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OPTIMIZATION OF NITROGEN APPLICATION UNDER IRRIGATED BARLEY PRODUCTION

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ABSTRACT: *The source and amount of nitrogen application at the right growth stage is important for malting barley producers to optimize yield and quality of barley. The objectives of the study were to determine the effects of different sources and levels of nitrogen on grain yield, nitrogen and kernel plumpness of malting barley. The experiment was conducted at Vaalharts Research Station and Taung Farmer's Field in Northern Cape and North West Provinces of South Africa, respectively. Split split plot design was applied with main plot being four N sources and sub-plots were different levels of application (100, 125 and 150 kg ha $^{-1}$). These were further divided into 100 and 66% applied as basal dressing while the remaining amounts of 34, 12 and 11% were applied as top-dressing. There was a significant difference ($p>0.05$) in the yield between Taung and Vaalharts localities where different N sources, nitrogen levels and split application were applied. Significant difference ($p>0.05$) was expressed within locality and within nitrogen sources on grain yield. Kernel plumpness significantly differed ($p>0.05$) between two localities and among different nitrogen sources. It is deduced from the findings that Urea be used at 66% basal dressing, 12% tillering, 11% stem elongation and 11% at heading stages to optimize malting barley yield and quality.*

KEYWORDS: Malting Barley, Grain Nitrogen, Nitrogen Sources, Kernel Plumpness.

INTRODUCTION

Barley (*Hordeum vulgare* L.) is the most popular cereal crop in the malting, brewing, human food and animal feed industries world-wide ranking forth among cereals (Brennan *et al*.1997). The World total production is 134.3 million tons with Russia producing 16.9 million tons, followed by Ukraine with 9.09 million tons while France and Germany are at par with 8.76 million tons (Food and Agriculture Organization, 2011).

It is originated from the Fertile Crescent areas of the Near East where voluminous literature citing barley and beer are documented in the early Egyptian and Sumerian writings that are more than 5000 years old. Archaeological evidence of barley cultivation dates back to 10 000 years (Consultative Group of International Agricultural Research, 2014).

Malt is the second largest use of barley and constitutes an important cash crop of resource poor farmers in many developing countries. The main use of malt is in the production of alcoholic beverages, even though malt and malt products are increasingly becoming important in the bakery and barley food industries. Barley contains 75% carbohydrates, 9% protein and 2% fat. Each grain contains 3.3 calories. It is rich in Zinc (50 ppm), Iron (60 ppm), and soluble fibres (Anneli and Bjom, 1981). Besides, it has a higher content of vitamin A and E than other major cereals. Protein content is converted into nitrogen by dividing by 6.25. This nitrogen determines the quality of alcohol as high concentration makes it bitter while low concentration

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makes an alcohol to be of poor taste. Therefore, the importance of nitrogen in Barley cannot be over-emphasized (Gotze, 2010).

In South Africa, total annual barley production is 250 000 tons with 80% being malting barley (Van der Vyver, 2013; Department of Agriculture, Forestry and Fisheries, 2011). Until 1997, it was only produced in the Western Cape Province under dryland conditions with small quantity from Northern Cape. But it is now widely grown in the Northern Cape where is produced under irrigation conditions. Approximately, 27% is produced in the Northern Cape, 3% Southern Cape under dryland conditions (Gotze, 2010). The quantity produced does not meet the country's requirement, hence 75 000 tons of malting barley is imported from Canada, United States, Denmark and France (Anonymous, 2001). Malting barley produced within the country does not meet the recommended standards of quality (Bureau for food and agricultural policy 2007). Therefore, a considerable effort is needed to increase malting barley production and quality. Since nitrogen is an essential active ingredient of malting barley that determines quality and yield, the correct amount, source and time of application are critical. Nitrogen is a very expensive nutrient which is subject to various losses such as volatization, immobilization and leaching justifying split application at the right time. The correct choice of nitrogen source which is cost effective, total amount of nitrogen and its split applications at the right growth stage can contribute significantly towards profitable, high quality barley production. The objectives of the study are three folds; (1) to optimize nitrogen application using four different nitrogen sources, (2) to determine the level of nitrogen application at which quality malt can be obtained, and (3) to determine high kernel plumpness at different nitrogen sources and split application.

MATERIALS AND METHODS

Study Area

The experiment was conducted at Vaalharts Agricultural Research Station and Taung Farmer's Field in Northern Cape and North West Provinces of South Africa, respectively. The climatic conditions in these areas are characterized by hot summer rainfall and cold dry winter periods. Rainy season starts from October to March. The average annual rainfall in the two areas is 400 – 550 mm. The annual average temperature is 30 ^{0} C with the maximum of 38 ^{0}C occurring in February. Soil type is alluvial and is described as Kalahari Sand (Hough and Rudolph 2003). This soil consists of 75% sand, 15% clay and 10% silt. Underlying the Kalahari sand is the Dwyka shale and tillite, calcrete and ventersdorp lava. There are areas where the calcrete is impermeable.

Experimental Design.

Split split plot design was applied with main plot being four N sources (Urea, Ammonium sulphate, Ammonium sulphate nitrate and Limestone Ammonium nitrate) and sub-plots were different levels of application (100, 125 and 150 kg ha $^{-1}$). These were further divided into 100, 99, 83 and 66% applied as basal dressing (Table 1). The remaining amounts were applied as top-dressing at four growth stages (tillering, stem elongation, flag and heading) as stated by Zadocks and Feeks (Agricultural Research Council, 2014).

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Table 1. Split Application of Different Nitrogen Sources

		Nitrogen kg ha $^{-1}$			
	Stages	Planting	Tillering	Stem elongation	Heading
	Week	0	6	10	13 - 14
Fertilizer level (N Kg)	100	100	0	0	0
		66	34	0	0
		66	0	34	0
		66	22	0	12
		66	12	11	11
	125	125	0	0	0
		83	42	0	0
		83	0	42	0
		83	28	0	14
		83	14	14	14
	150	150	0	0	0
		99	50	0	0
		99	0	50	0
		99	34	0	16
		99	17	17	16

Seed-bed was prepared using mould-board plough after which it was harrowed using tandem disc harrow to level and eliminate the low lying spots. Wintersteiger planter was used to plant the seed. The main experimental plot was 120 m x 22.44 m while sub-plots were 5 m x 2.55 m. Each plot consisted of 16 rows of 5 m length, with inter-row spacing of 17 cm. Treatments were replicated thrice. The cultivar used was Puma planted at 90 kg ha $^{-1}$. There were 180 plots in each location. The experiment was run for three years consecutively.

Data Collection

Parameters measured were grain yield, grain nitrogen, dry matter accumulation and kernel plumpness.

Statistical analysis

GenStat version 12 software package was used to perform Analysis of Variance for split split plot and separation of means by least significant difference.

RESULTS

Yield, Grain Nitrogen Percentage and Kernel Plumpness

The results of the experiment showed that there was a significant difference ($p>0.05$) in the yield between Taung and Vaalharts localities where different N sources, nitrogen levels and split application were applied (Table 2). Taung area exhibited a mean yield of 6.969 ton ha $^{-1}$ while Vaalharts obtained a mean yield of 5.9325 ton ha $^{-1}$. The same treatments were applied in both localities implying that the difference was as a result of environment. Significant

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difference (p>0.05) was expressed between localities and within nitrogen sources (Table 3). The highest yield obtained at Vaalharts was 6.459 ton ha^{-1} where urea was applied and the lowest yield of 5.415 ton ha^{-1} observed where lime ammonium nitrate was used. At Taung, the highest yield was 7.930 ton ha^{-1} where urea was also applied and the lowest was 6.271 ton ha^{-1} with an application of ammonium sulphate nitrate.

No significant difference was obtained on grain nitrogen percentage between Taung and Vaalharts and also within different nitrogen sources. Kernel plumpness showed a significant difference (p>0.05) between two localities and among different nitrogen sources. Where limestone ammonium nitrate and ammonium sulphate nitrate was applied in Vaalharts, kernel plumpness was high. In Taung areas, Ammonium sulphate, urea and Ammonium sulphate nitrate exhibited high kernel plumpness. Low kernel plumpness was experienced with Ammonium sulphate in Taung and Limestone ammonium nitrate in Vaalharts.

Table 2. Anova for Sites, Sources of Nitrogen, Splits Application and Years

Source of variation	df	Sum of squares	Mean squares	F-ratio
Replication	2	1.068	0.534	
Site	1	104.648	104.648	21.1268*
Error	2	11.734	5.867	
Fertilizer	3	72.776	24.259	3.5935*
Site x Fertilizer	3	72.156	24.052	3.5629*
Error	12	81.009	6.75075	
Split	14	30.655	2.1896	3.2877*
Site x Split	14	80.480	5.749	8.6321
Fertilizer x Split	42	241.203	5.743	8.6321*
Site x Fertilizer x Split	42	233.744	5.5653	8.3563
Error	224	149.260	0.666	
Covariates				
Year	2	89.739	44.870	30.62799*
Error	718	1052.220	1.465	
Total	1079	1757.428		

Table 3: Means for yield, % grain nitrogen and kernel plumpness where different nitrogen source.

Nitrogen sources	Vaalharts			Taung		
	Yield(ton ha^{-1})	(%grain nitrogen)	Kernel plumpness	Yield (ton ha^{-1})	(%grain nitrogen)	Kernel plumpness
AS	6.038[a]	1.554[a]	94.01[b]	6.522[ab]	1.573[a]	97.225[a]
ASN	5.786[ab]	1.572[a]	95.10[a]	6.271[ab]	1.524[a]	97.173[ab]
LAN	5.415[b]	1.586[a]	95.77[a]	6.763[a]	1.636[a]	96.607[b]
Urea	6.459[a]	1.547[a]	94.39[ab]	7.930[a]	1.552[a]	97.207[ab]
Mean	5.932	1.565	94.82	6.969	1.571	97.053
CV (%)	11.2	5.2	1.9	12.5	3.4	0.9
LSD (%)	0.8226	0.1616	1.519	0.9880	0.1060	0.6103

AS – ammonium sulphate, ASN – ammonium sulphate nitrate, LAN – limestone ammonium nitrate

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Split Applications

The analysis of variance for split application of nitrogen showed significant (P>0.05) differences. Where nitrogen was applied at 66% of 100 kg ha $^{-1}$ dosage as basal dressing, followed by 12% at tillering, 11% stem elongation and lastly another 11% at heading, significantly higher yield was obtained at both localities (Table 4). Similarly, where 66% of 125 kg ha $^{-1}$ nitrogen was applied at planting, followed by 12% at tillering, 11% at stem elongation and 11% at heading, significantly higher yield was observed. At an application rate of 150 kg ha^{-1} nitrogen and similar splits at the same percentages and stages, a significant yield was found in both Taung and Vaalharts. No significant difference was realized in grain nitrogen percentage among the different nitrogen sources, application rates and splits within each locality and between two localities.

Table 4: Average results on yield and N% grain for split application

Application rate	Nitrogen kg ha $^{-1}$				Yield (ton/ha)		N% grain	
	Planting	Tillering	Stem elongation	Heading	Vaalharts	Taung	Vaalharts	Taung
100	100	0	0	0	5.958	6.674	1.655	1.513
	66	34	0	0	5.688	6.776	1.643	1.584
	66	0	34	0	5.877	7.054	1.723	1.552
	66	22	0	12	5.996	6.895	1.726	1.553
	66	12	11	11	6.251*	7.990*	1.696	1.531
125	125	0	0	0	5.507	6.874	1.782	1.587
	83	42	0	0	5.738	7.028	1.731	1.533
	83	0	42	0	5.503	6.536	1.775	1.598
	83	28	0	14	6.030	7.348	1.696	1.653
	83	14	14	14	6.911*	6.882*	1.707	1.654
150	150	0	0	0	5.627	6.784	1.821	1.626
	99	50	0	0	5.604	6.860	1.770	1.592
	99	0	50	0	5.520	6.833	1.757	1.715
	99	34	0	16	5.810	6.721	1.767	1.643
	99	17	17	16	6.959*	7.285*	1.794	1.628
Mean					5.932	6.969	1.565	1.521
CV (%)					10.2	8.6	6.7	5.3
LSD(0.05)					0.475	0.476	0.304	0.188

DISCUSSION

Taung and Vaalharts localities showed a different yield potential brought about by differentials in temperature and relative humidity (Table 2). Taung out-yielded Vaalharts by 16% equivalent to 0.947 ton ha $^{-1}$. The two factors had a perceptible influence on photosynthetic and evapo-transpiration rate which accelerated growth and ultimately result in increased yield. Gordon and Moshe (2011) indicated that two or more localities which are spatially situated from each other may differ slightly or greatly due to micro-climate affecting genotypically similar crops in terms of yield and quality. Similarly, Young and Dent (2013) demonstrated with barley the differences that could be obtained by growing the same cultivar in five adjacent localities where more than one factor may cause a difference in yield.

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Where Urea was applied in both localities, highest yield was attained as a result of high concentration of nitrogen (46%) in urea compared to the other sources of nitrogen such as Ammonium Nitrate (34%), Limestone ammonium nitrate (28%) and Ammonium nitrate sulphate (21%). High nitrogen concentration results in high rate of chlorophyll formation and more solar radiation being absorbed required for photosynthetic reaction and energy transfer systems. Rantao (2013) conducted a study on growth, yield and quality response of *Beta vulgaris* on five nitrogen sources and found urea to excel in the three parameters that were measured. Grain nitrogen percentage revealed no significant difference among four nitrogen sources and split applications. This was predetermined to range between 1.6 and 1.9% since above or below this range the taste and flavour of beer made from it would be affected. Brian (2006) indicated that the most desirable nitrogen content for malting barley should be from 1.55 – 1.85 % and nitrogen application rate must ensure that this range is maintained. Similarly, Biscoe and Murell (2001) also emphasized the range of 1.8 – 1.85. It was therefore with the reason why significant difference was not aimed at as long as the recommended range was reached. The range was too narrow to make any difference. A high rate of direct nitrogen application increases barley grain nitrogen which may be desirable where the crop was to be used as animal feed. But where barley was used for malting, a low rate of nitrogen was required, hence it was important to match nitrogen rate and desirable yield and quality target.

Kernel plumpness in malting barley is most recommended if it is above 90% but in some places the minimum recommended is 70%. In this study, Kernel plumpness was above 94% and significant difference was obtained among the four nitrogen sources in both Vaalharts and Taung locations. Ammonium sulphate and urea revealed significantly high kernel plumpness at Vaalharts while Ammonium Sulphate, Urea, and Ammonium Sulphate Nitrate produced significantly ($p>0.05$) higher kernel plumpness. The high kernel plumpness was as a result of a large amount of photosynthates redistributed from the stem and other parts of the plant to fill the kernels. Once the kernels are initiated and developing, they become sinks drawing photosynthates from other parts of the plant. Mckenzie and Jackson (2005) conducted a study on the effects of different nitrogen sources and levels on malting barley yield, grain nitrogen and kernel plumpness and found kernel plumpness increases with increase in addition of nitrogen and decreased with increase in soil water deficit. The results of this study is consistent with the findings of Mckenzie *et al*.(2005) who investigated fertilization, seeding date and rate for malting barley yield and quality in Southern Alberta, Canada. Split application of different nitrogen sources showed a significant differences where nitrogen was applied at 66% basal dressing, 12% tillering, 11% stem elongation and lastly 11% heading. This showed that the consistent supply of nitrogen over four stages of growth met the demand of the crop adequately at the right time. However, this may be economically unjustified because of the cost of many applications. Baethgen and Lamothe (1995) found that application of nitrogen at tillering, stem elongation and heading increased the yield from 30% - 100% due to increase in the number of kernels m^2 and kernel weight. They concluded that adequate amount of nitrogen be applied at sowing to ensure good stand while an application of nitrogen at tillering ensures initial tiller development, further application of nitrogen at stem elongation stimulated ear-formation and increases flora primordial. At flag leaf, nitrogen application contributes towards increase in protein content in the kernel.

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REFERENCE

Agricultural Research Council. 2014. Guidelines for the production of small grains in the summer rainfall. Sherino, Pretoria.

Anneli, T. and Bjom, E. 1981. The nutritional value of high lysine barley genotypes. Quality Plant Foods Human nutrition. 31:151 – 161.

Anonymous. 2001. Trends in the Agricultural sector: Barley. Government printers, Pretoria.pp1 -388

Baethgen, W. E. and Lamothe G. A. 1995. Nitrogen fertilization effects on growth, grain yield and yield component of barley. 43 (2): 87-92.

Bascoe, P. and Murell I. 2001. Introduction to Malting Barley. Caledonia House, London.

Brennan, C.S., Harris, N., Smith. and Shrewry, D. 1997. Structural differences in mature endosperms of good and poor malting barley cultivars. Journal of Cereal Science 24: 171-177.

Brian, C. 2006. The barley guide: Houston Gun Collector Association. Caledonia House, London.

Consultative Group of international Agricultural Research. 2014. Research on Gender and Agriculture. http://www.cgair.org/our-research-on-agriculture.

Department of Agriculture, Forestry and Fisheries. 2011. Barley: market value chain profile 2020-2011. Government Printers, Pretoria.

Food and Agriculture organization. 2011. Statistical year book of crop production-oil-bearing crops. FAO: Italy.

Gotze, G. Z. 2010. Production guide-line for barley. Agricultural Research Council, Pretoria.

Jackson, G. D. 2000. Nitrogen fertilization on dryland malt barley for yield and quality. Fertilizer Fact Sheet No.24.

Mckenzie, R.,Jackson G. 2005. Barley production in Semi-arid regions-malting grade. Better Crops. **89**: 10-12.

Mckenzie, R., Middleton, A.B. and Bremer, E. 2005. Fertilization, seeding date and seeding rate for malting barley yield and quality in Southern Alberta. Canadian Journal Plant Science. 85:603-614.

Rantao, G. 2013. Growth, yield and quality response of Beet (*beta vulgaris* L.) to Nitrogen. MSc Thesis. University of Free State. Bloemfontein.

Young, A. and Dent T. 2013. Effects of climate on the performance of malting barley yield and quality. African Crop Science Journal. 3: 45 -55.

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