

Evaluation of triple layer hermetic storage bag (PICS) against *Prostephanus truncatus* and *Sitophilus zeamais*

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Abstract

A study simulating farmer storage practices was conducted to evaluate the triple layer Purdue Improved Cowpea Storage (PICS) airtight bags against two major storage insects. Two sets each of PICS, jute and polypropylene bags were filled with 45kg maize grain. Each set was replicated four times. In one set of PICS bags 50 insects each of the larger grain borer (LGB) *P. truncatus* and *S. zeamais* were introduced. One set of jute and polypropylene (PP) woven bags were treated with a cocktail of permethrin and pirimiphos-methyl. The remaining sets formed the controls. Gas analysis in the PICS bags followed the expected trend with oxygen levels falling sharply below 10% and carbon dioxide increasing to almost 10% up to 12 weeks hence resulting in death of infesting insects. After 16 weeks, increase in oxygen levels may be attributed to perforation of the bags by the LGB. Results of mean live insects, grain damage and weight of dust over the six month trial period showed significant differences between PICS and the other treatments especially at the 16th and 24th week but more pronounced at the end of the trial period. PICS bags performed better than all the other treatments. These results demonstrate the potential of PICS bags in protecting stored maize in LGB infested.

Keywords: PICS bags, *P. truncatus*, *S. zeamais*, farmer storage simulation

1. Introduction

The use of hermetic grain bags and solar drying to preserve durable commodities such as grains is now practiced in several countries (De bruin et al, 2012). Use of hermetically-sealed containers to control major insect pests principally works through a simple technology of modifying oxygen levels by respiration and metabolism of insects, fungi and grain to low levels while the level of carbon dioxide rises, causing death of insects and microorganism by asphyxiation (Murdock et al., 2012).

Hermetic storage technologies such as the triple layer Purdue Improved Cowpeas Storage (PICS), super grain bags, cocoons and others are being promoted as cheap and effective ways to control insect pests in Asia and recently in Africa (Quezada et al., 2006; Jones et al., 2011). PICS bags consisting of a double layer of high density polyethylene (HDPE) bags within the standard polypropylene woven bag were shown to effectively control cowpeas against bruchid beetles in West Africa (Baoua et al., 2012a, 2012b). On the other hand, super grain bags consisting of a single high density polyethylene bag used as a liner in the standard polypropylene bags have been successfully disseminated in Asia (Villers et al., 2008).

Integration of these simple technologies with the current existing ones would substantially reduce post harvest losses due to insects in stored maize estimated at 5% (de Lima, 1979) and 30-35% (Muhihu and Kibata, 1985; Mutambuki and Ngatia, 2012) after the entry of the larger grain borer (LGB) *Prostephanus truncatus* Horn. To reduce these losses research priorities should take into consideration these realities and hence develop effective options. A study was therefore set out to evaluate the efficacy of the PICS bags against the major occurring storage insects on maize namely, *Prostephanus truncatus* and *Sitophilus zeamais* Motsch. The simulation trial was conducted at KARI Kiboko subcentre situated 200 km south east of Nairobi along the main Nairobi Mombasa highway an area with abundant population of the larger grain borer.

2. Materials and methods

Properly sieved 50kg maize of hybrid 516 variety was weighed into 8 bags of PICS bags. Another lot of the same weight was weighed into 8 bags of polypropylene woven bags and the rest in 8 jute bags making a total of 24 replicates. In one set of the PICS bags made up of 4 replicates, 50 insects each of *Prostephanus* and *Sitophilus* spp. based on 1 insect per kilogram of grain were introduced. Hence each of the bags had in total 100 insects of both species. No insects were introduced in the remaining set of the PICS bag.

Two sets of the polypropylene and jute woven bags were treated with cocktail of permethrin and pirimiphos-methyl (Actellic super dust) with calculated amounts (28g) based on the recommended rate of 50g per 90 kg grain bag. A device known as a fuffle was used in the admixing to ensure proper mixing of the product in all the kernels. The other two sets of 4 replicates each were left untreated to form the control. Using a compartmentalized spear probe a representative sample of about 500 g was removed from each bag for baseline data. PICS bags were securely tied to ensure air tightness before gas analysis for both oxygen and carbon dioxide was measured using a Mocon for baseline information. This gas analysis continued during subsequent months of the trial period. All the bags were thereafter randomly distributed on pallets (dunnage) in the experimental area inside the barn.

As described above, the same grain probe was used to remove a 500g sample from each bag at 8, 16 and 24 weeks and analyzed in laboratory. Each sample was sieved to remove dust and free-living insects followed by grain moisture determination using a Dicky john moisture meter. The sample was then divided using a riffle divider until 4 sub-samples of approximately 65gm were obtained. Grains in 3 of the sub-samples were sorted into various damage categories. Grain in each damage category were counted and weighed and the weight expressed as a percentage of the original sample. The fourth sub-sample was reserved for reference. Data was analyzed using the Genstat software and variations among treatment means compared using ANOVA to determine the efficacy of each treatment as a grain protectant.

3. Results and discussion

3.1. Gas analysis

The gases analyzed initially followed the expected trend with oxygen levels falling sharply and carbon dioxide increasing in the PICS bags to create a hermetic environment. This trend was maintained up to 12 weeks where upon the oxygen levels started rising. After 16 weeks the increase of oxygen may be attributed to perforation of the bags by LGB. Before that it was rather

difficult to explain the phenomenon. However the important observation made was the ability for PICS bag to bring down O₂ quickly while CO₂ rose resulting in death of infesting insects. This agrees with earlier findings on hermetic storage where it was established that for small containers it took 4-6 weeks for O₂ to fall below 2% threshold level for insects to die.

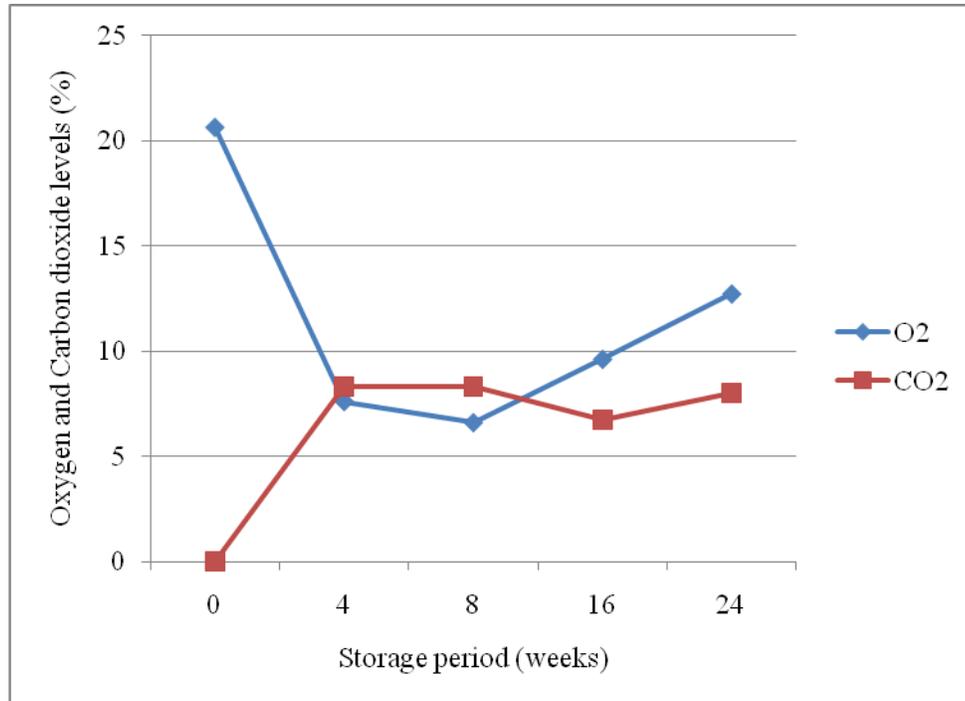


Figure 1 Per cent levels of carbon dioxide and oxygen.

3.2. Changes in moisture content

Moisture levels in all the treatments over the entire trial period were below the recommended 13.5% for safe storage within and between the storage periods (Table 1). Failure on efficacy of the treatments could therefore not be attributed to moisture content. The highest moisture content recorded was 13.3% in one of the PICs treatment. Over the trial period there was only a slight significant differences ($p < 0.05$) within and between the treatments as shown in Table 1.

Table 1 Percent mean grain moisture levels.

Treatment	Storage period (weeks)			
	0	8	16	24
T1	12.5bcdefg	12.7bcdef	12.6bcdefg	12.8abcde
T2	12.9abc	13.0ab	12.9abc	13.3a
T3	12.7abcdef	12.3cdei	12.1efghi	12.1fghi
T4	12.5bcdefg	12.6bcdefg	12.6bcdefg	12.0ghi
T5	13.0ab	12.8abcd	12.2defghi	11.8hi
T6	12.4bcdefh	12.4bcdefgh	11.7i	12.6bcdefg

Means followed by the same letter within a column and across the rows are not significantly different from each other at 5% probability level. LSD 0.6; SEM 0.4; Cv 3.7

Key

T1 PICS bag + maize

T2 PICS bag + maize +LGB + *Sitophilus zeamais*

T3 Polypropylene bag + maize treated with actellic super

T4 Polypropylene bag + maize non treated

T5 Jute bag + maize treated with actellic super

T6 Jute bag + maize non treated

3.3. Changes in amount of dust

The amount of dust produced in a sample reflects the rate of grain insect damage. It was apparent from Table 2 that amount of dust in PICS bag over the entire trial period was not significant different ($p < 0.05$). Neither was it significantly different between treatments at 8 weeks. Even though there was an increase in the amount of dust produced in polypropylene and jute bags, no significant differences ($p < 0.05$) were observed at 16 weeks except for the untreated maize in jute bags (57g). By the end of the trial the untreated grain in polypropylene bags (100g) and jute bags (117g) showed significant differences to PICS and treated grain. Actual amount of dust was significantly low at only 0.4 g in PICS bag at the 24th week an indicator of low population of insects. LGB is known to produce copious amount of dust during feeding. Hence the large amounts of dust in the controls compared to treated grain and grain held in the airtight PICS bag. Complementing high dust levels was the maize weevil *Sitophilus* spp. as it bored through the kernels.

Table 2 Mean weight of dust weight in 500g sample.

Treatment	Storage period (weeks)			
	0	8	16	24
T1	1.4f	1.4f (0)	1.6f (0.2)	1.8f (0.4)
T2	2.5f	3.0f (0.5)	3.1f (0.1)	3.4f (0.4)
T3	3.6f	3.2f (0)	7.0ef (3.4)	18.1e (14.5)
T4	3.5f	3.5f (0)	9.5ef (6.0)	100b (96.5)
T5	2.2f	2.5f (0.2)	6.0f (3.8)	33.9d (31.7)
T6	2.3f	3.7f (1.4)	57.2c (54.9)	116.9a (114.6)

Means followed by the same letter within a column and across the rows are not significantly different from each other at 5% probability level. LSD 13.9; SEM 9.9; Cv 60.9

() Figures in parenthesis denotes the actual dust over the trial period after adjustment from baseline.

3.4. Changes in number of live insects

Most of the insects in the PICS bag that were introduced at the beginning of the trial could not survive as shown in Table 3. Up to the 16th week only 1 to 2 insects were observed in the PICS bag all being *S. zeamais* and no LGB. All LGB in the sieved samples were dead. Perforation of the two layers of polyethylene by LGB started after the 16th week since quite a number of holes were observed at the end of the trial. However out of the samples sieved only 1 LGB, 8 *S. zeamais* 1 LGB, 9 *S. zeamais* were found in PICS/maize (T1) and PICS /insects (T2) bags respectively. Most of live LGB invading the bags from outside were congregated at the outer and inner layer where bags were tightly tied (knot) as they tried to reach the grain. Significant differences ($p < 0.05$) on the number of insects in PICS and the rest of the treatments were apparent at 16th and more so at the 24th week. No significant difference of live insect infestation was found between treated maize in polypropylene and jute bags by the end of the trial. In order of abundance LGB and *S. zeamais* were the most prevalent followed by *Tribolium castaneum*.

It is important to note that at the site of the trial, high population pressure of LGB, *S. zeamais* and other storage insects resulted from other activities on post harvest research on maize. Results from a farmers homestead could probably have been different owing to insect population levels.

Table 3 Mean number of live insects in 500g sample.

Treatment	Storage period (weeks)			
	0	8	16	24
T1	1e	1e	2e	15e
T2	0e	1e	1e	17e
T3	1e	9e	22e	195bc
T4	0e	3e	36e	402a
T5	0e	7e	43e	136cd
T6	0e	5e	271b	382a

Means followed by the same letter within a column and across the rows are not significantly different from each other at 5% probability level. LSD 93.8; SEM 66.5; Cv 103.3

3.5. Changes in damaged grains

Up to 16 weeks there was no significant differences ($p < 0.05$) in number of insect damaged grains within PICs bag T1 and T2 (Table 4). Differences however occurred at the end of the trial period. Between treatments no significant differences were observed in PICs and other treatments by the 8th week with the trend changing by the 16th and 24th week. Per cent insect damaged grain followed the pattern of insect population levels observed above. Perforation of the PICS bags by LGB towards the end of the trial is reflected by the slight rise of actual insect damaged grain of 4 and 6% in T1 and T2 respectively compared to over 90% in the rest of the treatments irrespective of the insecticide treatments.

Table 4 Per cent mean number of insect damaged grain.

Treatment	Storage period (weeks)			
	0	8	16	24
T1	4.8ij	6.0ghij (2.8)	4.3j (0)	8.8g (4.0)
T2	6.0ghij	7.7ghij (1.7)	8.4gh (2.4)	11.6f (5.6)
T3	5.4ghij	8.9fg (3.5)	24.9e (19.5)	93.8b (88.4)
T4	5.0ij	8.5fgh (3.5)	40.7d (35.7)	95.9ab (90.9)
T5	5.8ghij	9.2fg (3.4)	38.0d (32.2)	92.6b (86.8)
T6	6.8ghij	7.9ghij (1.1)	73.8c (67.0)	97.8a (91.0)

Means followed by the same letter within a column and across the rows are not significantly different from each other at 5% probability level. LSD 3.4; SEM 2.4; Cv 8.6

() Figures in parenthesis denotes the actual insect damage over the trial period after adjustment from baseline

4. Conclusions

The performance of the PICS bag in controlling LGB and *S. zeamais* was effective up to 16 weeks with the resultant low live insect infestation and low insect damaged grain. Compared to the other treatments, PICS performed reasonably well even at the end of the trial period considering the insect population pressure at the site that caused over 90% grain damage in all the other treatments. To get the actual performance of these bags in a normal environment it is suggested that the trial should be repeated in cluster of farmers' homesteads.

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