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Effect of Controlled Atmosphere on the Management of Lesser grain borer, [*Rhyzopertha dominica* (F.)] Infesting Stored Rice

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A B S T R A C T

An experiment was conducted at Post Harvest Technology Centre, Bapatla to study the survival of lesser grain borer, *Rhyzopertha dominica* in various controlled atmospheres. Initially, the permeability of different packing materials *viz*. Aluminium Pouch (AP), Poly Ethylene Glycol (PEG), Low Density Poly Ethylene (LDPE) and Plastic Containers (PC) was tested with different levels of O_2 (6, 10, 14 and 18%) to find out the suitable packing material for controlled atmospheric storage by using PBI Dansensor. Highest permeability of O_2 was recorded in PC, followed by LDPE, AP and PEG over a period of 60 h at all the four O_2 levels tested. Later, progeny build up of *R. dominica* in paddy was tested at various O_2 levels (6, 10, 14 and 18%) in all the packing materials for a period of 180 Days. In PEG, no progeny emergence was recorded at all levels of O_2 tested, whereas in AP, progeny was recorded at 14% and 18% O_2 levels only and no progeny was recorded at 10% and 6 % O_2 tested. In LDPE, progeny emergence was recorded in all 4 levels of O_2 tested.

Introduction

Rice is the most important staple food crop of India and second most important of the world next to wheat. About 65% of Indian population is dependent on rice as staple food. But it is damaged by several insect pests during storage like rice weevil *Sitophilus oryzae* (L.), lesser grain borer, *Rhyzopertha dominica* (F.) and rice moth (*Corcyra cephalonica* Stainton). In India the annual storage losses were estimated as 13.98 million tonnes of food grains worth of 6845 crores of rupees every year. Out of this, food grain losses due to insects alone accounts for 1275 crores (Mohan and Kavitharaghavan, 2008).

Lesser grain borer, *R. dominica* is known to have originated in tropical regions of the Indian subcontinent and now it is a cosmopolitan species, occurring in all areas of the world where grain is produced and stored (Potter, 1935 and Crombie, 1941). Losses due to this pest have been estimated as 15% or more of total grains stored each year (Batta, 2005). The grubs feed on paddy and turn the grains into chaff and the loss is up to 40% (Wilson, 1949). Application of insecticides is one of the management practices to reduce losses during storage. The continuous use of chemical insecticides for control of storage grain insect pests has also resulted in serious problems such as resistance to the insecticides, pest resurgence, and toxicity to humans (Padin *et al.*, 2002 and Hendrawan and Yusof, 2006). As an alternative to chemical fumigants, the normal gases of the atmosphere *viz*., oxygen, nitrogen and carbon dioxide can be altered to achieve control. Carbon dioxide is now being used in several countries for the treatment of stored product, particularly grain bulk to control insects (Cossentine *et al.,* 2004; Mahla and Singh, 2005 and Conyers and Bell, 2007). Vachanth *et al.,* 2010 reported that the mortality per cent of red flour beetle, *Tribolium castaneum* was higher in Aluminum Pouches (100%) followed by High Density Polypropylene (40%) and in the Low Density Polypropylene (20%) bags at the gas proportion of 35% CO_2, 52% N_2 and 13% O_2 in processed little millet. Keeping this in view, the permeability of Aluminium Pouches (AP), Poly Ethylene Glycol (PEG), Low Density Poly Ethylene (LDPE) and Plastic Containers (PC) to oxygen was tested with Checkmate II of PBI Dansensor and further tested for their suitability to avoid infestation by lesser grain borer, *R. dominica* in rice storage.

Materials and Methods

The present investigation on the effect of controlled atmosphere on the management of lesser grain borer, *R. dominica* infesting stored rice was conducted at Entomology laboratory, Post Harvest Technology Centre (PHT Centre), Agricultural College campus, Bapatla, Guntur district, Andhra Pradesh during 2012-13. The packing material AP, PEG, LDPE and PC were used to test the permeability to oxygen to find out suitable packing material which were initially filled with four different levels of O_2 i.e. 6, 10, 14 and 18 %. Normal container without seal was used as control. Later, the permeability of AP, PEG, LDPE and PC to O_2 was tested for every 12 hours interval up to 60 hours with the help of Checkmate II of PBI Dansensor.

Paddy seed BPT 5204 (Samba mashuri) was used for the experiment. The seed was fumigated with 3 g celphos (Aluminium phosphide) tablets @ 3 per tonne for seven days to eliminate existing infestations, if any before releasing test insects. Each packing material was filled with 250 g of paddy and five pairs of freshly emerged adults of 0-24 h old (*R. dominica,*) were released into the bags and kept undisturbed upto one week for egg laying. After one week the released adults were removed from the bags and filled with different concentrations of O_2 (6, 10, 14 and 18%), CO_2 (10, 30, 50 and 70%) and the remaining N_2. Four replications were maintained for each treatment. Observations were recorded on progeny build up at monthly interval up to six months. Progeny emergence was determined by counting the number of all visible dead and live progeny found in paddy at the time of observation. The dead insects were discarded after counting. Progeny build up was transformed into square root values and was subjected to Complete Randomized Design (CRD).

Results and Discussion

The data pertaining to the permeability of different packing material to oxygen at 18, 14, 10 & 6% are given in Table 1. In PEG, the O_2

level reached to 18.5% in a period of 12 h and reached to 18.71% over a period of 60 h from the initial level of 18 %. In AP, the O_2 level reached to 18.61% in a period of 12 h and reached to 19.04% over a period of 60 h which was followed by LDPE with the O_2 level of 20.05% in a period of 12 h which gradually increased and reached to 20.67 over a period of 60 h. The highest rate of O_2 level was recorded in PC (20.3%) over a period of 12 h and slowly reached to 20.72% over a period of 60 h. Similarly, an oxygen level of 15.4% was recorded in PEG in a period of 12 h and reached to 16.2% over a period of 60 h from the initial O_2 level of 14%.

The O_2 level was also less in AP which was recorded 17.4% O_2 in a period of 12 h interval and reached to 18.46% over a period of 60 h which was followed by LDPE with the O_2 level of 19.2% for 12 h and reached to 20.08% over a period of 60 h. The maximum level of O_2 was recorded in PC which was 19.9% in a period of 12 h and reached to 20.7% over a period of 60 h.

Similar trend was continued in initial O_2 levels of 10 and 6% also. In PEG, the oxygen levels are increased and reached to 12.20 and 9.12% over a period of 60 h from the initial concentration of 10 and 6% $O_{2,}$ respectively. In AP, the oxygen levels are increased and reached to 15.53 and 13.88% over a period of 60 h from the initial concentration of 10 and 6% $O_{2,}$ respectively. Similarly, in LDPE the oxygen levels are increased and reached to 19.73 and 20.48% over a period of 60 h from the initial concentration of 10 and 6% $O_{2,}$ respectively.

In PC, the oxygen levels are increased and reached to 20.55 and 20.55% over a period of 60 h from the initial concentration of 10 and 6% $O_{2,}$ respectively. From the above data which was recorded during different intervals, it is evident that the rate of oxygen ingression was highest in PC, followed by LDPE and AP and least was in PEG at all levels of O_2 tested.

As per the data, the packing material which was initially filled with 18% O_2 have recorded an oxygen ingression of 1.04, 0.71, 2.67 and 2.72 in AP, PEG, LDPE and PC, respectively over a period of 60 h. Likewise, the packing material which was initially filled with 14% O_2 have recorded an oxygen ingression of 4.46, 2.20, 6.08 and 6.70 in AP, PEG, LDPE and PC, respectively over a period of 60 h. Similar trend was observed when the packing material was initially filled with 10 and 6% oxygen, where in 5.53, 2.20, 9.73, 10.55 and 7.88, 3.12, 14.48, 14.55% oxygen ingression was recorded in AP, PEG, LDPE and PC, respectively over a period of 60 h. Among different levels of O_2 (18, 14, 10 & 6) tested, the rate of oxygen ingression was highest in 6% followed by 10, 14 and 18%, which was due to the oxygen gradient prevailing between packing material and the atmosphere. Further, all the packing material was tested for their suitability to prevent damage caused by lesser grain borer, *R. dominica.*

The progeny build up of *R. dominica* in the paddy grains treated with different levels of O_2 at 15 days interval up to 180 days in AP is given in table 2. There was no progeny emergence at 6 and 10% O_2 up to 180 DAT. From this data it is evident that the O_2 at 6 and 10% completely protected the paddy seed in AP up to 180 days. The progeny recorded at 30 DAT in the grains treated with 14 and 18% O_2 were 2 and 3, respectively whereas 20.67 and 26.33 progeny were recorded in PC and control, respectively. The data recorded at 60 DAT on the progeny build up was 41.33 and 57.33 at 14 and 18% O_2, respectively which were significantly different from the progeny in PC (131.67) and control (211.67). At 90 DAT the progeny recorded were 109.33 and 142.67 in the grains treated with 14 and 18% O_2, respectively whereas 224 and 343 progeny of *R. dominica* were recorded in the PC and control, respectively. The observations at 120 DAT recorded 180.67 and 243.67 progeny of *R. dominica* in the grains treated with 14 and 18% O_2, respectively and 303.33 and 431 progeny in PC and control, respectively. The progeny development at 150 DAT followed the similar trend with least no. of progeny in 14% O_2 (149.67) followed by 18% O_2 (222.67), while 401 and 483 were recorded in PC and control, respectively. The no. of *R. dominica* progeny recorded at 180 DAT in the grains treated with 14 and 18% O_2 were 179.33 and 221.33, respectively whereas 398 and 520 progeny were recorded in PC and control, respectively.

The progeny build up of *R. dominica* in PEG at different levels of O_2 from 30 days interval up to 180 days is given in table 3. No progeny was recorded in the grains treated with 6, 10, 14 and 18% O_2 from 30 DAT up to 180 DAT, whereas 22, 143.67, 239, 320.33, 400.33 and 427.67 progeny of *R. dominica* were recorded at 30 DAT to 180 DAT at 30 days interval in PC. Similarly, in control 27.67, 221.67, 353.33, 421, 476 and 502.67 progeny of *R. dominica* were recorded from 30 DAT to 180 DAT at 15 days interval which were significantly different from all the four O_2 levels tested.

The progeny build up of *R. dominica* in LDPE at different levels of O_2 from 30 days interval up to 180 days is given in table 4. The progeny build up at 30 DAT was 14 and 14 in the grains treated with 14 and 18% O_2, respectively and were on par with each other, while a progeny of 10.67 and 11 were recorded in the grains tested with 6 and 10% O_2, respectively. The no. of progeny recorded in PC and control were 20.33 and 21.33l, respectively. The data recorded at 60 DAT on progeny development recorded a progeny of 155.33 in the paddy grains treated with 18% O_2 which was on par with PC (144.33), whereas 83.67, 97.67 and 130.67 progeny were recorded in the grains treated with 6, 10 and 14% O_2, respectively and were significantly different from the control (202.33). The observations at 90 DAT recorded a progeny development of 160.33 and 183.67 in the grains treated with 6 and 10% O_2, respectively and a progeny build up of 209.67 and 221.33 in the grains treated with 14 and 18% O_2, respectively. A progeny build up of 239.67 were recorded in PC. All the treatments were significantly different from the control (332.67). Similar trend was observed on progeny development at 120 DAT in the grains treated with 6% O_2 (243) followed by 10% (265.33), 14% (304.67) and 18% O_2 (319.33). A progeny build up of 361.67 and 426.33 were recorded in PC and control, respectively. The data at 150 DAT recorded a progeny build up of 323.33, 367, 386.33 and 412.67 in the grains treated with 6, 10, 14 and 18% O_2, respectively whereas 407.33 and 498.33 progeny were recorded in PC and control, respectively. The progeny build up at 180 DAT followed the similar trend with the progeny development of 340.33, 384, 416.67 and 428.67 in the grains treated with 6, 10, 14 and 18% O_2, respectively. A progeny build up of 412.67 and 535.67 were recorded in PC and control, respectively.

The observations on progeny build up of *R. dominica* at 45 DAT in AP, PEG and LDPE is given in fig 1. No progeny were recorded in the grains treated with 6 and 10% O_2 in AP and PEG, whereas 28 and 45.33 progeny were recorded, respectively at these two O_2 levels in LDPE. There was no progeny build up in PEG even at 14 and 18% O_2. A progeny build up of 22.67 & 59 were recorded, respectively in the grains treated with 14% O_2 in AP and LDPE and 25.67 and 69.67 progeny in the grains treated with 18% O_2.

Table.1 Ingression of oxygen into different packing materials initially filled with different levels of O_2 over a period of 60 h

S. No	Treatments	Initial oxygen level																			
		18%					**14%**					**10%**					**6%**				
		12h	**24h**	**36h**	**48h**	**60h**	**12h**	**24h**	**36h**	**48h**	**60h**	**12h**	**24h**	**36h**	**48h**	**60h**	**12h**	**24h**	**36h**	**48h**	**60h**
1	**AP**	18.61^{a}	18.90^{b}	18.97^{b}	19.02^{b}	19.04^{b}	17.40^{b}	18.00^{b}	18.30^{b}	18.46^{b}	18.46^{b}	14.60^{b}	15.20^{b}	15.33^{b}	15.45^{b}	15.53^{b}	10.70^{b}	12.10^{b}	13.10^{b}	13.60^{b}	13.88^{b}
2	**PEG**	18.50^{a}	18.60^{a}	18.67^{a}	18.70^{a}	18.71^{a}	15.40^{a}	15.95^{a}	16.10^{a}	16.20^{a}	16.20^{a}	11.70^{a}	11.83^{a}	11.90^{a}	12.08^{a}	12.20^{a}	7.90^{a}	8.70^{a}	8.98^{a}	9.09^{a}	9.12^{a}
3	**LDPE**	20.05^{b}	20.33^{c}	20.42^{c}	20.57^{c}	20.67^{c}	19.20^{c}	19.75^{c}	19.83^{c}	20.08^{c}	20.08^{c}	18.50^{c}	19.30^{c}	19.45^{c}	19.63^{c}	19.73^{c}	16.50^{c}	19.30^{c}	20.00^{c}	20.30^{c}	20.48^{c}
4	**PC**	20.30^{b}	20.53^{d}	20.55^{c}	20.64^{c}	20.72^{d}	19.90^{d}	20.23^{d}	20.45^{d}	20.70^{d}	20.70^{d}	18.60^{c}	19.73^{d}	20.28^{d}	20.45^{d}	20.55^{d}	16.80^{d}	19.48^{c}	20.30^{c}	20.50^{c}	20.55^{c}
5	**Control**	20.93^{c}	20.88^{e}	20.90^{d}	20.93^{d}	20.93^{e}	20.83^{e}	20.83^{e}	20.98^{e}	20.90^{d}	20.90^{d}	20.93^{d}	20.98^{e}	20.93^{e}	21.00^{e}	20.98^{e}	20.88^{e}	20.95^{d}	21.00^{d}	21.00^{d}	20.98^{d}
	SEm ±	0.07	0.05	0.06	0.04	0.01	0.09	0.06	0.05	0.08	0.08	0.12	0.09	0.05	0.04	0.09	0.09	0.12	0.13	0.14	0.12
	CD (0.05)	0.22	0.17	0.19	0.13	0.04	0.26	0.19	0.15	0.25	0.25	0.35	0.27	0.14	0.11	0.27	0.29	0.35	0.39	0.42	0.36

h – hours
In each column values with similar alphabet do not vary significantly at 5%

Table.2 Effect of O_2 against the progeny build up of lesser grain borer, *R. dominica* in AP under ambient conditions

Treatments	Progeny adult build-up (No.)										
	30 DAT	**45 DAT**	**60 DAT**	**75 DAT**	**90 DAT**	**105 DAT**	**120 DAT**	**135 DAT**	**150 DAT**	**165 DAT**	**180 DAT**
18% O_2 +10% CO_2 +72% N_2	3.00 (1.73)^{c}	25.67 (5.06)^{c}	57.33 (7.57)^{c}	102.67 (10.13)^{c}	142.67 (11.94)^{c}	201.33 (14.18)^{c}	243.67 (15.60)^{c}	225.00 (15.00)^{c}	222.67 (14.91)^{c}	247.67 (15.73)^{c}	221.33 (14.87)^{c}
14% O_2 +30% CO_2 +56% N_2	2.00 (1.23)^{b}	22.67 (4.76)^{b}	41.33 (6.42)^{b}	81.33 (9.01)b	109.33 (10.45)^{b}	139.67 (11.81)^{b}	180.67 (13.44)^{b}	181.00 (13.45)^{b}	149.67 (12.21)^{b}	211.33 (14.53)^{b}	179.33 (13.38)^{b}
10% O_2 +50% CO_2 +40% N_2	0.00 (0.71)^{a}	0.00 (0.71)^{a}	0.00 (0.71)^{a}	0.00 (0.71)^{a}	0.00 (0.71)^{a}	0.00 (0.71)^{a}	0.00 (0.71)^{a}	0.00 (0.71)^{a}	0.00 (0.71)^{a}	0.00 (0.71)^{a}	0.00 (0.71)^{a}
6% O_2 +70% CO_2 +24% N_2	0.00 (0.71)^{a}	0.00 (0.71)^{a}	0.00 (0.71)^{a}	0.00 (0.71)^{a}	0.00 (0.71)^{a}	0.00 (0.71)^{a}	0.00 (0.71)^{a}	0.00 (0.71)^{a}	0.00 (0.71)^{a}	0.00 (0.71)^{a}	0.00 (0.71)^{a}
Plastic container with air tight seal (PC)	20.67 (4.54)^{d}	87.00 (9.32)^{d}	131.67 (11.47)^{b}	172.67 (13.14)^{d}	224.00 (14.96)^{d}	255.00 (15.97)^{d}	303.33 (17.40)^{d}	361.00 (19.00)^{d}	401.00 (20.02)^{d}	411.00 (20.27)^{d}	398.00 (19.95)^{d}
Control	26.33 (5.13)^{e}	141.00 (11.07)^{e}	211.67 (14.55)^{d}	261.67 (16.17)^{e}	343.00 (18.52)^{e}	410.00 (20.25)^{e}	431.00 (21.73)^{e}	444.67 (21.09)^{e}	483.00 (21.97)^{e}	498.67 (22.33)^{e}	520.00 (22.48)^{e}
SEm ±	**0.04**	**0.07**	**0.08**	**0.08**	**0.09**	**0.13**	**0.12**	**0.09**	**0.18**	**0.13**	**0.15**
CD (0.05)	**0.11**	**0.22**	**0.26**	**0.26**	**0.29**	**0.39**	**0.46**	**0.27**	**0.56**	**0.41**	**0.47**

DAT – Days After Treatment
The values in parentheses are square-root transformed values
In each column values with similar alphabet do not vary significantly at 5%

Table.3 Effect of O_2 against the progeny build up of lesser grain borer, *R. dominica* in PEG under ambient conditions

Treatments	Progeny build-up (No.)										
	30 DAT	**45 DAT**	**60 DAT**	**75 DAT**	**90 DAT**	**105 DAT**	**120 DAT**	**135 DAT**	**150 DAT**	**165 DAT**	**180 DAT**
18% O_2 +10% CO_2 +72% N_2	0.00 (0.71)[a]	0.00 (0.71)[a]	0.00 (0.71)[a]	0.00 (0.71)[a]	0.00 (0.71)[a]	0.00 (0.71)[a]	0.00 (0.71)[a]	0.00 (0.71)[a]	0.00 (0.71)[a]	0.00 (0.71)[a]	0.00 (0.71)[a]
14% O_2 +30% CO_2 +56% N_2	0.00 (0.71)[a]	0.00 (0.71)[a]	0.00 (0.71)[a]	0.00 (0.71)[a]	0.00 (0.71)[a]	0.00 (0.71)[a]	0.00 (0.71)[a]	0.00 (0.71)[a]	0.00 (0.71)[a]	0.00 (0.71)[a]	0.00 (0.71)[a]
10% O_2 +50% CO_2 +40% N_2	0.00 (0.71)[a]	0.00 (0.71)[a]	0.00 (0.71)[a]	0.00 (0.71)[a]	0.00 (0.71)[a]	0.00 (0.71)[a]	0.00 (0.71)[a]	0.00 (0.71)[a]	0.00 (0.71)[a]	0.00 (0.71)[a]	0.00 (0.71)[a]
6% O_2 +70% CO_2 +24% N_2	0.00 (0.71)[a]	0.00 (0.71)[a]	0.00 (0.71)[a]	0.00 (0.71)[a]	0.00 (0.71)[a]	0.00 (0.71)[a]	0.00 (0.71)[a]	0.00 (0.71)[a]	0.00 (0.71)[a]	0.00 (0.71)[a]	0.00 (0.71)[a]
Plastic container with air tight seal (PC)	22.00 (4.69)[b]	92.00 (9.59)[b]	143.67 (11.99)[b]	188.00 (13.71)[b]	239.00 (15.46)[b]	265.33 (16.29)[b]	320.33 (17.90)[b]	356.00 (18.87)[b]	400.33 (20.00)[b]	410.33 (20.25)[b]	427.67 (20.80)[b]
Control	27.67 (5.26)[c]	129.00 (11.36)[c]	221.67 (14.88)[c]	273.33 (16.44)[c]	353.33 (18.79)[c]	390.00 (19.74)[c]	421.00 (20.51)[c]	431.33 (20.77)[c]	476.00 (21.81)[c]	495.67 (22.26)[c]	502.67 (22.42)[c]
SEm ±	**0.03**	**0.05**	**0.08**	**0.06**	**0.09**	**0.07**	**0.09**	**0.07**	**0.12**	**0.09**	**0.10**
CD (0.05)	**0.8**	**0.15**	**0.25**	**0.18**	**0.28**	**0.22**	**0.28**	**0.19**	**0.37**	**0.27**	**0.32**

DAT – Days After Treatment
The values in parentheses are arc sine transformed values
In each column values with similar alphabet do not vary significantly at 5%

Table.4 Effect of O_2 against the progeny build up of lesser grain borer, *R. dominica* in LDPE under ambient conditions

Treatments	Progeny build up (No.)										
	30 DAT	**45 DAT**	**60 DAT**	**75 DAT**	**90 DAT**	**105 DAT**	**120 DAT**	**135 DAT**	**150 DAT**	**165 DAT**	**180 DAT**
18% O_2 +10% CO_2 +72% N_2	14.00 (3.74)^{b}	69.67 (8.14)^{d}	155.33 (12.46)^{d}	215.33 (14.67)^{d}	221.33 (14.88)^{cd}	283.67 (17.74)^{c}	319.33 (17.87)^{bc}	356.33 (18.86)^{c}	412.67 (20.31)c	426.67 (20.64)^{c}	428.67 (20.69)^{c}
14% O_2 +30% CO_2 +56% N_2	14.00 (3.74)^{b}	59.00 (7.67)^{c}	130.67 (11.42)^{c}	183.67 (13.55)^{c}	209.67 (14.48)^{c}	270.00 (16.64)^{b}	304.67 (17.45)^{b}	336.00 (18.33)^{bc}	386.33 (19.79)^{bc}	408.00 (20.16)^{c}	416.67 (20.40)$^{\backslash c}$
10% O_2 +50% CO_2 +40% N_2	11.00 (3.34)^{a}	45.33 (6.73)^{b}	97.67 (9.87)^{b}	159.67 (12.63)^{b}	183.67 (13.54)^{b}	237.67 (15.25)^{a}	265.33 (16.26)^{a}	327.67 (18.10)^{b}	367.00 (19.15)^{b}	344.33 (18.55)^{b}	384.00 (19.59^{b}
6% O_2 +70% CO_2 +24% N_2	10.67 (3.26)^{a}	28.00 (5.29)^{a}	83.67 (9.14)^{a}	143.67 (11.98)^{a}	160.33 (12.66)^{a}	215.00 (14.78)^{a}	243.00 (15.58)^{a}	267.67 (16.35)^{a}	323.33 (17.96)^{a}	317.67 (17.82)^{a}	340.33 (18.44)^{a}
Plastic container with air tight seal (PC)	20.33 (4.51)^{c}	73.00 (8.54)^{e}	144.33 (12.01)^{d}	228.33 (15.10)^{d}	239.67 (15.48)^{d}	303.33 (17.40)^{c}	361.67 (18.47)^{c}	383.33 (19.58)^{d}	407.33 (20.17)^{c}	433.00 (20.80)^{c}	412.67 (20.31)^{c}
Control	21.33 (4.61)^{d}	122.67 (11.07)^{f}	202.33 (14.22)^{e}	255.33 (16.09)^{e}	332.67 (18.20)^{e}	371.67 (19.46)^{d}	426.33 (20.64)^{d}	442.33 (21.02)^{e}	498.33 (22.34)^{d}	500.33 (22.36)^{d}	535.67 (23.13)^{d}
SEm ±	**0.06**	**0.10**	**0.16**	**0.21**	**0.23**	**0.19**	**0.25**	**0.20**	**0.24**	**0.22**	**0.26**
CD (0.05)	**0.19**	**0.32**	**0.50**	**0.63**	**0.71**	**0.59**	**0.78**	**0.63**	**0.74**	**0.69**	**0.76**

DAT – Days After Treatment
The values in parentheses are transformed values
In each column values with similar alphabet do not vary significantly at 5%

Fig. 1. Progeny build up of *R. dominica* in different packing materials filled with different O_2 levels at 45 DAT

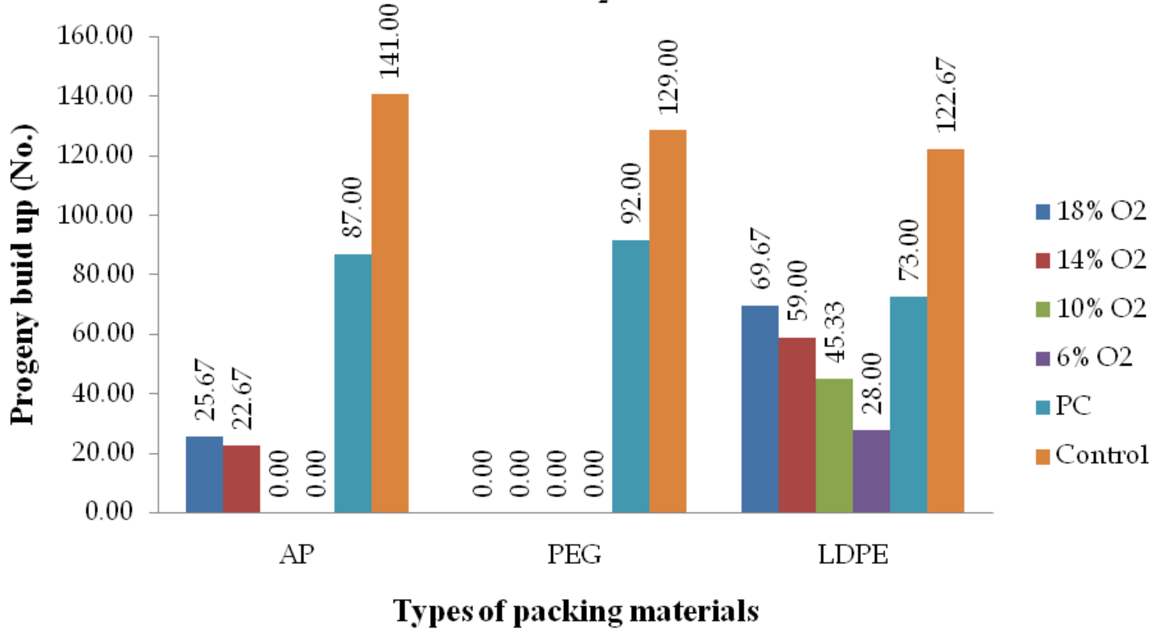


Fig. 2. Progeny build up of *R. dominica* in different packing materials filled with different O_2 levels at 90 DAT

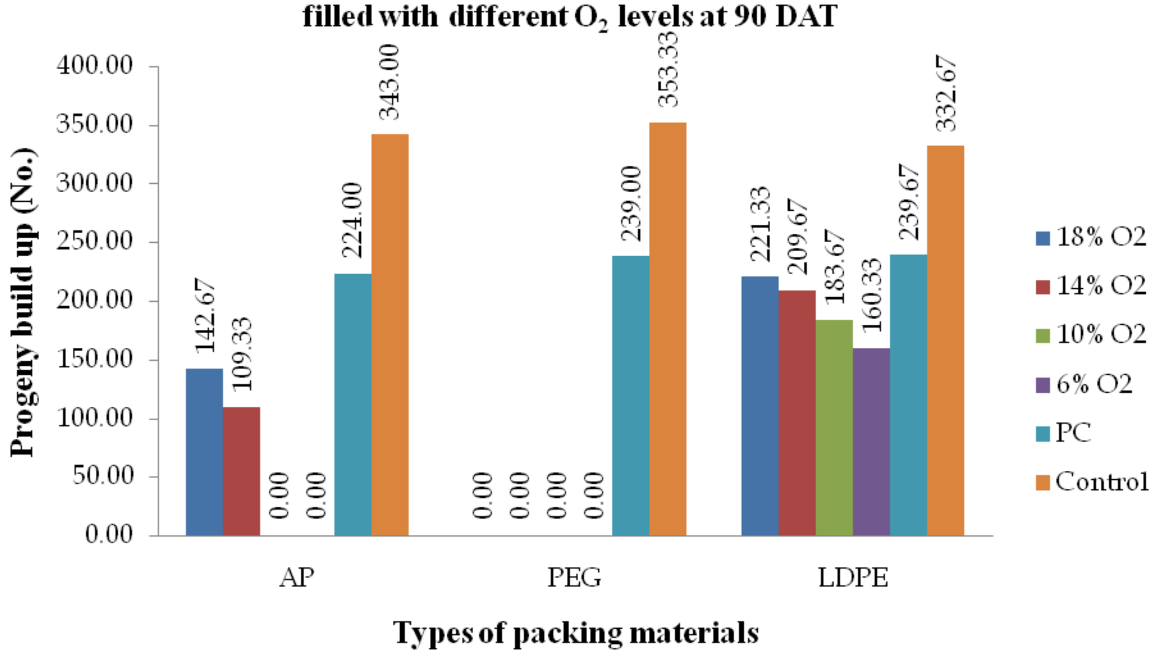


Fig. 3. Progeny build up of *R. dominica* in different packing materials filled with different O_2 levels at 135 DAT

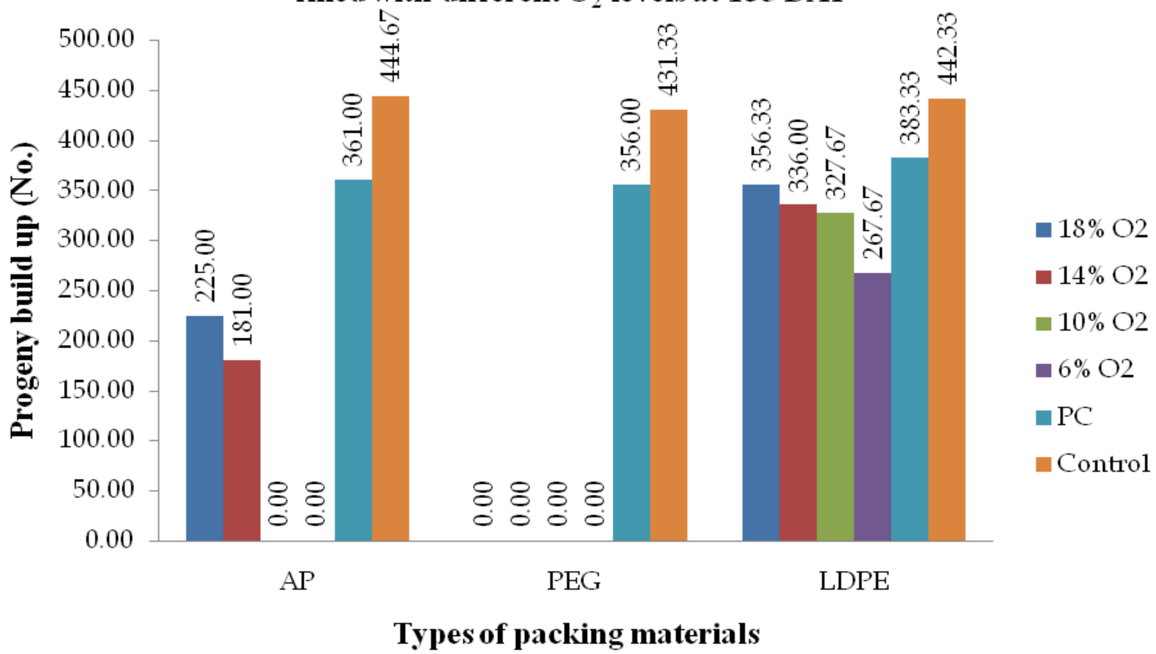
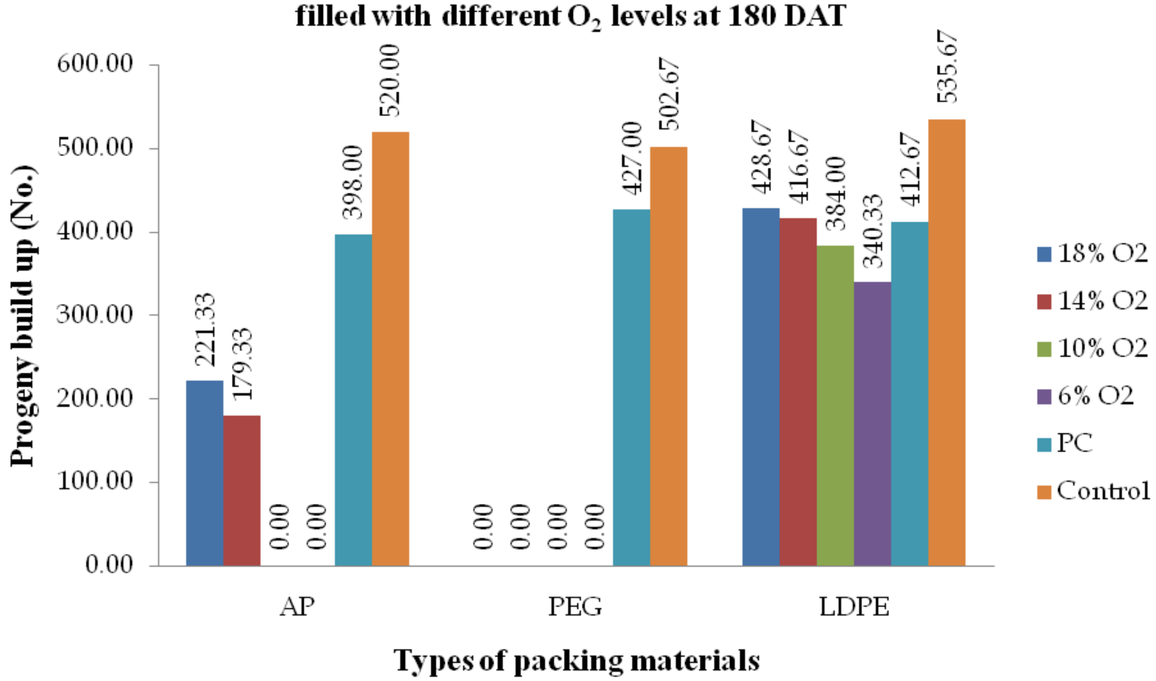


Fig. 4. Progeny build up of *R. dominica* in different packing materials filled with different O_2 levels at 180 DAT



The data on progeny build up at 90 DAT recorded no progeny in the grains treated with 6 and 10% O_2 in PEG and AP, whereas 160.33 and 183.67 progeny were recorded, respectively at these two levels of O_2 in LDPE. There was no progeny build up at 14% O_2 in PEG, while a progeny of 109.33 and 209.67 were recorded in AP and LDPE, respectively. There was no progeny build up even at 18% O_2 in PEG, while a progeny build up of 142.67 and 221.33 were recorded in AP and LDPE, respectively. In control a progeny of 520, 502.67 and 535.67 were recorded in AP, PEG and LDPE, respectively (Fig 2).

Similar comparison was made at 135 DAT on the progeny build up of *R. dominica*. No progeny build up was at 6 and 10% O_2 in PEG and AP whereas a progeny of 267.67 and 327.67 were recorded, respectively in LDPE at these two levels of O_2. There was no progeny build up at 14% O_2 in PEG, whereas 181 and 336 progeny were recorded in AP and LDPE, respectively. There was no progeny build up even at 18% O_2 in PEG, whereas 225 and 356.33 were recorded in AP and LDPE, respectively and in control 431.33, 444.67 and 442.33 progeny of *R. dominica* were recorded in AP, PEG and LDPE, respectively (Fig 3).

Likewise, the progeny build up at 180 DAT was compared in AP, PEG and LDPE in fig 4. There was no progeny build up at 6 and 10% O_2 in PEG and AP, whereas 340.33 and 384 progeny were recorded in LDPE, respectively. There was no progeny build up at 14% O_2 in PEG, whereas 179.33 and 416.67 progeny of *R. dominica* were recorded in AP and LDPE, respectively. There was no progeny recorded even at 18% O_2 in PEG, while a progeny build up of 221.33 and 428.67 were recorded in AP and LDPE, respectively. The no. of progeny recorded in control of AP, PEG and LDPE were 520, 502.67 and 535.67, respectively.

The present results are in agreement with Mahla and Singh (2005) who indicated that at 60% CO_2 the mortality of *R. dominica* was 0, 30, 90, 95 and 100% after 1, 3, 7, 15 and 30 days exposure, respectively whereas at 70% CO_2, the mortality was 60, 90, 100, 100 and 100% after 1, 3, 7, 15 and 30 days of exposure periods, respectively. Vachanth *et al.*, (2010) reported that the mortality per cent of red flour beetle, *T. castaneum* was higher in aluminum pouches (100%) followed by high density polypropylene (40%) and in the low density polypropylene (20%) bags at the gas proportion of 35% CO_2, 52% N_2 and 13% O_2 in processed little millet. Mekali *et al.*, (2013) reported that in sorghum containing 20% CO_2 up to 315 days resulted in mortality of *R. dominica*. Further, there were no adult emergence, no mass loss (%) and no loss in germination of grains. The grain damage caused by *R. dominica* varied from 0.2 to 8.5% in all the treatments excluding the control where the grain borer incidence was 2-18.5%.

PEG is proved to be the best packing material for controlled atmospheric storage of paddy grains as it does not support the growth and development of *R. dominica* since it is very low permeable to O_2. The next best packing material is AP, as this material is moderately permeable to O_2. At low levels of O_2 (6 and 10%) the *R. dominica* couldn’t survive in it. LDPE is not suitable for controlled atmospheric storage because the progeny build up of *R. dominica* was more due to its high permeability to O_2.

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