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Plant Growth, Bulb Yield and Quality of Two Onion (*Allium cepa* L.) Cultivars as Affected by Storage Conditions of Three Set Sizes.

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Abstract: The objective of this research was to investigate the effect of storage conditions of different onion set sizes on plant growth, yield and quality of the bulb crop. Treatments comprised two cultivars (Kamlin and Saggai), two storage conditions (refrigeration at 2-4 °c and room temperature around 32°c) and three set sizes (large-bulb diameter 2.2-2.7 cm, medium 1.6-2.1cm and small 1-1.5 cm). Experimental design was split-split plot design with three replications. Cultivars were in the main plots, set sizes in the sub-plots and storage conditions in the sub-sub plots. Sets were stored in the cold storage for 8 weeks; the other set lot was kept at room temperature in the shade for the same period. Results indicated that refrigerated storage of sets resulted in significantly higher plant fresh and dry weights than room storage. Large set size gave significantly more vegetative growth than medium and small set size. Response of cultivars was not consistent in both seasons for vegetative growth. Set size and set storage temperature did not significantly affect average bulb weight, total and marketable yields, bulb shape index and dry matter. Yet, refrigerated storage of sets resulted in an increase in average bulb weight ranging from 5 % to 13 % and in total yield from 9 % to 18 %. Large sets resulted in increase in total yield ranged from 21 % to 23 %. The proportion of marketable yield to the total yield ranged from 67 % to 90 % in Kamlin and from 51 % to 84 % in Saggai cultivar. Regarding bulb quality, cultivars were not significantly consistent in their effect on bulb diameter and shape index in both seasons. Bulb dry matter was significantly higher in Kamlin than Saggai. Pre-mature bolting was negligible, if not at all, in the first season. Refrigerated storage of planted sets did not significantly affect bulb attributes in the first season. In the second season, however, it significantly affected bulb diameter, splitting and bolting such that it was more promotive than room temperature storage. Set size significantly affected bulb splitting and bolting such that large sets gave the highest percentage (undesirable) and the small size sets gave the lowest (desirable). It is concluded that refrigerated storage of onion sets significantly enhanced early vegetative growth, increased total and marketable yields, but also increased bulb splitting and bolting.

Key words: onion set, bulb splitting, bulb doubling, pre-mature bolting, *Allium cepa* L., onion.

INTRODUCTION

Onion bulb crop production can be done using three planting materials i.e. transplants, direct seeds and onion sets. Use of the former two has been the norm I the tropics, including Sudan, while the latter has been rarely used. Yet, production of onion using sets is of substantial commercial importance in many onion growing areas in the world. One of the problems experienced with set use, however, has been bulb splitting and pre-mature (annual) bolting, where plants produce seed stalk (flowering) before bulbs reach marketable size thereby negatively affecting bulb quality. Such bolting has been attributed to many factors such as large sets, storage conditions of sets prior to planting and to the prevailing weather condition during vegetative growth stage of plants. Thompson and Smith (1983) studied the effect of storage temperature of sets on pre-mature bolting and found that the highest percentage and the earliest development of seed-stalk was obtained from sets that had been stored at 40°F followed by those kept at 60°F and 32°F.The least amount of bolting was obtained from sets stored at 60-70°F. Moreover bolting has been reported to be eliminated by storing the sets at 30ºc for a period of 8 weeks(Lackman and Michelson 1960) or significantly decreased (Lackman and Uphan 1954) compared by to storage at 0°c. Not only that but bolting was delayed more in plants produced from sets given warm than cold storage. Size of sets were also reported to determine bulb quality attributes such that large sets were more effective in inducing bolting and splitting (El-Murabaa *et al.* 1974; Robinowitch 1979; Shalaby *et al.* 1991)

More recently, using sets as planting material to produce bulb crop has become increasingly popular because of its convenience to handle in the field and to its flexibility and adaptability to the changing environments in the main growing areas in northern and central Sudan. Such sets, however, must be produced in the preceding season, which necessitates their storage for at least about 2-3 months before use. The objective of this research was to investigate the effect of storage conditions of different set sizes on growth, yield and quality of the bulb crop using sets.

MATERIALS AND METHODS

This research was carried out at the Research Farm of the Faculty of Agriculture at Shambat, University of Khartoum for two consecutive seasons 2010/11 and 2011/12. Shambat lies at 15° 40´N and 32° 32´E; its climate is semi-arid tropical with mean maximum and minimum temperature as high as 41.6° c in summer and as low as 14.1°c in winter (Adam 1996). One lot of three set sizes (large, medium and small) of two cultivars (Kamlin and Saggai) was stored at a commercial cold store (set at 2-4°c) for 8 weeks. The second lot of the same set sizes and cultivars was stored at ambient room temperature, around 30°c- representing farmers' traditional storage. Set sizes were large with bulb diameter 2.2-2.7cm, medium 1.6-2.1 cm and small 1-1.5 cm. Treatments were arranged in a split-split plot design with three replications, where cultivars were in the main plots, set sizes in the sub plots and storage in the sub-sub plots. The experiment was planted in July 15 in the first season and in August 15 in the second season because of the prevailing extremely high temperature in July. Sets were planted on both sides of the ridge at 10 cm spacing. Experimental plots comprised 4 ridges, 3 meter long and 0.7 m wide. Plots were irrigated immediately after planting and thereafter at regular interval of about one week. Other necessary cultural practices were carried out as needed. Two months after planting, data on plant height (cm), number of leaves per plant, plant fresh and dry weights (g) were recorded from 10 randomly selected plants from each experimental plot. Harvesting was done when 50 % of the plants in the plot have shown neck breaking (bending to the ground). After curing for 10 days plants were topped and data were calculated for total and marketable yields (t/ha.), average bulb weight(g), percentage bulb splitting and bolting, bulb diameter (cm), bulb shape index (ratio of bulb length to diameter) and bulb dry matter content (%).

Collected data were statistically analyzed using SAS soft ware version 9.00 (SAS 2000).

RESULTS AND DISCUSSION

Vegetative growth:

Cultivars were not consistent in their effect on vegetative growth in both seasons; but large set size resulted in significantly more vegetative growth than medium and small set size (Table 1). Similar results for set size were reported by Nourai (1993) and Ali (1998). Refrigerated storage of sets resulted in significantly higher plant fresh and dry weight in both seasons. This could be attributed to the fact that cold storage conserved carbohydrates and other nutrient reserves in the sets till planting, which helped enhance vegetative growth vigour more than those kept in traditional storage that increased depletion of reserves in sets due to high respiration resulting from ambient warm temperature. Contrarily, however, Mohamed (1979) reported that storage temperature of sets had no significant effect on plant fresh and dry weights. This discrepancy might be due to the different range of storage temperatures and different cultivars used.

Table 1. Effect of storage conditions of three set sizes on plant height(cm), number of leaves per plant, plant fresh and dry weights (g) of cultivars Kamlin and Saggai two months after planting for seasons 2010/11 and 2011/12.

Treatment	Plant height	Leaves/plant	Fresh weight	Dry weight
Cltivars		First season 2010/2011		
Kamlin	41.7	6.3	37.0	3.0
Saggai	38.9	5.8	33.0	3.6
SE±	0.56	0.28	0.98	1.80
Set sizes				
Large	42.9[a]	6.4	38.6[a]	4.0
Medium	39.5[b]	5.8	32.5a	3.6
Small	38.4[b]	5.9	24.1[b]	3.5
SE±	0.75	0.15	1.30	1.40
Storage condations				
Refrigerated	39.8	6.1	38.3[a]	4.1[a]
Traditional	40.7	5.9	31.8[b]	3.a[b]
SE±	0.82	0.18	3.20	2.80
Cultivars		Second season 2011/2012		
Kamlin	39.8	8.2	50.0[b]	5.2[b]
Saggai	41.1	5.8	62.7[a]	7.1[a]
SE±	0.83	0.24	1.20	0.09
Set sizes				
Large	42.1[a]	7.9	71.6[a]	6.9
Medium	40.5a	8.5	55.5b	6.6
Small	38.8b	8.6	42.0c	4.9
SE±	0.50	0.23	0.94	0.23
Storage condations				
Refrigerated	40.7	8.3	61.6[a]	7.0[a]
Traditional	40.3	8.4	51.2[b]	5.4[b]
SE±	0.72	0.17	0.74	0.16

Means within columns followed by the same letter(s) are not significantly different at $P \leq 0.05$ according to Duncan's Multiple Range Test.

Yield and yield components:

Set size and storage conditions did not significantly affect average bulb weight, total and marketable yields (Tables 2); yet refrigerated storage of sets resulted in increase in average bulb weight ranging from 5 % to 13 % and in total yield ranging from 9 % to 18 % in both seasons. Refrigerated large set storage resulted in increase in total yield ranged from 21 % to 23 % in both seasons over medium and small sets. The proportion of marketable to total yield ranged from 67 % to 90 % in Kamlin and from 51 % to 84 % in Saggai cultivars in both seasons. It also ranged from 54 % to 86 % in refrigerated storage and from 63 % to 87 % in traditional storage in both seasons (Table 2). The insignificant effect of storage temperature of sets on average bulb weight and total yield was reported in earlier research by Mohamed (1979); furthermore, Aura(1963) and Lackman and Uphan (1954) indicated that ambient temperature storage of sets increased yield over 0°c storage of sets. This can be understandable since these two researches were carried out in high temperate zone where ambient temperature may well be lower than $0\ ^{\circ}$c. Such discrepancies in reported research could be attributed to differences in storage temperature ranges used, environmetal conditions and cultivars used.

Bulb quality attributes:

Table 3 shows bulb quality attributes as affected by treatments. Cultivars were not significantly consistent in their effect on bulb diameter and shape index. Bulb dry matter was significantly higher in Kamlin than in Saggai. Yet, bulb splitting was significantly higher in Saggai than Kamlin in both seasons. Bolting was negligible in the first season in all treatments. Refrigerated storage did not significantly affect bulb quality attributes in the first season. In the second season, however, it significantly increased bulb diameter, splitting and bolting such that it was more effective than traditional storage *i. e.* more adversely affected bulb quality. Set size significantly affected bulb splitting and bolting in both seasons such that large set size gave the highest value (undesirable) and small size gave the lowest (desirable). Of all bulb quality attributes, splitting and bolting are the most important from consumption and marketable point of view. Reduction of bolting at traditional storage (high temperature) reported above was also reported by Lackman and Michelson (1960) and by Smith (1961) who found that bolting incidence was completely eliminated by storing onion sets at warm temperature of 30°c for a period of 8 – 17 weeks. Bulb splitting which is shown above to be increasing with increasing set size (Table 3) was also reported by Shalaby *et al*. (1991); Pandey *et al*. (1992) and by Nourai (1993). While cold storage of sets significantly affected bulb splitting in this study, Lackman and Michelson (1960) reported that storage temperature of set did not significantly affect splitting. Increasing of splitting reported in this research could be because it enhanced vegetative growth (Table 1). After all, splitting is a function of early vigorous vegetative growth.

Table2. Effect of storage conditions of three set sizes on average bulb weight (g), total and marketable yields (t/ha.) of Kamlin and Saggai cultivars in 2010/11 and 2011/12.

Treatments	Average bulb weight	Total yield	Marketable yield
Cltivars		First season 2010/2011	
Kamlin	24.0 (+3)	6.1 (+20)	5.5 (90 %)
Saggai	23.4	1.5	4.3 (84 %)
SE±	0.60	0.29	0.22
Set sizes			
Large	25.5	6.3 (+21)	4.8 (76 %)
Medium	24.6	5.4	4.8 (89 %0
Small	21.1	5.2	5.1 (98 %)
SE±	1.00	0.41	0.42
Storage condations			
Refrigerated	24.3 (5)	5.9 (+9)	5.1 (86%)
Traditional	23.2	5.4	4.7 (87%)
SE±	1.60	0.31	0.19
Cultivars		Second season 2011/2012	
Kamlin	18.6	12.1	8.1 (67 %)
Saggai	17.3	13.3 (+10)	6.8 (51 %0
SE±	0.28	0.15	0.25
Set sizes			
Large	65.1	14.7 (+23)	8.1 955 %)
Medium	64.3	11.9	7.3 (61 %)
Small	64.8	12.0	6.9 (58 %)
SE±	3.80	0.33	0.51
Storage condations			
Refrigerated	68.6 (+13)	13.8 (+18)	7.5 (54 %)
Traditional	60.9	11.7	7.4 (63 %)
SE±	3.10	0.26	0.23

Means within columns followed by the same letter(s) are not significantly different at $P \leq 0.05$ according to Duncan's Multiply Range Test.
Values in parentheses are percent increase of the parameter in the treatment (+) or proportion of marketable to total yield (%).

Table 3. Effect of storage conditions of three set sizes on bulb dry matter (%), diameter (cm), shape index, splitting and bolting percentage of cultivars Kamlin and Saggai in 2010/11 and 2011/12.

Treatments	Dry matter	Diameter	Shape index	Splitting	Bolting
Cltivars			First season 2010/2011		
Kamlin	19.5[a]	3.1	1.16[b]	9.9[b]	0.00
Saggai	17.2[b]	3.2	1.22	14.2[a]	0.00
SE±	0.23	0.07	0.05	0.70	
Set sizes					
Large	17.9	3.2	1.16	24.4[a]	0.00
Medium	18.5	3.2	1.16	9.5b	0.00
Small	18.7	3.2	1.20	1.3c	0.00
SE±	0.24	0.06	0.03	1.50	0.00
Storage condations					
Refrigerated	18.4	3.1	1.16	12.9 (+)	0.00
Traditional	18.4	3.2	1.20	11.2	0.00
SE±	0.33	0.09	0.20	2.20	0.00
Cultivars			Second season 2011/2012		
Kamlin	18.6	4.4	1.1	14.3[b]	15.1[b]
Saggai	17.3	4.6	1.2	30.9[a]	17.8[a]
SE±	0.28	0.03	0.02	0.18	0.45
Set sizes					
Large	17.5	4.4[b]	1.1	25.4[a]	20.2[a]
Medium	18.3	4.4[b]	1.2	23.6[b]	16.6[b]
Small	18.3	4.7[a]	1.2	18.8[c]	12.6[c]
SE±	0.26	0.07	0.02	0.29	0.16
Storage condations					
Refrigerated	18.6	4.6[a]	1.2	26.9 [a] (+46)	19.1[a] (+38)
Traditional	17.3	4.3[b]	1.15	18.4[b]	13.8[b]
SE±	0.26	0.05	0.02	0.26	0.32

Means within columns followed by the same letter(s) are not significantly different at $P \leq 0.05$ according to Duncan's Multiple Range Test.

Values in parentheses are percent increase of the specific parameter in the treatment.

CONCLUSIONS

- Refrigerated storage of onion sets significantly enhances early vegetative growth of onion plants of cultivars Kamlin and Saggai, and increases total yield by about 9-18% over traditional storage.
- Refrigerated storage also increases bulb splitting by a range of 15 – 46 % and bolting by 0 – 38 % over traditional storage.
- To minimize bulb splitting and bolting , it is advisable to use medium and small sets after refrigerated storage.

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تأثير تخزين ثلاثة أحجام من البصيلات على نمو النبات وإنتاجية ونوعية الأبصال لصنفين من البصل (*Allium cepa* L.)

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المستخلص: هدف هذا البحث كان التقصي عن أثر التخزين التقليدي والمبرد لاحجام مختلفة للبصيلات على نمو النبات وإنتاجية ونوعية محصول الابصال لصنفين من البصل. تكونت معاملات التجربة من صنفين من البصل(كاملين وسقاي) ونوعين من التخزين (مبرد على 4-2 درجة مئوية وتقليدي في درجة حرارة الغرفة حوالي، 32 درجة مئوية) وثلاثة أحجام من البصيلات (كبير بقطر 2.7-2.2 سم، متوسط 1.6-2.1 سم وصغير1- 1.5 سم) تصميم التجربة كان القطاعات المنشطرة لمستويين وبثلاثة مكررات؛ وضعت الأصناف في القطع الرئيسة وأحجام البصيلات في قطع الأنشطار الاول ونوعي التخزين في قطع الإنشطار الثاني. تم تخزين البصيلات في مخزن مبرد على درجة 4-2 درجة مئوية لمدة 8 اسابيع، كا تم تخزين الجزء الثاني في درجة حرارة الغرفة بالظل 32 درجة مئوية لنفس المدة. اظهرت النتائج ان التخزين المبرد أدى إلى زيادة معنوية (إحصائياً) في الوزن الرطب والجاف للنباتات مقارنة بالتخزين التقليدي. البصيلات الكبيرة أعطت زيادة معنوية إحصائياً أعلى في النمو الخضري من الحجمين المتوسط والصغير. إستجابة الأصناف، فيما يتعلق بالنمو الخضري، لم تكن ثابتة في الموسمين. حجم البصيلات ونوع التخزين لم يؤثرا تأثيراً معنوياً على متوسط وزن البصلة، الإنتاج الكلي والإنتاج القابل للتسوق، شكل البصله ومحتواها من المادة الجافة. ولكن التخزين المبرد للبصيلات أدى إلى زيادة في متوسط وزن البصلة يتراوح بين 5%-13 % والإنتاج الكلي من 9 %- 18%. الحجم الكبير للبصيلات أعطى زيادة في الإنتاج الكلي تراوح بين 21%- 23%. نسبة

الانتاج القابل للتسوق إلى الإنتاج الكلي تراوحت بين 67 % إلى 90 % للصنف كاملين و 51%-84 % للصنف سقاي . التخزين المبرد للبصيلات لم يؤثر معنوياً على صفاة الأبصال في الموسم الاول؛ ولكنه أثر معنوياً على قطر البصلة، نسبة التفلق والإزهار المبكر بدرجة أعلى من التخزين التقليدي في الموسم الثاني. أثر حجم البصيلة تأثيراً معنوياً على نسبة التفلق والإزهار المبكر بحيث ان أعطى الحجم الكبير اعلى نسبة (غير مرغوب فيه) وأعطى الحجم الصغير النسبة الأدنى (مرغوب فيه).
تخلص التجربة إلى أن التخزين المبرد للبصيلات أدى إلى زيادة معنوية في النمو الخضري المبكر وأدى إلى زيادة الإنتاج الكلي والقابل للتسوق ولكنه أيضاً أدى إلى زيادة نسبة التفلق والإزهار المبكر.