Effects of nitrogen rate and cultivar on vegetative growth, yield and storability of onion (*Allium cepa* L.), River Nile State, Sudan

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ABSTRACT

Onion is one of the most important vegetable crops in the Sudan. Nitrogen fertilization and cultivars are crucial factors for onion production and storability in the River Nile State. Therefore, the objective of this study was to determine the effects of nitrogen rate and cultivar on vegetative growth, yield and storability of onion (*Allium cepa* L.) in the River Nile State, Sudan. Experiments were carried out at Shendi Research Station farm during two consecutive seasons of 2014/15 and 2015/16. Treatments consisted of three nitrogen rates, 0, 43 and 86 kg N ha^{-1} applied in the form of urea and two cultivars, Baftaim and Abufrewa. Treatments were arranged in a randomized complete block design with three replicates. Results showed that application of nitrogen at 86 kg N/ha significantly resulted in the most vigorous vegetative growth and the highest total yield for both cultivars in both seasons. However, the highest values of doubles and bolters were recorded for the highest nitrogen rate and the lowest values were recorded for the unfertilized control for both cultivars in both seasons. The cultivar Baftaim had more vigorous vegetative growth, larger bulb size and higher total yield than the local cultivar Abufrewa in both seasons. However, Abufrewa cultivar had higher dry matter content and better storability than Baftaim. The highest values of weight loss were recorded for Baftaim cultivar with the highest nitrogen rate (86 kg N/ha) and the lowest values were recorded for unfertilized Abufrewa in both seasons. Application of nitrogen at the higher rate generally resulted in higher postharvest losses than the unfertilized control in both cultivars and seasons. It is recommended to apply 86 kg N/ha to both cultivars, grow Baftaim cultivar for immediate marketing and Abufrewa for long term storage.

INTRODUCTION

Nutrients play a significant role in improving productivity and quality of vegetable crops. Therefore, increasing the productivity of good quality onion is an important target for production. Nitrogen is the primary macronutrient taken up in large quantities by plants from the soil relative to other nutrients (Nourai, 1992). It comprises 1.5 % to 2.5 % of total dry matter of plants and is a constituent of many fundamental biomolecules The beneficial effect of nitrogen application on onion yield was well documented (Abdel-Mawgoud *et al*., 2005).

It has been found that the highest values for plant height and bulb diameter were obtained at N rates of 180 and 240 kg N/ha, respectively (Nourai, 1992). Increasing nitrogen application rates significantly enhanced plant height, number of leaves / plant, fresh weight of plants, bulb weight, marketable and total yields. However, N application increased percentage of doubles and bolters and decreased total soluble solids (Nasrdeen *et al*., 2007). Abdissa *et al*. (2011) concluded that number of leaves increased by 8% in response to the application of 92 kg N/ha, whereas, leaf diameter and bulb length were not influenced by N fertilization rates. Regardless of the rate of application, N fertilization increased bulb diameter and average weight of bulbs by 12%-21.5%, respectively, over the control. Increasing N application rates generally increased vegetative growth parameters of onion and significantly increased yield (Nasrdeen *et al*., 2007).

Excessive Nitrogen has been reported to have adverse effects on storability of onion. The crop grown with high doses of nitrogen tended to mature late in the season and rot and sprout earlier during storage (Kumar *et al*., 2007). Early applications of moderate amounts of N can hasten crop maturity while low N levels can advance maturity (Brewster, 2008). He also found that late season applications of N or high residual N concentrations in the soil encouraged vegetative growth and delayed or prevented bulbing.

The onion cultivar Baftaim has been recently introduced in the Sudan. It is a high yielder with low dry matter content and poor storability. Generally, cultivars with high total soluble solids (TSS) and dry matter content and high pungency have longer shelf lives compared to mild cultivars with low TSS (Elkashif *et al*. 2006). Ahmed *et al*. (2015) reported highly significant differences among onion cultivars in weight loss. The least weight loss was recorded for Fadasi, while the highest weight loss was recorded for Baftaim. These results were explained by the fact that Fadasi had higher dry matter and total soluble solids contents compared to Baftaim. Despite the achievements in post-harvest technology, losses during storage still pose a great problem (Kukanoor, 2005). Therefore, the objective of this study was to determine the effects of nitrogen rate and cultivar on vegetative growth, yield and storability of onion (*Allium cepa* L.) in the River Nile State, Sudan.

MATERIALS AND METHODS

Study site

This experiment was carried out at Shendi Agricultural Research Station Farm during two consecutive seasons (2014/15 and 2015/16). Shendi is located at 16º 42′N and 33º 62′E and altitude of 366 masl. It lies close to the eastern bank of the river Nile, River Nile State, Sudan. The soil is classified as Entisol. The parent material of the soil is river Nile alluvium deposits. It is very deep (more than 2 meters), well drained, leveled and uniform. It has dark grayish brown color on the top (0 – 40 cm) to dark yellowish brown in the sub-soil while the structure is clay loam.

Treatments

Treatments consisted of three nitrogen rates; 0, 43 and 86 kg N ha^{-1} applied in the form of urea and two cultivars, Baftaim and Abufrewa. Baftiam was obtained from Shendi Agricultural Research

Station and Abufrewa was bought from farmers in Shendi area. Baftiam was chosen because it is a popular cultivar which has been recently introduced in the area. Abufrewa is the local cultivar which has been cultivated for a long time and has a good storability.

The land was disc plowed, harrowed and made into plots of 3×4 m. Seeds of the two cultivars were sown in the nursery and seedlings were transplanted on flat plots. Inter- and intra- row spacing was 15 and 10 cm, respectively. Cultural practices of irrigation, pest and weed control were carried out as recommended by the Agricultural Research Corporation (ARC), Sudan. Treatments were arranged in a randomized complete block design with three replicates.

Data collected

Plant height

Plant height (cm) was measured from the ground level to the tip of the longest leaf of five plants randomly selected from the middle rows in each plot, using a meter ruler, starting at one month after sowing and at monthly intervals until maturity.

Bulb diameter

Bulb diameter (cm) was measured using a vernier caliper.

Bulb dry matter content

A random sample of sliced fresh onion (five onion bulbs) from each treatment was weighed and then placed in an oven at 80°C for 48 hours. The sample was weighed several times till a constant weight was obtained. Dry matter content of bulbs (%) was calculated using following equation (Elkashif *et al*. 2006).

$$\text{Dry matter (\%)} = \frac{\text{Dry weight}}{\text{Fresh weight}} \times 100$$

Bulb yield

One square meter from the middle rows of each treatment was harvested and total yield (ton/ha) was determined.

Bulb sorting

The percentages of doubles and bolted bulbs were determined for each treatment.

Storability of onion bulbs

Samples of 5 kg of bulbs were taken randomly from each treatment after harvest , packed in jute bags and stored in a well-ventilated store. Bulbs were weighed monthly for a period of 4 months. Cumulative weight loss of onion bulbs was calculated using the following formula:

$$\text{Weight loss (\%)} = \frac{\text{Initial weight – weight at designated time}}{\text{Initial weight}} \times 100$$

Statistical analysis

Data were statistically analysed using the standard analysis of variance procedure. Treatment means were separated using Duncan's Multiple Range Test at 5% level of significance.

RESULTS AND DISCUSSION

Growth parameters

Table 1 shows significant effects of nitrogen rate on growth parameters of onion in both seasons. The highest values of plant height and bulb diameter were recorded for the high rate of nitrogen and the lowest values were recorded for the unfertilized control. However, the dry matter content was highest in the unfertilized control and lowest in the highest nitrogen rate in both seasons. This was probably due to the fact that nitrogen application at the higher rate increased bulb size and water content which adversely affected dry matter percentage. Abdissa *et al*. (2011) indicated that the high supply of nitrogen by organic and inorganic fertilizers promoted vegetative growth. Nourai (1992) reported that increasing N application rates significantly increased vegetative growth parameters of onion and increased yield but resulted in lower dry matter content.

Table 1. Main effects of nitrogen rate on growth parameters of onion during both seasons.

Season	Nitrogen rate (kg N/ha)	Plant height (cm)	Bulb diameter (cm)	Bulb dry matter (%)	2015/16
			Season 2014/15		
	0	35.5 c	5.6 b	22.6 a	
	43	41.0 b	7.3 a	20.3 b	
	86	45.3 a	7.5 a	19.7 c	
	Sig. level	**	*	**	
	0C.V (%)	32.2 c 15.9	5.2 b 14.4	23.1 a 13.7	
			Season 2015/16		
	43	38.5b	7.4a	21.3b	
	86	42.9 a	7.5 a	19.4c	
	Sig. level	*	*	**	
	C.V.%	9.4	13.9	14.5	

Means in each column followed by the same letter(s) are not significantly different according toDuncan's Multiple Range Test.

* and** indicate significance at 5% and 1% levels, respectively.

Table 2 shows significant effects of cultivars on growth parameters of onion in both seasons. The maximum values of plant height and bulb diameter were recorded for Baftaim and the minimum values were recorded for Abufrewa in both seasons. However, the dry matter percentage was highest in Abufrewa and the lowest in Baftaim. These results indicated that the introduced cultivar, Baftaim, had more vigorous vegetative growth which resulted in larger bulbs compared to the local cultivar Abufrewa. Mofadal *et al.* (2000) reported that the local genotypes had the highest values of dry matter content compared with introduced ones. Mohammed (2008) found that the introduced genotypes had vigorous vegetative growth, large bulb size and high yields but low dry matter content compared with local genotypes. Interaction effects of nitrogen rate and cultivar on growth parameters of onion were not significant.

Table 2. Main effects of cultivars on growth parameters of onion during both seasons.

Cultivar	Plant height (cm)	Bulb diameter (cm)	Bulb dry matter (%)
	Season 2014/15		
Baftaim	45.5	7.5	**15.3**
Abufrewa	38.8	6.2	**22.8**
Sig. level	**	*	**
C.V (%)	15.9	12.6	**11.7**
	Season 2015/16		
Baftaim	46.6	7.4	**15.4**
Abufrewa	40.4	6.3	**23.3**
Sig. level	*	*	**
C.V (%)	9.4	13.9	**14.8**

* and ** indicate significance at 5% and 1% levels, respectively.

Table 3 shows significant effects of nitrogen rate on bulb quality and total yield of onion in both seasons. The highest values of doubles, bolters and total yield were recorded for the highest nitrogen rate and the lowest values were recorded for the unfertilized control, in both seasons. This was most probably due to the fact that N encouraged vegetative growth which resulted in large bulbs and high yields. However, large-sized bulbs were always associated with premature bolting and splitting. These findings were in accordance with those reported by Nourai (1992) who found that the application of nitrogen at the rate of 86 kg N/ha significantly increased total onion yield but also increased the percentages of doubles and bolters.

Table 3. Main effects of nitrogen rate on bulb quality and total yield of onion during both seasons

2015/16 Nitrogen rate (kg N/ha)	Bolters (%)	Doubles (%)	Total yield (t/ha)	Season
	Season 2014/15			
0	48.0c	23.5c	33.2c	
43	53.0b	26.4b	41.5b	
86	64.0 a	33.0a	46.1a	
Sig. level	*	**	**	
C.V (%)	15.4	12 .2	19.0	
0	42c	Season 2014/15 21.5c		30.0c
43	50b	29.0b		39.3b
86	61a	35.0a		44.7a
Sig.	*	*		**
C.V.%	16.3	19.2		20.8

Means in each column followed by the same letter(s) are not significantly different according to Duncan's Multiple Range Test.

* and** indicate significance at 5% and 1% levels, respectively.

Table 4 shows significant effects of cultivars on bulb quality and total yield in both seasons. Baftaim cultivar had the lowest values of doubles and bolters but had the highest total yield, whereas Abufrewa cultivar recorded the highest values of doubles and bolters and the lowest total yield in both seasons. These results indicated that the introduced cultivar Baftaim was superior to the local cultivar Abufrewa in total yield but not in bulb quality. These results were in agreement with those of Mofadal *et al.* (2000) who reported that the introduced cultivars such as Baftaim showed higher values of bulb weight compared to the local cultivar such as Abufrewa. Ansari (2007) reported that the doubles phenomenon was related to genetic factors and affected by specific cultural practices such as sowing date and plant density. Interaction effects of nitrogen rate and cultivar on bulb quality and total yield of onion were not significant.

Table 4. Main effects of cultivars on bulb quality and total yield of onion during both seasons.

Cultivars	Bolters (%)	Doubles (%)	Total yield (t/ha)
		Season 2014/15	
Baftiam	28.6b	20.0b	45.0 a
Abufrewa	45.0a	29.5a	28.4 b
Sig. level	*	*	**
C.V (%)	15.4	12.2	21.0
		Season 2015/16	
Baftaim	35b	19b	42a
Abufrewa	46a	32a	23b
Sig. level	*	**	**
C.V (%)	18.3	15.7	21.6

* and** indicate significance at 5% and 1% levels, respectively.

Table 5 shows significant effects of nitrogen rate on weight loss of onion during storage in both seasons. Generally, weight loss increased with increasing nitrogen rate. The highest values of weight loss were recorded for the highest nitrogen rate (86 kg N/ha) and the lowest values were recorded for the unfertilized control in both seasons. This was most probably due to the fact that the high nitrogen rate resulted in large bulbs with low dry matter and high water content which made them more vulnerable to increased water loss. These results are in agreement with those reported by Ahmed *et al.* (2015) who stated that cultivars of low dry matter content and less pungency were grown for the fresh market for consumption and generally did not store very well. Similar results were reported by Kukanoor (2005) who found that high levels of nitrogenous fertilizer resulted in reduced onion storage life.

Table 5. Main effects of nitrogen rate on weight loss (%) of onion during storage in both seasons.

Nitrogen rate (kg N/ha)	Months			
	1	2	3	4
	Season 2014/15			
0	12.0c	18.0c	24.4c	31.1c
43	15.7b	21.4b	28.5b	35.5b
86	21.4a	27.3a	33.7a	39.9a
Sig. level	***	***	***	***
C.V (%)	13.9	11.8	10.2	7.2
	Season 2015/16			
0	14.2c	21.1c	27.2b	33.7c
43	17.3b	23.2b	29.7b	36.9a
86	22.8a	28.4a	34.2a	38.7a
Sig. level	***	**	**	**
C.V (%)	11.8	11.6	8.1	6.7

Means in each column followed by the same letter(s) are not significantly different according to Duncan's Multiple Range Test.
** and *** indicate significance at 1% and 0.1% levels, respectively.

Table 6 shows significant effects of cultivars on weight loss of onions during storage in both seasons. Abufrewa recorded the least percentage of weight loss compared to Baftaim which recorded the highest percentage of weight loss in both seasons. This was most probably due to the fact that the local cultivar Abufrewa had higher dry matter content and higher pungency which resulted in lower weight loss compared to Baftaim cultivar. These results were in line with the reports of Ahmed *et al.* (2015) who found that the characteristics which enhanced superior storage quality of onion were high total soluble solids, high dry matter content and pungency. They also reported that the introduced genotypes had poor keeping quality while the local genotypes had good storability. Interaction effects of nitrogen rate and cultivar on weight loss of onion during storage were not significant.

In conclusion, it is recommended to apply 86 kg N/ha to both cultivars, grow Baftaim cultivar for immediate marketing and Abufrewa for long term storage.

Table 6. Main effects of cultivar on weight loss (%) of onion during storage (seasons 2014/15 and 2015/16).

Cultivar	Months			
	1	2	3	4
	Season 2014/15			
Baftaim	17.3	22.5	29.9	46.1
Abufrewa	10.6	16.3	17.8	27.7
Sig. level	*	*	*	*
C.V (%)	13.9	11.8	10.2	7.2
	Season 2015/16			
Baftaim	25.3	38.0	50.6	57.5
Abufrewa	11.6	14.7	18.9	27.3
Sig. level	*	*	*	*
C.V (%)	11.8	11.6	8.9	6.8

* indicate significance at 5% level.

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النمو الخضرى و الإنتاجية والقدرة التخزينية لمحصول تأثير معدل النتروجين والصنف علي بولاية نهر النيل، السودان(*Allium cepa* L)البصل

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الخلاصة

يعتبر البصل من اهم محاصيل الخضر في السودان . المعاملات الفلاحية مثل التسميد بالنيتروجين والاصناف تعتبر من العوامل الهامة جداً في انتاج وتخزين البصل في ولاية نهر النيل. هدفت الدراسة إلى معرفة تأثير التسميد بالنيتروجين والصنف علي النمو الخضري والإنتاجية والقدرة التخزينية للبصل. أجريت هذه التجربة بالمزرعة التجريبية بمحطة بحوث شندي ، ولاية نهر النيل في الموسمين 15/2014 و16/2015. اشتملت المعاملات علي ثلاثة معدلات من النتروجين وهى صفر و43 و86 كجم نتروجين للهكتار اضيفت في شكل يوريا مع صنفين من البصل وهى بافطيم و ابوفريوة. استخدم تصميم القطاعات العشوائية الكاملة بثلاث مكررات. أظهرت النتائج أن اضافة النتروجين بمعدل 86 كجم للهكتار اعطى معنويا افضل نمو خضري وأعلى إنتاجية لكلا الصنفين من البصل وفى كلا الموسمين. ولكن اعلى معدلات الخلف والازهار المبكر كانت بإضافة أعلى معدل للنتروجين وادناها كانت للشاهد غير المسمد في كلا الموسمين. الصنف بافطيم اعطى افضل نمو خضري واكبر الابصال حجما واعلى انتاجية بالمقارنة مع الصنف المحلى ابوفريوة في كلا الموسمين. لكن الصنف أبوفريوة أعطى أعلى نسبه من المادة الجافة وأفضل قدرة تخزينية مقارنة بالصنف بافطيم. أعلى معدلات فقدان الوزن كانت للصنف بافطيم المسمد بالمعدل الاعلى للنتروجين وادناها كانت لابوفريوة غير المسمد في كلا الموسمين. اضافة النتروجين بالمعدل الأعلى اعطى أعلى فاقد ما بعد الحصاد بالمقارنة مع البصل غير المسمد في كلا الموسمين. يوصي بإضافة 86 كجم نتروجين للهكتار لكلى الصنفين وزراعة الصنف بافطيم للتسويق العاجل وزراعة ابوفريوة للتخزين طويل الأجل.