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Research Article

On Farm Evaluation of *Eucalyptus globulus Labill* Leaf and *Chenopodium ambrosioides* L. Whole Plant Powder against Storage Insect Pests in Stored Maize at Sokoru District in Jimma Zone of Oromia Regional State, Ethiopia

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Maize is the second most widely grown cereal and gaining importance as a highly nutritious crop in Ethiopia. However, it is severely destroyed by storage insect pests and needs further research to minimize losses. In line with this, research was initiated to evaluate the efficacy of two botanical plant powders (*Eucalyptus globulus Labill* leaf and *Chenopodium ambrosioides* L. whole plant) against storage insect pests of maize grains of two maize varieties (BH-661 and Limu) in polypropylene sacks storage conditions at Jimma Zone, Sokoru district. The plant powders were compared with untreated control, and completely randomized design was used in the experiment with three replications for each treatment. Germination capacity, thousand grain weights, percent of insect damage, and weight loss of the stored grains were evaluated and reported in the range of 69.67–94.33%, 318.7–339.3 g, 3.67–50%, and 0.2843–5.22%, respectively, after five months of storage for grains treated with botanicals. However, germination capacity of 10% and 65.33%, percent insect damage of 80.33% and 48%, and weight loss of 23.53% and 5.89% were observed for BH-661 and Limu varieties, respectively, after five months of storage for untreated control. The result indicated that both tested botanicals were effective in protecting the storage insect pests and maintaining the quality of the grains tested in comparison with control and *Chenopodium ambrosioides* L. whole plant powder is more effective. Although there was significant protective effect compared to untreated control, their effectiveness was decreased drastically after five and three months of storage for *Chenopodium ambrosioides* L. whole plant powder and *Eucalyptus globulus Labill* leaf powder, respectively. It is recommended that further research should be done to check if the increasing rate of application increases protection duration of these botanicals and the toxicity of *Chenopodium ambrosioides* L. should be further studied to use it as a storage insect protectant of maize grains intended for food purpose.

1. Introduction

Cereal crops play a major role in smallholder farmers' livelihoods in sub-Saharan Africa, with maize (*Zea mays* L.) being the most important food and cash crop for millions of rural farm families in the region [1]. In Ethiopia, maize is one of the major cereal crops grown for its food and feed values. It is one of the most important staple food and cash crops providing calories for the consumers and income for the traders [2].

Ethiopia is a tropical country in general, and maize is grown in low- and mid-altitude areas where there is relatively high temperature which favors insect infestation. Moreover, the greater proportion of maize is produced by resource-deficient farmers in remote villages, and they store maize using a poor postharvest storage facility, which often makes them incur high postharvest losses [3]. Furthermore, high yielding maize varieties were developed by Ethiopian Institute of Agricultural Research in collaboration with other centers to increase production and productivity and were reported to be highly susceptible to insect pest attacks both in the field and storage [4].

Storage insects are the primary cause of loss for maize grains in storage and constitute a great constraint to the realization of food security. Sori and Ayana [2] reported 64.50% grain damage and 58.85% weight losses due to insect pests in maize stored in traditional farmers storage between three to six months of storage in Jimma Zone, Ethiopia. Demissie et al. [4] also found 11 adult weevil emergence holes per ear and 59 adult weevils per ear in husk-covered maize stored at Bako, Ethiopia, after one month of storage. Moreover, Hengsdijk and de Boer [5] reported 37% loss of maize in Ethiopia due to insects based on self-reported postharvest loss. In western Kenya, farmers reported 26–75% maize grain damage due to storage insects during storage [1].

In Jimma Zone of Oromia regional state, Ethiopia, during postharvest storage, maize grains are vulnerable to many insects. Sori and Ayana [2] reported rice weevil *Sitophilus oryzae* (L.), maize weevil *S. zeamais*, Motschulsky, confused flour beetle *T. confusum* Jacquelin du Val, and Angoumois grain moth *Sitotroga cerealella* (Olivier) are the major insect pests associated with stored maize. These species are also cosmopolitan pests in stored grains globally [2].

A number of approaches ranging from cultural to use of pesticides have been advanced for management of post-harvest pests, considering the dual necessity to achieve food security and food safety, especially in developing economies [1]. Synthetic chemical insecticides have been widely used for the control of pests of stored grains. But, widespread use of synthetic pesticides has led to serious environmental pollution affecting human health and causing death of nontarget organisms [6, 7]. Therefore, the replacement of these synthetic insecticides in stored product protection by nontoxic substances is important to prevent environmental pollution and control of nontarget organisms.

Eucalyptus globulus Labill, which belongs to the family Myrtaceae and commonly known as Tasmanian blue gum, is one of the earliest species of eucalypts to be both validly named and formally described by the French botanist Jacques-Julien Houtou de Labillardière in 1800 [8]. It is one of well adapted species, widely planted, and having multipurpose uses and thus economic importance in Ethiopia. It is designated as Barzafi adi in Jimma Zone, Ethiopia, and 1,8-cineole is reported as the main constituents of *Eucalyptus globulus Labill* leaf essential oil [9, 10]. *Chenopodium ambrosioides* L., commonly known as Mexican tea or American worm wood or West Indian goose foot or epazote (family *Chenopodiaceae*), is a native of Central and South America and now distributed throughout the tropical parts of the world, and α-terpinene followed by p-cymene was reported as the main constituents of *Chenopodium ambrosioides* L. leaf essential oil [11]. In Jimma, Ethiopia, it is recognized as Fara-gonda.

So far, different attempts have been made to come up with an appropriate maize insect pest control method having promising results and being safer for environment and human. Mwangangi and Mutisya [12] evaluated performance of basil powder as insecticide against maize weevil. Muzemu et al. [13] used *Eucalyptus tereticornis*, *Tagetesminuta*, and *Carica papaya* as stored maize grain protectants against maize weevil. Longe [14] used cheese wood, lemon-scented gum, ginger, lime, mint and tobacco against maize weevil. Moges et al. [15] used ethanol extract of *A. indica*, *C. ambrosioides*, *M. lanceolata,* and diatomaceous earth. It has been shown that losses of grains due to weevil damage decrease with application of these botanical plants.

Gemechu et al. [16] reported high percent adult mortality, reduced progeny emergence, and low percent grain damage in using *Chenopodium ambrosioides* L. leaf powder against maize weevil, *Sitophilus zeamais*, under laboratory conditions. *Eucalyptus globules Labill* leaf powder provided good protection against pulse beetle, *Callosobruchus maculatus*, for black gram seeds by reducing insect oviposition and reduced progeny emergence and grain infestation rates [17].

Some of other botanicals that gave good control against storage insect pests include *Eucalyptus tereticornis* [13, 18], seed oil of *Brassica carinata* and *Gossypium hirsutum* [16], leaf powder of *Vitex negundo* and *Ipomoea sepiaria* K. [17], and leaf powder of *Azadirachta indica* A. [19].

Even though all the aforementioned botanicals are known for their effectiveness under laboratory conditions, only few studies were done under farmers' storage conditions. In order to reduce the stored maize losses by insect pests using safe, cheap, ecologically sound, and locally available alternative botanical pesticides, testing their efficiency under farmers' storage conditions were urgently required. Therefore, it was aimed to study the effectiveness of two locally available plant materials (*Eucalyptus globulus Labill* and *Chenopodium ambrosioide*s L.) against storage insect pests of grain maize under farmer's storage conditions.

2. Materials and Methods

2.1. Study Area. The study was conducted in Jimma Zone, Sokoru district, Ethiopia. It is located in southwestern part of Ethiopia at 345 km from Addis Ababa and lies between 7°33″N latitude and 36°57°E longitude with an elevation of 1710 m.a.s.l. The study area (Sokoru district) was selected based on agroecology (lowland) and maize production volume. The mean maximum and minimum temperature of the study area during the study period were 28.8°C and 14.8°C, respectively, and the mean maximum and minimum relative humidity were 88.4% and 56.8%, respectively.

2.2. Collection and Preparation of Experimental Materials. Whole part of *Chenopodium ambrosioides* L. plant and fresh leaves of *Eucalyptus globulus Labill* were collected from fields around Jimma town. The collected leaves were dried in a well-ventilated area under shade and then ground to a fine powder. The powders were stored in airtight containers and placed in a cool dark place until needed.

About 360 kg of BH-661 variety and 360 kg of Limu variety maize grains harvested in 2016 was purchased from a selected farmer in Liben kebele, Sekoru district (the farmer was given the BH-661 variety and Limu variety maize to cultivate on his land, and they were used after harvest without any other treatments). BH-661 and Limu maize varieties were used in this experiment because they were reported as moderately susceptible to infestation and damage by the maize weevil [20, 21].

2.3. Experimental Design and Treatments. The experiment was laid out in a completely randomized design (CRD) with factorial arrangement in three replications. The factors consisted of maize variety with two levels (BH-661 and Limu) and botanicals with two levels (*Eucalyptus globulus Labill* leaf powder, *Chenopodium ambrosioides* L. whole plant powder, and one untreated control). Of all the botanicals reported as effective against stored maize insect pests, *Eucalyptus globulus Labill* leaf powder and *Chenopodium ambrosioides* L. whole plant powder were used in this experiment since these are easily available in the area and were also reported by different researchers that they gave a promising result in stored maize insect pest control [16, 17, 22–24].

Botanical plant powders were added to maize grains with the ratio of 10% v/v, and both treated and untreated grains were added to polypropylene sacks (40 kg/bag) and stored in the storage house of the farmer training center (the storage house is made of wooden walls covered with metal sheets and with metal sheet roofing). All the stored maize (treated and untreated) for the storage study were left to be infested naturally.

Bag storage is used purposely because it is reported that from different storage methods used in Ethiopia, about 46% of the cereals are stored in bags in the house [5].

2.4. Data Collected. To evaluate the efficacy of botanical plant powders in protecting the maize grains from insect infestation, storage conditions similar to those of actual farmer stores in the study area were used. The grains were then stored for six months (the maximum storage period in the farmer store of the study area), and different analyses were carried out at 30 days intervals.

2.4.1. Percentage of Weight Loss. About 1000 grains were taken randomly and assessed for damage due to natural insect infestations. The grains were segregated into undamaged and insect damaged grains, the grains were counted and weighed, and the percent weight loss of maize grains in storage was computed according to the methods described in Gwinner et al. [25], as follows:

$$\text{weightloss}\,(\%) = \frac{U\text{Nd} - D\text{Nu}}{U\,(\text{Nd} + \text{Nu})} \times 100, \qquad (1)$$

where U is the weight of undamaged grains, D is the weight of insect damaged grains, Nu is the number of undamaged grains, and Nd is the number of insect damaged grains.

2.4.2. Percentage of Insect Damage. About 50 g of sample was taken, and the grains were segregated into undamaged and insect damaged grains. Each group was counted, and percentage insect damage of the grains was calculated as follows:

$$\text{insect damage}\,(\%) = \frac{\text{number of insect damaged grains}}{\text{total number of grains}} \times 100. \qquad (2)$$

2.4.3. Thousand Grain Weight. About 50 g of sample was taken, weighed, and counted. The thousand grain weight was calculated as follows:

$$\text{TGM} = \frac{\text{wt grain}}{\text{number of grains}} \times 100, \qquad (3)$$

where TGM is the thousand grain mass and wtgrain is the weight of the grain sample.

2.4.4. Seed Germination Percentage. To carry out the germination test, one hundred randomly selected seed samples were placed in Petri dishes containing moistened soft paper and kept at 30°C in an incubator (Model MJX-150B, China). The number of germinated seedlings from each Petri dish was counted and recorded after 7 days of planting. The percent germination was computed as described in Zibokere [26], as follows:

$$\text{germination}\,(\%) = \frac{\text{number of seeds germinated}}{\text{total number of seeds}} \times 100. \qquad (4)$$

2.4.5. Grain Moisture Content. The grain moisture content was determined by using the grain moisture meter.

2.5. Statistical Analysis. Statistical analysis was performed over the storage periods, and all the data collected were first homogenized using appropriate logarithmic and square-root transformations [27] before being subjected to analysis of variance (ANOVA), and the result was analyzed using Minitab version 16. Mean separations were conducted using Tukey's honestly significant difference (HSD) test at 5% level of significance.

3. Results and Discussion

The influence of botanical powder treatments in maintaining the quality of maize grains was investigated, and the thousand grain weight, germination percentage, percent insect damage, percent weight loss, and percent moisture content of grains over six months of storage are presented in tables and discussed. The results showed that there was a significant difference between treatments ($P < 0.05$) in all quality parameters tested during six months of storage.

Of the two tested botanicals, *Chenopodium ambrosioides* L. resulted in better protecting efficacies than *Eucalyptus globulus Labill*. Difference in insect resistance was also observed between the two maize varieties used in this work. The difference in insect resistance in the two maize varieties may be due to difference in their seed size since the seed size of the BH-661 maize variety is larger than that of the limu variety. Keba and Sori [20] reported the existence of positive correlation between seed size and the susceptibility weevil damage in which bigger grains were reported as susceptible to insects. In addition to this, difference in insect resistance in the two maize varieties used in this work may be due to difference in their inherent ability to combat specific insect pests. Keba and Sori [20] reported that BH-661 is the most susceptible variety among thirteen varieties and hybrids developed by National Maize Research Coordination Center-Bako Agricultural Research Center and under production in different maize belts of Ethiopia.

3.1. Thousand Grain Weight. Significant differences ($P < 0.05$) were observed in thousand grain weight of the two maize varieties treated with *Chenopodium ambrosioides* L. and *Eucalyptus globulus Labill* at all storage times (Table 1). On the first day of storage, the BH-661 variety had higher thousand grain weight than the Limu variety. Fluctuating result (Decrease and increase) in thousand grain weights was observed for both varieties as the storage time increased. The decrease in thousand grain weights may be due to weight loss due to insect infestation, and an increasing trend may be observed due to variation in moisture content of the grains as the relative humidity of the storage environment changes.

Among all samples, the treated samples had highest thousand grain weight, and the control (untreated) samples had the lowest value of thousand grain weight beyond two months of storage for both varieties. This may be due to low percentage of insect damage in treated samples compared to untreated control. In similar manner, Sori [3] reported *Chenopodium* sp. whole plant powder gave maximum corrected mortality (66.67%) which is comparable with the standard checks (Actellic dust (70.39%)) on adult maize weevils under the laboratory. High percent adult mortality, reduced progeny emergence, and low percent grain damage in *Chenopodium*-treated samples were reported [16, 28]. The protective effect of *Eucalyptus* leaf powder against maize weevil has been reported by [17] who concluded *Eucalyptus globules Labill* leaf powder provided good protection for grain seeds by reducing insect oviposition, progeny emergence, and grain infestation rates. Utilization of different botanical products as stored crop grain protectants has been reported by different researcher [3, 14, 15, 29].

3.2. Germination Capacity (%). The effect of botanical powders on seed viability (germination percentage) of maize seeds revealed that there was a significant difference ($P < 0.05$) between untreated control and botanically treated grains. The result indicated that the minimum germination percentage of around 10% was recorded from the untreated control seeds while all treated grains recorded more than 65.33% of germination capacity.

Higher germination percentages of seeds were recorded from grains treated with *Chenopodium ambrosioides* L. followed by *Eucalyptus globulus Labill* (Table 2). Germination percentages of 86% and 10% were recorded after 5 months of storage for BH-661 variety maize of *Chenopodium ambrosioides* L. treated and untreated samples, respectively. Germination percentages of 93.33% and 65.33% were recorded after 5 months of storage for Limu variety maize of *Chenopodium ambrosioides* L. treated and untreated samples, respectively. The germination percentages of seeds treated with *Eucalyptus globulus Labill* were 69.67% and 81% for BH-661 and limu varieties, respectively, after 5 months of storage.

Of the two varieties of maize, the BH-661 variety showed the highest decrease in percentage of germination compared to the Limu variety and the Limu variety was more resistant to insect infestation than the BH-661 variety. The higher germination percentage recorded in the treated samples in both varieties of maize could be due to strong and positive correlation between the percentages of grain damage and germination capacity in which damaged grains are low in germination capacity. Similar trends were reported by Moges et al. [15] who reported that the ethanol extract of selected botanicals and diatomaceous earth do not adversely affect the germination capacity of maize grains. A large decrease in germination percentages was observed after five months of storage for both varieties of maize treated with botanical powders. This indicates that the protective effect of both botanicals was high up to 5 months and decreased greatly after five months.

3.3. Insect Damage (%). There was a significant treatment effect for percent insect damage of maize (Table 3). A maximum percentage of seed damage was obtained from the untreated control followed by *Eucalyptus globulus Labill* leaf powder treated maize grains, and *Chenopodium ambrosioides* L. treated samples showed the lowest percentage of insect damage for both varieties over all storage durations.

The percent insect damage of *Chenopodium ambrosioides* L. treated samples was 5%, 12%, and 45.67% for the BH-661 variety and 1%, 3.67%, and 31.33% for the Limu variety after four, five, and six months of storage, respectively. The percent insect damage of *Eucalyptus globulus Labill* leaf powder treated maize grains was 43%, 50%, and 88.67% for the BH-661 variety and 31%, 44%, and 82.33% for the Limu variety after four, five, and six months of storage, respectively. The percent insect damage of untreated maize grains was 64%, 80.33%, and 97% for the BH-661 variety and 34%, 48%, and 84% for the Limu variety after four, five, and six months of storage, respectively. The result shows an increasing trend in percent insect damage of the maize samples as storage duration advances, and the trend was faster in *Eucalyptus globulus Labill* leaf powder treated samples. This indicated the protective effect of *Chenopodium ambrosioides* L. was higher than that of *Eucalyptus globulus Labill* leaf powder and it has relatively long persistence (up to the fifth month) than *Eucalyptus globulus Labill* leaf powder.

The efficacy of these botanicals in protecting grains from insect pest could be as a result of biologically active compounds they contain. Upon characterization, Singh et al. [11] reported that *Chenopodium ambrosioides* L. leaf essential oil contains α-terpinene (47.37%), p-cymene

Table 1: Effect of botanicals and variety on log of thousand grain weight (mean ± SD) of maize.

Variety	Botanicals	Months of storage						
		0	1	2	3	4	5	6
BH-661	Control	(2.6^{a}) ± 0.0002	2.51^{d} ± 0.0001	2.56^{b} ± 0.0004	2.48^{c} ± 0.01	2.46^{d}	2.41^{d} ± 0.09	2.35^{c} ± 0.04
	Chenopodium	2.6^{a} ± 0.0002	2.56^{a} ± 0.0008	2.58^{a} ± 0.0003	2.5^{a} ± 0.01	2.51^{a} ± 0.00	2.5^{b} ± 0.00	2.44^{a} ± 0.03
	Equaliptus	2.6^{a} ± 0.0008	2.55^{b} ± 0.001	2.58^{a} ± 0.0001	2.5^{a} ± 0.01	2.49^{b} ± 0.00	2.5^{b} ± 0.00	2.44^{a} ± 0.02
Limu	Control	2.59^{b} ± 0.0015	2.50^{e} ± 0.001	2.53^{c} ± 0.0004	3.5^{a} ± 0.00	2.43^{e} ± 0.00	2.48^{c} ± 0.00	2.39^{b} ± 0.03
	Chenopodium	2.59^{b} ± 0.0024	2.5^{e} ± 0.0001	2.55^{c} ± 0.002	2.49^{b} ± 0.00	2.48^{c} ± 0.00	2.52^{a} ± 0.00	2.45^{a} ± 0.02
	Equaliptus	2.59^{b} ± 0.0023	2.54^{c} ± 0.0000	2.57^{ab} ± 0.001	2.47^{d} ± 0.00	2.48^{c} ± 1.28	2.53^{a} ± 0.00	2.39^{b} ± 0.03

Mean ± SD values in the same column followed by the same letter do not differ significantly at $P < 0.05$ (Tukey's test).

Table 2: Effect of botanicals and variety on germination capacity (mean ± SD) of maize.

Variety	Botanicals	Months of storage						
		0	1	2	3	4	5	6
BH-661	Control	98.7^{a} ± 1.57	94.0^{a} ± 5.29	96.33^{a} ± 2.46	45^{c} ± 3	48^{c} ± 2.00	10^{d} ± 1.00	1.33^{d} ± 1.15
	Chenopodium	98.0^{a} ± 1	98.0^{a} ± 2	98^{a} ± 0.86	88^{a} ± 2.64	88^{a} ± 2	86^{a} ± 1.00	31.33^{ab} ± 1.15
	Equaliptus	97.3^{a} ± 1.15	96.0^{a} ± 3.46	96.7^{a} ± 2.08	74^{b} ± 2.00	68^{b} ± 0.00	69.67^{bc} ± 4.5	36^{a} ± 2.00
Limu	Control	92.0^{b} ± 2	97.3^{a} ± 1.1	94.67^{a} ± 1.52	85.67^{a} ± 0.70	74^{b} ± 2.00	65.33^{c} ± 0.57	9.33^{c} ± 1.15
	Chenopodium	92.0^{b} ± 1	96.7^{a} ± 1.1	94.33^{a} ± 0.28	96^{a} ± 0.00	92^{a} ± 2.00	94.33^{a} ± 0.57	42.67^{a} ± 1.15
	Equaliptus	92.0^{b} ± 2	90.7^{a} ± 5	91.33^{a} ± 2.3	85.33^{a} ± 5.03	87^{a} ± 3.00	81^{ab} ± 1.73	23.33^{b} ± 1.15

Mean ± SD values in the same column followed by the same letter do not differ significantly at $P < 0.05$ (Tukey's test).

Table 3: Effect of botanicals and variety on percent insect damage (mean ± SD) of maize.

Variety	Botanicals	Months of storage						
		0	1	2	3	4	5	6
BH-661	Control	0.00	0.00	20^{a} ± 2	34.33^{a} ± 1.52	64^{a} ± 0.00	80.33^{a} ± 2.08	97^{a} ± 1.00
	Chenopodium	0.00	0.00	0.33^{d} ± 0.57	1^{d} ± 0.00	5^{d} ± 0.00	12.04^{d} ± 0.06	45.67^{d} ± 1.52
	Equaliptus	0.00	0.00	11.33^{b} ± 1.52	18.67 ± 3.5^{b}	43^{b} ± 0.00	50^{b} ± 1.00	88.67^{c} ± 0.57
Limu	Control	0.00	0.00	2.67^{c} ± 0.57	2^{d} ± 1	31^{c} ± 0.00	44^{b} ± 1.00	84^{ab} ± 1.00
	Chenopodium	0.00	0.00	0.67^{d} ± 0.57	1.33^{d} ± 0.57	1^{d} ± 0.00	3.67^{e} ± 0.57	31.33^{e} ± 1.52
	Equaliptus	0.00	0.00	1.33^{cd} ± 0.57	6^{c} ± 1	34^{c} ± 0.00	48^{c} ± 0.00	82.33^{b} ± 2.5100

Mean ± SD values in the same column followed by the same letter do not differ significantly at $P < 0.05$ (Tukey's test).

(25.77%), *cis*-ascaridole 14.75%, and *trans*-ascaridole 4.46% as major compounds. Slimane et al. [10] characterized *Eucalyptus globulus Labill* leaf essential oil profile and reported α-pinene of 13.61% and 1.8-cineole of 43.18% as major compounds. In a similar manner, Lee et al. [30] reported that 1,8-cineole shows promise as a material with potential for use as a fumigant to be used against three major stored grain insects (*S. oryzae*, *R. dominica*, and *T. Castaneum*).

3.4. Weight Loss (%). No grain weight loss was recorded in the first month of storage for all treatments, and highest percentage of maize weight loss was recorded in untreated control followed by grains treated with *Eucalyptus globulus Labill* leaf powder for both varieties of maize at all storage durations starting from the second month of storage (Table 4). *Chenopodium ambrosioides* L. treated samples showed the lowest percent of weight loss of 0.76%, 2.37%, and 10.8% for the BH-661 variety and 0.15%, 0.28%, and 6.66% for the Limu variety after four, five, and six months of storage, respectively. The percent weight loss of *Eucalyptus globulus Labill* leaf powder treated maize grains was 4.71%, 5.22%, and 9.27% for the BH-661 variety and 3.12%, 4.16%, and 7.91% for the Limu variety after four, five, and six months of storage, respectively. However, the percent weight loss of untreated maize grains was 6.21%, 23.53%, and 32.55% for the BH-661 variety and 4.21%, 5.89%, and 20.17% for the Limu variety after four five and six months of storage, respectively.

The result clearly indicates that both treatments significantly reduced weight loss compared to the untreated grains. Of the two treatments, *Chenopodium ambrosioides* L. treated samples resulted in the least grain weight loss and untreated grains highly suffered with weight loss. Similar observation was made by different researchers by testing different botanical products as stored crop grain protectants [3, 14, 15, 29].

3.5. Moisture Content. Significant differences were observed for percentage of moisture content of the samples among the treatments (Table 5) although there is no clear increasing or decreasing trend of variation with the storage durations.

Table 4: Effect of botanicals and variety on percentage weight loss (mean ± SD) of maize.

Variety	Botanicals	Months of storage 0	1	2	3	4	5	6
BH-661	Control	0.00	0.00	$2.411^{a} \pm 0.078$	$5.225^{a} \pm 0.1$	$6.2146^{a} \pm 0.03$	$23.5327^{a} \pm 0.84$	$32.5537^{a} \pm 1.77$
	Chenopodium	0.00	0.00	$0.002^{d} \pm 0.003$	$0.014^{d} \pm 0.00$	$0.7650^{d} \pm 0.00$	$2.3022^{c} \pm 0.01$	$10.8625^{c} \pm 0.23$
	Equaliptus	0.00	0.00	$2.428^{a} \pm 0.13$	$3.760^{b} \pm 0.01$	$4.7120^{b} \pm 0.00$	$5.2261^{b} \pm 0.06$	$9.2705^{cd} \pm 0.13$
Limu	Control	0.00	0.00	$0.301^{b} \pm 0.24$	$0.826^{c} \pm 0.16$	$4.2195^{b} \pm 0.07$	$5.8964^{b} \pm 0.00$	$20.1787^{b} \pm 1.01$
	Chenopodium	0.00	0.00	$0.335^{b} \pm 0.29$	$0.658^{c} \pm 0.1$	$0.1538^{d} \pm 0.00$	$0.1883^{d} \pm 0.06$	$6.6608^{e} \pm 0.09$
	Equaliptus	0.00	0.00	$0.189^{c} \pm 0.00$	$0.091^{d} \pm 0.01$	$3.1267^{c} \pm 0.01$	$4.1632^{bc} \pm 0.01$	$7.9151^{de} \pm 0.16$

Mean ± SD values in the same column followed by the same letter do not differ significantly at $P < 0.05$ (Tukey's test).

Table 5: Effect of botanicals and variety on square root of moisture content (mean ± SD) of maize.

Variety	Botanicals	Months of storage 0	1	2	3	4	5	6
BH-661	Control	$3.79^{a} \pm 0.02$	$3.63^{b} \pm 0.000$	$3.84^{a} \pm 0.01$	$3.47^{a} \pm 0.02$	$3.11^{a} \pm 1.28$	$2.97^{b} \pm 0.01$	$3.46^{a} \pm 0.02$
	Chenopodium	$3.78^{a} \pm 0.02$	$3.58^{c} \pm 0.008$	$3.82^{a} \pm 0.00$	$3.52^{a} \pm 0.04$	$2.93^{b} \pm 1.28$	$2.92^{b} \pm 0.01$	$3.15^{b} \pm 0.00$
	Equaliptus	$3.79^{a} \pm 0.01$	$3.43^{d} \pm 0.043$	$3.75^{a} \pm 0.01$	$3.53^{a} \pm 0.02$	$2.98^{b} \pm 0.00$	$3.13^{a} \pm 0.00$	$3.25^{b} \pm 0.01$
Limu	Control	$3.66^{b} \pm 0.13$	$3.74^{a} \pm 0.000$	$3.48^{b} \pm 0.61$	$3.58^{a} \pm 0.09$	$3.05^{a} \pm 2.56$	$3.02^{a} \pm 0.04$	$3.24^{b} \pm 0.01$
	Chenopodium	$3.64^{b} \pm 0.007$	$3.6^{b} \pm 0.008$	$3.75^{a} \pm 0.00$	$3.5^{a} \pm 0.00$	$3.2^{a} \pm 0.00$	$3.2^{a} \pm 0.04$	$2.96^{c} \pm 0.00$
	Equaliptus	$3.64^{b} \pm 0.007$	$2.85^{e} \pm 1.41$	$3.51^{b} \pm 0.24$	$3.07^{b} \pm 0.15$	$3.14^{a} \pm 1.28$	$3.13^{a} \pm 0.02$	$3.18^{b} \pm 0.02$

Mean ± SD values in the same column followed by the same letter do not differ significantly at $P < 0.05$ (Tukey's test).

The average moisture content of maize during storage was 14.37% and 13.37% for BH-661 and limu varieties, respectively. Both treated and untreated maize grains of both varieties lost moisture as storage time increased, reaching less than 11%. It is observed that percent moisture content of all samples fluctuates as storage time increases, and this may be due to fluctuation in weather conditions and relative humidity of storage environment as a weather condition of the environment changes. The surrounding relative humidity fluctuated between 56.8 and 88% from the start to the end of the experiment, and this could be the possible cause for moisture fluctuation. Dubale et al. [31] observed similar moisture content variation (decrease and abrupt increment) in maize grains stored in Gombisa and Sacks.

4. Conclusion and Recommendations

The use of plant powders (*Chenopodium ambrosioides* L. and *Eucalyptus globulus Labill*) have resulted in higher germination capacity and thousand grain weight and low percentage of weight loss and insect damage as a result of protection effect of the plant materials. This result confirms that *Chenopodium ambrosioides* L. and *Eucalyptus globulus Labill* have a potential for maize protection against storage insect pests during farmer's storage. But, it was observed that protection of *Chenopodium ambrosioides* L. was effective up to five months and that of *Eucalyptus globulus Labill* leaf powder was up to 3 months. and this indicates that their protective effect is nonpersistent and repeated applications are required for long storage durations. Further research should be done to check that increasing rate of application increases duration of protection by the botanicals. In addition to the use of *Chenopodium ambrosioides* L. for insect control of maize grains intended for food purpose, the toxic mechanism of *Chenopodium ambrosioides* L. and its major constituents should be further studied.

Data Availability

The corresponding author can provide the data used to report these results upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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