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Effect of Seeding Rates and Nitrogen Levels on Yield and Yield Components of Wheat (Triticum Aestivum L.) on Vertisols in Central High-Lands of Ethiopia

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Abstract
Field experiments were conducted at two locations in central high-lands of Ethiopia (Ginchi and Becho) to study the effect of seeding rates and different levels of nitrogen fertilizer on yield and yield components of wheat for two years (2014 to 2015). The experimental treatments at both locations considered were a factorial combination of five Nitrogen rates (0, 30, 60, 90 &120 Kg N/ha) and three seed rates (125, 150 and 175 kg/ha) laid out in a randomized complete block design in three replications where wheat variety 'Hidase' was used as a taste crop. Based on the significance of the F test ($p<0.05$), all parameters tasted: plant height, spike length, number of fertile tiller per plant, biomass yield, grain yield and harvest index were significantly affected by the main effect of nitrogen fertilizer rates at both locations. The highest grain yield kg/ha (5063) at Ginchi site and (5110.4) at Becho site as well as the highest harvest index (0.431) at Ginchi site (0.42) at Becho site were recorded at nitrogen level of 90 kgN/ha. The main effect of seeding rates significantly affect number of fertile tillers per plant, biomass yield and harvest index but plant height and spike length were not significantly changed due to seed rate effect at both locations. The highest number of fertile tiller per plant(4) at Ginchi site and (5) at Becho site was recorded at the lowest (125 kg/ha) seed rate level but the highest biomass yield was recorded at maximum (175 kg/ha) seed rate level at both sites. The interaction effect of nitrogen fertilizer rate and seed rate do not significantly alter all parameters tasted at both locations.
Keywords: Nitrogen, seed rate, vertisol, wheat, yield components

1. Introduction

Wheat is one of the most important cereal crops globally and is a staple food for about one third of the world's population (Hussain *et al.*, 2002). Ethiopia is the second largest producer of wheat in sub-Saharan Africa, following South Africa. In Ethiopia, it is grown annually on 1.68 million ha with a total production of 3.08 million tons which makes the country the largest wheat producer in Sub-Saharan Africa (CSA, 2010). Nationally, wheat ranks fourth in total area coverage and production. It is also third in productivity (after maize and sorghum) among cereals. Because of its importance for the food security and income of small scale producers and its overall contribution to the economic growth of the agricultural sector, wheat has been among priority crops which have been enjoying better research and development attention.

Nitrogen and phosphorus deficiency is often encountered in wheat growing areas of Ethiopia, in which the severity of the problems predominate the frequently water-logged soils of high land vertisols (Tekalign *et al.*, 1988; Syers *et al.,* 2001). Reports have shown that about 50% of applied N fertilizer remains unavailable to a crop due to N losses (Zafar and Muhammad, 2007). Legg and Meisinger (1982) also reported that not more than 50 to 60% of applied N is usually recovered under average field conditions.

The main factors responsible for low yield are less or more plant population and inadequate crop nutrition. Plant density is a major factor determining the ability of the crop to capture resources and generate yield. It can be developed by using a suitable seeding rate. Growth and yield of wheat are affected by environmental conditions and can be regulated by sowing time and seeding rate (Ozturk *et al*., 2005). As the plant density increases, the competition for resources especially for nitrogen also increases that badly affect the ultimate yield. Numerous studies have documented how N fertilization (Campillo *et al*., 2010; Hirzel et al., 2010; Zecevic *et al*., 2010; Nikolic *et al*., 2012), seeding rate, planting date, row spacing, and seeding depth affect yield and yield components of wheat (Wajid *et al*., 2004; Guberac *et al*., 2005; Schillinger, 2005; Kristó *et al*., 2007; Maric *et al*., 2008; Otteson *et al*., 2008; Valério *et al*., 2009). Provision of additional nitrogen can be hypothesized to further enhance the yield by increasing plant population but up to an optimum level. Further higher nitrogen can lead to the lodging of plants at higher seed rate (Nazir *et al*., 2000). Nitrogen occupies a conspicuous place in plant metabolism. All vital processes in plant are associated with protein, of which nitrogen is an essential constituent. Proper use of nitrogen is also considered for farm profitability and environment protection (Makowski *et al*., 1999). Reports indicated that appropriate level of nitrogen application has increased wheat yield significantly (Gwal *et al*., 1999; Ali *et al*., 2000). Among all the essential nutrients applied in the field, nitrogen is the most important for vegetative crop growth, plant productivity and grain quality (Frink *et al*., 1999). As appropriate nitrogen level and seeding rate is very limiting factors, the current research was conducted to determine appropriate nitrogen levels and seeding rates for optimum grain yield of wheat on high land vertisols.

2. Materials and Methods

The experiment was conducted at two locations: Ginchi (2200 m.a.s.l.) and Becho (2333 m.a.s.l.) sites on farmer's field for two years (2014-2015). The long term average annual rain fall was 1126 mm for Ginchi and 1000 mm for Becho site. Annual average temperature ranges 5 ^{0}C - 25 ^{0}C at Ginchi site and 16 ^{0}C -25 ^{0}C at Becho site. The soil types at both locations was Pellic Vertisol. The experiment was carried out during the main rainy season of two years from 2014-2015 to study the effect of nitrogen fertilizer and seeding rates on yield and yield components of wheat on high land vertisols. Three seeding rates (125, 150 and 175 kg/ha) and five nitrogen fertilizer rates (0, 30, 60, 90 & 120 kgN/ha) were combined in a factorial experimental arrangement with RCBD design in three replications at both sites where the plot size was 4 x5 m^2. Wheat was planted on seed bed prepared by ridge and furrow in order to avoid excess water from the plot. Urea was used as the N source. All plots received recommended P as triple super phosphate. All the P, and half of the N, were applied at planting but half of N was applied at tillering stage immediately after first weeding. All recommended cultural practices were adopted to manage the experimental field. All the data were subjected to analysis of variance (ANOVA) using the GLM procedure of SAS. The LSD test was used to separate significantly differing treatment means after they were found significant at $P \leq 0.05$.

3. Results and Discussions

The experiment was carried out at two locations on vertisol for two years during the main cropping season. The general trend of the data from both location indicated that nitrogen fertilizer rate is more limiting factor than seed rate to significantly alter agronomic and economic yield of wheat crop on vertisol areas.

3.1 Plant height

Plant height was statistically affected by nitrogen levels at both locations (Table 1). The tallest plants (99.09 cm) at Ginchi and (97.4 cm) at Becho were recorded at nitrogen level of 60 kgN/ha and 90 kgN/ha respectively while the smallest plants were recorded at zero level of nitrogen (Table 2) at both sites. This is because of N fertilizer has plays vital role in vegetative growth and resulted for significant influence on plant height (Haftom *et al,;* 2009). But non optimal application of N, resulted in significantly reduction on heights (Zewdu *et al,;* 1992: Alcoz *et al,;*1993). This study study also indicated that main effect of Seeding rate as well as interaction effect of nitrogen levels and seeding rates were found statistically non-significant (Table 1) to alter plant height.

3.2 Spike length

Spike length was statistically affected by application of different nitrogen levels at both locations (Table 1). Maximum spike length (6.08 cm) at Ginchi site and (6.55 cm) at Becho site were recorded at nitrogen level of 120 kgN/ha and 90 kgN/ha respectively while the smallest spike length was recorded at zero level of nitrogen (Table 2) at both sites. The main effect of Seeding rate and interaction effect of nitrogen levels and seeding rates were found non-significant (Table 1) to alter spike length.

3.3 Number of fertile tillers per plant

Crop yields are generally dependent upon many yield contributing agents. Among these, number of fertile tillers are the most important because of its contribution in final yield. Numbers of fertile tillers per plant of wheat crop were statistically affected by seeding rate and nitrogen levels (Table 1). More number of fertile tillers per plant (4 at Ginchi site and 5 at Becho site) were observed at seeding rate of 125 kg/ha while less number of fertile tillers (3 at both locations) were recorded at seeding rate of 175 kg/ha (Table 2). Number of fertile tillers per plant was also affected by nitrogen fertilization (Table 1). Less number of fertile tiller per plant was recorded at zero level of nitrogen and increases as the level of nitrogen applied increases at both locations. In agreement with this finding, Botella *et al*. (1993) reported that stimulation of tillering with optimal application of N might be due to its positive effect on cytokinin synthesis. The interaction effect between seeding rates and nitrogen levels was found non-significant to affect number of fertile tillers per plant (Table 1).

3.4 Biological Yield

Biological yield represent overall growth performance of the plant as well as the crop and is considered to be the essential yield parameter to get useful information about overall growth of the crop of wheat. Biological yield was statistically affected by seeding rate and nitrogen levels (Table 1). Highest biological yield was obtained at seeding rate of 175 kg/ha while lowest biological yield was recorded at seeding rate of 125 kg/ha. This is because at high seeding rates early dry matter accumulation and weed competitiveness increases , but it may have negligible impacts on grain yield due to increased inter-plant competition (Park *et al*., 2003). Nitrogen fertilization also has prominent effect on biological yield of wheat (Table 1). Maximum biological yield was obtained at highest nitrogen level while lowest biological yield was recorded at zero level of nitrogen (Table 2). The interaction effect of seeding rate and nitrogen levels were found non-significant to alter biological yield (Table 1). Increased in biomass production might be attributed to the increased plant population due to higher seeding rate with better nitrogen application. These results are in agreement with Islam *et al.* (2002), Mojiri and Arzani (2003) and Soylu *et al.* (2005). Otteson *et al.* (2007) found that biological yield was increased by increasing nitrogen up to optimum levels which is may be due to encouragement of vegetative growth by application of high N fertilizer (Albert, *et al,;* 2005). Nayyar *et al.* (1992) obtained the highest biological yield at higher seeding rate of 100 kg/ha.

3.5 Grain yield

Grain yield of wheat is the function of its unique yield components in response to nitrogen level and seed rate for the yield of the crop. The combined analysis of the two year data indicated that significant ($P< 0.01$) grain yield difference was recorded only due to the main effect of nitrogen fertilizer rate but the main effect of seed rate and the interaction effect of nitrogen fertilizer and seed rate were not significant to alter grain yield (Table 1). Hiroshi and Satoshi (2009) also reported as seed rate do not significantly alter grain yield of wheat. The maximum mean grain yield (5063.7 kg/ha at Ginchi and 5110.4 kg/ha at at Becho) was recorded using 90 kg N/ha (Table 2) while the lower grain yield was recorded at zero nitrogen level at both locations. Similar results were obtained by Pandy *et al.* (2001) and Singh *et al.* (2002). They reported that increasing nitrogen rates increased grain yield.

3.6 Harvest index

The capacity of a crop to convert the dry matter into economic yield is indicated by its harvest index. The higher the harvest index value, the greater the physiological potential of the crop for the converting dry matter to grain yield. Harvest index showed significant difference due to the main effect of seeding rate and nitrogen levels (Table 1). Highest harvest index (0.38 at Ginchi 0.37 at Becho) was calculated at seeding rate of 125 and 150 kg/ha respectively (Table 2). Maximum harvest index 0.43 was obtained at nitrogen level of 190 kg/ha while minimum harvest index was recorded at zero level of nitrogen (Table 2). The interaction of seeding rate and nitrogen levels was found significant at both locations (Table 1) which supports the findings of Singh *et al*. (2002) which reported that increase in nitrogen level increased harvest index.

4. Conclusion and recommendations

Investigated yield and yield component variables (plant height, spike length, number of fertile tiller per plant, biomass yield, grain yield and harvest index) varied significantly between different nitrogen levels but seed rate significantly alters only some of the tasted variables (number of fertile tiller per plant, biomass yield and harvest index). Out of the tasted nitrogen fertilizer levels, application of 90 kgN/ha gives the highest grain yield. This high amount of nitrogen is needed because of the unavailable nature of the nutrient due to high losses on high land vertisols. litratures explaned that much of the applied nitrogen fertilizer was lost on soils having water logging problems. Grain yield was not significantly varied by the effect of seed rate in which the high grain yield was recorded at 150 kg/ha at Becho site and at 175kg/ha at Ginchi site but it was not statistically different from the yield obtained by the lowest seed rate (125 kg/ha) at both locations. The general trend of the data indicated that the fertilizer rate has a greatest impact on grain yield compared to the seed rate of wheat crop. Based on this study using 125 kg/ha seed rate and application of 90 kgN/ha gives high grain yield for wheat crop production on high-land vertisol areas of Ethiopia. However, it is advisable to undertake further research across soil type, years and locations to draw sound recommendation on a wider scale.

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Table 1.Summary of the analyses of variance computed with data of yield and yield component parameters from Ginchi and Becho sites.

Source of variation	Ginchi site						Becho site					
	Plant height (cm)	Spike Length (cm)	No. of fertile tillers /plant	Biomass yield (kg/ha)	Grain yield (kg/ha)	HI	Plant height (cm)	Spike Length (cm)	No. of fertile tillers/ plant	Biomass yield (kg/ha)	Grain yield (kg/ha)	HI
Nitrogen rate	**	**	**	**	**	**	**	**	**	**	**	**
Seed rate	ns	ns	**	**	ns	**	ns	ns	**	**	ns	*
Seed rate * Nitrogen rate	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Mean	91.2	5.5	3.45	9534.4	3468.1	0.35	91.6	6.38	4.27	9751	3597	0.354
CV(%)	11.7	10.5	15.09	14.54	14.73	11.78	8.9	7.57	15.97	14.4	19.8	17.33

where **= significant at 1% probability level, *= significant at 5% probability level; ns= non significant at 5% probability level.

Table 2. Effect Of Seed Rate And Fertilizer Rate On Wheat (2014-2015)

Factors	**Ginchi site**						**Becho site**					
	Mean Plant height (cm)	Mean Spike Length (cm)	Mean No.of fertile tillers/ plant	Mean Biomass yield (kg/ ha)	Mean Grain yield (kg/ha)	HI	Mean Plant height (cm)	Mean Spike Length (cm)	Mean No. of fertile tillers/plant	Mean Biomass yield (kg/ha)	Mean Grain yield (kg/ha)	HI
Seed rate												
125	89.9a	5.54a	4.18a	8811.2b	3425a	0.38a	89.8a	6.28a	5a	8799c	3391.9a	0.368a
150	89a	5.3a	3.4b	9214.2b	3350a	0.34b	91.01a	6.38a	4.6b	9854b	3740.8a	0.364a
175	94a	5.7a	2.79c	10578a	3628a	0.34b	94.2a	6.5a	3.4c	10601a	3658.4a	0.329b
$LSD_{0.05}$	ns	ns	0.27	713.95	ns	0.022	ns	ns	0.35	725.1	ns	0.032
Fertilizer rate												
0	76.2c	4.9d	2.83d	4611.3e	1222.5e	0.27d	82.5c	5.99b	3.05c	5651d	1200.3d	0.222c
30	87.2b	5.3cd	3.18c	7193.9d	2485.4d	0.35c	88.7b	6.39a	4.02b	7893.7c	2725.1c	0.348b
60	99.09a	5.54cb	3.53bc	10696c	4090.5c	0.38b	93.6a	6.48a	4.13b	10974b	4484.7b	0.408a
90	96.7a	5.71ab	3.93a	11812b	5063.7a	0.43a	97.4a	6.55a	5.06a	11991a	5110.4a	0.431a
120	96.8a	6.08a	3.81ab	13357a	4478.4b	0.33c	96.8a	6.53a	5.07a	12247a	4464.7b	0.361b
Mean	91	5.5	3.45	9534	3468	0.35	91.6	6.38	4.26	9751	3597	0.35
$LSD_{0.05}$	7.14	0.39	0.35	921.7	339.6	0.028	5.4	0.32	0.45	936.1	367.4	0.0408
CV (%)	11.79	10.57	15.09	14.54	14.7	11.78	8.9	7.57	15.97	14.44	19.8	17.33

NB: Means in a column followed by the same letters are not significant at 5% probability levels.