Academic Journal of Plant Sciences 13 (3): 64-77, 2020
ISSN 1995-8986

DOI: 10.5829/idosi.ajps.2020.13.3.64.77

Effects of Seed Rates and Sowing Methods on Phenology, Growth, Yield and Economic Feasibility 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 but its productivity is very low due to poor agronomic practices like inappropriate seeding rate, improper of sowing method and use of local varieties. This in view, a field experiment was conducted on farmer's field at Kolobo kebele in Abaay Chomman District, in Horro Guduru Wollega zone, during 2019/2020 cropping season with the objective to determine the effects of seed rates and sowing methods on phenology, growth, yield and economic feasibility of bread wheat varieties. 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). The experiment was laid out in randomized complete block design with factorial arrangement in three replications. The mean days to 50% emergence, days to physiological maturity, grain filling, plant height and grain yield of wheat were significantly ($p<0.05$) affected by the main effect of seeding rate, sowing method and varieties. Higher net benefit EB 46, 812.52 ha^{-1} with marginal rate of return of 1330 % and value to cost ratio of EB 3.17 per unit of investment was obtained from 125 kg ha^{-1} seeding rate for bread wheat. The use of 125 kg ha^{-1} seeding rate with row method of sowing for Liben variety of wheat was performed better and gave higher grain yield 5.26 t ha^{-1} and net benefit of bread wheat which confirm the national recommendation. Therefore, the use of 125 kg ha^{-1} seed rate with row method sowing significantly improved grain yield of bread wheat and recommended for Abbay Chommen district and similar agroecologies.

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

INTRODUCTION

Bread wheat (*Triticum aestivum* L.) is the world's leading cereal grain where more than one-third of the population of the world uses as a staple food [1]. Wheat is the most important grain crop in the world, providing nearly twenty percent of total food requirements. It ranks first in the world cereal production and is a staple food of about one third of the world's population [2]. Currently, it is also becoming the most important cereals grown on the large scale in the tropical and sub-tropical regions of the world [3]. Wheat is mainly grown in the highlands of Ethiopia, which lie between 6° and 16°N latitude and 35 and 42°E longitude, at altitudes ranging from 1500 to 2800 meters above sea level and with mean minimum temperatures of 6 to 11°C [4, 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, 7]. Ethiopia is the second largest wheat producer of bread wheat in the Sub-Saharan Africa, with yearly estimated production of 4.8 million tons on 13.73% (1, 747, 939.31 hectares of land [8].

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Wheat (*Tritium spp*.) is one of the world's most important staple food crops, providing 20% of humanity's dietary energy supply and serving as the main source of protein in developing nations [9]. It is a major source of food grain and high adaptation of this crop as well as its diverse consumptions in the human nutrition lead as the most important cereal in the world, especially in developing countries [10]. Bread wheat in Ethiopia is used in different forms such as bread, porridge, soup and roasted grain. In addition to the grain, the straw of bread wheat is used for animal feed, thatching roofs and bed decking. In spite of its tremendous importance, wheat production in Ethiopia faced immense production constraints that are affecting both its yield potential and industrial quality [6]. Furthermore, wheat has been selected as one of the target crops in the strategic goal of attaining national food self-sufficiency, income generation, poverty alleviation and achieving socio-economic growth of the county [11]

Despite its importance and production occupy in large area, , the national average yield of wheat in Ethiopia is about 2.76 t ha^{-1} [8] as compared to the world's average about 3 t ha^{-1} [12]. This is because of depleted soil fertility, low levels of chemical fertilizer usage, limited knowledge on time and rate of fertilizer application and the unavailability of other modern crop management inputs [13]. 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 higher grain yield [2]. 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 has significant influence on majority of agronomic traits of bread wheat Nizamani *et al.* [14]. High seed rate increases the competition among crops for common resource particularly water, nutrients and sunlight which resulting in low quality and low yield. If low seed rate is used yield will be less due to lesser number of plants per unit area [15]. The use of inappropriate seed rates by small holder farmers leads to low yield as compared to research field. This is due to higher seed rate which leads to higher competition, shorter spike length and lower number of grains per spike [16]. Besides, seed rate determines the crop vigor and ultimately yield [17]. 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 [18]. The use of proper seed rate encourages nutrient availability, proper sun light penetration for photosynthesis, good soil environment for uptake of soil nutrients and water use efficiency; and all necessary for crop vigor and consequently increase the production and productivity of the crop [6]. This indeed in need to determine the optimal seed rate with methods of planting for wheat varieties to improve production and productivity of wheat.

A number of bread wheat varieties which differing in plant height, maturity and tillering capacity have been developed in Ethiopia. However, the recommended seed rate for all the varieties being used across the country is 150 kg ha^{-1} with broadcasting methods of sowing [7]. Moreover, there is a trend by farmers uses higher seed rates greater than 125 kg ha^{-1} for row methods of sowing and broadcasting in the area. Hence, it is important to determine optimum seeding rates for released bread wheat varieties for the maximum yield of the crop. Production and productivity of wheat yield in Ethiopia also decline through time in the case of cultivation of local low yielding varieties, inadequate and erratic rainfall, poor agronomic practices, diseases and insect pests are among the principal limitations to wheat production in Ethiopia [19]. Among the factors responsible for low wheat yield, traditional sowing methods, inappropriate seed rate are very important [2]. Yet, there is no information on the effect of seed rate and sowing method on yield of bread wheat varieties in the study area. Therefore, the objective of this study was to determine the effects seed rates and sowing methods on phenology, growth, yield and economic feasibility 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, Abay Chomen District, Horro Guduru Wollega Zone, Oromia National Regional State. Abay Chomen district is one of the twelve districts of Horro Guduru Wollega Zone. 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,

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.

Niger seed, bean, field pea and barely [20]. Traditionally the district was classified in to two agro-ecological zones, namely, Waina Dega and Kola. The Waina Dega covers the largest part which accounts about 60% and Kola 40% [20].

Experimental Materials, Treatment and Experimental Design: 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. 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:

- Days to 50% heading: was recorded from planting to when 50% of the plants gave heads in the plot.
- Days to 90% physiological maturity: was recorded from sowing to when 90% of the plants in the plot matured.
- Number of days to grain filling: was recorded time from heading to maturity in the plot.
- Plant height: average height was measured from the base to the tip of the plant excluding the awns at maturity for 10 randomly selected plants in the plot.
- Grain yield: the weight of the grain was taken after threshing for each net plot area and adjusted at 12.5% moisture level.

Data Analysis: Analysis of variance was done using SAS computer software (SAS, 9.4 versions) [21]. Significant means was separated by List Significant Differences at 5% probability levels [22]. A Pearson correlation analysis was made to see the relationship between phenology, growth and yield of wheat.

Economic Analysis: Partial budgeting was conducted if the treatment differences found significant [23]. Grain yield was adjusted downward by 10% to reflect between well managed and farmers management practices .The price wheat grain was EB 15 kg^{-1}. The improved seed cost of wheat was EB 25 kg^{-1}.

RESULTS AND DISCUSSION

Days to 50% Heading: The mean days to 50% heading of bread wheat was highly significantly (P<0.01) affected by the main effect of sowing method and seeding rates (Table 2). While the two-way interaction of variety with sowing methods was showed significant (p<0.05) effect on the days to 50% heading of wheat (Table 3). Variety Hidase reached days to 50% heading earlier 61 days while variety Liben late was late 61.05 days (Table 2). Similarly, Habtamu and Ahadu [24] reported that days to 75% of heading of bread wheat was different among varieties and shorter (58 days) days to heading was recorded form Kekeba variety and longer (75 days) days to heading was revealed by variety. Jemal *et al*. [7] reported that significant difference in days to 50% heading among wheat varieties and earlier (61.27 days) for Kakaba variety and late (77.87 days) to 50% heading for Digalu variety as compared to the other varieties of bread wheat. Kifle *et al*. [25] found that Digelu, Alidoro and Pavon-76 varieties were matured late whereas Kakaba was

Table 2: Main effects of varieties, sowing method and seeding rate on days to 50% heading, days to 90% maturity, grain filling and plant height of bread wheat as affected by the in Abbay Chomman district

Treatment	Days to 50% heading	Number of days to grain filling	Days to 90% physiological maturity	Plant height (cm)	Grain yield (t ha^{-1})
Varieties					
Liben	61	42^b	102^b	80.44^b	4.02^a
Hidase	61	43^a	104^a	81.00^a	3.79^b
LSD (5%)	NS	0.72	0.62	0.31	0.068
Sowing methods					
Row	61^a	43^a	104^a	81.38^a	4.44^a
Broadcasting	60^b	42^b	102^b	80.05^b	3.36^b
LSD (5%)	0.35	0.72	0.62	0.31	0.068
Seeding rate (Kg ha^{-1})					
100	61^a	43^a	105^a	79^c	3.37^c
125	61^a	42^b	103^b	80.8^b	4.46^a
150	60^b	41^b	102^c	82.33^a	3.87^b
LSD (5%)	0.43	0.88	0.75	0.38	0.08
CV (%)	0.84	2.4	0.86	0.55	2.5

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

Table 3: Two-way interaction effects of varieties with sowing methods on days to 50% heading and days to 90% physiological maturity of bread wheat in Abbay Chomman district

Varieties	Sowing Methods	Days to 50% heading ng	Days to 90% physiological maturity
Liben	Row	61^a	103^b
Liben	Broadcasting	60^b	102^b
Hidase	Row	62^a	105^a
Hidase	Broadcasting	60^b	102^b
LSD (5%)		0.88	1.78
CV (%)		0.84	0.86

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

matured early at Kotergedra. Aman *et al*. [26] reported that wheat varieties exhibited inherent variations in days to heading and in days to physiological maturity due to genetic makeup difference among varieties.

The highest mean days to heading was 61 days for row sowing method and the lowest mean 60 days for broadcasting sowing method of wheat (Table 2) which might be due to competition between plants due to uneven distribution of seed.

Days to 50% heading of wheat was delayed 61 days when lower seeding rates 100 kg ha^{-1} of wheat was used. The earlier mean days to 50% heading 60 days was recorded from highest seeding rates 150 kg ha^{-1} of wheat (Table 2). The mean days to 50% heading increase as the seeding rate decreases and the highest mean was 61 days while lowest mean was 60 days for lower seed rate. Similarly, Khalil *et al*. [27] found that significantly higher seeding rates significantly reduced days to heading in bread wheat. Also, Abiot [28] reported that seeding rate had significantly influence on number of days to heading of bread wheat and significantly higher number of days to 50% heading was significantly delayed (62.88 days) when lower seeding rates (100 kg ha^{-1}) was used and earlier number of days to 50% heading (60.8 days) was recorded from highest seeding rates. Laghari *et al*. [29] also found significant improvement in bringing early maturity of crops by adopting suitable planting rate in wheat. The earliness to heading in highest seeding rate might be due to the higher competition to resources; this may help plants to escape terminal moisture stress. It could be due to the reason that the use of low seed rate in wheat shortened the intervals between the growth phases by facilitating the physiological activities of crops due to the accessibility of ample resource. The highest mean for days to heading was achieved 62 days for Hidase variety with broadcasting sowing method and the lowest mean for days to heading was achieved 60 days for Hidase variety with broadcasting sowing method (Table 3). Similarly, days heading started earlier at higher seeding rates [30]. Also, Worku [31] reported that increasing the levels of seeding rate decreased the days to heading consistently.

Number of Days to Grain Filling: The mean number of days to grain filling of wheat showed very highly significant (P<0.01) response due to varieties, sowing methods and seeding rate while the main effect of number of days to grain filling of wheat showed highly significant

(P<0.05) effect of number of days to grain filling of wheat (Table 2). The two-way interaction of sowing method with seeding rate was significantly (p<0.05) affected number of days to grain filling of wheat (Table 3).

The highest grain filling was achieved 43 days for the variety Hidase while the lowest mean grain filling was achieved 42 days for the variety Liben. Likewise, Dereje *et al*. [32] reported that difference in grain filling period of bread wheat varieties and Wane mature in short period than variety Lemu varieties. Kifle *et al*. [25] also reported that significant difference in grain filling period among bread wheat varieties which might be due to the genetic makeup difference of varieties.

Significantly the highest 43 days grain filling was achieved for row sowing method while the lowest mean was achieved 42 days for broadcasting sowing method. Similarly, Abebaw and Hirpa [33] found that sowing methods had significant effects on number of days to grain filling period of wheat and significantly higher 20.54 mean day grain filling was obtained from row methods of sowing wheat.

As seeding rate increased from 100 kg ha^{-1} to the highest 150 kg ha^{-1}, the grain filling of wheat correspondingly decreased from 43 days to 41 days (Table 4). The highest grain filling was achieved 43 days for 100 kg ha^{-1} and lowest grain filling was achieved 41 days for 150 kg ha^{-1}. Whereas, the results showed that the highest grain filling 44 days for row sowing method with 100 kg ha^{-1} seeding rate and the lowest grain filling 44 days for row sowing method with 150 kg ha^{-1} seeding rate.

Days to 90% Physiological Maturity: The main effect of varieties, sowing method and seeding rates had highly significant (p<0.01) effect on days to 90% physiological maturity (Table 2). While the two-way interaction of varieties with sowing method and sowing method with seeding rate was significantly (p<0.05) affected days to 90% physiological maturity of wheat (Table 3).

The highest days to 90% maturity was achieved 104 days for the variety Hidase while the lowest mean days to 90% maturity was achieved 102 days for the variety Liben (Table 2). Likewise, Amare and Mulatu [34] reported that significant difference in days to maturity of wheat varieties and Tay and Gassay varieties were mature in 107.22 and 105.33 days and Dinknesh and Picaflor varieties mature in 93.33 and 94.67 days to 90 % maturity. Wogene and Agena [35] reported that significant difference among varieties and Digalu variety mature (123.5 days) while Hidasse maturing (105.5 days) days to 90 % physiological maturity. Days to physiological maturity of wheat cultivars varies which might be due to inherent differences between cultivars [36].

Significantly the highest days to 90% maturity was achieved 104 days for row sowing method while the lowest mean days to 90% maturity was achieved 102 days for broadcasting sowing method (Table 2). This could be due to the presence of intense inter plant competition at the broadcasting method that might have led to the depletion of the available nutrient that results plants tend to mature earlier. Also, Abebaw and Hirpa [33] found that sowing methods had significant effects on number of days to maturity and significantly higher 87.29 mean days to maturity was obtained from row method of sowing.

The highest days to 90% maturity was achieved 105 days for 100 kg ha^{-1} seeding rate while the lowest mean days to 90% maturity was achieved 102 days for 150 kg ha^{-1} seeding rate (Table 2). Planting with lower seeding rate 100 kg ha^{-1} reached physiological maturity 3 days earlier than the highest seed rate 150 $kgha^{-1}$ (Table 2). Increasing seeding rate from 100 to 150 kg ha^{-1} decreased days to 90% maturity by 3 days (Table 2). This could be due to the reason that increasing in planting density enhances the competition and the crops will suffer from starvation due to the shortage of food prepared in the leaf by the process of photosynthesis which leads to late maturity of the crop. Decreasing seeding rate from 150 to 100 kg ha^{-1} day to physiological maturity increased from 102 to 105 days (Table 2). Similarly, Seleiman *et al*. [37] reported that increasing seeding rates from 250-400 m^{-2} grains prolong the number of days from sowing to maturity of wheat. The results indicated that the delay in maturity of bread wheat in response to the decreasing seeding rate, which delays physiological maturity by promoting vigorous vegetative growth and development of the plants. Similarly, Worku [31] noted that increasing the levels of seeding rate hastened physiological maturity of bread wheat. Likewise, Abiot [28] reported that seeding rate had significantly influenced on number of days to physiological maturity of bread wheat and the number of days to 90 % physiological maturity of the bread wheat was enhanced as increase in seeding rate. Increasing seeding rate from 100 to 175 kg ha^{-1} decreased days to 90% maturity by 8.44 days of bread wheat [28].

The two-way interaction of varieties with sowing method was significantly (p<0.05) affected days to 90% physiological maturity of bread wheat (Table 3). The highest 105 days to 90% maturity of bread wheat was recorded for Hidase variety with row method of sowing and lowest 102 days to 90% maturity was recorded for Liben and Hidase varieties with broadcasting method sowing (Table 3).

Table 4: Two interaction effects of sowing methods and seeding rates on number of days to grain filling, days to 90% maturity and plant height of bread wheat in Abbay Chomman district

Sowing Methods	Seeding rate (kg ha^{-1})	Number of days to grain filling	Days to 90% physiological maturity	Plant height (cm)
Row	100	44^{a}	107^{a}	80^{c}
Row	125	42^{b}	104^{b}	81.5^{b}
Row	150	41^{b}	102^{cd}	82.66^{a}
Broadcasting	100	43^{b}	103^{bc}	78^{d}
Broadcasting	125	41^{b}	102^{d}	80^{c}
Broadcasting	150	42b	101^{d}	82^{b}
LSD (5%)		1.5	1.4	0.66
CV (%)		2.4	0.86	0.55

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

Table 5: Two-way interaction effects of varieties with sowing methods on grain yield of bread wheat in Abbay Chommen district

Varieties	Sowing Methods	Grain yield (t ha^{-1})
Liben	Row	4.6^{a}
Liben	Broadcasting	3.43^{b}
Hidase	Row	4.28^{a}
Hidase	Broadcasting	3.3^{b}
LSD (5%)		0.5
CV (%)		2.5

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

Two-way interaction of sowing methods with seeding rate was significantly ($p<0.05$) affected days to 90% physiological maturity of wheat (Table 4). Significantly, the highest 107 days to 90% physiological maturity was achieved from 100 kg ha^{-1} seeding rate with row method of sowing while the lowest 101 days to 90% maturity of bread wheat was achieved from 150 kg ha^{-1} seeding rate with broadcasting method sowing (Table 4). This might be due to effects of different cultural practices on the days to 90% physiological maturity of bread wheat.

Plant Height: The mean plant height of bread wheat had highly significantly ($p<0.01$) affected by the main effect of varieties, sowing method, seed rate effect of bread wheat (Table 2) and two-way interaction of sowing method with seeding rate showed significant ($p<0.05$) effect of bread wheat (Table 4).

Varieties Hidase had produced the tallest plant height of 81 cm, whereas, variety Liben produced the shortest plant height of 80.44 cm (Table 2). Height of the crop is mainly controlled by the genetic makeup of a genotype and it can also be affected by the environmental factors [36]. Abd El-Lattief [38] found that mean plant height of wheat was significantly affected by different cultivars and Giza 168 variety at higher seed rate gave significantly higher plant height. The difference in plant height of the varieties could be attributed to the difference in their genetic makeup. Similarly finding was reported by Khaliq *et al.* [39]. The highest plant height (84.88cm) was obtained from Alidoro whereas the lowest (66.57cm) was recorded from Mekelle 4. This indicates that Alidoro is the tallest variety and Mekelle 4 is the shortest as compared to all tested varieties [25]. Similarly, Desalegn [40] found that mean plant height of bread wheat was showed significant (difference among varieties and significantly higher (118cm) plant height was obtained from Ogolcho variety which was differed from Liben and Hidase varieties by 8.50% and 4.24%, respectively. Likewise, Arega *et al.* [41] reported that significant differences in plant height among wheat varieties. Shahzad *et al*. [36] also stated that height of the crop is mainly controlled by the genetic makeup of a genotype and it can also be affected by the environmental factors. Esayas *et al.* [42] reported that significant differences in plant height that among wheat varieties. Aman *et al.* [26] suggests that varieties differences in plant height and spike length could be attributed to the difference in their genetic makeup. Al-Hilfy and Wahid [43] found that significant difference varieties on plant height of bread wheat and significantly higher (112.92 cm) plant height of bread wheat was obtained from Rasheed cultivar as compared to others.

Wheat planted by rowing method of sowing resulted in taller plants height up to 81.38 cm followed 80.05 cm by seed broadcasting method of sowing (Table 2). This might be due to the plant competition as broadcasting left uneven distribution and space whereas drilling provided uniform space. Similarly, Abebaw and Hirpa [33] found that sowing methods had significant effects on plant height wheat and significantly higher mean plant height of wheat was obtained from row methods of sowing as compared to broadcasting method. Also, Soomro *et al*.

[44] found that wheat planted by drilling method resulted in taller plants up to 101.95 cm followed by seed broadcasting 97.49 cm of bread wheat. Methods of sowing were significant for plant heights and line sowing was the best followed by broadcast sowing [45]. Kabesh *et al.* [46] reported that significantly taller plant height was produced from row method sowing in wheat. Pirzada *et al.* [47] reported that drilling method of planting recorded significant maximum (93.14 cm) plant height of bread wheat as compared to 89.76 cm broadcasting method of sowing. Radwan *et al.* [48] found that sowing methods was significantly influenced mean plant height of wheat and sowing wheat in ridges followed by drilling gave greater increase in plant height as compared to broadcasting method of sowing in wheat. Soomro *et al.* [44] found that wheat planted by drilling method produced significantly taller plants height up to 101.95 cm followed by seed broadcasting 97.49cm of bread wheat.

As seeding rate increased from the 100 kg ha^{-1} to the highest 150 kg ha^{-1}, the plant height of wheat correspondingly increased from 79 cm to 82.3 cm (Table 2). Similarly, Soomro *et al*.[44] noted that wheat sown at higher seeding rate 175 kg ha^{-1} produced greater plant height i.e. 101.25 cm followed by 150 kg ha^{-1} with 99.09 cm and 125 kg ha^{-1} with 94 27cm. Also, Worku [31] also concluded that plant height increased consistently with increasing seeding rate from 72.7 cm at the seeding rate of 100 kg ha^{-1} to 80.4 cm at the seed rate of 150 kg ha^{-1}. Haile *et al.* [49] found that seed rates had significant difference on plant height of wheat and higher mean plant height was obtained with higher seed rate 125-175 kg ha^{-1} and significantly lower plant heights was obtained when wheat sown at seeding rates 100 kg ha^{-1}. Baloch *et al.* [50] also reported that the maximum plant height 103.3 cm was observed with seed rate of 150 kg ha^{-1} followed by 175 kg seed ha^{-1} which produced plants of 93.2 cm in wheat. Sharma *et al.* [51] found that mean plant height of bread wheat significantly affected by seed rate and wheat sown at the seed rate of 140 kg ha^{-1} produce significantly higher (70.89 and 71.41cm) of taller plants of bread during both the years.

Likewise, Abd El-Lattief [38] found that mean plant height of wheat was significantly affected by different seeding rates and significantly higher plant height was obtained with higher seed rates of different bread wheat varieties. Al-Hilfy and Wahid [43] found that significant difference of seed rates on mean plant height and significantly increased plants height with increasing seeding rate and plants sown at seeding rate 180 kg ha^{-1} gave the tallest plants (104.57 cm), while 80 kg ha^{-1} seeding rate gave the shortest plants (96.44 cm). this might be due to higher seed rate caused to changing plant height because of the lower light penetrating in to plants canopy bed and more inter specific competition to more absorption light [43]. Baloch *et al.* [52] reported that significantly higher plant height of wheat with seed rate of 150 kg ha^{-1}. Abiot [28] reported that plant height of bread wheat significantly affected by seed rates and significantly increasing seeding rate from the lowest (100 kg ha^{-1}) to the highest (175 kg ha^{-1}) plant height of bread wheat correspondingly increased from 76.86 to 81.76cm.

In contrary, Sulieman [53] reported that increase in the seeding rate resulted in a slight increment in the heights of the wheat. Higher seeding rate caused to changing plant height and stem thickness because of the lower light penetrating in to the plants canopy bed and more inter specific competition to more absorption light. These factors higher seeding rate and lower light penetration increasing inter node length, reducing stem thickness and increasing plant height [54]. Plant height of wheat grown at the lowest seeding rate was significantly lower than the height of plants grown at higher seeding rates [49, 55].

Two-way interaction of sowing method with seeding rate showed significant ($p<0.05$) effect of bread wheat (Table 4). Significantly higher 82.66cm plant height of bread wheat was obtained from 150 kg ha^{-1} seed rates with row method of sowing while the lowest 78 cm plant height was recorded from 100 kg ha^{-1} seed rate with broadcasting method of sowing of bread wheat. The mean plant height of bread wheat was significantly higher using higher seed rate with row and broadcasting method of sowing. Therefore, the use of higher seed enhanced the vertical growth of bread wheat varieties.

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 2). 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 5). 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 2). 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

Table 6: The interaction effects of sowing method and seed rate on grain yield 0f wheat in Abbay Chommen district

Sowing Methods	Seeding rate (kg ha^{-1})	Grain yield (t ha^{-1})
Row	100	3.73^{c}
Row	125	5.16^{a}
Row	150	4.44^{b}
Broadcasting	100	3.02^{e}
Broadcasting	125	3..75^{c}
Broadcasting	150	3.32^{d}
LSD (5%)		0.76
CV (%)		2.5

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

controlled by genetic background. Likewise, Obsa and Yeared [56] 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*. [51] found that varieties significantly affected the grain yield of bread wheat. Sharshar and Ei-Said [57]; Nadeem [58] reported that wheat varieties significantly differed in grain yield and most of yield related traits. Costa *et al.* [59] found that mean grain yield of wheat was significantly different among varieties.

The row method of sowing has produced significantly higher 4.44 tha^{-1} grain yield of bread wheat as compared to broadcasting method 3.36t ha^{-1} (Table 2). 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.* [60] 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.* [61] 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 [33] 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. Awoke *et al.* [61] 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. Drilling method is considered suitable because of its uniform seed distribution and sowing at desired depth and resulted higher germination and uniform stand [47]. Therefore, Easson *et al.* [62] 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 2). 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*. [61] 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*. [49] 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.* [60] 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 [28] reported that seeding rate of 150 kg ha^{-1} gave significantly higher (4462 kg ha^{-1}) grain yield followed by 175 kg ha^{-1}. Haile *et al*. [49] 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*.

[37] 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*. [63]; Haile and Girma [64]. Similarly, Sikander *et al*. [65] concluded that increasing seeding rate from 150 to 250 seeds/m^{-2} resulted in higher grain yield. Sharma *et al.* [51] 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*. [66] 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 [38] 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 [67] found that significantly higher grain yield of bread wheat was obtained with higher seeding rate of 150 kg ha^{-1}. Mennan and Zandstra [68] 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.* [69] found that number of grain yield was higher under seeding rate of 150 kg ha^{-1}. Kiliç and Gürsoy [70] found that seeding rate affected grain yield and yield components of bread wheat and 253 seed per m2 was predicted to be an optimum seed rate for producing the highest average grain yield (5162 kg ha^{-1}) over years. Costa *et al*. [59] 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*. [52] reported that significantly higher grain yield of wheat with seed rate of 150 kg ha^{-1}. Naveed *et al.* [71] 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 were showed significant (P<0.05) effect on mean grain yield of bread wheat (Table 5). 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.* [47] 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 were 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.* [72] 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 [73] all necessary for crop vigor and yield. The optimum seeding rate results in increasing grain yield of bread wheat.

Pearson Correlation Between Phenology, Growth and Yield Parameters of Bread Wheat Due to Seed Rates, Sowing Methods and Varieties: The correlation between phenology, growth, yield and yield components of bread wheat is indicated in (Table 7). Plant height has positive and significant correlation with grain yield (0.52) of wheat. Similarly, Zewdie *et al*. [74] reported that a positive association between yield and plant height, thus taller plants resulted higher dry biomass and yield. The number of days to 90 % physiological maturity has positive and significant correlation with days 50% heading (0.72) and number of days to grain filling period (0.87) of bread wheat.

Effects of Seed Rate on Economic Feasibility of Bread Wheat Production: The partial budget analysis for bread wheat due to seed rate is indicating in Table 8. The highest net benefit EB 46, 812.52 ha^{-1} with marginal rate of return of 1330 % and value to cost ratio of EB 3.17 per unit of investment was obtained from 125 kg ha^{-1} seeding rate for bread wheat. Similarly, Shah *et al.* [75] reported that the highest net benefit and marginal rate of return were obtained from the use of 120 kg ha^{-1} seed rate

Table 7: Pearson correlation between phenology, growth and yield of Bread Wheat in Abbay Chommen district

	DH	DM	GF	PH	GY
DH		0.72***	0.29	-0.18	0.41*
DM			0.86***	-0.207	0.10
GF				-0.20	-0.16
PH					0.52**
GY					

DE = days to 50% emergence, DH = days to 50% heading, DPM = days to 90% physiological maturity PH = plant height and GY=grain yield

Table 8: Effects of seed rate on economic feasibility of bread wheat production

	Seeding rate (tha^{-1})		
Items	100	125	150
Average yield (t ha^{-1}) bread wheat	3.31	4.4585	3.8772
Adjusted yield (t ha^{-1}) bread wheat	3.034	4.0128	3.489
Gross field benefit of bread wheat	44,381.34	61,567.52	51,649.32
Total field benefit (EB ha^{-1})	44,381.34	61,567.52	51,649.32
Costs that vary (EB ha^{-1})			
Supply cost (EB ha^{-1}) Seed cost (EB ha^{-1}) Labor cost (EB ha^{-1})	403321207400	438123887986	467826688514
Total costs that vary (EB ha^{-1})	13,553	14,755	15,860
Net benefit	30,829.34	46,812.52	35,789.32D
Value to cost ratio	2.27	3.17	2.25
Marginal rate of return (%)		1330 %	

D = dominated, Grain price EB = 15 kg^{-1} Seed cost EB = 25 kg^{-1}

as compared lower and higher seed rates for bread wheat. In contrary, Abiot [28] found that the highest net benefit of EB 28, 526 ha^{-1} was obtained from 150 kg ha^{-1} seeding rate while 125 kg ha^{-1} seed rate was the second alternative options for bread wheat production to farmers in Gozamin District, East Gojam Zone. The use of 125 kg ha^{-1} seed rate was better as compared to 100 and 150 kgha^{-1}. Therefore, the use of 125 kg ha^{-1} seeding rate and with row sowing method with Liben and Hidase varieties was recommended for the area.

CONCLUSION

The use of 125 kg ha^{-1} seed rate gave significantly higher grain yield of bread wheat as compared to100 and 150 kg ha^{-1}. The use of Liben variety with 125 kg ha^{-1} seeding rate and row method sowing was performed better and gave higher grain yield (5.26t ha^{-1}) bread wheat. The 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 phenology, growth and grain yield of bread wheat. The interaction effect of seeding rate, sowing method and varieties were highly significant for days to 50% emergence of bread wheat. Significantly higher mean plant height 81.19 cm was obtained for the variety Hidase while the lowest 80.38 cm plant height of bread wheat was obtained for Liben. There was positive and strong correlation between days to 90% physiological maturity with days to grain filling of bread wheat. The highest net benefit EB 46, 812.52 ha^{-1} with marginal rate of return of 1330 % and value to cost ratio of EB 3.17 per unit of investment was obtained from the use of 125 kg ha^{-1} seeding rate with row method of sowing for bread wheat varieties. Therefore, 125 kg ha^{-1} seeding rate with row methods of sowing for Liben variety was economically profitable and can be recommended for smallholder farmers in study area and other areas with similar agroecological conditions. However, the experiment was carried out only in one location for one cropping season, so further studies at different locations for several years or seasons should be considered to make reliable and acceptable recommendation.

ACKNOWLEDGEMENTS

We would like to thank the almighty God who lead us to see seed of our work. We are very grateful to Abbay Chommen district of Agriculture and Natural Resource Office for providing the chance and all necessary fund for the research work. We want to thank farmer for providing us the land for field research work and their assistance in field managements.

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