Adaptation of high-temperature storage for multiplier bulb sets under Philippine condition

Renita SM. Dela Cruz*, Edgar D. Flores, May Ann F. Galapon

(*Socioeconomics and Policy Research Division, Philippine Center for Postharvest Development and Mechanization, Department of Agriculture, 3120 CLSU Compound, Science City of Muñoz, Nueva Ecija, Philippines*)

Abstract: The study addressed the problem of inadequate technologies that could be utilized for the storage of multiplier bulb sets considering the limited on-farm resources and practices of the farmers producing multiplier onions. The application of high temperature storage which was found to be technically and financially viable under certain conditions by several researchers was evaluated in comparison with the existing storage practices. The storage study was done for two cropping seasons, 2016-2017, with a total of six farmer-cooperators from Ilocos Norte, Ilocos Sur and Nueva Ecija. Comparison of the quality and quantity indicators as affected by the high temperature storage structure (HTSS) and the farmers' practice was done using the t-test at 5% level of significance. Partial budget analysis was done to assess the potential benefits that could be derived from the use of the technology in comparison with the present practice.

HTSS significantly reduced storage loss of multiplier bulb sets by 20.39 percentage points in six months. The values of onions saved were higher than the value of installing and operating the HTSS giving positive change in income of PhP 16.15 kg^{-1} of bulb sets stored for six months. Acceptability of the technology was high among the potential farmer-users with 93.6 percent of them convinced of its effectiveness and indicated willingness to adopt. About 427,400 kg which is conservatively valued at PhP 34.19 to PhP 51.20 million annually can be saved using the HTSS. Approximately 7,000 farmers of multiplier onion using bulb sets as planting material specifically the farmers in the northern and central provinces of the Philippines, could benefit from HTSS technology. HTSS will work best in multiplier that have not been rained down before harvesting.

Keywords: multiplier onion, bulb sets, non-refrigerated storage, high-temperature storage, storage loss

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1 Introduction

The Philippines produces both bulb and multiplier onions (also known as shallot or cluster onion). Multiplier onion specifically the Batanes strain is native to the Philippines (Rosario, 1994). Although mainly propagated vegetatively, flowers and seeds are produced by farmers for the next season's planting. While bulb onion is commonly produced through seeds, more than 90 percent of multiplier onions are produced in the Philippines through bulb sets (PSA, 2014). Three-fourth of the farmers planting multiplier onions produce and store their own bulb sets while the rest either procure bulb sets during planting time or plant seeds instead of bulb sets. The average area planted to multiplier onion is 0.227 ha. About 642 kg of clean bulb sets are needed to plant a hectare area of multiplier onion.

Multiplier bulb sets are stored for six to seven months as source of seeds for the next season's planting. While in storage, onions are subjected to quantity and quality losses. The major sources of losses in storage are sprouting, decay due to disease infection and physiological loss in weight or moisture loss or shrinkage (Ko et al., 2002; Opara, 2003; Tripathi and Lawande, 2006; Idago et al., 2015).

Several studies have shown that high temperature

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* **Corresponding author: Dela Cruz R. SM.,** Ph.D., Socioeconomics and Policy Research Division, Philippine Center for Postharvest Development and Mechanization, Department of Agriculture, Science City of Muñoz, Nueva Ecija 3120, Philippines. Email: renitadelacruz@yahoo.com.

conditions can be used to store bulb onion for three to four months after harvest (Tripathi and Lawande, 2006; Jallorina, 2012; Idago et al., 2015). The latest study of Idago et al. (2015) showed that high temperature storage, with temperature range of 27°C-39°C using plastic structures can potentially be used to store bulb onion with relatively lower postharvest losses than storage at ambient conditions for a period of 3-4 months. The authors also found out that adoption of high temperature storage could potentially give farmers an incremental income of PhP 11.50 kg^{-1} of initial bulb onion stored compared to selling immediately after harvesting when price of bulb onion is generally at its lowest. The additional income was mainly due to increased price after four months storage.

Short-term storage studies on bulb onion from one to three months using HTSS and other storage strategy is being practiced for the purpose of price speculation. Idago et al. (2015) studied the application of HTSS on multiplier bulb sets in a limited scale and was found promising in extending storability. Improving the current practice of storing multiplier bulb sets that will be appropriate for small volume of seeds will directly help farmers reduce their storage losses. Reducing the volume of losses will translate to higher areas planted to bulb sets or higher income from more bulb sets available at the end of the storage period.

Although multiplier onion constitutes only 23 percent of the total domestic supply, it has desirable characteristics such as its higher pungency which is preferred for specific culinary purposes. Its adaptability under local conditions and longer storability than the bulb onion under ambient conditions also makes it suitable for year-round planting. Sustainability of producing multiplier onion is high since farmers of multiplier onion can produce their own seeds and sets for planting. They do not rely on seeds from other countries unlike the farmers of bulb onion who are entirely reliant on imported seeds to produce bulb onions.

Improvements on the storage technology of multiplier onion has its immediate effect of reducing losses and extending storability and has its potential far-reaching effect of providing opportunities to produce and make onion available throughout the year. The study was designed to compare the advantages of HTSS over the farmer's practice of storing bulb sets in terms of quantity and quality losses and financial viability. The evaluation was done under farmers' field conditions where other farmers could also observe.

2 Methodology

2.1 Description of high-temperature storage structure

The HTSS consist of a tunnel type shed covered with 4-6 mil thick UV-stabilized plastic (Figure 1). Another layer of net is placed on top or underneath the plastic to help regulate the intensity of heat during intense sunshine. A suction fan is also provided to suck warm air when temperature goes beyond the recommended level. The design capacity was primarily based on the average volume of multiplier bulb sets stored by farmers. One module can store enough multiplier bulb sets (250-300 kg) that can plant one fourth hectare which is the average area planted to multiplier onion in the Ilocos Region. If the volume of multiplier to be stored is higher than 300 kg, additional unit can be easily added.

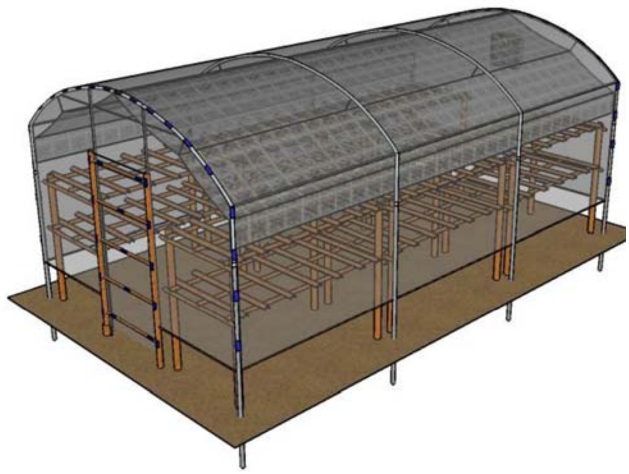

Figure 1 Isometric view of the tunnel-type plastic-covered HTSS

2.2 Research design

The project followed a comparative research between HTSS and the farmers' practice (FP) of storing onion. The performance of the HTSS was compared with the existing practices of six cooperating farmers, two in 2016 and four in 2017.

In each location, six bags were randomly selected from each of the two storage treatments of multiplier onion. Each bag served as replication in each location and the whole bag of multiplier served as the experimental unit.

2.3 Data collection and sampling

The quantity and quality losses were measured from six sample bags from each storage treatment taking all the contents of each bag as samples. The initial weight and the total number of onion for each sample bag were noted down. Quality measurements were done monthly until the sixth month of storage. This length of storage typified the practice of storing multiplier bulb sets by farmers in Ilocos Region. The quantity and quality indicators were measured using the following formula.

1. Percentage of good bulbs (*GB*) is the number or weight of good bulbs expressed as the percent of bulbs that are still good at the time of measurement based on the initial number or weight of the bulbs stored. Good bulbs are characterized by the absence of sprouts and visible disease infection.

$$GB(\%) = (\textit{No. of good bulbs}/\textit{Total initial number of bulbs stored}) \times 100 \quad (1)$$

or

$$GB(\%) = (\textit{Weight of good bulbs}/\textit{Total initial weight of bulbs stored}) \times 100 \quad (2)$$

2. Percentage weight loss (*WL*) is the reduction in weight of the samples due to rotten bulbs, sprouted bulbs and moisture loss. It was computed using the formula below.

$$WL(\%) = ((\textit{Initial weight} - \textit{Final weight of good bulbs weight})/\textit{Initial weight}) \times 100 \quad (3)$$

3. Percentage rotten bulbs (*RB*) is the intensity of rotten bulbs expressed as the percent of bulbs that were rotten at the time of measurement based on the total initial number of bulbs stored.

$$RB(\%) = (\textit{Number of rotten bulbs}/\textit{Total initial number of bulbs}) \times 100 \quad (4)$$

4. Percentage sprouting (*SB*) is the intensity of sprouted bulbs expressed as the percent of bulbs that sprouted at the time of measurement based on the total initial number of bulbs stored.

$$SB(\%) = (\textit{Number of sprouted bulbs}/\textit{Total initial number of bulbs}) \times 100 \quad (5)$$

Other information were gathered which were needed in the determination of financial benefits such as the cost of using and maintaining the storage structure and the price of onion within the province during specific period of time (e.g., harvesting time, regular period after harvesting).

Feedbacks from the co-operators and the farmers present during the validation and presentation of the results organized in the production areas were taken using structured questionnaires. Forty-seven farmers planting multiplier onions in Ilocos Norte and Ilocos Sur were interviewed . The farmer-respondents included those that tried the technology and the farmers who frequently visited and/or saw the technology.

2.4 Data analyses

The data gathered in two years, 2016 (n=6) and 2017 (n=24) were pooled after testing for normality and subjected to analysis using independent sample t-test at $P \leq 0.05$ (SPSS Statistics 20).

Partial budget analyses were done to determine the benefits that could be derived from adopting the technology. Frequencies and percentages were taken as a descriptive measure of the feedbacks from farmer-cooperators and potential technology users.

3 Results and discussion

3.1 Storage conditions

Table 1 shows the temperature and relative humidity conditions in the areas where farmer-cooperators stored multiplier bulb sets for the cropping years 2016 and 2017. The mean daily temperature in the areas where the farmer-cooperators stored their multiplier bulb sets was 27.50^{o}C in 2016 and 29.39^{o}C in 2017 while the relative humidity was 80.85% and 78.94% in 2016 and 2017, respectively. On the other hand, the temperature and relative humidity inside the HTSS in 2016 were 35.17^{o}C and 49.39%, respectively, and had 36.36^{o}C and 57.31% in 2017, respectively. The temperatures under HTSS was hotter by 6.97^{o}C-7.67^{o}C while the relative humidity was lower by 21.63%-31.46%.

The conditions for high temperature storage (Opara, 2003; Tripathi and Lawande, 2006) were met by the ordinary conditions where the farmers stored their bulb sets for planting. Similarly, the temperature inside the HTSS was also within the range found by previous researchers where storability of onion was prolonged (Jallorina, 2012; Idago et al., 2015). While the relative humidity under FP was within the range found to minimize moisture loss (70%-75%), the relative humidity level inside HTSS was lower at 49.39%-57.31%.

Table 1 Mean daily temperature and relative humidity under HTSS and FP conditions, 2016-2017

Year	Mean Daily Temperature (^{o}C)	Mean Daily Relative Humidity (%)
Average of 2016		
FP	27.50	80.85
HTSS	35.17	49.39
Difference (HTSS-FP)	7.67	31.46
Average of 2017		
FP	29.39	78.94
HTSS	36.36	57.31
Difference (HTSS-FP)	6.97	21.63

3.2 Postharvest Losses

The measures of quantity and quality losses are the *WL*, *RB*, *SB*, and *GB*. High WL + *RB* + *SB* will reduce *GB* while low *WL* + *RB* + *SB* will increase *GB*. Multiplier bulb sets were harvested in April, cured for 2-3 weeks, and then stored. Storage was terminated in October in preparation for their main season planting. Table 2 shows the results of storing multiplier bulb sets in different locations for two cropping seasons (2016 and 2017), six months after harvest.

All the means of the indicators measured were significantly different between the use of HTSS and FP. In terms of initial weight of bulb sets stored, the mean differences between HTSS and FP in terms of percentage good bulbs (20.39%, $p\leq$ 0.01) and percentage weight loss (20.39%, $p\leq$0.01) six months after harvest were significantly different. The mean percentage good bulbs was significantly higher (51.0%) while the percentage weight loss (49.0%) was conversely lower in multiplier bulb sets stored in HTSS.

,n terms of initial number of bulb sets stored, the mean differences between the HTSS and FP were significantly different in percentage rotten bulbs (14.2%, $p\leq$0.01), sprouted bulbs (2.31%, $p\leq$0.05) and good bulbs (16.5%, $p\leq$0.01). The percentage rotten (15.10%) and sprouted bulbs (1.5%) were significantly lower while percentage good bulbs (83.59%) after storage was significantly higher in multiplier bulb sets stored in HTSS.

Weight loss six months after harvest was 69.39 percent in FP and 49 percent in HTSS. HTSS can potentially minimize weight loss (moisture loss + rotten + sprouted bulbs) by as much as 20.39 percentage points. Although there were no direct measurements of the moisture loss, it can be inferred that the major source of reduction in postharvest loss was brought about by the reduction in weight due to rotten and sprouted bulb sets. Despite the lower relative humidity inside the HTSS, the combined percentage rotten and sprouted bulb sets in HTSS was significantly lower by 16.51 percentage points compared to the samples stored under FP.

Table 2 Performance indicators of multiplier onions stored six months after harvest using HTSS and FP, 2016-2017

Indicator	Storage Practice		Mean Difference
	HTSS	FP	
1. Good bulbs (% of initial weight)	51.00	30.61	20.39**
2. Weight loss (based on initial weight)	49.00	69.39	–20.39**
3. Rotten bulbs (% initial no. of samples)	15.10	29.30	–14.2**
4. Sprouted bulbs (% initial no. of samples	1.30	3.61	–2.31**
5. Good bulbs (% initial no. of samples)	83.59	67.09	16.5**

Note: Pooled samples of 2016 and 2017; ** significant at 1% level of significance.

The low percentage of sprouted bulbs could have been brought about by the high temperature in HTSS. The mean daily temperature under HTSS was in the range of 35.17^{o}C-36.36^{o}C, higher by 6.97^{o}C-7.67^{o}C than the conditions under the FP. Gubb and MacTavish (2002) as cited by Chope (2006) mentioned that the inhibition of sprouting in high temperature condition may be related to the dormancy observed in hot seasons. Dormancy or the state when bulbs are at resting stage determines to a large extent the storability of onion (Gummagolmath, 2013). Dormancy is affected by temperature where lower (0^{o}C) and higher (30^{o}C) temperature increase the dormant state of onion bulbs and moderate (10^{o}C-15^{o}C) temperature enhance the sprouting losses by breaking dormancy.

In addition to this, Gummagolmath (2013) further mentioned that storage temperature and humidity affect weight loss, respiration rate, and rotting of bulbs in storage. Higher temperature and higher relative humidity increases rotting. On the other hand, desiccation or water loss is reduced at higher humidity but rotting and rooting are hastened.

Storability of multiplier cultivars. The commonly used multiplier cultivars in Ilocos Region are the Australian and Batanes cultivars. Although the storability of Batanes was observed by farmers to be shorter than Australian cv, some farmers from Ilocos Norte, preferred to use Batanes because flowering is not prevalent as in

Australian cv. The measures of storability six months after harvest were compared between Australian and Batanes and shown in Table 3. Australian cv had significantly higher percentage good bulbs (48.23%) after six months while higher weight loss due to moisture loss and rotten and sprouted bulbs were observed in Batanes (66.62%). The result conformed with and validated the observation and experiences of farmers that Batanes has more rotten bulbs at the end of five to six months of storage.

Table 3 Performance indicators of multiplier onions stored six months after harvest, Australian and Batanes cultivars, 2016-2017

Indicator	Australian cv	Batanes cv	Mean Difference
1. Good bulbs (% of initial weight)	48.23	33.38	14.85**
2. Weight loss (based on initial weight)	51.77	66.62	–14.85**
3. Rotten bulbs (% initial no. of samples)	19.46	26.78	–7.32**
4. Sprouted bulbs (% initial no. of samples	2.53	2.33	0.20ns
5. Good bulbs (% initial no. of samples)	78.02	70.89	7.13ns

Note: ** significant at 1% level; ns = not significant.

3.3 Financial analysis

The financial benefit of adopting the technology in relation to the present practice of storing multiplier was determined by applying the partial budget analysis. The analysis considered the added returns and reduced cost as well as the reduced returns and added cost associated in using the HTSS versus the traditional practice of storing bulb sets for planting.

There was an estimated positive change in income of PhP 16,150.11 for the 1,000 kg of multiplier stored in HTSS for a period of six months (Table 4). The additional cost of putting up and adopting HTSS for 1,000 kg capacity multiplier was PhP 4,239.89. However, due to substantial reduction in storage loss, additional returns amounting to PhP 20,390 was generated. This resulted to an increase in the bulb sets that would be available after six months of storage which could either be used for planting or could be sold.

3.4 Perceptions on HTSS

Perceptions on the technology by the users and those that observed the technology are important inputs in formulating strategies for technology dissemination and/or improving the technology toward hastening adoption. The initial results of the 2017 set-up for multiplier onions were presented to the farmer-cooperators, neighboring farmers, local traders, and provincial and municipal agricultural extension workers from La Union, Ilocos Sur and Ilocos Norte. Table 5 shows the summary of perceptions taken from 47 respondents producing and/or storing multiplier onions.

All of the respondents believed that HTSS can help farmers recover high percentage of bulbsets after storage and 93.6 percent of them would like to store in HTSS if situations permit. Although all of them had been convinced of the advantages of HTSS, some of them do not have space near their homes where they can install HTSS. The regular observations made by farmers from the existing technology setups convinced the farmer-observers that HTSS could provide relatively better storage conditions which could give better quality of stored onion, longer storability and therefore higher percentage recovery (56.8%) while the rest were still undecided. Based on their individual experiences and/or observations of the technology some recommendations were forwarded by potential technology users.

Table 4 Partial budget analysis of storing 1,000 kg multiplier bulb sets intended for seed purposes in HTSS versus FP, Ilocos Sur and Norte, 2017

Proposed Technology: High temperature storage versus farmers' practice			
Added Costs (A)		Added Returns (B)	
1. Plastic enclosed structure depreciation	PhP 1,422.09	Reduced losses (69.39% down to 49.00%) 1000 kg × 0.2039 × P100/kg	PhP 20,390.00
2. Red bag	1,040.00		
40 bags × 13.00/bag × 2 times/6months			
24 bags × 13.00/bag	312.00		
3. Electricity	415.80		
69.30/month × 6 months of storage			
4. Labor (installation and dismantling of storage structure)	1,050.00		
Reduced Returns	nil	Reduced Costs	nil
Subtotal A =	PhP 4,239.89	Subtotal B =	PhP 20,390.00
Estimated change in income (B less A) = **PhP 16,150.11**			

Table 5 Perception of the multiplier onion farmers on non-refrigerated storage, Ilocos Sur and Ilocos Norte, 2017

	ITEM	Frequency (*N*=47)	Percent Reporting
1	Storage in HTSS can help farmers recover high percentage of planting material stored		
	Yes	47	100.0
2	If given the chance, would you like to store multiplier in HTSS		
	Yes	44	93.6
3	Reasons for the interest to adopt the technology		
	Good storage condition; better quality of stored onion; prolong shelf life; prevent loss; high percentage recovery	20	45.4
	Results of demo was satisfying and convincing	5	11.4
4	What improvements can you recommend to enhance the utilization of HTSS		
	Bigger storage capacity	18	81.8
	Provide additional cover to prevent sun scalding	2	9.09

4 Conclusion and recommendation

The application of HTSS on multiplier bulb sets significantly reduced losses by 20.39 percentage points, thereby resulting to higher bulb set recovery. The application of the technology could open-up opportunities to generate additional income and/or plant more areas because of more seeds available at the end of the storage period or at the time of planting. Farmer-adopters could potentially benefit by about PhP 16.15 kg^{-1} of bulb sets stored. Farmer-cooperators and onion farmers who have witnessed the performance of the technology gave positive feedbacks and 93.6 percent of them were ready to adopt the technology. Convinced of the satisfactory performance of HTSS for storing multiplier bulb sets, a local government unit within the area immediately installed a demonstration set-up for their community of multiplier growers which was already used in their April 2018 harvest.

The HTSS can potentially save 427,400 kg of multiplier bulb sets per year (2,137 ha planting once a year × 1,000 kg bulbset required per ha × .20 reduction in loss) which is conservatively valued at PhP 34.19 to PhP 51.29 million (PhP 80 to PhP 120 kg^{-1} of bulb sets).

The HTSS technology can be used by approximately 7,000 multiplier farmers producing their own bulb sets and practicing direct seeding especially in the northern and central provinces of the Philippines. The technology will work best in multiplier that have not been rained down before harvesting. Future studies should consider the provision of solar-powered and controlled fans to provide aeration inside the farm structure.

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