A Comparative Study of the Effects of Local Botanicals on Storage Pests of Beans (Phaseolus Vulgaris L.) in Metal Container

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Abstract

The study investigated the comparative effects of three local botanicals Plant parts powders and their combinations. The three plant species are Vernonia amygdalina (B) (bitter leaf), Alluim Sativum (G) (Garlic cloves), Azadirachta indica (N) (neem) in the suppression of the stored insect pests damages in Phaseolus vulgaris L. (Common Bean) grains in the storage packaging containers (PSC). Studies have revealed that stored Common Bean is prone to stored insects damages and deteriorates very fast when kept in storage packaging containers and this study aimed to determine storability of common Bean using metal container as storage packaging containers with the Purdue Improved Crops Storage (PICS) bag as control sack to determine the most appropriate material for the storage of the produce. The botanicals were applied at two levels (3grams and 17grams) per 100grams (g) of the Bean seeds stored in these materials for sixteen (16) weeks. The two indices used are Weight loss (W_{loss}) and Mortality rate (D_{rate}) for measuring the storage stability. The weight loss of the bean grains due to storage insects was prevented by the botanicals activeness from the most active to least superior in the storage packaging container. In the Metal container, the main treatments and combination effective means (W_{loss}) are found to be 2.40%, 8.61%, 9.59%, 9.70%, 9.71%, 11.76% and 11.93% for N, G, B, GN, BN, BGN and BG respectively. It was significantly at 5% ($P<0.05$) in the storage packaging container for weight loss. The death count, of storage insect pests in the bean grain due to the local botanicals effectiveness, to prevented damaged cause to the Common Bean grains by the storage insect pests from the most active botanical to least superior in the storage packaging container. In the Metal container, the main treatments and combination effective means (D_{rate}) are found to be 79.20%, 69.54%, 67.10%, 65.58%, 65.44%, 64.68% and 63.87% for N, G, GN, B, BGN, BG and BN respectively. It was significantly at 5% ($P<0.05$) in the storage packaging container for death count of storage insect pests. The amount of weight loss was found to be 1.90%, and 5.20% for PICS bag and metal container respectively. The mortality rate (death count) was found to be 96.07% and 25.08%, for PICS bag and metal container respectively. It was also observed that Common Bean stored in PICS bags had the lowest case of weight loss (damages) and storage insect pest infestation or damage.

Key Note: Local Botanicals Plant Parts Powders, Stored Insect Pests, Phaseolus vulgaris L. (Common Bean) grains, Metal Container. The Purdue Improved Crops Storage (PICS) Bag, Weight Loss, Mortality Rate (death count)

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Introduction

Background of the Study

Common bean, *Phaseolus vulgaris L.,* evolved from wild plants growing as vines distributed in the highlands of Middle American and Andes with domestication occurring around 2500 years for Mesoamerican and 4400 years for Andean beans. More than 30 species exist but five of them *P. vulgaris, P. lunatus, P. coccineus, P. acutifolius and P. polyanthus* were domesticated with *P. vulgaris* being mostly grown (Debouck, 2000). The crop is now widely spread and cultivated as a major food crop in many tropical, subtropical and temperate areas of America, Europe, Africa and Asia (Wortmann *et al.,* 2006). Two market classes of *P. vulgaris* also exist known as snap beans and dry beans with the later having large production and consumption (Blair *et al.,* 2006). Dry beans are normally harvested in America, Argentina and Mexico are the centers of common bean origin and primary center of domestication based on morphological and molecular levels (Mensack *et al.*, 2010). Now the crop is distributed throughout the world and consumed as essential part of human diet. The diseases such as common bacterial bright (CBB), angular leaf spot (ALS), bean common mosaic virus (BCMV) and bean common mosaic necrotic virus (BCMNV) have been a constraint in bean production whereby tremendous decrease in yield has been reported due to these disease attacks. This is exemplified by angular leaf spot which has been reported to cause a yield loss of up to 50-80% (Tryphone *et al.,* 2015).

In controlling storage pests, farmers are using several methods which include the use of plant materials with insecticidal properties (Swella and Mushobozy, 2007), hermetic storage, solarisation, sunning and sieving regimes (Akintobi and Adebisi, 2001), contact insecticides and fumigants. The geographical distribution of both species is now almost cosmopolitan (Hill, 2002; Thakur, 2012). The quality of grains and seeds during storage depends on various factors such as crop or variety, initial seed quality, storage conditions, seed moisture content, insect pests, bacteria and fungi (Amruta *et al.*, 2015). The insect pests not only damage the grain but also depreciate the weight and quality of stored grains (Rayhan, 2014).

Pesticides are chemical substances used in agricultural practices to aid the production and yield by repelling, preventing, and destroying pests (Kumar *et al.,* 2012). However, over the years, continuous application of synthetic pesticides in agriculture has caused accumulation of pesticidal residues in the environment leading to various chronic illnesses (Bag, 2000). According to a report by the United Nations Environment Program (UNEP) and the World Health Organization (WHO), pesticides are responsible for poisoning around three million people and causing ~200,000 deaths each year, worldwide. Such cases are reported more in developing countries (95%) than in developed countries (World Health Organization, 1990; Yadav *et al.,* 2015). On the basis of the types of pest controlled, pesticides are divided into subcategories including insecticides, fungicides, herbicides, rodenticides, pediculicides, and biocides (Gilden *et al.,* 2010). Synthetic insecticides can leave potentially toxic residues in food products and can affect non- target organisms in the environment (Isman, 2006).

The use of insecticides (synthetic chemicals) in storage of grains gives a lot of life challenges', this indiscriminate uses of chemical pesticides and fumigants in storage have led to a number of problems including insect resistance, deleterious effects to non-target organism, toxic residues in food grains and environmental pollution. This

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has left most stored grains in the tropics especially Nigeria, with huge amount of pesticide residue (Mailafiya *et al.*, 2014). Suleiman and Yusuf (2011) reported that, chemicals are unavailable, expensive, poses hazard to man and livestock. Adebiyi and Tedela (2012) reported health issues and resistance of pest against chemicals. Recent revelations have shown that synthetic insecticides were found to penetrate into grains and may be toxic (Adebiyi and Tedela, 2012).

Materials and Methods

Experimental Materials

Plastic containers, metal containers, small size hessian/polythene bags, small size hessian bags and Purdue Improved Crop Storage bags small size were used to store common bean for sixteen weeks. Clean, 50 kg of common bean cultivars are used as test materials. The grains were obtained at 12% moisture content (dry basis) and were not previously treated with any chemicals. The bean seeds were further dried to 9.8% moisture content (db).

Three botanicals pesticides viz., *Vernonia amygdalina* (Bitter leaf) powder, *Azadirachta indica* (Neem leaf) powder, and *Allium sativum* (Garlic) powder are used.

Table 1 and 2, shows the botanicals plant parts used, the treatments and their levels or dosage respectively while the active ingredients of the local Protectants used are shown in table 3.

There are three factors, *B*, *G*, and *N*, each at two levels, is of interest. The design is called a 2^3 factorial design ($2^3 = 8$), and then eight treatment combinations can now be displayed using the "- and +" orthogonal coding to represent the low and high levels of the factors, we may list the eight runs in the 2^3 design as in Table 4, we write the treatment combinations in standard order as (1), *b*, *g*, *bg*, *n*, *bn*, *gn*, and bgn.

The Metal containers, Plastic containers, hessian/polythene bags and hessian bags were use to store common bean for more than three months including PICS bags. Each of the treatments has 2 replicates at 2 levels, that is, 3 grams for lower concentration (-1) and 17 grams for high concentration (+1). All the storage packaging containers filled with common bean are placed in a well-ventilated room for a period of study at two weeks interval.

Layout of Experiment

A full factorial (2^3) design, replicated twice, calls for 8 x 2 = 16 runs total at 2 levels (low and high). In 2^3 full factorial experiment, the low and high levels of the factors were coded as minus (-1) and plus (+) respectively (Douglas, et al., 2003; Douglas C. Montgomery, 2013). The SPC including Purdue Improved Crops Storage (PICS) bag, each would containing 100grams of common beans seeds (white beans) which replicated two (2) times. The bean grains and botanical pesticide powder of all Protectants are tumble mixed thoroughly for about some minutes. The SPC are then sealed and top cover for aeration and placed randomly in the two replications.

Conduct of Experiment and data presentation

Data were drawn from 2^3 full factorial experiments conducted in a randomized order in two replicates according to the design matrix. The values of the varying factors and their coded level are presented in table 2. The mean experimental observations are presented in table.

Factor settings in standard order with replication we now have constructed a design table the full (2^3) factorial design including the combinations of the factors in two levels and two replicates. The mean experimental observations are presented in Table 5 and 6 for weight loss and death counts.

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Table 1: List of botanical plant parts used

Botanical Plants				
S/N	**Scientific name**	**Common name**	**Family**	**Parts used**
1	Vernonia Amygdalina	Bitter leaf	Asteraceae	Leaf
2	Azadirachta Indica	Neem leaf	Meliaceae	Leaf
3	Allium Sativum	Garlic	Liliaceae	Glove

Table 2: Treatments and their Coded Levels

		Treatments		
Factor Levels	**Code**	**(B) Bitter Leaf Powder**	**(G) Garlic Glove Powder**	**(N) Neem Leaf Powder**
1 Low	-1	3 grams/ 100 grams	3 grams/ 100 grams	3 grams/ 100 grams
2 High	1	17 grams/ 100 grams	17 grams/ 100 grams	17 grams/ 100 grams

Table 3: Active ingredients in the local Protectant used

Bitter Leaf (Vernonia amygdalia)	**Garlic (Allium sativum)**	**Neem leaf (Azadiractaindica)**
Alkaloids	**Allicin**	**Azadrichtin**
Flavonoids	**Enzymes**	**Nimbolinin**
Glycosides	**Diallyl polysulfides**	**Nimbin**
Saponins	**Saponins**	**Nimbidol**
Steroids	**Vinyldithiins**	**Nimbidin**
Tannins	**S-allylcysteine**	**Sodium ninbinate**
Terpenes	**Alliin**	**Gedunin**
Coumarins	**Ajoenes**	**Salannin**
Resins	**Flavonoids**	**Quercetin**
Lignans	**Maillard Reaction**	
Phenolic acids		
Xanthoes		
Edotides		
Anthraquinone		
Sesquiterpenes		
Source References:		
Ebenezer and Olatude 2011 Oladosu-Ajayi et al., 2017	**Shang et al, 2019**	**Mohammad, (2016)**

Table 4: Algebraic Sign for Calculating Effects in the Full Factorial (2^3) Design

		Factorial Effects							
Run	**Treatment combination**	**I**	**B**	**G**	**BG**	**N**	**BN**	**GN**	**BGN**
1	**0(I)**	+	-	-	+	-	+	+	-
2	**b**	+	+	-	-	-	-	+	+
3	**g**	+	-	+	-	-	+	-	+
4	**bg**	+	+	+	+	-	-	-	-
5	**n**	+	-	-	+	+	-	-	+
6	**bn**	+	+	-	-	+	+	-	-
7	**gn**	+	-	+	-	+	-	+	-
8	**bgn**	+	+	+	+	+	+	+	+

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Table 5: Mean weight Loss data for Common Bean (g/100g)

Run No.	Experimental mean ŷ
SPC	Metal Container
1	1.36
2	1.25
3	3.21
4	3.77
5	5.54
6	26.26
7	28.63
8	37.66

Table 6: Mean Mortality Rate data for Storage Insect Pest

Run No.	Experimental mean ŷ
SPC	Metal Container
1	0.00
2	43.73
3	59.10
4	56.77
5	75.81
6	77.72
7	79.17
8	84.12

Statistical analysis and model simulation

The main effects can be estimated by:

Multivariate regression analysis was used in relating the variables (Douglas C. Montgomery, 2013). There are seven degrees of freedom between the eight treatment combinations in the 2^3 design. Three degrees of freedom are associated with the main effects of B, *G*, and N. Four degrees of freedom are associated with interactions; one each with *BG*, *BN*, and *GN* and one with *BGN*.

Consider estimating the main effects. First, consider estimating the main effect *B*. The effect of *B* when *G* and *N* are at the low level is [b - (1)]/*n*. Similarly, the effect of *A* when *B* is at the high level and *C* is at the low level is [bg - g]/*n*. The effect of *A* when *C* is at the high level and *B* is at the low level is [bn - n]/*n*. Finally, the effect of *A* when both *B* and *C* are at the high level is [bgn - gn]/*n*. Thus, the average effect of *A* is just the average of these four, or

$$= \frac{1}{4n} [b - bg - bn - bgn - (I) - g - n - gn] \qquad (1)$$

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This equation can also be developed as a contrast between the four treatment combinations in the right face of the cube. That is, the *B* effect is just the average of the four runs where *B* is at the high level (+) minus the average of the four runs where *B* is at the low level (-), or

$$B = \bar{y}_B^+ - \bar{y}_B^-$$

$$= \frac{b + bg + bn + (bgn)}{4n} - \frac{(I) + g + n + gn}{4n}$$

This equation can be rearranged as

$$= \frac{1}{4n}\,[b + bg + bn + bgn - (I) - g - n - gn]$$

which is identical to Equation 1.

In a similar manner, the effect of *G* is the difference in averages between the four treatment combinations in the front face of the cube and the four in the back. This yields

$$G = \bar{y}_G^+ - \bar{y}_G^-$$

$$= \frac{1}{4n}\,[g + bg + bn + bgn - (I) - b - n - bn] \quad \text{...(2)}$$

The effect of *N* is the difference in averages between the four treatment combinations in the top face of the cube and the four in the bottom, that is,

$$N = \bar{y}_N^+ - \bar{y}_N^-$$

$$= \frac{1}{4n}\,[n + bn + gn + bgn - (I) - b - g - bg] \quad \text{.............................. (3)}$$

The two-factor interaction effects may be computed easily. A measure of the *BG* interaction is the difference between the average *B* effects at the two levels of G. Symbolically,

$$BG = \bar{y}_{BG}^+ - \bar{y}_{BG}^-$$

$$= \frac{bgn - bg - n - (I)}{4n} - \frac{gn - g - bn - b}{4n} \quad \text{.............................. (4)}$$

We could write Equation 4 as follows:

$$= \frac{1}{4n}\,[bgn - gn + bg - g - bn + n - b + (I)]$$

In this form, the *AB* interaction is easily seen to be the difference in averages between runs on two diagonal planes in the cube. Using similar logic and we find that the *AC* and *BC* interactions are

$$BN = \frac{1}{4n}\,[(I) - b + g - bg - n + bn - gn + bgn] \quad \text{...(5)}$$

and

$$GN = \frac{1}{4n}\,[(I) + b - g - bg - n - bn + gn + bgn] \quad \text{................................ (6)}$$

The *BGN* interaction is defined as the average difference between the *BG* interaction at the two different levels of *N*. Thus,

$$BGN = \frac{1}{4n}\,\{[bgn - gn] - [bn - n] - [bg - g] + [b - (I)]\}$$

$$BGN = \frac{1}{4n}\,[bgn - gn - bn + n - bg + g + b - (I)] \quad \text{......................................(7)}$$

As before, we can think of the *BGN* interaction as the difference in two averages. If the runs in the two averages are isolated, they define the vertices of the two tetrahedra that comprise the cube.

In Equations 6 through 7, the quantities in brackets are Contrasts in the treatment combinations. A table of plus and minus signs can be developed from the contrasts, which is shown in Table 4. Signs for the main effects are determined by associating a plus with the high level and a minus with the low level. Once the signs for the main effects have been established, the signs for the remaining columns can be obtained by multiplying the appropriate preceding columns row by row. For example, the signs in the *BG* column are the product of the *B* and *G* column signs in each row. The contrast for any effect can be obtained easily from this table.

Table 4, has several interesting properties: (1) Except for column *I*, every column has an equal number of plus and minus signs. (2) The sum of

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the products of the signs in any two columns is zero. (3) Column *I* multiplied times any column leaves that column unchanged.

That is, *I* is an identity element. (4) The product of any two columns yields a column in the table. For example, $B \times G = BG$, and

$BG \times G = BG^2 = BG$

We see that the exponents in the products are formed by using Modulus 2 Arithmetic. (That is, the exponent can only be 0 or 1; if it is greater than 1, it is reduced by multiples of 2 until it is either 0 or 1.) All of these properties are implied by the Orthogonality of the 2^3 design and the contrasts used to estimate the effects.

Sums of squares for the effects are easily computed because each effect has a corresponding single-degree-of-freedom contrast. In the 2^3 design with *n* replicates, the sum of squares for any effect is

$$SS = \frac{(\text{Contrast})^2}{n2^k} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (8)$$

$$= \frac{(\text{Contrast})^2}{8n}$$

the model sum of squares is

$$SS_{\text{Model}} = SS_B + SS_G + SS_N + SS_{BG} + SS_{BN} + SS_{GN} + SS_{BGN}$$

Thus the statistic

$$F_0 = \frac{MS_{\text{Model}}}{MS_E}$$

is testing the hypotheses

$H_0{:}\beta_1 = \beta_2 = \beta_3 = \beta_{12} = \beta_{13} = \beta_{23} = \beta_{123} = 0$

$H1$: at least one $\beta \neq 0$

Because F_0 is large, we would conclude that at least one variable has a nonzero effect. Then each individual factorial effect is tested for significance using the *F* statistic. The ordinary R^2 is

$$R^2 = \frac{SS_{\text{Model}}}{SS_{\text{Total}}}$$

and it measures the proportion of total variability explained by the model. A potential problem with this statistic is that it always increases as factors are added to the model, even if these factors are not significant. The **adjusted** *R*2 statistic, defined as

$$R^2_{\text{Adj}} = 1- \frac{SS_E/df_E}{SS_{\text{Total}}/df_{\text{Total}}}$$

The next portion of the output presents the regression coefficient for each model term and the **standard error** of each coefficient, defined as

$$se(\beta) = \sqrt{V(\beta)} = \sqrt{\frac{MSE}{n2k}} = \sqrt{\frac{MSE}{N}}$$

The standard errors of all model coefficients are equal because the design is **orthogonal**. The 95 percent confidence intervals on each regression coefficient are computed from

$$\hat{\beta} - t_{0.025,N-p}\,se(\beta) \leq \beta \leq \beta + t_{0.025,N-p}\,se(\beta)$$

where the degrees of freedom on *t* are the number of degrees of freedom for error; that is, *N* is the total number of runs in the experiment (16), and *p* is the number of model parameters (8). The full model in terms of both the coded variables and the natural variables is also presented.

The standard error of an effect is easy to find. If we assume that there are *n* replicates at each of the 2^k runs in the design, and if $yi1, yi2, \ldots\ldots\ldots, y_{in}$ are the observations at the *i*th run, then

$$S^2{}_i = \frac{1}{n-1} \sum_{j=1}^{n} (yij - \bar{y}i)^2 \qquad i = 1, 2, 3, \ldots\ldots\ldots\ldots\ldots\ldots 2^k$$

is an estimate of the variance at the *i*th run. The 2*k* variance estimates can be combined to give an overall variance estimate:

$$S^2 = \frac{1}{(n-1)} \sum_{j=1}^{2k} \sum_{j=1}^{n} (yij - \bar{y}i)^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 9$$

This is also the variance estimate given by the error mean square in the analysis of variance.

The *variance* of each effect estimate is

$$V(\text{Effect}) = V\left(\frac{Contrast}{n\,2^{k-1}}\right)$$

$$= \frac{1}{(n\,2^{k-1})^2} V\,(Contras\,)$$

Each contrast is a linear combination of 2*k* treatment totals, and each total consists of *n* observations. Therefore,

$V(\text{Contrast}) = n^2k^2$

and the variance of an effect is

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V (Effect) = $\frac{1}{(n2^{k-1})^2}$ n$2^k\delta^2$ = $\frac{1}{n2^{k-1}}\delta^2$

The estimated standard error would be found by replacing _2 by its estimate S^2 and taking the square root of this last expression:

Se(Effect)= 2S ……………………………………………………………(10)

√ n2^k

Notice that the standard error of an effect is twice the standard error of an estimated regression coefficient in the regression model for the 2*k* design. It would be possible to test the significance of any effect by comparing the effect estimates to its standard error

$t_0 = \frac{\text{Effect}}{Se(\text{Effect})}$

This is a *t* statistic with *N* - *p* degrees of freedom.

The 100(1 - α) percent confidence intervals on the effects are computed from Effect ± $t_{\alpha/2,N-p}$ *Se*(Effect), where the degrees of freedom on *t*

are just the error or residual degrees of freedom (*N*- *p* = total number of runs - number of model parameters).

Table 30: The Estimated Effects, Confidence Interval and t-Values for Weight Loss in Metal Container (m)

Treatment combination	Regression coefficient	Estimated effect	Confidence interval	t-value (calculated table value/1.860)
I	X_0	13.34	±0.05	9.390
b	X_1	7.49	±0.05	2.635
g	X_2	9.46	±0.05	3.329
n	X_3	21.88	±0.05	7.699
bg	X_{12}	-2.81	±0.05	0.989*
bn	X_{13}	7.26	±0.05	2.555
gn	X_{23}	7.28	±0.05	2.562
bgn	X_{123}	-3.15	±0.05	1.108*

*
Statistically insignificant

Table 31: ANOVA for replicated 2^3 Factorial Bean Grain Weight Loss Experiment in Metal Container

Storage Packaging Container (SPC)	Source of Variation (SOV)		Effect	Sum of Squares (SS)	Degree of Freedom (DF)	Mean Squares (MS)	F- ratio Calculated Table values Value (5%) 5.32
Metal	**b**	**X_1**	**7.49**	**224.4**	**1**	**224.40**	**6.94**
	g	**X_2**	**9.46**	**358.34**	**1**	**358.34**	**11.09**
	n	**X_3**	**21.88**	**1914.06**	**1**	**1914.06**	**59.23**
	bg	**X_{12}**	**-2.81**	**31.58**	**1**	**31.58**	**0.98***
	bn	**X_{13}**	**7.26**	**210.83**	**1**	**210.83**	**6.52**
	gn	**X_{23}**	**7.28**	**211.99**	**1**	**211.99**	**6.56**
	bgn	**X_{123}**	**-3.15**	**39.82**	**1**	**39.82**	**1.23***
	Error			**258.50**	**6**	**32.31**	
	Total			**3249.54**	**15**		

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* Statistically insignificant at 5%

Table 35: The Estimated Effects, Confidence Interval and t-Values for Mortality Rate (Death Count) in Metal Container

Treatment combination	Regression coefficient	Estimated effect	Confidence interval	t-value (calculated table value /1.860)
I	X_0	59.43	±0.05	33.860
b	X_1	12.32	±0.05	1.510*
g	X_2	20.23	±0.05	5.764
n	X_3	39.56	±0.05	11.271
bg	X_{12}	-10.55	±0.05	2.530
bn	X_{13}	-8.88	±0.05	3.006
gn	X_{23}	-15.34	±0.05	4.370
bgn	X_{123}	12.02	±0.05	3.425

* Statistically insignificant

Table 36: ANOVA for replicated 2^3 Factorial Storage Bean Insect Mortality Rate Experiment in Metal Container

Storage Packaging Container (SPC)	Source of Variation (SOV)		Effect	Sum of Squares (SS)	Degree of Freedom (DF)	Mean Squares (MS)	F- ratio Calculated values (5%) Table Value 5.32
Metal	**b**	X_1	**12.32**	**606.76**	**1**	**606.76**	**12.31**
	g	X_2	**20.23**	**1636.4**	**1**	**1636.4**	**33.21**
	n	X_3	**39.56**	**441.32**	**1**	**441.32**	**8.96**
	bg	X_{12}	**-10.55**	**6258.79**	**1**	**6258.79**	**127.02**
	bn	X_{13}	**-8.88**	**315.68**	**1**	**315.68**	**6.41**
	gn	X_{23}	**-15.34**	**941.72**	**1**	**941.72**	**19.11**
	bgn	X_{123}	**12.02**	**578.04**	**1**	**578.04**	**11.73**
	Error			**394.2**	**8**	**49.27**	
	Total			**11172.9**	**15**		

* Statistically insignificant at 5%

Fitted model equation for Weight losses in metal containers

$\hat{y}_m = 13.34 + 7.40\ X_1 + 9.46\ X_2 + 21.88\ X_3 + 7.26X_{13} + 7.28\ X_{23}$..(23)

Fitted model equation for Mortality rates in metal containers

$\hat{y}_m = 59.43 + 20.23\ X_2 + 39.56\ X_3 - 10.55\ X_{12} - 8.88\ X_{13} - 15.34\ X_{23} + 12.02\ X_{123}$................(31)

Discussion and Interpretation Of Model

The equations (23), expresses the fitted model for predicting weight losses level in common bean grain under storage ambient conditions and packaging conditions for hessian sack. From the statistical analysis, the following (botanicals) regression coefficient X_{12} and X_{123} in the metal containers were found statistically insignificant at confidence coefficient $\alpha = 0.05$. Two of the main effects and their interactions have significant influence on the level of weight loss of bean grain under storage ambient condition and packaging conditions. However, the weight

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losses with coefficient X_{12} = -2.81 and X_{123} = -3.15, have higher influence on the weight loss level of the bean grains. The high level of the weight loss of the grains will lead to drastic damages on the bean grains. The interaction of the botanicals with coefficient X_{13} = 7.26 has negative influence that many damages also.

Comparing the predicted values based the fitted model with the mean experimental value for the eight experimental runs, it can be that storage and packaging condition of the experiment 8 (with predicted value, $\hat{Y}_8$ = 37.66 g/ 3 g botanical powders) maintains the highest weight loss for the bean grains optimal loss, and storage duration of 16 weeks.

For the metal containers, the equation (31) expresses the fitted model for predicting stored bean insect mortality rate level in common bean grain under storage ambient conditions and packaging conditions for metal container. From the statistical analysis, the following (botanicals) regression coefficient $X_{2,}$ $X_{3,}$ $X_{12,}$ $X_{13,}$ X_{23} and X_{123} were found statistically insignificant at confidence coefficient α = 0.05. Only one main effect has significant influence on the level of insect mortality rate in bean grain under storage ambient condition and packaging conditions. However, the death counts with coefficient X_1 = 12.32 has higher influence on the death counts level of the stored insect pests which some are negative. The high level of the death counts on the grains will show the activeness of the local botanicals. The interaction of the botanicals with coefficient X_{12} = -10.55 also has positive influences with few damages. Comparing the predicted values based the fitted model with the mean experimental value for the eight experimental runs, it can be seen that storage and packaging condition of the experiment 8 (with predicted value, $\hat{Y}_8$ = 84.12 % death count of stored insect pests per 3 g botanical powders) in the stored bean grains maintains the highest mortality rate of the stored bean insect pest optimal death counts rate, and storage duration of 16 weeks.

Conclusion

The results revealed that, the tested botanical powders (*Vernonia amygdalina*, *Allium sativum, Azadirachta indica* and their combination) showed high effectiveness against bean storage pest insects, with respect to bean grain damages and storage insect's pest mortality. In hessian sacks the various botanicals powder, that is bitter leaf, neem leaf, and garlic clove independently and their mixtures used are effective between 2 to 12 weeks of storage period, and using the indices of weight loss and insect mortality on the common bean. Both botanicals are active and also significant within the periods of storage. The effective botanical dose as Protectants concentration can be as low as 3 g per 100 g of the bean grains.

References

Adebiyi, A. O. and Tedela, P. O. (2012). Pesticidal effects of *Barbula indica* on *Callosobruchus maculatus* (Coleoptera: Bruchidae). *Nature and Science*, 10(9): 113-115.

Akintobi D.C.A., Adebisi M.A. (2001). Effect of oil treatments against bruchid infestation on cowpea seed quality. Afr. Crop Sci. Conf. Proc. Vol. 5: 241–246.

Amruta, N., Sarika, G., Umesha, Maruthi, J.B. and Basavaraju, G.V.,(2015). Effect of botanicals and insecticides seed treatment and containers on seed longevity of black gram under natural ageing conditions. J. App. Nat. Sci., 7 (1): 328 – 334.

Bag, D. (2000). Pesticides and health risks. Econ. Polit. Wkly. 35, 3381–3383.

Blair, M.W., Iriarte, G. and Beebe, S. (2006). QTL analysis of yield traits in an advanced backcross population derived from a cultivated Andean× wild common bean (*Phaseolus vulgaris* L.) cross. Theoretical and Applied Genetics 112 (6): 1149 - 1163.

Debouck, D.G. (2000). Biodiversity, ecology and genetic resources of *Phaseolus* beans - seven answered and unanswered questions. *Proceedings of the 7th MAFF International*

DOI: https://doi.org/10.5281/zenodo.17462071

Workshop on Genetic Resources, Part 1: Wild Legumes, October 13 - 15, Ibaraki – Japan, pp. 95 - 123.

Douglas C. Montgomery, 2013. Design and analysis of experiments (Eighth edition) John Wiley & Sons, Inc., 111 River Street, Hoboken, New York. Pp 234-253.

Douglas C. Montgomery, George, C. Runger 2003. Applied Statistics and I rob-ability for Engineer. John Wiley & Sons, Inc., 605 Third Avenue, New York, NY. P. 506-564

Ebenezer O. Farombi, Olatunde Owoeye, (2011). Antioxidative and Chemopreventive Properties of Vernonia amygdalina and Garcinia biflavonoid. International journal of environmental research and public health 8 (6), 2533-2555

Gilden, R. C., Huffling, K., and Sattler, B. (2010). Pesticides and health risks. J. Obstet. Gynecol. Neonatal Nurs. 39, 103–110.

Hill, D.S., 2002. Pests of Stored Food stuffs and Their Control. Kluwer Academic Publishers, Dordrecht, The Netherlands.

Isman, B. M (2006). Botanical insecticides, deterrents, and Repellents in modern agriculture and an increasingly regulated world. *Annu. Rev. Entomol.51:45–66.*
Doi:10.1146/annurev.ento.51.110104.15114.

Kumar, N., Pathera, A. K., Saini, P., and Kumar, M. (2012). Harmful effects of pesticides on human health. Ann. Agri Bio Res. 17, 125–127.

Mailafiya, D. M., Maina, Y. T., Degri, M. M., Gadzama, U. N.(2014). Traders Perception of Food grain Storage Pest Managementin Daiwa Market, Borno State Nigeria. *Journal of Agricultural and Cooperative Research, Vol.2 Issue 4, 2014.*

Mensack, M.M., Fitzgerald, V.K., Ryan, E.P., Lewis, M.R., Thompson, H.J. and Brick, M.A. (2010). Evaluation of diversity among common beans *(Phaseolus vulgaris L.)* from two centers of domestication using 'omics' technologies. BMC genomics 11 (1), 686 p.

Mohammad A. Alzohairy, (2016). Therapeutics Role of Azadirachta indica (Neem) and Their Active Constituents in Diseases Prevention and Treatment. Article ID 7382506
https://doi.org/10.1155/2016/7382506

Oladosu-Ajayi R.N., Dienye H.E., Ajayi C.T., Erinle O.D., (2017). Comparative Screening of Phytochemical Compounds in Scent Leaf (Ocimumgratissimum) and Bitter Leaf (Vernonia amygdalina) Extracts. J Fish Aquac Dev: JFAD-112. DOI:10.29011/JFAD-112/100012

Rayhan, M.Z., Das, S., Sarka,r R., Adhikary, S.K., Tania, S.N., Islam, M.M. and Rabbani, M.G. 2014. Bioefficacy of neem, mahogoni and their mixture to protect seed damage and seed weight loss by rice weevil in storage. J. Biod. Env. Sci., 5(1): 582-589.

Shang A. O., Shi-Yu Cao, Xiao-Yu Xu, Ren-You Gan, Guo-Yi Tang, Harold Corke, Vuyo Mavumengwana, Hua-Bin Li, (2019). Bioactive Compounds and Biological Functions of Garlic (Allium sativum L.). Foods 8 (7), 246

Swella G. B., Mushobozy D.M.K. 2007. Evaluation of the efficacy of protectants against cowpea bruchid Callosobruchus maculates (F) on cowpea seeds (Vigna unguiculata (L.) Walp.). *Plant Protection Sci. 43: 68–72.*

Thakur D.R., 2012. Taxonomy, distribution and pest status of Indian biotypes of *Acanthoscelides obtectus*(Coleoptera: Chrysomelidae: Bruchinae) – a new record. *Pakistan Journal of Zoology 44, 189-195.*

Tryphone G.M., Chilagane A.L., Nchimbi-Msolla, S. and Kusolwa, P.M. (2015).Genetic characterization of angular leaf spot resistance in selected common bean landraces from Tanzania. *African Journal of Biotechnology 14 (43): 2943 - 2948.*

Suleiman, M. and Yusuf, M. A. (2011). The potential of some plant powders as biopesticides against *Sitophilus zeamais* (Motsch.) (Coleoptera: Curculionidae) and *Callosobruchus maculatus* (F.) (Coleoptera: Bruchidae) on stored grains: a review. *Bayero Journal of Pure and Applied Sciences*, 4(1): 204-207.

World Health Organization (1990). Public Health Impact of Pesticides Used in Agriculture. Geneva: World Health Organization.

Wortmann, C.S., Brink, M., Belay, G., (2006). Phaseolus vulgaris L. (common bean). Record from PROTA 4U. Bring M. and Belay, G. (Editors). PROTA *(Plant Resource of Tropical Africa)* Wageningen, Netherlands, 608 p.

Yadav, I. C., Devi, N. L., Syed, J. H., Cheng, Z., Li, J., Zhang, G., et al., (2015). Current status of persistent organic pesticides residues in air, water, and soil, and their possible effect on neighboring countries: a comprehensive review of India. *Sci. Total Environ. 511, 123–137*.