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Studies on impact of storage materials and methods on potato tuber moth, *Phthorimaea operculella* Zeller (Lepidoptera: Gelechiidae) on potato

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Abstract
Potato tuber moth (PTM), *Phthorimaea operculella* Zeller originated in Latin America and co-evolved with its host plant potato (*Solanum tuberosum* L.). It has become one of the most serious insect pests around the world, including in India. Laboratory studies were conducted against PTM for the pest build-up; % tuber dried and rot and extent of tuber tunneling. The mean% infestation of PTM using different storage materials after 90 days of storage was witnessed highest (56.92%) in wooden bins and it was least in cartoon box stored tubers (48.59%), while among different storage methods, it was recorded highest with 61.88% in plastic bin stored tubers and was lowest in low temperature stored tubers (5.45%).% tubers dried after 90 days of storage period was maximum in tubers inserted with agave leaf bits (40%) and it was minimum in nylon mesh bags (5%) among different storage materials. The same was resulted with no tubers dried in both low temperature and pit stored tubers among different storage methods and it was highest in heap method with paddy straw cover (10%). A maximum of 85.00% tuber rot was recorded in tubers inserted with agave leaf bits and a minimum of 10.00% in tubers stored in wooden bins among the storage materials. Among different storage methods, percent tuber rot ranged from 10.00 to 75.00% in tubers storage in low temperature and heap method, respectively. Extent of tuber tunneling among storage materials ranged from 22.22% (40 mesh nylon bags stored tubers) to cent percent (tubers stored in wooden bins and bamboo bins). The same was witnessed with a minimum of 0.33% in low temperature storage method in polythene bags and a maximum of 73.33% in plastic bin stored tubers. Therefore, the development of control technologies and intensive monitoring is necessary in future days to come, for stable potato production as well as potato post-harvest.

Keywords: Potato tuber moth (PTM), *Phthorimaea operculella*, storage, materials, methods

1. Introduction
Potato (*Solanum tuberosum* L.) is a root vegetable native to America, a starchy tuber of the plant and a perennial in the family of solanaceae. The potato is a staple food belonging to the tuber and root family. It is one of the top four crops in the world after rice, wheat and maize (Ross, 1986; Douches *et al*., 2004) [8, 3]. Potato is an essential food in developing countries claiming fourth place after rice, wheat and corn. These countries produce approximately one-third of the worldwide production of potato. It is a fat-free food containing protein, vitamins and minerals (Meyhuay, 2001) [7]. Unfortunately, severe losses may occur in storage, especially in the developing countries where, low-income farmers cannot afford cold storages.

A worldwide pest of potatoes is a major challenge that farmers are facing as they are intensifying their production techniques to satisfy the increasing demands of the international market. Among them, potato tuber moth (PTM), *Phthorimaea operculella* Zeller is a major pest of potato throughout the world, but prefer sub-tropical, tropical and Mediterranean climates. It is also known as potato tuber moth, potato tuber worm, potato tubeworm moth, potato moth, potato leaf miner; tobacco split worm and tobacco leaf miner. It is an oligophagous pest, feeds on crops belonging to the family solanaceae (mainly potato, tomato, tobacco, brinjal, bell pepper, cape-gooseberry and other solanaceous weeds like black night shade, datura etc.). Earlier it was a minor pest of tobacco for more than 100 years, but recently over last five years in North Carolina, it has emerged as a problem in tobacco plantings Also, it has been reported in tropical, subtropical and Mediterranean agro-zones (Flanders *et al*., 1999; Golizadeh and Esmaeili, 2012) [4-5].

PTM is the most economical potato pest in the mid-hills and plateau areas of India causing severe damage particularly in rustic, non-refrigerated stores during summer. Nearly 90% of the production is kept in stores after harvesting. Storage facilities are traditional, non-refrigerated, low cost "*kutcha*" stores allowing free access of PTM to stored potatoes. PTM damage in stores depends mainly on tuber infestation at harvest. Infected tubers brought into traditional stores are the primary source of infestation. Without control measures, tuber infestation can reach up to cent% (Chandel *et al*., 2001) [2]. Farmers depend more on non-selective pesticide applications to reduce storage losses and there is concern to reduce pesticide usage and finding alternate control strategies and to integrate them for effective management of PTM. Temperature is an important factor in the survival rate and development of PTM, so they are typically found in warmer climates, preferring subtropical and tropical habitats.

2. Materials and methods

Experiment was conducted at Horticulture Research and Extension Center (HREC), Somanahalli Kaval, Hassan. For storage studies, Kufri Jyoti tubers were used after harvesting of *Kharif* season crop by following Complete Randomized Block Design and the tubers were stored in different storage studies for observation up to 90 days through destructive sampling method of storage, to study the influence of storage materials and methods on PTM incidence.

2.1 Storage materials

Three kilograms of potato tubers were used for the study with three replications and 11 treatments. The treatments are as follows,

T_1: Wooden bin
T_2: Bamboo bin
T_3: Polypropylene bag
T_4: Onion jute sack
T_5: Gunny bag
T_6: 40 mesh nylon bags
T_7: Sand cover
T_8: Straw cover
T_9: Inserting Agave leaf bits (10 cm x 3 cm)
T_{10}: Cartoon box
T_{11}: Control

2.2 Storage methods

Four kilograms of potato tubers were used for the study with four replications and five treatments. The treatments are as follows,

T_1: Heaping method with straw cover
T2: Pit storage with straw cover
T_3: Plastic bin
T_4: Low temperature storage in polythene bag (4°C)
T_5: Control

In heap method of storing, each replication of potato tubers was grouped under one heap and was covered with dry plant straw. In pit storage method, a pit of 30 x 20 inch was dug out and cow dung slurry was pasted along the walls and base of the pit, to avoid termite damage to the tubers and the whole set up was covered by asbestos or roof structure for preventing the rain water entering the pits. In plastic bins storage method, the tubers were normally stored in an open condition. In low temperature storage method, the potato tubers were kept in top chest refrigerator at 4 °C.

Observations noted

1. % tuber damage at pre-treatment, 30, 60 and 90 days after storage (DAS)
2. Tuber rot at 90 DAS
3. Tuber drying at 90 DAS
4. Extent of tunneling at 90 DAS

3. Statistical analysis

All the collected data were précised and suggested to analysis of variance (ANOVA) for Complete Randomized Block Design (CRBD) using the OPSTAT analysis at 5% level of significance after necessary transformations are required.

4. Results and Discussion

4.1 Storage materials

Experimental findings using locally available materials for storing potato tubers differed statistically and few were superior over control in preventing the damage to potato tubers by PTM as well as pest build-up (Table 1). The PTM incidence in tubers before storing ranged from zero to 6.62% as the natural incidence was at varied level of expression measured by visible symptoms. Among treatments 30 days after storage period, the% mean tuber infestation was minimum in cartoon box stored tubers (8.62%) and maximum in wooden bins stored tubers (41.19%). The corresponding pest build-up was very low in tubers stored with sand cover followed by straw cover, agave leaf bits insertion, control and gunny bags with less than 50 folds increase in pest compared to more than 1000 folds increase in 40 mesh nylon bags.

After 60 days of storage, the% mean tuber infestation ranged from a minimum of 82.26% (wooden bin stored tubers) to cent% infestation (tubers stored in gunny bags, sand cover and straw cover). After storing the potato tubers for 90 days, the% mean tuber infestation recorded a minimum of 94.56% infestation (polypropylene bag stored tubers) while it recorded cent% infestation in rest of the treatments sparing bamboo bins, polypropylene bags, cartoon box which were statistically superior over the rest (Table 1). The pest build-up was highest in cartoon box stored tubers followed by 40 mesh nylon bags and bamboo bins after both 60 and 90 days of storing the tubers. Irrespective of the stored period among the treatments, tubers stored in cartoon box registered lowest% mean tuber infestation (48.59%) compared to damage of tubers stored in wooden bins (56.92%) after 90 days after of storage (Table 1). After 90 days of storage, mean PTM pest build-up was highest (more than 2000 folds) in cartoon box stored tubers followed by 40 mesh nylon bags and the lowest (about 700 folds) pest build-up was in gunny bags.

% tubers dried after 90 days of storage period was minimum (5%) in nylon mesh bags and in straw covered tubers while maximum tubers dried (40%) in tubers inserted with agave leaf bits (Table 1).% tubers rot after 90 days of storage period was minimum with tubers stored in wooden bin storage (10%) and was maximum of 85% tubers dried in tubers inserted with agave leaf bits. Extent of tuber tunneling by PTM was minimum (22.22%) in 40 mesh nylon bag stored tubers and it was cent% in tubers stored in wooden bins and bamboo bins which were indifferent from control. The tunneling observation at 90 days after storage could be documented only in seven out of 11 treatments due to severe pest build-up leading to complete drying and/or rot.

4.2 Storage methods

Different methods for storing potato tubers differed statistically and were superior over control in preventing the damage to potato tubers by PTM as well as pest build-up (Table 2)

Table 1:% tuber damage by potato tuber moth, *P. operculella* in different storage materials for up to 90 days of storage

Treatments	% incidence of tuber damage due to PTM*									90 DAS *			
	Pre-treatment	30 DAS		60 DAS		90 DAS		Mean		PI reduction over control (%)	Percent tuber dried	Percent tuber rot	Tunneling (%)
		% PI	% PBP	% PI	% PBP	% PI	% PBP	% PI	% PBP				
T_1: Wooden bins	4.21 (11.84)	41.19 (39.91)	878.38	82.26 (65.06)	1853.92	100.00 (89.96)	2275.30	56.92 (48.96)	1251.90	0.78 (5.05)	15.00 (22.78)	10.00 (18.43)	100.00 (89.96)
T_2: Bamboo bins	3.80 (11.24)	31.17 (33.92)	720.26	86.55 (68.46)	2177.63	97.62 (81.09)	2468.95	54.79 (47.73)	1341.71	4.49 (12.23)	10.00 (18.43)	15.00 (22.78)	100.00 (89.96)
T_3: Polypropylene	4.32 (11.99)	32.62	655.09	95.49	2110.42	94.56	2088.89	56.75	1213.60	1.07 (6.43)	10.00	30.00	95.21

bags		(34.82)		(77.11)		(76.48)		(48.86)			(18.43)	(33.20)	(77.33)
T4: Onion jute sack	0.00 (0.05)	29.56 (32.91)	29.56	95.54 (77.78)	95.54	100.00 (89.96)	100.00	56.28 (48.59)	56.28	1.89 (7.90)	20.00 (26.55)	36.00 (36.86)	94.78 (76.76)
T_5: Gunny bags	6.62 (14.90)	9.85 (18.28)	48.79	100.00 (89.96)	1410.57	100.00 (89.96)	1410.57	54.12 (47.34)	717.48	5.65 (13.75)	15.00 (22.78)	25.00 (29.99)	31.67 (34.23)
T_6: 40 mesh nylon bags	2.36 (8.83)	26.80 (31.16)	1035.59	96.57 (79.30)	3991.95	100.00 (89.96)	4137.29	56.43 (48.68)	2291.21	1.62 (7.30)	5.00 (12.92)	30.00 (33.20)	22.22 (28.11)
T_7: Sand cover	0.00 (0.05)	10.14 (18.54)	10.14	100.00 (89.96)	100.00	100.00 (89.96)	100.00	52.54 (46.43)	52.54	8.41 (16.85)	10.00 (18.43)	65.00 (53.71)	70.56 (57.12)
T_8: Straw cover	0.00 (0.05)	17.02 (24.36)	17.02	100.00 (89.96)	100.00	100.00 (89.96)	100.00	54.26 (47.42)	54.26	5.41 (13.45)	5.00 (12.92)	25.00 (29.99)	42.00 (40.38
T_9: Inserting Agave leaf bits	0.00 (0.05)	24.14 (29.42)	24.14	96.57 (79.30)	96.57	100.00 (89.96)	100.00	55.18 (47.95)	55.18	3.80 (11.24)	40.00 (39.22)	85.00 (67.19)	62.78 52.38)
T_{10}: Cartoon box	1.45 (6.91)	8.62 (17.07)	494.48	85.96 (67.97)	5828.28	98.33 (82.54)	6681.38	48.59 (44.17)	3251.03	15.29 (23.01)	25.00 (29.99)	15.00 (22.78)	31.67 34.23)
T_{11}: Control	0.00 (0.05)	29.44 (32.85)	29.44	100.00 (89.96)	100.00	100.00 (89.96)	100.00	57.36 (49.21)	57.36	-	25.00 (29.99)	55.00 (47.85)	100.00 (89.96)
S.Em(±)	0.14	0.45		0.41		0.23				0.28	1.28	2.05	1.84
CD	0.42	1.32		1.21		0.67				0.84	3.78	6.06	5.42

* Figures in parentheses are arcsine transformed data PI: Pest incidence PBP: Pest Build-up over Pre-treatment DAS: Days after storage

PTM incidence in the tuber before storing ranged from 4.35 to 13.25% or the natural incidence which was at varied level of expression as measured by visible symptoms. Among the treatments after 30, 60 and 90 days of storage period, the% mean tuber infestation was minimum in low temperature (4 °C) storing tubers in polythene bags (4.65%, 1.19% and 2.72% infestation, respectively) and it was maximum in plastic bin stored tubers (53.03%, 88.48% and 100% infestation).

After 30 and 60 days of storage, the pest build-up was very low with tubers stored in pit with almost 47 and 87 folds increase, respectively followed by low temperature storage (almost 64 and 91 folds increase). After 90 days of storage, storing tubers in low temperature in polythene bags resulted lowest pest build-up and it was around 79 folds increase, followed by pit storage method (177-fold increase) (Table 2). After 90 days storage period resulted lowest of only 5.45% infestation in low temperature stored tubers followed by pit storage method and it was highest in plastic bin stored tubers (61.88%). The mean pest build-up after lowest in low temperature storage method (-58.85%) followed by pit storing of tubers with paddy straw cover with almost 78 folds increase compared to heaping method of storage (1100 folds increase). After 90 days of storage, low temperature method of storing tubers resulted maximum pest incidence reduction over control (91.24%) followed by pit storage method with 82.68% compared to plastic bins and heap method of storage.

No tubers dried after 90 days of storage in both low temperature and pit storage method, while a maximum tuber drying was recorded in control (20.00%) followed by heaping method of storage with 10.00% tuber drying (Table 2). Percent tubers rot after 90 days of storage ranged from 10.00% in low temperature storage method to 80.00% in control followed by heaping method (75.00%). Extent of tuber tunneling by PTM by destructive sampling method was minimum in low temperature storage method (0.33%) followed by pit storage method (1.08%) compared to 73.33% tunneling with plastic bins storage method.

The present findings borrow support from the findings of Basavaraju *et al*. (2010) [1]. They have evaluated different materials and found that, the use of ragi straw mulch and sand mulch resulted in 42.00 and 33.67% PTM infested tubers during 2005 and 2.34 and 1.33% during 2006, respectively after 60 days of storage. Kufri Jyothi potato tubers covered with saw dust and treated with fenvalerate at 1.0 ml/l registered least PTM infestation up to 60 days storage. Percent weight of tubers infested and damaged by potato tuber moth was significantly higher in the storage inside residue of teff than the others, which is the normal practice among potato farmers of western Oromia, Ethiopia (Ibrahim, 2015) [16].

From the studies it is clear that, a substrate and method which prevents the exposure of tubers to moth; free movement of larvae and moths and accumulation of moisture within the heap will protect the stored tubers from PTM besides, reducing rotting and drying.

Table 2:% tuber damage by potato tuber moth, *P. operculella* in different storage methods for up to 90 days of storage

Treatments	% incidence of tuber damage due to PTM *									90 DAS *			
	Pre-treatment	30 DAS		60 DAS		90 DAS		Mean		PI reduction over control (%)	% tuber dried	% tuber rot	Tunneling (%)
		% PI	% PBP	% PI	% PBP	% PI	% PBP	% PI	% PBP				
T_1: Heaping method with paddy straw cover	4.35 (12.03)	39.78 (39.09)	814.48	66.66 (54.71)	1432.41	100.00 (89.96)	2198.85	52.70 (46.53)	1111.44	15.31 (23.02)	10.00 (18.43)	75.00 (59.98)	58.33 (49.78)
T_2: Pit storage with paddy straw cover	6.05 (14.23)	8.95 (17.40)	47.93	11.32 (19.65)	87.11	16.79 (24.18)	177.52	10.78 (19.16)	78.14	82.68 (65.38)	0.00 (0.05)	30.00 (33.20)	1.08 (6.96)
T_3: Plastic bins	5.99 (14.16)	53.03 (46.42)	785.31	88.48 (70.13)	1377.13	100.00 (89.96)	1569.45	61.88 (51.85)	932.97	0.56 (4.29)	5.00 (12.92)	45.00 (42.11)	73.33 (58.88)
T_4: Low temperature storage in polythene bags (4 °C)	13.25 (21.34)	4.65 (12.45)	-64.91	1.19 (6.26)	-91.02	2.72 (9.49)	-79.47	5.45 (13.49)	-58.85	91.24 (72.75)	0.00 (0.05)	10.00 (18.43)	0.33 (3.29)
T_5: Control	6.00 (14.17)	42.89 (40.90)	614.83	100.00 (89.96)	1566.67	100.00 (89.96)	1566.67	62.22 (52.05)	937.04	-	20.00 (26.55)	80.00 (63.41)	100.00 (89.96)
S.Em(±)	0.23	0.40		0.37		0.08				0.73	0.73	0.82	0.69
CD	0.75	1.27		1.19		0.26				2.42	2.33	2.61	2.19

* Figures in parentheses are arcsine transformed data PI: Pest incidence PBP: Pest build-up over pre-treatment DAS: Days after storage

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