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Effect of Nitrogen Rates and Varieties on Grain Yield and Nitrogen Use Efficiency of Bread Wheat (*Triticum aestivum* L.)

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ABSTRACT

Wheat is most important cereal crop in Ethiopia and its productivity is partly constrained by the low N content of the soil. A field experiment was carried out on-farm at Kokate village, Sodo Zuria district, Wolaita, Ethiopia, from July to November 2014, during main cropping season, in order to determine grain yield and yield components, and nitrogen use efficiency using factorial combinations of five N rates (0, 30, 60, 90 and 120 kg/ha) and three bread wheat varieties (Hidase, Hulluka and Tay) in randomized complete block design with three replications. The increase in N rate from 0 to 120 kg/ha increased days to flowering from 75 to 77, days to maturity 107 to 112, plant height 77.73 to 101.66 cm, productive spikes/m^2 217 to 399 and seeds per spike 45 to 58. The increase in N rate from 0 to 120 kg/ha increased biomass yield from 7361 to 15506 kg/ha, grain yield 2500 to 4917 kg/ha and 1000-seed weight 39.01 to 44.44 g. Nitrogen use efficiency decreased from 114 to 41 with the increase in N rate from 30 to 120 kg/ha. Variety Hulluka exhibited high productive spikes/m^2, seeds per spike, N use efficiency and grain yield compared to varieties Hidase and Tay. This study suggests that N fertilization recommendations would consider not only the increase in grain yield but also the decline in N use efficiency as N supply increases.

Key words: Bread wheat, grain yield, nitrogen, Nitrogen use efficiency, *Triticum aestivum*

INTRODUCTION

Bread wheat (*Triticum aestivum* L.) is most important cereal crop in Ethiopia. It occupies about 1.66 million ha of land (16.35% of the area allocated to cereals), producing about 4.23 million tons of grain (17.92% of total production of cereals) per year (CSA, 2015). Low soil fertility is one of the major factors which contribute to the low productivity of wheat in Ethiopia (Tanner et al., 1993). Indeed, N is deficient in almost all soils (Woldeab et al., 1991) and P is deficient in about 70% of soils (Mamo and Haque, 1991).

Nitrogen is a constituent of proteins, nucleic acids and chlorophyll (Mengel and Kirkby, 2001). It influences both vegetative and reproductive phases of growth because of its influence on cell division and elongation (Marschner, 2012), leaf area (Marschner, 2012; Lad et al., 2014), leaf chlorophyll content (Salem et al., 2011) and nutrient uptake (Hussaini et al., 2008). Thus, N fertilizer supply has been reported to increase grain and biomass yields, and plant height (Ibrahim et al., 2014), number of tillers, and seeds per spike (Ali et al., 2003; Ullah et al., 2013;Tayefe et al., 2014). However, excess N fertilizer supply leads to environmental pollution due to its loss through leaching, volatilization, denitrification and soil erosion (Mengel and Kirkby, 2001).

Nitrogen use efficiency, the ratio of grain yield to N supply, consists of uptake efficiency (ratio of total plant N to N supply) and utilization efficiency (ratio of grain yield to total plant N) (Moll et al., 1982). It varies with N supply as well as crop genotypes due to variation in uptake and utilization of internal nitrogen in grain formation (Moll et al., 1982; Ortiz-Monasterio et al.,1997). The present experiment was conducted in order to determine grain yield and yield components, and nitrogen use efficiency for different N rates and bread wheat varieties.

MATERIALS AND METHODS

An experiment was conducted on-farm at Kokate village (6^{0}52'44''N, 37^{0}48'22''E, and 2300 meter above sea level), 6 km from Wolaita Sodo, Sodo Zuria district, Wolaita, Ethiopia. Wolaita Sodo receives annual average rainfall of 1394 mm with the monthly average minimum and maximum temperatures of 14.7 and 25.4^{0}C, respectively . The average monthly rainfall during experiment duration (July to November, 2014) was 205 mm and the average monthly minimum and maximum temperatures were 14.9 and 24.0^{o}C, respectively. The soils of the experimental field at 0-30 cm depth is loam (sand 51%, silt 33% and clay 16%) with the pH 5.4, organic carbon 1.97%, total N 0.17%, P 1.88 ppm (Olsen), and CEC 23.2 meq/kg.

The present experiment was conducted using factorial combinations of five N rates (0, 30, 60, 90, and 120 kg/ha) and three commonly grown bread wheat varieties (Hidase, Hulluka and Tay) obtained from Hawassa Agricultural Research Centre, Hawassa, Ethiopia, using randomized complete block design with three replications. Planting was done on July 26, 2014 using seeding rate of 150 kg/ha, on a plot of six rows with the row length of 2.5 m, and distance between rows, plots, and replications of 20 cm, 80 cm and 1.5 m, respectively. The 46 kg/ha P_20_5 was applied at planting time in the form of triple super phosphate and N in the form of urea was split applied at planting time and during tillering stage. Manual handing weeding was used to control weeds throughout the experiment.

Days to flowering and maturity, plant height(cm) and seeds per spike (average for 10 random plants at maturity), 1000-seed weight(g), productive spikes/m^2 (average for two random quadrants of 50 cm x 60 cm), grain yield (kg/ha) (adjusted to 12.5% seed moisture), biomass yield (kg/ha), and harvest index (ratio of grain yield to biomass yield) were recorded on four central rows leaving 30 cm edge from each row. Nitrogen use efficiency was calculated according to Moll et al. (1982) as:

$$NUE = GY/ Ns$$

Where NUE is nitrogen use efficiency, GY is grain yield and Ns is fertilizer N supply.

The data for grain yield and yield components, and N use efficiency were analysed using Genstat software (VSN International, 2012).

RESULTS

Days to flowering and maturity, plant height, productive spikes and seeds per spike

The effect of N and variety was significant ($p<0.01$) for days flowering and maturity, plant height, productive spikes/m^{2}and seeds per spike except the effect of N x variety interaction. The respective percent increase in days to flowering, days to maturity, plant height(cm), productive spikes and seeds per spike with the increase in N rate from 0 to 120 kg/ha was 2.67 (75 to 77), 4.67(107 to 112), 30.79(77.73 to 101.66), 83.87(217 to 399), and 28.89(45 to 58). However, each increase in days to flowering and maturity with the increase in N rate beyond 0 kg/ha, and that of plant height and seeds per spike beyond 30 kg/ha N were not significant. On the other hand, variety Hulluka significantly exceeded varieties Hidase and Tay in days to maturity, productive spikes and seeds per spike. However, variety Tay (100.90 cm) significantly exceeded both Hidase (82.84 cm) and Hulluka (88.75 cm) in plant height (Table 1).

Table 1. Significance of F-ratios and mean values of five yield components of bread wheat for five N rates and three varieties grown during 2014 main cropping season

N rate, kg/ha	DTF	DTM	PHT	PS	SPS
0	75	107	77.73	217	45
30	75	108	86.06	261	51
60	76	109	91.88	308	54
90	76	110	96.83	356	56
120	77	112	101.66	399	58
Mean	76	109	90.83	308	53
$LSD_{0.05}$	1.32	2.11	5.03	31	4.09
Variety					
Hidase	73	100	82.84	307	53
Hulluka	78	116	88.75	335	57
Tay	77	110	100.90	283	49
Mean	76	109	90.83	308	53
$LSD_{0.05}$	1.02	1.63	3.90	24	3.17
F-ratio					
N(4)	**	**	**	**	**
Variety(2)	**	**	**	**	**
N x variety(8)	ns	ns	ns	ns	ns
CV (%)	1.80	2.00	5.70	10.30	8.00

DTF = days to flowering, DTM = days to maturity, PHT= plant height (cm), PS= productive spikes/m^2, SPS= seeds per spike; numbers in the parenthesis are degree of freedom; ** = significant at $p<0.01$, ns= not significant.

Biomass and grain yields, harvest index, 1000-seed weight and N use efficiency

The effect of N and variety was significant ($p<0.01$) for 1000-seed weight, biomass yield, grain yield and N use efficiency and that of variety effect was significant ($p<0.01$) for harvest index. However, the effect of N x variety interaction was not significant for these parameters. The respective percent increase in biomass yield, grain yield and 1000-seed weight with the increase in N rate from 0 to 120 kg/ha N was 110.65 (7361 to 15506 kg/ha), 96.68(2500 to 4917 kg/ha), and 13.92(39.01 to 44.44 g). However, the increase in these parameters declined with the increase in N rate beyond 30 k/ha. Moreover, N use efficiency declined by 64.04% (114 to 41) with the increase in N rate from 30 to 120 kg/ha. On the other hand, variety Hulluka significantly exceeded varieties Hidase and Tay by grain yield and N use efficiency. Variety Tay (13083 kg/ha) however exhibited significantly higher biomass yield than variety Hidase (11050kg/ha) and lower harvest index (0.28) than both varieties Hidase(0.36) and Hulluka (0.35) (Table 2).

Table 2. Significance of F-ratios and mean values of biomass and grain yields, harvest index,1000-seed weigh and N use efficiency of bread wheat for five N rates and three varieties grown during 2014 main cropping season

N rate, kg/ha	BY	GY	HI	TSW	NUE
0	7361	2500	0.35	39.01	-
30	10500	3417	0.33	41.68	114
60	12694	4072	0.32	42.89	68
90	14383	4539	0.32	43.81	50
120	15506	4917	0.32	44.44	41
Mean	12089	3889	0.33	42.37	68
$LSD_{0.05}$	1270	393	ns	1.30	7.83
Variety					
Hidase	11050	3900	0.36	42.49	68
Hulluka	12133	4233	0.35	43.12	75
Tay	13083	3533	0.28	41.49	63
Mean	12089	3889	0.33	42.37	68
$LSD_{0.05}$	984	305	0.035	1.01	6.78
F-ratio					
N(4)	**	**	ns	**	**(3)
Variety(2)	**	**	**	**	**(2)
N x variety(8)	ns	ns	ns	ns	ns(6)
CV (%)	10.90	10.50	14.20	3.20	11.70

BY = biomass yield (kg/ha), GY= grain yield (kg/ha), HI = harvest index, TSW = 1000-seed weight (g), NUE = N use efficiency; numbers in the parenthesis are degree of freedom; ** = significant at p<0.01, ns = not significant.

DISCUSSION

As to the present experiment, the increase in days to flowering and maturity (Fisseha, 2004), plant height (El-Razek and Sheshtawy, 2013;Ullah et al., 2013), seeds per spike and 1000-seed weight (Ali et al., 2003; El-Razek and Sheshtawy, 2013; Ullah et al., 2013;), biomass and grain yields (Cassman et al.,1992; Ullah et al., 2013; Ibrahim et al., 2014), and number of spikes/m^2(Delogu et al.,1998; El-Razek and Sheshtawy, 2013; Ibrahim et al., 2013) has been reported in the previous studies indicating that N supply influences both source and sink formation. On the other hand, the low increase in 1000-seed weight (13.92%) compared to seeds per spike (28.89%) with the increase in N rate from 0 to 120 kg/ha would indicate that seed number is more sensitive to varying environments than seed weight (Elbehri et al., 1993).Thus, the increase in grain yield with the increase in N rate was primarily to the increase in seeds per spike other than the increase in seed weight and harvest index. This agrees with the previous studies for amaranth (Elbehri et al., 1993). On the other hand, low grain weight at low N supply could be due to a decrease in the import of carbohydrate into the grains during grain filling period (Mengel and Kirkby, 2001).On the other hand, the high grain yield of variety Hulluka could be because of its high productive spikes/m^2 and seeds per spike.

Harvest index measures the proportion of total above ground biomass partitioned into the grain. The reports on the effect of N supply on harvest index are not consistent. As to the present experiment, non-significant effect of N supply on harvest index has been reported for wheat (Ibrahim et al., 2014), rice (Jamil and Hussain, 2000; Tayefe et al., 2014) and bean (Phaseolus vulgaris L.) (Lad et al., 2014). On the other hand, the increase in harvest index for wheat (El-Razek and Sheshtawy, 2013; Ullah et al., 2013) as well as its the decrease for wheat (Ortiz-Monasterio et al., 1997; Delogu et al., 1998), rice (Ahmed et al., 2005) and barley (Bulman and Smith, 1993; Delogu et al., 1998; Shafi et al., 2011) with the increase in N rate has been reported.

As to the present experiment, the variation in N use efficiency has been reported for maize (Moll et al., 1982) and wheat (Dhugga and Waines, 1989; Ortiz-Monasterio et al., 1997).The decline in N use efficiency with the increase in N rate has also been reported for wheat (Dhugga and Waines, 1989; Ortiz-Monasterio et al., 1997; Kaur et al., 2015), amaranth (Elbehri et al., 1993) and maize (Moll et al., 1982; Akintoye et al., 1999)which could be because the rate of increase in grain yield was less than the rate of increase in N supply. This study suggests that N fertilization recommendations would consider not only the increase in grain yield but also the decline in N use efficiency as N supply increases.

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