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Full Length Research Paper

Designing and evaluation of onion storage structures for Indian conditions

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India is the second largest producer of onion in the world. A large quantity of onion is stored to fulfill domestic and export demand at ambient atmospheric conditions. The storage losses in these ambient atmospheric stores are high. To minimized storage losses and develop efficient onion storage structure, seven storage structures i.e. Traditional double row storage structure, Modified bottom ventilated storage structure, Top and bottom ventilated storage structure with mud-plastered walls, Modified bottom ventilated storage structure with chain linked side walls, Traditional single row storage structure, Modified bottom ventilated single row storage structure, Bottom ventilated single row low cost thatched roof storage structure, were designed and constructed at NRC for Onion and Garlic, Rajagurunagar, Pune, India. These storage structures were evaluated for storage of onion. The physiological loss of weight (PLW) was lowest (15.92 %) in Top and bottom ventilated structure with mud plaster walls followed by Bottom ventilated single row low cost thatched roof storage structure (17.44%). Physiological loss of weight was significantly lower in bottom ventilated structures (19.06%) as compared to traditional without bottom ventilated structures (22.11%). The rotting was significantly higher (22.72 %) in Traditional without bottom ventilated double row structure as compared Top and bottom ventilated structure with mud plastered sidewalls (7.52 %). The rotting was statistically lower in bottom-ventilated structures (12.69%) than traditional without bottom-ventilated structures (19.92%). The highest sprouting (3.29 %) was recorded in Modified bottom ventilated storage structure with chain-linked sidewalls. The net return per tonne was highest (Rs 1207-) in Bottom ventilated single row low cost thatched roof storage structure. The findings of the experiment indicates that bottom ventilated structures were found efficient in reduction of storage losses in onion stored at ambient atmospheric conditions.

Key words: Onion, storage structure, ambient atmospheric conditions, bottom ventilated, storage losses.

INTRODUCTION

India is the second largest producer of onion in the world accounting for 16 percent of area and 13 percent of production. In our country, onion is grown in 0.83 million hectare with production of 13.56 million tons (Anonymous, 2010). A considerable quantity of onion is stored to fulfill domestic and export demand during the lean season i.e. July to September. Onion is stored in ambient storage condition in India where the storage losses are very high. These losses comprises of physiological loss in weight (PLW) i.e. moisture losses and shrinkage (30-40 %), rotting (10-12%) and sprouting (8-10%) for 4 to 5 months storage. The storability of onion is influenced by several factors such as varieties, cultural practices, pre-harvest treatments and post harvest handing practices (Bruce et al., 1997; Maini and Chakrabarthy, 2000; Shinde *et al.,* 2001). The storage environment during the period of storage plays an important role in the storage life and losses during the storage. The storage losses in onion are low at two temperature regions *i.e*. 0-5 ^{O}C and 25 –30 ^{O}C and one humidity regime *i.e*.65-70 % (Bruce *et al*, 1997 and Tripathi and Lawande, 2007). Since onion is stored at

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ambient temperature in our country, the storage structures are designed to achieve 25 to 30 ^{o}C temperatures and 65-70 percent humidity. Various types of onion storage structures are used for storage of onion in different onion growing areas of the country. Most of these are traditional type made by the farmers as per their requirements majority of them are improperly ventilated and storage losses are higher (Tripathi *et al.*, 2003 & 2005). The bottom-ventilated structures have been found better than traditional structures for storage of onion (Kale *et. al*. 1992; Maini *et al*., 1997, Shukla and Gupta, 1994). But these structures have some problems such as improper ventilation, short roof span and are costly and beyond the reach of small farmers. Considering these points in mind, seven different types of storage structures were designed, constructed and evaluated.

MATERIAL AND METHODS

Seven-onion storage structures namely Traditional double row storage structure, Modified bottom ventilated storage structure, Top and bottom ventilated storage structure with mud-plastered walls, Modified bottom ventilated storage structure with chain linked side walls, Traditional single row storage structure, Modified bottom ventilated single row storage structure, Bottom ventilated single row low cost thatched roof storage structure were designed and constructed at NRC Onion and Garlic. These structures are designed based on storage structures used in different parts of the country for the storage of onion. The details of these structures are as follows:

Traditional double row storage structure

This was designed and constructed on the basis of onion storage structure used by the farmers and traders in the Nasik region of India. The framework of the structure was made with GI channels. The floor was made with cement: concrete. The sidewalls were made constructed with wooden bantam, while roof was made of asbestos sheets. The structure has 6 stakes for storing of onion, which are separated by a central pathway (Table 1).

Modified bottom ventilated storage structure

This structure was developed by modification over the earlier structures recommended structures. This has provision ventilated floor made of wooden bantams, central ventilated pathway and extended roof. The framework of the structure was constructed with galvanized iron channels. The floor and sides walls were made with wooden bantam of 2.5cm thickness and gap of 2.5 cm in kept between the bantams. The roof is constructed with asbestos sheets. The roof was extended to 1 meter to avoid splashes of rain (Table 1)

Top and bottom ventilated storage structure with mud-plastered walls

This is a modification over bottom ventilated storage structure, which was design for hot and humid areas. The framework of the structure was constructed with galvanized iron channels. The floor was constructed with wooden bantams while the side walls constructed with made of bamboo rafters plastered with paste of 15 cm thick layer cow dung and straw both the sides. A full wall length side ventilator of 45 cm height was provided at lower portion of western sidewall and similar size ventilator was provided in upper portion of eastern side wall for regulation of ventilation and entry of hot and humid winds. The roof is constructed with asbestos sheets (Table 1).

Modified bottom ventilated storage structure with chain-linked sidewalls

This is modification over modified bottom ventilated storage structure. The difference is that the sidewalls were constructed with chain link instead of wooden bantams. This was done to reduce the cost of the construction. Other features were similar to modified bottom ventilated structure. The details of the structure are given in Table 1.

Traditional single row storage structure

The traditional single row structures have single row for storage of onion are mostly used by small famers and they are usually of 5 to 10 tonnes capacity. The structure was constructed on raised PCC platform with galvanized iron framework. The roof was made with Mangalore tiles and split bamboo bantams were used for floor and sidewalls (Table 1).

Modified bottom ventilated single row storage structure

This structure is modification over the traditional single row structure. The structure was constructed with GI channels and angles. A bottom ventilated of 45 cm was provided and the floor was constructed with half split bamboos (3.0- 4.0 cm width), which were fixed at the distance of 2.5 cm. The sidewalls were made from split (1/4) bamboos and were fixed at the distance of 2.5 cm. The roof was constructed with Mangalore tiles. The details of the structure are given in Table 1.

Bottom ventilated single row low cost thatched roof storage structure

This structure is also modification over the modified bottom ventilated single row structure. In order to reduce the cost of construction, the galvanized iron framework

Table 1. Storage capacity and cost of storage in various types of onion storage structures designed and constructed.

Particulars	Traditional double row storage structure	Modified bottom ventilated double row storage structure	Top and bottom ventilated storage structure with mud plastered walls	Modified Bottom ventilated storage structure chain linked side walls	Traditional single row storage structure	Bottom Ventilated single row storage structure	Bottom ventilated single row low cost thatched roof storage structure
Cost of construction (in million Rs)	0.225	0.19	0.149	0.125	0.035	0.040	0.005
Length (m)	9.60	9.9	9.9	9.9	5.0	5.0	4.9
Width (m)	7.5	6.0	4.75	3.6	1.2	1.2	1.2
Side height (m)	2.25	2.25	2.25	2.25	1.2	1.2	1.6
Central height (m)	3.50	4.5	4.0	4.0	2.2	2.2	1.9
Storage capacity (tones)	38	42	31	25	5	5	5
Expected life (years)	20	20	20	20	20	20	5
Cost of storage (Rs. /Kg/year)	0.38	0.23	0.30	0.25	0.35	0.40	0.20
Construction material							
Roof	Asbestos	Asbestos with extended roof	Asbestos	Asbestos	Mangalore tiles	Mangalore tiles	Sugarcane leaves/thatch
Side wall	Wooden bantam	Wooden bantam	Split bamboo plastered with mud	Chain link	Split Bamboo	Split Bamboo	Split Bamboo
Floor	PCC	Wooden bantam with C channel support	Wooden bantam with C channel support	Wooden bantam with C channel support	PCC	Split bamboo bantam with C channel support	Split bamboo bantam supported on brick block
Foundation	PCC	RCC Pillar	RCC Pillar	RCC Pillar	PCC	Grouted C channel	Brick support

was substituted by bamboo framework and roof was made with sugarcane leaves. The structure is constructed with bamboo rafters. The whole solid bamboos are used for pillars and roof beams. The iron angle supports are provides to all pillars. The bottom ventilation is provided with bricks fixed at the base of all iron angle pillars. The floor was constructed by half split bamboos, which were fixed on bricks fixed at the bases of iron angle erected for supporting the bamboo poles. The sidewalls are made by split (1/4) bamboos mats. The roof was made with sugarcane leaves with inner lining of gunny cloth. The details of the structure are given in Table 1.

One hundred fifty one tones of *rabi (*winter season) *onion* cv. N-2-4-1 produced in April -May (winter crop) were stored in these storage structures from May to October for three consecutive years. These onions were field cured

for 3 days and shade cured for 15 days before filing in these storage structures for storage studies. All damaged, diseased onions were removed. The staking height was 5 feet. The onions were stored for 120days and were taken out from the storage in the month of October. The observations on total weight, sprouted bulbs, rotted bulbs and black mould infected bulbs were recorded. The physiological loss weight (PLW) was recorded on the basis of initial weight and final weight.

The physiological loss weight and rotting were taken as quantitative losses while sprouting and black mould was used for qualitative losses. The data were analyzed statistically as described by Panse and Sukhatme (1995) using F-test. The economics was calculated on the basis of the average price of last 10 years in local wholesale market.

RESULTS AND DISCUSSION

Storage losses in onion in different storage structures

Quantitative losses

Physiological loss of Weight (PLW)

The physiological loss of weight (PLW) was lowest (15.92 %) in Top and bottom ventilated structure with mud plaster walls. This was closely followed by Bottom ventilated single row low cost thatched roof storage structure (17.44%). These were significantly lower than Modified bottom ventilated structure with chain-linked sidewalls (22.73 %), Traditional double row storage structure (22.18%) and Traditional single row structure (20.63%). There was quit variation in the physiological loss of weight (PLW) in different years. It was highest (25.47 %) in 2003 and lowest (13.44%) in the 2005. The higher losses in Modified bottom ventilated structure with chain linked sidewalls may be attributed to more aeration, which allowed entry of more hot and dry air in the initial months of storage. The higher losses in Traditional double row structures may be due to more rotting which enhanced rate of physiological weight losses. The variation in the physiological loss of weight in different years can be attributed to the rainfall and humidity during storage months in these years. The physiological loss of weight was more in drier years (Table 2). The year wise difference in the physiological loss of weight may be related to the temperature and humidity conditions of that particular year (Brice *et al*.1997; Shinde *et al*., 2001; Warade *et al*., 1997).

The ventilation and number of rows of the structure were found to have great influence on the storage losses. Physiological loss of weight was significantly lower in bottom ventilated structures (19.06%) as compared to traditional without bottom ventilated structures (22.11%). There was no significant difference in the physiological loss of weight in single row storage structures and double row storage structures (Table 3). The results suggests that bottom ventilation is beneficial in reduction of physiological loss of weight but single row and double row has no significant effect on the weight loss.

Rotting

The rotting was significantly higher in all the traditional without bottom-ventilated structures as compared to bottom ventilated structures. The highest rotting (22.72 %) was recorded in Traditional without bottom ventilated double row structure while lowest losses (7.52 %) were found in Top and bottom ventilated structure with mud plastered sidewalls. Comparatively lower rotting (17.12%) was recorded in traditional single row structure and modified double row bottom ventilated storage structure (17.94 %) but it was statistically higher than Bottom ventilated single row storage structure(13.43%) and Bottom ventilated single row low cost thatched roof storage structure (10.88%). This suggests that the bottom and side aeration play vital role in the rotting during storage. The better horizontal and vertical aeration in Top and bottom ventilated storage structure resulted in lowest rotting. Further the higher rotting in modified bottom ventilated structure with chain linked sidewalls was due to the injury to onions caused by wires of chain link which u led to more rotting. This reveals that the use of wire is not good for construction of the sidewalls. There was distinct difference in the rotting in different years. The rotting was highest (21.66 %) in 2003 and lowest in 2005(5.13%). It was observed that there was higher rainfall during the maturity period of the onion in 2003. This might have affected the internal quality of bulbs prior to storage. It has been reported earlier irrigation or rain fall after maturity increases rotting in onion during storage (Brice *et al*., 1997).

The ventilation and number of rows of the structure have influenced rotting. The rotting was statistically lower in bottom-ventilated structures (12.69%) than traditional without bottom-ventilated structures (19.92%). The rotting losses in single row structures were statistically lesser (15.17%) than double row structures (17.44 %, Table 3). This suggests that aeration and removal of excessive moisture play important role in rotting in storage of onion.

The losses due removal of scales were very lower and there was no significantly different among various storage structures. As far as total quantitative losses are concerned, It was lowest (23.82%) in Top and bottom ventilated storage structure followed by Bottom ventilated single row low cost thatched roof storage structure (28.66 %; Fig 1). This is due to the lower PLW and rotting. The highest quantitative losses (46.11%) recorded in Traditional double row storage structure. The higher PLW and rotting in non-ventilated structures may be attributes to accumulation of moisture and heat produced by the

Table 2. Quantitative losses in Rabi onion cv. N-2-4-1 stored in different storage structures.

Storage structures	PLW (%)				Rot (%)				Scale (%)				Total (%)			
	2003	2004	2005	Av.	2003	2004	2005	Av.	2003	2004	2005	Av.	2003	2004	2005	Av.
Traditional double row storage structure	33.63	19.69	13.23	22.18	28.85	29.37	9.93	22.72	0.30	0.3	0.34	0.31	62.78	52.06	23.5	46.11
Modified bottom ventilated double row storage structure	24.49	20.81	12.98	19.43	18.52	25.41	9.89	17.94	0.40	0.35	0.22	0.32	43.41	46.57	23.09	37.69
Top and bottom ventilated storage structure with mud plastered walls	14.72	19.16	13.89	15.92	13.39	7.02	2.16	7.52	0.30	0.4	0.44	0.38	28.38	26.58	16.49	23.82
Modified Bottom ventilated storage structure chain linked side walls	34.7	19.89	13.83	22.73	22.44	14.65	5.49	14.19	0.40	0.35	0.39	0.38	57.31	34.89	19.71	37.30
Traditional single row storage structure	25.76	22.71	13.41	20.63	28.20	19.55	3.61	17.12	0.30	0.4	0.37	0.36	54.26	42.66	17.39	38.10
Bottom ventilated single row storage structure	23.27	22.97	13.94	20.06	20.21	17.68	2.39	13.43	0.40	0.4	0.37	0.39	43.88	41.05	16.70	33.88
Bottom ventilated single row low cost thatched roof storage structure	21.98	17.55	12.8	17.44	20.02	10.18	2.44	10.88	0.30	0.3	0.42	0.34	42.30	28.03	15.66	28.66
Average	**25.47**	**20.40**	**13.44**	**19.77**	**21.66**	**17.69**	**5.13**	**14.82**	**0.34**	**0.36**	**0.36**	**0.35**	**47.47**	**38.83**	**18.93**	**35.08**
CD (0.05)	**1.75**	**1.81**	**0.75**	**1.92**	**3.85**	**3.34**	**3.31**	**1.52**	**NS**	NS	NS	NS	**3.84**	**3.31**	**2.96**	**3.35**

onions due to respiration. The inadequate aeration was not able to remove the heat and moisture. In ventilated structures the better aeration was able to remove the moisture and heat produced by the onions resulting lower losses. As it is well establish fact that proper aeration and optimum humidity level reduces storage losses in onion (Brice *et al*., 1997; Mondal and Pramanik, 1992; Skultab and Thompson, 1992; Maini *et al* 2000; Naik *et al* , 2008).

Qualitative losses

Sprouting

The highest sprouting (3.29 %) was recorded in Modified bottom ventilated storage structure with chain-linked sidewalls. This was followed by Modified bottom ventilated storage structure with asbestos roof (2.96%). Significantly lower sprouting was recorded in Traditional single row storage structure (1.29%) and Bottom ventilated single row low cost thatched roof storage structure (1.35 %). The lower sprouting losses were found in without bottom-ventilated structures than bottom ventilated structures. There was year wise variation in the sprouting. The highest sprouted bulbs were recorded in 2003 while lowest in 2005 (Table 4).

The ventilation and number of rows of the structure have negatively influenced sprouting losses. The sprouting was significantly higher (2.42 %) in bottom-ventilated structures than traditional storage structures (0.93%, Table 5). This may probably be due to more exposure of stored onions to comparatively cooler winds in the later part of storage. The increase in sprouting by low temperature is reported by Brice *et al*. (1997) and Tripathi and Lawande (2007).

Table 3. Effect of ventilation and number of rows on quantitative losses in onion cv. N-2-4-1.

Type of ventilation	Type	PLW	Rot	Scales	Total
Ventilated	Single row	18.75	13.22	0.36	31.27
	Double row	19.36	12.16	0.36	32.94
Average		**19.06**	**12.69**	**0.36**	**32.11**
Traditional non ventilated	Single row	20.03	17.12	0.36	38.10
	Double row	22.10	22.72	0.31	46.11
Average		**21.11**	**19.92**	**0.33**	**42.11**
CD (A)		1.41	2.21	NS	1.89
CD(B)		NS	2.24	NS	1.01
CD(AxB)		NS	3.39	NS	1.65

Table 4. Qualitative losses in Rabi onion cv. N-2-4-1 stored in different storage structures.

Storage structures	Sprouting (%)				Black mould (%)				Total (%)			
	2003	2004	2005	Av.	2003	2004	2005	Av.	2003	2004	2005	Av.
Traditional double row storage structure	0.55	0.7	0.44	0.56	4.63	1.3	8.02	4.65	5.18	2.0	8.46	5.21
Modified bottom ventilated double row storage structure	6.89	1.83	0.15	2.96	14.12	4.19	6.36	8.22	21.01	6.52	6.51	11.06
Top and bottom ventilated storage structure with mud plastered walls	5.31	1.52	0.63	2.49	29.35	0.0	4.44	11.26	34.67	1.52	5.07	13.75
Modified Bottom ventilated storage structure chain linked side walls	8.40	1.22	0.26	3.29	10.77	1.06	4.92	5.58	19.17	2.28	5.18	8.88
Traditional single row storage structure	1.82	1.13	0.93	1.29	13.31	0.97	5.43	6.57	15.13	2.1	6.36	7.86
Bottom ventilated single row storage structure	4.43	1.47	1.57	2.49	15.15	3.27	3.71	7.38	19.58	4.74	5.28	9.87
Bottom ventilated single row low cost thatched roof storage structure	2.43	1.35	0.26	1.35	2.38	1.10	2.85	2.11	4.81	2.45	3.11	3.46
Average	**4.26**	**1.32**	**0.61**	**2.06**	**12.82**	**1.70**	**5.11**	**6.54**	**17.08**	**3.02**	**5.72**	**8.60**
CD(0.05)	**0.36**	**0.13**	**0.19**	**0.23**	**2.20**	**0.71**	**1.91**	**195**	**1.47**	**0.19**	**1.88**	**1.75**

Table 5. Effect of ventilation and number of rows on qualitative losses in onion cv. N-2-4-1.

Type of ventilation	Type	Sprouting	Black mould	Total
Ventilated	Single row	1.92	8.35	10.27
	Double row	2.91	4.75	7.66
Average		**2.42**	**6.55**	**8.97**
Traditional non ventilated	Single row	1.29	6.57	7.86
	Double row	0.56	4.65	5.21
Average		**0.93**	**5.61**	**6.54**
CD (A)		0.5	0.32	0.79
CD(B)		0.4	0.32	0.61
CD(AxB)		0.6	0.48	NS

Black mould infection

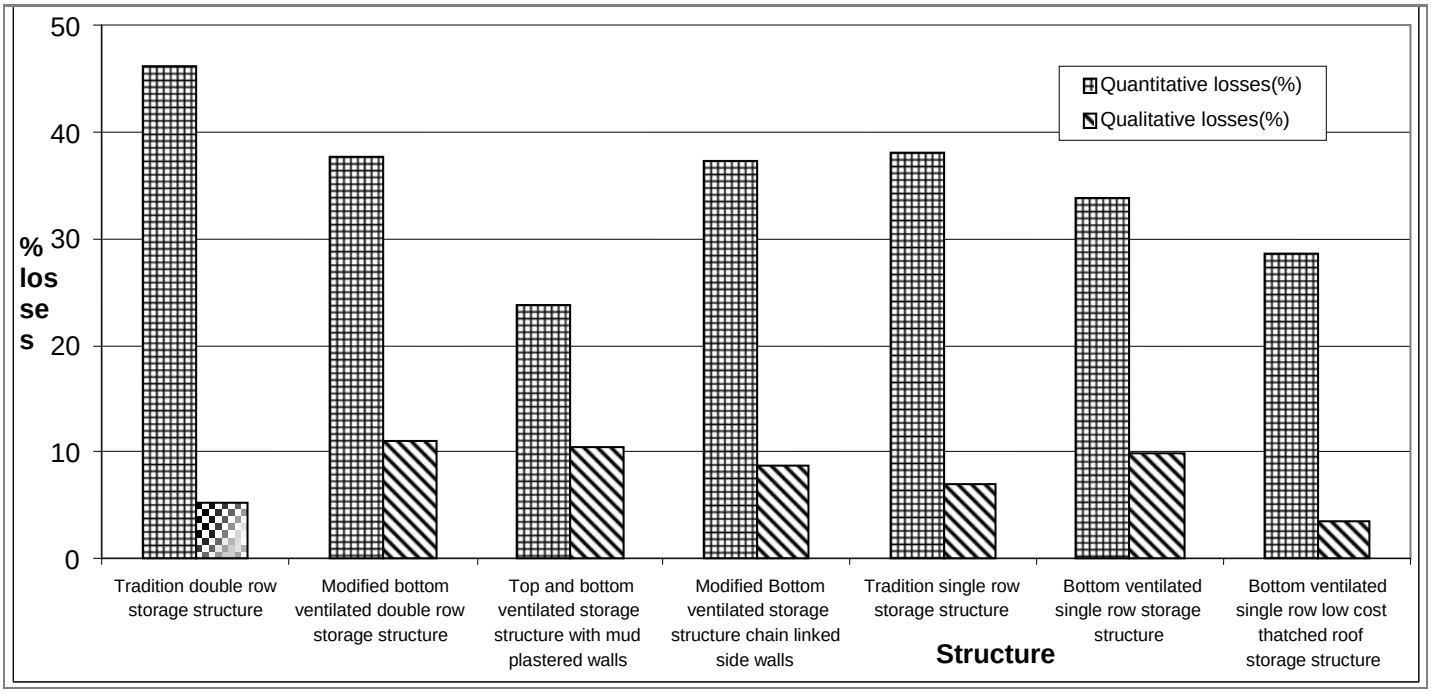
The percentage of black mould affected bulbs was significantly higher in Top and bottom ventilated structure (11.26 %) and Modified bottom ventilated double row storage structure (8.22%). The lowest black mould infection (2.11 %) was recorded in Bottom ventilated low cost thatched roof storage structure (Table 6). Lower black mould infection in single row structure was also reported by Naik *et al.* (2008).

Table 6. Economics of storage of onion in different storage structures.

Type of storage structures	Total expenditure (Rs)	Total expenditure (Rs/tonne)	Total Return *(Rs)	Net Profit (Rs)	Net Profit (Rs/t)
Tradition double row storage structure	101360	2667	102848	1488	39
Modified bottom ventilated double row storage structure	109040	2596	123210	14170	337
Top and bottom ventilated storage structure with mud plastered walls	78550	2618	112442	33892	1130
Modified Bottom ventilated storage structure chain linked side walls	82090	2565	98068	15978	499
Tradition single row storage structure	13600	2720	15463	1863	373
Bottom ventilated single row storage structure	13850	2770	17418	3568	714
Bottom ventilated single row low cost thatched roof storage structure	12850	2570	18884	6034	1207

*Cost of onion: A grade- @ Rs 5500/t, Sprouted & black mould affected-@ Rs1500/t.

Figure 1. Average quantitative and qualitative losses in different storage.



Higher black mould infection was found in 2003 than other two years.

The total qualitative losses were lowest in Bottom ventilated single row low cost structure (3.46 %) followed by Traditional double row storage structure (5.21 %; Table 5 & Fig 1). Highest qualitative losses (13.75 %)were recorded in Top and bottom ventilated storage structure with mud plastered walls followed by Modified bottom ventilated double row storage structure(11.06%). The results indicated that the bottom ventilation was not found efficient in reduce qualitative losses in double row structures.

Economics of storage structures

The economics of onion storage structure was calculated. The expenditure on storage of onion including cost of onion, cost of construction of onion was highest in Modified bottom ventilated double row structure while lowest cost was in Bottom ventilated single row low cost

thatched roof storage structure. The cost of per tonne of storage was highest in Bottom ventilated single row structure (Rs.2770/-) and Traditional single row (Rs2720/-).It was lowest (Rs2565/-tonne) in Modified Bottom ventilated storage structure chain linked side walls .The total net return was highest (Rs. 33892/-) in Top and bottom ventilated storage structure with mud plastered walls but net return per tones was highest (Rs 1207/tonne) in Bottom ventilated single row low cost thatched roof storage structure. The lowest net return (Rs. 1488) and net profit per tonne (Rs. 39 /tonne) was found in Traditional double row storage structure (Table 6). Over all Top and bottom ventilated storage structure with mud plastered sidewalls and Bottom ventilated single row low cost thatched roof storage structure were found most profitable.

The findings of the experiment indicate that bottom ventilated structures were found efficient in reduction of storage losses in onion stored at ambient temperature. There was no significant effect of bottom ventilation on reduction physiological loss of weight. The rotting was significantly reduced by bottom ventilation. The excess ventilation may increase weight loss as well as sprouting as observed the Modified Bottom ventilated storage structure chain linked side walls. Both single row and double row structures bottom ventilated structures were found effective in reduction of losses at ambient atmospheric conditions.

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