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Influence of Rate and Time of Application of Nitrogen Fertilization on Yield and Quality of Two Wheat Genotypes

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Abstract

Field experiments were conducted at Hudeiba Research Station farm, River Nile state, for two seasons (2007 –2009) to assess grain yield and quality of two wheat genotypes as affected by different nitrogen fertilization recipes. Nitrogen fertilizer comprised four rates (0 kgN/ha, 43 kgN/ha, 86 kgN/ha and 129 kgN/ha) applied at different stages of growth (tillering, booting and heading) and the two wheat genotypes (N5732/HER//CASKOR and Bohain) Experiments were arranged in a split-plot trail where the nitrogen fertilizer treatments were in the main plots and wheat genotypes in the sub-plots. Combined analysis for the two growing seasons (2007/08 and 2008/09) revealed that N- fertilizer treatments significantly affected yield and yield components of wheat. However, slightly higher yield was obtained at 86kgN/ha at Tillering+43kg.N/ha at Booting (T7) and 86kgN/ha at Booting+ 43kg.N/ha at Heading (T10) relative to the other treatments. High protein and gluten contents were obtained when N-fertilizer applied at 86kg.N/ha rate at booting and 43kg.N/ha at heading stages. Generally genotype (N5732/HER//CASKOR) showed relatively better quality attributes when compared with Bohain, particularly protein and gluten contents.

Keywords: wheat, N fertilizer, grain yield, gluten, genotypes

Introduction

Wheat (*Triticum asetivum* L.) is an important food crop. In the Sudan, wheat has become an important staple food. Being a temperate crop, it is not indigenous to Sudan; yet it was traditionally grown since early times in the Northern States of Sudan (Lat. 18-22° N) that have a relatively cooler and longer winter season the Central Sudan (Mohammed, 2011).

According to climatic data, Sudan's average temperature in the coolest months is more than 20ºC, which is considered very hot for the production of good quality wheat (Ishag and Ageeb1991). Different genotypes react differently to heat stress. In addition to heat stress, wheat growth in Sudan is restricted by nutrients deficiencies. Heat stress on wheat can be modulated by manipulation of fertilization and moisture adjustments.

Nitrogen is one of the major factors that affect wheat productivity. Addition of N fertilizer to wheat is required throughout the growing season due to its important role in promoting high vegetative and reproductive growth and dry matter production would eventually be invested in yield. High yielding wheat varieties need large and regular supply of N to develop high photosynthetic capacity and maintain the proper nitrogen concentration in the leaves so that CO_2 assimilation is not affected when large rates are required for ear growth and grain filling-period (Lawlor, 1995).

The time and rate of N application are critical management factors that influence the N-fertilizer uptake efficiency (Alcoz *et al*., 1993) and tillering (Weisz *et al*., 2001), which are highly correlated with wheat yields. Good management practices, like placement and time of nitrogen application can be synchronized to meet the crop demands for efficient utilization of N by the crop. Nitrogen fertilization increases wheat protein contents (Robinson *et al*., 1979) which is a good indicator of grain quality.

Nitrogen is one of the most effective nutritional factors that affect wheat quality. The degree of N influence on wheat quality is affected by annual weather conditions and by residual soil N (López-Bellido *et al*., 2005). Proper management of N fertilization is essential to ensure high quality wheat production. Designing of fertilizer application regimes should combine rate, timing, splitting, and source of application that can optimize wheat yield and quality (Blankenau *et al*., 2002; Abedi *et al*., 2010). N fertilization increases the total quantity of flour proteins, resulting in an increase in both gliadins and glutenins (Luo *et al*., 2000).

The objective of this study is to determine the optimum time and rate of N fertilizer and their effect on wheat yield, phenology and quality in River Nile State.

Materials and method

The experiment was conducted at Hudeiba Research Farm, River Nile State, Sudan during 2007/08 and 2008/09 cropping seasons. The experimental design was a split plot in which Ten N fertilizer treatments, comprising four doses (0, 43, 86 and 129kg.N/ha.) applied at different growth stages (tillering, booting and heading) were in the main plots and two wheat genotypes Bohain, (a released variety), and (N5732/HER//CASKOR) (genotype from verification yield trial) were the sub plots. Treatments were replicated thrice.

Sub plot treatments were as follows:

1- T1 = 0N
2- T2 = 86kg.N/ha. at tillering
3- T3 = 43kg.N/ha at Tillering+43kg.N/ha at Booting
4- T4 = 86kgN/ha at booting
5- T5 =43kg.N/ha at Tillering+43kg.N/ha at Heading
6- T6 =43kg.N/ha at Booting+43kg.N/ha at Heading
7- T7 =86kgN/ha at Tillering+43kg.N/ha at Booting
8- T8 = 86kgN/ha at Tillering+43kg.N/ha at Heading
9- T9 =86kgN/ha at Booting+ 43kg.N/ha at Heading
10- T10 = 43kg.N/ha at Tillering+43kg.N/ha at Booting+43kg.N/ha at Heading

The total subplot size was 8 m^2 each plots, consisting of 8 rows 5m long with 0.2 m row spacing. Seeds were dressed with Gaucho, at a rate of 1 gram of the product per 1 kg of seed, to control termites and aphids. Weeds were controlled manually twice. Crop was planted at 23 of November in both seasons at a seeding rate of 120 kg/ha. Irrigation was applied at 10 days intervals. The net harvested area was 6 rows *0.2 (inter-row spacing) in the middle 6 rows suing 4m length of each row 4.8 m^2.

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N fertilizer as a form of Urea was broadcasted by hand and applied after 20 days at tillering, 40 days from sowing at to maturity as days from sowing until 50% maturity. Plant height was measured at maturity. Yield and yield components were determined from harvested area. Determination of hectoliter weight (kg/hl) was determined according to (AACC 2000). Grain protein content of seeds was determined by Kjeldahl method. In addition the other quality parameters analyses were carried out according to the revised standard ICC method No. 155 and 158 (1995).

Statistical analysis was performed according to MSTAT-C software program, and data were analyzed according to split plot design, with two factors performing analysis of variance (ANOVA) for each treatment separately and for each season and then combined. In addition correlation coefficients were done among yield and other parameters.

Results and discussion

Nitrogen treatments effect

booting, 50 days at heading stage. Days to heading were determined as number of days from sowing until 50% of heading and days Grain yield, spikes/m² and biomass were significantly affected by N fertilizer packages for the both seasons (Table1). The highest grain yield (3.0 ton/ha) for the first season was obtained at T7 (86 kgN/ha at tillering +43 kg N/ha at booting) andT10 (43 kg N/ha at tillering +43 kg N/ha at booting and 43 kg N/ha at heading). The second season it gave the highest yield at T10. These highest yield in the two seasons were due to the highest biological yield which were more correlated with grain yield (r=0.98*** and r=0.97*** respectively). This result agreed with Al-Abdulsalam, (1997). Data of the first and second seasons showed that delay in N application until booting stage will affected sink- source relationship and the assimilates will not contributed much the economic yield due to negatively influenced on number of spikes/m^2 and biomass but they increased the protein and gluten contents (Table1 and 5).

Table 1: The effect of different levels and time of N application on yield and some yield components of wheat (Seasons 2007/08 – 2008/2009)

Parameters	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	Mean	Sig. level	SE±
Season 20017/2008													
Spike/m²	338	432	474	434	432	403	465	494	492	433	440	**	21.6
Biomass (ton/ha.)	4.8	8.2	8.4	7.3	7.7	7.6	9.2	8.0	6.7	9.2	7.7	**	0.5
Grain yield (ton/ha.)	1.4	2.7	2.5	2.3	2.5	2.4	3.0	2.4	2.1	3.0	2.4	***	0.2
Season 2008/2009													
Spike/m²	344	404	431	448	410	384	490	499	476	484	437	***	20.2
Biomass (ton/ha.)	4.8	6.1	6.2	7.0	5.5	6.5	7.0	6.4	5.4	7.3	6.2	**	0.4
Grain yield (ton/ha.)	2.3	2.6	2.6	3.0	2.4	2.8	3.0	2.8	2.3	3.2	2.7	*	0.2

Statistical combined analysis revealed that N fertilizer treatments had significantly affected yield and yield components of wheat. However, no effect was observed on phenology and plant height (Table 2).

Table 2: The effect of time and rate of N application on phenology, yield and yield components ofwheat (season 2007/08 -2008/09)

Treatments	Days to heading	Days to maturity	Plant height (cm)	No. of spikes/m²	1000 kernel wt (g)	Biomass (ton./ha)	Grain Yield ton./ha)(	HI%
T1	52	85	63.6	347	36.0	4.8	1.9	38.3
T2	52	86	66.1	423	40.2	7.1	2.6	37.5
T3	52	88	67.4	448	36.0	7.4	2.6	35.8
T4	52	88	67.2	400	40.3	7.1	2.5	36.0
T5	52	80	64.2	414	41.3	6.7	2.5	37.8
T6	52	87	64.2	398	40.5	6.8	2.4	36.2
T7	52	88	68.6	472	39.9	7.9	2.9	37.7
T8	52	88	65.9	490	40.9	7.4	2.7	36.8
T9	52	89	64.8	369	41.3	6.3	2.3	36.5
T10	53	88	66.6	442	40.6	7.9	2.9	37.2
Mean	52	87	65.9	434	40.3	6.9	2.5	37.0
Sig. level	NS	NS	NS	***	*	***	**	NS
SE±	0.3	2.3	1.6	14.1	1.0	0.38	0.15	0.8

* Significantly different at P = 0.05, **: Significantly different at P = 0.01 ***: Significantly different at P = 0.005
NS: Not significant.
Legend as table (1).

Highest wheat yield (2.9 t/ha) was obtained at 129 kg N/ha split in to two doses; 46 kg N/ha at tillering and 43 kg N/ha at booting (T7) and when split into three doses; 43kg N/ha at tillering, 43 kg N/ha at booting and 43 kg N/ha at heading (T10), Similar results were reported by Zahran and Mosalem (1993). Increase in grain yield could largely be attributed to the increased number of tiller/m² and biomass which are highly positive correlated with grain yield (0.70* and 0.99** respectively).

Genotypes effect

Significant differences were found between variety Bohain and (N5732/HER//CASKOR) in yield and yield components (Table 3). Variety Bohain was superior in grain yield due to higher number of spikes/m^2, 1000-kernal weight and biomass. On the other hand, (N5732/HER//CASKOR) showed better quality attributes comparative to Bohain, reflected in higher protein content (15.8%) when an extra nitrogen dose was applied at heading (T9). late season nitrogen application to wheat was reported to increase protein contents of the grains (Curt *et al.*, 2002)

Table 3: Phenology, yield and yield components of wheat (Seasons 2007/08 -2008/09)

Genotypes	Days to heading	Days to maturity	Plant height (cm)	No. of spikes /m²	1000 kernel wt (g)	Biomass (ton/ha.)	Grain yield (ton/ha)	Harvest index (%)
Bohain	51	85	64	463	41.3	7.1	2.6	37.7
N5732/HER//CASKOR	53	88	68	405	39.3	6.8	2.4	36.2
Sig.level	***	NS	***	***	***	*	*	***
SE±	0.1	1.1	0.4	5.3	0.3	0.1	0.06	0.2

* significantly different at P= 0.05, **: Significantly different at P= 0.01 ***: Significantly different at P= 0.005 NS: Not significant

Influence of rate and time of N fertilizer on Wheat quality

Table (5) shows that the quality analysis for season 2007/08 revealed that an incremental rates of N fertilizer resulted in higher grain protein contents in both genotypes. These results are in agreement with the findings of Vaughan *et al.*, (1990), Kelley, (1995). Likewise, Bohain and (N5732/HER//CASKOR) gave the highest protein contents (14.2 and 15.8 respectively) in response to the addition of 86 kg N/ha at booting and 43 kg N/ha at heading (T9). These results are consistent with the finding of Wuest and Cassman (1992). Bohain gave the highest wet gluten content (%) at T9 (47.2) in contrast with N5732/HER//CASKOR which gave highest values at T6 (45.7%). There are inverse relationships between quality and grain yield but in this study there was an increase of 12% in yield, 8% in protein and 13% in gluten at T7. However, these increments were 12%, 14% and 23% for yield, protein and gluten, respectively at T10 compared to the recommended N fertilizer (Table 4).

Table 4: % increase or decrease on wheat grain yield and quality as compared to the recommended treatment

Treatments	% increase in yield	% increase in protein	% increase in wet gluten
T1	0%	0%	0%
T2 (recommended)	0%	0%	0%
T3	0%	3%	6%
T4	-4%	13%	27%
T5	-4%	10%	20%
T6	-8%	19%	40%
T7	**12%**	**8%**	**13%**
T8	**4%**	**13%**	**28%**
T9	-12%	27%	43%
T10	**12%**	**14%**	**23%**

Table 5: Effect of rate and time of N-fertilizer on wheat quality (Seasons 2007\08)

Treatments	Analysis factor											
	Hectoliter weight (kg/hl)			Protein (11%mb)			Wet gluten (%)			Falling No. /Second		
	Bohain	(N5732/HER//C ASKOR)	Means	Bohain	(N5732/HER//C ASKOR)	Means	Bohain	(N5732/HER//C ASKOR)	Means	Bohain	(N5732/ HER//C ASKOR)	Means
T1	83.3	80.3	81.8	9.2	9.6	9.4	21.3	25.0	23.2	528	522	525
T2	83.5	80.9	82.2	11.2	12.5	11.9	30.0	33.5	31.8	582	524	553
T3	83.7	79.5	81.6	11.9	12.5	12.2	33.7	33.8	33.8	578	511	545
T4	84.4	80.8	82.6	12.4	14.3	13.4	35.9	44.7	40.3	606	514	560
T5	84.9	81.3	83.1	12.7	13.4	13.1	37.9	38.6	38.3	607	529	568
T6	83.8	80.9	82.4	13.5	14.8	14.2	43.4	45.7	44.6	643	520	582
T7	80.9	79.5	80.2	12.1	13.6	12.9	33.9	38.1	36.0	530	526	528
T8	84.3	79.3	81.8	13.0	13.7	13.4	39.4	41.7	40.6	594	592	593
T9	83.9	80.7	82.3	14.2	15.8	15.0	47.2	43.5	45.4	574	639	607
T10	85.1	80.4	82.8	13.0	13.9	13.5	38.8	39.5	39.2	592	508	550

Legend as table

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Conclusions

Based on the results obtained, the following conclusions were drawn:

1. The highest wheat yield was obtained when 129kgN/ha. was added at tillering and booting
2. Split applications of nitrogen fertilizer at different growth stages resulted in higher yield than single application.
3. Protein content and wet gluten increased when N fertilizer was added in split doses, especially at booting and heading stages.
4. High protein content was obtained from 129kg, N/ha when split in three equal doses at tillering, booting and heading stages of growth.
5. Upon application of some nitrogen packages, the quality of the studied genotypes was improved; this gives an indication that other Sudanese wheat verities may be improved.

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تاثير معدل وزمن إضافة السماد النتروجيني علي إنتاجية ونوعية سلالتين من القمح

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المستخلص

أجريت تجربة حقلية بمزرعة محطة بحوث الحديبة بولاية نهر النيل لموسمي (2007–2008 و 2008–2009) لتقييم إنتاجية ونوعية سلالتين من القمح الطري لحزم مختلفة من التسميد النيتروجيني. السماد النتروجيني تالف من أربعه معدالات (0، 43، 86و129كجم/هكتار) أضيف في فترات نمو مختلفه(الخلف، الحمله والسنبله) وسلالتين من القمح (بوهين و N5732/HER//CASKOR). أستخدم تصميم القطع المنشقة بحيث كانت هناك معاملات التسميد النيتروجيني في القطع الرئيسية بينما وضعت في القطع الفرعية سلالا ت القمح. أظهر التحليل المشترك للموسمين الزراعيين (2007–2008 و 2008–2009) أن معاملات السماد النيتروجيني أثرت معنويا علي الانتاج ومكونات الانتاجية وقد تم الحصول علي أعلي إنتاجية غلة من الحبوب بإضافة 86 كيلو جرام نيتروجين للهكتار عند إكتمال ظهور الخلف و 43 كيلوجرام نايتروجين للهكتار في مرحلة الحَمَله (T7) و 86 كجم /للهكتار في الحمله+ 43 كجم /للهكتارعند ظهورالسنبله (T10). كان أعلي محتوي للبروتين والقلوتين عند إضافة 86 كجم /للهكتار في الحمله +43 كيلوجرام نيتروجين للهكتار في مرحلة ظهور السنابل. عموما أظهرت سلالة القمح (N5732/HER//CASKOR) سمات جودة أفضل وذلك بمحتوي أعلي من البروتين والقلوتين عند مقارنتها بالصنف بوهين.

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