*U. of K. J. Agric. Sci.* 26, 68-83, 2018

# Growth, Yield and Bulb Quality as Affected by Nitrogen Fertilization and Intra-row Spacing of Two Onion (*Allium cepa* L.) Cultivars.

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(Received 15/12/2019, Accepted 12/03/2020, Published on line March2020)

**Abstract:** In response to the rising demand and escalating prices due to several internal demographic reasons in the last few years, interest in increasing productivity and bulb quality has been a major concern. The objective of this research was, therefore, to improve yield and quality of onion through determining more relevant and contemporary nitrogen and population density that cope with the changing production environment in Sudan. So an experiment to study the effect of three nitrogen fertilization levels (0, 120 and 240 kg N/ha.) and three population densities (intra-row spacing of 5, 10 and 15 Cm) on growth, yield and quality of two widely consumed cultivars [Kamlin and Texas Early Grano(TEG)] was carried out for two seasons. Treatments were arranged in a split-split plot design with three replications; cultivars were randomized in the main plots, intra-row spacing in the sub-plots and nitrogen fertilization in the sub-sub plots. Results indicated that nitrogen application at the rate of 120 kg N/ha significantly increased vegetative growth, bulb size, total and marketable yields. Moreover, bolting percentage (a main quality defect) decreased with increasing nitrogen fertilization. Nitrogen fertilization had no significant effect on bulb shape, dry matter and TSS. Although high plant density (5cm intra-row spacing) reduced plant growth and increased bolting, it also increased total and marketable yields and reduced bulb splitting (a defect). Cultivar TEG exceeded Kamlin in plant growth aspects and consequently average bulb weight, total and marketable yields; however, bulb splitting was also high. In conclusion, planting onion at 5cm intra-row spacing and applying 120 kg N/ha., significantly increased productivity and improved bulb quality in central Sudan.

**Key words**: *Allium cepa* L., vegetable crops, bolting, N fertilization, intra-row spacing, cultural practices.

## INTRODUCTION

Onion (*A. cepa* L.) is an important vegetable crop grown in almost all parts of the world for fresh consumption and for processing. In Sudan onion ranks first among vegetable crops, area and production –wise. It is being valued for its flavour and nutritional value. Onion, in Sudan, is produced predominantly in winter season using transplants on an estimated area of 48000 ha (Hamad and Nourai 2011). The improvement of growth and yield of onion crop is associated with the physiological processes in the plant where nitrogen is always the limiting factor, than any other element, for obtaining optimum yield. Therefore the volume of research relating onion production to nitrogen fertilization is considerable, to mention a few (Hassan 1977; 1984; Jitendra and Dhankar 1989; El-Gizawy 1993; Brewster 1994; Bosch and Currah 2002 and Nourai 2005). Plant population was reported to have a significant effect on the yield and quality of onion crop. Bulb yields increased with plant density which has been correlated with the percentage of light interception by the crop leaf canopy (Brewster 1977). Moreover, number of green leaves,, bulb size, and bolting initiation were decreased as plant density increased(Smith 1961; Moursi *et al.* 1975; Hassan 1978; Hatrige and Bennet 1980).

In all of the above reported research, levels of nitrogen fertilization, type of nitrogen source as well as range of population density used varied greatly, which might make them irrelevant to a specific environment. So the objective of this research was to determine the optimum levels of nitrogen fertilization associated with the optimum population density for onion production under north central Sudan environment.

## MATERIALS AND METHODS

Field experiments were carried out in the demonstration farm of the Faculty of Agriculture, University of Khartoum at Shambat for two consecutive seasons, 2010/11 and 2011/12. Shambat lies at 15° 39' N, 32° 32' E and 381m above sea level. The climate is semi-arid, tropical with mean maximum and minimum temperatures as high as 41.6°c in summer and as low as 14°c in winter (Adam 1996).Seeds of local cultivar Kamlin were obtained from Huddeiba Research Station and canned seeds of cultivar Texas Early Grano(TEG) were bought from certified vegetable seeds merchant at Khartoum North market. Treatments were two cultivars (Kamlin and TEG), three intra-row spacing (5, 10 and15 cm) and three nitrogen levels (0,120 and 240 kg N/ha) in the form of urea. They were arranged in a split-split plot design with three replications; cultivars were in the main plots, intra-row spacing in the subplots and nitrogen fertilization in the sub-sub plots. Plot sizes were 3mx2.1m comprising 3 ridges 3m long and 0.7 m wide. Eighty kgs/ha of phosphorus in the form of triple super phosphate were applied to the plots before planting. Eight weeks old seedlings were transplanted in December 10 for the two seasons. Nitrogen fertilization was applied in two equal dozes; one applied 3 weeks after transplanting and the second two months after transplanting. All cultural practices required were carried out as recommended.

For growth assessments, a random sample of ten plants was taken from each plot three month after transplanting to record data on plant height, number of leaves per plant, plant fresh and dry weights. Percentage of premature bolting was calculated in each plot one week before harvesting. At crop maturity, plants of the middle ridge were harvested, cured for ten days and data on total and marketable yields were calculated as well as average bulb weight, percent of bulb splitting, bulb diameter bulb shape index(bulb height/bulb diameter), total soluble solids (%) and percent dry matter.

Collected data were statistically analyzed using SAS (2000) soft ware version 9.00. Means were separated according to Duncan Multiple Range Test at P< 0.05.

## RESULTS AND DISCUSSION

Vegetative growth:
Cultivars were significantly different in all of their vegetative growth components.TEG was higher than Kamlin in plant height, plant fresh eight, while Kamlin was higher in number of leaves per plant and plant dry weight (Table1).Intra-row spacing significantly affected number of leaves per plant, plant fresh and dry weights in both seasons with wider spacing giving higher values, which could be attributed to less competition. That is total uptake of mineral nutrients, water and light absorption/interception per unit area increased with the decrease of plant density/high intra-row spacing leading to high total uptake per plant which in turn resulted in high vegetative growth. This finding was also reported by Moursi et al.(1975) and by Hatridge and Bennet (1980). Results in Table 1 also indicate that plant height was not significantly affected by intra-row spacing. Moreover, there was no significant difference between 10 and 15 cm intra-row spacing for all vegetative growth components in both seasons. Plant height, number of leaves per plant and plant fresh weight showed a significantly increasing pattern with increasing level of nitrogen fertilization in both seasons. The intermediate level of fertilization (120kg N/ha.) was the optimum rate for highest vegetative growth components in both seasons. Likewise, Pande and Mundra (1971), Jitendra and Dhankar (1989) and Sharma (1998) came to the same conclusion of the effect of nitrogen on vegetative growth of onion.

Yield and Yield components:

Average bulb weight, total and marketable yields were significantly different between the two cultivars in both seasons with TEG giving higher values than Kamlin. Marketable yield of Kamlin ranged between 84 and 93 % of the total yield in both seasons, while that of TEG ranged between 74 and 99% (Table 2).

Intra-row spacing significantly affected average bulb weight, total and marketable yields, but in different ways. While average bulb weight increased with increasing intra-row spacing i.e. decreasing plant population, total and marketable yields decreased with increasing intra-row spacing (decreasing plant population) in both seasons (Table 2). Specifically, average bulb weight at 15cm spacing (low population) increased by 60 % over that of 5 cm (high population) in the first season and by 52 % in the second season. On the other hand, total yield declined by 23 % in the first season and by34 % in the second season. That is, in spite of the fact that low plant population resulted in larger bulb size, yet such increase did not compensate the decreasing effect of low population on total yield. This could be attributed to the low number of bulbs harvested with low plant population (wide intra-row spacing). In fact total and marketable yields were reported to have significantly increased by increasing plant population, while average bulb weight has increased by decreasing plant density/population (Shalaby *et al.*1991; Rizk *et al.*; Galmarini and Gaspera 1995; Abu-zied and Farghali 1996 and El Rahim *et al.* 1997).

Average bulb weight, total and marketable yields were significantly and positively affected by increasing rates of nitrogen fertilization in both seasons (Table 2). Average bulb weight increased by 27 % in the first season and by 28 % in the second season with the high rate (240 kg N/ha) compared with the control(0 fertilization). Total yield increased by 10 % over the control in the first season and 17 % in the second season. There was no, however, significant difference between fertilization with 120 kg N/ha and 240 kg N/ha on average bulb weight, total and marketable yields. The proportion of marketable to total yield ranged from 74 % to 97 % for the high fertilization rate (240 kg N/ha.) compared to 81 % to 97 % for the control. For intra-row spacing, the range of proportion of marketable to total yield was 72 %-98 % for low population (15 cm intra-row spacing) and 83 % - 97 % for high population (5 cm intra-row spacing). The above results are in line with those of Paterson et al.(1960) and with Nourai (2005). However, Viegas and Abreu (1990) reported that nitrogen application did not significantly affect yield and other bulb characters.

Bulb quality:

Cultivars were significantly different in bulb dry matter, bulb TSS, bulb diameter, and bulb shape index in both seasons (Table 3). Kamlin exceeded TEG in bulb dry matter,TSS and shape index. Nitrogen fertilization did not significantly affect bulb dry matter, TSS, diameter and shape index in both seasons. Of the bulb indices, only bulb diameter was significantly affected by intra-row spacing in both seasons.

Bulb splitting was significantly different between the two cultivars in both seasons. Kamlin produced the highest percentage in the first season and the reverse was true foe TEG in the second season (Table 3). Intra-row spacing significantly affected bulb splitting and bolting only in the second season. The highest splitting percentage of19.9 in the second season and 1.7 % in the first season was recorded with the lowest population (15 cm intra-row spacing) while the lowest of 7.7% in the second and 1.4 % in the first season resulted from the high plant population( 5 cm intra-row spacing)(Table 3). These results are in line with those of Shalaby *et al.* (1991) and El-Rahim *et al.* (1997) who concluded that doubling percentage was significantly decreased by increasing plant density. In contrast, however, bolting increased with high plant density (narrow inter-row spacing of 5 cm). It was as high as 2 % in the first season and 10.6 % in the second season compared to 1.0 % in the first season and 7.9 % in the second season for the low population (15 cm intra-row spacing). Similar results were reported by Hassan 1978); however, Abu-zeid and Farghali (1996) and El-Rahim *et al. (*1997) claimed that percentage of bolting was significantly reduced by increasing plant density. Shalaby *et al*. (1991) reported that percentage of bolting was not affected by plant density.

Nitrogen fertilization significantly bolting and splitting in both seasons, with the high rate of 240kg N/ha suppressing bolting to 1.1 % compared to 1.7 % for the control in the first season and to 6.2 % compared to 13.1 % for the control in the second season. The low bolting under the high nitrogen doze could be due to the promotion of continuous vegetative growth of plants at the expense of flowering, specially the weather condition around November was not conducive for flowering induction. Nitrogen fertilization also significantly affected bulb splitting in both seasons, with the highest percentage in the first season (1.9 %) and 19.0 % in the second being produced by the high rate of 240kg N/ha., compared to 1.4 in the first and 10.3 in the second season for the control. Since splitting in onion is essentially a type of vegetative growth, it is axiomatic that it was stimulated by the increased supply of N fertilization. A decrease in bolting with high nitrogen doze was reported by Paterson et al. (1960), Bottcher and Kolde (1975), Pandey et al. (1988) and Singh and Dhanar (1989). Increase in bulb splitting with increased nitrogen addition has also been reported by Hassan (1977), Hassan and Ayoub (1978), and Pandey et al. (1988). As increasing N application increases bulb size, it might be that larger bulbs are more susceptible to splitting.

Table 1. Effect of N fertilization and intra-row spacing on plant height(cm),number of leaves, plant fresh and dry weights (g) of onion cultivars Kamlin and TEG three month after transplanting.

| Treatments | Plant height | Number of leaves | Fresh weight/plant | Dry weight/plant |
|---|---|---|---|---|
| Cultivars | | First season2010/11 | | |
| Kamlin | 61.6$^{b}$ | 11.5$^{a}$ | 146.3$^{b}$ | 19.7$^{a}$ |
| TEG | 74.3$^{a}$ | 10.5b | 169.5$^{a}$ | 16.7$^{b}$ |
| SE± | 0.04 | 0.15 | 4.30 | 0.42 |
| Spacings | | | | |
| 5 cm | 67.5$^{a}$ | 10.1$^{b}$ | 126.4$^{b}$ | 14.9$^{b}$ |
| 10cm | 68.7$^{a}$ | 11.2$^{ab}$ | 164.4a | 18.9a |
| 15cm | 67.5$^{a}$ | 11.6$^{a}$ | 182.9$^{a}$ | 20.9$^{a}$ |
| SE± | 1.10 | 0.24 | 6.02 | 0.61 |
| N fertilization | | | | |
| 0 kg N/ha | 64.8$^{b}$ | 10.8$^{b}$ | 141.4$^{b}$ | 17.5$^{a}$ |
| 120 kg N/ha | 71.0$^{a}$ | 11.5$^{a}$ | 162.5$^{ab}$ | 18.8$^{a}$ |
| 240 kg N/ha | 67.8$^{b}$ | 10.7$^{b}$ | 169.8$^{a}$ | 18.4$^{a}$ |
| SE± | 1.7 | 0.17 | 5.90 | 0.65 |
| Cultivars | | Second season2011/12 | | |
| Kamlin | 57.3 | 11.8 | 136.7 | 17.7 |
| TEG | 65.4 | 13.2 | 159.4 | 14.8 |
| SE± | 1.34 | 0.32 | 7.50 | 0.65 |
| Spacing | | | | |
| 5 cm | 60.3$^{a}$ | 10.9$^{b}$ | 116.9$^{b}$ | 12.9$^{c}$ |
| 10 cm | 61.9$^{a}$ | 12.9$^{a}$ | 154.4$^{a}$ | 16.9$^{b}$ |
| 15 cm | 61.8$^{a}$ | 13.7$^{a}$ | 172.8$^{a}$ | 18.9$^{a}$ |
| SE± | 1.44 | 0.34 | 7.50 | 0.53 |
| N fertilization | | | | |
| 0 kg N/ha. | 56.6$^{b}$ | 11.8$^{b}$ | 131.4$^{b}$ | 15.5$^{a}$ |
| 120 kg N/ha. | 64.2$^{a}$ | 12.9$^{a}$ | 153.0$^{a}$ | 16.8$^{a}$ |
| 240 kg N/ha. | 63.3$^{a}$ | 12.8$^{a}$ | 159.7$^{a}$ | 16.4a |
| SE± | 0.98 | 0.31 | 6.8 | 0.77 |

Means within columns followed by the same letter(s) are not significantly different at P< 0.05 according to Duncan's Multiple Range Test.
SE± = standard error of the means.

Table 2. Effect of nitrogen fertilization and intra-row spacing on the average bulb weight (g), total and marketable yields (t/ha.) of onion cultivars Kamlin and TEG for two seasons.

| Treatments | Average bulb weight | Total yield | Marketable yield |
|---|---|---|---|
| Cultivars | | First season 2010/11 | |
| Kamlin | 116.2[b] | 24.2[b] | 22.4[b] (93%) |
| TEG | 224.7[a] (+93%) | 45.5[a] (+88%) | 45.2[a] (99%) |
| SE± | 1.3 | 0.58 | 0.43 |
| Spacing | | | |
| 5 cm | 135.8[b] | 38.4[a] | 36.9[a] (96%) |
| 10 cm | 158.8[b] (+17%) | 36.5[a] | 35.4[a] (97%) |
| 15 cm | 216.8[a] (+60%) | 29.7[b] | 29.1[b] (98%) |
| SE± | 3.70 | 1.39 | 1.40 |
| N fertilization | | | |
| 0 kg N/ha. | 138.5[b] | 32.5[b] | 31.4[b] |
| 120kg N/ha. | 182.4[a] (+32%) | 36.4[a] (+12%) | 35.5[a] (98%) |
| 240kg N/ha. | 175.3[a] (+27%) | 35.6[ab] (+10%) | 34.6[ab] (97%) |
| SE± | 2.80 | 0.89 | 0.95 |
| Cultivars | | Second season 2011/12 | |
| Kamlin | 89.3[b] | 19.4[b] | 16.3[b] (84%) |
| TEG | 143.4[a] | 31.8[a] (+64%) | 23.6[a] (74%) |
| SE± | - | 0.82 | 0.31 |
| Spacing | | | |
| 5 cm | 89.3[b] | 31.7[a] | 26.2[a] (83%) |
| 10 cm | 124.8[a] (+40%) | 25.1[b] | 18.6[b] (74%) |
| 15 cm | 135.6[a] (+52%) | 20.9[c] | 15.1[b] (72%) |
| SE± | 11.70 | 0.83 | 0.79 |
| N fertilization | | | |
| 0 kg N/ha. | 98.5[b] | 23.4[b] | 18.9[a] (81%) |
| 120 kg N/ha. | 124.9[a] (+27%) | 25.9[a] (+11%) | 20.7[a] (80%) |
| 240 kg N/ha. | 126.2[a] (+28%) | 27.4[a] (+17%) | 20.2[a] (74%) |
| SE± | 5.96 | 0.61 | 0.78 |

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

Values in parenthesis are percent increase (+ ) or proportion of marketable to total yield ( ).

Table Table3. Effect of nitrogen fertilization and intra-row spacing on bulb quality indices of onion cultivars Kamlin and Texas Early Grano(TEG) for two growing seasons.

| Treatments | Bulb dry matter(%) | Bulb TSS | Bulb diameter(cm) | Shape index[w] | Splitting(%) | Bolting(%) |
|---|---|---|---|---|---|---|
| Cultivars | | | First growing season 2010/11 | | | |
| Kamlin | $17.8^{a}$ | $15.3^{a}$ | $6.4^{b}$ | $1.4^{a}$ | $2.0^{a}$ | |
| TEG | $7.6^{b}$ | $6.7^{b}$ | $7.3^{a}$ | $1.0^{b}$ | $1.2^{b}$ | |
| SE± | 0.09 | 0.18 | 0.09 | 0.03 | 0.06 | |
| Spacing | | | | | | |
| 5 Cm | 12.9 | 11.5 | $6.4^{b}$ | 1.1 | 1.4 | 2.0 |
| 10 Cm | 12.9 | 11.1 | $6.8^{ab}$ | 1.2 | 1.6 | 1.3 |
| 15 Cm | 12.5 | 11.3 | $7.2^{a}$ | 1.2 | 1.7 | 1.0 |
| SE± | 0.38 | 0.26 | 0.13 | 0.03 | 0.12 | 0.27 |
| N Fertilization | | | | | | |
| 0 kg N/ha. | 13.4 | 11.5 | 6.7 | 1.2 | $1.4^{b}$ | $1.7^{a}$ |
| 120 kg N/ha. | 12.4 | 11.2 | 6.9 | 1.2 | $1.5^{b}$ | $1.5^{a}$ |
| 240kg N/ha. | 12.5 | 11.3 | 6.8 | 1.2 | $1.9^{a}$ | $1.1^{b}$ |
| SE± | 0.23 | 0.12 | 0.10 | 0.02 | 0.11 | 0.16 |

Table 3.continued

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | Second season 2011/12 | | | |
| Cultivars | | | | | | |
| Kamlin | 18.6[a] | 17.9[a] | 5.5[b] | 1.4[a] | 7.0[b] | |
| TAG | 7.0[b] | 7.6[b] | 6.1[a] | 1.0[b] | 22.2[a] | |
| SE± | 0.44 | 0.01 | 0.09 | 0.09 | 2.7 | |
| Spacing | | | | | | |
| 5 Cm | 13.0 | 11.9 | 5.4[b] | 1.2 | 10.6[a] | 7.7[b] |
| 10 Cm | 12.9 | 11.9 | 5.9[a] | 1.2 | 16.2[ab] | 8.7[b] |
| 15 Cm | 12.5 | 11.8 | 5.9[a] | 1.2 | 19.9[a] | 7.9[b] |
| SE± | 0.22 | 0.24 | 0.09 | 0.01 | 3.00 | 0.11 |
| N fertilization | | | | | | |
| 0kg N/ha. | 13.1 | 11.8 | 5.5 | 1.2 | 10.3[c] | 13.1[a] |
| 120kg N/ha. | 12.8 | 11.8 | 6.9 | 1.2 | 14.6[b] | 7.9[b] |
| 240kg N/ha. | 12.5 | 12.0 | 5.9 | 1.2 | 19.0[a] | 6.2[b] |
| SE± | 0.24 | 0.25 | 0.11 | 0.02 | 1.30 | 0.34 |

Means within columns followed by the same letter(s) are not significantly different at $P< 0.05$ according to Duncan's Multiple Range Test.
SE= standard error of the means

## CONCLUSION

- Onion plants' vegetative growth is significantly affected by nitrogen fertilization and intra-row spacing.
- Total and marketable yields increase with increasing nitrogen fertilization (120-240 kg N/ha.), yet 120kg N/ha. Is the optimum as increase in yield beyond it is not significant.
- Nitrogen fertilization and intra-row spacing significantly affect bulb quality (splitting and bolting).
- High nitrogen fertilization (240 kg N/ha.) result in high yield, low bolting but high bulb splitting.
- Bulb splitting significantly decrease with increasing plant density/narrow intra-row spacing; however, bolting increases with high plant density.
- Physical and chemical bulb characteristics are significantly affected neither by nitrogen fertilization nor by intra-row spacing.
- Planting onion at 5cm intra-row spacing and fertilizing with 120 kg N/ha. Increase yield and improve quality of onion crop under north central Sudan.

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## تأثير التسميد الآزوتى ومسافات الزراعة بين النباتات فى الخط على نمو وإنتاج ونوعية الأبصال فى صنفين من البصل.

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**المستخلص:** إستجابة لتنامى الطلب والأسعار المتصاعدة للبصل فى السودان، لأسباب داخلية، خلال السنوات العشر الماضية، تزايد الإهتمام بالإرتقاء بإنتاجية ونوعية محصول البصل؛ لذلك هدف هذا البحث لإستكشاف العمليات الفلاحية المثالية لتحقيق ذلك. تمثلت معاملات البحث فى ثلاثة مستويات للتسميد بعنصر الآزوت (0، 120 و240 كجم N/ هكتار) وثلاثة كثافات للنبات(5، 10 و15 سم) بين النبات والآخر فى الخط واستخدام صنفين من الأكثر إستهلاكا هما (كاملين وتكساس إرلى قرانو). أجريت تجربة هذا البحث لموسمين متتاليين، بالحقل التجريبى لكلية الزراعة، جامعة الخرطوم. أشارت النتائج إلى أن التسميد بمعدل 120 كجم N/ هكتار أدى إلى زيادة معنوية فى النمو الخضرى والحجم البصلة والإنتاج الكلى والقابل للتسوق؛ ليس هذا فحسب، بل أن نسبة الإزهار المبكر(الحولى) وهو صفة رديئة، تدنت مع الزيادة فى معدل التسميد الآزوتى. لم يؤثر التسميد الآزوتى معنويا على شكل البصلة ولا على محتواها من المادة الصلبة ولا على نسبة المواد الصلبة الذائبة الكلية بها. على الرغم من أن أعلى كثافة للنباتات (5سم بين النباتات) أدت إلى تدنى النمو الخضرى، وزيادة فى نسبة الإزهار المبكر/الحولى، إلا أنها أدت أيضا إلى زيادة الإنتاج الكلى والإنتاج القابل للتسوق وتدنى نسبة تفلق الأبصال (صفة رديئة). الصنف تكساس إرلى قرانو تفوق على الصنف كاملين فى النمو وبالتالى فى متوسط وزن البصلة وفى الإنتاج الكلى وفى الإنتاج القابل للتسوق، إلا أن نسبة تفلق الأبصال كانت أيضا عالية. خلصت التجربة إلى أن زراعة البصل على مسافة 5 سم بين النبات والآخر فى الخط والتسميد ب 120 كجم N للهكتار أدت إلى زيادة معنوية فى الإنتاجية وتحسين نوعية الأبصال فى بيئة شمال وسط السودان.