www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277- 7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2021; SP-10(10): 398-404

www.thepharmajournal.com
Received: 18-07-2021
Accepted: 08-09-2021

HS Varma
Assistant Research Scientist, Main Maize Research Station, Anand Agricultural University, Godhra, Gujarat, India

DB Sisodiya
Professor and Head, Department of Entomology, B. A. College of Agriculture, Anand Agricultural University, Anand, Gujarat, India

MB Zala
Assistant Research Scientist, Agricultural Research Station, Anand Agricultural University, Sansoli, Gujarat, India

MB Patel
Associate Research Scientist & Unit Head, Main Maize Research Station, Anand Agricultural University, Godhra, Gujarat, India

JK Patel
Assistant Research Scientist, Agricultural Research Station, Anand Agricultural University, Sansoli, Gujarat, India

KH Patel
Assistant Research Scientist, Main Maize Research Station, Anand Agricultural University, Godhra, Gujarat, India

PK Borad
Retd. Professor and Head, Department of Entomology, B. A. College of Agriculture, Anand Agricultural University, Anand, Gujarat, India

Corresponding Author
PK Borad
Assistant Research Scientist, Main Maize Research Station, Anand Agricultural University, Godhra, Gujarat, India

Evaluation of indigenous materials against fall armyworm, *Spodoptera frugiperda* (J.E. Smith) in Maize

HS Varma, DB Sisodiya, MB Zala, MB Patel, JK Patel, KH Patel and PK Borad

Abstract
The present investigation was carried out to evaluate the indigenous materials against fall armyworm, *Spodoptera frugiperda* (J.E. Smith) in maize. The multi-location field experiment was conducted at three places *viz*., Main Maize Research Station, AAU, Godhara, Entomology farm, Department of Entomology, BACA, AAU, Anand and Agricultural Research Station, AAU, Sansoli during *kharif* 2019 and 2020 in Randomized Block Design with seven treatments including control and three replications to evaluate indigenous materials on *S. frugiperda* infesting maize. Effect of different indigenous materials was evaluated by recording observations on number of FAW larvae/10 plants, plant damage (%), cob damage (%), grain yield (kg/ha) and dry fodder yield (kg/ha). The significantly lowest (1.90 larvae /10 plants) *S. frugiperda* incidence and highest grain and dry fodder yield was recorded in the treatment of whorl application of soil @ 5 g/ plant and it was found equally effective with whorl application of sand @ 5 g/plant. Among all the indigenous materials evaluated, the whorl application of saw dust @ 4 g/plant recorded the highest FAW incidence and lowest grain and dry fodder yield of maize and proved as most inferior indigenous material in their efficacy. Whorl application of soil @ 5 g/plant or whorl application of sand @ 5 g/plant at 30 and 45 days after sowing was emerged as effective in controlling fall armyworm, *S. frugiperda* infesting maize. The eco-friendly, no cost input indigenous materials that showed high efficacy against FAW can be used as components of Integrated Pest Management (IPM) for FAW management by small and marginal farmers to obtain the rich harvest and to keep the environment safe forever.

Keywords: Indigenous materials, maize, *Spodoptera frugiperda*, sustainable pest management

Introduction
Maize, *Zea mays* L. is the third most important cereal grain after wheat and rice globally, which is also called as the "Queen of Cereals" because of its highest genetic yield potential (Jeyaraman, 2017) [13]. Indian cultivation of maize cover over 9.86 million hectares of area with production of 26.26 million tonnes with productivity of 2664 kg/ha (Anon., 2018_a) [1]. In Gujarat, it occupies 4.00 lakh hectares of area producing 6.65 lakh tonnes with a productivity of 1663 kg/ha of maize (Anon., 2018_b) [2]. Maize is a traditional crop that is generally cultivated as a source of food, feed and fodder. Demand of maize crop is increasing in higher amount every year due to the higher nutritional benefits. Nutritionally, maize grains have 10% protein, 4% oil, 70% carbohydrate, 2-3% crude fibers, besides having Vitamin A and E, nicotinic acid and riboflavin but its protein Zein is deficient in tryptophan and lysine among essential acids and is deficient in calcium (Joshi, 2015) [14]. One of the major reasons for the decline in maize productivity is due to the insect pest infestation. It is attacked by nearly 130 species of insect pests in India causing considerable yield losses (Atwal and Dhaliwal, 2002) [6].

Recently, new invasive pest fall armyworm (FAW), *Spodoptera frugiperda* J.E. Smith (Lepidoptera: Noctuidae) causes significant damage to crops resulted in huge economic losses since its appearance in Africa during 2016. As of March 2019, it has been reported from 10 states in India - Andhra Pradesh, Bihar, Chhattisgarh, Gujarat, Karnataka, Maharashtra, Orissa, Tamil Nadu, Telangana, and West Bengal (Anon., 2019) [4] since its first appearance in Karnataka during May 2018 (Sharanabasappa *et al*., 2018) [19]. However, there have been reports of its spread to other Indian states-Rajasthan, Arunachal Pradesh, Assam, Manipur and Mizoram. Favourable weather conditions play a major role in FAW dispersal and subsequent infestation.

In Gujarat, it was also reported from Anklav village, of Anand district of Gujarat (Sisodiya *et al.*, 2018) [20]. FAW larvae cause damage to the plant by consuming foliage. Young larvae mainly feed on epidermal leaf tissue and also make holes in leaves, which is the typical damage symptom of FAW. In older plants, the larger larvae in the whorls can feed on maize cob or kernels, reducing yield and quality (Abrahams *et al*., 2017, Capinera, 2017) [5, 7]. Damage due to this pest attack can reduce corn grain yield up to 34 per cent as reported from Brazil (Lima *et al.,* 2009) [17], 20 to 50 per cent as reported from Africa (Early *et al*., 2018) [9] and has also caused huge yield losses in India during last year. According to Hruska and Gould (1997) [12], infestation during the mid-to-late corn stage resulted in yield losses of 15-73%, when 55-100% of the plants were infested with *S. frugiperda*. Farmers in the invaded area were not prepared for this devastating pest, resulting in heavy losses on one hand, but also a drastic increase of insecticide use on the other [Kansiime *et al*., 2019] [15]. Such over-reliance on insecticides is highly problematic due to potential environmental and health risks as well as the strong capability of the fall armyworm to quickly develop resistance (Zhu *et al*., 2015) [25]. Moreover, numerous applications of insecticides are increasing production costs; in particular, the often-used broad-spectrum products may disrupt current production systems of small holder farmers, which are often based on low inputs (Meagher *et al*., 2016) [18]. Aiming to solve these problems more sustainably, a strong need exists to identify alternative solutions for farmers that would be effective, affordable, in line with Integrated Pest Management (IPM) and tailored to suite the local conditions and farming practices. The indigenous materials can be effective for FAW management by various mode of action like sand is very abrasive and can scar insect larvae; ash too, ash is also very alkaline; ash, sand and sawdust may desiccate young larvae, soil can harbor pathogens that can kill FAW larvae, more effective especially when applied directly into the whorls of infested plants as it barely have a pre-harvest interval, eco-friendly, economical, have no relevant residues, and are safer to applicators and consumers (Anon., 2018_c) [3].

With the aim of testing the efficacy of the indigenous materials/practices for the management of FAW in maize, and ultimately with the aim of developing recommendations that can be used at scale especially for small and marginal farmers; a study was conducted on multi location basis to evaluate the different indigenous materials against FAW infesting maize.

Materials and methods

Study area, experimental design and treatments

The multi-location field experiment was conducted at three places *viz*., Main Maize Research Station, AAU, Godhara, Entomology farm, Department of Entomology, BACA, AAU, Anand, and Agricultural Research Station, AAU, Sansoli during *kharif* 2019 and 2020 in Randomized Block Design with seven treatments and three replications to evaluate different indigenous materials on *S. frugiperda* infesting maize. The maize variety GAYMH 1 was grown by following all standard agronomical practices except plant protection. The treatments were: whorl application of ash, 5 g/plant; whorl application of soil, 5 g/plant; whorl application of sand, 5 g/plant; whorl application of slurry (soil and water), 20 ml/plant; whorl application of saw dust, 4 g/plant; whorl application of mixture of 50 g ground black pepper +2 kg ash, 5 g/plant and control.

Application protocol

The first application of various indigenous materials was given at 30 days after germination in whorl of the plant and second after 15 days of first application.

Estimation of damage and yield

For recording FAW population and its damage, 10 plants were selected randomly from each net plot. The number of larva (e) and damaged plants were counted from randomly selected plants before as well as 3, 5, 10 and 15 days after each application. Numbers of damaged cobs were also recorded at harvest from each net plot. The grain and fodder yield were recorded from each net plot and converted into kg/ha.

Statistical analysis

The obtained data were subjected to statistical analysis of variance (ANOVA) after appropriate transformation to draw valid conclusion (Steel and Torrie, 1980) [21].

Results and Discussion

Larval population (No. of larvae/10 plants)

The data on larval population of *S. frugiperda* pooled over periods, locations and years of first application differed significantly to each other in both years at all three locations *i.e.,* Godhra, Anand and Sansoli (Table 1). The whorl application of soil @ 5 g/plant recorded the lowest (2.27 larvae/10 plants) larval population followed by whorl application of sand @ 5 g/plant (2.67 larvae /10 plants). The whorl application of ash @ 5 g/plant (3.48 larvae/10 plants), whorl application of slurry (soil and water) @ 20 ml/plant (3.50 larvae/10 plants) and whorl application of mixture of 50 g ground black pepper + 2 kg ash @ 5 g/plant (3.62 larvae/10 plants) were found at par with each other and remained mediocre treatments for the control of *S. frugiperda* larvae. The whorl application of saw dust @ 4 g/plant recorded the highest (4.32 larvae/10 plants) larval population. The data on pooled over periods, locations and years of second application indicated that whorl application of soil @ 5 g/ plant recorded the lowest (1.54 larvae /10 plants) larval population and it was found at par with whorl application of sand @ 5 g/plant (1.78 larvae /10 plants). Of the tested indigenous materials, whorl application of saw dust found least effective by recording the highest (4.68 larvae /10 plants) larval population (Table 1).

Table 1: Evaluation of local practices against fall armyworm, S. frugiperda infesting maize (Pooled over applications, locations and years)

Tr. No.	Treatments	No. of larva(e)/10 plants						
		1st application			2nd application			Pooled over applications, locations and years
		2019	2020	Pooled	2019	2020	Pooled	
1	Whorl application of ash @5 g/plant	1.74^{b} (2.53)	2.22^{bc} (4.43)	1.97^{c} (3.48)	1.79^{b} (2.70)	1.98^{b} (3.42)	1.88^{b} (3.03)	1.93^{b} (3.25)
2	Whorl application of soil @5 g/plant	1.48^{a} (1.69)	1.83^{a} (2.85)	1.65^{a} (2.27)	1.32^{a} (1.24)	1.53^{a} (1.84)	1.43^{a} (1.54)	1.54^{a} (1.90)

3	Whorl application of sand @5 g/plant	1.67^{b} (2.29)	1.90^{a} (3.11)	1.78^{b} (2.67)	1.42^{a} (1.52)	1.61^{a} (2.09)	1.51^{a} (1.78)	1.65^{a} (2.22)
4	Whorl application of slurry (soil and water) @ 20ml/plant	1.85^{c} (2.92)	2.17^{b} (4.21)	2.00^{c} (3.50)	1.99^{bc} (3.46)	1.87^{b} (3.00)	1.92^{b} (3.19)	1.96^{b} (3.36)
5	Whorl application of saw dust@ 4 g/plant	1.97^{d} (3.38)	2.40^{c} (5.26)	2.18^{d} (4.32)	2.19^{c} (4.30)	2.36^{c} (5.07)	2.27^{c} (4.68)	2.23^{c} (4.50)
6	Whorl application of mixture of 50 g ground black pepper +2 kg ash @ 5 g/plant	1.76^{bc} (2.60)	2.27^{bc} (4.65)	2.01^{c} (3.62)	1.83^{b} (2.85)	2.08^{b} (3.83)	1.95^{b} (3.3)	1.98^{b} (3.46)
7	Control	2.48^{e} (5.65)	2.94^{d} (8.14)	2.71^{e} (6.89)	2.85^{d} (7.62)	3.28^{d} (10.26)	3.07^{d} (8.92)	2.89^{d} (7.90)
S. Em.± Treatment (T)		0.03	0.06	0.04	0.09	0.08	0.06	0.04
Period (P)		0.11	0.05	0.05	0.02	0.07	0.04	0.04
Year (Y)		-	-	0.02	-	-	0.02	0.01
Application (A)		-	-	-	-	-	-	0.07
Location (L)		0.02	0.03	-	0.02	0.02	-	0.03
T x P		0.07	0.08	0.05	0.06	0.07	0.05	0.03
T x Y		-	-	0.06	-	-	0.06	0.04
P x Y		-	-	0.05	-	-	0.04	0.03
A x Y		-	-	-	-	-	-	0.02
A x P		-	-	-	-	-	-	0.04
A x T		-	-	-	-	-	-	0.03
T x L		0.06	0.07	-	0.06	0.06	-	-
L x Y		-	-	-	-	-	-	-
P x L		0.04	0.05	-	0.04	0.05	-	-
A x L		-	-	-	-	-	-	-
T x P x Y		-	-	0.13	-	-	0.12	0.09
Y x A xT		-	-	-	-	-	-	0.06
A x P x T		-	-	-	-	-	-	0.05
Y x A x P		-	-	-	-	-	-	0.04
T x P x L		0.13	0.14	-	0.11	0.13	-	-
Y x T x L		-	-	-	-	-	-	-
Y x A x P x T		-	-	-	-	-	-	0.13
C.D. at 5%		Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
C. V. %		12.12	10.91	11.47	10.79	11.02	10.93	11.17

Note:
1. Figures in parenthesis are retransformed values; those outside are Vx+0.5 transformed values.
2. Treatment mean(s) with the letter(s) in common are not differing significantly by DNMRT at 5% level of significance
3. Significant interactions: T, L, LS, LP, LT, AT, PT, LAP, LAT, where T=Treatment, P=Period, A=Application and Y = Year

Overall, the data on pooled over periods, applications and locations over years indicated significantly the lowest (1.90 larvae /10 plants) larval population of *S. frugiperda* in the treatment of whorl application of soil @ 5 g/ plant and it was found equally effective with whorl application of sand @ 5 g/plant (2.22 larvae /10 plants) [Table 1]. The whorl application of ash @ 5 g/plant (3.25 larvae/10 plants), whorl application of slurry (soil and water) @ 20 ml /plant (3.36 larvae /10 plants) and whorl application of mixture of 50 g ground black pepper + 2 kg ash @ 5 g/plant (3.46 larvae /10 plants) were found at par and remained as next effective treatments for the control of this pest. Among all the indigenous materials evaluated, the whorl application of saw dust @ 4 g/plant recorded the highest (4.50 larvae /10 plants) larval population of FAW in maize and proved as most inferior indigenous material in their efficacy.

The perusal of data presented in Table 3 on larval population of FAW over three locations over years revealed that lowest larval population was registered at Anand and sansoli (1.78 larvae/10 plants) followed by Godhra (2.09 larvae/10 plants).

Plant damage (%)

The data on plant damage (%) due to incidence of *S. frugiperda* pooled over periods, locations and years of first application differed significantly to each other in both years at all three locations (Table 2). The whorl application of soil @ 5 g/plant (16.84 %) recorded the lowest plant damage followed by whorl application of sand @ 5 g/plant (20.30%). The whorl application of slurry (soil and water) @ 20ml/plant (25.41%), whorl application of mixture of 50 g ground black pepper + 2 kg ash @ 5 g/plant (25.92%) and whorl application of ash @ 5 g/plant (26.39%) were found at par with each other and remained mediocre treatments for the control of *S. frugiperda*. The whorl application of saw dust @ 4 g/plant (32.04 %) recorded the highest plant damage (Table 2). The data on pooled over periods, locations and years of second application indicated that whorl application of soil @ 5 g/ plant (13.54%) recorded the lowest plant damage and it was found at par with whorl application of sand @ 5 g/plant (16.10%). Among all the evaluated indigenous materials, whorl application of saw dust @ 4 g/plant (39.59%) found least effective by recording the highest plant damage due to FAW (Table 2).

Overall, the data on pooled over periods, applications and locations over years indicated significantly the lowest plant damage due to *S. frugiperda* in the treatment of whorl application of soil @ 5 g/ plant (15.19 %) and it was found equally effective with whorl application of sand @ 5 g/plant (18.20 %). The whorl application of slurry (soil and water) @ 20 ml /plant (26.57 %) and whorl application of mixture of 50 g ground black pepper + 2 kg ash @ 5 g/plant (26.58%) and whorl application of ash @ 5 g/plant (26.85%) were found at par and remained as next effective treatments for the control of this pest. Of the tested indigenous materials, the whorl application of saw dust @ 4 g/plant (35.82 %) recorded the highest plant damage due to FAW in maize and proved as most inferior treatment in their efficacy.

The perusal of data presented in Table 3 on plant damage due to FAW over three locations over years revealed that the lowest plant damage was registered at Anand (13.78%) followed by Godhra (15.10%) and sansoli (16.05%).

Table 2: Evaluation of local practices against fall armyworm, S. frugiperda infesting maize (Pooled over applications, locations and years)

Tr. No.	Treatments	Plant damage (%)						
		1st application			2nd application			Pooled over applications, locations and years
		2019	2020	Pooled	2019	2020	Pooled	
1	Whorl application of ash @ 5 g/plant	27.74^{cd} (21.67)	33.91^{cd} (31.12)	30.83^{c} (26.39)	31.16^{bc} (26.77)	31.86^{bc} (27.86)	31.51^{b} (27.31)	31.16^{b} (26.85)
2	Whorl application of soil @ 5 g/plant	21.79^{a} (13.78)	26.49^{a} (19.90)	24.14^{a} (16.84)	20.91^{a} (12.74)	22.25^{a} (14.34)	21.58^{a} (13.54)	22.86^{a} (15.19)
3	Whorl application of sand @ 5 g/plant	24.83^{b} (17.63)	28.64^{b} (22.97)	26.74^{b} (20.30)	22.86^{ab} (15.09)	24.44^{a} (17.12)	22.65^{a} (16.10)	24.69^{a} (18.20)
4	Whorl application of slurry (soil and water) @ 20ml/plant	28.15^{d} (22.26)	32.31^{c} (28.57)	30.23^{c} (25.41)	34.63^{cd} (32.29)	28.79^{b} (23.19)	31.71^{b} (27.74)	30.97^{b} (26.57)
5	Whorl application of saw dust @ 4 g/plant	30.60^{e} (25.91)	38.16^{e} (38.18)	34.38^{d} (32.04)	39.92^{d} (41.18)	38.06^{d} (38.01)	38.99^{c} (39.59)	36.68^{c} (35.82)
6	Whorl application of mixture of 50 g ground black pepper +2 kg ash @ 5 g/plant	25.84^{bc} (19.00)	34.97^{d} (32.85)	30.40^{c} (25.92)	28.9^{bc} (23.36)	33.92^{cd} (31.14)	31.41^{bc} (27.25)	30.90^{b} (26.58)
7	Control	40.26^{f} (41.76)	45.62^{f} (51.08)	42.94^{e} (46.41)	53.81^{e} (65.14)	55.42^{e} (67.79)	54.61^{d} (66.46)	48.77^{d} (56.44)
S. Em.± Treatment (T)		0.72	0.67	0.61	2.11	1.45	1.31	0.99
Period (P)		1.82	0.75	0.96	1.12	1.30	0.72	0.54
Year (Y)		-	-	0.45	-	-	0.46	0.32
Application (A)		-	-	-	-	-	-	1.67
Location (L)		0.47	0.44	-	0.42	0.49	-	0.57
T x P		1.45	1.34	0.99	1.30	1.50	1.00	0.70
T x Y		-	-	1.21	-	-	1.23	0.86
P x Y		-	-	0.91	-	-	0.93	0.65
A x Y		-	-	-	-	-	-	0.46
A x P		-	-	-	-	-	-	0.86
A x T		-	-	-	-	-	-	0.85
T x L		1.25	1.16	-	1.13	1.30	-	-
L x Y		-	-	-	-	-	-	-
P x L		0.94	0.88	-	0.85	0.98	-	-
A x L		-	-	-	-	-	-	-
T x P x Y		-	-	2.42	-	-	2.47	1.73
Y x A xT		-	-	-	-	-	-	1.22
A x P x T		-	-	-	-	-	-	1.00
Y x A x P		-	-	-	-	-	-	0.92
T x P x L		2.51	2.33	-	2.26	2.60	-	-
Y x T x L		-	-	-	-	-	-	-
Y x A x P x T		-	-	-	-	-	-	2.45
C.D. at 5%		Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
C. V. %		15.28	11.78	13.38	11.83	13.43	12.61	13.02

Note:
1. Figures in parenthesis are retransformed values; those outside are arc sine transformed values
2. Treatment mean(s) with the letter(s) in common are not differing significantly by DNMRT at 5% level of significance
3. Significant interactions: T, L, LS, LP, LT, AT, PT, LAP, LAT, where T=Treatment, P=Period, A=Application and Y = Year

Table 3: Evaluation of local practices against fall armyworm, *S. frugiperda* infesting maize (Pooled over locations over years)

Tr. No.	Treatment	No. of larva(e)/10 plants*			Plant damage (%) **		
		Godhra	Anand	Sansoli	Godhra	Anand	Sansoli
1	Whorl application of ash @ 5 g/plant	1.95^{b} (3.30)	1.99^{b} (3.46)	1.85^{bc} (2.92)	29.17^{bc} (23.76)	31.80^{b} (27.77)	32.42^{b} (28.74)
2	Whorl application of soil @ 5 g/plant	1.61^{a} (2.09)	1.51^{a} (1.78)	1.51^{a} (1.78)	22.87^{a} (15.10)	21.79^{a} (13.78)	23.62^{a} (16.05)
3	Whorl application of sand @ 5 g/plant	1.72^{a} (2.46)	1.61^{a} (2.09)	1.62^{ab} (2.12)	24.47^{a} (17.16)	24.52^{a} (17.22)	26.32^{a} (19.66)
4	Whorl application of slurry (soil and water) @ 20 ml/plant	1.99^{b} (3.46)	2.02^{bc} (3.58)	1.90^{c} (3.11)	28.74^{b} (23.12)	31.29^{bc} (26.97)	32.50^{b} (28.87)
5	Whorl application of saw dust @ 4 g/plant	2.22^{c} (4.43)	2.27^{d} (4.65)	2.20^{d} (4.34)	32.46^{c} (28.81)	38.04^{d} (37.97)	39.68^{c} (40.77)
6	Whorl application of mixture of 50 g ground black pepper +2 kg ash @ 5 g/plant	1.99^{b} (3.46)	2.12^{c} (3.99)	1.85^{bc} (2.92)	28.07^{b} (22.14)	32.73^{c} (29.23)	31.81^{b} (27.78)
7	Control	3.19^{d}	2.79^{e}	2.69^{e}	49.47^{d}	46.08^{e}	51.06^{d}

		(9.68)	(7.28)	(6.74)	(57.77)	(51.88)	(60.50)
S. Em.± Treatment (T)		0.06	0.07	0.08	1.10	0.96	1.79
Year (Y)		0.02	0.16	0.02	0.55	3.78	0.29
T x Y		0.05	0.11	0.04	1.45	2.23	0.78
C. D. at 5%		Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
C. V. %		12.17	10.63	10.50	15.71	12.35	11.22

Note:
1. *Figures in parenthesis are retransformed values; those outside are Vx+0.5 transformed values
2. **Figures in parenthesis are retransformed values; those outside are arc sine transformed values
3. Treatment mean(s) with the letter(s) in common are not differing significantly by DNMRT at 5% level of significance
4. Significant parameters and its interactions: T, Y, T x Y where T=Treatment and Y= Year

Cob damage (%)

The data on cob damage (%) due to FAW pooled over locations and years showed significant difference among the various indigenous materials evaluated (Table 4). Whorl application of soil @ 5 g/plant (19.92 %) recorded the lowest cob damage and it was at par with whorl application of sand @ 5 g/plant (22.62 %). The treatment of whorl application of of slurry @ 20 ml/plant, whorl application of ash @ 5 g/plant and whorl application of mixture of 50 g ground black pepper + 2 kg ash @ 5 g/plants found mediocre against the pest. The highest cob damage recorded in whorl application of saw dust @ 4 g/plant (40.75 %) and proved as least effective in controlling the FAW in maize (Table 4).

Grain yield (kg/ha)

Among the tested indigenous materials; based on the data of pooled over locations and years, the highest grain yield recorded in the treatment of whorl application of soil @ 5 g/plant (2958 kg/ha) which was at par with whorl application of sand @ 5 g/plant (2952 kg/ha) [Table 4]. The lowest grain yield was recorded in the treatment of whorl application of saw dust @ 4 g/plant (2354 kg/ha).

Dry fodder yield (kg/ha)

Among the tested indigenous materials; based on the data of pooled over locations and years, the highest dry fodder yield recorded in the treatment of whorl application of sand @ 5 g/plant (4096 kg/ha) which was at par with whorl application of soil @ 5 g/plant (3987 kg/ha) [Table 4]. The lowest dry fodder yield was recorded in the treatment of whorl application of saw dust @ 4 g/plant (3284 kg/ha).

A number of publications have recently assessed the spread and impact of FAW, as well as farmer practices, in order to fight against the pest (Tambo *et al*., 2020; De Groote *et al*., 2020) [22, 8]. There is a lack of studies on innovative and sustainable management approaches for FAW including local methods used by farmers in many parts of the world, despite wide agreement that there is urgent need for these (Hruska, 2019) [11]. For the ash and soil based treatments, reports indicate that a number of farmers use these methods in Africa (Kansiime *et al*., 2019, Tambo *et al*., 2020, Kumela *et al*., 2019) [15, 22, 16], as well as in the Americas (Wyckhuys *et al*., 2019) [24]. A recent study showed that less than 1% of farmers in Ghana and about 5% of farmers in Zambia use ash for FAW control. Decision making of farmers in five African countries found that between 2.5 and 17.7% of farmers apply ash or sand to the whorl, of which 48-77 % responded positively that they are efficacious, compared to 92-97 % responding positively for synthetic insecticides (Tambo *et al*., 2020) [23]. In Central America, soil has been used against *S. frugiperda* for a long time (Wyckhuys *et al*., 2019) [24]. The fall armyworm menance can be reduced by the whorl application of soil, sand, ash or saw dust (Anon., 2018_c) [3]. Application of dry sand in to the whorl of affected maize plants soon after observation of FAW incidence in the field was reported by Firake *et al*. (2019). Kansiime *et al*. (2019) [10, 15] reported that farmers in Zambia practiced handpicking of eggs, crushing of larvae and adding ash/sand to crop whorls. Hence, all these reports support the present investigations on efficacy of indigenous materials against *S. frugiperda*.

Table 4: Evaluation of local practices against fall armyworm, S. frugiperda infesting maize (Pooled over locations and years)

Tr. No.	Treatments	Cob damage (%)			Yield (kg/ha)					
					Grain			Fodder		
		2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled
1	Whorl application of ash @5 g/plant	33.13^{b} (29.87)	36.91^{cd} (36.07)	35.02^{b} (32.93)	2480^{bc}	2789^{abc}	2634^{bc}	3491^{c}	3900^{abc}	3696^{abc}
2	Whorl application of soil @5 g/plant	24.41^{a} (17.08)	28.60^{a} (22.91)	26.51^{a} (19.92)	2856^{a}	3059^{a}	2958a	3938^{a}	4037^{abc}	3987^{a}
3	Whorl application of sand @5 g/plant	26.06^{a} (19.3)	30.74^{ab} (26.13)	28.40^{a} (22.62)	2716^{ab}	3188^{a}	2952^{a}	3834^{ab}	4358^{a}	4096^{a}
4	Whorl application of slurry (soil and water) @ 20ml/plant	34.40^{b} (31.92)	34.90^{bc} (32.74)	34.67^{b} (32.36)	2543^{bc}	2868^{ab}	2706^{ab}	3529^{bc}	4089^{ab}	3809^{ab}
5	Whorl application of saw dust@ 4 g/plant	35.75^{b} (34.13)	43.60^{e} (47.56)	39.67^{c} (40.75)	2365^{c}	2342^{cd}	2354^{c}	3427^{c}	3141^{cd}	3284^{c}
6	Whorl application of mixture of 50 g ground black pepper +2 kg ash @ 5 g/plant	33.10^{b} (29.82)	40.31^{de} (41.85)	36.71^{bc} (35.73)	2614^{abc}	2484^{bc}	2549^{bc}	3608^{abc}	3321^{bcd}	3465^{bc}
7	Control	44.18^{c} (48.57)	51.28^{f} (60.87)	47.73^{d} (54.76)	1806^{d}	1963^{d}	1885^{d}	2652^{d}	2635^{d}	2643^{d}
S. Em.± Treatment (T)		1.91	1.57	1.33	85.13	156.42	95.88	105.25	292.29	159.31
Year (Y)		-	-	0.87	-	-	60.42	-	-	76.96
Location (L)		0.77	0.95	-	51.17	68.43	-	71.30	82.23	-
T x Y		-	-	2.30	-	-	159.86	-	-	203.63
T x L		2.05	2.52	-	135.38	181.07	-	188.66	217.58	-

L x Y	-	-	-	-	-	-	-	-	-
Y x T x L	-	-	-	-	-	-	-	-	-
C.D. at 5%	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
C. V. %	10.80	11.49	11.22	9.44	11.74	10.74	9.34	10.35	9.88

Note:
1. Figures in parenthesis are retransformed values; those outside are arc sine transformed values
2. Treatment mean(s) with the letter(s) in common are not differing significantly by DNMRT at 5% level of significance
3. Significant interactions: T, L and Y, where T = Treatment, L = Location and Y = Year

Conclusion
In nutshell, whorl application of soil @ 5 g/plant or whorl application of sand @ 5 g/plant at 30 and 45 days after sowing was emerged as effective in controlling fall armyworm, *S. frugiperda* infesting maize. These indigenous materials are eco-friendly, no cost input and can be best suited in the components of Integrated Pest management (IPM) for sustainable pest management.

Acknowledgement
Authors thanks to Hon. Vice Chancellor, Dr. K.B. Kathiria and Director of Research & Dean, PG Studies, Dr. M.K. Jhala AAU, Anand for giving permission to carry out research and publication of this manuscript.

Add-on Information
Authors' contribution
H.S. Varma: Conceived and designed the experiments, Experimental Research
D.B. Sisodiya: Experimental Research.
M.B. Zala: Experimental Research.
M.B. Patel: Experimental Research.
J.K. Patel: Experimental Research
K.H. Patel: Experimental Research
P.K. Borad: Manuscript writing and data analysis.

Research content
The research content is original and has not been published elsewhere.

Ethical approval
Not Applicable

Conflict of interest
The authors declare that there is no conflict of interest.

Data from other sources
Not Applicable

Consent to publish
All authors agree to publish the paper in Journal of The PhermaI Innovation International Journal.

References
1. Anonymous. Annual report 2017-18. Department of agriculture, cooperation & farmers welfare, Ministry of agriculture & farmers welfare, Government of India, New Delhi. Retrieved from http://www.agricoop.nic.in 2018a.
2. Anonymous. Crop wise fourth advance estimate of area, production and yield of food grains, oilseeds and other crops for 2017-18 of Gujarat state, Directorate of Agriculture, Agriculture Co-operation Department, Government of Gujarat. Retrieved from https://dag.gujarat.gov.in/index.htm 2018b.
3. Anonymous. Integrated management of the Fall Armyworm on maize. Retrieved from http://www.fao.org/3/i8665en/i8665en.pdf 2018c.
4. Anonymous. EPPO Reporting Service No. 03 – 2019. Num. article: 2019/053.
5. Abrahams P, Bateman M, Beale T, Clottey V, Cock M, Colmenarez Y *et al*. Fall Armyworm: Impacts and Implications for Africa; Evidence Note 2019, 2.
6. Atwal AS, Dhaliwal GS. Agricultural Pests of South Asia and Their Management. Kalyani Publishers, Ludhiana 2002, 189-192p.
7. Capinera JL. Fall Armyworm, Spodoptera frugiperda (J. E. Smith) (Insecta: Lepidoptera: Noctuidae), 2017. Available online: http://edis.ifas.ufl.edu/in255 2017.
8. De Groote H, Kimenju SC, Munyua B, Palmas S, Kassie M, Bruce A. Spread and impact of fall armyworm (Spodoptera frugiperda JE Smith) in maize production areas of Kenya. Agric. Ecosys. Environm 2020;292:106804.
9. Early R, Gonzales-Moreno P, Murphy ST, Day R. Forecasting the global of invasion of the cereal pest *Spodoptera frugiperda*, the fall armyworm. Neobiota 2018;40:25-50.
10. Firake DM, Behere GT, Babu Subhash, Prakash N. Fall Armyworm: Diagnosis and Management (An extension pocket book). ICAR Research Complex for NEH Region, Umiam-793 103, Meghalaya, India 2019,48p.
11. Hruska AJ. Fall armyworm (*Spodoptera frugiperda*) management by smallholders. CAB Rev 2019;14:1-11.
12. Hruska A, Gould F. Fall Armyworm (Lepidoptera: Noctuidae) and *Diatraea lineolata* (Lepidoptera: Pyralidae): Impact of Larval Population Level and Temporal Occurrence on Maize Yield in Nicaragua. Journal of Economic Entomology 1997;90(2):611-622.
13. Jeyaraman S. Field Crops Production and Management Vol I. New Delhi: Oxford and IBH Publishing Co. Pvt. Ltd 2017.
14. Joshi M. Text Book of Field Crops. New Delhi: PHI Learning Private Limited 2015.
15. Kansiime MK, Mugambi I, Rwomushana I, Nunda W, Lamontagne-Godwin J, Rware H. Farmer perception of fall armyworm (*Spodoptera frugiderda* J.E. Smith) and farm-level management practices in Zambia. Pest Manag Sci 2019;75:2840-2850.
16. Kumela T, Simiyu J, Sisay B, Likhayo P, Mendesil E, Gohole L *et al*. Farmers' knowledge, perceptions, and management practices of the new invasive pest, fall armyworm (*Spodoptera frugiperda*) in Ethiopia and Kenya. Int. J. Pest Manag 2019;65:1-9.
17. Lima MS, Oliveira OF, Silva PSL, Silva KMB. Corn yield response to weed & fall armyworm controls. Planta Daninha 2009;28(1):103-111.
18. Meagher RL, Nuessly GS, Nagoshi RN, Hay-Roe MM. Parasitoids attacking fall armyworm (Lepidoptera: Noctuidae) in sweet corn habitats. Biol. Control 2016;95:66-72.
19. Sharanabasappa D, Kalleshwaraswamy CM, Asokan R, Mahadevaswamy HM, Marutid MS, Pavithra HB *et al*.

First report of the fall armyworm, *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera: Noctuidae), an alien invasive pest on maize in India. Pest Management in Horticultural Ecosystems 2018;24(1):23-29.
20. Sisodiya DB, Raghunandan BL, Bhatt NA, Verma HS, Shewale CP, Timbadiya BG *et al*. The fall armyworm, *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera: Noctuidae); first report of new invasive pest in maize fields of Gujarat, India. Journal of Entomology & Zoology Studies 2018;6(5):2089-2091.
21. Steel RGD, Torrie JH. Principles and procedures of statistics. Publ. McGraw Hill Book Company, New York 1980, 137p.
22. Tambo JA, Day RK, Lamontagne-Godwin J, Silvestri S, Beseh PK, Oppong-Mensah B *et al*. Tackling fall armyworm (*Spodoptera frugiperda*) outbreak in Africa: An analysis of farmers' control actions. Int. J Pest Manag 2020;66:298-310.
23. Tambo JA, Kansiime MK, Mugambi I, Rwomushana I, Kenis M, Day RK. Smallholders' responses to fall armyworm invasion: Cross-country evidence from sub-Saharan Africa. Glob. Env. Change, In review 2020.
24. Wyckhuys KA, O'Neil RJ. Local agro-ecological knowledge and its relationship to farmers' pest management decision making in rural Honduras. Agric. Human Values 2007;24:307-321.
25. Zhu YC, Blanco CA, Portilla M, Adamczyk J, Luttrell R, Huang F. Evidence of multiple/cross resistance to Bt and organophosphate insecticides in Puerto Rico population of the fall armyworm, Spodoptera frugiperda. Pestic. Biochem. Physiol 2015;122:15-21.