International Journal of Botany Studies
www.botanyjournals.com
ISSN: 2455-541X
Received: 31-12-2021, Accepted: 15-01-2022, Published: 31-01-2022
Volume 7, Issue 1, 2022, Page No. 708-717

Effect of seed rate on yield and yield components of bread wheat (*Triticum aestivium* L.*)* varieties at anlemo woreda, Hadiya zone, southern Ethiopia

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Abstract
In Ethiopia, wheat (Triticum aestivum L.) is one of the most vital staple food crops among all cereals. However, the yield of the crop in the study area is adversely affected by lack of improved agronomic practice such as appropriate seed rate per unit area. Thus, a field trial was conducted during the 2020 main cropping season in Hadiya Zone at Anlemo Woreda with the objective of evaluating the effect of different seeding rates on yield components and yield of bread wheat varieties. The experimental treatments consisted of a factorial combination of three bread wheat varieties (Danda'a, Lemu and kakaba) and five seed rates (75, 100, 125, 150 and 175 kg ha-1). The treatments were laid out in a randomized complete block design (RCBD) with three replications. Data on phenological parameters,growth, yield and yield components were recorded and analysed. The results of the experiment showed that there were differences (P<0.05) in all measured parameters. The maximum grain yield (5580 kg ha-1) was attained from the variety ‘Lemu’ at a seed rate of 150 kg ha^{-1}. Thus, the variety ‘lemu’ at a seed rate of 150 kg ha-1 could be recomended for the study area. However, to reach at a decisive recommendation, the study should be repeated across location and over season.

Keywords: grain yield, optimum seed rate, varieties, yield attributes

Introduction

Wheat is Ethiopia's most important grain crop, and it is widely grown and developed across the country's various agro-ecological zones (Jemal *et al*., 2015). Ethiopia is cosidered the second-largest interms of wheat-producing country in Sub-Saharan Africa, after South Africa (Gashaw *et al*., 2014). The crop is one of the country's most important staple crops in terms of production and consumption (Amare *et al*., 2015), and it is primarily utilized for domestic food, seed, and industrial reasons (Abu, 2013). Besides the use of its grains for food, wheat residues and other by-products are commonly used to overcome the shortage of livestock feed (Mathewos *et al*., 2012).

However, small-holder farmers in Ethiopia produce roughly 2.5 t ha-1 of wheat on average (CSA, 2016), which it is much lower than the yields other wheat-producing countries throughout the world (White *et al*., 2001); and research station outputs of over 6 t ha-1 inside the country (Hawkesford *et al*., 2013); and global average grain yields of around 3 t ha-1 (White *et al*., 2001). (Assefa *et al*., 2015). The low productivity is mostly reported because of the cultivation of unimproved varieties and inadequate seed rate (Jemal *et al*., 2015). Seed rate is considered as one of the cultivation practices that most influence grain yield and other agronomic characteristics which need great emphasis during wheat production (ICARDA, 2013). In many parts of Ethiopia, including the research area, adequate seed rate is the most common concern in most grain production, including wheat. This is due to farmers using either very high or lower seed rates than recommended, which leads to low grain yield in wheat as compared to yields of the research fields (Assefa *et al*., 2015).

High seed rates result in high plant density, which promotes competition among crops for common growth resources like water, nutrients, and sunlight, affecting the crop's quality and output (Ayalew *et al*., 2017). It also causes plant lodging, exhaustion of available nutrients and water before maturity, and may create an environment that is conducive to insects and diseases, as well as influencing seed size and weight in particular (Haile *et al*., 2013). Maximum seed rates can result in a bigger plant population, but poor crop growth and development will negatively impact the number of productive tillers, number of grain spike-1, spike length, number of spiklets spike-1, grain weight, and ultimately grain production (Shah *et al*., 2016). Reduced plant density, on the other hand, could result in lower harvests due to fewer plants per unit area, land waste, weed infestation, and inefficient use of light, water, and nutrients (Hameed *et al*., 2002). Decreased seed rate may result in more tillers and spike length plant-1, as well as more spikelets spike-1, but in certain cases, it also leads to lower grain output per unit area (Shah *et al*., 2016). In addition to this, low seed rates generally increase the weight of single spikes, but decrease the number of spikes per unit area, whereas the opposite occurs under high seed rates (Baloch *et al*., 2010). Furthermore, seeding rates that are above or below the optimum have a negative impact on both yield components and yield of bread wheat. Plant height, number of days until heading, number of tillers, spike length, number of spikelet spike-1, 1000-kernel weight, biomass yield, and final crop output can all be considerably influenced (Laghari *et al*., 2011).

As a result, getting a high economic yield per unit area requires an optimal seed rate (Abiot, 2017). In general, optimal seed rates, proper crop stands that promote nutrient availability, proper sunlight access for photosynthesis, minimal disease and pest infestation, low plant lodging, and a good soil environment for soil nutrient uptake and water use efficiency (Rahim *et al*., 2012). However, the optimal seed rate varies greatly depending on location, climatic conditions, water, nutrient, and sunlight availability; length of the growing season; potential plant size, soil, sowing time, seed quality and size, and the plant's ability to change its form in response to changing environmental conditions (Drew, 2009). Since varieties are genetically different for yield components and yield, individual varieties need to be tested at a wide range of seeding rates to determine their optimum seeding rates and genetic potential response to different growth factors (Lloveras *et al*., 2004).

Ethiopian bread wheat cultivars differ in height, maturity, tillering and yielding capacity. For all cultivars in use across the country, the recommended seed rate is 150 kg ha–1 (Jemal *et al*., 2015). Despite the fact that there is a national seed rate recommendation for wheat, there is no reliable data for the investigation as to whether the nationally suggested seeding rate is optimal or not for achieving the highest yield in the studied area. Hence the objective of this research was to evaluate the effect of different seed rates on the response of bread wheat varieties.

Materials and Methods

Description of Experimental Site

A field trail was conducted at Anlemo district, Haddiya Zone during the 2020/21 main cropping season. Anlemo district is located about 214 km away south of the capital city of Addis Ababa and its altitude is 2350 masl. The mean annual rainfall ranges from 1001 to 1200 mm and its mean temperature is 25 0C. The soil type is clay loam and the rainy season extends from June to September, whereas the maximum rainfall is received in the months of June, July and August.

Treatments and Experimental Design

The experimental treatments consisted of three bread wheat varieties (Danda’a, Lemu and Kakaba) and five levels of seed rates (75, 100, 125, 150 and 175 kg ha^{-1}). The description of the varieties is presented in Table 1. The treatments were aloted a randomized complete block design (RCBD) in a factorial wayt with three replications. Each plot consisted of 2 m wide and 3 m long with a total area of 6 m^2. Seeds were hand drilled at 3 cm depth with row spacing 20 cm. The space between the plots and blocks were maintained at 0.5 m and 1m respectively.

Table 1: Description of the selected wheat varieties (Marco *et al.*, 2014)

Variety	Year of release	Rainfall (mm)	Days to maturity	Productivity (kg ha^{-1})	Breeder
Lemu	2016	500-800	121	4200-6000	Kulimisa
Danda’a	2010	>600	110-145	3500-5500	Kulimisa
Kakaba	2010	500- 800	90-120	3300-5200	Kulimisa

Agronomic practices

The experimental field was prepared four times by using an oxen ploughs and manually leveled to smooth the seed bed. The sowing activity was done in mid-July of 2020 in the main growing season under rain fed condition. The recommended amount of NPS (100 kg ha^{-1}) and 82 kg ha^{-1} nitrogen in the form of urea was applied at planting (Marco *et al.,* 2014). All management practices such as seed bed preparation and weeding was applied homogeneously to all treatments. All data on growth, yield component and yield were measured from the central areas of each plot.

Data Collection and Measurement

The number of days to 50% heading was taken when the panicles became fully visible on 50% of the plants from each plot. The days for physiological maturity were recorded in the time of when 90% of each plant reaches physiological maturity. Plant height (cm) was measured when the crop reached maturity from 10 randomly selected plants. Similarly, spike length (cm) was measured from 10 randomly selected plants from the net plot area at maturity. The number of spikelet's per spike was taken by counting the number of spiklets per plant from 10 randomly selected plants per plot. The numbers of tillers was counted from 10 randomly selected plants, whereas the numbers of tillers bearing spikes were counted at the time of harvest from 10 randomly selected plants from the net plot area. The thousand grain weight (g) was weighing 1000 grains and it was adjusted to 12% moisture content. Aboveground biomass yield (kg ha^{-1}) was recorded after harvest by weighting the bundles of each net plot after sun drying. Grain yield (kg ha^{-1}) was measured from a net plot area after threshing, winnowing and adjusting to 12% moisture by using a sensitive balance. Finally, the harvest index was calculated as the ratio of grain yield to the biomass yield and expressed in percentage. These collected data were analyzed statistically using SAS computer software version 9.2 (SAS, 2008); and the means were compared using the Least Significant Differences (LSD) test at 5% probability level.

Result and Discussion

Table2 Mean squares of analysis of variance for yield and yield related parameters of wheat as affected by varieties and seed rates.

Source	DH	DM	PH	SL	NSPS	NTPP	NET	TGW	BMY	GY	HI
Rep	0.0^{NS}	0.06 ^{NS}	9.65^{NS}	0.10^{NS}	0.92^{NS}	1.36 ^{NS}	1.18 *	0.86 ^{NS}	0.20 ^{NS}	0.03^{NS}	0.438 ^{NS}
Variety	93.8*	297.26*	259.26*	3.98*	603.42*	19.68*	19.69*	37.26*	6.55*	3.99*	259.92*
Rate	191.47*	416.96*	585.65*	3.305*	471.24*	30.00*	23.19*	120.74*	25.77*	6.80*	239.12*
V x R	3.57*	11.60 ^{NS}	2.52^{NS}	0.099*	2.80 ^{NS}	0.60 ^{NS}	0.51*	1.62 ^{NS}	0.28 ^{NS}	0.186*	7.39*

Where, DH=days to 50% heading, DM=days to 90% maturity, PH=plant height, SL=spike length, NSPS=number of spikelet's per spike, NTPP=Number of tillers per plant, NET=number of effective tillers. TGW=thousand grain weight, BMY=biomass yield, GY= grain yield, HI=harvest index, VxR=variety interaction with seed rates

Days to 50% heading

The main and interaction effects of varieties and seed rates pointed out in significant difference ($p<0.05$) from days to 50% heading (Table 2). The maximum days to heading (65.3) were recorded for the variety 'Lemu' at seed rate of 75 kg ha^{-1}, followed by the variety 'Danda'a' (60.3days). The shortest number of days to heading (47) was recorded for the variety 'Kakaba' at seed rate of 175 kg ha^{-1}. The variation of 11.6 days for 'Danda'a', 14.7 days for 'Lemu' and 9.6 days for 'Kakaba' were scored among the lowest and highest seed rates for the varieties of studied. From this result, the variety 'Kakaba' was relatively earlier to 50% heading followed by 'Danda'a' as compared to variety 'Lemu'. This result revealed that crops headed earlier when planted at a higher seeding rate (175 kg ha^{-1}) and headed late when planted at lower seed rates (75 kg ha-1) (Table 3). Increasing seeding rates from 75 kg ha-1 to 175 kg ha^{-1} might increase competition among plants for growth resources, which could have hastened the phenological development of the crop (Abiot, 2017), while at low plant density, due to efficient utilization of growth resources, plants flowered later in this result (Worku, 2008) similar finding was reported by Ghulam (2014).

Table 3: Days to 50% heading of wheat as affected by interaction of varieties and seed rates

Variety	Seed rates kg ha^{-1}					
	75	100	125	150	175	Mean
Danda'a	60.3^{b}	57^{c}	55^{e}	52.7^{f}	48.7^{h}	54.74
Lemu	65.3^{a}	59.3^{b}	56.3^{cd}	54.3^{e}	50.6^{g}	57.16
Kakaba	56.6^{c}	55.3^{de}	52.3^{f}	49.6^{gh}	47^{i}	52.16
Mean	60.73	57.2	54.53	52.2	48.76	
LSD = 1.12 CV (%) = 1.22						

Days to physiological maturity

Varieties showed significant differences ($p<0.05$) from days to 90% physiological maturity, while interaction effect with seed rate was non-significant (Table 2). The longest days to maturity (114.86) were recorded for variety 'Lemu' followed by 'Danda'a,' with days to maturity of 109.73, while the shortest days to maturity (106) was recorded for variety 'Kakaba' (Table 4). This result is in conformity with the reports of Shahzad *et al*. (2007) and Hassan (2008) who reported that there is variation in the days to physiological maturity of wheat varieties due to their inherent differences. Similarly, significant differences were detected due to the effect of seed rate on days to physiological maturity (Table 2). In this result, days to physiological maturity tend to decrease with increasing seed rates from 75 kg ha^{-1} to 175 kg ha^{-1}. The longest days to physiological maturity (119.77) was obtained from the seed rate of 75 kg ha^{-1} followed by seed rate of 100 kg ha-1 and 125 kg ha^{-1} with the days to maturity of 111.66 and 112.1 respectively. The shortest days to physiological maturity (102.32) was recorded at a seed rate of 175 kg ha^{-1}. The difference of 17.44 days was recorded between the lowest and highest seed rates. This result revealed that crops matured earlier when planted at higher seed rates (175 kg ha^{-1}) and matured late when planted at a lower seed rate (75 kg ha^{-1}) (Table 4). which is similarly articulated by Abiot (2017). In such conditions, the crop is forced to mature earlier rather than continuing its vegetative growth, which in turn affects the period for accumulation of photosynthesis of reproductive organs (Worku, 2008). Additionally, the shortest days to maturity at the highest plant density might be related to the fact that overplant density imposes stress on plants due to intense competition for environmental resources, which in turn brings phenological plasticity in plants (Azam and Squire, 2002).

Table 4: Days to 90% physiological Maturity of wheat as affected by varieties and seed rates

Variety	Plant height (cm)
Danda'a	109.73^{b}
Lemu	114.86^{a}
Kakaba	106^{c}
LSD	1.9
Seed rate ha^{-1}	
75	119.77^{a}
100	111.66^{b}
125	112.1^{b}
150	105.11^{c}
175	102.33^{d}
LSD	2.46
CV (%)	2.31

Plant height

Varieties exhibited significant differences ($p<0.05$) in plant heights while interaction effects with seed rate were non-significant (Table 2). The tallest plant height (87.99 cm) was recorded for varieties 'Lemu', while the shortest plant height (81.08 cm) was recorded for varieties 'Kakaba'. Plant height is controlled by the genetic makeup of the plant and the environmental factors (Shahzad *et al.,* 2007). Similarly, significant differences were detected due to the effect of seed rate on plant heights (Table 2). Generally, plant height tends to increase with increasing seed rate from 75 kg ha^{-1} to 175 kg ha^{-1}. The maximum plant height (93.91cm) was obtained from the seeding rate of 175 kg ha^{-1} followed by a seed rate of 150 kg ha^{-1} with a plant height of 87.92 cm. The minimum plant height (73.27 cm) was obtained at the seed rate of 75 kg ha^{-1} (Table 6). In this result, higher seed rates resulted in taller plants whereas lower seed rates resulted in shorter plants, which might be justified on the basis of high plant -to- plant competition in higher seed rates for sunlight. Similar findings were reported by Rahim *et al*. (2012) and Haile *et al.* (2013). Under a lower seed rate, there is reasonably high solar radiation capture through the crop canopy, less competition among plants, better utilization of growth resources, which leads to the shortest plant height at the lowest seed rate. Similar finding was pointed out by (Fani *et al.,* 2014) who indicated that at higher seed rates, plant height increased as the result of competition for light among plants.

Spike length

Analysis of variance for main and interaction effects of varieties and seed rate on spike length per plant showed that there were significant differences ($p<0.05$) (Table 2). Generally, spike length per plant decreased for all varieties with increasing seed rates from 75 kg ha^{-1} to 175 kg ha^{-1} (Table 5). The tallest spike length per plant (10.38 cm) was recorded for the variety 'Lemu' at a seed rate of 75 kg ha^{-1} followed by the same variety at a seed rate of 100 kg ha^{-1} with a spike length of 9.85 cm. The shortest spike length per plant (7.5 cm) was seen for the variety 'Danda'a' at a seed rate of 175 kg ha^{-1} (Table 5). Variety 'lemu' was relatively more responsive to seed rate as compared to others with respect to spike length per plant. This might be due to less intra-plant competition for available resources that resulted in higher spike lengths and shorter plant heights. Spike length is directly related to the number of spikelets per spike and the number of grains and longer spikes produces a maximum number of grains. Hence, the length of spike take a crucial role in wheat towards the number of grains per spike as well as yield (Madic *et al.,* 2010). The result is in harmony with the findings of Seleiman (2010) and Zewdie *et al.* (2014) who suggested that increasing seed rates resulted in shorter spike length and decreasing seed rate resulted in longer spike length per plant.

Table 5: Spike length of wheat affected by interaction of varieties and seed rates

Variety	Seed rates kg ha^{-1}					
	75	100	125	150	175	Mean
Danda'a	9.46^{c}	8.86^{ef}	8.47^{h}	8.0^{i}	7.5^{j}	8.46
Lemu	10.38^{a}	9.85^{b}	9.43^{c}	9.0^{de}	8.78^{fg}	9.49
Kakaba	9.51^{c}	9.16^{d}	8.86^{ef}	8.63^{gh}	8.48^{h}	8.92
Mean	9.78	9.29	8.92	8.54	8.25	
LSD = 0.209 CV (%) = 1.39						

Number of spikelet's per spike

Varieties exhibited significant differences ($p<0.05$) in the number of spikelet's per spike while interaction of varieties by seed rates on number of spikelet's per spike was non-significant (Table2). The maximum number of spikelet's per spike (72.8) was recorded for the variety 'Lemu', followed by the variety 'Danda'a' with a number of spikelet's per spike of 63.14. The minimum number of spikelets per spike (60.84) was recorded for the variety 'Kakaba' (Table 6). The difference in the number of spikelet's per spike among varieties might be the genetic variation among varieties of wheat in utilizing existing resources which are used for plant growth and later for formation of a greater number of spikelet's per plant. The result is in accordance with the findings of Demelash *et al.* (2014) and Akhter *et al.* (2017) who reported that there was a significant difference among wheat varieties in the number of spikelet's per spike. On the other hand, significant differences were observed due to the effect of seed rate on the number of spikelet's per spike (Table2). In general, the number of spikelet's per spike tends to decrease with increasing seed rates from 75 kg ha^{-1} to 175 kg ha^{-1} (Table 6). The maximum number of spikelet's per spike (74.65) was recorded at a seed rate of 75 kg ha-1 whereas the lowest number of spikelet's per spike (56.13) was achieved from the seed rate of 175 kg ha^{-1} (Table 6). The variation of 18.52 of spikelet's per spike was recorded between the lowest and highest seed rates. This result is in line with the findings of Worku (2008) and Abiyot (2017).

Table 6: Plant height Number of spikelet's per spike and number of tillers of wheat as affected by varieties and seed rate

Treatment	PH	NTPP	NSP
Danda'a	80.53^{b}	6.79^{b}	63.14^{b}
Lemu	87.99^{a}	8.41^{a}	72.8^{a}
Kakaba	81.08^{b}	6.20^{c}	60.84^{c}
LSD(0.05)	1.54	0.265	0.74
Seed rate (kg haG1)			
75	73.27^{e}	9.60^{a}	74.65^{a}
100	78.27^{d}	8.12^{b}	70.24^{b}
125	82.61^{c}	7.10^{c}	65.43^{c}
150	87.92^{b}	5.95^{d}	61.52^{d}
175	93.91^{a}	4.91^{e}	56.13^{e}
LSD	2.48	0.34	0.966
CV	1.99	4.97	1.525

Number of tillers per plant

Analysis of variance showed that varieties showed significant differences in the number of tillers per plant, while interaction of varieties with seed rates the number of tillers per plant were non-significant (Table 2). The highest number of tillers per plant (8.14) was obtained from variety 'Lemu' followed by variety ' Danda'a' with a number of tillers per plant of 6.79. The least number of tillers per plant (6.20) was recorded for the variety ' Kakaba' (Table 6). The difference in number of tillers per plant could be likely due to the inherent variability of varieties in bearing tillers. The results of Ghulam *et al.* (2014) proved that there is genetic variability among varieties in bearing tillers. Similarly, significant differences were detected due to the effect of seed rate on the number of tillers per plant (Appendix 2). In general, the number of tillers per plant decreased with increasing seed rates from75 kg ha^{-1} to 175 kg ha^{-1} (Table 6). The difference of 4.67 tillers per plant was recorded between the lowest and highest seed rates. In this regard, the highest number of tillers per plant (9.60) was observed at the seed rate of 75 kg ha^{-1} followed by seed rate of 100 kg ha^{-1} with a number of tillers per plant of 8.12 while the lowest number of tillers per plant (4.91) was achieved from seed rate of 175 kg ha^{-1} (Table 6). Similarly reported by Fioreze *et al.* (2014) and Ayalew *et al.* (2017). In such cases, the plant is forced to invest more biomass in a single plant height growth rather than in lateral growth to prevent being completely shaded by neighboring plants. The production of more tillers at a lower seeding rate might be due to better utilization of nutrition, water and sunlight; plants tend to bear more tillers per plant, which is similarly reported by Baloch *et al*. (2010). This result is in lined with the work of Veselinka *et al.* (2014) who pointed out that lower seed rate produced maximum number of tillers per plant when compared with higher seed rates in wheat.

Number of effective tillers per plant

Significant differences ($p<0.05$) were observed due to the main and interaction effects of varieties and seed rate on number of effective tillers per plant (Table 2). Generally, the number of effective tillers per plant decreased for all varieties with an increasing seed rate from 75 kg ha^{-1} to 175 kg ha^{-1} (Table 7). The highest number of effective tillers per plant (9.10) was recorded for the variety 'Lemu' at a seed rate of 75 kg ha^{-1} followed by the same variety at a seed rate of 100 kg ha-1 (Table 7). The minimum number of effective tillers per plant (2.23) was recorded from the variety 'Kakaba' at seed rate of 175 kg ha^{-1}. Variety ‘Lemu’ was relatively more responsive to seed rate as compared to other varieties in number of effective tillers per plant. The number of effective tillers depends on varieties and the growing environment, and is strongly affected by seeding rates that can regulate the micro-environment of the production system through affecting the competition for space and production resources as the result not all tillers produce spikes in wheat, and many tillers abort before anthesis (Ozturk *et al.*, 2006). Similar findings reported by Veselinka *et al.* (2014) and Ayalew *et al.* (2017) suggested that lower seed rate produced the maximum number of effective tillers per plant when compared with higher seed rates in wheat.

Table 7: Number of effective tillers of wheat as affected by interaction of varieties and seed rates

Variety	Seed rates kg ha^{-1}					
	75	100	125	150	175	Mean
Danda’a	6.5^{c}	5.26^{ef}	4.83^{fg}	4.26^{h}	2.93^{i}	4.76
Lemu	9.10^{a}	7.26^{b}	6.4^{c}	5.43^{de}	4.6^{gh}	6.57
Kakaba	6.5^{c}	5.8^{d}	4.7^{gh}	3.03^{i}	2.23^{j}	4.45
Mean	7.39	6.10	5.31	4.24	3.25	
LSD = 0.47 CV (%) = 5.35						

Thousand Kernel weights

Analysis of variance showed that varieties significantly differed ($p<0.05$) with respect to a thousand kernel weight (TKW) while varieties by seed rate interaction did not result in significant differences on TKW (Table 2). The highest TKW (55.8 g) was obtained from the variety ‘Lemu’ followed by the variety 'Danda’a' with a TKW of 53.93 g. The lowest TKW (52.66 g) was achieved from the variety ‘Kakaba’ (Table 8). This finding indicated that varieties exhibited inherent genetic differences in assimilating partitioning efficiency to the seed. Hence, the variations in TKW of varieties were likely reflected by the ability of genotypes to utilize environmental resources and partitioning dry matter into the seed, which is in the same way reported by (Li *et al.*, 2016). This work agrees with findings of Otteson *et al.* (2007) who reported that wheat varieties responded differently to variable seeding rates regarding the TKW. In line with this, seed rates had effects on TKW (Table 2). With increasing seed rates from75 kg ha^{-1} to 175 kg ha^{-1}, the TKW tended to decline from 58.66 g to 49.22 g (Table 8). The variation of 9.44 g was recorded between the lowest and highest seed rates. In this regard, the highest TKW (58.66 g) was recorded at a seed rate of 75 kg ha^{-1} followed by the seed rate of 100 kg ha^{-1} with TKW of 56.44 g while the lowest TKW (49.22 g) was recorded at seeding rate of 175 kg ha^{-1} (Table 8). Increasing seed rates negatively impacted TKW due to the intra and interplant competition, which in turn reduces leaf area, the photosynthetic ability of the plant and finally leads to decrease of assimilate formation and mobilization to the reservoirs. In such conditions, most grains would diminish at early stage because of higher competition between growing grains to absorb conserved matter and, as a result, lower grains would be produced (Rahim *et al.*, 2012). This result is in agreement with the works of Laghari *et al.* (2011) and Ayalew *et al.* (2017) who reported that lower seed rate produced heavier grains compared with higher seed rates.

Table 8: Thousand kernel weight and biomass yield of wheat as affected by varieties and seed rate

Treatment	TKW	BMY
Danda’a	53.93b	11450b
Lemu	55.8a	11860a
Kakaba	52.66c	10560c

LSD(0.05)	0.86	0.236
Seed rate (kg haG1)		
75	58.66a	9140e
100	56.44b	10180d
125	54.11c	11297c
150	52.22d	12550b
175	49.22e	13280a
LSD	1.11	0.339
CV	2.12	3.12

Biomass yield

Varieties showed significant differences ($p<0.05$) in biomass yield, while varieties by seed rate interaction did not result in significant differences in biomass yield (Table 2). The greatest biomass yield (11860 kg ha^{-1}) was obtained from 'Lemu' followed by 'Danda'a' with a pool mean of 11450 kg ha^{-1}. On the other hand the variety Kakaba recorded the shortest biomass yield (10560 kg ha-1) (Table 8). Rahman *et al.* (2004) and Bavar (2008) suggested that the biomass production of crops is closely related with the amount of solar radiation intercepted by the crop canopy, which in turn depends on plant densities per given area. This result is in line with the work of Jemal *et al.* (2015) who reported that the biomass yield of wheat was significantly varied for varieties. Similarly, biomass yield significantly differed due to the effect of seed rate (Table 2). The highest biomass yield (13280 kg ha^{-1}) was recorded at a seed rate of 175 kg ha^{-1}, followed by a seed rate of 150 kg ha^{-1} with a biomass yield of 12550 kg ha^{-1}. The lowest biomass yield (9140 kg ha^{-1}) was obtained from a seed rate of 75 kg ha^{-1} (Table 8). In this result, the difference of 4140 kg biomass yield was observed between the highest and lowest seed rates. The increase in biomass yield as the seeding rate increased might be related to the increase in the number of plants per unit area and the associated increase in plant height, which is similarly reported by Zewdie *et al.* (2014). Similar findings were reported by Ali *et al.* (2004) and Gafaar (2007), who indicated that biomass yield increased by increasing seeding rate in wheat.

Grain yield

Analysis of variance showed significant differences ($p<0.05$) due to the main and interaction effects of varieties and seed rate on grain yield (Table 2). Generally, grain yield increased for all varieties of studied with respect to seed rate increasing from 75 kg up to 150 kg ha^{-1} and then declined when the seed rate exceeds above it (Table 9). The highest grain yield (5580 kg ha^{-1}) was recorded from 'Lemu' at a seed rate of 150 kg ha^{-1} whereas, the lowest grain yields (2160 and 2040 kg ha^{-1}) were obtained for varieties 'Danda'a' and 'Kakaba' at a seed rate of 75 kg ha^{-1} respectively. Thus, the seed rate of 150 kg ha^{-1} seems to be optimum for all varieties. Among varieties, an observable dominance of the variety 'Lemu' was found over other varieties (Table 9) which might be due to the greater number of tillers, the highest number spikelet's per spike, the tallest spike length, higher TKW and higher biomass yield when compared to other varieties since grain yield is attributed to the cumulative effects of these various yield components. These processes are affected by crop varieties and seed rates (Lollato *et al.*, 2017). Differences in varieties and seed rates in this study caused an insightful impact on wheat grain yield by affecting growth, yield components and yield. The same impact was reported by Sayed *et al.* (2017) who stated that the seed rate is below the optimum, leading to inefficient use of available resources.

Table 9: Grain yield of wheat as affected by interaction of varieties and seed rate

Variety	Seed rates kg ha^{-1}					
	75	100	125	150	175	Mean
Danda'a	2160^{g}	2880^{f}	3590^{d}	4410^{b}	2820^{f}	3172
Lemu	2800^{f}	3640^{d}	4440^{c}	5580^{a}	3720^{d}	4036
Kakaba	2040^{g}	2730^{f}	3400^{e}	4020^{b}	3390^{e}	3116
Mean	2333	3083	3810	4670	3310	
LSD = 0.174 CV (%) = 3.025						

Harvest Index

The main and interaction effect of varieties and seed rates resulted in significant differences ($p<0.05$) on HI (Table 2). This result indicated that wheat varieties differ in their response to harvest index with different seed rates (Table 10). In general, HI increased with increasing seed rates up to 150 kg ha^{-1} for all varieties and then tended to decrease for further increase in seed rate (Table 10). The highest HI (41.07%) was recorded for the variety 'Lemu' at a seed rate of 150 kg ha^{-1}, followed by the same variety at a seed rate of 125 kg ha-1 with a HI of 37.53%, while the minimum HI (21.27%) was recorded for variety 'Danda'a' at seed rate of 175 kg ha^{-1} (Table 10). In similar way, Iqbal *et al.* (2012) and Abiyot (2017) stated that the highest harvest index was obtained at a seeding rate of 150 kg ha-1 compared to 125 and 175 kg ha^{-1}. The higher the harvest index value, the greater the physiological potential of the crop for converting dry matter to grain yield, since HI has interrelationship with grain yield and above ground biomass yield (Rahim *et al.*, 2012). The difference in HI among varieties with respect to varied seed rates might be due to the ability of the varieties to partition its dry matter into seeds and straws, and maintain the right balance between seed and biomass yield. Similar findings was indicated by Jemal *et al.* (2015) who reported that HI varies for wheat varieties at different seed rates.

Table 10: Harvest index of wheat as affected by interaction of varieties and seed rates

Variety	Seed rates kg ha^{-1}					
	75	100	125	150	175	Mean
Danda'a	23.17^{h}	27.65^{fg}	31.05^{e}	35.53^{c}	21.27^{i}	27.73
Lemu	29.18^{f}	35.07^{c}	37.53^{b}	41.07^{a}	27.03^{g}	33.97
Kakaba	23.94^{h}	28.27^{fg}	32.65^{d}	34.86^{c}	27.36^{g}	29.41
Mean	25.43	30.33	33.74	37.15	25.22	
LSD = 1.55 CV (%) = 3.054						

Conclusions

The results for the mean performance of the studied varieties showed, there were significant differences in grain yield and most of the growth and agronomic parameters as well as different seeding rates. All varieties had the highest grain yield at a seed rate of 150 kg ha-1, where the variety 'Lemu' yielded was followed by the remaining two varieties, 'Danda'a' and 'Kakaba', at the same seeding rate respectively. Varieties 'Lemu' at seed rate of 150 kg ha-1 could be the best option for wheat production in the study area. However, as the experiment was done in one season for one location, repeated similar studies over season and across location need to be done to come up with a conclusive recommendation.

Acknowledgment

The authors wish to acknowledge Wachemo University and Anlemo Woreda for financial support and providing the necessary input to do this research

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