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EFFECTS OF BULB SIZE, DEPTH OF STORAGE AND BULB ORIENTATION ON STORAGE LOSS OF ONION *(Allium cepa L.)*

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ABSTRACT

Onion is a major crop grown in northern Nigeria. It is popular for its nutritional and medicinal benefits worldwide. However, a lot of postharvest losses occurs especially during the storage of onion. This work was carried out to investigate the effects of bulb size, depth of storage and bulb orientation on physiological weight loss, sprouting and rotting of onion (red creole variety) in the modified IAR open rack onion storage structure for a sampling period of three months. A Complete Randomized Design (CRD) Anova was employed. Data were collected for a sampling period of 12 weeks and analysed using the Statistical Analysis Software (SAS) at 1% and 5% significant levels. Duncan Multiple Range Test (DMRT) was used for the mean separation of the significant variables. The results obtained showed that the total weight loss of onions during the sampling period was 19.6%. Bulb orientation had a major effect on sprouting and physiological weight loss. Medium bulb sizes of (5 – 7cm Major Diameter) were better suited for storage.

Keywords: Onion storage; Bulb orientation; Physiological weight loss; Depth of storage; Bulb size.

INTRODUCTION

Onion (*Allium cepa* L.) is a vegetable crop grown mainly in the Northern part of Nigeria mostly in Kano, Kaduna, Jigawa, Sokoto, Plateau, Bauchi and Kebbi State. It is a biennial plant but is usually grown as an annual plant during the dry season (October to April) and it is majorly available in surplus from February to April. Nigeria ranks sixth amongst the top ten producers of green onion, and eleventh in terms of dry onion production in the world (Oladeji, 2018).

Onion is often chopped and used as an ingredient in various hearty warm dishes and may also be used as the main ingredient. They are also used raw in cold salad, or as a thickening agent for curries providing a bulk of the base. Onion picked in vinegar is eaten as a snack. These are often served as a side serving in pubs, fish and chip shops throughout the world and in many tropical countries; onion is an essential part of the traditional diet (Adamicki, 2015).

According to Petropoulos *et. al.* (2016), The storage life of onion is dependent on the cultivar and the storage conditions, together with other factors, including harvest and postharvest management and cultural practices such as rotation, sanitation, optimum fertilization, preventive chemical applications, harvest timing and proper handling, affects the storability of onions.

Storage is an important aspect of post-harvest management of onion in Nigeria especially during the surplus period of February to April. The growers temporarily store their produce in field, under shelters, sheds or rooms under ambient conditions, which reduce post-harvest rots and retain quality. During off-season, the efficient storage facility for onion plays an important role for the consumers as well as for the producers, which ultimately prevents serious losses due to rotting and sprouting. There are different types of storage structures used in different parts of the country. Most of these structures lack proper ventilation resulting in higher storage losses. The poor aeration and air movement resulted in rise of storage temperature, which in turn adversely affected the product physiology and pathology (Olanipekun, 2018).

The aim of this study is to check the effects of bulb size, depth of storage and bulb orientation on storage loss of onion in an open rack storage structure.

Farmers of onions incur lots of storage loss due to inadequate knowledge on onion storage and less efficient methods of storage. The findings from this study proffers suitable solutions to minimizing storage losses due to bulb degradation especially sprouting, rotting and physiological weight loss.

MATERIALS AND METHODS

Description of the modified IAR Open Rack Onion Structure

The structure was constructed using two major materials namely: African white wood (*Arere*) and mild steel angle iron. The African white wood was used for construction of the ventilated onion crates where the onion bulbs are loaded. While, the mild steel angle iron was used for the structural framework construction. The structure has a basal area of 1.36 m^2, a total height of 190 cm and a total capacity of 0.5 tonnes carrying 125 kg at each level. The picture of the structure is as shown in Plate I.

Plate I: Pictorial view of the structure

Experimental samples preparation

Fresh harvested red creole variety of onions were procured from Sabon Gari market, Zaria. The onion bulbs were properly sorted by removing the diseased and injured bulbs from the lot. The onions were cured by direct sun drying for a period of one week to reduce the moisture content and increase the toughness of the outer skin. The onion bulbs after being examined physically to ensure its storability, were resorted and grouped according to their sizes into three groups as prescribed by Bahanasawy *et. al.* (2004); small (< 5cm Major Diameter), medium (5 – 7cm Major Diameter) and big ($\geq$ 7cm Major Diameter) sizes.

Experimental factors and levels

The experimental factors are: bulb size (S), depth of storage (L) and bulb orientation (O). The factors and levels are as presented in Table I

Table I: Experimental Factors and Levels

Factors	Levels
Bulb Size (S)	S_1 –< 5cm Major Diameter
	S_2 – 5 – 7cm Major Diameter
	S_3 – $\geq$ 7cm Major Diameter
Depth of Storage (L)	L_1 – 100mm
	L_2 – 200mm
Bulb Orientation (O)	O_1 – Bulb facing upwards
	O_2 – Bulb facing downwards

Experimental design and layout

The experiment was conducted using a 3×2×2 factorial experiment in a completely randomized design with 12 treatments. Each of the treatment was repeated thrice.

Experimental procedures, data collection and analysis

The sorted onions were arranged some facing upwards and others facing downwards at two levels of storage depth in the ventilated wooden boxes. The boxes were then placed in the storage framework structure according to the randomized experimental layout

The initial weight of the bulbs was taken and recorded. Thereafter, the weights were taken weekly for a period of three months. The data collected were analyzed using the Statistical Analysis Software (SAS) to determine significance difference of the treatments.

The effect of the treatments (main factors and their interactions) were verified at significance levels of $p<0.05$ and $p<0.01$. The significant factors and interactions were further analyzed using the Duncan Multiple Range Test (DMRT).

Performance indicators

The indicators used for the performance evaluation were the physiological weight loss, sprouting loss and rotting loss.

i. Determination of Physiological Weight Loss

Physiological weight loss in onion is the weight lost due to its normal biological activities. Physiological weight loss was calculated using equation 1 (Falayi and Yusuf, 2014).

$$PWL(\%) = \frac{Initial\ Weight(g) - Final\ Weight(g)}{Initial\ Weight(g)} \times 100 \quad (1)$$

ii. Sprouting loss

Sprouting loss is the weight lost due to growth of plant emerging from the bulbs. The weight of the sprouted bulbs was taken from the storage structure at 7 days interval with an electronic balance and the sprouting loss was calculated using equation 2 (Wolelaw *et al.*, 2014).

$$Sprouting\ Loss(\%) = \frac{Weight\ of\ sprouted\ bulb(g)}{Initial\ Weight(g)} \times 100 \quad (2)$$

iii. Rotting Percentage

This is the percentage of deterioration as a result of gradual decomposition caused by fungi and bacteria. The percentage weight of the rotted bulbs was determined at 7 days interval using equation 3 (Wolelaw *et al*, 2014)

$$Rotted(\%) = \frac{Weight\ of\ rotted\ bulbs(g)}{Initial\ Weight(g)} \times 100 \quad (3)$$

RESULTS AND DISCUSSION

Percentage weight loss due to sprouting of onion bulbs

The result of the analysis of variance (ANOVA) for the percentage weight loss as a result of sprouting of onion bulbs for week 1 - 4 is presented in the Table II. The table shows that the effect of bulb orientation was found to be highly significant and the interaction effect of depth of storage and bulb size was found to be significant. The result also shows that there was an immediate and obvious effect of bulb orientation from the early stage of storage on the percentage weight loss due to sprouting of onion bulbs. Also, there was an effect of the interaction of size and depth at the early stage of storage.

Table II: ANOVA for Effects of Bulb Size, Depth of Storage and Orientation of Bulb on Percentage Weight Loss in Onion Bulbs due to Sprouting for week 1 - 4.

Source	DF	Anova SS	Mean Square	F Value	Pr > F
Size, S	2	0.0097635	0.00488177	0.27NS	0.7633
Depth, L	1	0.0018063	0.00180625	0.10NS	0.7533
Orient., O	1	36.330756	36.33075625	2032.79**	<.0001
Size*Depth	2	0.176876	0.08843802	4.95*	0.0159
Size*Orient.	2	0.0142406	0.00712031	0.40NS	0.6758
Depth*Orient.	1	0.029184	0.02918403	1.63NS	0.2135
Size*Depth*Orient.	2	0.049567	0.02478351	1.39NS	0.2692
Error	24	0.4289375	0.01787240		
Corrected Total	35	37.0411312			

NS= Not significant * = Significant at ($P \leq 0.05$) ** = Significant at ($P \leq 0.01$)

The means of the significant variables were further analysed using the DMRT and the results are as shown in Tables III and IV.

Table III: Mean separations of Orientation of Bulb on Percentage Weight Loss in Onion Bulbs due to Sprouting for Week 1 - 4

Orientation of Bulb	Means
O_2	1.18b
O_1	3.19a
SE±	0.032

From Table III, it was observed that there is significant difference in weight loss due to sprouting between the two orientations of the bulb. The bulbs facing downward O_2 has the lowest value of 1.18% of weight loss due to sprouting compared to 3.19% of weight loss due to sprouting for the bulbs facing upward O_1.

Table IV: Mean Separation for the Interaction of Size and Depth on Percentage Weight Loss in Onion Bulbs due to Sprouting for Week 1 - 4

Size (S) × Depth (L)	Means
S_3L_2	2.07b
S_1L_1	2.14ab
S_2L_1	2.15ab
S_1L_2	2.19ab
S_2L_2	2.26a
S_3L_1	2.28a
SE±	0.055

Means followed by same letter(s) in the same column are not different statistically at *P=0.05* using DMRT.

From the Table IV, it was observed that there is significant difference in percentage weight loss in the interactions which is observed between S_3L_2 and S_3L_1. This implies that the interaction effect between bulb size and depth is very minimal.

For week 5 – 8, the results of the analysis of variance (ANOVA) for the percentage weight of sprouted onion bulbs are presented in Table V. The Table shows that the effects of bulb size and bulb orientation were found to be highly significant. The first order interaction effect of size and depth was found to be highly significant and the second order interaction effect of bulb size, depth of storage and bulb orientation was found to be highly significant.

Table V: ANOVA for Effects of Bulb Size, Depth of Storage and Orientation of Bulb on Percentage Weight Loss in Onion Bulbs due to Sprouting for week 5 - 8

Source	DF	Anova SS	Mean Square	F Value	Pr > F
Size, S	2	0.07630313	0.03815157	6.85**	0.0044
Depth, L	1	0.00795069	0.00795069	1.43NS	0.2437
Orient., O	1	35.09575069	35.09575069	6304.04**	<.0001
Size*Depth	2	0.16493993	0.08246997	14.81**	<.0001
Size*Orient	2	0.01010035	0.00505018	0.91NS	0.4171
Depth*Orient	1	0.02200278	0.02200278	3.95NS	0.0583
Size*Depth*Orient	2	0.26328993	0.13164497	23.65**	<.0001
Error	24	0.13361250	0.00556719		
Corrected Total	35	35.77395000			

NS= Not significant * = Significant at ($P \leq 0.05$) ** = Significant at ($P \leq 0.01$)

The means of the significant variables were further analysed using the DMRT and the results are shown below in the Tables 6, 7, 8 and 9.

The mean separation for the size of bulb on percentage weight loss in onion bulbs due to sprouting for week 5 - 8 is presented in Table VI.

Table VI: Mean Separation for the Size of Bulb on Percentage Weight Loss in Onion Bulbs due to Sprouting for Week 5 - 8

Size of Bulb (S)	Means
S_1	2.10b
S_2	2.19a
S_3	2.20a
SE±	0.022

Means followed by same letter(s) in the same column are not different statistically at *P=0.05* using DMRT

From the Table VI, Percentage weight loss due to sprouting increased with increase in size of onion bulbs. Weight loss of S_2 and S_3 are statistically at par but significantly different from S_1. This agrees with El-Okene (1996) who reported that larger bulbs are more prone to sprouting.

The mean separation for the orientation of bulb on percentage weight loss in onion bulbs due to sprouting for week 5 – 8 are presented in Table VII

Table VII: Mean Separation for the Orientation of Bulb on Percentage Weight Loss in Onion Bulbs due to Sprouting for Week 5 - 8

Orientation of Bulb(O)	Means
O_2	1.17b
O_1	3.15a
SE±	0.018

From Table VII, there is significant difference in percentage weight loss due to sprouting between the two orientation of the bulbs, with the bulbs facing downward O_2 having a lower mean when compared with the bulbs facing up O_1

The mean separation for the first level interaction effects of bulb size S and depth of storage L is presented in Table VIII

Table VIII: Mean Separations for the Interaction Effects of Size and Depth on Percentage Weight Loss in Onion Bulbs due to Sprouting for Week 5-8

Size (S) × Depth (L)	Means
S_3L_1	2.09b
S_1L_1	2.10b
S_2L_1	2.11b
S_1L_2	2.24a
S_2L_2	2.26a
S_3L_2	2.31a

SE+	0.055

Means followed by same letter(s) in the same column are not different statistically at *P=0.05* using DMRT

From Table VIII, there is significant difference in percentage weight loss due to sprouting between the combinations of all sizes with the storage depth L_1 and the combinations of all sizes with the storage depth L_2. There is no significant difference of the combination within the storage depth L_1 or L_2 and the bulb sizes. This implies that at any of the suitable storage depth could be used without it having a significant difference in weight loss due to sprouting.

The mean separation for the second level interaction effects of bulb size S, depth of storage L and orientation of bulb O is presented below in Table IX.

Table IX: Mean Separations for the Interaction Effects of Size, Depth and Orientation on Percentage Weight Loss in Onion Bulbs due to Sprouting for Week 5 - 8

Size (S) × Depth (L) × Orientation (O)	Means
$S_2L_1O_2$	0.15f
$S_1L_1O_2$	0.29e
$S_3L_1O_2$	0.37de
$S_3L_2O_1$	0.42de
$S_3L_2O_2$	0.46d
$S_2L_1O_1$	0.61c
$S_2L_2O_2$	0.64c
$S_3L_1O_1$	0.86b
$S_1L_1O_1$	0.91ab
$S_1L_2O_2$	0.95ab
$S_2L_2O_1$	0.99ab
$S_1L_2O_1$	1.02a
SE+	0.043

Means followed by same letter(s) in the same column are not different statistically at *P=0.05* using DMRT

From Table IX, the interaction effect of medium bulb size S_2, 100 mm depth of Storage L_1 and bulbs facing downwards O_2 was found to have 0.15% of weight loss in onion bulbs due to sprouting which is the minimum weight loss and significantly different from the rest combination.

For week 9 – 12, the results of the analysis of variance (ANOVA) for the percentage weight loss in onion bulbs due to sprouting is presented in Table X. The effect of bulb orientation was found to be highly significant. The first order interaction of bulb size and depth of storage was found to be significant. This implies that medium sized onion bulbs placed facing downwards at a depth of 100 mm are better suited for storage.

Table X: ANOVA for Effect of Bulb Size, Depth of Storage and Orientation of Bulb on Percentage Weight Loss in Onion Bulbs due to Sprouting for week 9-12

Source	DF	Anova SS	Mean Square	F Value	Pr > F
Size, S	2	0.02311250	0.01155625	0.72NS	0.4989
Depth, L	1	0.01995156	0.01995156	1.24NS	0.2773
Orient., O	1	38.34189601	38.34189601	2375.23**	<.0001
Size*Depth	2	0.13187917	0.06593959	4.08*	0.0297
Size*Orient	2	0.01680972	0.00840486	0.52NS	0.6007
Depth*Orient	1	0.05270851	0.05270851	3.27NS	0.0833
Size*Depth*Orient	2	0.07116806	0.03558403	2.20NS	0.1322
Error	24	0.38741667	0.01614236		
Corrected Total	35	39.04494219			

NS= Not significant * = Significant at (P≤0.05) ** = Significant at (P≤0.01)

The means of the significant variables were further analysed using the DMRT and the results are shown below in the Tables XI and XII.

Table XI: Mean Separations for the Orientation of Bulb on Percentage Weight Loss in Onion Bulbs due to Sprouting for Week 9-12

Orientation of Bulb (O)	Means
O_2	1.08b
O_1	3.14a
SE±	0.03

From Table XI, there is significant difference in percentage weight loss due to sprouting between the two orientations of the bulbs with bulbs facing downwards O_2 having 1.08% weight loss in onion bulbs due to sprouting compared with bulbs facing upward O_1 which has a higher percentage weight loss due to sprouting of 3.14%.

The mean separation for the first level interaction effects of bub size and depth of storage is presented below in Table XII

Table XII: Mean Separations for the Interaction Effects of Size and Depth on Percentage Weight Loss in Onion Bulbs due to Sprouting for Week 9-12

Size (S) × Depth (L)	Means
S_3L_2	1.98b
S_2L_1	2.08ab
S_1L_2	2.13ab
S_1L_1	2.15a
S_2L_2	2.17a
S_3L_1	2.18a
SE±	0.052

Means followed by same letter(s) in the same column are not different statistically at *P=0.05* using DMRT

From Table XII, there is significant difference in percentage weight loss in the interactions which is observed only between S_3L_2 when compared to the combinations of S_3L_1, S_1L_1 and S_2L_2. This implies that the interaction effect between bulb size and depth is very minimal.

Percentage weight loss in onion bulb due to rotten

The Table XIII shows the mean summary of the effects of the factors on the percentage weight loss in onion bulbs due to rotten for the whole storage period. There was no significant difference in the treatments and its interactions on the percentage weight loss in onion bulbs due to rotten.

Table XIII: Effect of Bulb Size, Depth of Storage and Orientation of Bulb on Percentage Weight Loss in Onion Bulbs due to Rotten

	Sampling Periods (week)		
Treatment	1 - 4	5 - 8	9 - 12
Size of Bulb			
S_1	1.17	0.79	0.37
S_2	0.60	0.60	0.29
S_3	0.60	0.53	0.24
SE±	0.198	0.14	0.071
Depth of Storage			
L_1	0.65	0.53	0.23
L_2	0.92	0.75	0.37
SE+	0.026	1.00	0.058
Orientation of Bulb			
O_1	0.76	0.80	0.30
O_2	0.82	0.48	0.30
SE±	0.026	0.12	0.058
Interaction			
Size*Depth	S	NS	NS
Size*Orientation	NS	NS	NS
Depth*Orientation	NS	NS	NS
Size*Depth*Orient	NS	NS	NS

Means followed by same letter(s) in the same column are not different statistically at *P=0.05* using DMRT NS= Not significant

Percentage Physiological Weight Loss

The result of the analysis of variance (ANOVA) for the percentage physiological weight loss in onion bulb for week 1 – 4 of storage is presented in Table XIV. The effect of bulb orientation was found to be highly significant, while, other factors showed no significant effect.

Table XIV: ANOVA for Percentage Physiological Weight Loss in Onion Bulbs for Week 1 – 4 of storage

Source	DF	SS	MS	F-value	Pr > F
Size, S	2	1.44008960	0.72004480	1.25NS	0.3038
Depth, L	1	0.09203479	0.09203479	0.16NS	0.6926
Orient., O	1	9.75289883	9.75289883	16.97**	0.0004
Size*Depth	2	0.16192224	0.08096112	0.14NS	0.8693
Size*Orientation	2	1.26646366	0.63323183	1.10NS	0.3486
Depth*Orientation	1	0.05142209	0.05142209	0.09NS	0.7674
Size*Depth*Orient	2	3.89597135	1.94798567	3.39NS	0.0506
Error	24	13.79627495	0.57484479		
Total	35	30.45707750			

NS= Not significant ** = Significant at ($P \leq 0.01$)

The mean of the significant variable was further analysed using the DMRT and the result is shown in Table XV.

Table XV: Mean Separations for the Orientation of Bulb on Percentage Physiological Weight Loss in Onion Bulbs for Week 1 - 4

Orientation of Bulb (O)	Means
O_2	1.76b
O_1	2.80a
SE±	0.179

From Table XV, there is significant difference in the bulb orientation with bulb facing downwards O_2 found to have a mean of 1.76% of physiological weight loss in onion bulbs compared to bulb facing upwards O_1 which has a mean of 2.80% of physiological weight loss.

The result of the analysis of variance (ANOVA) for the percentage physiological weight loss in onion bulb for week 5 – 8 of storage is presented in Table XVI. The effect of bulb orientation was found to be highly significant and all other factors showed no significant effect.

Table XVI: ANOVA for Percentage Physiological Weight Loss in Onion Bulb for Week 5 – 8 of Storage

Source	DF	SS	MS	F-value	Pr > F
Size, S	2	2.90932224	1.45466112	2.60NS	0.0954
Depth, L	1	1.42640439	1.42640439	2.55NS	0.1237
Orient., O	1	17.59845584	17.59845584	31.40**	<.0001
Size*Depth	2	1.35592342	0.67796171	1.21NS	0.3158
Size*Orientation	2	0.02003822	0.01001911	0.02NS	0.9823
Depth*Orientation	1	0.09866199	0.09866199	0.18NS	0.6785
Size*Depth*Orient	2	0.32367809	0.16183905	0.29NS	0.7517
Error	24	13.44934715	0.56038946		
Total	35	37.18183134			

NS= Not significant ** = Significant at ($P \leq 0.01$)

The means of the significant variable was further analysed using the DMRT and the result is shown in Table XVII.

Table XVII: Mean Separations for the Effect of Bulb Orientation in the Percentage Physiological Weight Loss for Week 5 - 8

Orientation of Bulb (O)	Means
O_2	1.21b
O_1	2.61a

SE+	0.176

From Table XVII, there is significant difference in the bulb orientation with bulb facing downwards O_2 found to have a mean of 1.21% of physiological weight loss in onion bulbs compared to bulb facing upwards O_1 which has a mean of 2.61% of physiological weight loss.

The result of the analysis of variance (ANOVA) for the percentage physiological weight loss in onion bulbs for week 9 – 12 of storage is presented in Table XVIII. The effect of bulb orientation was found to be highly significant.

Table XVIII: ANOVA for Percentage Physiological Weight Loss in Onion Bulb for Week 9 – 12 of storage

Source	DF	SS	MS	F-value	Pr > F
Size, S	2	0.10570672	0.05285336	0.43NS	0.6584
Depth, L	1	0.05975213	0.05975213	0.48NS	0.4947
Orient., O	1	7.29800012	7.29800012	58.74**	<.0001
Size*Depth	2	0.23481120	0.11740560	0.94NS	0.4027
Size*Orientation	2	0.02141390	0.01070695	0.09NS	0.9177
Depth*Orientation	1	0.04585391	0.04585391	0.37NS	0.5492
Size*Depth*Orient	2	0.33545391	0.16772695	1.35NS	0.2782
Error	24	2.98199364	0.12424974		
Total	35	11.08298554			

NS= Not significant ** = Significant at ($P \leq 0.01$)

The means of the significant variable was further analysed using the DMRT and the result is shown in Table XIX.

Table XIX: Mean Separations for the Effect of Bulb Orientation on Percentage Physiological Weight Loss of Onion Bulbs for Week 9 - 12

Orientation of Bulb (O)	Means
O_2	0.82b
O_1	1.72a
SE+	0.083

From Table XIX, there is significant difference in the bulb orientation with bulb facing downwards O_2 found to have a mean of 0.82% of physiological weight loss in onion bulbs compared to bulb facing upwards O_1 which has a mean of 1.72% of physiological weight loss.

CONCLUSION AND RECOMMENDATIONS

The effects of bulb size, orientation and depth of storage were used as factors to check sprouting, rotting and physiological weight loss on stored onions for 3 months storage period.

i. The total weight loss of onions stored in the structure was 19.6%.

ii. Bulb orientation has a major effect on sprouting and physiological weight loss of the onions all through the sampling period. Onion bulbs placed facing downward are more suitable for storage in the storage structure.

iii. Medium onion bulb sizes (5 - 7cm major diameter) are more suited and would do better in storage.

iv. Sprouting was minimal at a storage depth of 100mm in the storage structure.

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