ACTA SCIENTIFIC AGRICULTURE (ISSN: 2581-365X)

Volume 3 Issue 4 April 2019

Research Article

# Evaluation of Weevil Infestation and Seed Quality Attributes of Maize on Different Storage Conditions

**Rabin Aryal[1]*, R Panta[1], R Pudasaini[1] and G Bhandari[2]**

[1] *Institute of Agriculture and Animal Science, Tribhuvan University, Lamjung, Nepal*

[2] *Nepal Agricultural Research Council (NARC), Seed Science and Technology Division (SSTD), Khumaltar, Lalitpur, Nepal*

***Corresponding Author:** Rabin Aryal, Institute of Agriculture and Animal Science, Tribhuvan University, Lamjung, Nepal.

**Received:** February 15, 2019; **Published:** March 08, 2019

## Abstract

Inappropriate storage and moisture content of seed leads to weevil infestation within a month of storage. So, an experiment was conducted to evaluate the effect of various storage structures and moisture content on weevil infestation and seed quality attributes of maize seed. Quality protein maize (QPM-1) and manakamana-4 were tested in two different improved hermetic storage structures (PICs and super grain bags) under two different moisture regimes (11% and 9%) at Seed Science and Technology Division, Khumaltar, Nepal during June 2015 to October 2017. The experiment was laid out in three factor factorial experiment based on completely randomized design (CRD). Data on electrical conductivity (EC), Change in Moisture content (CM), germination percentage and seedling length was measured at start and end of the experiment. Maximum germination percentage and seedling length was found on PICs bags (93% and 23cm respectively). Manakamana- 4 show greater resistances against weevil but variety alone have no significant difference on germination and seedling length. Interaction of low moisture and Perdue Improve crop storage (PICS) showed better result on weevil infestation, weight loss by weevil and CM, but no significant difference was observed on germination percentage and seedling length. During the experiment period maximum weevil infestation and weight loss was found on super grain bags 21% and 2.59% and lowest in PICs bags 9% and 1.1% respectively. The findings evidenced that PICs bag with low moisture content can be safest approach in reducing the weevil infestation and retaining seed quality of maize seed for more than two years.

**Keywords:** Conductivity; Hermetic; PICs Bag; Sitophilus; Vigor

## Introduction

In relation to area and production maize is the second most important food crop in Nepal [1]. According to Krishi Diary [2] maize occupied about 29.9% of total cultivated agriculture land. The maize kernel has nutritional properties that are comparable to other cereals such as rice and wheat. The nutritional composition of maize consists of carbohydrates, protein and small quantities of fat, vitamins, dietary fibers and minerals such as iron and phosphorus [3].

Since storage of maize for a month or more lead to weevil infestation, effective storage condition is the prime concern for long term storage of maize seed. It is estimated that 1% to 5% of stored grain in developed countries and 20% to 50% of stored grain in developing countries are lost due to insect damage [4,5]. Despite increased in production, postharvest loss due to insect infestation is a major challenge in maize [6]. Stored maize grain are prone to insect pest among which maize weevil (*Sitophilus zeamais*), Angoumois grain moth (*Sitotroga cerealella*) and larger grain borer (*Prostephanus truncatus*) are the major ones [7]. Adult of these insect feed on undamaged grains which in turn change into dust making them unfit for human consumption [8].

Infestation by weevil is prevalent during field [9,10] but most damage is done during storage condition. Low germination, poor quality and weight loss are the major outcome of damage grain by weevil infestation [11]. Maize weevils are extremely destructive to maize under favorable condition of tropic and sub tropic temperature. Adult weevils damage by feeding on endosperm of stored maize. The female deposits egg on kernel and hatch into larva that feed on endosperm inside the kernel [12].

In orthodox seed like maize, moisture content is the most important single factor in determining seed longevity [13]. Maize grain is hygroscopic and its moisture content easily equilibrates with the surrounding air, in open-air storage. This, in addition to high relative humidity and temperature in the tropics, promotes the rapid infestation and multiplication of insects, molds as well as rodents and birds attack in open-air storage [14]. Reduction in moisture content cause reduction in respiration and thus slows down ageing of seed and prolongs viability. Below 8-9% moisture insect activity is much reduced that could be maintain by hermetic storage. Under hermetic technology system metal silos was introduced which is effective in reducing grain damage and loss from insect [15]. Although they work well in controlling maize weevils they are quite expensive for small farmers in terms of cost effectiveness [16]. Hermetic bags like PICs bags and super grain bags are quite affordable and easy to handle than metal silos.

Inappropriate seed moisture and storage condition are the major concern for long term storage of maize seed. The uses of hermetic storage structures which reduce weevil infestation to extreme level are not popular in developing countries like Nepal. So, extension of such storage structures can help majority of Nepali farmers to combat with weevil infestation problem during the storage. Hence weight loss of storage grain and quality of maize seed can be retained for longer than that of the traditional storage structures.

## Materials and Method

The experiment was conducted in laboratory of Seed Science and Technology Division (Longitude 85°10' E and Latitude 27°39'N; Altitude, 1335m), Khumaltar, Nepal during June, 2015 to October, 2017.The experiment was carried out in complete randomized design (CRD) consisting three factors which consist of 8 treatments with 3 replications. Seeds of maize were used which was collected from NARC, Khumaltar. Maize seed of two different varieties

- $V_1$: Manakamana-4 and
- $V_2$: Quality protein maize (QPM-1)

Was selected and each variety was stored under two different storage structure;

- $S_1$: super grain bag and
- $S_2$: Perdue Improve crop storage (PICs bag)

The moisture content of each variety were maintained at 11% and 9% through sun drying and week desiccation with help of zeolite beads using drying bead calculation and stored in two different storage structure;

- $M_1$: 11%
- $M_2$: 9%

Eight treatments comprising 2 verities at 2 different moisture regimes were stored in two different storage conditions and laid out in completely randomized design (CRD). The initial seed quality attributes like germination, EC and seed moisture content were recorded during initial stage of experiment.

Treatments details

| Treatments | Details |
|---|---|
| $S_1V_1M_1$ | Super grain bag, Manakamana-4, moisture content -11% |
| $S_1V_1M_2$ | Super grain bag, Manakamana-4, moisture content-9% |
| $S_1V_2M_1$ | Super grain bag, Quality Maize Protein (QPM-1), moisture content -11% |
| $S_1V_2M_2$ | Super grain bag, Quality Maize Protein (QPM-1), moisture content-9% |
| $S_2V_1M_1$ | PICs bag, Manakamana-4, moisture content -11% |
| $S_2V_1M_2$ | PICs bag, Manakamana-4, moisture content-9% |
| $S_2V_2M_1$ | PICs bag, Quality Maize Protein (QPM-1), moisture content -11% |
| $S_2V_2M_2$ | PICs bag, Quality Maize Protein (QPM-1), moisture content-9% |

Table a

### Weevil infested seed count

Before counting infested and non-infested seed fuchsin acid solution was made by adding 0.5 gm. of fuchsin acid in 950 ml distil water and 50 ml glacial acetic acid solution. 100 seed of each treatment were randomly selected and soaked on warm water for 5 minutes and then water was drained. After draining water presoaked seed were put in the petridish containing fuchsin acid solution of about 250 ml and left for 3 minutes. After soaking the seed in fuchsin acid solution, the solution was drained and seed were washed with tap water and left in petri dish for drying purpose. The fuchsin acid solution make colorful at whole made by weevil and infected seed was easily observed. Then seed were observed under microscopic view.

The infested and non-infested seed of each randomly selected sample were replicated 3 times. Then the percentage of weevil infested seed was calculated in percentage basis by using following formula;

$$\text{Percentage of weevil infested seed} = \frac{\text{number of weevil infested seed}}{\text{total number of sample seed of each replicate}} * 100$$

### Grain weight loss percentage

A subsample of about one kg seed were taken from each bag of each treatment. 100 seed from each subsample were randomly selected for each replicate. Then grains are separated by eye into two groups i.e. damaged and undamaged grains. The damaged and undamaged grains in each group are then counted.

After that weight loss percentage of stored maize are calculated separately for each subsample using conversion factor method given in Harris and Lindblad [17] as shown:

$$\text{Weight loss\%} = \frac{(Nd) * 100}{(Nu+Nd) * 8}$$

Nd= number of damaged grains and Nu= number of undamaged grains

### Moisture content (MC)

Oven dry method was used for assessing moisture content of seed. The handful of seed for each treatment was grinded in the grinder and weight was measured fixing on the range of 4.9 to 5.1 gram. Seed in powdered form was put in the can after weighing the empty can. The can weight can weight with grinded seed were taken and put in the oven dry at 130 degree centigrade degree for 4 hours. After four hours the oven dried sample of respective treatment were weighed and data were recorded. The moisture content of each treatment was calculated using formula

$$MC = \frac{\text{(weight of grinded seed with can) - (weight of grinded seed with can after oven dried)}}{\text{weight of oven dried sample with can}}$$

### Electrical conductivity

According to the method of seed vigor testing [18] fifty seeds of each treatment was selected and weighed. Weighed seed were placed in a separate beaker for each treatment containing 250 ml of distilled water. Beaker was sealed with aluminum paper and was kept at room temperature for 24 hours. The ppm, temperature and µ value was recorded using EC Meter of Hanna Instruments.

E.C was calculated by using formula:

$$E.C = \frac{\text{conductivity reading } (\mu scm^{-1}) \text{ - background reading}}{\text{weight of replicate (gm)}}$$

### Viability percentage, Germination percentage and seedling length

0.1% Tetrazolium solution was made for each treatment and viability percentage was determined by the following formula

$$\text{Viability percentage} = \frac{\text{viable seed}}{\text{total seed sample}} * 100$$

Between paper methods was used to evaluate germination percentage and value was calculated by using the following formula

$$\text{Germination percentage} = \frac{\text{total germinated seed for each replicate}}{\text{total seed sample of each replicate}} * 100$$

Seedling length was calculated at the $7^{th}$ day of the germination test by calculating root and shoot length in cm.

## Result and Discussion

| Treatment | Infested seed percent | Weight loss Percent | Change in moisture % |
|---|---|---|---|
| Factor A(Maize) | | | |
| $V_1$ (Manakamana-4) | $13^b$ | $1.64^b$ | $0.37^b$ |
| $V_2$ (QPM-1) | $17^a$ | $2.06^a$ | $0.97^a$ |
| F test | ** | ** | *** |
| Factor B(moisture) | | | |
| $M_1$ (11%) | $18^a$ | $2.26^a$ | $0.81^a$ |
| $M_2$ (9%) | $12^b$ | $1.44^b$ | $0.53^b$ |
| F test | *** | *** | *** |
| Factor C(storage) | | | |
| $S_1$ (super bag) | $20.75^a$ | $2.59^a$ | $1.14^a$ |
| $S_2$ (PICs bag) | $9^b$ | $1.10^b$ | $0.19^b$ |
| F test | *** | *** | *** |
| LSD (5%) | 1.935 | 0.2419 | 0.119 |
| CV% | 15.11 | 15.11 | 20.61 |
| Factor B: factor | | | |
| $M_1S_1$ | $25.17^a$ | $3.14^a$ | $1.38^a$ |
| $M_1S_2$ | $11^c$ | $1.37^c$ | $0.24^c$ |
| $M_2S_1$ | $16.33^b$ | $2.04^b$ | $0.90^b$ |
| $M_2S_2$ | $6.67^d$ | $0.833^d$ | $0.15^c$ |
| F test | * | * | ** |
| LSD (%) | 2.953 | 0.369 | 0.182 |
| CV% | 15.11 | 15.11 | 20.61 |
| Factor A: B: C | | | |
| F test | NS | NS | * |
| LSD (5%) | 4.391 | 0.548 | 0.271 |
| CV% | 15.11 | 15.11 | 20.61 |

**Table 1:** Effect of different factors on weevil infestation, weight loss and change in moisture in 2 years stored maize at Seed Science and Technology Division, NARC, 2017.

Mean separation in columns followed by same letters are not significantly different at p=0.05 Note: NS= Non-significant, * = significant at 5% level of significance, ** = significant at 1% level of significance, ***=significant at 0.1% level of significance.

### Effect of different factors on weevil infested seed (%) and weight loss by weevil (%)

The effect of variety on weevil infestation and weight was found highly significant. Weevil infestation and weight loss was found maximum in QPM-1(17% and 2.06%)) and least in Manakamana-4 (14% and1.63%) respectively. The result obtain above is similar with the findings observed by Paneru and Thapa [19], number of weevil emergence and weight loss was highest in QPM-1 in no choice test and least in Manakamana-4. The reason behind high weevil infestation and weight loss may be due to Opaque-2 (O-2) mutant gene in QPM-1 that changes protein composition and increases the content of lysine and tryptophan in the maize endosperm [20]. The endosperm of the O-2 gene corn endosperm was found to be light and soft [21]. The softness of the endosperm of the O-2 maize make very attractive to the stored grain pest [22,23] and make QPM maize susceptible.

The effect of moisture on weevil infestation was found highly significant. In relation to moisture, highest weevil infestation and weight loss was found in maize seed stored at initial moisture content of 11% (19% and 2.26%) and least in seed with initial moisture content of 9% (12% and1.43%) respectively. The highest weevil infestation at higher moisture may be due to insect activity favor by high grain moisture [24]. The lower weight loss at 9% seed moisture content may be due to lower number of weevil infestation in which biological activity of insect pest reduced at low seed moisture content [25].

The effect of storage on weevil infestation and weight loss was found highly significant. In response to storage structure, maximum weevil infestation and weight loss was found in maize seed stored in super grain bags (21% and 2.59%)) and least in PICs bags (9% and1.10%) respectively. The low weevil infestation in PICs bag is due to low permeability HDPE liners which have low permeability to outside air and thus maintain low oxygen level and increase the carbon dioxide level inside due to respiration of grain and stopping insect activity [26,27]. The greater increase of weight loss in super grain bags is due to high weevil infestation [28,29]. Though insect infestation is low in PICs bag at 9 percent moisture content, reduction in weight loss may be due to increase humidity and storage period [30]. The finding of this study is in concordance with 0.3% weight loss reported by Hell., *et al.* [31] over six month storage in PICs.

### Interaction

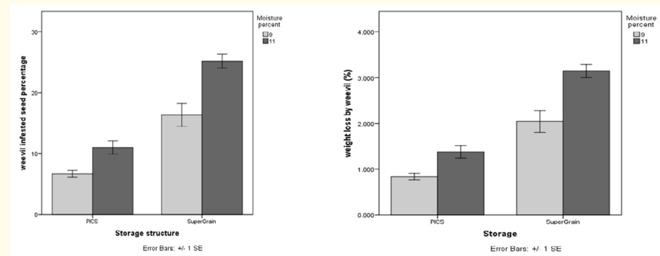


**Figure 1:** A. Influence of moisture and storage on; B. Influence of moisture and storage on weight.

Weevil infestation loss by weevil.
Seed Science and Technology Division, NARC, 2017.

### Change in moisture content in PICs and super grain bags

The highest change in moisture content was found in Maize seed stored in super grain bag (1.54%) and least in PICs bag (0.19%). Similar supported works revealed in hermetic 500 gauge plastic bags, where 12% MC was just increased to 12.5% in 10 month storage in ambient room temperature in Srilanka [32].

| Sample No. | pH | Temperature (°C) | ORP (mV) | EC (mS/cm) | Salt (ppm) |
|---|---|---|---|---|---|
| Sample-1 | 7.46 | 26.9 | 177 | 0.892 | 444 |
| Sample-2 | 7.49 | 27.1 | 138 | 1.555 | 772 |
| Sample-3 | 6.91 | 26.8 | 158 | 1.344 | 671 |
| Sample-4 | 6.70 | 26.1 | 153 | 1.291 | 645 |

**Table 2:** Data of the Laboratory Analysis of the Soil Samples of the Study Area.

### Effect of different factors on viability, germination and seedling length

No significant differences on viability were found in any factors. The effect of variety and initial seed moisture on germination and seedling length was found non-significant.

The effect of storage structure on germination and seedling length was found highly significant. The highest germination and seedling length was found on seed stored in PICs bag (93% and

23 cm) and lowest germination and seedling length was found in maize seed stored in super grain bags (88% and 20cm) respectively. The highest germination in PICS bags is due to maintenance of seed viability in PICs bag [33]. This experiment was in accordance with Williams., *et al*. [34] where germination of maize stored in PICs ranged between 70 and 95% across eight month study period.

Moisture and storage interaction on germination (%) and seedling length

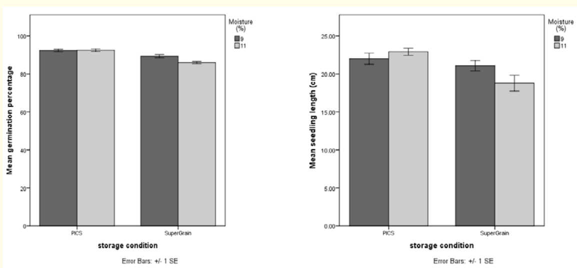


**Figure 2:** A. Influence of moisture and storage on germination. B. Influence of moisture and storage on seedling length.

Seed Science and Technology Division, NARC, 2017.

No significant difference on germination and seedling length was observed on PICs bag at either of moisture regime. But significant difference was observed on super grain bag. This may be due to the highest weevil infestation in super grain bag that reduce the germination and seedling length.

The lower rate of germination in seed with original moisture level of 11% in super grain could be due to the growth of insects which had infested the grain [35-37].

### Effect of different factors on electrical conductivity

The highest electrical conductivity was found in maize with initial seed moisture content 11% (62.16) and lowest in seed with initial moisture content of 9% (53.27). This result was found concurrent with the experiment conducted by Bhandari., *et al*. [38] where electrical conductivity was found lower at 9% moisture than at 11%. The reason behind lower electrical conductivity may be due to lower weevil infestation. Higher conductivity in the seed at 11% moisture may be due to higher weevil infestation which in turn rupture the seed wall of seed and hence favor leaching of solutes [39,40]. Seed stored at either of moisture content can retain the viability up to 2 years of storage since Soybean seed lots with EC within the limits of 60 to 70 µS $cm^{-1}$ $g^{-1}$ are considered of high vigor and between 70 to 80 µS $cm^{-1}$ $g^{-1}$ are considered of medium vigor [41].

The highest electrical conductivity was found in Maize seed stored in super grain bag (64.98) and least in PICs bag (50.45). The reason behind lower electrical conductivity may be due to lower weevil infestation. Higher conductivity in super grain bags may be due to higher weevil infestation due to its single liner bag which can be bored easily by the weevil and larger grain borer in the storage. Which in turn rupture the seed wall of seed and hence favor leaching of solutes [39]. Seed stored in either of storage structures retain seed vigor up to 2 years of storage since Soybean seed lots with EC within the limits of 60 to 70 µS $cm^{-1}$ $g^{-1}$ are considered of high vigor and between 70 to 80 µS $cm^{-1}$ $g^{-1}$ are considered of medium vigor (Vieira, 1994).

### Moisture *storage interaction

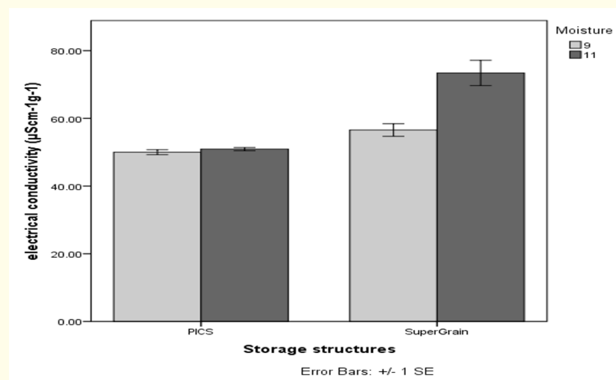


**Figure 3:** Influence of moisture and storage on electrical conductivity, Seed Science and Technology Division, NARC, 2017.

No significant difference on EC value was observed within PICs at either of moisture regime but found significant within super grain at two moisture regime. Higher conductivity value (74) was found in seed with initial moisture content of 11% stored in super grain bag. Seed stored in PICs bag was found highly vigor at either of moisture and lowest in PICs bag at 9% moisture (50). Seed stored in either of the storage condition were found highly vigor but at 11% moisture content seed stored in PICs was highly vigor and seed stored in super bag was found medium vigor according to Vieira., *et al*. [41]. EC within the limits of 60 to 70 µS $cm^{-1}$ $g^{-1}$ are considered of high vigor and between 70 to 80 µS $cm^{-1}$ $g^{-1}$ are considered of medium vigor [41].

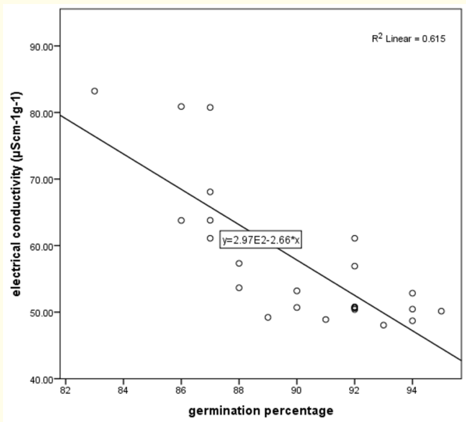


**Figure 4:** Correlation of Electrical conductivity and germination in maize variety from various containers and MC in two year storage in Khumaltar, 2017.

The close relationship between the electrical conductivity and germination percentages was illustrated in figure 4. By plotting electrical conductivity and germination of 2 years stored maize seed sample, negative correlation was obtained. The result showed that, 61.5% germination value was found indirectly proportional to EC value. Similar trend was obtained in one year stored QPM maize seed (r= -0.697) [38]; in soybean with r= -0.67 [42]; in cauliflower and cabbage r= -0.96 and -0.96 [43] have been documented. EC value was strongly related to germination and was found significant.

The process of ageing is said to be started by the loss of cell membrane integrity and increased leakage [44]. The attack of insects on grains also leads to an increase in electrical conductivity by rupturing the outer wall and perforating the grain tegument [39]. These factors cause damage to cell membranes, resulting in greater electrolytic leaching of solutes and, consequently, higher electrical conductivity [40]. The conductivity value was found significantly related with germination and was clearly higher for samples with lower germination [45-49].

## Discussion and Conclusion

The study found that PICs bag reduces the weevil infestation and maintain the physiological quality of maize seed better than the Super grain bag. Hence, maintaining low moisture content and using PICs bag as a storage structure significantly contributes in maintaining the vigor of seeds in sub-tropical environmental condition. Similarly, Manakamana-4 shows greater resistance to weevil infestation than QPM-1(maize variety). PICs bag as a storage structure for seeds, not only protect seeds from quality deterioration but also helps in conserving seeds for two years that eventually reduces the demand and procurement of seeds in successive season. Moreover, maize seed can be stored at as low as 9% moisture content that greatly reduces the weevil infestation and maintain the seed quality for two years long storage period.

## Acknowledgement

I am indebted towards Seed Science and Technology Division, NARC and Institute of Agricultural and Animal Science for giving me the platform and materials support for my research work. I would like to express my deepest appreciation and profound gratitude to my advisors Assistant professor Rameshwor Pudasaini and Technical officer Gopal Bhandari, for their excellent guidance, caring, patience and encouragement throughout my research period.

## Bibliography

1. Upadhyay SR., *et al.* Development of QPM (Quality Protein Maize) Varieties for the Hills of Nepal. Proceedings of the 25th National Summer Crops Research Workshop, National Maize Research Program, Nepal Agricultural Research Council, Kathmandu, Nepal (2007): 31-38.
2. Krishi Diary. Government of Nepal, Agriculture Information and Communication centre, Hariharbhawan, Lalitpur (2017).
3. Iken JE., *et al.* "Nutrient composition and weight evaluation of some newly developed maize varieties in Nigeria". *Journal of Food Tech in Africa* 7 (2002): 27-29.
4. Ileleji KE., *et al.* "Evaluation of different temperature management strategies for suppression of Sitophilus zeamais (Motschulsky) in stored maize". *Journal of Stored Products Research* 43.4 (2007): 480-488.
5. Nukenine E. "Stored product protection in Africa: Past, present and future". *Julius-Kühn-Archiv* (2010): 26-41.
6. FAO. "Postharvest losses aggravate hunger". Media -Centre - FAO, Rome, Italy (2009).
7. Chebet F., *et al.* "Bioactivity of selected plant powders against prostephanus truncatus (Coleoptera: Bostrichidae) in stored maize grains". *Plant Protection Science* 49.1 (2013): 34-43.
8. Ofuya TI., *et al.* "Ability of Sitophilus zeamais Motschulsky (Coleoptera: Curculionidae) from four locations in Nigeria to infest and damage three varieties of maize, Zea mays L". *Niger Journal of Entomology* 25 (2008): 34-39.

9. Demissie G., *et al.* "Importance of husk covering on field infestation of maize by Sitophilus zeamais Motsch (Coleoptera: Curculionidea) at Bako, Western Ethiopia". *African Journal of Biotechnology* 7.20 (2008): 3777-3782.

10. Caswell GH. "Agricultural Entomology in the Tropics". Edward Arnold, London, (1962): 145.

11. Enobakhare DA and Law-Ogbomo KE. "Reduction of postharvest loss caused by Sitophilus zeamais (Motsch.) in three varieties of maize treated with plant products". *Postharvest Science* 1 (2002). 1-6.

12. Hill DS. (1983). Agricultural Insect Pests of the Tropics and their Control. Technology and Engineering (2010): 746.

13. Holmes GD and G Buszewicz. "The storage of seed of temperate forest tree species". *Seed Technology* 19.3 (1958): 455-475.

14. IRRI. "Grain storage and pest management". *Hermetic Grain Storage Systems* (2008).

15. Tefera T., *et al.* "The metal silo: An effective grain storage technology for reducing post-harvest insect and pathogen losses in maize while improving smallholder farmers' food security in developing countries". *Crop Protection* 30.3 (2011): 240-245.

16. Simon C and Groote D. "Economic Analysis of Alternative Maize Storage Technologies in Kenya". In 3rd international Conference of the African Association of Agricultural Economists (AAAE) (2010).

17. Harris KL and Lindblad CJ. "Post harvest grain loss assessment methods. A manual of methods for the evaluation of post harvest losses". *American association of Cereal Chemists* (1978).

18. ISTA. "International Rule for Seed Testing". The international seed testing association (ISTA), Zurichstr. 50 Switzerland (2011): 15A-4.

19. Paneru RB and Thapa RB. "Screening of promising maize genotypes against maize weevil (Sitophilus zeamais Motschulky) in storage condition". 3 (2017): 108-119.

20. Mertz ET., *et al.* "Mutant Gene That Changes Protein Composition and Increases Lysine Content of Maize Endosperm". *Science* 14 (1964): 279-280.

21. Dimler RJ. "Report on kernel structure and wet milling of high lysine corn". Proc. High Lysine Corn conf. Purdue University, U.S.A (1966): 121-127.

22. Whitney WK. "Control of insects by non-chemical methods". Tropical Stored Products Information. London, 25 (1973): 20-21.

23. Ortega A., *et al*., "Disease - insect interaction in quality protein maize". Hutchinson Ross Publishing Stroudsberg (1975): 178.

24. Paneru RB and Sah YP. "Botanicals and other indigenous knowledge systems for the control of post-harvest insects of maize". (2001): 23-29.

25. Jayas DS and White NDG. "Storage and drying of grain in Canada: low cost approaches". *Food Control* 14.4 (2003): 255-261.

26. Murdock LL., *et al.* "Death by desiccation: Effects of hermetic storage on cowpea bruchids". *Journal of Stored Production Resource* 49 (2012): 166-170.

27. Williams SB., *et al.* "Assessing Purdue Improved Crop Storage (PICS) bags to mitigate fungal growth and Aflatoxin contamination". *Journal of Stored Products Research* 59 (2014): 190-196.

28. Lazzari FA. "Humidity, fungi and mycotoxins as seeds, grains and feeds". SS (1997): 134.

29. Beti JA., *et al.* "Effects of maize Weevils (Coleoptera: Curculionidae) on Production of Aflatoxin B by Aspergillus flavus in Stored Corn". *Journal of Economic Entomology* 88.6 (1995): 1517-1838.

30. Christensen CM and Meronuck RA. "Dry matter loss in yellow dent corn resulting from invasion by storage fungi". *Plant Diseases* 73.6 (1989): 501-503.

31. Hell K., *et al.* "Maize stored pests control by PICS- bags: technological and economic evaluation". In: Tamo M., *et al.* (Eds.), Improving livelihoods in the cowpea value chain through advancements in Science. Proceedings of the 5th World Cowpea Research Conference, 26 September - 1 October 2010, Saly, Senegal.

32. Mettananda KA., *et al.* "Effects of Storage Environment, Packing material, and Seed Moisture content on Storability of Maize (Zea mays L.) Seeds". *Annals of the Sri Lanka Department of Agriculture* 3 (2001): 131-142.

33. Baoua IB., *et al.* "PICS bags for postharvest storage of maize grain in West Africa". *Journal of Stored Products Research* 58 (2014): 20 -28.

34. Williams SB., *et al.* "Storage of maize in Purdue Improved Crop Storage (PICS) bags". *PLoS ONE* 12.1 (2017): 1-12.

35. Moreno M., *et al.* "Effect of fungi and chemical treatment on viability of maize and barley seeds with different storage characteristics". *Seed Science and Technology* 22.3 (1994): 541-549.

36. Kabeere F., *et al.* "Effect of maize seed storage conditions on survival of Fusarium spp". *Seed Science and Technology* 25.2 ( 1997): 329-332.

37. Joao Abba E and Lovato A. "Effect of seed storage temperature and relative humidity on maize (Zea mays L.) seed viability and vigour". *Seed Science and Technology* 27 (1999): 101-114.

38. Bhandari G., *et al.* "Effects of storage structures and moisture contents on seed quality attributes of quality protein maize. *Journal of Maize Research and Development* 3.1 (2017): 77-85.

39. Vieira RD., *et al.* "Electrical conductivity of soybean seeds after storage in several environments". *Seed Science and Technology* 29 (2001): 599-608.

40. Alejand ra PM., *et al.* "Level of natural fungus infection related to the quality of peanut seeds". SciELO Analytics 29 (2007): 53-59.

41. Vieira RD., *et al.* "Electrical conductivity and field performance of soybean seeds". *Seed Technology* 21 (1994): 15-24.

42. Yaklich RW., *et al.* "Evaluation of vigor tests in soybean seeds: relationship of ATP, conductivity, and radioactive tracer multiple criteria tests to field performance". *Crop Science* 19 (1979): 806-810.

43. Mirdad Z., *et al.* "Prediction of germination in artificially aged seeds of Brassica spp using the bulk conductivity test". *Seed Science and Technology* 34 (2006): 273-286.

44. McDonald, M.B. "Seed deterioration; physiology, repair and assessment". *Seed Science and Technology* 27 (1999): 177-237.

45. Thornton JM., *et al.* "Investigation of the relationship between seed leachate conductivity and germination of Brassica seeds". *Annuals of Applied Biology* 117 (1990): 129-135.

46. Doijode SD. "Solute leakage in relation to loss of seed viability in chilli cultivars". *Indian Journal of Plant Physiology* 31 (1988): 285-287.

47. Kimenju S and Groote H De. "Economic analysis of alternative maize storage technologies in Kenya". 3rd International Conference of the African Association of Agricultural Economists (AAAE) (2010).

48. MoAC. Statistical information on Nepalese Agriculture, Agribusiness Promotion and statistical Division, Ministry of Agriculture and Cooperatives, Kathmandu, Nepal (2010).

49. MoAD. Nepal Portfolio Performance Review (NPPR). Ministry of Agricultural Development (2015).


**Volume 3 Issue 4 April 2019**