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Response of Bread Wheat (Triticum aestivum L.)Varieties to Different Seeding Rate for Growth, Yield and Yield Components in Kombolcha District, North-Eastern Ethiopia

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Abstract
In Kombolcha district the productivity of wheat is for below the crop's potential mainly due to biotic and a biotic constraint. Seeding rate and local low yielding varieties are among the most important agronomic factors which need great emphasis for maximum yield of crops.Field experiment was conducted in Kombolcha in 2016/2017main growing season to investigate response of bread wheat varieties to different seeding rate for growth, yield and yield components. The experiment was laid out using randomized complete block design (RCBD) with three replications in factorial arrangement of three different seeding rates (100, 125 and 150 kg seed ha^{-1}) and four bread wheat varieties (Picaflor, Gassay, Dinknesh and Tay). The result sowed that days to 50% heading, days to 90% physiological maturity, plant height, spike length and thousand kernel weight were significantly ($p<0.01$) affected by the main effect of seeding rates and varieties whereas, effective tiller number at ($p<0.05$), biomass yield at ($p<0.05$), grain yield at ($P<0.01$) and harvest index at ($P<0.01$) was affected by only seeding rates. Number of kernels per spike also affected by seed rate at ($p<0.05$) significant level and varieties at ($p<0.01$) significant level. Moreover, the interaction effect of seed rate and variety also affected both days to 50% heading and spike length at ($p<0.01$) significant level but other parameters was not affected by the interaction effect of seed rate and variety. Therefore based on the result of growth, yield and yield component parameters and economic analysis result wheat sown at seeding rate of 100 kg ha^{-1} had better growth, yield and yield component and economically profitable compared to higher seeding rate (150 kg ha^{-1}). The interactive effect of pikaflore with 100 kg ha^{-1} seed rate was face superior for achieving higher yield in the study area. However, further study has to be done under different locations and seasons with a wide range of seed rates and varieties to exploit tentative recommendation of the present study.
Keywords: Bread wheat, Seed rate, Variety, Grain yield

1. INTRODUCTION

Wheat belongs to the grass family *Poaceae* and to the tribe *Hordea* in which several flowered spikelets are sessile and alternate opposite side of the rachis forming a true spike. Wheat (*Triticum aestivum* L) is one of the most important cereal crops globally and is a stable food for about one third of the world population (Hussain and Sheh, 2002). Wheat is grown annually on 1.66 million hectare of land in Ethiopia with a total production of 4.23 million tons with an average productivity of 2.54 t ha^{-1} which makes the country the second largest wheat producers in sub-Saharan Africa (CSA, 2015). Wheat provides more protein than any other cereal crops (Hussein *et al*., 2006). It is a major source of energy and proteins for population inhabiting most highlands in Ethiopia (Abera, 1991). Furthermore, wheat has been selected as one of the target crops in the strategic goal of attaining national food self-sufficiency, income generation, poverty alleviation and achieving socio-economic growth of the county (Mulatu, 2015).

Wheat is one of the most important small cereal crops in Ethiopia widely cultivated in wide range of altitudes. Most wheat producing area in Ethiopia lie between 6^{o} and 16^{o} N latitude and 35^{o} and 42^{o} E longitudes of an altitude range from 1500 to 3000 meters above sea level (masl). The most suitable agro-ecological zones, however, fall between 1900 to 2700 meters above sea level (Bekele *et al*., 2000). Wheat in Ethiopia is produced exclusively under rain fed conditions with rain fall amount ranging from 600 mm to 2000 mm. Currently, Oromia, Amhara, Southern Nations Nationalities and peoples region (SNNPR) and Tigray regions are the major wheat producing areas in Ethiopia. Amhara National Regional State is among the most important wheat growing areas of the country which accounts for 529609.63 hectare of the area coverage and 1195823.247 tons of the total production with an average productivity of 2.3 t ha^{-1} (CSA, 2015).

Besides, the total production of wheat in south wollo which accounts 4.2 % which is one of the major wheat producing zone in Amhara region next to east Gojam and north Gonder zones (ATA, 2014). In Kombolcha district, wheat is a major crop produced by small holder farmers and the total area coverage which accounts 34.9 % and 2127.3 tons of the total production with on average productivity of 2.1 t ha^{-1} (KWAO, 2015). However, its productivity is for below the crop's potential mainly due to biotic and a biotic constraint. Cultivation of local low yielding varieties, inadequate and erratic rainfall, poor agronomic practices, diseases and insect pests are among the principal limitations to wheat production in Ethiopia (Gorfu and Hiskias, 2000). Seeding rate is one of the most important agronomic factors which need great emphasis for maximum yield of crops. High seed rate increases the competition among crops for common resource particularly water, nutrients and sunlight which resulting in low quality and low yield. If low seed rate is used yield will be less due to lesser number of plants per unit area (Hameed *et al*., 2002).

The use of inappropriate seed rates by small holder farmers leads to low yield as compared to research field. This is due to higher seed rate which leads to higher competition, shorter spike length and lower number of grains per spike (Ejaz *et al.,* 2002). Besides, seed rate determine the crop vigor and ultimately yield (Korres and Froud, 2002). Reducing seed rate may result in more tillers and spike per plant and more spikelet per spike but in many cases reduced grain yield per hectare (Ozturk *et al.,* 2006). On the other hand, research results indicated that use of proper seed rate encourages nutrient availability, proper sun light penetration for photosynthesis, good soil environment for uptake of soil nutrients and water use efficiency; and all necessary for crop vigor and consequently increase the production and productivity of the crop (Alemayehu, 2015). This indicates that the need to conduct research to determine the optimal seed rate in each growing area as one of the important agronomic management to improve production and productivity of wheat.

A number of bread wheat varieties differing in height, maturity and tillering capacity have been developed in Ethiopia. However, the recommended seed rate for all the varieties being used across the country is 150 kg ha^{-1} (Jemal *et al*., 2015). Different organizations recommend different seeding rates. Moreover, there is a trend by farmers uses higher seed rates greater than150 kg ha^{-1} in the area. Hence, it is important to determine optimum seeding rates for released bread wheat varieties for the maximum yield of the crop. However, limited research has been done to evaluate different seeding rates of wheat varieties in the study area. Therefore, this study was initiated with the following specific objectives:

- to evaluate the effect of seed rates on the growth, yield and yield components of bread wheat varieties and
- to determine the optimum seeding rate for maximum productivity of bread wheat variety.

2. MATERIALS AND METHODS

2.1 Description of the Experimental Site

Rain fed field experiment was conducted at Metenie Keble farmers training center station in Kombolcha district, South Wollo Zone of the Amhara National Regional State during the 2016/2017 main cropping season to investigate the response of seeding rates on the growth, yield and yield components of bread wheat varieties (Figure 1). The site is situated at 11°5` N latitude and 39° 44`E longitude with an elevation between 1895 and 1954 meters above sea level. The average maximum annual temperature is 26.12 °C and the average minimum temperature is 8.8ºc (Figure 2). Based on 20 years meteorological data, the annual rainfall is 1025.5 mm (Figure 2). The rain season occurs during June to September and the maximum rain is received in the month of July and August.

The texture class of the soil is clay with a composition of 18% sand, 22% silt and 60% clay (Appendix Table I). The soil has a pH of 6.8 which is slightly acidic. According to FAO (2008), the soil pH is within the suitable range for the growth of most crops. Wheat grows under a wide range of soil pH, with permissible ranges of 5.5-7.0 (Gooding and Davies, 1997). According to Roy *et al.* (2006), the soil had low organic carbon content (1.25%) which indicates that it has low N supplying potential to plants as organic matter content is often used as an index of N availability. Cation exchange capacity (CEC) is an important parameter of soil, because it gives an indication of the type of clay mineral present in the soil and its capacity to retain nutrients against leaching. According to Hazelton and Murphy (2007), the soil had high CEC (39.5 c mol kg^{-1} soil). The soil had low available P (3.72mg kg^{-1}) (FAO, 2008). The soil had low total N (0.1%) content (TekalignTadese, 1991), which indicates that the nutrient is a limiting factor for wheat production in the area (Appendix Table I). Bread wheat, teff, wild Oat and chickpea are the dominant crops cultivated in their order of area coverage at present in the study area (KWAO, 2015).

2.2. Planting Material

Four bread wheat varieties where obtained from Adet Agriculture Research Center. The varieties have similar maturity date on average 125 days and ecological requirements (Table1). Urea (46% N) and NPS (19%N, 38 % P_2O_5 and 7% S) were used as sources of N, P and S respectively.

Table 1.Bread wheat variety used for the experiment.

Variety	Year of release	Breeder	Plant height (cm)	Grain yield t ha^{-1} on Station	Grain yield t ha^{-1} on farm	Altitudinal adaptation (masl)
Picaflor	2010	KARC	89-95	3.3-4.8	3.0-4.0	1500-2000
Gassay (HAR-3730)	2007	ADARC	84-97	4.4-5.0	3.5-4.7	1890-2800
Dinknesh (HAR-3919)	2007	SRARC	75-100	4.0-5.0	3.0-4.5	1900-2800
Tay (HAR-604)	2005	ADARC	85-102	2.5-6.1	3.4-5.8	1900-2800

Source: MOA, 2013.
ADARC= Adet Agriculture Research Center; KARC=Kulumsa Agriculture Research Center; SRARC=Sirinka Agriculture Research Center; masl= meters above sea level.

2.3. Treatments and Experimental Design
The treatments consisted of three seeding rate (100, 125, and 150 kg ha^{-1}) and four bread wheat varieties (Picaflor, Dinknesh, Gassay and Tay). The experiment was laid out with randomized complete block design (RCBD) in a factorial arrangement and replicated three times. The gross plot size of 2.40 m x3 m (7.2 m^2) with 0.3 m row spacing and a total of 7 rows were used. The net plots size was 1.5 m x2 m (3 m^2) leaving one outer most rows of both sides of each plot and 0.5 m row length at both ends as border. The distance between the plots and blocks were used 0.5 m and 1m apart respectively.

2.4. Experimental Procedure
2.4.1. Land preparation
The land was prepared following the conventional tillage practice by using, oxen driven local plow (Maresha) before planting the wheat varieties. Accordingly, the field was ploughed four times, the last ploughing was used for seed covering in accordance with the specifications of the design, a field layout was prepared and each treatment were assigned randomly to experimental plots.
2.4.2. Application of mineral fertilizer
The full rate of the NPS fertilizer (100 kg ha^{-1}) and one-third of the nitrogen fertilizer (33 kg ha^{-1} urea) were applied in basal application prior to planting for all plots and incorporated into the soil. The remaining 67 kg ha^{-1} urea was applied as side-dressing at mid tillering stage of the crop (35 days after emergence).
2.4.3. Sowing and Harvesting
Wheat seeds were sown by drilling in 3 m long rows in each plot placed 30 cm apart at the seed rate of as per treatment on July 14, 2016. Weeds were removed by hand weeding at early tillering, maximum tillering and booting stages of growth. Harvesting was done manually using hand sickles at physiological maturity of the crop.

2.5. Crop Data Collection and Measurements
Each crop growth, yield and yield components were measured from each net plot across the treatment level by using the following sampling and analytical procedures.
2.5. 1. Phenological parameters
Days to 50% crop emergency: It was recorded when 50% of the plants in each plot emerges.
Days to 50% heading per plot: It was recorded by counting number of days from the date of sowing until when 50% of the plants in a plot produced spikes above the sheath of the flag leaf that was determined by visual observation.
Days to 90% physiological maturity per plot: It was recorded by counting the number of days from date of sowing until when 90% of the plants changed green color to yellowish, loose its water content and attain to physiological maturity in each plot.
2.5.2. Growth parameters
Plant height (cm): Plant height was measured from 10 randomly selected plant samples per plot as the height from ground level to the tip of the spike excluding the owns. It will be recorded as the average of ten selected main tillers from each plot at maturity across the treatment level.
Spike length (cm): The main spikes from the ten sample spikes were measured in cm and the average represents the spike length in cm for each plot across the treatment level.
2.5.3. Yield and Yield components
Effective tiller number (ETN): The number of effective (fertile) tillers bearing spikes from two randomly selected 0.5m row length was counted from each plot at physiological maturity across the treatment level.
Number of kernels per spike (NKPS): Number of kernels per spike from the ten randomly selected spikes from the middle rows of each plot was taken.
Thousand kernels weight (g): Thousand grains were counted after harvesting at random from each plot and their weights were measured with accurate balance.

Biomass yield (t ha^{-1}): Total biomass or biological yield were measured by weighing the sun dried total above ground plant biomass (straw + grain) of the net plot and converted to ton per hectare.
Grain yield (t ha^{-1}): The grain yield were measured by taking the weight of the grains from the net plot area and converted to ton per hectare after adjusting the grain moisture content to 12.5%.
Straw yield (t ha^{-1}): Straw yield were determined by subtracting grain yield from total above ground biomass.
Harvest index (HI): It was computed as the ratio of grain yield to the grain plus straw of each plot expressed as a percentage.

2.6. Statistical Analysis

Data were subjected to analysis of variance using the general linear model (GLM) procedure of SAS 9.2 (SAS Institute, 2003).Whenever treatment deference was found to be significant difference among the treatment means was compared using Duncan's multiple range test at 5% level of significance. Correlation analysis was carried out by calculating simple correlation coefficients between yield and yield components. Economic analysis was performed following the CIMMYT partial budget analysis methodology (CIMMYT, 1988) to identify the economically profitable seed rates for the experimental tested varieties. The mean grain and straw yield data was adjusted down by 10% and subjected to partial budget analysis. Total costs that varied for each treatments was calculated and treatments were ranked in order of ascending total variable cost (TVC) and dominance analysis was used to eliminate those treatments costing more but producing a lower net benefit than the next lowest cost treatment. The prices of the inputs that were prevailing at the time of their use were considered for working out the cost of cultivation (Sale price of wheat grain ETB 7 kg^{-1}; Field price of wheat grain ETB 15 kg^{-1}; sale price of wheat straw ETB=0.50 kg^{-1}; Cost of fertilizer ETB 13 kg^{-1}; Cost of harvesting, threshing, winnowing ETB 20 per 100 kg for each; Packing and material cost Birr 10 per 100 kg; Transportation Birr 20 per 100 kg and labor cost ETB 100 per day per man) were considered and other input costs used as constant for all treatments. Net benefits per hectare were calculated by subtracting cost of production per hectare (TVC) from gross benefit per hectare. A treatment which is non-dominated and having the highest net benefit is said to be economically profitable (CIMMYT, 1988).

3. RESULTS AND DISCUSSION

3.1. Phenological Parameters

3.1.1. Days to 50% emergence

The analysis of variance indicated that the main factor of seed rate and variety did not show significant (p>0.05) difference on days to 50% crop emergence. Similarly, the interaction effect of seed rate and variety did not significantly influence days to 50% crop emergence (Appendix Table II).

3.1.2. Days to 50% heading

Days to 50% heading was significantly affected by both the main and interaction effect of seed rate and variety (Appendix Table II). The use of different seed rates resulted in variations in days to 50% heading of the four wheat varieties. The current results indicated that the mean for days to heading of tested varieties ranged from 53.44 days (Dinkenesh) to 69.88 days (Tay) variety. Plants grown at the highest seed rate of 150 kg ha^{-1} attained early heading than seed rate of 100 kg ha^{-1}and 125 kg ha^{-1}. The earliness to days to heading might be due to the higher competition to resources as the result plants no longer to stay in vegetative stage (Alemayehu, 2015). Though significant difference was observed between the highest and others two seed rates, the difference was more than five days (Table 2). Similar result was obtained by Gaffar (2007) who found that increasing sowing density from 200 up to 400 grains per meter square in wheat crop significantly decreased the number of days to 50% heading. This result also in agreement with Abiot (2017) who reported that days to 50% heading was delayed (62.88 days) when lower seeding rates (100 kg ha^{-1}) was used on the other hand, earlier days to 50% heading (60.8 days) was recorded from highest seeding rates.

In contrast, Jemale *et al.* (2015) reported that increasing seeding rates from 100-200 kg ha^{-1} grains caused a significant increase in the number of days from sowing to 50% heading in wheat. The delayed in days to 50% heading (73.67days) was recorded from Tay variety at 100 kg ha^{-1} seed rate while Dinknesh variety exhibited earliness to attain days to 50% heading (50 days) at 150 kg ha^{-1} seed rate (Table 2). Earliness for days to heading had the advantage to escape terminal moisture stress which is a good character to cope up with the rainfall variability in the growing area but the productivity potential and other important characters depend on the varieties. Therefore, varieties exhibiting earliness for days to heading might have such advantage in area where terminal moisture stress is as one problem of wheat production. This result is in agreement with the results reported by Tewodros *et al.* (2014) who noted that days to heading showed significant difference among wheat varieties.

Table 2. Interaction and main effects of seed rate and variety on days to 50 % heading of bread wheat.

Varieties	Seed rates (kg ha^{-1})			Varieties Mean
	100	125	150	
Picaflor	59.67^{g}	54.33^{i}	52.33^{j}	55.44^{c}
Gassay	65.67^{d}	64^{e}	61.33^{f}	63.67^{b}
Dinknesh	57.67^{h}	52.67^{j}	50^{k}	53.45^{d}
Tay	73.67^{a}	68.67^{b}	67.33^{c}	69.89^{a}
Seed rates Mean	64.17^{a}	59.91^{b}	57.74^{c}	
	SR	VAR	SR*VAR	
LCR	0.464	0.536	0.928	
CV (%)		0.1		

Means with the same letter(s) in the same column and rows of each trait are not significantly different at 5% probability level, CV (%) = Coefficient of variation in percent, LCR=Least critical range, SR= Seed rate and VAR= Variety.

3.1.3. Days to 90% physiological maturity

Analysis of variance indicated that days to 90% physiological maturity was significantly ($p<0.01$) influenced by the main effects of both varieties and seed rates. However, the interaction effect of variety and seed rate did not show significant influence on days to 90% physiological maturity (Appendix Table II). The data showed that increasing seed rate from 100 to 150 kg ha^{-1} decreased days to 90% physiological maturity. The higher seed rate (150 kg ha^{-1}) attained days to 90% physiological maturity date earlier than seed rate of 100 kg ha^{-1} and 125 kg ha^{-1} (Table 3). The earlier maturity observed with the seed rate of 150 kg ha^{-1} might be due to the increased plant population that increased intra-plant competition for nutrients and light which make plants stay no longer in vegetative stage. This may have also contributed to the reduction in grain filling period, because at higher seed rate heading and maturity hastened as compared to lower seed rate (Alemayehu, 2015). The result of this study is in line with that of Alemayehu (2015) and Abiot (2017) who reported that increasing seed rate from 100 to 150 kg ha^{-1} decreased days to 90% physiological maturity. The result is also in agreement with Melaku (2008) who reported that increasing levels of seed rate promoted early physiological maturity of teff. Similarly, Worku (2008) also noted that increasing the levels of seeding rate hastened physiological maturity of bread wheat. In contrast, Seleiman *et al*. (2010) and Jemale *et al.* (2015) reported that increasing seeding rates from 250-400 m^{-2} and 100-200 kg ha^{-1} grains prolong the number of days from sowing to maturity of wheat, respectively.

Variety also had significant effect on physiological maturity. Tay and Gassay varieties were late maturing which took the longest duration 107.22 and 105.33 days, respectively, whereas Dinknesh and Picaflor variety took the shortest durations 93.33 and 94.67 days, respectively (Table 3). This result is in agreement with the results reported by Shahzad *et al*. (2007) who reported that the days to physiological maturity of wheat cultivars varies due to inherent differences between cultivars. In conformity with the present result Geng (1984) reported that differences in maturity can be caused by the combined effect of genetic and environmental factors during their growth and grain filling of the crops.

Table 3. Main effect of seeding rate and variety on days to 90 % physiological maturity of bread wheat.

Varieties	DPM (days)	Seed rates (kg ha^{-1})	DPM (days)
Picaflor	94.67^{c}	100	103.58^{a}
Gassay	105.33^{b}	125	99.50^{b}
Dinknesh	93.33^{d}	150	97.33^{c}
Tay	107.22^{a}		
LCR	1.258		1.09
CV (%)		1.285	

Means with the same letter(s) in the same columns and row of each parameter are not significantly different at 5% probability level, CV (%) = Coefficient of variation in percent, DPM = Physiological maturity date, LCR=Least critical range.

3.2. Growth parameters

3.2.1. Plant height

The analysis of variance revealed that the main factors of variety and seeding rate had significant ($p<0.01$) effect on plant height. However, the interaction effect of seed rate and variety was not significant (Appendix Table III). Plant height was reduced slightly at the highest seeding rates. The highest plant height (80.07 cm) was recorded from 100 kg ha^{-1} seed rate whereas the lowest plant height (74.92 and 72.92 cm) was recorded from a seed rate of 125 and 150 kg ha^{-1}, respectively, which were statistically at par with each other (Table 4) . This could be because of at the highest seeding density increased intra-plant nutrient competition may have also contributed to the reduction in plant height.

The result obtained from this study is in agreement with Toaima *et al*. (2000) and Jemal *et al*. (2015) who reported that plant height was significantly decreased as seed rate increased in wheat crop. Similarly, Baloch *et al*. (2002) also reported that the maximum plant height (103.3 cm) was observed with the seed rate of 150 kg ha^{-1} followed by 175 kg seed ha^{-1} which produced plants of 93.2 cm in wheat. However, the result of this study is in contrast with that of Selieman *et al*. (2010) who reported that increase seeding rate a slight increment in the heights of the wheat. Haile *et al*. (2013) also reported that the height of plants grown at the lowest seeding rate (100 kg ha^{-1}) was significantly lower than the heights of plants grown at seeding rates ranging from 125-175 kg ha^{-1}. In addition, Ghulam *et al.* (2011) reported that low seeding rate less competition for space, nutrients and water and thus short erect plants and minimum or no lodging was noted.

In the case of variety the tallest plants (85.106 cm) were observed in variety Tay and the shortest plants (67.859 cm) were observed in variety Picaflor (Table 4). The difference in plant height of the varieties should be attributed to the difference in their genetic makeup (Jemal *et al*., 2015). The current result is in agreement with the results of Abdul *et al.* (2014) who reported that tallness in wheat plants is mostly associated with the genetic makeup of the variety. Similarly, Shahzad *et al.* (2007) who reported that height of the crop is mainly controlled by the genetic makeup of a genotype and it can also be affected by the environmental factors**.**

Table 4. Main effects of seeding rate and variety on plant height and main effect seed rate on effective tiller number of bread wheat.

Varieties	PH (cm.)	Seed rates (kg ha^{-1})	PH (cm.)	Effective tiller number/m^2
Picaflor	67.86^d	100	80.07^a	109.25^a
Gassay	79.99^b	125	74.92^b	100.17^{ab}
Dinknesh	70.93^c	150	72.92^b	96.58^b
Tay	85.11^a			
LCR	2.91		2.52	9.21
CV (%)		3.92		10.66

Means with the same letter(s) in the same columns and row of each parameter are not significantly different at 5% probability level, CV (%) = Coefficient of variation in percent, PH = Plant height, LCR=Least critical range.

3.2.2. Spike length

The statistical analysis results revealed that spike length was significantly ($p<0.01$) affected by seed rate and variety. The interaction effect of seed rate and variety had also highly significant ($p<0.01$) effect on spike length (Appendix Table III). Except variety Gassay, spike length of the other three varieties decreased significantly in response to increasing the rate of seed rate from 100 to 150 kg seed ha^{-1} (Table 5). The tallest spikes of three varieties were attained at 100 kg ha^{-1}. For Gassay, a similar decreased occurred in spike length with the increase in the rate of the seed from 100 to 125 and then the longest spike was attained at 150 kg seed ha^{-1} (Table 5). The longest spike length of (8.68 cm) was recorded from variety Tay at the plot treated with seed rate of 100 kg ha^{-1} while the shortest spike length (5.53 cm) was obtained from variety Picaflor with a seed rate of 150 kg ha^{-1} (Table 5). There was also significant difference observed among seed rates of 100 kg ha^{-1} and 125 kg ha^{-1} for variety Dinknesh and Tay and also 125 kg ha^{-1} and 150 kg ha^{-1} for Picaflor and Gassay varieties in spike length (Table 5).

Table 5. Interaction effect of seeding rate and variety on spike length (cm) of bread wheat

Varieties	Seed rates (kg ha^{-1})			Mean of variety
	100	125	150	
Picaflor	7.22^c	6.77^c	5.53^d	6.5056^b
Gassay	8.08^b	7.72^b	8.22^a	8.0056^a
Dinknesh	6.90^c	5.88^d	5.58^d	6.1222^c
Tay	8.68^a	7.80^b	7.73^b	8.0722^a
Mean of seed rate	7.7208^a	7.0417^b	6.7667^c	
	SR	VAR	SR*VAR	
LCR	0.24	0.277	0.48	
CV (%)		3.95		

Means with the same letter(s) in the same columns and row of each parameter are not significantly different at 5% probability level, CV (%) = Coefficient of variation in percent, SL = Spike length, LCR=Least critical range, SR=Seed rate and VAR=Variety.

At the lower seed rate the spike length was higher compared to higher seed rate. This could be due to the availability of ample resources required by the wheat crop for growth and development and there is presence of more free space between plants that are used to avoid competition between plants in the lower seeding rate rather than the higher seeding rate. This could have been reflects in lower rates of photosynthesis and growth of those plants, which was expressed in noticeable decrease in spike length in the higher seed rate (Seleiman, 2010). However, the varietal difference in spike length is governed by genetic makeup of the genotype and the environmental effect (Shahzad *et al.*, 2007). This result is in agreement with Jemal *et al*. (2015) who reported that with increasing seeding rate from 125 kg ha^{-1} - 200 kg ha^{-1}, the spike length was declined by 8.57%. Similarly, Alemayehu (2015) reported that increasing seeding rate from 100 kg ha^{-1} - 150 kg ha^{-1} decrease the spike length by 3.35%. Furthermore, Seleiman *et al.* (2010) noted that the shortest and highest spikes length was recorded by using the highest and lowest seeding rate, respectively. In addition to this, Gafaar (2007) studied the growth, yield and its components and quality characters of four bread wheat varieties as affected by the sowing densities, and found that increasing sowing density from 200 up to 400 grains per m^2 significantly increased each of plant height, number of spikes per m^2 and yields, but significantly decreased the number of days to 50% heading, spike length, number of spikelet per spike, number of kernels per spike and 1000-kernel weight.

3.3. Yield and Yield Components

3.3.1. Effective tiller number

Crop yields are generally dependent upon many yield contributing agents. Among these, number of effective tillers is the most important because of the final economic yield of most of the cereals is determined by the number of fertile tillers. Analysis of variance indicated that the main effect of seed rate showed significant ($p<0.05$) effect on effective tiller number. However, the main effect of variety and interaction effect did not show significant difference on effective tiller number (Appendix Table III). The maximum productive tillers (109.25) were recorded when plots were seeded with 100 kg ha^{-1}, While minimum productive tiller (96.58) were recorded from a seed rate of 150 kg ha^{-1} (Table 4). The higher population in 150 kg ha^{-1} might have resulted in more intra-specific competition for limited resources, thus late growing tillers might be died because of high competition and resulted in low number of productive tillers would formed per 1 m length row.

Higher seed rate produced many number of tillers but it might not produce many numbers of effective tillers per unit area due to competition of tillers for growth factors that lead to the production of low numbers of productive tillers per unit area. The current result is in agreement with Alemayehu (2015) who reported that maximum productive tiller was recorded from minimum seed rate and vice versa. Similarly, Rahel and Fekadu (2016) reported that maximum productive tiller was recorded from lower seed rate than higher seed rate because of productive tiller per plant higher at lower seed rate than higher seed rate. Furthermore, Sarker *et al*. (2007) reported that at higher seed rates, competition among the plants started before maximum tillering stage, which was manifested in low increase in tiller production. However, the current result is in contrast with Jemal *et al*. (2015) who reported that maximum effective tiller number was recorded from the higher seed rate than the lower seed rate. Moreover, Iqbal *et al*. (2010) found that maximum productive tillers at 200 kg ha^{-1} seed rates than at lower seed rates. The present result also in contrast with Ali *et al.* (2010), Seleiman *et al***.** (2010) who stated that increase seeding rate up to 350 or 400 grains m^{-2} increased number of tillers per m^{-2} but significantly decreased grain filling rate.

3.3.2. Number of kernels per spike

The potential of wheat spike is determined by the grains $spike^{-1}$ which is an important yield component of grain yield. The current result revealed that the main effect seed rates showed significant ($p<0.05$) difference on number of kernels per spike. While, the main effect of variety had highly significant ($p<0.01$) effect on number of kernels per spike. However, the interaction effect of seed rate and variety did not show significant difference (Appendix Table IV). Maximum number of kernels $spike^{-1}$ (41.33) was obtained from the plot that received seed rate of 100 kg $ha^{-1}$and minimum number of kernels $spike^{-1}$ (37.03) obtained from the plot that received seed rate of 150 kg ha^{-1} (Table 6). As the seed rate was increased from 100 kg ha^{-1} to 150 kg ha^{-1}, the number of kernels per spike decreased by 10.42%. This is because at higher plant density most grains would fade at early stage because of competition between growing grains to absorb preserved matters and as the result low grains per spike would be produced (Rahim *et al.*, 2012). The result of this study is consistent with the findings of Rahim *et al.* (2012) who reported that higher seed rates produced significantly decreased number of grains (kernels) $spike^{-1}$. Similarly, Jemal *et al*. (2015) reported that seed rates up to 150 kg ha^{-1} gave the higher number of kernels per spike across varieties while seed rates of 175 and 200 kg ha^{-1} gave fewer kernels per spike. Furthermore, Gaffar (2007) reported that increasing sowing density from 200 up to 400 grains per m^2 significantly decreased the number of spikelet per spike and number of kernels per spike.

In case of variety the current result indicated that variety Gassay produced the highest number of kernels per spike (41.66) while the smallest number of kernels per spike (34.19) was recorded from Dinknesh variety (Table 6). Statically variety Picaflor, Gassay and Tay had similar kernels per spike. The result of this study is in line with Majid and Mohsen (2012) who reported that significant differences were found among varieties in terms of the number of kernels spike-^{1}. However, the current result is in contrast with Igorpirez *et al*. (2013) who stated that the wheat genotypes did not influence the number of grains per ear obtained in distinct seeding densities.

Table 6. Main effect of seed rates and variety on number of kernels per spike and thousand kernels weight of bread wheat.

Varieties	NKPS	TKW(gm)	Seed rates (kg ha^{-1})	NKPS	TKW (gm)
Picaflor	38.48^{a}	42.3^{a}	100	41.33^{a}	41.3^{a}
Gassay	41.66^{a}	41.3^{a}	125	38.56^{ab}	39.6^{b}
Dinknesh	34.19^{b}	40.7^{a}	150	37.03^{b}	39.0^{b}
Tay	41.57^{a}	35.6^{b}			
LCR	3.344	1.53		2.896	1.325
CV (%)			8.77		3.91

Means with the same letter(s) in the same columns and row of each parameter are not significantly different at 5% probability level, CV (%) = Coefficient of variation in percent, NKPS = Number of kernels per spike, LCR=Least critical range, TKW = Thousand kernels weight.

3.3.3. Thousand kernels weight

Thousand kernel weight is an important yield determining component of wheat. The analysis of variance revealed that the main effect of seed rate and variety had highly significant ($p<0.01$) effect on thousand kernel weight. However, the interaction effect of seed rate and variety did not show significant effect on thousand kernel weight (Appendix Table IV). Maximum thousand kernel weight (41.3 gm.) was recorded from a seed rate of 100 kg ha^{-1}, while minimum thousand kernel weight was recorded from a seed rate of 150 kg ha^{-1} which is (39 gm.) followed by 125 kg ha^{-1} which is (39.6 gm) (Table 6). Statically seed rate of 125 kg ha^{-1} and 150 kg ha^{-1} had similar result. Increasing seeding rate from 100 kg ha^{-1} to 125 kg ha^{-1} and 150 kg ha^{-1}, thousand kernel weights decreased by 4.2% and 5.6%, respectively. This could be due to high density caused to increasing total number of tillers and as a result competition would increase and little photosynthesis would be available to grain filling and finally thousand kernels weight would be reduced. The current result is in agreement with Spink *et al.* (2000), Baloch *et al.* (2010) and Laghari *et al.* (2011) who reported that the higher seed rate in bread wheat resulted in decreased 1000-kernel weight. Furthermore, Jemal *et al*. (2015) reported that increasing seeding rate significantly decrease 1000-kernel weight. However, the current result is in contrast with Veselinka *et al*. (2014) who reported that 1000-kernels weight was increased with increasing seeding rate in studied varieties of winter wheat. Rahel and Fekadu (2016) also reported that different seeding rate did not significantly affected thousand kernel weight. The result also showed that Picaflor variety recorded maximum thousand kernel weight (42.3 gm.) while minimum thousand kernel weight (35.6 gm.) was recorded from Tay variety (Table 6). This could be due to the late maturity of variety Tay relative to other three tested varieties which might have suffered from unfavorable environmental condition late in the growing season. As a result it leads to decrease grain filling of bread wheat.

3.3.4. Biomass yield

Result of the analysis of variance indicated that the main effect of seed rate showed significant ($p<0.05$) effect on biomass yield. However, the main effect of variety and the interaction effect did not show significant effect on biomass yield (Appendix Table V). Maximum biological yield (9.535 t ha^{-1}) were recorded at seeding rate of 100 kg ha^{-1} whereas minimum biomass yield (8.25 t ha^{-1}) was recorded at seed rate of 150 kg ha^{-1} (Table 7). This is because biomass yield mostly related with plant height and tiller number. The current result revealed that maximum plant height and effective tiller number was recorded from the lower seed rate than the higher seed rate, this leads to maximum biomass yield recorded at lower seed rate. The current result is in agreement with the findings of Rahel and Fekadu (2016) who reported that maximum biomass yield was recorded at seeding rate of 100 kg seed ha^{-1} than 125 and 150 kg ha^{-1}. Similarly, Allam (2003) reported that, in wheat higher seed rates, higher number of plants and tillers failed to produce higher biomass yield. However, the current result is in contrast with Alemayehu (2015) and Jemal *et al*. (2015) who reported that maximum biological yield was recorded at higher seed rate than lower seed rate.

Table 7. Main effect of Seed rate on Biomass yield, Grain yield and Harvest index of wheat at Kombolcha, north eastern Ethiopia in 2016.

Seed rates(kg ha^{-1})	Biomass yield (t ha^{-1})	Grain yield (t ha^{-1})	Harvest index (%)
100	9.535^{a}	3.69^{a}	38.64^{a}
125	8.58^{ab}	3.03^{b}	35.14^{b}
150	8.25^{b}	2.86^{b}	34.48^{b}
LCR	1.185	0.5264	1.745
CV (%)	15.93	19.46	5.71

Means with the same letter(s) in the same columns and row of each parameter are not significantly different at 5% probability level, CV (%) = Coefficient of variation in percent, LCR=Least critical range.

3.3.5. Grain yield

Grain yield is a function of the integrated effect of the yield components which were influenced differently by growing conditions. The analysis of variance showed that the main effect of seed rate showed highly significant ($p<0.01$) effect on grain yield. However, the main effect of variety and the interaction effect of seed rate and variety did not show significant effect on grain yield (Appendix Table IV). Sometimes this may happen due to similar environmental condition for the growing season of the varieties as a result the yield is not far apart each other and also the interaction was not show significant change. It is also the productivity range of Picaflor, Dinknesh and Gassay varieties are not far apart each other and in case of Tay variety the productivity range is higher than the other three verities (MOA, 2013). But in the current result the yield of Tay variety decrease and approach to the range of the three varieties due to decreasing of moisture in the grain filling period because of it might have suffered from unfavorable environmental condition late in the growing season and it is not ease to take nutrients. Maximum grain yield (3.69 t ha^{-1}) was recorded from a seed rate of 100 kg ha^{-1} (Table 7). This could be due to its longest spike length which plays a vital role in wheat on the number of grains per spike and finally the yield. Thousand kernel weight also plays a vital role for increasing grain yield. The minimum grain yield (2.86 t ha^{-1}) was recorded from a seed rate of 150 kg ha^{-1} (Table 7).

This is because in the higher seed rate there is a presence of competition between plants for common resource like moisture, nutrients and also light. This leads to little partitioning of photo assimilates to the harvested part of the plant because the yield of crops depends on the translocation of assimilates from the leaves. The current result is in agreement with Rahel and Fekadu (2016) who reported that the maximum grain yield 2.78 t ha^{-1} was obtained in plots seeded with 100 kg seed ha^{-1} rather than a seed rate of 75, 125 and 150 kg ha^{-1}. Similarly, Rafique *et al.* (1997), Chaudhary *et al*. (2000) and Ali *et al*. (2010) explained that lower seeding rates significantly increased the number of grains and vice versa. However, the current result is in contrast with Alemayehu (2015) who reported that maximum grain yield recorded from a seed rate of 150 kg ha^{-1} and variety was not show significant effect on grain yield.

3.3.6. Straw yield

The current result showed that the main effect of seed rate and variety did not have significant effect on straw yield. Similarly, the interaction effect also did not affect straw yield (Appendix Table V).

3.3.7. Harvest index

The analysis of variance indicated that the main effect of seed rate showed highly significant ($p<0.01$) difference on harvest index. However, the main effect of variety and the interaction effect of seed rate and variety did not show significant difference (Appendix Table V). Maximum harvest index (38.64 %) was recorded at seeding rate of 100 kg seed ha^{-1}, while minimum harvest index (35.14 %) and (34.48 %) was recorded at seeding rate of 125 kg ha^{-1} and 150 kg ha,$^{-1}$ respectively, which is statically similar (Table 7). Harvest index had inter- relationship with grain yield and above ground biomass yield that the highest harvest index was the result of greater grain yield. The current result is in agreement with the findings of Richards *et al.* (2002) who demonstrated that harvest index is indicators of the genetic potential of plant to produce economic yield, high harvest index under control treatment can be accompanied with high grain yield under water stress. Similarly, Koocheki *et al*. (2006) reported that a positive relationship found between grain weight and harvest index. It means that increased of grain weight results increased harvest index.

3.4. Correlation Analysis

Correlation analysis among growth parameters, yield and yield related traits is indicated in Table 8. The current analysis result showed that the growth parameters plant height and spike length were positively correlated with effective tiller number (r=0.18, 0.29), number of kernel per spike ($r=0.74^{**}$, 0.9^{**}), biomass yield (r=0.04, 0.22^{*}) and harvest index (r=0.46, 0.56) respectively. However, thousand kernel weight was negatively correlated with plant height (r= -0.5) and spike length (r= -0.3) (Table 8).

Grain yield was positively correlated with plant height (r=0.18), spike length (r=0.35) and significantly correlated with effective tiller number ($r=0.6^{*}$), number of kernel per spike ($r=0.58^{*}$), thousand kernel weight ($r=0.7^{**}$), biomass yield ($r=0.96^{**}$) and harvest index ($r=0.81^{**}$). This indicated that increasing those attributes, invariably resulted increased in grain yield. In most of the previous studies, similar results have been reported by Mehasen *et al*. (2009), Ahmadi *et al*. (2011), Haile *et al*. (2013) and Reza Yadi *et al.* (2016). The same as true for biological yield and harvest index which was positively correlated with growth and yield component parameters, straw yield and with each other (Table 8).

Table 8. Simple correlation analysis among growth, yield and yield component parameters of bread wheat.

	PH	SL	ETN	NKPS	TKW	BMY	GY	SY	HI
PH	1								
SL	0.89**	1							
ETN	0.18	0.29	1						
NKPS	0.74**	0.9**	0.45	1					
TKW	-0.5	-0.3	0.19	-0.02	1				
BMY	0.04	0.22*	0.57*	0.52	0.71**	1			
GY	0.18	0.35	0.6*	0.58*	0.7**	0.96**	1		
SY	-0.1	0.08	0.49	0.43	0.67	0.97**	0.3	1	
HI	0.46	0.56	0.51	0.56	0.46	0.63*	0.81**	0.43	1

**,* Correlation is significant at the 0.01 and 0.05 significant difference level respectively. PH=Plant height, SL=Spike length, ETN=Effective tiller number, NKPS=Number of kernel per spike, TKW=Thousand kernel weight, BMY=Biomass yield, GY=Grain yield, SY=Straw yield, HI=Harvest index.

3.5. Economic Analysis

The result of economic analysis showed that the maximum net benefit (ETB 28469 ha^{-1}) with an acceptable MRR was obtained from 100 kg ha^{-1} seed rate for Picaflor variety (Table 9). This has resulted in the net benefit advantage of birr 12090 over the least benefit treatment (Tay 125 kg ha^{-1}) with net benefit of (birr 16379). In case of Gassay variety the maximum net benefit (ETB 23702 and 16669 ha^{-1}) with an acceptable MRR was obtained from 100 and 125 kg ha^{-1} seed rate, respectively (Table 12). This has resulted in the net benefit advantage of (birr 7323 and 290) over the least benefit treatment (Tay 125 kg ha^{-1}) with net benefit of (birr 16379) (Table 9). The maximum net benefit (ETB 20695 and 17550 ha^{-1}) with an acceptable MRR was obtained from Dinknesh and Tay varieties with seed rates of 100 kg ha^{-1} respectively (Table 9). This has resulted in a net benefit advantage of birr 4316 and 1171 over the least benefit treatments (Tay 125 kg ha^{-1}) respectively. However other treatments were eliminated by dominance analysis (CIMMYT, 1988) since the net benefit obtained decreased as the cost increased. Therefore in the study area a seed rate of 100 kg ha^{-1} is optimum tentatively within acceptable marginal rate of return and very large net benefit for all tested varieties in a seed rate point of view. Based on the four tested varieties, Pikaflore variety is more preferable for maximum productivity and production in the study area. Variety Gassay with a seed rate of 125 kg ha^{-1} also profitable with an acceptable marginal rate of return and recommended as second option tentatively.

Table 9. Economic analysis for response of seeding rate on yield of bread wheat varieties.

Varieties	SR (kg /ha)	AVGY (Kg /ha)	AJGY (Kg /ha)	AVSY (Kg /ha)	AJSY (kg /ha)	GB (Birr /ha)	TVC Birr /ha)	NB (Birr /ha)	MRR (%)
Tay	125	2930	2637	5330	4797	27688	11309	16379	-
Gassay	125	2970	2673	5220	4698	28066	11397	16669	320
Tay	100	3100	2790	5300	4770	29295	1174	17550	230
Dinknesh	100	3440	3096	5230	4707	32508	12157	20695	763
Gassay	100	3820	3438	5650	5085	36099	12497	23702	884
Picaflor	100	4400	3960	7200	6480	41580	13111	28469	776

Were SR=Seed rate, AVGY=Average grain yield, AJGY=Adjusted grain yield, AVSY =Average straw yield, AJSY=Adjusted straw yield, GB=Gross benefit, MRR= Marginal rate of return, NB=Net benefit and TVC=Total variable cost.

4. SUMMARY AND CONCLUSION

Wheat is one of the most important cereal crops globally and is a stable food about one third of the world population. It has been selected as one of the target crops in the strategic goal of attaining national food self- sufficiency, income generation, poverty alleviation and achieving socio-economic growth of the county. In Kombolcha district, wheat is a major crop produced by small holder farmers. However, its production and productivity is low due to the use of inappropriate seed rate and local low yielding varieties in the study area. This indicates that the need to conduct research and determine the optimum seeding rate for maximum productivity of bread wheat crop. Therefore, this study was conducted at kombolcha, north eastern Ethiopia to investigate response of bread wheat varieties to different seeding rate for the growth, yield and yield components with the objectives of to evaluate the effect of seeding rate on the growth, yield and yield components of bread wheat variety and to determine the optimum seeding rate for maximum productivity of bread wheat varieties.

The result of this study revealed that the main effect of seed rate and variety showed significant effect on days to 50% heading and 90 % physiological maturity. The use of 150 kg ha^{-1} seeding rate attained early heading than seed rate of 100 kg ha^{-1}and 125 kg ha^{-1}. Among the varieties, Tay had delayed heading (73.67days) while

Dinkenesh variety exhibited early heading (50 days). The higher seed rate (150 kg ha^{-1}) attained early maturity than seed rate of 100 kg ha^{-1} and 125 kg ha^{-1}. Plant height, spike length, number of kernel per spike and thousand kernel weight was also affected by both the main effect of seed rates and varieties. The use of 100 kg ha^{-1} seeding rate increases those growth and yield component parameters rather than higher seed rates (150 kg ha^{-1}). Days to 50% heading and spike length also affected by the interaction effect of seed rate and variety. However, effective tiller number, biomass yield, grain yield and harvest index were affected by only seeding rates and were not affected by the main effect of variety and interaction effect. The correlation analysis indicated positive relation among most of the yield components. The use of 100 kg ha^{-1} seed rate gave maximum net benefit and economically profitable for all tested varieties. For variety Gassay a seed rate of 125 kg ha^{-1} also gave maximum net benefit. The presence of significance difference among seeding rates and varieties in most parameters suggested that the importance of using appropriate seed rate and improved varieties to increase yield of bread wheat in the study area. Therefore based on the result of growth, yield and yield component parameters and economic analysis result, wheat sown at seeding rate of 100 kg ha^{-1} had better growth, yield and yield component and economically profitable compared to higher seeding rate (150 kg ha^{-1}). The interactive effect of pikaflore with 100 kg ha^{-1} seed rate was face superior for achieving higher yield in the study area.

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