EFFICACY OF PLANT MATERIALS AND STORAGE CONTAINERS AGAINST MAIZE WEEVIL, Sitophilus zeamais (Motschulsky) IN MAIZE STORAGE

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ABSTRACT

The experiments were conducted in laboratory condition (room temperature: Max 24-32°C and Min 18 - 27°C) at Khumaltar, Lalitpur (27˙39˙312m N latitude, 85˙19˙586m E longitude and 1322 masl) using botanicals: Corcuma domestica (Valot) rhizome flake and dust, Acorus calamus (Hamilt) stolen dust, Zingiber officinale (Roscoe) rhizome flake, Azadirachta indica (A. Juss) leaf dust, Citrus limon (Burmann) leaf dust, Juglans nigra (L.) leaf dust, Debregeasia saeneb (Forssk leaf dust, Cattle dung ash, Oryza sativa (L.) husk ash, Agave americana (L.) leaf ash, and in another experiment botanical with storage containers: Aluminium pot, earthen pot, polythene pot and jute bag each with botanicals (A. calamus dust, A. indica leaf dust and O. sativa husks ash) as treatments against Sitophilus zeamais (Mostch.) in CRD with 3 replications. The studies revealed that extent of grain damage varied depending upon types of botanicals and storage containers. A. calamus dust @ 25g/kg was effective against S. zeamais for 230 days, which was 16 times better than control in terms of bored grains. Regarding the storage containers with botanicals, aluminium container with A. calamus treatment was 28 times better than jute bag without botanical treatment (82.5%) in term of grain damage. Hence, the findings indicated potential use of A. calamus and aluminium storage container with A. calamus against weevils in maize storage.

Keywords: Botanicals, dust, maize grains, Sitophilus zeamais, storage containers

INTRODUCTION

Cereals are major food crops in Nepal, of which maize is the second most important cereal crop in terms of area cultivated (891583 ha) and productivity (2.5 t/ha) after rice (1362908 ha and 3.2 mt/ha) (MOAD, 2015/016). Post harvest loss in maize is high. Golob (1994) reported 50-100% infestation by weevils in maize storage for 8 months period and Paneru et al. (1996) reported storage losses of up to 32% (grain weight) due to the maize weevils. About 2400 species of botanicals inherited with pesticide properties are reported in the world (Grainge and Ahmed, 1988), and among them 311 species are commonly available in Nepal (Neupane, 1999). NARC (1999) recommended various botanicals such as *A. indica* containing 0.15% azadirachtin (MargoSom 0.15%) and *A. indica* seed dust, respectively @ 1ml and 1g per 100g of grains, *A. calamus* rhizome dust @ 1g in 100g of stored maize and *C. domestica* dust @ 2g in 100g of stored grains to protect stored grains. Gyawali (1993) reported farmers traditionally using more than 50 plant species against insect pests in crops and stored grains. G.C. (2006) reported that the metal bin was found superior to jute bag and bamboo mat to store maize grains for six months. Malla et al. (2007) reported that jute bag with inner plastic lining was superior to plastic jar and plastic bag to store grains for the period of 75 days. Nepalese farmers follow diverse maize storage practices using locally made containers (metallic containers, earthen pots, bamboo baskets and jute bags) and botanicals. However, these practices are reported to be inconsistent and unscientific in terms of their dose, application methods and container types, which vary depending upon the location, and being the least effective against *S. zeamais* in farmer storage conditions (Paneru et al., 2010). In Nepal, very little efforts have been made to develop affordable alternatives to chemical pesticides. Therefore, this study was undertaken to evaluate the efficacy of locally available materials and storage containers against *S. zeamais*.

MATERIALS AND METHODS

Experimental materials

Maize (Manakamana-1) was procured from reliable farmer in Lalitpur and kept free from pest and moisture maintained at 12%. Weevil culture was maintained in the laboratory of Entomology Division, Khumaltar, Lalitpur to produce homogenous population (F_2-progeny) for the experiment. The male and female weevils were sexed as per Walker (2008) and Halstead (1963). Botanicals (*Corcuma domestica* (Valot) rhizome, *Acorus calamus* (Hamilt) stolen, *Zingiber officinale* (Roscoe) rhizome, *Azadirachta indica* (A. Juss) leaf, *Citrus limon* (Burmann) leaf, *Juglans nigra* (L.) leaf, *Debregeasia saeneb* (Forssk leaf, Cattle dung, *Oryza sativa* (L.) husk, *Agave americana (*L.*)* leaf) were collected; shade dried and prepared their dusts, ash and flakes as treatments. Similarly, bamboo basket (*Dhaki*) (40cm diameter and 47.5cm height), aluminium pot (41.5cm height and 19cm diameter), earthen pot (44cm height and 21.5cm diameter), polythene pot (39cm height and 22.5cm diameter) and Jute bag (25kg capacity with 77cm height and 45cm breadth) were procured from nearby market.

Laboratory experiments

The first experiment was set up in a complete randomized design (CRD) in bamboo basket (*Dhaki*) with 3 replications under the laboratory condition (room temperature: Max 24-32°C and Min 18-27°C) at Entomology Division, Khumaltar (27˙39˙312^m N latitude, 85˙19˙586^m E longitude and 1322 masl). Twelve treatments; i) *C. domestica* rhizome flakes, ii) *C. domestica* rhizome dust, iii) *A. calamus* stolen dust, iv) *Z. officinale* rhizome flakes, v) *A. indica* leaf dust, vi) *C. limon* leaf dust, vii) *J. nigra* leaf dust, viii) *D. saeneb* leaf dust, ix) cattle dung ash, x) *O. sativa* husk ash, xi) *A. americana* leaf ash, and xii) untreated control, were tested against *S. zeamais*. Ten kg maize grain was kept in each bamboo basket, which was admixed with each plant material @ 25g/kg. The flake material was placed in 3 layers of grains at bottom, middle and top. Then, 20 days old 10 pairs F_2-progeny of fresh *S. zeamais* (adult male and female) were released in each container as inoculums. The container was covered with its lid and well labeled for further observation. The experiment was set on last week of January, 2016 and the first observation was made on the first week of March at 45 days with subsequent observations taken up to 230 days.

Another set of experiment was carried out in the same laboratory condition in CRD with three replications at Entomological Division, Khumaltar during February–September, 2016. In each container, 10 kg maize grains were admixed with selected botanicals as earlier (25g/kg grains), then 20 days old 10 pairs F_2-progeny of fresh *S. zeamais* (adult male and female) were released in each container as inoculums. The treatments were: i) Aluminium pot + *A. calamus* stolen dust, ii) Aluminium pot + *A. indica* leaf dust, iii) Aluminium pot + *O. sativa* husk ash, iv) Aluminium pot + control, v) Earthen pot + *A. calamus* stolen dust, vi) earthen pot + *A. indica* leaf dust, vii) earthen pot + *O. sativa* husk ash, viii) Earthen pot + control, ix) Polythene pot + *A. calamus* stolen dust, x) Polythene pot + *A. indica* leaf dust, xi) Polythene + *O. sativa* husk ash, xii) Polythene pot + control, xiii) Jute bag + *A. calamus* stolen dust, xiv) Jute bag + *A. indica* leaf dust, xv) Jute bag + *O. sativa* husk ash, xvi) Jute bag + control. The storage container was the main factor and the botanical treatment as sub-factor. The first observation was made on the third week of April at 40 days and the subsequent observations continued up to 180 days.

Observations were taken randomly sampling maize grains from each treatment by using 200 ml plastic bottle. The grains bored by weevils were sorted and counted for statistical analysis. Weevils damaged grains were distinguished through appearance of shape and size of their exit holes. Exit hole made by weevils was near to kernel tip, a bit larger, irregular and dirty (Insect waste). Grains bored percent data were transformed into arcsine and analyzed using R package for analysis of variance (ANOVA) in CRD and Duncan Multiple Range Test (DMRT) was used for significant mean separation at 5% level.

RESULTS AND DISCUSSION

Effects of botanicals against *S. zeamais*

Up to 130 day of storage, there were no variations among the treatments for grains damage. At 150 days of storage, significant differences were observed at <1% level (Table 1). The grain damage ranged from 1.1 to 14.8%, which was low in *C. domestica* rhizome dust, cattle dung ash, *A. calamus* stolen dust, *A. americana* leaf ash and *O. sativa* husk ash treatment indicating their strong effect against *S. zeamais*, with the highest grain damage in control treatment.

Table1. Effect of botanical treatments on maize grain damage by *S. zeamais*, Khumaltar, Lalitpur, 2016

SN	Treatments	Mean bored grains (%)±SE at indicated days ^{0}					
		130 days	150 days	170 days	190 days	210 days	230 days
1.	Cattle dung ash	1.4±0.5 (0.12)	1.7± 0.2 (0.13) c	1.4±0.5 (0.11)c	2.2± 0.4 (0.15) e	16.1±3.9 (0.41) d	43.8±6.2 (0.72)d
2.	*Oryza sativa* L. rice husk ash	2.0±0.6 (0.14)	2.3± 0.4 (0.15) c	2.9±0.9 (0.16)c	5.4±1.7 (0.23) de	19.7±5.0 (0.45) d	63.2±3.5 (0.92)cd

3.	*Agave americana* L., century plant leaf ash	1.7±0.3 (0.13)	2.1± 0.3 (0.15) c	1.5±0.5 (0.12)c	3.6±0.2 (0.19) de	23.0±3.3 (0.50) d	47.3±6.8 (0.76)d
4.	*Corcuma domestica* (Valot) turmeric rhizome flake	2.2±1.3 (0.14)	7.7± 1.3 (0.28) b	27.2±0.5 (0.55)ab	49.7±8.3 (0.78)ab	80.9±1.3 (1.12)ab	84.4±2.4 (1.17)ab
5.	*Corcuma domestica* (Valot) turmeric rhizome dust	0.8±0.2 (0.09)	1.4± 0.1 (0.12) c	2.5±1.2 (0.15)c	12.2±4.2 (0.35) d	57.1±9.5 (0.86) c	78.5±4.4 (1.09)abc
6.	*Acorus calamus* (Hamilt) sweet flag stolen dust	2.0±0.1 (0.14)	1.8± 0.4 (0.13) c	1.6±0.4 (0.13)c	0.9±0.1 (0.09) e	4.3±2.6 (0.19) e	4.6±2.2 (0.21)e
7.	*Zingiber officinale* (Roscoe) ginger rhizome flake	2.9±0.4 (0.17)	14.7± 4.4 (0.39) a	33.9±5.4 (0.62)a	58.9±7.9 (0.88) a	85.1±3.4 (1.18) a	89.3±3.6 (1.25)a
8.	*Azadirachta indica* (A. Juss) neem leaf dust	1.5±0.1 (0.12)	3.8± 0.9 (0.19) bc	19.6±9.4 (0.43)ab	35.7±3.2 (0.64) bc	83.0±0.6 (1.15) a	83.4±3.4 (1.16)ab
9.	*Citrus limon* (Burmann) Lemon leaf dust	1.2±0.2 (0.11)	4.2± 0.7 (0.21) bc	17.5±9.2 (0.41)b	26.2±4.2 (0.53) c	74.6±2.8 (1.04)ab	82.3±2.1 (1.14)ab
10.	*Juglans nigra* L. walnut leaf dust	1.9±0.6 (0.13)	4.9± 2.8 (0.21) bc	17.1±5.4 (0.42)ab	55.9±7.6 (0.85) a	68.2±2.2 (0.97) bc	86.2±3.2 (1.20)ab
11.	*Debregeasia saeneb* (Forssk) Tusharo leaf dust	2.2±0.8 (0.14)	4.4±0.9 (0.21) bc	20.5±4.3 (0.46)ab	56.0±4.7 (0.85)a	79.3±3.9 (1.10)ab	70.1±13.8 (1.01)bc
12.	Control	2.4±0.5 (0.16)	14.8±2.1 (0.40) a	26.3±7.1 (0.53)ab	56.2±4.9 (0.85) a	76.4±2.8 (1.06)ab	87.4±2.5 (1.21)a
	F-value	1.185	9.453	8.94	34.03	48.99	21.52
	P-value	0.348	$2.75e^{-06}$	$4.53e^{-06}$	$6.05e^{-12}$	$1.03e^{-13}$	$8.5e^{-10}$
	CV (%)	25.8	25.0	32.7	17.5	10.3	11.4

[0]Values are means of 3 replications; SE= Standard error; Means followed by the same letters within each column are not significantly different at 5% level by DMRT

Highly significant differences occurred among the treatments after 170 to 230 days of observations (Table 1). Up to 210 days of storage, *A. calamus* stolen dust, cattle dung ash, *O. sativa* husk ash and *A. americana* leaf ash treatments were superior to the rest of other treatments against *S. zeamais,* but they were not significant among themselves. Only *A. calamus* stolen dust treatment was effective against *S. zeamais* up to 230 days of grain storage (Table 1).

The findings showed that *A. calamus* stolen dust was the most effective against *S. zeamais* for the storage period of 230 days, in which the bored grain was the lowest (5.6%) as compared to the control (87.4%) (Table 1). Ashes of cattle dung, *O. sativa* husks and *A. americana* leaf also provided satisfactory control (16-23% bored grains) of *S. zeamais* as compared to the control (76% bored grains) up to 210 days.

Effects of botanicals with containers against *S. zeamais*

There were significant differences among the botanical treatments at <10% level for mean proportion bored grains (Table 2). *A. calamus* stolen dust was superior to *A. indica* leaf dust and *O. sativa* husk ash against *S. zeamais* (Table 3). Whereas, no variations were observed among the selected storage containers at <10% level in term of grain damage (Table 4).

Table 2. Effect of storage container with botanicals on maize grain damage by *S. zeamais*, Khumaltar, Lalitpur (March-June, 2016)

SN	Treatments		Mean bored grains (%)±SE at indicated days⁰					
	Container	Botanicals	80 day	100 day	120 day	140 day	160 day	180 day
1.	Aluminium pot	*A. calamus* rhizome dust	2.6±0.2	2.3±0.4	3.1±0.2	2.9±0.6	2.9±0.4	2.9±0.3
		A. indica leaf dust	3.3±0.6	3.8±0.8	3.5±0.1	3.5±0.7	3.9±0.7	4.7±1.5
		O. sativa husk ash	4.3±0.4	4.0±0.7	3.5±0.2	4.3±0.8	4.5±1.4	3.98±1.0
		Control	4.4±0.8	3.5±1.0	3.8±0.8	10.5±7.0	5.1±0.9	5.4±1.1
2.	Earthen pot	*A. calamus* rhizome dust	3.1±0.6	3.5±0.6	2.3±0.6	1.4±0.3	3.7±0.7	3.1±1.0
		A. indica leaf dust	3.7±0.7	3.1±0.6	4.2±0.7	21.1±2.3	43.9±3.1	75.8±2.8
		O. sativa husk ash	3.5±0.9	4.9±0.9	3.3±0.7	3.3±0.9	7.3±2.2	40.7±11.9
		Control	3.8±1.0	3.9±0.8	7.9±1.0	28.1±5.2	52.1±4.2	76.5±3.0
3.	Plastic pot	*A. calamus* rhizome dust	2.7±0.4	3.1±0.5	3.6±0.3	3.8±1.3	4.5±0.6	3.1±1.0
		A. indica leaf dust	3.7±1.1	2.6±0.3	2.9±0.4	3.4±0.7	7. 8±3.1	15.4±9.2
		O. sativa husk ash	3.8±0.6	3.5±0.1	3.8±1.7	3.2±0.2	4.1±1.1	3.9±0.5
		Control	3.6±0.3	5.3±0.6	4.2±0.9	11.3±1.0	16.4±1.9	37.1±12.4
4.	Jute bag	*A. calamus* rhizome dust	3.1±0.5	2.7±0.7	3.0±0.2	8.7±6.7	2.4±0.5	6.0±1.1
		A. indica leaf dust	4.0±1.0	3.0±0.8	8.1±1.0	38.1±5.5	54.5±10.1	70.0±6.3
		O. sativa husk ash	4.2±0.4	2.6±0.4	4.6±0.3	3.2±0.8	9.211.2	41.8±6.7
		Control	3.9±0.6	3.6±0.5	7.3±2.7	44.6±2.3	67.1±8.5	82.5±4.0
F-value			0.263	1.13	1.972	6.508	16.48	9.325
Probability			0.98	0.37	0.077	3.19e-⁰⁵	1.14e-⁰⁹	8.83e-⁰⁷
CV (%)			16.7	16.5	19.7	27.9	20.3	21.9

[0]Values are means of 3 replications; SE= Standard error

Table 3. Effect of botanicals on maize grain damage by *S. zeamais*, Khumaltar, Lalitpur (March-June, 2016)

SN	Botanicals	Mean bored grain % ±SE at indicated days					
		80 day	100 days	120 days	140 days	160 day	180 days
1.	*A. calamus* rhizome dust	2.9±0.2 (0.17) b	2.9±0.3 (0.17) b	3.0±0.2 (0.17) c	4.2±1.7 (0.18) c	3.4±0.3 (0.18) c	3.8± 0.6 (0.19) d
2.	*A. indica* leaf dust	3.7±0.4 (0.19) ab	3.1±0.3 (0.18) ab	4.7±0.7 (0.21) ab	16.5±4.5 (0.38) b	27.5±7.1 (0.51) b	41.5±9.9 (0.66) b
3.	*O. sativa* husk ash	3.98±0.27 (0.20) a	3.73±0.4 (0.19) ab	3.8±0.4 (0.19) bc	3.5±0.33 (0.19) c	6.3±0.9 (0.25) c	2.6±6.3 (0.45) c
4.	Control	3.9±0.3 (0.20) a	4.1±0.4 (0.20) a	5.8±0.9 (0.24) a	23.6±4.6 (0.48) a	35.2±7.9 (0.60) a	50.4±9.9 (0.77) a
	F-value	2.425	2.87	5.547	35.490	81.30	61.910
	Probability	0.08	0.05	0.004	$2.70e^{-10}$	$4.67e^{-15}$	$2.03e^{-13}$
	CV (%)	16.7	16.5	19.7	27.9	20.3	21.9

SE= Standard error; Arcsine transformed mean values in parenthesis, Means followed by the same letters within each column are not significantly different at 5% level by DMRT

Table 4. Effect of storage containers on maize grain damage by *S. zeamais*, Khumaltar, Lalitpur (March-June, 2016)

SN	Containers	Mean bored grain (%)±SE at indicated days					
		80 day	100 day	120 day	140 day	160 day	180 day
1.	Aluminium pot	3.7±0.3 (0.19)	3.4±0.4 (0.18)	3.5±0.2 (0.19) b	5.3±1.8 (0.21) c	4.1±0.5 (0.20) c	4.3±0.5 (0.20) c
2.	Earthen pot	3.5±0.4 (0.19)	3.9±0.4 (0.19)	4. 5±0.7 (0.21) ab	13.5±3.7 (0.33) b	26.8±6.6 (0.50) a	49.0±9.5 (0.75) a
3.	Plastic pot	3.5±0.3 (0.19)	3.6±0.4 (0.19)	3.6±0.5 (0.19) b	5.4±1.1 (0.22) c	8.2±1.7 (0.27) b	14.9±5.3 (0.35) b
4.	Jute bag	3.8±0.3 (0.19)	3.0±0.3 (0.17)	5.8±0.9 (0.24) a	23.6±5.7 (0.46) a	33.3±8.9 (0.57) a	50.1±0.1 (0.77) a
	F-value	0.247	1.44	3.863	21.049	60.18	76.318
	Probability	0.86	0.25	0.018	$1.02e^{-07}$	$2.98e^{-13}$	$1.14e^{-14}$
	CV (%)	16.7	16.5	19.7	27.9	20.3	21.9

SE= Standard error; Arcsine transformed mean values in parenthesis, Means followed by the same letters within each column are not significantly different at 5% level by DMRT

In 120 days of storage, there were variations among the botanical treatments and significant difference was observed at <1% level in term of mean proportion bored grains (Table 2). The mean proportion of grains bored was low in *A. calamus* stolen dust treatment indicating its strong effect to *S. zeamais* (Table 3). Similarly, there were variations among the storage containers and

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the significant difference was observed at < 5% level for mean proportion of bored grains. The grain damage level was low in aluminium container as compared to other containers (Table 4).

Significant differences occurred among the botanicals with storage containers treatments after 140 to 180 days of observations (Table 2). There were variations among the botanicals and storage containers, and the significant difference was observed at <1% level for the mean proportion of bored grains (Table 3). *A. calamus* rhizome dust treatment was the most effective one to cause low grain damage by *S. zeamais*. Similarly, aluminium container was most effective to reduce grain damage by *S. zeamais* in maize storage (Table 4).

The study showed that there were variations among botanicals with storage containers and the significant differences were observed at <1% level for mean proportion of bored grains. *Acorus* dust treatment was superior to *A. indica* leaf dust and *O. sativa* husk ash treatments against *S. zeamais* and similarly aluminium container was superior to earthen pot, polythene and jute bag to reduce maize grain loss by *S. zeamais* in storage.

DISCUSSION

This study focused on grain damage (bored grains) as an important indicator of weevil response to different treatment in maize grain storage. The low proportion bored grains could be due to effect of treatments which prevented weevil attack. *A. calamus* rhizome dust @ 25g/kg maize grain was the most effective treatment to reduce weevil attack in maize grain storage. Paneru et al. (1997) reported that the β-asarone (pest killing property) content of the *A. calamus* rhizome dust was determined by GC-MS as 6.4 and 4.7% w/w (mature section of rhizomes collected at high and low altitudes, respectively) and 3.6 and 4.0% w/w (young sections of rhizomes collected at high and low altitudes, respectively). Active phytochemicals such as alkaloids have been found to disrupt growth and reduce larval survival by hindering loss of exoskeleton during larval development (Ileke and Ogungbite, 2014). Other active principles such as isoflavonoids, flavonoids and terpenoids have also been reported to inhibit reproduction and fertility among Coleopterons (Adesina et al., 2015; Chebet et al., 2013). The insecticidal and anti-feedant properties of ß-Asarone (Z-2, 4,5-trimethoxyp ropenylbenzene), a constituent of the rhizome of certain varieties of *A. calamus*, have been reviewed by Streloke et al. (1989). Paneru (1996) reported that some farmers of eastern hills of Nepal use local resources and herbal plants to control maize weevils. There are references reported by Grainge and Ahmed (1988), Stoll (1988), Golob and Webley (1980), Neupane (1999), and Neupane (2001), suggesting to use plant materials to protect storage grains from weevil. Including the wood-ash, as traditionally transferred technologies, farmers use botanicals, like *A. calamus*, *Zanthoxylum alatum* (Roxb.), *Artemisia vulgaris* (L.), *A. indica*, *Adhatoda vascica* (Nees), etc. particularly to protect stored grains against weevils (Joshi and Paneru, 1999). Ahmed et al. (1984) also suggested to use century plant (*A. americana*) against weevils. The use of botanical treatment is safe to human consumption and eco-friendly, i.e. no negative side effects like chemical pesticides. Similarly, maize grains were safe from weevil attack in aluminium container followed by polythene pot, earthen pot and jute bag. In addition, *A. calamus* rhizome dust was the most effective to reduce weevil damage in all four containers as compared to other treatments. This treatment was 13.7, 12.0, 24.7 and 1.9 times better than untreated grains in jute bag, polythene pot, earthen pot and aluminium pot containers, respectively, to reduce weevil damage for 180 days. Farmers can practice this treatment in semi-airtight storage containers. Manandhar and Shrestha (2000) reported farmers using various storage structures, such as bamboo baskets, earthen pots, metal bins, timber bins, jute bags for grain storage as traditional practice. Hence, present finding indicates that there is great potential of using botanicals as grain protectants and storage containers admixed with botanicals against insect pests in storage.

CONCLUSIONS

It is evident that the extent of grain damage varied depending upon the types of botanicals and storage containers. Among the treatments, *A. calamus* rhizome dust was the most effective against *S. zeamais* up to 230 days, which was 16 times better than control in terms of bored grains. Ashes of cattle dung, *O. sativa* husks and *A. americana* leaf were also satisfactory treatments to reduce grain damage for up to 6 months. Regarding the storage containers with botanicals, aluminium container with *A. calamus* treatment was 28 times better than jute bag without botanical treatment (82.5% bored grains) in term of grain damage. Hence, the findings indicated potential use of *A. calamus* and aluminium storage container with *A. calamus* against weevils in maize grain storage.

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