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Effect of controlled atmosphere on the management of maize weevil, *Sitophilus zeamais* (L.) in Maize under ambient storage

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Abstract
The results show that, 100% mortality of adults of *Sitophilus zeamais* (L.) was obtained in 70% CO_2 + 30% Air after 3.5 days of exposure, whereas, only 26.70% mortality was obtained in 50% CO_2 + 50% Air after 3.5 days of exposure. No mortality of Maize weevil was observed in 10% CO_2 + 90% Air and 30% CO_2 + 70% Air after 3.5 days exposure. Progeny adult beetle emergence of 34.67 was recorded in 10% CO_2 + 90% Air when compared to 142.33 and 248.67 in HDPE Container with air tight lid and Normal container covered with muslin cloth, respectively and no progeny was emerged in remaining 3 gas combinations i.e. 30% CO_2 + 70% Air, 50% CO_2 + 50% Air & 70% CO_2 + 30% Air after 8 weeks of experiment. Similarly, weight loss of 1.14%, 2.04% and 4.28% was recorded in 10% CO_2 + 90% Air, HDPE Container with air tight lid and Normal container covered with muslin cloth, respectively.

Keywords: Controlled, atmosphere, management, weevil, Maize, *Sitophilus zeamais* L.

Introduction
The non-toxic fumigation treatments consist of low levels of oxygen and increased temperature, where applicable, and these conditions are kept for a period that is specific to the commodity and insect being treated. This method eradicates insects in all life stages: eggs, larvae, pupae and adults. The Controlled Atmosphere technique is environmentally friendly, without the use of toxic gasses, and it does not leave any residue. Another aspect of this technique is that no resistance can occur in the pest population.
Toxic effects of CO_2 rich atmosphere on several insect pests of stored products were reported by Annis, 1987 [1]. Maximum mortality of adults (99%) and eggs (85) of *Cryptolestes ferrugineus* were obtained at high CO_2 (88-91.7%1) and low O_2 (0-0.5%1), over an exposure period of 96 hours. Calderon and Navarro (1979) [3] found that mortality of *Tribolium castaneum* adults at given O_2 concentrations was higher when the level of the added CO_2 was increased, the temperature was higher and the exposure time extended.
Methyl bromide and Phosphine are only two universally available fumigants remaining for disinfestations of durable commodities. Methyl bromide is facing a phase-out in developed countries by year 2005 and worldwide by year 2015 under Montreal Protocol (UNEP, 2002) [8]. Phosphine is useful fumigant but slow acting and insects in various countries have developed resistance to Phosphine (Winks, 1987) [7]. Hence, the present investigation was conducted to study the effect of carbon dioxide (CO_2) treatment on the mortality/survival of storage insect pest and on seed quality attributes under ambient conditions.

Material and Methods
The experiment was conducted at Post Harvest Technology Centre, Agriculture College, Bapatla, Guntur District, Andhra Pradesh during the year 2010-11. Fresh seed of Maize with good germination and free from insect infestation was selected for this study. The seed was fumigated with Celphos Tablets prior to use to ensure complete kill of field infestation, if any. HDPE containers of 0.5 kg capacity with rubber septa on its lid to insert syringe to remove air and add required proportion of CO_2, N_2 and O_2 in the containers were used.
Four gas combinations *viz.* 10% CO_2 + 90% air, 30% CO_2 + 70% air, 50% CO_2 + 50% air & 70% CO_2 + 30% air along with HDPE container with air tight lid and control with normal container covered with muslin cloth were used for this purpose. The above gas combinations were tested for storage periods *viz*. 1 week, 2 weeks, 3 weeks & 4 weeks for identifying best gas combination to kill and to reduce progeny build up in Maize weevil.

Three such replications were maintained (6 treatments*4 exposure periods* 3 replications = 72 containers). Two sets of 72 containers, one with test insects preferably of the same age group and other without test insects were kept to find out effect of gases on germination of seed. Two fifty gram of seed was kept in each plastic container and 10 pairs of test insects were released in the container marked 'with insects' before sealing the container. The PBI Dan sensor equipment was used to measure and fill the gases in to the plastic containers. CO_2, N_2 and O_2 gas cylinders with metering device are attached to PBI Dan sensor to fill required gases into air tight containers. To create a particular concentration (% v/v) for each treatment, the equivalent volume of air is removed using an airtight syringe through the rubber septum and subsequently calculated volume of CO_2 injected through the same thoroughly. After filling the gases N_2, O_2 and CO_2, the concentrations were rechecked with checkmate for accuracy. The concentration of the gases was also checked periodically to confirm leakage, if any and to plug it. Normally a properly airtight container retains desired concentration of gas.

Results and Discussion

The data on adult mortality was recorded after 3.5 days, 1, 2, 4 and 8 weeks after storage. The results show that, 100% mortality was obtained in 70% CO_2 + 30% Air after 3.5 days of exposure, whereas, only 26.70% mortality was obtained in 50% CO_2 + 50% Air after 3.5 days of exposure. No adult mortality was observed in 10% CO_2 + 90% Air and 30% CO_2 + 70% Air, HDPE Container with air tight lid & Normal container covered with muslin cloth up to 1 week storage (Table 1). An adult mortality of 66.70, 76.70, 93.30 was recorded after 8 weeks of storage in 10% CO_2 + 90% Air, 30% CO_2 + 70% Air, 50% CO_2 + 50% Air when compared to 100% adult mortality in 70% CO_2 + 30% Air. Only 40% and 26.70% adult mortality was recorded in HDPE Container with air tight lid and Normal container covered with muslin cloth, respectively. The results are in agreement with Krishnamurthy *et al.* (1993) [6] used 80 per cent CO_2 to get 100 per cent mortality of *T. castaneum* (Herbst) and *Sitophilus oryzae* (L.) adults. Jay, 1984 [5] reported that emergence of immature stages (1-15 week old) of *S. oryzae* and *Rhizopertha dominica* (F.) stopped completely by exposing them for 2 weeks to 60 per cent CO_2 and low O_2 (<12%) at high relative humidities (>50%).

No Progeny adult beetles were emerged in 30% CO_2 + 70% Air, 50% CO_2 + 50% and 70% CO_2 + 30% Air whereas, 34.67, 142.33 and 248.67 Progeny adult beetles were emerged in 10% CO_2 + 90% Air, HDPE Container with air tight lid and Normal container covered with muslin cloth, respectively after 2 months of storage (Table 2). Weight loss of 1.14%, 2.04% and 4.28% was recorded in 10% CO_2 + 90% Air, HDPE Container with air tight lid and Normal container covered with muslin cloth, respectively. No weight loss was recorded in three gas treatments i.e. 30% CO_2 + 70% Air, 50% CO_2 + 50% Air and 70% CO_2 + 30% Air. Gas concentrations and exposure times to cause >95% mortality of storage insects was assessed by Banks and Fields (1995) [2]. Jayas *et al.*, (1995) [4] reported that all life stages of most stored product insects were killed within 8.5, 11 and 17 days when exposed to 80, 60 and 40 per cent CO_2 concentration.

Per cent mean germination was recorded at 3 months and 6 months of storage without insects. Mean per cent germination of 68.67 and 67.67 after 6 months of storage was recorded in 10% CO_2 + 90% Air and 30% CO_2 + 70% Air, respectively and significantly different from mean germination after 6 months in Normal container covered with muslin cloth (40%). Similarly moisture content in grains was also recorded after 3 months and 6 months of storage without insects. Relatively higher mean per cent moisture was recorded in HDPE Container with air tight lid (11.43%) followed by 10% CO_2 + 90% air (11.33%) when compared to mean low per cent moisture of 10.93% in Normal container covered with muslin cloth (Table 3). Gas retention in the experimental containers was also recorded at 3.5 days and 1 week after experiment. After 3.5 days 1.6, 2.7, 2.7 and 3.2% CO_2 was recorded in 10% CO_2 + 90% Air, 30% CO_2 + 70% Air, 50% CO_2 + 50% Air and 70% CO_2 + 30% Air when compared to < 0.1% in Normal container covered with muslin cloth. After 1 week experimental containers lost most of the CO_2 and attained normal ranges of N_2, O_2 & CO_2 in atmosphere.

Table 1: Mortality of maize weevil, *Sitophilus zeamais* adults in Controlled atmospheric conditions

S. No	Treatment	Average Mortality (%)				
		3.5 days	1 week	2 weeks	4 weeks	8 weeks
1.	10% CO_2 + 90% air	0.00	0.00	10.00	30.00	66.70
2.	30% CO_2 + 70% air	0.00	0.00	13.30	53.30	76.70
3.	50% CO_2 + 50% air	26.70	50.00	83.30	76.70	93.30
4.	70% CO_2 + 30% air	100.00	100.00	100.00	100.00	100.00
5.	HDPE Container with air tight lid	0.00	0.00	16.70	23.30	40.00
6.	Normal container covered with muslin cloth	0.00	0.00	0.00	20.00	26.70

Table 2: Progeny build-up and per cent weight loss of Maize weevil after 2 months of experiment in Controlled atmospheric conditions

S. No	Treatment	Progeny adults emerged (Nos)	Weight loss (%)
1	10% CO_2 + 90% air	34.67	1.14
2	30% CO_2 + 70% air	-	-
3	50% CO_2 + 50% air	-	-
4	70% CO_2 + 30% air	-	-
5	HDPE Container with air tight lid	142.33	2.04
6	Normal container covered with muslin cloth	248.67	4.28
	CD (0.05)	95.161	2.606

Table 3: Per cent Germination and moisture content in Maize after 3 and 6 months of storage after exposure to Controlled Atmospheric Conditions

S. No	Treatment	% Germination in treatments without insects		Mean % Germination	% Moisture content In treatments without insects		Mean % Moisture content
		3 months	6 months		3 months	6 months	
1	10% CO_2 + 90% air	70.33	66.33	68.67[a]	11.47	11.20	11.33[b]
2	30% CO_2 + 70% air	70.00	65.33	67.67[a]	10.90	11.17	11.07[b]
3	50% CO_2 + 50% air	67.00	61.67	64.33[ab]	10.80	11.03	10.93[a]
4	70% CO_2 + 30% air	57.67	54.67	56.33[c]	10.77	10.83	10.83[a]
5	HDPE Container with air tight lid	41.67	40.00	41.00[e]	11.33	11.47	11.43[b]
6	Normal container covered with muslin cloth	42.00	38.00	40.00[e]	11.03	10.80	10.93[a]
	CD (0.05%)	6.92	9.13	5.03	0.43	0.41	0.38

Table 4: Gas retention period in the experimental containers

Period	Treatment					
	10% CO_2 + 90% air	30% CO_2 + 70% air	50% CO_2 + 50% air	70% CO_2 + 30% air	HDPE Container with air tight lid	Normal container covered with muslin cloth
3.5 days	N_2 - 77.4	N_2 - 77.1	N_2 - 76.3	N_2 - 76.5	N_2 - 78.3	N_2 - 78.3
	O_2 - 21.0	O_2 - 20.2	O_2 - 20.5	O_2 - 20.8	O_2 - 21.6	O_2 - 21.6
	CO_2 – 1.60	CO_2 –2.70	CO_2 –2.70	CO_2 –3.20	CO_2 – 0.1	CO_2 – 0.1
1 week	N_2 - 78.2	N_2 - 78.3	N_2 - 77.8	N_2 - 78.6	N_2 - 78.3	N_2 - 78.3
	O_2 - 21.3	O_2 - 21.1	O_2 - 20.9	O_2 - 21.1	O_2 - 21.5	O_2 - 21.6
	CO_2 – 0.5	CO_2 – 0.6	CO_2 – 0.6	CO_2 – 0.3	CO_2 – 0.2	CO_2 – 0.1

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