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Influence of Seed Rates and Sowing Methods on Yield and Yield Components of Bread Wheat (*Triticum aestivum* L.) Varieties in Abbay Chommen District, Western Oromia, Ethiopia

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Abstract: Bread wheat (*Ttriticum aestivum* L.) is the most important crop in Horro Guduru Wollega Zone of Ethiopia. However, its productivity is very low as compared to the productivity of world bread wheat which is attributed due to poor agronomic practices like inappropriate seeding rate, improper of sowing method and use of local varieties. Therefore, a field experiment was conducted on farmer's field at Kolobo kebele in Abay choman District, in Horro Guduru Wollega zone, during 2019/2020 cropping season. The experiment consisted of three levels of seeding rates (100, 125 and 150 kg ha^{-1}) and two sowing methods (row and broadcasting) and two bread wheat varieties (Liben and Hidase) and laid out in randomized complete block design with factorial arrangement in three replications. Spike length, number of kernels per spike, thousand seed weight, dry biomass yield, grain yield and harvest index of wheat were significantly (P<0.05) influenced by the main effect of seeding rate, sowing method and varieties. The interaction effect of seeding rate, sowing method and variety were highly significant effects for thousand seed weight, dry biomass yield and harvesting index of bread wheat. The interaction of sowing methods and seed rates significantly improved number of productive tillers per plant, number of spikes per spikelet's and thousand seed weight of wheat. Significantly higher grain yield of bread wheat was obtained with 125 kg ha^{-1} seeding rate planted row method using Liben variety of bread wheat. Therefore, the use of Liben variety with 125 kg ha^{-1} seed rate by row method of planting significantly improved grain yield of bread wheat and recommended for the area and similarly agroecologies.

Key words: Bread Wheat · Seeding Rate · Sowing Method · Varieties · Yield

INTRODUCTION

Soil fertility degradation in regions is for most importance due to permanent and irreversible degradation of soil quality and productivity. Soil fertility management processes, the application of inorganic amendments is used for increasing yield and productivity. The use of fertilizers for soil fertility amendment with improved varieties of wheat could sustainably increase production and productivity [1]. Wheat (*Triticum aestivum* L.) is an essential crop for national and global food security [2]. It is King of the cereals and important staple food crop [3]. Nutritious food grain of all grains in the world and grows worldwide according to its genotypic adaptability [4]. In Ethiopia, wheat made up of 15.33% (48, 380, 740.91 quintals) of the grain cereal production in the country [5]. Its area coverage is 1, 747, 939.31 ha with a total production of 48, 380.741 t and 2.67 t ha^{-1} yield [5]. Bread wheat is one of the most staple food crops in the world and is one of the most important cereals cultivated in Ethiopia [6]. It is one of the most important cereals cultivated in Ethiopia [7]. Furthermore, wheat

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has been selected as one of the target crops in the strategic goal of attaining national food self-sufficiency, income generation, poverty alleviation and achieving socio-economic growth of the county [8]. However, the national yield of wheat is very low as compared to the global average yield. Despite the large area under wheat, the national average yield of wheat in Ethiopia is about 2.67 t ha^{-1} [5] which is below the world's average which is about 3 t ha^{-1} [9]. This might be due to depleted soil fertility, low levels of chemical fertilizer usage, limited knowledge on time and rate of fertilizer application and use inappropriate improved cultural crop management practies [10].

Bread wheat sowing at the optimum seeding rate and used improved variety 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 [11]. Moreover, the cultural broadcasting sowing method influence the availability of adequate space for each plant and consequently influence the uptake and utilization of resources such as nutrients. Seeding rate had significant influence on majority of agronomic traits of bread wheat [12]. The use lower seed rate was significantly reduced grain yield of wheat due to lower number of plants per unit area [13]. Reducing seed rate may result in more tillers and spike per plant and more spikelet per spike but in many cases reduced grain yield per hectare [14]; In contrary, the use of higher seed rate which leads to higher competition, shorter spike length and lower number of grains per spike [13]. Higher seeding rates compensate for reduced tillers formation and promote more main stem spikes which can be favorable, particularly for genotypes that tend to produce a smaller number of tillers [15]. High seeding rates increases the competition among crops for common resource particularly water, nutrients and sunlight which resulting in low quality and low yield [7]. The use of optimum seed rate encourages nutrient availability, proper sun light penetration for photosynthesis, good soil environment for uptake of soil nutrients and water use efficiency; and all necessary for crop vigor and consequently increase the production and productivity of the crop [6]. Arif *et al.* [16], Khan *et al.* [17] reported higher grain yield, spike length and grains spike with 150 kg ha^{-1} seed rate. Likewise, Misgana *et al.* [18] reported that 125 kg ha^{-1}seed rate with row planting produce 3.9 t ha^{-1} of bread wheat production in the Senegal and Senmamer areas. Ghulam *et al.* [19] concluded that the Kiran-95 variety with 125 kg ha^{-1} seed rate performed best, followed by TD-1 and Sarsabz which also produced more yield at 125 kg ha^{-1}. Chaudhary *et al.* [20] reported that seed rate of 150 kg ha^{-1} increased the number of grains $spike^{-1}$ and depressed the number of fertile tillers m^{-}; ^{2} Therefore, knowing the optimum seeding rate for bread and durum wheat varieties had great importance to improve production and productivity of both wheat types in the study area.

Improved bread wheat varieties were released and adapted to a wider range of environmental of conditions in Ethiopia [21]. Wheat grain yield potential has significantly increased in Ethiopia [22]. However, increasing yield requires successful adoption of improved agricultural technologies [23], which includes use of improved varieties. Amsal *et al.* [24] reported that released cultivars are highly responsive to improved crop management systems. Improved semi-dwarf bread wheat cultivars gave higher potential grain yield than many traditional crops and had better demand by farmers [25]. Jemal *et al.* [7] also reported that there is difference in days to 50% heading among wheat varieties. Aman *et al.* [26] suggests that varieties exhibited inherent variations in days to heading and in days to physiological maturity due to genetic makeup difference among themselves. Alam *et al.* [27] reported the introduction of new varieties with their high yield potential and wide range of adaptability is an important factor responsible for enhancing wheat production. Cultivars differed significantly due to difference in number of tillers m^{-2} [28, 29], number of grain $spike^{-1}$ [30], 1000 grain weight [27] and grain yield [31]. Hossain *et al*. [4] reported these varieties were shown to have higher biomass. Different varieties respond differently to varying environment and hence differ in their yield. Sharshar and Ei-Said [32] noted that wheat varieties significantly differed in grain yield and most of yield related traits. Likewise, a significant variation among wheat varieties for all the agronomic traits was observed [33]. Habtamu and Ahadu [34] reported that there is the difference in spike length in different bread wheat cultivar due to the presence of genetic difference among varieties. The availability of newly released high yielding seed varieties and the practice of improved agricultural technology will prove a strong opportunity to improve production and productivity of wheat [35]. Therefore, it is essential to observe the performance of different wheat varieties with respect to phenological, growth, yield and yield components traits. Proper sowing method is most important management factor affecting the agronomic characteristics of wheat [36, 37]. There is no information regarding the improved cultural practices with improved varieties of wheat in the area. Thus, in deed need knowing the influence of cultural practices with improved varieties of bread wheat for sustainable production in the Abbay Chommen district. Therefore, the objective was to determine the influence seed rate and sowing methods on yield and yield components of bread wheat varieties in Abbay Chommen district.

MATERIALS AND METHODS

Description of The Study Area: The study was conducted on farmer field in Kobolo kebele 2019/2020 cropping season, Abbay Chommen District, Horro Guduru Wollega Zone, Oromia National Regional State. Geographical it lies 10°59' 33''N latitude and 32°28' 66'' E longitude with an altitude of 2354 meter above sea level. The slope of the land was 8%. The area was characterized by Unimodal rain fall pattern and with rainfall period from May to October. The average rainfall was 1329 mm and the minimum and maximum air temperature of the area was 21 and 30°C, respectively. The district was suitable for the production of different crops and raising of livestock. The dominant crops growing around the study area were maize, teff, wheat, Niger seed, bean, field pea `and barely [38]. Traditionally the district was classified in to two agroecological zones, namely, Badaa Darree and Gammojii. The Badaa Darree (waina Dega) covers the largest part which accounts about 60% and Gammojii (Kola) 40% [38].

Experimental Materials: Two bread wheat Liben and Hidase varieties were obtained from Wollega University and Abay Choman Cooperative union. The description of the two varieties used in the study were indicated in Table 1.

Treatment and Experimental Design: The treatments consist of two bread wheat (Liben and Hidase) varieties and three seed rates (100, 125 and 150 kg ha^{-1} and two sowing methods (row and broadcasting) were used in a randomized complete block design with factorial arrangements in three replications. 2x 3 x2 factorial combination totaling to 12 treatments. The growth and net plot size for data collection were 1.20mx 3m=3.6m^2 and 1 x 3m =3m^2. Seeds were sow in rows of 25 cm spacing by rowing and broadcasting.

Experimental Procedures: The experimental field was prepared following the conventional tillage practice, which includes five times plowing using with oxen power before sowing of the bread wheat varieties. As per the specifications of the design, a field layout was prepared; the land was clean, level and make suitable for crop establishment. Sowing was done on 23 July, 2019. The recommended fertilizer rates of 100 kg NPS ha^{-1} at planting and the Urea was applied in spilt form (1/3) at planting and the remaining (2/3) at tillering stage. The seeds were sown by drilling and broadcasting and covered by hand. All cultural practices such as weeding, insect pest and disease management was applied uniformly to all plots and managed as per recommendation. Harvesting and threshing was done by hand.

Data Collection:

- *Number of Productive Tillers per Plant*: the average number of productive tillers per plant was recorded for 10 randomly selected plants in the plot at maturity.
- *Spike Length*: the average length of spike excluding awns was recorded for 10 randomly selected plants in the plot at maturity.
- *Number of Spikelet's per Spike*: the average number of spikelet's per spike was recorded for 10 randomly selected plants in the plot at harvesting time.
- *Number of Kernels per Spike*: the average number of kernels per spike was recorded for 10 randomly selected plants in the plot at harvesting.
- *Thousand Seed Weight*: was determined by carefully counting 1000 small grains from the bulk of threshed yield and weighing them using a sensitive balance at 12.5 moisture content.
- *Dry Biomass Yield*: was weighted the harvested crop from the net plot area after sun drying for three days and then expressed in kg ha^{-1}.
- *Grain Yield*: was taken after threshing for each net plot area and adjusted at 12.5% moisture level and the yield was expressed in t ha^{-1}.
- *Harvesting Index*: was calculated as the ratio of grain yield per plot to the above ground dry biomass yield per plot expressed as a percentage.

Data Analysis: Analysis of variance was done using SAS computer software (SAS, 9.4 versions) [39]. Significant means was separated by List Significant Differences at 5% probability levels [40]. A Pearson correlation analysis was made to see the relationship between yield and yield components of bread wheat.

Table 1: Description of Bread wheat varieties used in the research study

			Adaptation			Yield t ha^{-1}		
Local Name	Varieties Name	Year of Release	Altitude	Rainfall (mm)	Days Maturity	On station	On farm	Center
Liben	(ETBW5653)	2015	2300-2500	>900	118	5-7	3.5-4	BARC
Hidase		2012	2200-2600	500-800	121	4.5-7	3-4	KARC

Source: MoA (2018), BARC= Bako Agricultural Research Center, KARC= Kulumsa Agricultural Research Center

RESULTS AND DISCUSSION

Number of Productive Tillers per Plant: The main effect of sowing methods and seed rate had highly significant effect (P<0.01) effect on the number of productive tillers per plant of bread wheat but non-significantly affected by main effects of varieties, two and three-way interaction effects of varieties, seed rates and sowing methods (Table 2). The number of productive tillers per plant of bread wheat was non-significantly affected by varieties indicating similarity of the two varieties with number of productive tillers per plant. In contrary, Jemal *et al.* [7]; Obsa and Yeared [41], Kifle *et al*. [42] significant difference was observed among the tested varieties of bread wheat for number of tillers per plant bread wheat. Al-Hilfy and Wahid [43] found that significant difference varieties on number of tillers m^{-2} and significantly higher (418.3) number of tillers m^{-2} of bread wheat was obtained from Rasheed cultivar.

Main effect of sowing methods had highly significant (P<0.01) effect on the number of productive tillers per plant of bread wheat (Table 2). The maximum (3.05 $plant^{-1}$) number of productive tillers per plant was counted from row methods of sowing as compared to broadcasting (2.16 $plant^{-1}$). Similarly, Khan et al. [44] found that sowing method had highly significant effect on fertile tiller of bread wheat and row method of sowing gave more fertile tillers m^{-2} as compared to that of broadcast method. This indicated that row methods sowing made favorable condition for bread wheat to produce number of productive tillers per plant.. Increased number of fertile tillers in pore method could be ascribed to proportionate distribution of seed and better start as compared to the broadcast method [44]. Also, Abebaw and Hirpa [45] found that sowing methods had significant effects on number of number of tillers per plant of wheat and significantly higher mean number of tillers per plant of wheat was obtained from row methods of sowing as compared to broadcasting method. Tanveer *et al*. [46] reported that row planting method of wheat produce significantly higher 7.41 tillering number per plant as compared to broadcast method of sowing which was 4.75. Likewise, Soomro *et al*. [47] found that wheat planted by drilling method produced significantly higher number of average tillers (10.32/Plant) and broadcasting (9.58/Plant) due to less plant competition and proper sowing methods. Pirzada *et al*. [48] reported that drilling method of planting recorded significant maximum (406) tillers m^{-2} of bread wheat as compared to 400 tillers m^{-2} broadcasting method of sowing.

Main effect of seed rate had highly significant (P<0.01) effect on the number of productive tillers per plant of bread wheat (Table 2). The use of 100 kg ha^{-1} seed rate was produced significantly higher (3.08 $plant^{-1}$) number of productive tillers per plant while the lowest (2.25 $plant^{-1}$) number of productive tillers per plant of bread wheat was obtained from 150 kg ha^{-1} seed rate which was statistically in par with the number of productive tillers per plant obtained with 125 kg ha^{-1} seeding rate (Table 2). The number of productive tillers increased consistently with decreasing seeding rate. The number of productive tillers per plant was higher at lower at seed rate, when compared with higher seed rates. This might be due to that the productive tillers decreased with increase in seeding rate, because, by increasing seed rate per unit area, the inter plant competition for space, nutrient, moisture and sun light increases which results in lower productive tillers. . In contrary, Al-Hilfy and Wahid [43] found that significant difference of seed rates on mean number of tillers per plant and significantly higher (463.6) number of tillers m^{-2} were recorded at seeding rate of 140 kg ha^{-1} and reduced trend of tillers beyond 140 kg ha^{-1}.

Sharma *et al*. [49] found that wheat sown at the seed rate of 140 kg ha^{-1} significantly showed promising results (372.33 and 376.44) maximum number of effective tillers m^{-2} of bread wheat during both the years. Higher number of tillers produced up to a certain level of seeding rate and then the number of tillers decreased were reported [50-52]. Khan *et al.* [44] found that seed rate had highly significant effect on number of fertile tillers m^2 of bread wheat and a seed rate of 175 kg ha^{-1} produced maximum average number of fertile m^{-2}. Haile *et al.* [53] found that seeding rates was significantly influenced number of fertile spikes m^{-2} of bread wheat and number of fertile spikes m^{-2} was increased proportionally with the seeding

Table 2: Main effects of varieties, sowing method and seeding rate on number of productive tillers per plant, spike length, number of spikes per spikelet's, number of kernels per spike and thousand seed weight of bread wheat grown at Abbay Chommen district

Treatment	Number of productive tillers per plant	Spike length (cm)	Number of spikes per spikelet's	Number of kernels per spike	Thousand seed weight (g)
Varieties					
Liben	2.71	7.48[b]	13.88	50.5[a]	40.61[a]
Hidase	2.70	7.98[a]	14.00	49.66[b]	40.05[b]
LSD (5%)	NS	0.14	NS	0.48	0.26
Sowing methods					
Row	3.05[a]	8.14[a]	14.55[a]	51.33[a]	41.33[a]
Broadcasting	2.16[b]	7.32[b]	13.33[b]	48.8[b]	39.33[b]
LSD (5%)	0.26	0.14	0.28	0.48	0.26
Seeding rate (Kg ha^{-1})					
100	3.08[a]	8.26[a]	14.33[a]	51[a]	42.33[a]
125	2.5[b]	7.74[b]	14.08[a]	50[b]	40.8[b]
150	2.25[b]	7.19[c]	13.42[b]	48[c]	37.8[c]
LSD (5%)	0.33	0.16	0.34	0.58	0.33
CV (%)	14.78	2.5	2.9	1.39	0.96

Means followed by different letter(s) in a column are significant at 5% level of probability

Table 3: Interaction effects of varieties and seeding rate on spike length, dry biomass and harvest index of bread wheat in Abbay Chommen district

	Seeding rate								
	Number of kernels per spike			Dry biomass (t ha^{-1})			Harvest index (%)		
Varieties	100	125	150	100	125	150	100	125	150
Liben	7.87[bc]	7.5[bcd]	7.05[d]	8.3[b]	9.7[a]	9.45[a]	41.65[abc]	46.07[a]	42.69[abc]
Hidase	8.65[a]	7.95[b]	7.34[cd]	8.69[b]	9.66[a]	9.48[a]	37.75[c]	44.96[ab]	39.1[bc]
LSD (5%)	0.59			0.5			0.76		
CV (%)	2.5			1.6			2.9		

Means followed by different letter(s) in a column are significant at 5% level of probability

rate and higher number (382 spikes m^{-2}) was recorded from seeding rate of 200 kg ha^{-1}. Iqbal *et al.* [11] found that significantly and linear increase in number of fertile tillers and total tillers with increased seed rate of wheat and 200 kg ha^{-1} seed rate produced significantly higher (278.75) number of fertile tillers and (294.33/m^{-2}) total tillers followed by 175 kg ha^{-1} seed rate (263.97 fertile tillers and 280.33 total tillers m^{-2}). Baloch *et al.* [54] reported that significantly higher number of tillers of wheat with seed rate of 150 kg ha^{-1}.

Abiot [55] reported that seeding rate significantly affected number of effective tillers per m^2, number of fertile tillers increased consistently with increasing seeding rate up to 150 kg ha^{-1} and significantly higher (88) number of effective tillers per m^2 was observed from 150 kg ha^{-1} seeding rate while the lowest (67) number of effective tillers per m^{-2} observed 100 kg ha^{-1} seeding rate. Ali *et al.* [52] reported that the number of effective tillers increased as seeding rate increased. Similarly, Jemal *et al.* [7] found that the highest (69.33) number of effective tillers per 0.5 m row length was obtained at 200 kg ha^{-1} seeding rate while the lowest (25.66) number of effective tillers per 0.5 m row length was obtained from 100 kg ha^{-1} seeding rate. Iqbal *et al.* [56] indicated that higher number of tillers (503) was observed from 175 kg ha^{-1} seeding rate while lower (404) number of tillers was recorded from 125 kg ha^{-1} seeding rate. In contrary, Naveed *et al.* [57] found that increasing seed rate was increased number of tillers m^{-2} (287) of dual-purpose wheat. Matsuyama and Ookawa [58] found that with the decreasing seeding rate the number of tillers per plant of bread wheat decreased.

Spike Length: The spike length of bread wheat was very highly significantly ($P<0.001$) affected by varieties, sowing methods and seeding rate and the two-way interaction effect of varieties with seeding rate was significant ($P<0.05$) affected mean spike length of bread wheat (Tables 2 and 3). Hidase variety of bread wheat was produced the longest spike length of 7.98 cm while, variety Liben produced the shorter 7.48 cm spike length of bread wheat (Table 2). Likewise, Otteson *et al.* [59] reported that individual genotypes responded differently to spike length for varying seeding rates in wheat. This result indicated that the different varieties has different spike length which could be controlled by genetic background of varieties. Also, Desalegn [60] found that mean spike length of wheat was showed significant difference between bread wheat varieties. Haile *et al.* [53] found that varieties had significant difference on spike length of wheat and Illani variety of wheat was produced longer (6.9 cm) spike length of wheat as compared to others.

The mean spike length of bread wheat was very highly significantly (P<0.001) affected by sowing methods (Table 2). Significantly higher 8.14 cm mean spike length of bread wheat was recorded from row method of sowing while lower 7.32 cm spike length of bread wheat was obtained from broadcasting method of sowing. Similarly, Abebaw and Hirpa [45] found that sowing methods had significant effects on spike length wheat and significantly higher 7.78 cm mean spike length of wheat was obtained from row methods of sowing as compared to broadcasting method. Pirzada *et al*. [48] reported that drilling method of planting recorded significant maximum (10.69 cm) spike length of bread wheat as compared to (9.45 cm) in broadcasting method of sowing.

The spike length of bread wheat was very highly significantly (P<0.001) affected by seeding rate (Table 2). Seeding rate of 100 kg ha^{-1} produced the longest 8.26 cm spike length and seeding rate of 150 kg ha^{-1} produced the shortest 7.19 cm spike length of bread wheat (Table 2). This could be due to the availability of ample resources required by the wheat crop for growth and development in lower seeding rates. Likewise, Abiot [55] reported that plant spike length of bread wheat was significantly affected by seeding rate and significantly higher spike length of 8.93 cm was recorded from 100 kg ha^{-1} seeding rate while minimum 7.33 cm spike length was obtained from 175 kg ha^{-1} seed rate of bread wheat. Also, Zewdie *et al*. [61] reported that spike length is negatively interrelated to seed rate. Shorter plant produces longer spike length and long plant produce shorter spike and higher biomass production. Also, Gafaar [62] stated that increasing sowing density from 200 up to 400 grains m^{-2} significantly decreased spike lengths. Also, Naveed *et al*. [57] found that higher spike length (11.99 cm) was obtained from 100 kg seed ha^{-1} and decreased as seed rates increased up to 220 kg ha^{-1} which might possibly due to optimum availability of nutrients that enabled wheat plants to effectively carryout photosynthesis and hence more assimilate translocation occurred which ultimately increased the spike length. In contrary, Suleiman *et al*. [63] reported that the longest spikes were obtained from 250 and 300 grains per m 2 but without significant differences between both of them. In opposing, Baloch *et al*. [54] reported that significantly higher spike length of wheat with seed rate of 150 kg ha^{-1}.

The two-way interaction effect of varieties with seeding rate was significant (P<0.05) affected mean spike length of bread wheat (Tables 3). The maximum 8.65 cm spike length of bread wheat was achieved from Hidase variety with of 100 kg ha^{-1} seeding rate while the minimum 7.05 cm spike length of brae wheat was achieved from Liben variety with 150 kg ha^{-1} seeding rate (Table 3). The lower seeding rate of 100 kg ha^{-1} was produced higher spike length as compared to higher seeding rate of 150 kg ha^{-1}. Therefore, the different varieties had different spike length with different seed which could be controlled by genetic background and morphology of the bread wheat varieties.

Number of Spikes per Plant: The mean number of spikes per plant of wheat was highly significantly (P<0.01) affected by sowing methods and seeding rate but non-significantly affected by varieties of bread wheat (Table 2). Non significantly higher (14 $plant^{-1}$) mean number of spikes per plant of wheat was for Hidase variety while the lowest (13.88 $plant^{-1}$) mean value for spike length was for the variety Liben. This indicates that the different varieties have varied in number of spikes per plant which could be controlled by genetic background. In contrary, Haile *et al*. [53] found that varieties had significant difference on number of fertile spikes m^{-2} and higher (360 and 345) number of fertile spike m^{-2} were recorded from Oda and Bakalcha varieties of wheat.

Significantly higher (14.55 $plant^{-1}$) and lower (13.33 $plant^{-1}$) number spikes per plant of bread wheat was recorded from row and broadcasting methods sowing, respectively (Table 2). Likewise, Soomro *et al.* [47] found that wheat planted by drilling method produced significantly higher number of grain per spike (10.55/Plant) of bread wheat as compared to broadcasting methods of sowing. The increase in spike numbers per plant of wheat row method of sowing with decreasing in spike numbers per plant of wheat broadcasting method seeding rate might be due to more suitable environments created for plants established in row method of planting.

Significantly lower number of spikes per plant (13.42 $plant^{-1}$) of wheat was achieved with 150 kg ha^{-1} seed rate and higher number of spikes per plant (14.33 $plant^{-1}$) of wheat was achieved with 100 kg ha^{-1} seed rate (Table 2). Similarly, Whaley *et al.* [64] found that the number of kernels per wheat spike increased by 50% of bread wheat as wheat density decreased from 338 to 19 plants m^{-2}. Also, Ozturk *et al.* [14] reported that less than 10% increases number of kernels per spike of wheat when seed rate of bread was decreased from 625 to 325 seeds m^{-2}. Matsuyama and Ookawa [58] found that

Table 4: Interaction effects of varieties and sowing methods on number of kernels per spike of bread wheat in Abbay Chommen district

	Sowing methods					
	Number of kernels per spike		Dry biomass (t ha^{-1})		Grain yield (t ha^{-1})	
Varieties	Row	Broadcasting	Row	Broadcasting	Row	Broadcasting
Liben	52[a]	48.77[c]	9.45[a]	8.8[b]	4.6[a]	3.43[b]
Hidase	50[b]	48.88[bc]	9.33[a]	9.13[a]	4.28[a]	3.3[b]
LSD (5%)	1.57		0.66		0.5	
CV (%)	1.39		1.6		2.5	

Means followed by different letter(s) in a column are significant at 5% level of probability

with the decreasing seeding rate percentage of fertile spikelet of bread wheat was increased. Haile *et al.* [53] found that seeding rates was significantly influenced number of seeds $spike^{-1}$ of bread wheat and higher (29.8) number of kernels $spike^{-1}$ wheat was obtained from 100 kg ha^{-1} seeding rate of wheat. Naveed *et al*. [57] found that increasing seed rate was increased number of spike m^{-2} (281) dual purpose wheat.

Number of Kernels per Spike: The main effects of varieties, sowing method and seeding rate had very highly significant (P<0.01) effect on number of kernels per spike of bread wheat and two-way interaction effect of varieties with sowing method was significant (P<0.05) effect of number of kernels per spike of wheat (Table 2 and 4). The highest (50) number of kernels per spike of bread wheat were obtained for Liben variety while the lowest number 49 of kernels per spike was obtained for the Hidase variety. Similarly, Aman *et al*. [26] found that variation kernels per spike of bread wheat varieties and variety Gassay produced significantly higher (41.66) number of kernels per spike while lower (34.19) number of kernels per spike from Dinknesh variety. Similarly, Esayas *et al.* [65] found significant differences in number of kernels per spike among wheat varieties. Lemi and Negash [66] found that varieties had significant difference on number of grains per spike. Abd El-Lattief [67] found that number of grains $spike^{-1}$ of bread significantly affected by different cultivars used. Haile *et al.* [53] found that varieties had significant difference on number of seeds $spike^{-1}$ of wheat and Oda and Illani varieties of bread wheat produced higher 39 and 37 numbers of seeds $spike^{-1}$ of bread wheat. This indicates that the different variety has different number of kernels per spike which could be controlled by genetic background.

The main effects of sowing methods had very highly significant (P<0.01) effect on number of kernels per spike of bread wheat (Table 2). Significantly the highest number 50 of kernels per spike of bread wheat was obtained for row method sowing while the lowest 49number of kernels per spike was obtained from broadcasting method sowing of bread wheat. Similarly, Abebaw and Hirpa [45] found that sowing methods had significant effects on number of spikelet's per spike of wheat and significantly higher mean number of spikelet's per spike of wheat was obtained from row methods of sowing as compared to broadcasting method. Also, Khan *et al.* [44] found that the number of grains $spike^{-1}$ by sowing methods and row method of sowing showed slightly a greater number of grains $spike^{-1}$ as compared to broadcast method. Likewise, Soomro *et al.* [47] found that wheat planted by drilling method produced significantly higher number of grain per spike (60.60/spike) of bread wheat as compared to broadcasting methods of sowing.

The mean number of kernels per spike of wheat was very highly significantly (P<0.01) influenced by the main effect of seeding rate (Table 2). Maximum 51 number of kernels per spike of bread wheat was obtained from the 100 kg ha^{-1} seeding and minimum 48number of kernels per $spike^{-1}$ obtained from 150 kg ha^{-1} seeding rate (Table 2). The lowest number of kernels per spike of wheat was achieved from seed rate 150 kg ha^{-1}. Seeding rate of 100 and 125 kg ha^{-1} produced statistically similar number of kernels per spike (Table 2). Likewise, Twizerimana *et al.* [68] reported that the kernel number per spike showed a significant decrease with the seed rate increase of wheat. Matsuyama and Ookawa [58] found that with the decreasing seeding rate grain number per spike bread wheat was significantly increased. As seeding rate increased from 100 to 150 kg ha^{-1} the number of kernels per spike of wheat was decreased by 3 %. The increase in number of kernel spike with decrease in seed rate might be due to the plant nutrients present in the soil were enough for the vegetative growth and grain formation when there were smaller number of plants per unit area and less competitive for all essential elements as compared to the greater number of plants per unit area.

Similarly, Hussain *et al*. [69] reported that the higher grain number obtained in the lowest seed rate can be attributed to more light penetration through plant canopy. Rahim *et al*. [70] stated that significant difference was observed between plant densities of durum wheat cultivar in terms of grains per spike. Likewise, Worku [71] concluded that increasing the rate of seeding from 100 to 150 kg ha^{-1} decreased the number of grains per spike from 51 to 48 at the seed rate 100 and 150 kg ha^{-1} respectively. Khan *et al.* [44] found that the number of grains $spike^{-1}$ by seeding rates and significantly higher 58.13 number of grain $spike^{-1}$ was obtained from 175 kg ha^{-1} whereas minimum number 43.95 number of grain $spike^{-1}$ was recorded from 100 kg ha^{-1} seed rates. Also, Mehrvar *et al*. [72] reported that by increasing seed rate the number of grains per spike was reduced. Abd El-Lattief [67] found that number of grains $spike^{-1}$ significantly affected by different seeding rates and consistent decrease in kernels per spike with increasing seed rates of bread wheat. Number of kernels per spike was not significantly affected by main effect of sowing. In contrary, Sharma *et al.* [49] found that wheat sown at the seed rate of 140 kg ha^{-1} significantly showed promising results (58.0 and 58.67) grains $spike^{-1}$ of bread wheat during both the years. Iqbal *et al*. [11] reported that wheat planted at 125 kg ha^{-1} gave maximum grains spike. Shah [73] reported that different seed rate had significant effect on seed spike.

The two-way interaction effect of varieties with sowing method was significant ($P<0.05$) affected number of kernels per spike of bread wheat (Table 4). Significantly higher 52mean number of kernels per spike of wheat was achieved from Liben variety with row method sowing while the lowest 48number of grains spike of wheat was recorded from Hidase variety with broadcasting methods of sowing of bread wheat (Table 4). The greatest of number kernel/spike in 100 kg ha^{-1} seed rate with row methods sowing was due to less plant competition and proper seed placement.

Thousand Seed Weight: Main effects of varieties, sowing method and seed rate had highly significant ($p<0.01$) effect on thousand seed weight of bread wheat (Table 2) and also the two-way interaction effect of sowing method with seeding rate was significant ($p<0.05$) effect on mean thousand seed weight of bread wheat (Table 6). Three-way interaction effect of varieties, sowing method and seeding rate were showed significant ($p<0.05$) effect thousand seed weight of bread wheat (Table 7).

The highest mean value of thousand seed weight was 40.61 g for Liben variety while the lowest mean value for thousand kernel weight 40 g for Hidase variety of wheat (Table 2). This indicated that the different varieties have different thousand seed weight which could be controlled by genetic background of different varieties of bread wheat. Similarly, Obsa *et al*. [74] reported that significant variation in thousand seed weight between the eight bread wheat varieties and ranged from 30.67 to 43.4 g. Amare and Mulatu [75] found significant difference and Picaflor variety recorded higher (42 g.) thousand kernel weight of bread wheat while minimum (35.6 g.) thousand kernel weight was recorded from Tay variety of wheat. Also, Melaku [76] found that significant difference among bread wheat varieties and significantly (37 g) thousand seed weight from Wane variety and (35.3 g) from Kingbird variety. Likewise, Ghuluma *et al*. [77] reported that significant differences among three varieties of wheat on thousand seed weight. Desalegn [60] found that significantly higher mean thousand seed weight of wheat was obtained from Hidase and Ogolcho varieties as compared to Liben variety. Similarly, Esayas *et al*. [65] reported significant differences in thousand kernel weights among wheat varieties. Sharma *et al.* [49] found that varieties significantly affected the 1000 grain weight and they reason out that the difference in 1000- grain weight among the wheat cultivars maybe attributed to their variable inherent potential. Likewise, Tesfaye [78] found that significantly higher mean thousand seed weight was obtained from Molgo over Digelu variety of sowing (Table 2). The highest 41.33 g thousand seed weight of bread wheat was obtained from row method sowing and lowest 39.33 g thousand kernels weight was from broadcasting methods of sowing (Table 2). Similarly, Abebaw and Hirpa [45] found that sowing methods had significant effects on mean thousand seed weight of wheat and significantly higher 35.94 g mean thousand seed weight of wheat was obtained from row methods of sowing as compared to broadcasting method. Also, Khan *et al.* [44] found that higher 38.00 g of 1000 seed weight of wheat was recorded in row method sowing and minimum 37.96 g weight of was recorded in broadcast method. Likewise, Soomro *et al.* [47] found that wheat planted by drilling method produced significantly higher thousand seed weight 42g of bread wheat as compared to broadcasting method of sowing. The thousand kernel weight of wheat was highly influenced by the sowing method for two consecutive years [68]. The thousand kernel weight was affected by the sowing methods in two cropping seasons [79].

Mean thousand seed weight of bread wheat was significantly affected by main effects of seed rate (Table 2). Significantly higher 42.33 g thousand weight was obtained from 100 kg ha^{-1} seed rate and significantly reduced as seed rates of bread wheat increase from 100-150 kg ha^{-1} . Similarly, Tesfaye [78] found that main effect of seed rate significantly affected mean thousand seed weight of bread wheat and significantly higher and lower values of were observed at 125 and 200 kg ha^{-1}

Table 5: Main effects of varieties, sowing method and seeding rate on dry biomass, grain yield and harvest index of bread wheat in Abbay Chommen district

Treatment	Dry biomass (t ha^{-1})	Grain yield (t ha^{-1})	Harvest index (%)
Varieties			
Liben	9.17^{b}	4.02^{a}	43.47^{a}
Hidase	9.28^{a}	3.79^{b}	40.60^{b}
LSD (5%)	0.104	0.068	0.85
Sowing methods			
Row	9.4^{a}	4.44^{a}	46.75^{a}
Broadcasting	9.01^{b}	3.36^{b}	37.3^{b}
LSD (5%)	0.104	0.068	0.85
Seeding rate (kg ha^{-1})			
100	8.5^{c}	3.37^{c}	39.69^{c}
125	9.7^{a}	4.46^{a}	45.52^{a}
150	9.47^{b}	3.87^{b}	40.9^{b}
LSD (5%)	0.12	0.08	1.04
CV (%)	1.6	2.5	2.9

Means followed by different letter(s) in a column are significant at 5% level of probability

Table 6: Interaction effects of sowing method and seed rate on tthousand seed weight, dry biomass, grain yield and harvest index of bread wheat in Abbay Chommen district

Sowing Methods	Seeding rate (kg ha^{-1})	Thousand seed weight (g)	Dry biomass (t ha^{-1})	Grain yield (t ha^{-1})	Harvest index (%)
Row	100	42.8^{a}	8.45^{d}	3.73^{c}	44.13^{bc}
Row	125	42.16^{b}	10.35^{a}	5.16^{a}	49.5^{a}
Row	150	39^{c}	9.5^{b}	4.44^{b}	46.6^{b}
Broadcasting	100	41.8^{b}	8.56^{d}	3.02^{e}	35.26^{d}
Broadcasting	125	39.5^{c}	9.05^{c}	3..75^{c}	41.48^{c}
Broadcasting	150	36.66^{d}	9.4^{b}	3.32^{d}	35.2^{d}
LSD (5%)		1.5	0.55	0.76	6.6
CV (%)		0.96	1.6	2.5	2.9

Means followed by different letter(s) in a column are significant at 5% level of probability

Table 7: Three-way interaction effects of variety, sowing method and seed rate on tthousand seed weight, dry biomass and harvest index of bread wheat in Abbay Chommen district

Varieties	Seeding rate (kg ha^{-1})	Sowing Methods	Thousand seed weight (g)	Dry biomass (t ha^{-1})	Harvest index (%)
Liben	100	Row	43^{a}	8.2^{h}	46.9^{b}
Liben	100	Broadcasting	42^{cd}	8.4^{h}	36.35^{f}
Liben	125	Row	42.33^{bc}	10.55^{a}	49.3^{a}
Liben	125	Broadcasting	40..33^{e}	8.9^{fg}	42.85^{cd}
Liben	150	Row	39.33^{f}	9.59^{c}	49^{ab}
Liben	150	Broadcasting	36.66^{h}	9.3d^{e}	36.38^{f}
Hidase	100	Row	42.66^{ab}	8.69^{g}	41.3^{de}
Hidase	100	Broadcasting	41.66^{d}	8.69^{g}	34.17^{g}
Hidase	125	Row	42^{cd}	10.16^{b}	49.8^{a}
Hidase	125	Broadcasting	38.66^{g}	9.16^{ef}	40.12^{e}
Hidase	150	Row	38.66^{g}	9.44^{cd}	44.19^{c}
Hidase	150	Broadcasting	36.66^{h}	9.5^{cd}	34.02^{g}
LSD (5%)			0.65	0.25	2.07
CV (%)			0.96	1.6	2.9

Means followed by different letter(s) in column are significant at 5% level of probability

seed rate, substantial decrease in mean value of the parameter as the seed rate increased. The thousand kernel weight of wheat was highly influenced by the sowing method for two consecutive years [68, 79]. Naseri *et al*. [80], Helms and Orf [81] stated that the negative relationship between the plant density and thousand grain weight might be attributed to the fading of most grains at a higher density in the early stage, because of competition between growing grains to absorb the preserved matters and, as the result, small grains would be produced. This might be due to the higher planting density from the higher seed rate used, which increased the plant competition and eventual decline in the individual grain weight [82]. In contrary, Sharma *et al.* [49] found that wheat sown at the seed rate of 140 kg ha^{-1} significantly showed promising results (39.64 and 39.78 g) 1000 grain weight during both the years. Khan *et al*. [44] found that higher 40.95 g of 1000 seed weight of wheat was recorded from planting of 175 kg ha^{-1} seed rates. Baloch *et al.* [54] reported that significantly higher 1000-grain weight of wheat with seed rate of 150 kg ha^{-1}.

Chaudhary *et al*. [20] reported that, low seed rates significantly increased thousand kernels weight. Similarly, Jan *et al*. [83] reported that, as the seeding rate was increased, the number of plants emerged per unit area also increased but thousand seed weight decreased in wheat crop. Khan *et al*. [84], Mehrvar and Asadi [72] concluded that, by increasing seed rate the thousand grains weight was reduced in wheat. Similarly, Baloch *et al*. [54] concluded that the higher the seeding rate in bread wheat resulted in decreased 1000 seed weight. Hiltbrunner *et al*. [85], Dubis *et al*. [86] also noted that as seeding rate increased, 1000 seed weight decreased. Iqbal *et al*. [11] concluded that lower seeding rates 125 kg ha^{-1} produced significantly heavier grains 41 g than higher seeding rate 200 kg ha^{-1} that produced lighter 39 g grains.

Two-way interaction effect of sowing methods with seeding rate was significant ($p<0.05$) affected mean thousand seed weight of bread wheat (Table 6). The highest 42.8g thousand seed weight of bread wheat was obtained from 100 kg ha^{-1} seed rate with row method sowing and the lowest 36, 66g thousand seed weight was recorded from 150 kg ha^{-1} seed rate with broadcasting methods of sowing (Table 6). Therefore, the use of lower seed rate with row method of sowing gave higher thousand seed weight of bread wheat which might be due favourable environment created for plant growth in row methods of sowing with lower seed rate without competition and tillering of bread wheat.

Three-way interaction effects of varieties with sowing methods and seed rate was significantly ($P<0.05$) affected mean thousand seed weight (Table 7). Significantly higher 43g thousand seed weight of bread wheat was obtained from Liben variety with 100 kg ha^{-1} seed rate planted in row method of sowing. This might be due to less competition of resources in lower seed rates in row methods of sowing. In contrary, Tesfaye [78] found that three-way interaction effects of varieties with sowing methods and seed rate was non-significantly affected thousand seed weight of bread wheat.

Dry Biomass: Dry biomass represents overall growth performance of the plant as well as the crop and was considered to be the essential yield parameter to get useful information about overall growth of the crop. The main effect of varieties significant ($P < 0.05$), sowing m ethods and seeding rate had very highly significant ($P < 0.01$) effect on dry biomass yield of wheat (Table 5). The two-way interaction varieties with sowing method was showed significant ($P < 0.05$) (Table 4) and also varieties with seeding rate, sowing methods with seeding rate and three-way interaction effect of varieties, sowing methods and seeding rate had very highly significant ($P < 0.01$) effect on dry biomass of bread wheat (Table 3, 6 and 7).

The maximum 9.28 t ha^{-1} dry biomass of bread wheat was achieved from Hidase variety and the minimum 9.17t ha^{-1} dry biomass of bread wheat was recorded from Liben variety. Similarly, Aman *et al*. [26] found that significantly higher (8221 kg ha^{-1}) dry biomass yield was recorded for variety 'Danda'a' followed by variety 'Kakaba' with mean dry biomass yield of 7664 kg ha^{-1}. Also, Al-Hilfy and Wahid [43] found that significant difference varieties on biological yield of bread wheat and significantly higher biological yield (13.559 t ha^{-1}) of bread wheat was obtained from Rasheed cultivar. Habtamu and Ahadu [34] reported that significance difference in biomass yield of bread wheat varieties ranging from 7.6 to 11.3 t ha^{-1}. The difference in dry biomass yield of bread wheat varieties might be due to the genetic make difference of the varieties used.

Significantly higher dry biomass 9.4 t ha^{-1} of wheat was obtained from row method sowing method and the minimum 9.01t ha^{-1} dry biomass was achieved for broadcasting methods of sowing of bread wheat (Table 5). Similarly, Khan *et al*. [44] found that biological yield of wheat was highly significantly affected by methods of sowing and row method of sowing gave higher 13085 kg ha^{-1} biological yield of wheat as compared to that of broadcast method of sowing 10793.5 kg ha^{-1}. Likewise, Abebaw and Hirpa [45] found that sowing methods had significant effects on mean dry biomass of wheat and significantly higher 3.05 t ha^{-1} mean dry biomass of wheat was obtained from row methods of sowing as compared to broadcasting method. Also, Pirzada *et al.* [48] reported that drilling method of planting recorded significant maximum (12227 kg ha^{-1}) biological yield of bread wheat as compared to (11608 kg ha^{-1}) in broadcasting method of sowing.

Significantly higher 9.7 t ha $^{-1}$ dry biomass of bread wheat was obtained from 125 kg ha^{-1} seeding rate while the lowest 8.5 t ha^{-1} dry biomass was obtained 100 kg ha^{-1} seeding rate of bread wheat (Table 5). The higher dry biomass yield 9.7 and 9.47 t ha^{-1} were obtained by seed rate of 125 and 150 kg ha^{-1} respectively, which were statistically at par with each other while, the lowest dry biomass yields 8.5t ha^{-1} was produced by 100 kg ha^{-1} seed rate of bread wheat (Table 5). In contrary, Jemal *et al*. [7] reported that higher dry biomass was recorded on increased seeding rates of 200 and 175 kg ha^{-1}. Iqbal *et al*. [55] also found that biological yield was increased as seeding rate increased from 125 to 150 kg ha^{-1}. Likewise, Abiot [55] reported that seeding rate had very highly significant effect on the dry biomass yield of bread wheat and significantly higher biomass yield (12755 kg ha^{-1}) was observed from 175 kg ha^{-1} seeding rate while lower (9696 kg ha^{-1}) dry biomass yield was obtained from 100 kg ha^{-1} seeding rate. Naveed *et al.* [57] found that increasing seed rate was increased biological yield (11690 kg ha^{-1}) of dual-purpose wheat.

El-Hebbasha [87], Ali *et al*. [88] found that biological yield was increased by increasing seeding rate in wheat. Gafaar [62] reported that the highest value of biological yield was obtained with increasing seed rate up to 400 grains m^{-2} in wheat crop. Similarly, Ali *et al.* [52] found that higher straw yield increased with the increase in seeding rate and higher (4.35, 4.52 and 4.58 t ha^{-1}) straw yield for the first, second and third cropping seasons. were obtained with seeding rate 200 kg ha^{-1}. Seleiman *et al*. [51] found that increasing seeding rates up to 350 or 400 grains m^{-2} increased biomass yields of bread wheat. Laghari *et al.* [89] found significant increase in biological yield by using different seeding rates. Al-Hilfy and Wahid [43] found that significant difference of seed rate on biological yield of bread wheat and biological yield of bread wheat increased with increasing seeding rate from 80 to 140 kg ha^{-1} and significantly higher (13.586 t ha^{-1}) biological yield was recorded with seeding rate of 140 kg ha^{-1}.

The interaction of varieties with seed rates had significant effect on biomass yield of bread wheat (Tables 3). Significantly higher dry biomass yields 9.7 t ha^{-1} of bread wheat was obtained from Liben variety with 125 kg ha^{-1} seeding rate (Tables 3). Similarly, Abd El-Lattief [67] found that mean straw yield of bread wheat significantly affected by interaction of varieties with seed rate and significantly higher straw yields were 7.077 and 7.472 t ha^{-1} were obtained from seeding 300 seeds m^{-2} for Giza 168 in both years. Al-Hilfy and Wahid [43] found that the interaction varieties with seeding rates had a significant effect on biological yield of bread wheat and higher (14.054 t ha^{-1}) biological yield of bread wheat was obtained from Rasheed variety at seeding rate of 140 kg ha^{-1}, whereas the lowest (10.397 t ha^{-1}) biological yield was produced from planting of Bohooth 158 variety at 180 kg ha^{-1} seeding rate.

The two-way interaction varieties with sowing method had significant ($P < 0.05$) effects on dry biomass of bread wheat (Table 4). Significantly higher dry biomass yields 9. 45 t ha^{-1} of bread wheat was obtained from Liben variety with Lben variety with row method sowing (Tables 4).

The interaction of seed rates with sowing methods had significant effects on dry biomass yield of bread wheat (Table 6). Significantly higher 10.35 t ha^{-1} dry biomass of bread wheat was obtained with 125 kg ha^{-1} seed rate planted in row methods. The higher dry biomass yield of bread wheat with row methods of sowing as compared to broadcasting method might be due to better resource utilization in row method than broadcasting method.

The three-way interaction of varieties, seed rates and methods of sowing were significantly influenced the mean dry biomass of bread wheat (Table 7). Significantly, Higher 10.55 t ha^{-1} mean dry biomass of bread wheat was obtained from Liben variety with 125 kg ha^{-1} seed rate planted in row methods. The result confirmed that better dry biomass yield of bread wheat with recommended package for wheat production in Ethiopia.

Grain Yield: The main effect varieties, sowing methods and seeding rate had very highly significant ($P < 0.01$) effect on grain yield of bread wheat (Table 5). The two-way interaction effect of varieties with sowing methods was very highly significant ($P < 0.01$) influence on mean grain yield of bread wheat (Table 4). And also, the interaction effect of sowing methods with seeding rate was very highly significant ($P < 0.01$) effect of grain yield of bread wheat (Table 6).

The highest mean 4.02 t ha^{-1} for grain yield of bread wheat was obtained from Liben variety while the lowest mean 3.79 t ha^{-1} was for Hidase variety of bread wheat (Table 5). The difference in the grain yield of wheat varieties might be due to the difference in their genetic potential of varieties. This result indicated that the different varieties has different grain yield which could be controlled by genetic background. Likewise, Obsa and Yeared [41] reported that significance difference grain yield among varieties of bread wheat, which was ranged from 1.8 to 5.91t ha^{-1} with the mean value of 3.38t ha^{-1}. Alos, Sharma *et al.* [49] found that varieties significantly affected the grain yield of bread wheat. Sharshar and Ei-Said [32]; Nadeem [31] reported that wheat varieties significantly differed in grain yield and most of yield related traits. Costa *et al.* [90] found that mean grain yield of wheat was significantly different among varieties.

The row method of sowing has produced significantly higher 4.44t ha^{-1} grain yield of bread wheat as compared to broadcasting method 3.36t ha^{-1} (Table 5). This is might be due to increased competition for water as the seeds were placed closer together in the broadcasting method and ultimately may also have been related to reduction in wheat grain yield. In higher rainfall areas, where cereal crops have higher potential yields, significant yield decreases have been recorded with broadcasting method. Similarly, Khan *et al.* [44] found that sowing methods had highly significant effects on grain yield of wheat and significantly higher 4857 kg ha^{-1} mean grains yield was obtained from row method of sowing and the least 4318 kg ha^{-1} grain yield was found in broadcast method of sowing. Awoke *et al.* [91] found that sowing methods had significant effect on mean grain yield of wheat and significantly higher 3.5 t ha^{-1} grain yield of wheat was obtained from row planting and the least 3.13 t ha^{-1} was recorded from broadcast method. Also, Abebaw and Hirpa [45] found that sowing methods had significant effects on mean grain yield of wheat and significantly higher 1.5 t ha^{-1} mean grain yield of wheat was obtained from row methods of sowing as compared to broadcasting method.

Pirzada *et al*. [48] reported that drilling method of planting recorded significant maximum 5602 kg ha^{-1}) grain yield of bread wheat as compared to (5245 kg ha^{-1}) in broadcasting method of sowing. Awoke *et al.* [92] found that significantly maximum grain yield of 3.5 t ha^{-1} was obtained from row planting and the least 3.13 t ha^{-1} was recorded from broadcast method of bread wheat. Therefore, planting of bread wheat with row method was better than broadcasting. Therefore, Harishankar and Tomar [92] stated that proper methods of sowing enhance resource availability, such as sunlight capture, moisture and nutrient availability, leading to the proper root system development from the early stage of crop growth. Sowing methods guarantee proper crop establishment and optimum plant population in the field, as well as facilitating plants to utilize the land and other resources more efficiently and purposefully toward growth and development [93, 94]. Drilling method is considered suitable because of its uniform seed distribution and sowing at desired depth and resulted higher germination and uniform stand [48]. Therefore, Easson *et al.* [95] reported that planting with drill is recommended for better crop production.

The highest 4.46 t ha^{-1} grain yield of bread wheat was obtained with 125 kg ha^{-1} seeding rate and the lowest 3.37t ha^{-1} grain yield was obtained with 100 kg ha $^{-1}$ seeding rate which confirm the research recommendation for bread wheat production (Table 5). The increased seeding rate from 100 to 125 kg ha^{-1} produced grain yield which was significantly increased by 11.45% but decrease as seed rate increases up to 150 kg ha^{-1}. This might be due to increasing the competition among crops for common resource particularly water, nutrients and sunlight which resulting in low quality and low yield with high seeding rates [7]. The maximum grain yield obtained from the use of optimum seeding rate might be due to enough space of plants in row method and increased length of spikes per plants as a result number of grains and increased spike length in plants. Similarly, Awoke *et al*. [91] found that seed rate had significant effect on mean grain yield of wheat and higher grain yield of 3.9 t ha^{-1} and the minimum 2.7 t ha^{-1} were obtained from seed rate of 125 and 200 kg ha^{-1} of bread wheat.

Likewise, Haile *et al*. [53] reported that the lowest seeding rate 100 kg ha^{-1} resulted in lower grain yield of 3.37t ha^{-1}, which was significantly lower than the yields obtained at the other seeding rates 125 and 150 kg ha^{-1}. Khan *et al.* [44] found that seed rates had highly significant effects on grain yield of wheat and higher 5325 kg ha^{-1} mean grains yield was obtained from 175 kg ha^{-1} seed rates as compared to others. Abiot [55] reported that seeding rate o f 150 kg ha^{-1} gave significantly higher (4462 kg ha^{-1}) grain yield followed by 175 kg ha^{-1}. Haile *et al.* [53] found that seeding rates was significantly influenced grain yield of bread wheat and higher (4341 kg ha^{-1}) grain yield of wheat was obtained from 175 kg ha^{-1} seeding rate of wheat which was in statistical at parity with the yield obtained at the seeding rate of 150 kg ha^{-1}. Seleiman *et al*. [51] also confirmed that increasing seeding rates up to 350 or 400 grains m^{-2} increased grain yield. Higher grain yield with optimum seeding rates was also reported by Olsen *et al*. [96], Haile and Girma [97]. Similarly, Sikander *et al*. [98] concluded that increasing seeding rate from 150 to 250 seeds/m^{-2} resulted in higher grain yield. Sharma *et al*. [49] found that wheat sown at the seed rate of 140 kg ha^{-1} significantly showed promising (3.645 and 3.634 t ha^{-1}) grain yield during both the years. Ghulam *et al*. [19] reported that the Kiran-95 variety with 125 kg ha^{-1} seed rate performed best, followed by TD-1 and Sarsabz which also produced more yield at 125 kg ha^{-1}.

In contrary, Abd El-Lattief [67] found that grain yield of bread wheat significantly affected by seed rate and significantly higher grain yields were 4.357 and 4.605 t ha^{-1} in both years was obtained from seeding rate of 300 seeds m^{-2}. Tomar [99] found that significantly higher grain yield of bread wheat was obtained with higher seeding rate of 150 kg ha^{-1}. Mennan and Zandstra [100] reported that wheat grain yield increased with increasing seed rate and decreased with decreasing seed rate from 250 to 200 or 150 kg ha^{-1}. Ali *et al*. [52] found that number of grain yield was higher under seeding rate of 150 kg ha^{-1}. Kiliç and Gürsoy [101] found that seeding rate affected grain yield and yield components of bread wheat and 253 seed per m^2 was predicted to be an optimum seed rate for producing the highest average grain yield (5162 kg ha^{-1}) over years. Costa *et al.* [90] found that mean grain yield of wheat was significantly different among seed rate used and significantly increased grain yield of wheat with an increase in seeding rate of wheat in Mediterranean environments. Therefore, the use of 125 kg ha^{-1} seeding rate of bread wheat at gave significantly higher grain yield than 100 and 150 kg ha^{-1} seeding rate since row method causes higher leaf photosynthesis and suppresses weeds growth compared with broadcasting method. Baloch *et al.* [54] reported that significantly higher grain yield of wheat with seed rate of 150 kg ha^{-1}. Naveed *et al.* [57] found that increasing seed rate was increased grain yield (4741 kg ha^{-1}) of dual-purpose wheat.

The interaction effects of varieties with sowing methods was showed significant ($P<0.05$) effect on mean grain yield of bread wheat (Table 4). Significantly higher 4.6t ha^{-1} grain yield of bread wheat was obtained from Liben variety with row methods of sowing while minimum 3.3t ha^{-1} grain yield was from Hidase variety with broadcasting methods sowing (Table 4). The difference grain yield of varieties of wheat with sowing method might be due to the genetic potential difference of varieties using methods of sowing. Similarly, Pirzada *et al.* [48] reported that the interaction effect of varieties with sowing methods was significant effects for grain yield of bread wheat and significantly higher (5900 kg ha^{-1}) grain yield of bread wheat was recorded from Drilling sowing method in variety TD-1 whereas, minimum (4445 kg ha^{-1}) grain yield was recorded from Gurbi sowing method in variety Moomal.

The interaction effects of sowing methods with seed rate was significantly ($P<0.05$) affected mean grain yield of bread wheat (Table 6). Significantly the highest mean grain yield 5.16 t ha^{-1} of bread wheat was obtained from use of 125 kg ha^{-1} seeding rate with row method sowing while the lowest grain yield 3.73t ha^{-1} was obtained from 100 kg ha^{-1} seeding rate with broadcasting method sowing. Likewise, Misgana *et al.* [18] reported that 125 kg ha^{-1}seed rate with row planting produced 3.9 t ha^{-1} grain yield of bread wheat in the Senmamer areas of Senegal. This indicates that proper seeding rate with sowing method increased plant vitality and yield. It encourages nutrient availability, proper sun light penetration for photosynthesis good soil environment for up take soil nutrients and water use efficiency [102] all necessary for crop vigor and yield. The optimum seeding rate results in increasing grain yield of bread wheat.

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 harvest index of bread wheat was very highly significantly ($p<0.001$) affected by main effects of varieties, sowing methods and seeding rate (Table 5). The two-way interaction effect of varieties with seeding rate was showed significant ($p<0.05$) effect on harvest index of bread wheat (Table 3). The two-way interaction effect of sowing methods with seeding rate was showed highly significantly ($P<0.01$) effect of harvest index of wheat (Table 6). The three-way interaction effect of varieties, sowing methods and seeding rate had very highly significant ($p<0.01$) effect on mean harvest index of bread wheat (Table 7).

The highest harvest index (43.47%) was observed from Liben variety of wheat while lowest harvest index (40.6%) was recorded from Hidase variety. Likewise, Jemal *et al.* [7] reported that harvest index in bread wheat affected by varieties and Shorima and Kakaba varieties were gave significantly higher 40.45 and 38.1%, harvest index of bread wheat as compared to the other varieties. Also, Desalegn [60] found that significant difference among bread wheat varieties and significantly higher mean harvest index of bread wheat were obtained from Hidase and Ogolcho varieties as compared to Liben variety. Similarly, Esayas *et al.* [65] reported significant differences in harvest index among wheat varieties. Demisew [103]; Lemi and Negash [66] who stated that harvest index of bread wheat affected by varieties. Abd El-Lattief [67] found that mean harvest index of bread wheat significantly affected by interaction of varieties and significantly higher 44.38 % harvest index was obtained from Giza 168 produced as compared to Sohag 3 variety of bread wheat. Kiliç and Gürsoy [101] found that cultivars

Table 8: Pearson correlation between phenology, growth and Yield and Yield components of Bread Wheat in Abay Chommen district

	NPTP	SL	NSPS	NKPS	TKW	BM	GY	HI
NPTP		0.77**	0.71**	0.72**	0.71**	-0.11	0.29	0.45*
SL			0.77**	0.72**	0.74**	-0.11	0.21	0.33*
NSPS				0.75**	0.74**	0.04	0.47**	0.60**
NKPS					0.85**	-0.16	0.32	0.50**
TKW						-0.20	0.24	0.41*
BM							0.75**	0.44*
GY								0.92***
HI								

NPTPP = number of productive tillers per plant, SL = Spike length, NSPS = number of spikes per spikelet, NKPS = number of kernels per spike, TKW = thousand kernel weight, DBM = dry biomass, GY = grain yield and HI = Harvesting index

significantly affected the harvest index wheat and Firat-93 variety produced significantly higher harvest index than Aydin-93. Therefore, the use of different varieties of bread wheat had variation in harvest index due to their genetic potential of varieties.

Maximum harvest index (46.75%) of bread wheat was observed from row method while minimum harvest index (37.3%) was recorded from broadcasting method of sowing (Table 5). Likewise, Abebaw and Hirpa [45] found that sowing methods had significant effects on mean harvest index of wheat and significantly higher mean harvest index of wheat was obtained from row methods of sowing as compared to broadcasting method. In contrary, Khan *et al.* [44] found that harvest index of wheat was significantly affected by sowing methods and higher 41.18% of harvest index was obtained from broadcasting method sowing as compared to row methods of sowing 37.85%. Therefore, row methods of sowing were crucial for wheat production.

The highest harvest index (45.52%) was obtained from 125 kg ha^{-1} seeding rate while lowest harvest index (39.69%) was recorded from100 kg ha^{-1}seeding rate (Table 5). Similarly, Khan *et al.* [44] found that harvest index of wheat was significantly affected by seeding rates and higher 49.03% harvest index was obtained from 125 kg ha^{-1} seeding rates as compared to others. Kiliç and Gürsoy [101] found that seed rate had significant effect on harvest index of durum wheat and 50 and 150 seed m^{-2} produced higher harvest index for all three years. The higher harvest index obtained in the lowest seed rate can be attributed to more light penetration through plant canopy and nutrient elements are improved [101]. In contrary, Mollah *et al*. [104] reported that seed rate did not have significant effect on harvest index of wheat in bed planting condition.

The interaction of varieties with seed rates was showed significant ($P<0.05$) influence of mean harvest index of bread wheat (Table 3). Significantly higher (46.07%) mean harvest index of bread wheat was recorded from Liben variety with 125 kg ha^{-1} seeding rate and the lowest harvest index (37.75 %) from Hidase variety with 100 kg ha^{-1} seed rate for bread wheat. Likewise, Haile *et al.* [53] found that interaction of varieties with seed rates had significant difference on mean harvest index of wheat.

The two-way interaction effect of sowing methods with seeding rate was showed highly significant ($P<0.01$) effect on mean harvest index of bread wheat (Table 6). Significantly higher 49.5 % mean harvest index of bread wheat was obtained with 125 kg ha^{-1} seed rates with row methods of sowing of bread wheat which confirm the research recommendation for wheat production.

The three-way interaction effect of varieties, sowing methods and seeding rate had very highly significant ($p<0.01$) effect on mean harvest index of bread wheat (Table 7). Significantly higher 49.8 % mean harvest index of bread wheat was obtained from Hidase variety with 125 kg ha^{-1} seed rate planted in row methods. Therefore, the use of recommended packages for verities of bread wheat was enhanced harvest index and very important for production of bread wheat.

Pearson Correlation Between Yield and Yield Components of Bread Wheat Due to Varieties, Seed Rates and Methods of Planting: The correlation between yield and yield components of bread wheat are indicated in Table 8. The number of productive tillers per plant has positive and significant correlation with spike length (0.78), number of spikes per spikelet (0.71), number of kernels per spike (0.72), thousand seed weight (72) and harvest index (0.45). The spike length of bread wheat showed positive and significant correlation with number of productive tillers per plant (0.78), number of spikes per spikelet's (0.77), number of kernels per spike (0.72), thousand seed weight (0.74) and harvest index (0.33). The number of spikes per spikelet of wheat showed positive and significant correlation with number of productive tillers per plant (0.71), spike length (0.77), number of kernels per spike (0.75), thousand kernel weight

(0.74), grain yield (0.47) and harvest index (0.60) (Table 12). The number of kernels per spike showed positive and significant correlation with number of productive tillers per plant (0.72), spike length (0.72), number of spikes per spikelet (0.75), thousand seed weight (0.85) and harvest index (0.50).

Thousand seed weight showed positive and significant correlation with number of productive tillers per plant (0.71), spike length (0.74), number of spikes per spikelet (74), number of kernels per spike (0.85) and harvest index (0.41). Dry biomass of bread wheat showed positive and significant correlation with plant height (0.65), grain yield (0.75) and harvest index (0.44). Grain yield showed positive and significant correlation with its components such as plant height (0.29), number of spikes per spikelet (0.47), dry biomass (0.75) and harvest index (0.92). This means with increasing value of these parameters; grain yield increases as well and vice versa. Harvest index was positively and highly significantly correlated with plant height (0.37), number of productive tillers per plant (0.45), spike length (0.33), number of spikes per spikelet (0.60), number of kernels per spike (0.50), thousand seed weight 0.41), dry biomass (0.44) and grain yield (0.92).

CONCLUSION

Wheat (*Triticum species*) is an important food crop in Ethiopia. Significantly higher 4.46 t ha^{-1} mean grain yield of bread wheat was obtained from 125 kg ha^{-1} seeding rate as compared to 100 and 150 kg ha^{-1}. Row method of sowing at 125 kg ha^{-1} seed rate was optimal for better grain yield of bread wheat. The main effect of varieties and seeding rates were significantly improved all agronomic parameters of bread wheat considered. The use of 125 kg ha^{-1} seed rate gave significantly improved most agronomic traits of bread wheat as compared to 100 and 150 kg ha^{-1}. The combined use of Liben variety, 125 kg ha^{-1} seeding rate with row method sowing performed better and gave higher grain yield (5.26t ha^{-1}) of bread wheat. The interaction effect of seeding rate, sowing method and varieties were highly significant for thousand kernel weight, biomass yield and harvesting index of bread wheat. Positive and strong correlation between growth, yield and yield components of bread wheat. Therefore, 125 kg ha^{-1} seeding rate with row methods of sowing for Liben variety was recommended for smallholder farmers in study area and other areas with similar agroecologies. To make reliable and acceptable recommendation it is better to repeat this experiment across locations and over seasons.

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REFERENCES

1. Racioppi, M., M. Tartaglia, J.M. De La Rosa, M. Marra, E. Lopez-Capel and M. Rocco, 2020. Response of Ancient and Modern Wheat Varieties to Biochar Application: Effect on ormone and Gene Expression Involved in Germination and Growth. Agronomy, 10(5): 1-11.
2. Dhillon, J., E. Eickhoff, A.L. Lawrence, P. Omara, G. Weymeyer, E. Nambi, F. Oyebiyi, T. Carpenter and W. Raun, 2020. Nitrogen management impact on winter wheat grain yield and estimated plant nitrogen loss. Agronomy Journal, pp: 1-14.
3. Ali, S., M.S. Ibin-I Zami, M. Farid, M.A. Farooq, M. Rizwan, R. Ahmad and F. Hannan, 2016. Growth and yield response of wheat (*Triticum aestivum* L.) to tillage and row spacing in maize-wheat cropping system in semi-arid region. Eurasian Journal of Soil Science, 5(1): 53-61.
4. Hossain, I.I., I.S. Hossain, M.A. Rahman, A. Haque, S. Hasan and S. Haque, 2015. Yield potentials of recently released wheat varieties and advanced lines under different soil fertility. International Journal of Agronomy and Agricultural Research, 6(6): 91-99.
5. CSA, 2019. Area and production of major crops. Agricultural Sample Survey 2018/19 (2011 E.C.). V 1. Statistical Bulletin. 589. Addis Ababa, Ethiopia.
6. Amare, A., L. Adane and M. Mekonen, 2015. Yield Response of Bread Wheat to Timing of Urea Fertilizer Application in Eastern Amhara Region. Sirinka Agricultural Research Center, Woldia, Ethiopia. J. Biology, Agriculture and Healthcare, 5(3): 180-183.
7. Jemal, A., T. Tamado and E. Firdissa, 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.
8. Mulatu, K., 2015. Effect of Mineral NP and Organic Fertilizers on the Productivity and Nitrogen Use Efficiency of Bread Wheat (*Triticum aestivum* L.) in Gozamin District.North Western Ethiopia PhD Dissertation, Haramaya University, Haramaya.

9. Hawkesford, M.J., J.L.Araus, R. Park, D. Calderini and D. Miralles, 2013. Prospects of doubling global wheat yields. Food Energy Security, 2: 34-48.
10. Anderson, L. and K. Schneider, 2010. Yield Gap and Productivity Potential in Ethiopian Agriculture: Staple Grains & Pulses. Evans School Policy Analysis and Research (EPAR) Brief No. 98.
11. 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. Journal Agriculture Research, 48(2): 151-156.
12. Nizamani, G.S., S. Tunio, U.A. Buriro and 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): 232-236.
13. Hammed, E., W.A. Shah, A.A. Shad, F.H.J. Ta and J. Bakht, 2002. Yield and yield components of wheat as affected by different planting dates, seed rate and nitrogen levels. Asian Journal Plant Sciences, 1: 502-506.
14. Ozturk, A., O. Caglar and S. Bulut, 2006. Growth and yield response of facultative wheat to winter sowing, freezing sowing and spring sowing at different seeding rates. Journal of Agronomy and Crop Sciences, 192(1): 10-16.
15. Staggenborg, S.A., D.A. Whitney, D.L. Fjell and J.P. Shroyer, 2003. Seeding and nitrogen rates required to optimize winter wheat yields following grain sorghum and soybean. Agronomy Journal, 95: 253-259.
16. Arif, M., M. Ali, Q.M. Din, M. Akram and L. Ali, 2003. Effect of different seed rates and row spacing on the growth and yield of wheat. Journal Animal Plant Sciences, 13(3): 161-163.
17. Khan, M.A., J. Anwar, A. Sattar and M.A. Akhtar, 2001. Effect of seed rate on wheat yield under different sowing dates and row spacing. Journal of Agricultural Research, 39(3-4): 223-229.
18. Misgana, M., T. Awoke and Y. Tekle, 2017. Effect of Sowing Methods and Seed Rate on Yield of bread wheat (*Triticum aestivum* L.) At South Ari District, South Omo Zone, Snnpr, Ethiopia, 5: 2394-3629.
19. Ghulam, S.N., T. Shamsuddin, A.B. Umed and I.K. Muhammad, 2014. Influence of different seed rates on yield contributing traits in wheat varieties. Journal of Plant Sciences, 2(5): 232-236.
20. 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(Avenafatua) competition durations. Pakistan Journal. Agricultural Sciences, 37(3-4): 152-154.
21. Payne, T.S., D.G. Tanner and O.S. Abdalla, 1996. Current issues in wheat research and production in Eastern, Central and Southern Africa: Changes and challenges. pp: 1-27. In: D.G. Tanner, T.S. Payne and O.S. Abdalla, (Eds.). The Ninth Regional Wheat Workshop for Eastern, Central and Southern Africa. Addis Ababa, Ethiopia: CIMMYT.
22. Amsal, T., D.G. Tanner and G. Getinet, 1995. Improvement in yield of bread wheat cultivars released in Ethiopia from 1949 to 1987. African Crop Science Journal, 3: 41-49.
23. Dorosh, P. and S. Rashid, 2013. Food and Agriculture in Ethiopia: Progress and Policy Challenges. University of Pennsylvania Press. Philadelphia, USA.
24. Amsal, T., D.G. Tanner, T. Taye and M. Chanyalew, 1999. A study of variety by management interaction in bread wheat varieties released in Ethiopia, pp: 196-212. In: The Tenth Regional Wheat Workshop for Eastern, Central and Southern Africa. Addis Ababa, Ethiopia: CIMMYT.
25. Tadesse, D., G. Bedada, T.S. Payne, C.S. Van Deventer and M.T. Labuschagne, 2000. Sources of variation for grain yield performance of bread wheat in northwestern Ethiopia. pp: 16-24. In: The Eleventh Regional Wheat Workshop for Eastern, Central and Southern Africa. Addis Ababa, Ethiopia: CIMMYT.
26. Aman, A., L. Gobeze and H. Legese, 2018. Response of Bread Wheat (*Triticum aestivum* L.) Varieties to Nitrogen Fertilizer Application Rates at Wolaita Sodo, Southern, Ethiopia. Food Science and Quality Management, 82: 30-42.
27. Alam, Z., Z. Ali, T. Ahmad and A. Abdumanon, 2006. Physicochemical characteristics of wheat varieties growing in the same and different ecological regions of Pakistan. Pakistan Journal of Biological Sciences, 9(9): 1823-1828.
28. Jan, I., M. Usman, I.H. Khalil and T. Jan, 2003. Performance of recently released wheat cultivars. Asian Journal of Plant Sciences, 2(8): 627-632.
29. Irfan, M., T. Muhammad, M. Amin and A. Jabbar, 2005. Performance of yield and other agronomic characters of four wheat (*Triticum aestivum* L.) genotypes under natural heat stress. International Journal of Botany, 1(2): 124-127.

30. Akmal, M., S.M. Shah and M. Asim, 2000. Yield performance in three commercial wheat varieties due to flag leaf area. Pakistan Journal of Biological Sciences, 3(12): 2072-2074.
31. Nadeem, M., 2001. Growth, radiation use efficiency and yield of some new wheat cultivars under variable nitrogen rates. M.Sc. thesis. Department of Agronomy, University Agriculture Faisalabad.
32. Sharshar, M.S. and S. El-Said, 2000. Evaluation of some wheat cultivars and lines under low and high inputs. Journal of Agricultural Science, 25(6): 3109-3127.
33. Arega, G., B. Wondimu, T. Kebede and A. Legesse, 2013. Varietal differences and effect of nitrogen fertilization on durum wheat (*Triticum turgidum var.* durum) grain yield and pasta making quality traits. International Journal of Agronomy and Plant Production, 4(10): 2460-2468.
34. Habtamu, K. and M. Ahadu, 2019. Genetic Variation of Bread Wheat (*Triticum aestivum* L.) Varieties Based on Phenological, Morphological and Quality Traits at Guay Kebele in Debre Elias District, East Gojjam Zone, Northwestern Ethiopia, Journal of Biology, Agriculture and Healthcare, 9(11): 22-29.
35. AGP-AMDE (Agriculture Growth Program - Agribusiness and Market Development), 2014. USAID FY2014 Annual Report July 1, 2013 - June 30, 2014, pp: 205.
36. Ansari, M.A., H.R. Meman, S.D. Tunio and S.A. Keerio, 2006. Effect of planting pattern on growth and yield of wheat. Pakistan Journal Agriculture and Agricultural. Engginering, Veternary Sciences, 22(2): 25-33.
37. Marwat, M.I., H.K. Ahmad, H.H. Khan and A. Khan, 2002. Integrated weed management in wheat. 1. Weed density, dry weed biomass, absolute growth rate and grain yield. Pakistan Journal of Weed Sciences Research, 8(1-2): 81-93.
38. ACHWANRO. (Abay Choman Woreda of Agriculture and Natural Resource Office, 2019. Annual Report of Evaluation of *Meher* Crops, Report Submitted to Horro Guduru Wollega Zone Agricultural and Natural Resource Office, Shambu, Ethiopia.
39. SAS, 2012. SAS/STAT Software Syntax, Version 9.4. SAS Institute, Cary, NC. USA.
40. Steel, R.G.D. and J.H. Torrie, 1980. Principles and procedures of statistics a biometrical approach, 2nd edition, McGraw-Hill book company, New York, pp: 272-280.
41. Obsa, C. and T. Yeared, 2017. Participatory Variety Selection of Improved Bread Wheat Varieties for High Land Guji Zone, Southern Ethiopia. Journal of Biology, Agriculture and Healthcare, 7(7): 11-14.
42. Kifle, Z., T. Birhanu and G. Mekonen, 2018. Farmers participatory and selection of bread wheat (*Triticum aestivum*. L) varieties in Cheha district, Gurage Zone, Ethiopia. International Journal of Scientific and Research Publications, 8(12): 780-788.
43. Al-Hilfy, I., H.H. and S.A. Wahid, 2017. Seeding rates influence on growth and straw yield of some bread wheat cultivars and their relationship with accumulated heat units. American-Eurasian Journal of Sustainable Agriculture, 11(5): 49-58.
44. Khan, H., M.A. Khan, I. Hussain, M.Z. Muhamad Zaman Khan and M.K. Khattak, 2000. Effect of Sowing Methods and Seed Rates on Grain Yield and Yield Components of Wheat Variety Pak-81. Pakistan Journal of Biological Sciences, 3(7): 1177-1179.
45. Abebaw, T. and L. Hirpa, 2018. Effects of Fertilizer Rate (Blended) and Sowing Methods on Yield and Yield Components of Bread Wheat (*Triticum aestivum*) in Western Ethiopia. International Journal of Comprehensive Research Biology Sciences, 5(6): 1-16.
46. Tanveer, S.K., I. Hussain, M. Sohail, N.S. Kissana and S.G. Abbas, 2003. Effect of different planting methods on yield and yield components of wheat. Asian Journal of Plant Sciences, 2: 811-813.
47. Soomro, U.A., M.U. Rahman, E. A. Odhano, S. Gul and A.Q. Tareen, 2009. Effects of Sowing Method and Seed Rate on Growth and Yield of Wheat (Triticum aestivum). World Journal of Agricultural Sciences, 5(2): 159-162.
48. Pirzada, R., M.A. Chandio, N. Khaskheli, F.H. Magsi, A.A. Perzada and M. Siyal, 2018. Effect of varietal cum sowing methods trait on growth and yield of wheat (*Triticum aestivum* L.). National Journal of Advanced Research, 4(3): 68-73.
49. Sharma, R.L., A. Shalu, B. Rakesh, T. Tushar and O.M. Prakash, 2016. Yield and Yield Attributes of Wheat as Influenced by Different Seed Rates and Genotypes in Gariyaband District of Chhattisgarh Plains. International Journal of Agriculture Sciences, 8(49): 2117-2119.
50. Malik, A.U., M.A. Alias, H.A. Bukhsh and I. Hussain, 2009. Effect of seed rates sown on different dates on wheat under agroecological conditions of Dera Ghazi Khan. Journal of Animal and Plant Sciences, 19(3): 126-129.

51. Seleiman, M.F., M.E. Ibrahim, S.M. Abdel-Aal and G.A. Zahran, 2010. Effect of seeding rates on productivity, technological and rheological characteristics of bread wheat (*Triticum aestivum* L.). International Journal of Current Research, 4: 075-0.
52. 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 Vehai zone. Journal of Animal and Plant Sciences, 20(4): 225-230.
53. Haile, D., D. Nigussie, W. Abdo and F. Girma, 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): 7693-7710.
54. Baloch, M.S., I.T.H. 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 & Plant Sciences, 20(4): 239-240.
55. Abiot, M., 2017. 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. Journal of Biology, Agriculture and Healthcare, 7(4): 19-37.
56. Iqbal, J., K. Hayat, S. Hussain, A. Ali, A.M. Ahmad and B.H. Ahmad, 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.
57. Naveed, K., M.A. Khan, M.S. Baloch, K. Ali, M.A. Nadim, E.A. Khan, S. Shah and M. Arif, 2014. Effect of different seeding rates on yield attributes of dual-purpose wheat. Sarhad Journal of Agriculture, 30(1): 83-91.
58. Matsuyama, H. and T. Ookawa, 2020. The effects of seeding rate on yield, lodging resistance and culm strength in wheat, Plant Production Science, 23(3): 322-332.
59. 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.
60. Desalegn, A., 2019. Effects of NPS Fertilizer Rates on Yield and Quality Attributes of Bread Wheat (*Triticum aestivum* L.) Varieties in Munessa District, Arsi Zone, Ethiopia. M.Thesis Research. Arsi University, pp: 71.
61. Zewdie, B., C.S. Paul, J.G. Anthony and G. Van, 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): 2948-963.
62. 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.
63. Sulieman, S.A., 2010. The Influence of Triticum asetivum seeding rates and sowing patterns on the vegetative characteristics in Shambat soil under irrigation. Research Journal Agriculture Biological Sciences, 6: 93-102.
64. Whaley, J.M., D.L. Sparkes, M.J. Foulkes, J.H. Spink, Semere and R.K. Scott, 2000. The physiological response of winter wheat to reductions in plant density. Annals of Applied Biology, 137(2): 165-177.
65. Esayas, L., 2015. Effect of Blended Fertilizers on Yield and Yield Traits of Durum Wheat (*Triticum turgidum* L. Var. Durum) Varieties in Ada'a District, Central Ethiopia. M.Sc. Thesis. Haramaya University.
66. Lemi, A. and G. Negash, 2020. Effects of Variety and Fertilizer Rate on Yield of Bread Wheat (*Triticum aestivum*, L) Varieties in East Wollega Zone, Western Ethiopia, 6(2): 60-71.
67. Abd El-Lattief, E.A., 2014. Determining the optimization seeding rate for improved productivity of wheat under Southern Egypt conditions. International Journal of Agronomy and Agricultural Research, 4(1): 47-57.
68. Twizerimana, A., E. Niyigaba, I. Mugenzi, W.A. Ngnadong, C. Li, T.Q. Hao, B.J. Shio and J.B. Hai, 2020. The Combined Effect of Different Sowing Methods and Seed Rates on the Quality Features and Yield of Winter Wheat. Agriculture, 10(153): 1-20.
69. Hussain, S., A. Sajjad, M.I. Hussain and M. Saleem, 2001. Growth and yield response of three wheat varieties to different seeding densities. International Journal of Agricultural and Biology, 3: 228-229.
70. Rahim, N., S. Abas, K. Hamid, M. Amir and N. Kamvan, 2012. Effect of plant density on grain yield, yield components and associated traits of three durud wheat cultivar in western Iran. International Jornal of Agriculture.
71. Worku, A., 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. Haramaya University. Haramaya, Ethiopia.

72. Mehrvar, M.R. and H. Asadi 2006. Agronomical and economical assessment of planting methods and seeding rates in irrigated wheat. Journal Agronomy, 5(4): 626-633.
73. Shah, W.A., H.U. Khan, S. Anwar and K. Nawab, 2011. Yield and yield components of wheat as affected by different seed rates and nitrogen levels. Sarhad Journal of Agriculture, 27(1): 17-25.
74. Obsa, C., A. Kabna and A. Seyum, 2018. Participatory Variety Selection of Improved Bread Wheat Varieties for Moisture Stress Areas of Guji Zone, Southern Oromia. International Journal of Research in Agriculture and Forestry, 5(4): 1-6.
75. Amare, A. and K. Mulatu, 2017. Response of Bread Wheat (*Triticum aestivum* L.) Varieties to Different Seeding Rate for Growth, Yield and Yield Components in Kombolcha District, North-Eastern Ethiopia. Debre Markos University. Journal of Biology, Agriculture and Healthcare, 7(23): 79-91.
76. Melaku, T., 2019. Grain quality and yield response of bread wheat (*Triticum aestivum* L.) varieties to different rates of blended fertilizer at Kulumsa, South-eastern Ethiopia. Assela, Ethiopia. Journal of Agricultural Science and Practice, 4(4): 120-133.
77. Ghulam, M.L., C.O. Fateh, T. Shamasuddin, W. Allah, G. Adhayo, H.S. Muzzammil, W.J. Allah and M.O. Sono, 2010. Growth, yield and nutrient uptake of various wheat cultivarsunder different fertilizer regimes. Sarhad Journal Agriculture, 26(4): 489-497.
78. Tesfaye, G., 2015. Seed Rate and Sowing Method Effects on Seed Quality of Bread Wheat (*Triticum aestivum* L.) Varieties in Horo District, Western Ethiopia. Malaysia Journal Medical and Biological Research, 2(3): 273-283.
79. Ozberk, I., Y. Coskun, A. Ilkhan, M. Koten, B. Karli and J. Ryan, 2009. Comparison of Bed Planting-furrow Irrigation with Conventional Planting-flood Irrigation in Durum Wheat (*T. durum* Desf) in Southeastern Turkey. Pakistan Journal of Biological Sciences, 12: 772-778.
80. Naseri, R., A. Soleymanifard, H. Khoshkhabar, A. Mirzaei and K. Nazaralizadeh, 2012. Effect of plant density on grain yield, yield components and associated traits of three durum wheat cultivars in Western Iran. International Journal Agriculture Crop Science, 4: 79-85.
81. Helms, T. and J.H. Orf, 1998. Protein, oil and yield of soybean lines selected for increased protein. Crop Science, 38: 707-7011.
82. Tewodros, A., A. Bereket and Y. Tarekegn, 2017. Response of Wheat (*Tritium aestivum* L.) to Variable Seed Rates: The Case of Hawassa Area, Southern Ethiopia. Aifircan Journal of Agricultural Research, 12(14): 1177-1181.
83. Jan, A., M.Y. Khan, M.I. Marwat and T. Muhammed, 2000. Impact of intra –specific competition on the agronomic traits of wheat. Pakistan Journal Biological Sciences, 3: 2016-2019.
84. Khan, M.A. and I. Ullah, 2002. Effect of seed rate on the yield and yield components of wheat under irrigated conditions of Peshawar . Asian Journal Plant Science, 1: 513-515.
85. 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.
86. Dubis, B. and W. Budzynski, 2006. Response of winter wheat to the date and density of sowing. Acta Scientiarum Polonorum Agricultura, 5: 15-24.
87. El-Hebbasha, E.F., 2001. Effect of nitrogen fertilization on yield of some newly released wheat varieties under different seed rates. M.Sc. Thesis, Faculty of Agriculture, Al-Shams University, Egypt.
88. Ali, A.G., O.E. Zeiton, A.H. Bassiauny and A.R.Y. El-Banna, 2004. Productivity of wheat cultivars grown at El-Khattara and El-Arish under different levels of planting densities and N-fertilization. Zagazig Journal Agricultural Research, 31: 1225-1256.
89. Laghari, G.M., F.C. Oad, S. Tunio, G.C.Q.W. Allah and M.H. Siddiqui, 2011. Growth and yield attributes of wheat at different seed rates. Sarhad Journal of Agriculture, 27: 177-183.
90. Costa, R., N. Pinheiro, A.S. Almeida, C. Gomes, J. Coutinho, J.O. Coco, A. Costa and B. Maçãs, 2013. Effect of sowing date and seeding rate on bread wheat yield and test weight under Mediterranean conditions. Emirates Journal of Food Agriculture, 25(12): 951-961.
91. Awoke, T., Y. Tekle and M. Misgana, 2017. Effect of Sowing Methods and Seed Rate on Yield of Bread Wheat (*Triticum aestivum* L.) at South Ari District, South Omo Zone, Snnpr, Ethiopia. International Journal of Research- Granthaalayah, 5(6): 175-180.
92. Harishankar, G.P.P. and G.S. Tomar, 2017. Growth and Yield of Wheat (*Triticum aestivum* L.) as influenced by Methods of Sowing and Seed Rates. Progress. Research International Journal, 12: 401-403.

93. Gul, S., M. Khan, B. Khanday and S. Nabi, 2015. Effect of sowing methods and NPK levels on growth and yield of rainfed maize (*Zea mays* L.). Scientifica, 2: 1-6.
94. Singh, K. and R. Sharma, 2019. Effect of different methods of sowing and row orientation on growth, yield and quality of wheat (*Triticum aestivum* L.). Agriculture Science Digital Research Journal, 39: 51-54.
95. Easson, D.L., E.M. White and S.J. Pickles, 1993. The effects of weather, seed rate and cultivar on lodging and yield in winter wheat. Journal Agricultural Sciences, 121(2): 145-156.
96. Olsen, J., L. Kristensen, J. Weiner and H.W. Griepentrog, 2005. Increased density and spatial uniformity increase weed suppression by spring wheat (*Triticum aestivum*). Weed Research, 45: 316-321.
97. Haile, D. and F. Girma, 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.
98. 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 Journal Plant Science, 2: 811-813.
99. Tomar, S.K., 2004. Response of rainfed wheat to sowing methods and seed rate under Diara land condition. Madras Agricultural Journal, 91(1-3): 47-51.
100. Mennan, H. and B.H. Zandstra, 2005. Influence of wheat seeding rate and cultivars on competitive ability of bifra (Bifora radians). Weed Technology, 19(1): 128-136.
101. Kiliç, H. and S. Gürsoy, 2010. Effect of seeding rate on yield and yield components of durum wheat cultivars in cotton-wheat cropping system. Scientific Research and Essays, 5(15): 2078-2084.
102. Hossain, M.A. and A.F.M. Maniruzzaman, 1992. Response of Wheat (*Triticum aestivum*) to method of sowing and fertilizer placement. Indian Journal Agronomy, 37: 710-715.
103. Demisew, A., 2018. Effect of Blended NPS Fertilizer on Seed quality, yield and yield related traits of bread wheat (*Tritium aestivum* L.) varieties at Haramaya, Eastern Ethiopia. MSc. Thesis. Haramaya University, Haramaya, Ethiopia.
104. Mollah, M.I.U., M.S.U. Bhuiya and M.H. Kabir, 2009. Bed Planting: A New Crop Establishment Method for Wheat in Rice-Wheat Cropping System. Journal Agriculture Rural Development, 7(1-2): 23-31.