{gh}	86.67
T7	Neem soap 10%	10 ml	1.57 (1.43)	0.40 (0.94)^{cdef}	0.93 (1.20)^{bcd}	0.37 (0.93)^{cde}	0.30 (0.89)^{de}	0.50 (1.00)^{e}	66.67
T8	Diatomaceous earth	200 g	1.70 (1.47)	0.47 (0.98)^{cde}	1.00 (1.22)^{bcd}	0.47 (0.98)^{cd}	0.40 (0.95)^{cd}	0.58 (1.04)^{de}	61.11
T9	Sand	5 g/ plant	2.07 (1.60)	1.00 (1.21)^{b}	1.40 (1.38)^{ab}	0.93 (1.19)^{b}	0.87 (1.17)^{ab}	1.05 (1.24)^{b}	30.00
T10	Untreated check	-	1.80 (1.51)	1.63 (1.46)^{a}	1.80 (1.51)^{a}	1.40 (1.38)^{a}	1.17 (1.29)^{a}	1.50 (1.41)^{a}	-
	SEM ±	-	-	0.069	0.062	0.053	0.054	0.031	-
	CD (p=0.05)	-	NS	0.204	0.184	0.159	0.161	0.092	-
	CV (%)	-	8.63	11.79	9.01	9.45	9.98	5.17	-
Pooled									
T1	Chlorpyriphos 20EC	2 ml	1.72 (1.49)	0.72 (1.10)^{cd}	1.15 (1.28)^{bcd}	0.63 (1.06)^{bcd}	0.57 (1.03)^{cd}	0.77 (1.13)^{cd}	53.65
T2	Thiodicarb 75WP	0.6 g	1.97 (1.57)	0.43 (0.97)^{de}	0.78 (1.13)^{def}	0.35 (0.92)^{def}	0.27 (0.87)^{ef}	0.46 (0.98)^{ef}	72.29

contd...

(Table 1 contd.)

T3	Chlorantraniliprole 18.5 SC	0.4 ml	1.80 (1.52)	0.12 (0.78)^{f}	0.30 (0.89)^{g}	0.00 (0.71)^{g}	0.00 (0.71)^{g}	0.10 (0.78)^{h}	93.70
T4	Malathion 50EC	2 ml	1.90 (1.55)	0.83 (1.15)^{bc}	1.23 (1.31)^{bc}	0.70 (1.09)^{bc}	0.65 (1.07)^{bc}	0.85 (1.16)^{c}	48.36
T5	Spinosad 45 SC	0.4 ml	1.78 (1.51)	0.28 (0.88)^{ef}	0.67 (1.08)^{ef}	0.23 (0.85)^{efg}	0.10 (0.77)^{fg}	0.32 (0.91)^{fg}	80.60
T6	Emamectin benzoate 5 SG	0.4 g	1.97 (1.57)	0.22 (0.84)^{ef}	0.53 (1.01)^{fg}	0.13 (0.79)^{fg}	0.05 (0.74)^{g}	0.23 (0.86)^{gh}	85.89
T7	Neem soap 10%	10 ml	1.75 (1.49)	0.48 (0.99)^{de}	0.98 (1.22)^{cde}	0.40 (0.95)^{cdef}	0.32 (0.90)^{e}	0.55 (1.02)^{e}	67.00
T8	Diatomaceous earth	200 g	1.70 (1.48)	0.58 (1.04)^{cd}	1.05 (1.24)^{cd}	0.48 (0.99)^{cde}	0.40 (0.95)^{de}	0.63 (1.06)^{de}	61.96
T9	Sand	5 g/ plant	2.05 (1.60)	1.18 (1.29)^{b}	1.58 (1.44)^{ab}	0.97 (1.21)^{b}	0.88 (1.18)^{b}	1.15 (1.29)^{b}	30.23
T10	Untreated check	-	1.95 (1.57)	1.93 (1.56)^{a}	2.03 (1.59)^{a}	1.45 (1.40)^{a}	1.20 (1.30)^{a}	1.65 (1.47)^{a}	-
	SEM ±	-	-	0.051	0.056	0.056	0.039	0.031	-
	CD @ 5%	-	NS	0.152	0.167	0.167	0.119	0.092	-
	CV (%)	-	5.72	8.34	7.96	9.79	7.27	5.06	-
T1	Chlorpyriphos 20EC	2ml	1.72 (1.49)	0.72 (1.10)^{cd}	1.15 (1.28)^{bcd}	0.63 (1.06)^{bcd}	0.57 (1.03)^{cd}	0.77 (1.13)^{cd}	53.65

#- Observations mean of 10 randomly selected plants/ treatment; No. in parentheses $\sqrt{(x+0.5)}$ transformed values; Means followed by same letters do not differ significantly by DMRT (p=0.05); DAS- Days after sowing; DBT- Day before treatment; DAT- Days after treatment; NS- Non significant; *- Significant at ($p \leq 0.05$)

Table 2. Effect of insecticides mixed with sand on yield and cost economics of maize (kharif 2019-20- pooled)

T. No.	Treatments	Dosage*	Yield (q/ ha)	Cost of cultivation (Rs/ ha)	Gross income (Rs/ ha)	Net income (Rs/ ha)	C:B ratio
T1	Chlorpyriphos 20EC	2 ml	43.91^{cde}	37,273.00	65,857.50	28,584.50	1:1.77
T2	Thiodicarb 75WP	0.6 g	49.46^{bc}	38,124.00	74,187.50	36,063.50	1:1.95
T3	Chlorantraniliprole 18.5 SC	0.4 ml	60.34^{a}	39,535.00	90,507.50	50,972.50	1:2.29
T4	Malathion 50EC	2 ml	42.64^{cde}	37,295.00	63,957.50	26,662.50	1:1.71
T5	Spinosad 45 SC	0.4 ml	53.61^{ab}	40,730.00	80,417.50	39,687.50	1:1.97
T6	Emamectin benzoate 5 SG	0.4 g	58.60^{a}	37,340.00	87,902.50	50,562.50	1:2.35
T7	Neem soap 10%	10 ml	46.43^{bcd}	38,247.00	69,647.50	31,400.50	1:1.82
T8	Diatomaceous earth	200 g	51.29^{abc}	39,087.00	76,940.00	37,853.00	1:1.97
T9	Sand	5 g/ plant	40.31^{de}	36,847.00	60,470.00	23,623.00	1:1.64
T10	Untreated check	-	36.01^{e}	33,847.00	54,010.00	20,163.00	1:1.60
	SEM ±	-	3.052				
	CD @ 5%	-	9.070				
	CV (%)	-	10.96				

*- ml or g/kg of sand, (Market price of maize= Rs.1500/q); T1: Chlorpyriphos 20EC- 380 Rs/ l; T2: Thiodicarb 75WP – 3800 Rs/ kg; T3: Chlorantraniliprole 18.5 SC – 12000 Rs/ l; T4: Malathion 50EC – 400 Rs/ l; T5: Spinosad 45 SC – 17,333.33 Rs/ l;T6: Emamectin benzoate 5 SG – 2200 Rs./kg; T7: Neem soap 10% - 250 Rs/ kg; T8: Diatomaceous earth – 20 Rs/ kg ; T9: Sand – 2.5 Rs/ kg; No. of labour required/ application /ha – 4; Cost of labour: Rs. 200/ day; Quantity of sand required/ application /ha - 280 kg; Cost of production: 33,847/ ha

all around. The maize hybrid (Pioneer 3550) was used and seeds were dibbled at a spacing of 60x 30 cm during the last week of July 2019 on well prepared fine tilth land. The crop was raised adopting a standard package of practice except plant protection measures. A total of ten treatments were evaluated, of which six were insecticides mixed with river sand, one treatment with DE, one plant product (neem soap 10 %), while the sand alone was applied to whorl as check for comparison, and an untreated control.

Before application, the insecticides were properly mixed with sand having 7% moisture and applied to the whorl within an hour of mixing. All treatments were imposed twice, once at V6 and second at V10 stages of crop growth at the 20th and 35th day after sowing, respectively. In the first application, 5 g of treated sand or DE or neem soap was applied and 7 g was applied during 2nd application. The observations on the number of larvae/ plant in each treatment plot before and after the application were recorded with a sample of ten plants. Pretreatment count was taken one day before treatment by opening whorl, and post treatment ones at seven and 14 days after treatment. The leaf damage severity was recorded based on a 1 to 9 rating scale modified by CIMMYT, Mexico (Prasanna et al., 2018). Observations on the number of larvae/ plant were analysed after square root transformation. The data was subjected to Duncan's Multiple Range Test (DMRT). The grain yield recorded and expressed as q/ ha was also analysed. To know the economics of insecticides usage, data was pooled and the cost-benefit ratio calculated by considering the cost of plant protection and the final grain yield.

RESULTS AND DISCUSSION

In location-I, all the treatments significantly reduced the incidence of larvae at seven and 14 days after treatment; pretreatment counts it varied from 1.60 to 2.10 and was statistically non-significant; and overall reduction over control indicated that chlorantraniliprole 18.5SC is the most effective (94.47%), and the next best were emamectin benzoate 5SG (85.25 %) and spinosad 45SC (80.18 %). In location-II, pretreatment counts varied from 1.53 to 2.13, and at seven and 14 days after treatments there was reduction in incidence (92.78% with chlorantraniliprole 18.5SC followed by emamectin benzoate 5SG- 86.67% and spinosad 45 SC- 81.11 %). The pooled data indicated that chlorantraniliprole 18.5SC @ 0.4 ml/ kg of sand outperformed in terms of least larval load and % reduction of incidence. Emamectin benzoate 5SG @ 0.4 g, spinosad 45SC @ 0.4 ml and thiodicarb 75WP @ 0.6 g per kg of sand followed next. The least plant damage score (0.03) was shown with chlorantraniliprole 18.5SC followed by emamectin benzoate 5 SG (0.18) as aginst the maximum of 4.86 in untreated control (Table 1). Only chlorpyriphos 20EC @ 2.0 ml/ kg of sand had a phytotoxic effect. Chlorantraniliprole 18.5SC led to maximum grain yield of 60.34 q/ ha followed by emamectin benzoate 5SG (58.60 q/ ha), with the latter giving the maximum C: B ratio (1:2.35) (Table 2).

As the chemicals were evaluated at the recommended dose, the quantity required/ ha was much less than spraying- spray solution/ ha is 500 l, as against 280 kg of river sand (5g/ plant). Thus, nearly 50% insecticide/ unit area got reduced, also sand application into the whorl directly targets the larvae, as a result larva try to come out of the whorl and hence larvae got damaged through abrasion to the cuticle (Babendreier et al., 2020). Worku and Ebabuye (2019) found that there was no significant difference in the efficacy of insecticides between whorl application and foliar spray. The present study concludes that the quantity of insecticide/ unit area is reduced, also it increased effectiveness as it remained in the whorl for 4-5 days, with additional physical effects of sand (abrasion and other physical damage to cuticle). The applied sand slowly comes out of the whorl as the plant develops without interfering in the plant growth (Babendreier et al., 2020; Worku and Ebabuye, 2019).

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