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Effects of Seeding Rate and Row Spacing on Yield and Yield Components of Bread Wheat (Triticum Aestivum L.) in Gozamin District, East Gojam Zone, Ethiopia

Abiot Mekonnen
Department of Plant Science, Bahir Dar University, Bahir Dar, P.O.Box 26, Ethiopia

Abstract

Bread wheat (Ttriticum aestivum L.) is the most important crop in East Gojam Zone and in Ethiopia as well. However, its productivity is very low as compared to the productivity of world bread wheat which is attributed to poor agronomic practices like inappropriate seeding rate, improper adjustment of row spacing, and other factors. Therefore, a field experiment was conducted at Yebo Farmers Training Center (FTC) in Gozamin District, in East Gojam zone, during 2015 main cropping season. Four levels of seeding rates (100, 125, 150, and 175 kg ha^{-1}) and three row spacings (20, 25, and 30 cm) were tested in factorial arrangement in randomized complete block design (RCBD) with three replications. Phenological, growth, yield and yield related data were collected and their ANOVA was analyzed using SAS 9.1software. Mean separation for significant parameters was done by using least significant difference method. The results showed that almost all the agronomic parameters like days to heading, days to physiological maturity, plant height, effective tiller numbers, spike numbers, biomass yield, grain yield, thousand kernels weight and harvest index were significantly ($p<0.05$) affected by the main effect of seeding rate and row spacing. Whereas all yield and yield components of bread wheat were not affected by the interaction effect of seeding rate and row spacing. The results of this study indicated the importance of using appropriate seeding rate and row spacing to increase yield of bread wheat in the study area. Hence, Seeding rate of 150 kg ha^{-1} gave higher grain yield (4462.10 kg ha^{-1}) followed by 175 kg ha^{-1}. Among row spacings 20 cm performed better (4377.8kg ha^{-1}) as compared to other spacings (3552.3 -3690.1kg ha^{-1}). Based on the agronomic performance and yield result of this study, 150 kg ha^{-1} seeding rate and 20 cm row spacing are preferable. However, further study has to be done under different seasons and locations to exploit the recommendation of the present study.

Keywords: Bread wheat; grain yield; row spacing; seeding rates

1. INTRODUCTION

Bread wheat (*Triticum aestivum L.*) is an annual crop plant belonging to the family *Poaceae* (grass family) and native to the Mediterranean region and southwest Asia (Gibson and Benson, 2002). It is one of the several species of cultivated wheat, now grown in temperate climates worldwide. Currently, it is also becoming most important cereals grown on a large scale in the tropical and sub tropical regions of the world (Onwueme and Sinha, 1999; Gibson and Benson, 2002). The importance of wheat crop in the world trade is greater than that of all other crops produced (FAO, 2014). Wheat is mainly grown in the highlands of Ethiopia, which lie between 6 and 16°N and 35 and 42°E, at altitudes ranging from 1500 to 2800 meters above sea level and with mean minimum temperatures of 6^{o}C to 11^{o}C (Hailu Gebremariam 1991; MoA, 2012; Gashaw Tadesse *et al*., 2014).

There are two types of wheat grown in Ethiopia; bread wheat and durum wheat. Studies revealed that, currently bread wheat covers about 60% of the total wheat area from a15% in 1967 and a 40% in 1991, while durum wheat covers about 40% from an 85% in 1967 and a 60% in 1991 (Eyob Bezabeh *et al.,* 2015). Bread wheat is one of the most staple food crops in the world and is one of the most important cereals cultivated in Ethiopia (Amare Aleminew *et al.,* 2015). Ethiopia is the second largest wheat producer in Sub-Saharan Africa next to South Africa with the cultivated land of 1.6 million ha which accounts 13.5 percent of the national grain area (CSA, 2013). Total wheat production in Ethiopia during 2012/13 *meher* season was 3.4 million metric tons, which is accounting for 15 percent of the total grain production in the country (CSA, 2013; Gashaw Tadesse *et al*., 2014). It ranks fourth after tef (*Eragrostis tef*), maize (*Zea mays*) and sorghum (*Sorghum bicolor*) in area coverage and third in total production (CSA, 2014). Bread wheat is also one of the most important crops in Amhara Region and it is the third important crop next to tef and barley in area coverage and second in productivity (1640 kg ha^{-1}) after maize (2350 kg ha^{-1}). The total wheat cultivated area and production in the Amhara Region in 2014 were reported as 493,395.00 ha (27% of the country's coverage) and 1,626,604.5 tons, with the productivity of 2100 kg ha^{-1} (CSA, 2014). Similar to the national and regional pictures, bread wheat in East Gojam Zone of the Amhara Region is the second producing crop next to tef in the area coverage and it is third in productivity (1350 kg ha^{-1}) after maize and sorghum (CSA, 2014). While, in Gozamin District of East Gojam Zone, bread wheat is the first important crop in area coverage followed by tef and maize (GWAO, 2014).

Bread wheat in Ethiopia is used in different forms such as bread, porridge, soup and roasted grain. In addition to the grain, the straw of bread wheat is used for animal feed, thatching roofs and bed decking. In spite of the its tremendous importance, wheat production in Ethiopia faced immense production constraints that are affecting both its yield potential and industrial quality (Amare Aleminew *et al.,* 2015).

Hence, the average productivity of wheat in Ethiopia is very low; about 2400 kg ha^{-1} as which is much below that of the world's average about 2900 kg ha^{-1} (Amare Aleminew *et al.,* 2015).Wheat productivity in Ethiopia is even much below that of Kenya and African average by 29 and 13%, respectively (FAO, 2014b). Due to a number of constraints such as inappropriate use of seeding rate, fertilizer rate and row spacing, soil fertility degradation, soil erosion, and occurrence of different pests, the average productivity of wheat in Ethiopia is very low. Although different improved bread wheat varieties such as HAR-1685, HAR-604, Kakaba, Danphe, Digalu, Shorima, Huluka and others are produced widely in the country , the actual productivity of the varieties is still low due to improper utilization of agronomic practices including seeding rate and row spacing. Seeding rate has significant influence on majority of agronomic traits of bread wheat (Nizamani *et al.,* 2014). Bread wheat sowing at the optimum seeding rate and at the appropriate row spacing significantly enhance the number of grains per spike , the spike length, grain weight per spike and 1000- grain weight and then finally produce high grain yield (Iqbal, 2010).

In other words, optimum seeding rate and suitable cultivars play an important role in achieving potential yield of bread wheat (Nizamani *et al.,* 2014). But seeding rate above or below the optimum may reduce the yield significantly (Peter *et al*., 1988). Row spacing plays a significant role on growth, development, and yield of bread wheat at its optimum level beside it provides scope to the plants for efficient utilization of solar radiation and nutrients (Mali and Choudhary, 2012).

Optimum seeding rate and proper adjustment of row spacing are the most important production factors for higher grain yield as well as for quality crop. Hence, a research to evaluate different seeding rates and row spacings is found very important to enhance the productivity of bread wheat in the study area. Previously recommended seeding rates and row spacings for bread wheat also have to be evaluated to validate farmers' practices and take further action based on evidence-based results. Therefore, this experiment was proposed with the following core objectives:

- To evaluate the effect of different row spacing on yield and yield components of bread wheat in Gozamin District, East Gojam Zone, Ethiopia
- To determine the optimum seeding rate of bread wheat in the study area
- To assess the interaction effects of seeding rate and row spacing on yield and yield components of bread wheat in the study area
- To suggest the recommendable seeding rate and row spacing based on economic feasibility in the study area

2. MATERIALS AND METHOD

2.1 Experimental Site

The study was conducted in 2015 main cropping season at Yebo kebele farmers training centre (FTC) under field condition, in Gozamin District of East Gojam Zone, Amhara National Regional State. The District is located at 10^{o}2' – 10^{o}8' North and 37^{o}3' – 38^{o}1' East at about 300 km distance from Addis Ababa in Northwest direction. Yebo *kebele* farmers training centre is also located at 10^{o}30' North and 37^{o}69' East at about 10 kilometres from the District and Zonal capital, Debre Markos town in south west direction. The District covers a total land area of 179,672 ha with widely varying altitudinal ranges from 850 to 3000 m.a.s.l. The topography of the District is estimated to be 71% mountainous, 6% valley and 25% plane (GWAO, 2014). Moreover, about 90% of the cultivated land soil is Oxisols (Red in colour), while the study area has a soil of totally oxisols. The study site (Yebo) is located at an altitude of about 2168m.a.s.l. (GWAO, 2014).

The total annual rainfall in the study area for 2015 was 1010.6 mm (Table7.3), the mean maximum and minimum temperature recorded for the year 2015 were 23.6^{o}C and 11.2^{o}C, respectively (Appendix table7.4 and Appendix table7.5). The site receives more rainfall during crop growing period (June to November). The District is characterized by three sub-agro ecological zones, namely, M3-7 (cold to very cold moist mountain) covering 5%, M2-5 (tepid to cool plateau) covering 87% and M1-4 (hot to warm moist gorge) covering 8% of the total land area. The rainfall of Gozamin District as well as yebo *kebele* is characterized by a unimodal pattern that distributed uniformly over the growing season, which starts about the middle of May and extends to about the mid of October (GWAO, 2014). Over 98% of the population of Gozamin District are involved in agriculture and live on a very low annual income mainly due to very low land productivity attributed to poor agronomic practices like inappropriate seeding rate, improper adjustment of row spacing, inappropriate weeding practices and soil fertility depletion caused by crop removal of nutrients and accelerated soil erosion**.** Bread wheat, tef, maize, barley, and wild oat (local name "*Engido*"), are the dominant crops cultivated in Gozamin District. Bread wheat, barley and wild oat (local name "*Engido*") are the dominant cultivated crops listed in their order of in the area coverage at present in the study area (GWAO, 2014).

2.2 Experimental Planting Materials

Since it is well adapted in the agro-ecology of the study area, *Kakaba* bread wheat variety was used for this experiment. *Kakaba* is the most common and widely distributed bread wheat variety in the country and in the study area as well. The variety was released in the year 2010 by Kulumsa Agricultural Research Centre. The optimum altitude and rain fall range to produce this variety are 1500 - 2200 masl and 500 - 800 mm, respectively. The optimum seeding rate for this variety is 150-175 kg ha^{-1} and it needs 50 -70 and 90 -120 days to heading and maturity, respectively. It is also moderately resistant to stem rust. Moreover, it has a high dose of fertilizer requirement. Hence, phosphorus and nitrogen fertilizers were applied uniformly for all plots based on the recommendation of the area.

2.3 Experimental Treatments, Design and Procedures

The field experiment was conducted in factorial arrangement with combination of three row spacings (20cm, 25cm, and 30cm inter row spacing) and four seeding rates of bread wheat (100, 125,150 and 175 kg ha^{-1}). The experimental design was Randomized Complete Block Design (RCBD) with 3 replications**.** The gross plot size was 3m x 2m (6 m^2) containing 15 rows for 20cm, 12 rows for 25cm, and 10 rows for 30 cm inter row spacings, respectively. The space between blocks was 1m while spacing each plot in a block was 0.5m. The net plot size (harvestable area) was used by excluding two outer rows on both sides of each plot and 50cm row length at both ends of the rows to avoid possible border effects. Thus the net plot size was 2.2m x 1m (2.2m^2) for the 20 cm inter row spacing, 2m x 1m (2m^2) for the 25 cm inter row spacing, and 1.8m x 1m (1.8m^2) for the 30 cm inter-row spacing. In preparation of the experimental field, oxen driven local plow (*Maresha*) was used in accordance with the local farming practices of the farmers. Accordingly, the field was ploughed five times; (starting from mid-march to mid-July 2015). The plots were prepared as per the layout, leveled manually and the treatments were assigned randomly and the seed was drilled in furrows manually on July 22, 2015.

Phosphorus and nitrogen fertilizers were applied uniformly for all plots as per the area recommendation. Phosphorous at a rate of 92 kg P_2O_5 ha^{-1} and nitrogen at 148.12 kg N ha^{-1} were applied following the recommended fertilizer application rate to the area. Urea (46% N) and DAP (18% N and 46% P_2O_5) were used as sources of N and P fertilizers. The full rate of the phosphorous fertilizer (92 kg P_2O_5 ha^{-1}) and a portion of the nitrogen fertilizer (56.12 kg N) was applied as band application at the time of planting and the remaining 92 kg N was applied as top-dressing at mid tillering stage of the crop (40 days after emergence) after first weeding was completed on each plot. The field was cultivated and weeded as needed manually during the cropping season to control weeds and weed-crop competition. Moreover, all the necessary field management practices were carried out as required during the experimental period. Plot wise harvesting was done at harvest maturity of the crop as the crops get matured in each plot.

Table 2.1: Treatment combinations used for the study

Seeding Rate (kg ha^{-1})	Row Spacing (cm)	Treatment Combination
S1	R1	S1R1
	R2	S1R2
	R3	S1R3
S2	R1	S2R1
	R2	S2R2
	R3	S2R3
S3	R1	S3R1
	R2	S3R2
	R3	S3R3
S4	R1	S4R1
	R2	S4R2
	R3	S4R3

S1=100 kg ha^{-1}; S2=125 kg ha^{-1}; S3=150 kg ha^{-1}; S4=175 kg ha^{-1}; R1=20cm; R2=25cm; R3=30cm

2.4 Data Collection

2.4.1 Phenological parameters

Days to 50% Emergence (DE): It was taken when 50% of the plants emerge from each plot by visual observation.

Days to 50% Heading (DH): The data was taken when the ears or panicles were fully visible or produced spikes above the sheath of the flag leaf on 50% of the plants from each plot that was determined by visual observation.

Days to 90% physiological Maturity (DM): Days to physiological maturity 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. It also indicated by senescence of the leaves as well as frees threshing of seeds from the glumes when pressed between the thumb and the forefinger.

2.4.2 Vegetative growth parameters

Plant height (**PH**): The average height of ten randomly selected plants from the net plot area of each plot was measured in centimeters from the ground to the top of spike, excluding awns at maturity and means were taken.

Effective Tiller Numbers (ETN): Numbers of effective (fertile) tillers per 1m row length was counted from to randomly selected 0.5m row lengths from each plot at harvesting.

2.4.3 Yield and yield related parameters

Spike Length (SL): The spike length was measured from ten randomly selected plants of the inner rows in centimeter and the mean length was recorded on each plot by measured from the base to the upper most part of the spike excluding awns at maturity.

Spike Number (SN): The total number of spikes per 1m row length was counted from two randomly selected 0.5m lengths from each plot at harvesting.

Number of kernels per spike (NKPS): Number of kernels per spike was counted from ten randomly selected plants from the inner rows of each plot and the mean kernel number was taken at harvesting.

1000-kernel weight (g): Thousand grains were counted after threshing at random from each plot and their weights were measured with sensitive balance after adjusting the grain moisture content to 12.5%.

Biomass yield (BY): Total biomass or biological yield was measured by weighing the sun dried total above ground plant biomass (straw + grain) from the net plot area of each plot.

Grain yield (GY): Grain yield was measured by taking the weight of the grains threshed from the net plot area of each plot and converted to kilograms per hectare after adjusting the grain moisture content to 12.5%.

Straw Yield (SY): Straw yield was determined by subtracting grain yield from total above ground biomass.

Harvest Index (HI): Harvest index of each treatment was calculated as the percent ratio of grain yield to the total above ground biomass by using the formula of Donald (1962) as,

Harvest index = Grain yield /biological yield x 100

2. 5 Soil Sampling and Analysis

Soil samples were taken from 10 representative spots of the experimental field at 0-30 cm depth before sowing and one composite surface soil sample was made out of it for the purpose of characterization. The composite soil sample was prepared for analysis and was air- dried as well as grinded to pass through a 2mm sieve. The Soil sample was analyzed to determine soil pH, Soil texture, available P, Organic carbon content, cation exchange capacity (CEC) and total N using different methods and procedures in Debre Markos soil laboratory. Total N was determined by Kjeldhal method (Chapman, 1965), while available phosphorus were analyzed following the procedure described by Olsen *et al,* (1954) method, percent organic matter and organic carbon were also determined by using wet oxidation method (Walkiey and Black, 1934). Soil texture was analysed following Bouyoucos hydrometer method (Day, 1965). Furthuremore, soil pH was measured potentiometrically in the supernatant suspension of a 1:2.5 liquid mixture using pH meter in water (pH-H_2O) (Houba *et al*., 1989). While cation exchange capacity (CEC) was measured using 1M-neutral ammonium acetate (Jackson, 1967).

Based on the soil analysis result, the pH and CEC of the experimental soil was 4.81 and 32.56 meq/100g of soil, respectively. Whereas total nitrogen and available phosphorus were found 0.16% and 3.82ppm, respectively (Appendix table 7.6). Based on Landon (1991) conclusions on total nitrogen and available phosphorous, the experimental site is with low content of these nutrients. On the other hand, the organic carbon content was found 1.83% which is low (Landon, 1991) (Appendix table 7.6). The texture of the experimental site was 62% clay, 32% silt and 6% sand; which is classified as clay based on texture triangle classification system and this type of soil conducive for crop production since clay soils absorb and hold more water and exchangeable nutrients or cations than silty or sandy soils.

2.6 Statistical Analysis

The data collected from the experiment at different growth stages were subjected to statistical analysis as per the experimental designs for each experiment using SAS (Statistical Analysis Software) version 9.1 to analyze the data using ANOVA and GLM procedures. Mean separation of significant treatments were carried out using the least significant difference (LSD) test.

Moreover, correlation analysis was also carried out to study the nature and degree of relationship between yield and yield components of bread wheat. Correlation coefficient values (r) were calculated and test of significance was analyzed using Pearson correlation procedure found in SAS software.

The mean grain and straw yield data was adjusted down by 10% and subjected to partial budget and economic analysis was performed following the CIMMYT partial budget methodology (CIMMYT, 1988). Total costs that varied (seed and planting cost) 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. Net returns per hectare were calculated by deducting cost of production per hectare from gross income 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

Analysis of variance of the data revealed that days to 50% seedling emergence was not significantly ($p>0.05$) affected by seeding rates, row spacing and by their interaction effects. Favorable moisture condition, uniformly distributed rainfall during the sowing time and good seedbed preparation might have contributed to the same germination date across the treatment combinations . The same result was reported by Worku Awdie (2008) who concluded that seedling emergence was not significantly affected by seeding rates.

3.1.2 Days to 50% heading

Days to 50% heading was very highly significantly ($p<0.001$) affected by the main effect of seeding rate. On the other hand, the main effect of row spacing and its interaction effect with seeding rate did not significantly ($p>0.05$) affect days to 50% heading (Table 3.1). Days to 50% heading was delayed (62.88 days) when lower seeding rates (100kg ha^{-1}) was used. On the other hand, earlier days to 50% heading (60.8 days) was recorded from highest seeding rates (Table 3.1). The earliness to heading in highest seeding rate might be due to the higher competition to resources; this may help plants to escape terminal moisture stress.

The finding by Gafaar (2007) also indicated 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. Another research finding on the effect of seeding rate also revealed that heading started earlier at higher seeding rates (Read and Worder, 1981). Furthermore, Worku Awdie (2008) concluded that increasing the levels of seeding rate decreased the days to heading consistently.

Table 3.1: Effect of seeding rate and row spacing on phenology and vegetative growth of bread wheat at Yebo in 2015 main cropping season

Treatments	DE(days)	DH(days)	DPM(days)	PH(cm)
Seeding rate(kg ha^{-1})				
100	5.56	62.89^{a}	106.11^{a}	76.86^{d}
125	5.33	61.89^{b}	103.33^{b}	78.45^{c}
150	5.44	60.89^{c}	99.44^{c}	79.71^{b}
175	5.56	60.44^{c}	97.67^{c}	81.76^{a}
Sign. Difference	ns	***	***	***
SE $\pm$	0.15	0.36	1.39	0.65
Row spacing(cm)				
20	5.42	61.67	100.58	80.36^{a}
25	5.50	61.58	101.67	78.62^{b}
30	5.50	61.33	102.67	78.61^{b}
Sign. Difference	ns	Ns	ns	***
CV (%)	5.43	1.49	2.30	1.40
SE $\pm$	0.17	0.42	1.60	0.75

Means with the same letter(s) in the same column and row of each trait are not significantly different at 5% probability level, * , ** & *** indicates significant at 5% , 1% and 0.1% probability level, respectively. ns= non-significant, CV (%) = coefficient of variation in percent, DH = days to 50% heading, DPM = days to 90% physiological maturity and PH= plant height.

3.1.3 Days to 90% physiological maturity

Days to 90% physiological maturity showed significant response to seeding rates. Similar with days to 50% heading, the increment in seeding rate might enhanced physiological maturity of the bread wheat. Seeding rate had very highly significant ($P<0.001$) effect on physiological maturity of bread wheat. However, row spacing and its interaction effect with seeding rate did not show significant effect on days to 90% physiological maturity (Table 3.1). Increasing seeding rate from 100 to 175 kg ha^{-1} decreased days to 90% maturity by 8.44 days (Table 3.1). The highest seeding rate associated with early maturity might be due to plant competition for available resources. The present finding showed that as seeding rate decreases from 175 to 100 kg ha^{-1} days to physiological maturity increased from 97.67 to 106.11days (Table 3.1). Similar with the present finding, Worku Awdie (2008) also noted that increasing the levels of seeding rate hastened physiological maturity of bread wheat. Another research finding by Read and Worder (1981) also showed that maturity of shoots started earlier at higher seeding rates. Furthermore, Melaku Mengstie (2008) indicated that increasing levels of seeding rate promoted early physiological maturity of tef.

Although it was not significant, there was statistical different among row spacing on days to 90% physiological maturity, the closer inter row spacing (20 cm) hastened physiological maturity than other inter row spacings. In agreement with this finding Tesfaye Getachew *et al.*(2012) and Yordanos Ameyu (2013) also concluded that closer inter row spacing (increasing plants density) shortened days to physiological maturity in potato and Rice, respectively. This could be due to the presence of intense inter plant competition at the closer row spacing that might have led to the depletion of the available nutrient that results plants tend to mature earlier.

3.2 Vegetative Growth Parameters

3.2.1 Plant height

The analysis of variance indicated that both seeding rate and row spacing had very highly significant ($P<0.001$) effect on wheat plant height. Whereas, the interaction effect of seeding rates and row spacing did not show significant effect on plant height. As seeding rate increased from the lowest (100 kg ha^{-1}) to the highest (175 kg ha^{-1}), the height of the plant correspondingly increased from 76.86 to 81.76cm (Table 3.1). Similar with the present finding, Soomro *et al.*(2009) noted that wheat sown at higher seeding rate (175 kg ha^{-1}) produced greater plant height i.e 101.25 cm followed by 150 kg ha^{-1} i.e. 99.09 cm and 125 kg ha^{-1} i.e. 94 27cm. Another research finding by Worku Awdie (2008) also concluded that plant height increased consistently with increasing seeding rate from 72.7 cm at the seeding rate of 100 kg ha^{-1} to 80.4 cm at the seed rate of 150 kg ha^{-1}.

Higher seeding rate caused to changing plant height and stem thickness because of the lower light penetrating in to the plants canopy bed and more inter specific competition to more absorption light. These factors (higher seeding rate and lower light penetration) increasing inter node length, reducing stem thickness and increasing plant height (Otteson *et al*., 2007). Rahim *et al.* (2012) also reported that the significant difference on plant densities of 450 and 300 plants m^2 with highest and lowest plant height, respectively. Other researchers also reported in wheat that the height of plants grown at the lowest seeding rate was significantly lower than the height of plants grown at higher seeding rates (Haile Deressa *et al*., 2013; Ghulam *et al.,* 2011). Moreover, this result was in harmony with the finding of Fani *et al.* (2014) who indicated that with increasing density, plant height slightly increases and there after decreases that could be because restrictions on plant food sources therefore, in treatment 150 and 200 kg ha^{-1}, maximum plant height was observed.

Regarding to row spacing, as row spacing increased from 20 cm to 30 cm plant height decreased from 80.36 to 78.61. However, it was statistically in parity with plant height obtained in response to the spacing of 25 and 30 cm (Table 3.1). Tallest plants were likely from higher seeding rates and narrow row spacing might be due to the presence of increased competition for light as the plant population becomes denser.

3.2.2 Number of effective tillers

Crop yields are generally dependent upon many yield contributing agents. Among these, number of effective tillers is the most important because of the contribution in final yield.

The analysis of variance indicated that the main effects of seeding rate and row spacing highly significantly ($p<0.01$) and very highly significantly ($p<0.001$) affected number of effective tillers per 1m row length, respectively. However, the interaction effect of seeding rate and row spacing showed non- significant ($p>0.05$) effect on number of effective tillers of bread wheat. The number of fertile tillers in the present study increased consistently with increasing seeding rate up to 150 kg ha^{-1}. The highest number of effective tillers per 1m row length (87.56) was observed at seeding rate of 150 kg ha^{-1} while the lowest number of effective tillers per 1m length (67.33) observed at seeding rate of 100kg ha^{-1}. However, it was statistically in parity with the number of effective tillers obtained in response to the seeding rate of 100 and 125 kg ha^{-1} (Table 3.2).

In line with the present finding, Ali *et al.*(2010) reported that the number of effective tillers increased as seeding rate increased. Similarly, Jemal Abdulkerim *et al.* (2015) concluded that the highest number of effective tillers per 0.5 m row length (69.33) was obtained at 200 kg ha^{-1} seeding rate while, the lowest number of effective tillers per 0.5 m row length (25.66) was obtained at 100 kg ha^{-1} seeding rate. Such increment in number of effective tillers might be due to increasing sowing density that attributed to increasing number of plants per plot and also tillering capacity. The present finding also agree with Iqbal *et al.* (2012) who stated that more number of tillers (503.40) was observed at seeding rate of 175 kg ha^{-1} while less number of tillers (404.40) was recorded at seeding rate of 125 kg ha^{-1} and was statistically less (464.6) from seeding rate of 150 kg ha^{-1}. Increase in number of tillers per unit area is due to increased seeding rate (Ahmad *et al.,* 2000; Khan *et al.,* 2000; Hussain *et al.,* 2001; Naeem, 2001; Otteson *et al*., 2008). Another research finding by Iqbal *et al.*(2010) also stated that there was linear increase in number of fertile tillers with increased seeding rate and among seeding rates, 200 kg ha^{-1} produced significantly higher number of fertile tillers (278.75) followed by 175 kg ha^{-1} seeding rate (263.97 fertile tillers).

The present result also in harmony with Chaudhary *et al.,* (2000), Arif *et al*., (2003), and Ali *et al.*

(2010) who reported increased tillering with increased in seeding rate. Moreover, Rafique *et al.*, (1997), reported that linear increase in the number of tillers as the seeding rate was increased. Similarly, this result is in harmony with Abd El- Lattief (2011) who found that as seeding rate increased from 100 kg ha^{-1} to 175 kg ha^{-1}, number of effective tillers increased from 303.3 to 348.7 m^{-2}. Kumar *et al.* (1991) and Ahmad *et al.* (1999) confirmed the present result who reported that higher sowing rates increased the number of tillers m^{-2}. Likewise, Seleiman *et al.* (2010) 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.

Highest number of effective tillers (92.33) per 1m row length was recorded at row spacing of 20 cm while, the minimum number of effective tillers (66.75) per 1m row length was recorded at row spacing of 30 cm. However, it was statistically in parity with the number of effective tiller obtained in response to the spacing of 25 and 30 cm (Table 4.2). The present finding confirm the report of Pandey *et al.*(2013) who concluded that wheat cultivated at 20 cm row spacing produced significantly more effective tillers as compared to 15 and 25 cm row spacings. This finding also in agreement with the result of Iqbal *et al.*(2010) who noted that narrow row spacing increased number of fertile tillers and total tillers significantly over wider row spacing. Similarly, Al- Fakhry and Ali (1989) have also reported that narrow row spacing increased number of fertile tillers and total tillers significantly over wider row spacing. Number of effective tillers per unit area is one of the limiting factors of grain yield (Kakar *et al*., 2001). The greater tiller numbers at the narrow row spacing was likely due to more uniform spatial distribution and less in row plant to plant competition compared with the wider row spacing (Auld *et al.,* 1983). Increased light capture by a canopy has been reported in wheat with narrow row spacing configurations (Andrane *et al.,* 2002). Moreover, Kumar *et al.* (1991) also reported that higher sowing rates coupled with decrease in row spacing increased the number of tillers per square meter and grain yield per hectare.

3.3 Yield and Yield Related Parameters

3.3.1 Spike length

The statistical analysis results revealed that spike length was very highly significantly ($P<0.001$) affected by seeding rate. On the other hand, row spacing and its interaction with seeding rates had non-significant ($p>0.05$) effect on spike length (Table 3.2). The maximum spike length of 8.93 cm was recorded at those plots which received seeding rate of 100 kg ha^{-1} while minimum spike length of 7.33 cm was obtained from plots those receive seed rate of 175 kg ha^{-1}. However, it was statistically in parity with spike length obtained in response to the seeding rate of 100, 125 and150 kg ha^{-1} (Table 3.2).

There was no significant difference observed among seeding rates of 100, 125 and 150 kg ha^{-1} in spike length. At the lower seeding rate of 100 kg ha^{-1}, the spike length was higher compared to higher seeding rate of 175 kg ha^{-1}. This might be due to more free space between plants at the lower seed rates and less intra-plant competition for available resources that resulted in higher spike length. The current result is in agreement with the finding of Zewdie Bishaw *et al.* (2014) who reported that plant height and spike length are negatively interrelated. Shorter plant produce longer spike length and long plant produce shorter spike and higher biomass production. Another research finding by Gafaar (2007) also stated that increasing sowing density from 200 up to 400 grains m^{-2} significantly decreased spike length. Similarly, Seleiman *et al.*(2010) reported that the longest spikes were obtained from 250 and 300 grains per m^{2} but without significant differences between both of them. However, the shortest spikes were recorded by using the highest seeding rate (400 grains m^{-2}).

3.3.2 Number of kernels per spike

Data recorded on number of kernels per spike indicated that number of kernels per spike of bread wheat was very highly significantly ($P<0.001$) influenced by the main effect of seeding rate. However, row spacing and its interaction effect with seeding rate showed non-significant ($p>0.05$) effect on number of kernels per spike (Table 3.2). Maximum number of kernels per spike (53.06) was obtained from the seeding rate of 100 kg ha^{-1}and minimum number of kernels per spike^{-1} (46.73) obtained from the seeding rate of 175 kg ha^{-1} (Table 3.2). Seeding rate of 125 kg ha^{-1} and 150 kg ha^{-1} produced statistically similar number of kernels per spike. As seeding rate increased from 100 kg ha^{-1} to 175 kg ha^{-1}, the number of kernels per spike was decreased by 13.54%.

This result was in line with the finding of Rahim *et al.* (2012) who stated that significant difference was observed between plant densities of durum wheat cultivar in terms of grains per spike. The highest and lowest grains per spike observed at lowest and highest plant densities, respectively. In line with the results obtained from this study, Worku Awdie (2008) concluded from his research findings that increasing the rate of seeding from 100 to 150 kg ha^{-1} decreased the number of grains per spike from 32.02 to 29.60 at the seed rate 100 and 150 kg ha^{-1} respectively. Moreover, Hussins and Pan (1993) reported that the number of kernels per spike decreased with an increase in seeding rate.

Number of kernels per spike was not significantly affected by main effect of row spacing. The present finding is similar with the finding of Hussain *et al.* (2003). Moreover, the same result was obtained by Muhammad *et al*. (1999) who observed that grains spike^{-1} is purely inherent character of wheat varieties and not affected by row spacing. Spike length and kernels per spikes have positive relationship in this study. The increased spike length leads to increased kernels per spike and vice versa.

Table 3.2: Effect of seeding rate and row spacing on vegetative growth and yield related parameters of bread wheat at Yebo in 2015 main cropping season

Treatments	ETN	SL(cm)	NKPS	SN	TKW(g)
Seeding rate (kg ha^{-1})					
100	67.33c	8.93^{a}	53.06^{a}	94.56^{c}	35.44^{a}
125	76.11bc	8.85^{a}	50.06^{b}	108.00^{b}	33.85^{b}
150	87.56a	8.56^{a}	49.82^{b}	123.44^{a}	33.95^{b}
175	78.89ab	7.33^{b}	46.73^{c}	116.33^{ab}	33.04^{b}
Sign. Difference	**	***	***	**	**
SE±	2.39	0.21	0.83	3.05	0.43
Row spacing(cm)					
20	92.33^{a}	8.29	49.16	94.92^{c}	33.33^{b}
25	73.33^{b}	8.35	50.05	109.33^{b}	34.24^{ab}
30	66.75^{b}	8.61	50.53	127.50^{a}	34.65^{a}
Sign. Difference	***	Ns	ns	***	*
CV (%)	13.89	4.64	3.79	12.32	3.38
SE±	2.76	0.25	0.96	3.52	0.49

Means with the same letter(s) in the same column and row of each trait are not significantly different at 5% probability level, * , ** & *** indicates significant at 5% , 1% and 0.1% probability level, respectively. ns= non-significant, CV (%) = coefficient of variation in percent, ETN = effective tiller numbers, SL = spike length, NKPS = number of kernels per spike, SN = spike numbers, TKW = thousand kernel weight

3.3.3 Spike number

The main effects of seeding rate and row spacing were highly significantly (P<0.01) and very highly significantly (P<0.001) affected spike numbers per 1m row length, respectively. However, the interaction effect of seeding rate and row spacing did not significantly (p>0.05) affect spike numbers of bread wheat. The highest spike numbers per 1m row length (123.44) was obtained at the seeding rate of 150 kg ha^{-1} and minimum spike numbers per 1m row length (94.56) was counted at seeding rate of 100 kg ha^{-1} (Table 3.2). Similarly, the maximum (127.50) and the minimum (94.92) spike numbers per 1m row length were recorded at 30 and 20 cm row spacing, respectively (Table 3.2).

Compared with the lowest rate (100 kg ha^{-1}) of seeding rate treatment, the increment in spikes per 1m row length obtained due to the highest seeding rate (150 kg ha^{-1}) was 30.54%. The increase in spike numbers per 1m row length with increasing seeding rate might be due to more plants being established. The result of number of spikes per 1m row length obtained from this study is in line with the findings of Worku Awdie (2008) who reported that the number of productive spikes per 0.5 m row length increased linearly with increasing rates of seeding from 72.31 spikes per 0.5 m row length at the seeding rate of 100 kg ha^{-1} (the lowest rate) to 85.95 spikes per 0.5 m row length at the highest (150 kg ha^{-1}) seeding rate. Moreover, Willey and Holiday (1971) indicated that high seeding rates generally increase number of spikes per square meter.

Another research finding by Fani *et al.* (2014) also reported that the highest density of spikes obtained to the treatment of 300 kg ha^{-1}and minimum density of spikes to the treatment of 50 kg ha^{-1}. Similarly, Tunis *et al.* (1995) found that increase in spike number at higher wheat densities. Seleiman *et al*. (2010) also concluded that increase seeding rates up to 350 or 400 grains m^{-2} increased number of spikes per m^{-2}. As the result indicated that the number of fertile spikes per unit area has highly contributed than kernels per spike and kernel weight for the highest grain yield obtained in the highest seeding rate. This implies that increased crop density had strong and consistent positive effects on grain and biomass yield.

3.3.4 Thousand kernel weight

The analysis of variance revealed that both seeding rate and row spacing had highly significant (p<0.01) and significant (p<0.05) effect on thousand kernel weight, respectively. However, the interaction effect of seeding rate and row spacing did not influence significantly (p>0.05) thousand kernels weight of bread wheat. The highest thousand kernels weight (35.44 g) was recorded for seed sown at the seeding rate of 100 kg ha^{-1} whereas the lowest thousand kernel weight (33.04 g) was recorded at the seeding rate of 175 kg ha^{-1}. However, it was statistically in parity with in thousand kernels weight obtained in response to the seeding rate of 125, 150 and 175 kg ha^{-1} (Table 3.2).

Similarly, the maximum (34.65 g) and the minimum (33.33 g) thousand kernels weight recorded for seeds sowing at 30 and 20 cm row spacing, respectively (Table 3.2). The result showed that when seeding rate increased from 100 to 175 kg ha^{-1}, it decreased thousand kernels weight by 6.77%. However, increasing seed rate from 100 to 125 kg ha^{-1} and 125 to 150 kg ha^{-1} there was no significant different in thousand kernels weight. The lowest kernels weight produced from highest seeding rate might be due to thickening of population density which resulted competition of nearby plants in absorbing nutrients and moisture. Similar with the present finding, Baloch *et al.* (2010) concluded that the higher the seeding rate in bread wheat resulted in decreased 1000-kernels weight. Another research finding by Hiltbrunner *et al.*(2005) and Dubis and Budzynski, (2006) also noted that as seeding rate increased, 1000- kernel weight decreased but number of spikes m^{-2} increased. Similarly, Fani *et al.* (2014) showed that at high densities (250 and 300 kg ha^{-1}) thousand seeds weight declined whereas in low densities of 50 and 100 kg ha^{-1}, seed thousand weights increased. Moreover, Iqbal *et al.*(2010) concluded that lower seeding rates (125 kg ha^{-1}) produced significantly heavier grains (40.74 g) than higher seeding rate (200 kg ha^{-1}) that produced lighter (37.83 g) grains.

Maximum thousand kernel weight (34.65g) was recorded at row spacing of 30 cm (Table 3.2) while minimum thousand kernel weight (33.33g) was observed at row spacing of 20cm. This result is in agreement with the finding of Iqbal *et al.*(2010) who showed that wider row spacing (22.50 cm) produced more 1000- grain weight (40.16 g) as compared to narrow row spacing of 11.25 cm (38.81g). The present result also confirm the finding of Rafique *et al.*, (1997) who concluded that increased grain weight at wider row spaces.

3.3.5 Grain yield

Analysis of variance showed that the main effect seeding rate and row spacing had very highly significant effect ($P < 0.001$) on grain yield. However, the interaction effect of seeding rate and row spacing showed non-significant ($p>0.05$) effect on grain yield. The highest grain yield (4462.10 kg ha^{-1}) was obtained at the seeding rate of 150 kg ha^{-1} and the lowest grain yield (3069.00 kg ha^{-1}) was obtained at seeding rate of 100kg ha^{-1}. However, it was statistically in parity with in grain yield obtained in response to the seeding rate of 150 and 175 kg ha^{-1} (Table 3.3). Based on the result of the present study, increasing seeding rate results in increasing grain yield. The maximum grain yield obtained from the use of higher seeding rate might be due to high density of plants in rows and increased number of spikes per rows as a result number of grains and increased spike number in rows. Seeding rate of 150 and 175 kg ha^{-1} resulted in increasing yield by 45.39% and 38.19%, over the lowest seeding rate of 100 kg ha^{-1}, respectively. The increased seeding rate from 125 kg ha^{-1} to 150 kg ha^{-1} produced grain yield which was significantly increased by 20.06%.

Similar with the present finding, Haile Deressa *et al.* (2013) who reported that the lowest seeding rate (100 kg ha^{-1}) resulted in a grain yield of 3851 kg ha^{-1}, which was significantly lower than the yields obtained at the other seeding rates (150 and 175 kg ha^{-1}). Similarly, Hussain *et al.*(2010) and Worku Awdie (2008) reported that grain yield increased as seeding rate was increased from 50 to 150 and from 100 to 150 kg ha^{-1}, respectively. Moreover, Ali *et al.*(2010) concluded that the three years average data showed that grain yield was maximum at seeding rate of 150 kg ha^{-1} followed by 175 and 200 kg ha^{-1} as against the seeding rate of 125 kg ha^{-1}. The same result also reported by Iqbal *et al.*(2010) who concluded that seeding rate of 150 kg ha^{-1} produced significantly higher grain yield (4120 kg ha^{-1}) followed by 175 and 200 kg ha^{-1} seeding rates (3904 and 3785 kg ha^{-1}). However, seeding rate of 125 kg produced significantly lower grain yield (3.669 t). Another research finding by Nazir *et al.* (2000) also showed that 150 kg ha^{-1} seeding rate produced significantly the highest grain yield. Likewise, Jemal Abdulkerim *et al.*(2015) also reported that varieties Shorima and Kakaba gave maximum grain yield at seeding rate of 150 kg ha^{-1}and, variety Digalu produced highest yield at seeding rate of 175 kg ha^{-1} as compared to 100, 125, and 200kg ha^{-1}. Seleiman *et al.*(2010) also confirmed that increasing seeding rates up to 350 or 400 grains m^{-2} increased grain yield. Higher grain yield with higher seeding rates was also reported by Olsen *et al.* (2005) and Haile Deressa and Girma, Fana (2010). The same result has also been proved by Sikander *et al.,* (2003) who concluded that increasing seeding rate from 150 to 250 seeds/m^2 resulted in higher grain yield.

The data presented in Table 4.3 showed that row spacing of 20 cm produced maximum (4377.8kg ha^{-1}) bread wheat grain yield followed by 25 cm (3690.1 kg ha^{-1}) as against the minimum with 30 cm (3552.3 kg ha^{-1}) row spacing. However, 25 and 30 cm row spacings have not statistically significant difference (Table 3.3). Closer row spacing of 20 cm recorded significantly higher yield than wider row spacing of 30 cm. The increase in grain yield due to narrow row spacing was 23.23% higher than wider spacing. This result was in line with Amjad and Anderson (2006) who carried out an experiment to study the effects of row spacing on wheat yield and found that wider row spacing of 24 cm and 36 cm consistently reduced wheat yield compared with narrow row spacing of 18 cm. Based on this result average number of plants were reduced in the wider rows than narrow rows this is might be due to increased competition for water as the seeds were placed closer together in the wide rows and ultimately may also have been related to reduction in wheat grain yield.

In higher rainfall areas, where cereal crops have higher potential yields (greater than 3500 kg ha^{-1}), significant yield decreases have been recorded with wider row spacing (greater than 25cm). Then, the higher the yield potential, the greater the negative impact of wider rows on wheat and barley yields (GRDC, 2011). Kumar *et al.* (1991) also reported that higher sowing rates coupled with decrease in row spacing increased the number of tillers per square meter and grain yield per hectare. Gunri and Chaudhury (2004) reported that closer spacing (15cm x 10 cm) proved better in grain yield of rice, nitrogen use efficiency and N uptake was better than the wider row spacing. Similarly, Khan *et al.* (2001) and Frizzell *et al.* (2006) reported that yield of cereals increased in response to decreasing the spacing between rows. Moreover, Nazir (1990) and Thayer *et al.* (1987) stated that seeding rate of bread wheat at 150 kg ha^{-1} gave significantly higher grain yield than 100 kg ha^{-1} seeding rate since narrow row spacing causes higher leaf photosynthesis and suppresses weeds growth compared with wider row spacing. Another research finding by McConkey and Miller (1999) also stated that spring wheat consistently had lower yields and water use efficiency at 30 cm row spacing versus 20 cm row spacing.

3.3.6 Biomass yield

Biomass yield represents 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. Biomass yield is highly inclined by crop nutrition and planting distance. Analysis of variance showed that the main effect of seeding rate had very highly significant ($P < 0.001$) and row spacing had significant ($p<0.05$) effect on the above ground dry biomass yield. However, the interaction effect of seeding rate and row spacing was found no significant. Highest biomass yield (12754.50 kg ha^{-1}) was observed at the seeding rate of 175 kg ha^{-1} while lowest biomass yield (9696.30 kg ha^{-1}) was obtained at the seeding rate of 100 kg ha^{-1}. However, it was statistically in parity with in biomass yield obtained in response to the seeding rate of 100 and 125 kg ha^{-1} (Table 4.3). The increased in biomass production might be attributed to the increased plant population due to higher seeding rate and taller plants. The present result is in agreement with the finding of Zewdie Bishaw *et al.* (2014) who reported a positive association between biomass yield and plant height, thus taller plants resulted higher biomass yield. Similar with the present finding, Jemal Abdulkerim *et al.* (2015) also reported that higher biomass yield was recorded on increased seeding rates of 200 and 175kgha^{-1}. Similarly, Iqbal *et al.*(2012) also found that biological yield was increased as seeding rate increased from 125 kg ha^{-1} to 150 and 175 kg ha^{-1}. Moreover, Seleiman *et al.*(2010) confirmed that increasing seeding rates up to 350 or 400 grains m^{-2} increased grain, straw and biomass yields.

Row spacing also has prominent effect on biomass yield of wheat. Maximum biomass yield (11650.60 kg ha^{-1}) was observed at 20 cm row spacing followed by 25 cm row spacing (10970.50 kg ha^{-1}) while lowest biomass yield (10765.70 kg ha-1) was recorded at 30 cm row spacing. However, it was statistically in parity with in biomass yield obtained in response to the spacing of 25 and 30 cm (Table 3.3). In this study, higher biomass yield was obtained at the narrower row spacing than wider row spacing this might be due to better resource utilization in narrow rows than wider rows. This finding is in conformity with the finding of Mali and Choudhary (2012) who reported that more biomass was produced at narrow spacing than wider spacing. Similarly, Chen *et al.* (2008) reported that narrower row spacing produced higher biomass yield than wider row spacing in rice.

3.3.7 Straw yield

The main effect of seeding rate very highly significantly ($P < 0.001$) affected straw yield whereas the main effect of row spacing and its interaction effect with seeding rate didn't show significant ($p>0.05$) effect on straw yield (Table 3.3,). The highest (8508.4 kg ha^{-1}) straw yield was observed at seeding rate of 175 kg ha^{-1} while the lowest (6627.3 kg ha^{-1}) straw yield was found with seeding rate of 100kg ha^{-1}. There was a linear increase in straw yield as the seeding rate was increased. However, it was statistically in parity with in straw yield obtained in response to the seeding rate of 100, 125 and 150 kg ha^{-1} (Table 3.3).

Maximum straw yield was recorded from the plots where seeding rate of 175 kg ha^{-1} was used and this might be due to the fact that higher seeding rates result in more plant population and greater plant height which resulted in higher straw yield. This result is in harmony with Ali (2010) and Worku Awdie (2008) who exhibited that as seeding rate increased, correspondingly straw yield increased due to higher stand number at crop establishment period. Similarly, the increase in straw yield with increase in seeding rate was also reported by previous researchers (Bellatore, *et al.*, 1985 and Kumpawt, 1998). Moreover, Seleiman *et al.* (2010) confirmed that increasing seeding rates up to 350 or 400 grains m^{-2} increased grain, straw and biological yields.

Table 3.3: Effect of seeding rate and row spacing on yield and yield related parameters of bread wheat at Yebo in 2015 main cropping season

Treatments	GY(kg ha^{-1})	BY(kg ha^{-1})	SY(kg ha^{-1})	HI (%)
Seeding rate (kg ha^{-1})				
100	3069.00^{c}	9696.30^{c}	6627.30^{b}	31.69^{c}
125	3716.30^{b}	10343.70^{c}	6627.40^{b}	35.80^{ab}
150	4462.10^{a}	11721.10^{b}	7259.00^{b}	38.15^{a}
175	4246.10^{a}	12754.50^{a}	8508.4^{a}	33.27^{bc}
Sign. Difference	***	***	***	**
SE±	214.65	426.88	295.66	1.24
Row spacing(cm)				
20	4377.80^{a}	11650.60^{a}	7272.80	37.47^{a}
25	3690.10^{b}	10970.50^{b}	7280.30	33.67^{b}
30	3552.30^{b}	10765.70^{b}	7213.40	33.04^{b}
Sign. Difference	***	*	ns	**
CV (%)	9.70	6.93	9.93	9.83
SE±	247.57	492.33	341.00	1.43

Means with the same letter(s) in the same column and row of each trait are not significantly different at 5% probability level, * , ** & *** indicates significant at 5% , 1% and 0.1% probability level, respectively. ns= non-significant, CV (%) = coefficient of variation in percent, GY=grain yield, BY=biomass yield, SY=straw yield, HI= harvest index

3.3.8 Harvest index

The ability of a cultivar 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. The analysis of variance showed that harvest index was statistically highly significantly ($p<0.01$) affected by seeding rate and row spacing. However, the interaction effect of seeding rate and row spacing was found insignificant. The highest harvest index (38.15%) was calculated at seeding rate of 150 kg ha^{-1} while lowest harvest index (31.69%) was recorded at the seeding rate of 100 kg ha^{-1} and was statistically lower than the seeding rate of 175 kg ha^{-1} (33.27%) (Table 3.3). Similar with the present finding, Iqbal *et al.*(2012) stated that highest harvest index obtained at seeding rate of 150 kg ha^{-1} as compared to 125 and 175 kg ha^{-1}.

Maximum harvest index (37.47%) was observed at row spacing of 20 cm while minimum harvest index (33.04%) was recorded at row spacing of 30 cm. However, it was statistically in parity with harvest index obtained in response to the spacing of 25 and 30cm (Table 4.3).

This result is in line with the findings of Hussain *et al.* (2014) who stated that maximum harvest index at narrow row spacing while minimum harvest index was recorded at wider row spacing. Likewise, Hussain *et al.* (2012) found that higher harvest index was reported in 20 cm row spacing, but statistically similar with 25 cm row spacing in wheat crop. The same result also reported by Mondal *et al.* (2012) who found that the highest harvest index was observed in 20 cm row spacing in rice crop, but statistically similar with 25 cm row spacing. Harvest index had interrelationship with grain yield and above ground biomass yield that the highest harvest index was the result of greater grain yield. Lowest harvest index was mainly due to increased plant height and increased biomass yield excessively rather than grain yield which lead to decrease of harvest index.

3.5 Correlation Analysis on Yield and Yield Related Parameters on Bread Wheat

As it is indicated in Table 4.4 the correlation study among bread wheat agronomic parameters were quantified and strong correlation was observed between some of bread wheat yield components. Plant height has positive and significant correlation with effective tiller numbers (r=0.38) since there is competition for sun light under densely populated situation because of increased effective tiller numbers that may result taller plants. Spike length showed positive and significant correlation with number of kernels per spike (r=0.60) and thousand kernel weight (r=0.39) (Table 3.4). Biomass yield positively and highly significantly correlated with effective tiller numbers (r=0.57) and plant height(r=0.76). Whereas Straw yield was very highly and positively correlated with biomass yield (r=0.89) and plant height(r=0.59) (Table 3.4).

In this study Grain Yield showed positive and significant correlation with its components such as effective tiller numbers (r=0.78), biomass yield (r=0.77) and plant height (r=0.70). This means with increasing value of these parameters, grain yield increases as well and vice versa. Besides this, there was non-significant and positive correlation between grain yield and spike number (r=0.24). Whereas, there were negative correlations indicated among grain yield with spike length of bread wheat (r= -0.40), number of kernels per spike (r= -0.46) and thousand kernel weight (r= -0.59).

Harvest index was positively and highly significantly correlated with grain yield (r=0.74) and effective tiller numbers (r=0.57). On the other hand, thousand kernel weight (r= -0.33) and straw yield (r= -0.33) were negatively and significantly correlated with harvest index.

Table 4.4: Correlation analysis of Bread wheat agronomic parameters

	DTE	DTH	DTM	PH	ETN	SL	SN	NKPS	BY	GY	SY	TKW	HI
DTE	1	0.05^{ns}	0.53**	0.04^{ns}	-0.15^{ns}	-0.08^{ns}	0.03^{ns}	0.02^{ns}	-0.01^{ns}	-0.06^{ns}	0.03^{ns}	0.17^{ns}	-0.07^{ns}
DTH		1	0.46*	-0.47*	-0.27^{ns}	0.49*	-0.27^{ns}	0.51*	-0.59**	-0.46**	-0.53**	0.50*	-0.12^{ns}
DTM			1	-0.67**	-0.31^{ns}	0.51**	-0.23^{ns}	0.47*	-0.61**	-0.57**	-0.46*	0.41*	-0.2^{ns}
PH				1	0.38*	-0.73**	0.16^{ns}	-0.54**	0.76**	0.70**	0.59**	-0.54**	0.30^{ns}
ETN					1	-0.24^{ns}	-0.004 ns	-0.24^{ns}	0.56**	0.78**	0.26^{ns}	-0.51**	0.57**
SL						1	-0.09^{ns}	0.60*	-0.73^{ns}	-0.40^{ns}	-0.76^{ns}	0.39^{ns}	0.11^{ns}
SN							1	-0.52*	0.31**	0.24**	0.27**	-0.004*	0.06^{ns}
NKPS								1	-0.64**	-0.46**	-0.59**	0.41*	-0.05^{ns}
BY									1	0.77**	0.89**	-0.54**	0.14^{ns}
GY										1	0.38*	-0.59**	0.74**
SY											1	-0.35*	-0.33*
TKW												1	-0.33*
HI													1

DTE=days to 50% emergence, DTH=days to 50% heading, DTM=days to 90% physiological maturity, PH=plant height, ETN=effective tiller numbers, SL=spike length, SN=spike number, NKPS=number of kernels per spike, BY=biomass yield, GY=grain yield, SY=straw yield, TKW=thousand kernel weight, HI=harvest index

3.6 Partial Budgeting Analysis

In the result of present study, the costs for the different seeding rates, labor cost for row making, drilling the seed and fertilizer application varied according to their rates and spacings requirements being other costs were constant for each treatment. In order to recommend the present result for the study area, it is necessary to estimate the minimum rate of return acceptable to producers in the recommendation domain. Based on partial budget analysis, the highest net benefit (28, 526Birr ha^{-1}) was obtained from treatment combination of 150 kg ha^{-1} seeding rate with 20 cm inter-row spacing while the lowest net benefit (18, 863Birr ha-1) was obtained from the combination of 100 kg ha^{-1} seeding rate with 20 cm inter-row spacing with only in one growing season (Table 3.5 and Table 3.6).

According to CIMMYT (1988), the minimum acceptable marginal rate of return (MRR %) should be 100%. The highest 5.2 value cost ratio (VCR) was obtained from the use of 150 kg ha^{-1} seeding rate and 20 cm inter row spacing followed by 5.0 and 4.5 value cost ratio which were recorded from seeding rate of 125 and 175 kg ha^{-1} with 20 cm row spacing of each, respectively (Table 3.5). Therefore, the most attractive rates for small-scale farmers of the study area with low cost of production and higher benefits in this case were 150 kg ha^{-1} seeding rate and 20 cm inter-row spacing combination. However, 125 kg ha^{-1} seeding rate with 20 cm inter-row spacing combination was also profitable with the highest net benefit and recommended as 2nd option. And also 175 kg ha^{-1} with 20 cm inter-row spacing combination was also profitable with the highest net benefit and recommended as 3rd option.

Table 3.5: Partial budget analysis as influenced by row spacing and seeding rate of bread wheat

RS with SRT	UAGY	AGY	UASY	ASY	TVC	GB	NB	B: C
20/100	3333.33	3000.00	6699.99	6030.00	4,730.00	23593.00	18863.00	4.0
20/125	4577.78	4120.00	6718.52	6047.00	5,125.00	31259.00	26134.00	5.0
20/150	4983.33	4485.00	6850.00	6165.00	5,520.00	34046.00	28526.00	5.2
25/150	4236.36	3813.00	7445.45	6701.00	5,470.00	29572.00	24102.00	4.4
20/175	4616.67	4155.00	8322.72	7490.00	5,915.00	32306.00	26391.00	4.5

RS= row spacing (cm); SRT= seeding rates (kg ha^{-1}); UAGY= unadjusted grain yield (kg ha^{-1}); AGY= adjusted grain yield (kg ha^{-1}); UASY= unadjusted straw yield (kg ha^{-1}); ASY= adjusted straw yield (kg ha-1); TVC= total variable cost (Birr ha^{-1}); GB= gross benefit (Birr ha^{-1}); NB= net benefit (Birr ha^{-1}); B:C= benefit to cost ratio.

Table 3.6: Summary of partial budget analysis in bread wheat crop at yebo in 2015 cropping season

Row spacing (cm) with seeding rate (kg ha^{-1})	Total variable cost (Birr ha^{-1})	Average grain yield (kg ha^{-1})	Adjusted grain yield (kg ha^{-1})	Average straw yield (kg ha^{-1})	Adjusted straw yield (kg ha^{-1})	Gross benefit (Birr ha^{-1})	Net benefit (Birr ha^{-1})	Benefit to Cost ratio (B:C)
1. 20/100	4,730.00	3333.33	3000.00	6699.99	6030.00	23593.00	18863.00	4.0
2. 25/100	5,530.00	3022.22	2720.00	6477.78	5830.00	21547.00	16017.00	2.8
3. 30/100	5,330.00	2851.51	2566.00	6704.04	6034.00	20557.00	15227.00	2.8
4. 20/125	5,125.00	4577.78	4120.00	6718.52	6047.00	31259.00	26134.00	5.0
5. 25/125	5,925.00	3350.00	3015.00	6600.00	5940.00	23659.00	17734.00	2.9
6. 30/125	5,725.00	3221.21	2899.00	6063.64	5457.00	22639.00	16914.00	2.9
7. 20/150	5,520.00	4983.33	4485.00	6850.00	6165.00	34046.00	28526.00	5.2
8. 25/150	5,470.00	4236.36	3813.00	7445.45	6701.00	29572.00	24102.00	4.4
9. 30/150	5,420.00	4166.67	3750.00	7481.48	6733.00	29145.00	23725.00	4.3
10. 20/175	5,915.00	4616.67	4155.00	8322.72	7490.00	32306.00	26391.00	4.5
11. 25/175	5,865.00	4151.85	3737.00	8598.15	7738.00	29486.00	23621.00	4.0
12. 30/175	5,815.00	3969.70	3573.00	8604.37	7744.00	28341.00	22526.00	3.9

Cost of seed 15.80 Birr per kg; Planting Cost Birr 50 per person per day; Sale price of bread wheat grain Birr 7.0 per kg; Sale price of bread wheat straw 0.43 Birr per kg,

4. CONCLUSION AND RECOMMENDATIONS

4.1 Conclusion

From the present study it is possible to conclude that both seeding rate and inter row spacing affect most of yield and yield related traits of bread wheat. The results of the data indicated significant differences ($p < 0.05$) in all agronomic traits except days to emergence in response to the different seeding rates. Based on the result of this study, among four seeding rates the use of 150 kg ha^{-1} is superior in most of bread wheat agronomic traits such as effective tiller numbers, spike number per 1m row length, grain and biomass yield and harvest index than 100, 125 and 175 kg ha^{-1}.Therefore, this study investigated and concluded that seeding rate of 150 kg ha^{-1} performed better and gave higher grain yield (4462.10 kg ha^{-1}) and has 34.55 % grain yield advantage on average over the remaining three seeding rates. However, the highest seed per spike and thousand kernel weight were recorded in the lowest seeding rate (100 kg ha^{-1}) even though the lowest seeding rates were not advantageous in many of yield and yield component traits. Since denser population is characterized by stronger inter plant competition for water, nutrients, and sunlight, the highest seeding rate (175 kg ha^{-1}) also economically unacceptable.

The results of the data also indicated significant variations ($p < 0.05$) in some agronomic traits in response to the different row spacings. Among others, effective tiller numbers, spike numbers, plant height, and grain yield were the major agronomic traits highly affected by the row spacing. In contrast, other agronomic traits such as days to emergence, days to heading, days to maturity, spike length, number of kernels per spike and straw yield were not significantly affected by the row spacing. Grain yield was increased within narrow row spacing as far as this work is considered. Among row spacings in this experiment 20 cm row spacing produced higher grain yield (4377.8 kg ha^{-1}) as compared to 25 and 30 cm row spacings. Whereas all yield and yield components of bread wheat were not affected by the interaction effect of seeding rate and row spacing.

4.2 Recommendations

The present research finding showed that using of 150 kg ha^{-1} seeding rate and 20cm inter row spacing gave better grain yield (4462.10 kg ha^{-1}and 4377.8 kg ha^{-1}, respectively) of bread wheat and can be recommended tentatively for the study area as the first option. On the other hand based on partial budget analysis 125 kg ha^{-1} seeding rate with 20 cm row spacing and 175 kg ha^{-1} with 20 cm row spacing combination can be also recommended as 2nd and 3rd option, respectively. However, to make reliable and acceptable recommendation it is better to repeat this experiment across locations and over seasons.

5. REFERENCES

Abbas, G., M.A. Ali, G. Abbas, M. Azam and I. Hussain. 2009. Impact of planting methods on wheat grain yield and yield contributing parameters. *J. Anim. Plant Sci*. 19: 30-33.

Abd El-Lattief E.A. 2011. Bread wheat (*Triticum aestivum* L.) productivity and profitability as affected by method of sowing and seeding rate under Qena Environment. Department of Agronomy, Faculty of Agriculture, South Valley University, Qena, Egypt. *Asian journal of crop science* 3(4): 188-196.

Abu Tefera. 2013. Ethiopia: grain and feed mannual. GRAIN Report Number: ET–1301.

Acquaah, G., 2002. Principles of Crop Production: Theory, Techniques and Technology. Prentice Hall, Inc., USA. pp. 49-51

Ahmad, B., I. Muhammad, M. Shafi, H. Akbar, H. Khan and A. Raziq. 1999. Effect of row spacing on the yield and yield components of wheat. *Sarhad J. Agric*. 15: 103-106.

Ahmad, M.M., N. Yousaf and M.S. Zamir, 2000. Response of wheat growth, yield and quality to varying application of nitrogen and phosphorous. *J. Agric. Res*., 38: 289-29.

Al-Fakhry, A. K. and Y. A. Ali. 1989. Effect of plant densities and fertilization on yield of two wheat cultivars (*Triticum aestivum* L.) under rainfed conditions in Northern Iraq. *Mesopotamia J. Agric*. 21(1):221- 236 [Field Crops Absts. 42(8):5792:1989].

Ali, M., L.Ali, M.Sattar and M.A.Ali. 2010. Improvement in wheat (*Triticum aestivum* L.) Yield by manipulating seed rate and row spacing in vehari zone. Adaptive Research Farm, Vehari. *Journal of Animal and Plant sciences*, 20(4) pp. 225-230.

Ali, M.; A. Abouzar; B. Saeid; and A. Hashem, 2011. Effect of different levels of nitrogen and plant spacing on yield, yield components and physiological indices in high-yield rice (number 843), *American-Eurasian Journal Agricultural and Environment Science*, 10(5):893 – 900.

Amare Aleminew, Adane Legas, and Mekonen Misganaw. 2015.Yield Response of Bread Wheat to Timing of Urea Fertilizer Application in Eastern Amhara Region. Sirinka Agricultural Research Center, Woldia, Ethiopia. *Journal of Biology, Agriculture and Healthcare.* 5(3):180-183.

Amjad, M. and W. K. Anderson. 2006. Managing yield reduction from wide row spacing in wheat. *Aust. J. Exp. Agric*. 46(10):1313-1321.

Anderson, R., C. Assenheimer, N. Eshpeter, E. Griffiths, B. Metzger, L. Apworth, G. Ragan and J. Vanee, 2001. Investigation into Row Spacing with Direct Seeded Barley, Canola and Wheat. Agriculture and Agri-food Canada. pp. 1 - 8.

Anderson, W.K. and D. Sawkins, 1997. Production practices for improved grain yield and quality of soft wheat in Western Australia. *Aust. J. Exp. Agric*., 37:173-180.

Andrane, F.H., S.A. Uhart and M.I. Frugone, 1993. Intercepted radiation at flowering and kernel number in maize: Shade versus plant density effects. Crop Science, 33:482- 485.

Andrane FH, Calvino A, Cirilo A and Barbieri P 2002. Yield responses to narrow rows depend on increased radiation interception. *Agronomy Journal* 94: 975-980.

Aquino, P., Carrion, F., and Calvo, R. 2002. Selected wheat statistics. In ‘‘CIMMYT2000-2001 World Wheat Overview and Outlook: Developing No-Till Packages for Small-Scale Farmers. (Ed. J. Ekboir) pp. 52-62. (CIMMYT, Mexico DF).

Arif, M., M. Ali, Q. M. Din, M. Akram and L. Ali. 2003. Effect of different seed rates and row spacings on the growth and yield of wheat. *J. Anim. Pl. Sci.* 13(3):161-163.

Arnon, I. 1972. Plant population and distribution patterns in Corp Production in Dry Regions (ed. Arnon, I.) pp. 443-456,359-360. Vol.1 National Book Foundation, Islamabad, (Pakistan).

Auld BA, Kemp DR and Medd RW 1983. The influence of spatial arrangement on grain yield of wheat. *Australian journal of Agricultural Research* **34**:99-108.

Azam-Ali, S.N. and G.R. Squire, 2002.Principle of tropical Agronomy. CAB Publishing international, USA. Pp236.

Bakht, J., Z. Qamer, M. Shafi, H. Akber, M.U. Rahman, N. Ahmad and M.J. Khan. 2007. Response of different wheat varieties to various row spacing. Sarhad J. Agric. 23:839-845.

Baloch, A. W., A. M. Soomro, M. A. Javed, and M. Ahmed, 2002. Optimum plant density for high yield in rice (Oryza sativa L.). *Asian Journal of Plant Science*, 1(1): 25 – 27.

Baloch, S. M., I. T. Shah, M. A. Nadim, M. I. Khan, and A. A. Khakwani. 2010. Effect of seeding density and planting time on growth and yield attributes of wheat. *The Journal of Animal and Plant Sciences,* 20: 239-240.

Bellatore, G. P., C. D. Prima and R. Sarmo(1985). Effect of sowing density on biological performance and yield of various durum wheat cultivars. Rivista di Agronomica. 3(2-3): 159-169. [Field Crop Absts., 30(4): 2004; 1987].

Bergh, K., Chew A., Gugerty M.K., and Anderson C.L. 2012.Wheat value chain: Ethiopia. EPAR Brief No.204.

Berhane G., Paulos Z., Tafere K., and Tamiru S. 2011. Food grain consumption and calorie intake patterns in Ethiopia. ESSP II Working Paper No. 23, International Food Policy Research Institute (IFPRI). Addis Ababa, Ethiopia.

Beuerlein .J. 2001. Horticulture and Crop Science. Ohio State University Extension Fact Sheet. http://ohioline.osu.edu/agf-fact/0146.html 04/07/2002

Capouchova, I., J. Petr, Eva Bicanova, and O. Famera.2009. Effects of organic wheat cultivation in wider rows on the grain yield and quality. Czech University of Life Sciences Prague,Faculty of Agrobiology, Food and Natural Resources, Department of Plant Production. Czech Republic.

Chapman, H.D.1965. Cation exchange capacity by ammonium saturation. Chemical soil analysis. pp891-901.

Chaudhary, M.A., A. Ali, M.A. Siddique and R. Sohail, 2000. Growth and yield response of wheat to different seed rates and wild oat (*Avena fatua*) competition durations. *Pakistan J. Agri. Sci.,* 37: 152-154.

Cheema, M.S., M. Akhtar and A. Liaquat. 2003. Effect of seed rate and NPK fertilizer on growth and yield of wheat variety Punjnad. *Pak. J. Agron*., vol. 2, 185-189.

Chen, C.K., K. Neill, D. Wichman and C. Westcott 2008. Hard Red Spring Wheat Response to Row Spacing, Seeding Rate, and Nitrogen. *Agronomy Journal*, 100:1296-1302.

Chen, S., Zhang, X., Sun, H., Ren, T. and Wang, Y. 2010. Effects of winter wheat row spacing on evapo-transpiration, grain yield and water use efficiency. *Agricultural Water Management*, **97**, 1126-1132.

Ciha, A.J. 1993. Seeding rate and seeding date effects on spacing seeded small grain cultivars. *Agron. J.* 6 (1) 795-798.

CIMMYT [International Maize and Wheat Improvement Center]. 1988. *From Agronomic Data to Farmer Recommendations* (An Economics Training Manual Completely Revised Edition). Mexico, D.F.

CSA (Central Statistical Agency). 2013. Agricultural sample survey: area and production of major crops, meher season. Vol.I. Addis Ababa, Ethiopia.

CSA (Central Statistical Agency). 2014. Agricultural sample survey: area and production of major crops, meher season. Vol.I. Addis Ababa, Ethiopia.

CSA (Central Statistical Authority). 2006. Agricultural sample survey on area coverage and production of crops. Addis Ababa, Ethiopia.

Darwinkel, A. 1980. Ear development and formation of grain yield in winter wheat. *Neth. J. Agric. Sci*., 28: 156-163.

Darwinkel, A., D.A. Tenhag, and J. Kuizenga. 1977. Effect of sowing date and seeding rate on crop development and grain production winter wheat. *Neth.J. Agric. Sci*. 25: 83-94.

Day, P.R., 1965. Hydrometer method of particle size analysis. In: Back, C.A. (eds.), Methods of soil analysis. *American Society of Agronomy Journal* . 9 (2):562-563

Donald C.M. 1962. In search of yield. Journal of Australian Institute of Agricultural Sciences. 28: 171-178.

Donald, C.M. 1963. Competition among crop and pasture plants. *Adv. Agron*. 15: 1-118.

Dubis, B., and W. Budzynski. 2006. Response of winter wheat to the date and density of sowing. Acta Scientiarum Polonorum Agricultura, 5:15-24.

Eberbach, P., and M. Pala, 2005. Crop row spacing and its influence on the partitioning of evapotranspiration by winter-grown wheat in Northern Syria. Plant and Soil. 268, 195-208.

Ejaz H., W., Alishah, A.A. Shed, F. Hayat and J. Bakht. 2002. Yield and yield components of wheat as affected by different planting dates, seed rates and nitrogen levels. *Asian Journal of plant science*. 1 (5): 502-506.

Eyob Bezabeh, Tesfaye Haregewoin, Dejene Haile giorgis, Fitsum Daniel and Baye Belay. 2015. Change and growth rate analysis in area, yield and production of wheat in Ethiopia. Ethiopian Institute of Agricultural Research. *Research Journal of Agriculture and Environmental Management*. Vol. 4(4), pp. 189-191.

Fageria, N. K., V. C. Baligar and C. A. Jones, 2011. Growth and mineral nutrition of field crops. 3rd Edition, CRC Press, USA, 262p.

Fani E, J. S. Kazemi, M. Khosravi, and M. Bahdarvand. 2014. The Effect of Seed Density on Yield and Yield Components of Irrigated Wheat in the North East of Khouzestan. *Agric. sci. dev.,* Vol(3), No (9), pp. 292-295.

FAO (Food and Agriculture Organization of the United Nations). 2001. Crop and food supply assessment.

FAO (Food and Agriculture Organization of the United Nations). 2008. The state of Food and Agriculture.

FAO (Food and Agriculture Organization). 2011. FAOSTAT online database, available at link http://faostat.fao.org/. Accessed on December 2011.

FAO (Food and Agriculture Organization). 2014. Crop Prospects and Food Situation.

FAO (Food and Agriculture Organization). 2014b. Crop Production Data.

Frederick, J.R. and H.G. Marshal. 1985. Grain yield components of soft red winter wheat as affected by management practices. *Agron. J.* 77: 495-499.

Frizzell, D.L., C.E. Wilson, Jr., R.J. Norman, N.A Slaton, AL. Richards, and S.K. Runsick. 2006. Influence of row spacing and seeding rate on rice grain yield. In: R.J. Norman, J.F-. Mullenet, and K.A.K. Moldenhauer (eds.). B.R. Wells Rice Research Studies 2005. University of Arkansas Agricultural Experiment Station Research Series 540:270-275. Fayetteville, Arkanas.

Gafaar, N A. 2007. Response of some bread wheat varieties grown under different levels of planting density and nitrogen fertilizer. *Minufiya Journal of Agriculture*, 32: 165-183.

Gallegher, E.J. 1984. Cereal production.Royal Dublin society, Butter worth & CO Ltd, England. 354p.

Gashaw Tadesse , Alande Brauw, Nicholas Minot, and Tanguy Bernard. 2014. The Impact of the Use of New Technologies on Farmers Wheat Yield in Ethiopia: Evidence from a Randomized Controlled Trial. MoA.

Ghaffar and Shalidula. 1987. Effect of seed rate on wheat. *Pak. J. Agric*. 12: 19-21.

Ghulam Mustafa Laghari, Fateh Chand Oad, Shamasuddin Tunio, Qamaruddin Chachar, Allah Wadhayo

Gandahi, Muzzammil Hussain Siddiqui, Syed Waseem Ul Hassan And Abid Ali. 2011. Growth And Yield Attributes Of Wheat at Different Seed Rates. *Sarhad Journal of Agriculture*, 27 (2).

Gibson, L. and G. Benson. 2002. Origin, History, and Uses of Oat (Avena sativa) and Wheat (Triticum aestivum). Iowa State University, Department of Agronomy.3p

Gooding, M.J. and W,p. Davies, 1997. Wheat production and utilization. CAB Int.,Wallingford. UK.

Gorgy, N., 2010. Effect of transplanting spacing and nitrogen levels on growth, yield and nitrogen use efficiency of some promising rice varieties. *Journal of Agricultural Research Kafer El-Shiekh University*, 36(2):123-146.

GRDC (Grains Research and Development Corporation), 2011. Crop placement and row spacing fact sheet.

Gunri, S. K., and A. Choudhary, 2004. Effect of integrated nitrogen application and spacing on yield of rice (Oryza sativa) in foot-hills soils of West Bengal. *Indian Journal of Agronomy,* 49 (4): 248-250.

GWAO (Gozamen Woreda Agriculture Office), 2014. Annual report of 2014 cropping season. Agricultural and Rural Development Office of Gozamin district of East Gojjam zone, Amhara region, Ethiopia. Unpublished.

Haile Deressa and Girma, F. 2010. Integrated Effect of Seeding Rate, Herbicide Dosage and Application Timing on Durum Wheat *(Triticum Turgidum L. Var Durum)* Yield, Yield Components and Wild Oat (*Avena Fatua L.*) Control in South Eastern Ethiopia. Oromia Agricultural Research Institute, Sinana Agricultural Research Center, P.O. Box 208, Bale-Robe, Ethiopia.

Haile Deressa, Nigussie-Dechassa, Abdo W and Girma F. 2013. Seeding rate and genotype effects on agronomic performance and grain protein content of durum wheat (*Triticum turgidum* L. var. durum) in South-Eastern Ethiopia. *Afirican Journal of Food, Agriculture, Nutrition and Development,* 13 (3).

Hailu Gebre-Mariam. 1991. Wheat production and research in Ethiopia.pp.1-136.In: Hailu Gebre-Mariam,Tanner,D.G.and Mengistu Huluka(eds).Wheat research in Ethiopia: IAR/CIMMYT, Addis Ababa, Ethiopia.

Harper, J.L. 1977.Population biology of plants. Academic Press, London. pp: 41-54.

Hasanuzzaman, M., K., Nahar, T.S. Roy, M.L. Rahman, M.Z. Hossain and J.U. Ahmed, 2009. Tiller Dynamics and Dry Matter Production of Transplanted Rice as Affected by Plant Spacing and Number of Seedling per Hill. *Academic Journal of Plant Sciences*, 2 (3): 162-168.

Havalin, J.L, J.D. Beatan, S.L.Tsidale and W.L. Nelson. 1999. Soil Fertility and Fertilizer: An introduction to nutrient management. Six Editions. Printice Hall,Inc., New Jersey.http://en.wikipedia.org/wiki/Wheat#cite_ref-1 accesed

Hiltbrunner, J., M. Liedgens, P. Stamp, and B. Streit. 2005. Effects of row spacing and liquid manure on directly drilled winter wheat in organic farming. *European Journal of Agronomy,* 22: 441- 447.

Houba V.J.G, J.J Vander Lee, I. Novozamsky and I.Waligna.1989. Soil and plant analysis a sires of Syllabi..Part 5-soil Analysis procedures. Wageningen Agricultural University. The Netherlands.

Hussain, I., Muhammad Ayyaz Khan and Hayatullah Khan. 2010. Effect of seed rates on the agro-physiological traits of wheat. Department of Agronomy, Faculty of Agriculture, Gomal University, Dera Ismail Khan – Pakistan.

Hussain, I., M. A. Khan and K. Ahmad, 2003. Effect of Row Spacing on the Grain Yield and the Yield Component of Wheat (*Triticum aestivum* L.). *Journal of Agronomy, 2: 153-159.*

Hussain, M., Z. Mehmood, M. B. Khan, S. Farooq, D.J. Lee and M. Farooq, 2012. Narrow Row Spacing Ensures Higher Productivity of Low Tillering Wheat Cultivars. *International Journal of Agriculture and Biology*, 14:413 – 418.

Hussain, N., A. Yasmeen, M. Arif and H. Nawaz. 2014. Exploring the role of row spacing in yield improvement of wheat cultivars. Department of Agronomy, Faculty of Agricultural Science and Technology, Bahauddin Zakariya University, Multan-60800, Pakistan. *Pak. J. Agri. Sci.,* Vol. 51(1), 25-31.

Hussain, S., A. Sajjad, M.I. Hussain and M. Saleem, 2001. Growth and yield response of three wheat varieties to different seeding densities. *Int J. Agric. Biol.,* 3: 228-229.

Hussins, D. R. and W. L. Pan. 1993. Nitrogen efficiency components analysis: an evaluation of cropping system difference in productivity. *Agron. J.* 85: 898-905.

Iqbal, J., K. Hayat , S. Hussain , A. Ali, M. Ahmad Alias and H. Ahmad Bakhsh. 2012. Effect of Seeding Rates and Nitrogen Levels on Yield and Yield Components of Wheat (*Triticum aestivum* L.). *Pakistan Journal of Nutrition* 11 (7): 531-536.

Iqbal, N., N. Akbar, M. Ali, M. Sattar and L. Ali. 2010. Effect of seed rate and row spacing on yield and yield components of wheat (*Triticum aestivum* L.). Adaptive Research Farm, Vehari, *Pakistan.* J. Agric. Res. 48(2): 151-156.

Jackson, M.L., 1967. Soil chemical analysis. Practice Hall of India. New Delhi.

Jemal Abdulkerim, Tamado Tana and Firdissa Eticha. 2015. Response of Bread Wheat (*Triticum aestivum* L.)

Varieties to Seeding Rates at Kulumsa, South Eastern Ethiopia. *Asian Journal of Plant Sciences* 14 (2): 50-58.

Jeosph, K.S., M. Alley, D.E. Brann and W.D. Gravelle. 1985. Row spacing and seeding rate effect on yield and yield components of soft red wheat. *Agron. J.* 77: 211-214.

John Smith and Peter Martin. 2008. Wheat Seeding Rate and Nitrogen, Jerilderie. NSW DPI •VSAP Project.

Johnson, B.L. and B.K. Hanson. 2003. Row-spacing interactions on spring canola performance in the in Northern Great Plains. *Agron. J.* 95: 703-708.

Kakar, KM., Arif, M. and Ali, S. 2001. Effect of NP levels, seed rate and row spacing on wheat. *Pakistan Journal of Biological Science* 4: 1319-1322.

Khan PK, Musa M, Shazad MA, Adal NK and Nasim M.1996. Wheat performance on green manured and fertilized fields. *Pakistan Journal of Soil Science* 2: 84-86.

Khan, H., M.A. Khan, I. Hussain, M.Z. Khan and M.KKhattak, 2000. Effect of sowing method and seeding rates on grain yield and yield components of wheat variety Pak-81. *Pak. J. Biol. Sci*., 3: 1177-1179.

Khan, I.A., A. Ihsanullah, Jan. F.H. Taj, and N. Khan. 2002. Effect of sowing dates on yield and yield components of Mash bean. *Asian J. Pl. Sci. vol.* 1, pp. 622-624.

Khan, M.A., K. Ahmed, I. Hussain, M.A. Baloch and M.S. Baloch, 2001. Response of wheat varieties to different levels of nitrogen. *Sarhad Journal of Agriculture*, 4(3):276-278.

Khan, R.U. 1993. Effect of seeding rates on the grain yield and yield components of three wheat varieties under the rain fed condition of Elmary Libya. *Sarhad J. Agric*. 2 (1): 1-8.

Kumar, A., A.K. Sinha, B.P. Sinha, K.M.P. Singh, and S.S. Thakur. 1991. Response of wheat genotypes to seed rate and row spacing. *Indian J. Agron*. 36(1): 78 – 82.

Kumpawt, B. S. 1998. Response of late sown wheat to sowing method and seed rate. *Indian J. Agron.* 43(4): 650-652.

Kutcher, H.R., T.K. Turkington, G.W. Clayton and K.N. Harker, 2008. Impact of seed rates and row spacing on productivity of cereals. Un-published.

London, J.R. (Ed.), 1991. Booker tropical soil manual: A Handbook for Soil Survey and agricultural land evaluation in the tropics and sub tropics. Longman scientific and technical publishing, New York.

Lockhart, J.A.R. and A.J.L. Wiseman. 1983. Introduction to crop husbandry including grassland. Fifth edition. Royal agricultural college, Britain. 302p.

Makarim, A.K. and D. Ikhwani, 2010. Yield responses of two rice varieties to agronomic treatments. *Indonesian Journal of Agriculture,* 3(2):81 – 86.

Mali. H. and J.Choudhary.2012. Performance of bread wheat (*Triticum aestivum* L.) varieties under different row spacing. Department of Agronomy Rajasthan College of Agriculture. MPUAT, Udaipur (Raj.) *India. J. Wheat Res*. 4(2): 55-57.

Marshal, G.C. and H.W. Ohms. 1987. Yield response of 16 winter wheat cultivars to row spacing and seeding rate. *Agron. J.* 79 (4-8): 1027-1030.

Martin P., B. Scott, J.Edwards, B. Haskins and J. Smith 2010. Row spacing in Cereal and broadleaf crops. Mallee Sustainable Farming 2009 Research Compendium pp.147 – 152.

Mazurek, J. and A. Sabat.1984. Effect of sowing rate and nitrogen fertilizer application on yield of some triticale cultivars. Pamie hook tnikPulawski.vol. 83, 85-93.

McConkey, B. and P. Miller, 1999. Row Spacing effects on plant populations, canopy closure, water use, and grain yields in the brown soil zone. Pp.176-197. In: Proc Soils & Crops Workshop. Feb. 26-27, 1999. Saskatoon, SK.

Mehlich, 1953. Determination of pH,Ca,Mg,Na and Ammonium. North Carolina soil test Division mimeo. I double acid method.

Melaku Mengstie. 2008. *Effects of seeding and nitrogen rates on yield and yield components of Tef (Eragrostis Tef Zucc.*). M.Sc. Thesis, The School of Graduate Studies of Haramaya University. Harar. Ethiopia.

Mengel, K. and E.A. Kirkby. 1996. Principles of plant nutrition. Panima Publishing Corporation. New Delhi, India. 314p.

Mennan H, Zandstra BH. 2005. Influence of wheat seeding rate and cultivars on competitive ability of bifra (Bifora radians). Weed Technology 19, 128-136.

Ministry of Agriculture (MoA). 2012. Ministry of Agriculture. Animal and Plant Health Regulatory Directorate. Crop variety register, Issue No. 15. Addis Ababa, Ethiopia. Unpublished.

Mohamadzadeh, M., S.A. Siadat, M.S. Norof and R. Naseri. 2011. The effects of planting date and row spacing on yield, yield components and associated traits in winter safflower under rain fed conditions. Am-Euras. *J. Agric. & Environ. Sci*. 10: 200-206.

Mondal, M.M.A, M.I.K. Rana, M.H. Imam and J. Sultana, 2012. Determination of row spacing based on morphological characters in Aus rice. *International Journal of Sustainable Crop Production*, 7(1):34-37.

Muhammad, A., C.G. Rabbani, G.M. Subhani and I. Khaliq, 1999. Combining ability studies for some polygenic traits in aestivum species. *Pak. J. Biol. Sci*., 2: 434-437.

Naeem, M., 2001. *Growth, radiation use efficiency and yield of new cultivars of wheat under variable nitrogen rates*. M.Sc. (Hons) Agri. Thesis, Deptt. Agron. Univ. Agri., Faisalabad.

Naseem, K., A. R.H. Qureshi, J. Akhtar and M.A. Masood. 2002. Screening of wheat (*Triticum aestivum* L.) genotypes against salinity in solution culture. *Pakistan J. Agric. Sci., 37, pp. 1-6.*

Naseri, R., A. Soleymanifard, H. Khoshkhabar, A. Mirzaei and K. Nazaralizadeh. 2012. Effect of plant spacing on grain yield and yield components and associated traits of three durum wheat cultivars in western Iran. *Intl. J. Agri. Crop Sci*. 4: 79-85.

Nazir A. 1990. Crops for profit: In proceedings of Symposium on Maximum Yield Research August 1990.892[En ref. Satellite Symposium of 14th International Congress of Soil Science August 12-18, 1990.nitrogen. Indian J. Pl.Physiol., 6: 279–83nitrogen. *Indian J. Pl.Physiol., 6: 279–83.*

Nazir, M.S., A. Jabbar, Z. Waheed, A. Gaffar and M. Aslam, 2000. Response of late sown wheat to seeding density and nitrogen management. *Pak. J. Biol. Sci*., 3: 998-1001.

Nizamani, G.S., S. Tunio, U. A. Buriro, M. I. Keerio. 2014. Influence of different seed rates on yield contributing traits in wheat varieties. Plant Breeding and Genetics, Nuclear Institute of Agriculture (NIA), Tando Jam, Pakistan. Faculty of Crop Production, Sindh Agriculture University, Tando Jam, Pakistan. *Journal of Plant Sciences*. 2(5) pp. 232-236

Olsen, S.R., C.V., Cole, F.S., Watanabe and L.A., Dean, 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. USA Circular 939:1-19.

Olsen, J., Kristensen L., Weiner, J & Griepentrog, H. W. 2005. Increased density and spatial uniformity increase weed suppression by spring wheat (*Triticum aestivum*). *Weed Research*, 45:316–321.

Onwueme, I. C. and T. D. Sinha. 1999. Field crop production in tropical Africa, CTA Wageningen, Nether lands.

Osman, A.M. and Z.M. Mohamed. 1981. Yield and yield component of wheat and their inter relationships as influenced by N and seed rate in Sudan. *J. Agri. Sci. Camb.* 97: 611-618.

Otteson, B.N., M. Mergoum, and J.K. Ransom. 2007. Seeding rate and nitrogen management effect on spring wheat yield and yield components. *Agronomy Journal*, 99: 1615-1621.

Otteson, B.N., M. Mergoum, J.K. Ransom and B. Schatz, 2008. Tiller contribution to spring wheat yield under varying seeding and nitrogen management. *Agron. J.,* 100: 406-413.

Ozturk, A., O. Caglar and S. Bulut, 2005. Growth and yield response of facultative wheat to winter sowing, freezing sowing and spring sowing at different seeding rates. *J. Agron. Crop Sci., 192: 10-16.*

Pandey, B.P., Komal Bahadur Basnet, Madan Raj Bhatta, Shrawan Kumar Sah, Resham Bahadur Thapa, Tanka Prasad Kandel.2013. Effect of row spacing and direction of sowing on yield and yield attributing characters of wheat cultivated in Western Chitwan, Nepal. Vol.4, No.7, 309-316.

Peter, J., V. Cerny and L. Huska. 1988. Development in crop science (13): Yield formation in the main field crops. Elsevier Science Publishing Company, inc., New York, USA. 336 P.

Peterson, R. F. 1965. Wheat botany, cultivation and utilization. Inter science publisher inc., New York. 422p.

Power, I.F. and A. Alessi. 1978. Tiller development and yield standard and semi-dwarf spring wheat varieties as affected by N fertilizer. *J. Agric. Sci*. 90: 97-108.

Rafique, M., A. Ahmad, N. Muhammad, M. Siddique and M. Kamran.1997. Effect of seeding densities and planting techniques on late sown wheat (*Triticum aestivum* L.) yield. *J. Agric. Res.* 35(3):147-153.

Rahim Naseri, Abas Soleymanifard, Hamid Khoshkhabar, Amir Mirzaei and Kamvan Nazaralizadela. 2012. Effect of plant density on grain yield, yield components and associated traits of three durud wheat cultivar in western Iran. *International Jornal of Agriculte and Crop Sciences,* 4 (2):79-85.

Ranjbar, G.H., S.A.M. Cheraghi and M. Qadir. 2010. Yield response of different wheat genotypes in saline areas of lower karkhehriver basin of Iran. Am-Euras. *J. Agric. & Environ. Sci.* 8: 50-54.

Read, D.W.L. and F.G. Worder. 1981. Wheat and barley response to rates of seeding and fertilizer in southern Sasketchewan. *Agron. J.* 74: 33-36.

Reedy, S.R. 2006.Agronomy of field crops. Second revised edition.2004, Reddy SR-India.

Regassa Ensermu, Aleligne Kefyalew and W. Mwangi. 1992. On farm verification of improved bread wheat varieties and management practice in Gojjam region of Ethiopia. Pp 281-289. In: Tanner, D.G, and W. Mwangi , eds. The seventh Regional wheat workshop for Eastern, Central and Southern Africa, Nakuru, Kenya, CIMMYT.

Salem, A.K.M., 2006. Effect of nitrogen levels, plant spacing and time of farmyard manure application on the productivity of rice. *Journal of Applied Science and Research*, 2: 980–987.

Satorre, H.E. and G.A. Slafer. 2000. Plant density and distribution as modifiers of growth and yield, wheat ecology and physiology of yield determination (eds. Satorre, E. and G.A. Slafer) Viva Books Pvt. Ltd. India. 143p.

Schlehuber, A.M. and B.B. Tucker. 1967. Wheat culture. Pp. 117-180. In: K.S. Quisenberry and L.P. Reirtz (eds.). Wheat and wheat improvement. American Society of Agronomy Number 13 Series, Agronomy, inc., USA.

Seleiman, M.F., Ibrahim, M.E., Abdel-Aal, S.M. and Zahran,G.A. 2010. Effect of seeding rates on productivity, technological and rheological characteristics of bread wheat (*triticum aestivum* L.). *International Journal of Current Research*. Vol4, pp. 075-08.

Shah, P. 1994. Cereal crop, Rabi.In Crop Prod.(Eds. Nazir, S., E. Bashir and R. Bantel), National Book Foundation, Islamabad.pp. 238 –245.

Sikander, K., I. Hussain K. Tanveer, M. Sohail, N.S. Kissana and S.G. Abbas. 2003. Effects of different planting methods on yield and yield components of wheat. *Asian J. Plant Sci.,* vol. 2, pp. 811-813.

Singh, H. and R. Singh. 1984. Effect of nitrogen and seed rates on wheat. *Indian J. Agron.* 29(1): 129-130.

Singh, R. and S.K. Agarwal, 2001. Soomro, U.A., M. Ur Rahman, E.A. Odhano, S. Gul and A. Tareen, 2009. Effects of sowing method and seed rate on growth and yield of wheat (*Triticum aestivum* L.). *World J. Agr. Sci*., 5:159-162.

Sisodia, N.S. and J.C. Patel. 1985. Effect of seeding density in yield and yield components. Pp 309-319. Regional wheat workshop, Eastern, Centaral and Southern Africa and Indian Ocean, Najoaro, Kenya.

Soomro UA, Rahman MU, Odhano EA, Gul S, Tareen AQ. 2009. Effects of sowing method and seed rate on growth and yield of wheat (*Triticum aestivum* L.). *World Journal of Agricultural Sciences* 5, 159-162.

Spiertz, J.H. and J. Ellen. 1978. Effect of nitrogen on crop development and grain growth of wheat in relation assimilates and nutrients. *Neth. J. agric. Sci.* 26: 210-231.

Tanner, D. G., Amanuel Gorfu, and Kashun Zewde. 1991. Wheat agronomy research in Ethiopia. pp 95-136. In: Haillu Geber-mariam, D.G. Tanner and Mengsitu Huluka (Eds.). Wheat research in Ethiopia; a historical perspective, Addis Ababa, IAR/CIMMYT. the Free state, Republic South Africa.

Tesfaye Getachew, Derbew Belay and Solomon Tulu, 2012. Yield and growth parameters of potato (Solanum tuberosum L.) as influenced by intra row spacing and time of earthing up. International Journal of Agricultural Research, Pp 1-11. ISSN 1816-4897 / DOI:10.3923/ijar.

Thakur, S.S. I.S. Pandev. S.J. Singh and S.S. Mishr1996. Effect of seed rate and row spacing on late sown wheat in alluvial calcareous soil. *J. Res. Bisra Agric. Univ*. vol. 2, pp. 123-125,

Thayer, J.W., Jr. and H.C. Rather, 1987.The influence of rate of seeding upon certain plantcharacters in barley. *J. Am. Soc. Agron*., 29: 754-760.

Tomar S. K. 2004. Response of rainfed wheat to sowing methods and seed rate under Diara land condition. *Madras Agricultural Journal* 91, 47-51.

Tompkins, D.K., Hultgreen, G.E., Wright, A.T & Fowler, D.B. 1991b. Seed rate and row spacing of no-till winter wheat. *Agron. J.,* 83: 684–689.

Tunis, K.L., S.A. Qayyum, A.H. Ansari, A.Q. Rajpute and K.A. Mahar. 1995. Effect of different sowing rates on the growth and yield of wheat cultivars. *Pak J. Agric. Engg. & Vet. Sci.* 11(1-2):1-13.

United States Department of Agriculture (USDA). 2013. Grain: world markets and trade. Accessed at http://www.fas.usda.gov/data/grain ‐ world ‐ markets ‐ and ‐ trade.

Walkely, A and I.A.Black,1934. An examination of the Degtjareff method for determining soil organic matter and proposed modification of the chromic acid titration method. Soil Sci 37: 29-38.

Willey, R.W. and W. Holiday. 1971. Plant population, shading and thinning studies in wheat. *J. Agric. Sci. (Camb).* **77**: 453-461.

Worku Awdie. 2008. *Effects of nitrogen and seed rates on yield and yield components of bread wheat (triticum aestivum L.) in yelmana densa district, northwestern Ethiopia*. M.Sc. Thesis. The School of Graduate Studies of Haramaya University. Harar, Ethiopia.

Yordanos Ameyu. 2013. *Influence of row spacing and nitrogen rates on yield and yield components of direct-sown irrigated rice at Gode, south-eastern Ethiopia*. M.Sc. Thesis. School of Graduate Studies Haramaya University, Ethiopia.

Zewdie Bishaw, Paul C. Struik and Anthony J.G. Van Gastel. 2014. Assessment of on-farm diversity of wheat varieties and landraces: evidence from farmer's field in Ethiopia. *African Journal of Agricultural Research*, 9 (38): 2948-2963.