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Effect of seed rate and irrigation interval on yield components and yield of bread wheat (*Triticum aestivum* L.) at Mekane Selam district, South Wollo, Ethiopia

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Abstract
Determination of optimum seed rate and planning suitable irrigation strategy are important practices to increase productivity of wheat under irrigation. Thus, a study was undertaken to determine the effects of irrigation intervals (5, 8, 11 and 14 days) and seed rate (75, 100, 125 and 150 kg ha^{-1}) on yield components and yield of bread wheat during 2019 cropping season (November to April). Wheat variety ADEL-6 was used as test crop. The experimental design was split plot design with three replications using irrigation interval as the main plot factor and seed rate as sub-plot factor. Results showed that the interaction effect of irrigation interval and seed rate had highly significant ($P<0.01$) effect on number of total tillers, effective tillers, grain yield, aboveground dry biomass yield, straw yield and harvest index. The highest number of total tillers (54.33) and effective tillers (49.33) per 0.5 m mid length row were obtained from the seed rate of 150 kg ha^{-1} with irrigation interval of 5 days. On the other hand, the highest grain yield (5.40 t ha^{-1}), the highest biomass yield (13.34 t ha^{-1}) and the highest straw yield (7.95 t ha^{-1}) were obtained from seed rate of 100 kg ha^{-1} and irrigation interval of 11 days which were statistically at par with the seed rate of 100 kg ha^{-1} and irrigation interval of 8 days. The partial budget analysis also showed that the highest net benefit (37375 Birr ha^{-1}) was recorded from the combination of seed rate of 100 kg ha^{-1} and irrigation interval of 11 days followed by seed rate of 100 kg ha^{-1} and irrigation interval of 8 days with net benefit of 34156 Birr ha^{-1}. Thus, from the result of the study, it can tentatively be concluded that use of 100 kg ha^{-1} seed rate and irrigation interval ranging from 8 to 11 days can improve the productivity of bread wheat in the study area.

Keywords: Field capacity, irrigation frequency, seed rate

Introduction
Wheat (*Triticum aestivum* L.) is one of the important grain crops produced worldwide and is a staple food for about one third of the world's population. Wheat flour has many uses, but its main use is to make bread, a staple food for many people around the world (Hussain and Shah, 2002) [14]. Important wheat producing countries include China, India, United States, Russia and France. In 2010 the estimated world production was 650,881,002 metric tons (FAOSTAT, 2010) [8], which corresponds to about 94 kg per person (in 2010 the world had about 6.9 billion persons). Wheat is primarily used as a staple food providing more protein than any other cereal crop (Iqtidar *et al.,* 2006) [15]. Bread wheat *(Triticum aestivum)* accounts for more than 90% of global wheat production and is grown on a substantial scale (over 100,000 ha) in more than 70 countries on 5 continents (Lantican *et al.,* 2005) [20]. Ethiopia is the second largest producer of wheat in Sub-Saharan Africa, following South Africa (White *et al.,* 2001) [30]. Wheat is an important cereal crop in Ethiopia; it ranks third in terms of area after teff and maize, and second after maize in terms of productivity (FAO, 2005) [6]. However, the productivity of wheat in Ethiopia is much lower than the yields of other wheat producing countries of the world (White *et al.,* 2001) [30]. Wheat is one of the various cereal crops largely grown in the highlands of Ethiopia and it is produced largely in the southeast, central and northwest parts of the country. However, wheat yield in Ethiopia is low as compared to the attainable yield of 5 t ha^{-1} (MoA, 2012) [22]. Various biotic and abiotic factors are responsible for this low yield. Cultivation of unimproved low yielding varieties, insufficient and erratic rainfall, poor agronomic practices, diseases and insect pests are among the most important constraints to wheat production in Ethiopia (Dereje and Yaynu, 2000) [5].
Seed rate plays a vital role for optimum plant densities which is a pre-requisite for increased seed yield.

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Higher seed rate produces more plants in unit area resulting in less intra-crop competition thereby affecting the yield and production cost. On the other hand, lower seed rate may reduce the yield drastically. Solomon *et al.* (2003) [28]; and Ozturk and Aydin (2004) [25] also found yield reductions of 79.7% and 65.5% when water stress was imposed either at earlier stages or at grain formation, respectively. Optimum seeding rate is considered as an important management factor for improving yield of wheat. It is of particular importance in wheat production because it is under the farmers control in most cropping systems. Baloch *et al.* (2010) [4] reported that 150 kg seed ha^{-1} produced higher grain yield. In Ethiopia seed rates ranging from 125 to 175 kg ha^{-1} are recommended for different varieties of bread wheat (MoA, 2009) [21].

Irrigation frequency has a significant influence on growth and yield of wheat. Besides rainfall, land type and soil texture are two important factors that determine the status of soil moisture. In light textured soil with high infiltration rate, wheat crop is more vulnerable to moisture stress. Mid-term drought around the heading period is more common. Recently, numerous studies dealing with crop production and water use efficiency under irrigation showed that proper irrigation intervals can increase crop yield, by improving soil water condition and their water use efficiency (Richards *et al.*2002) [26].

Recently in Mekane Selam area wheat is growing under irrigation condition. Even though; adapted wheat varieties were released in the area with recommended seed rates, agro pastoralists in the area are usually apply their specific seed rates and irrigation water frequency for various reasons. Due to these reason production and productivity of irrigated wheat is low as compared to optimum irrigation applied yield. In these observed fact, proper irrigation water management and use of proper seed rate are highly important to improve wheat yield under agro pastoralist field. Although; there is huge potential to produce wheat under irrigation, the necessary agronomic recommendations are lacking.

Thus, this study was conducted with objective of assess the effect of seed rate and irrigation intervals on yield components and yield of bread wheat.

Materials and Methods
Description of the Study Site
The study was conducted in Northern high land Ethiopia, Amhara Regional State, Mekane Selam district. The area is located at 10º 45' N latitude and 38º 45' E longitudes and an altitude of 1827masl. The study was conducted in 2019 crop season Mekane Selam district. The main agricultural activities are carried out mixed crop livestock production system is found in both high and low land areas of south wollo zone. The highland mixed crop livestock production system is largely based on intensive cultivation of cereals, pulses, tubers, vegetables and same oil crops. According to Ethiopian agro-ecological classification the area is grouped under weina dega with the major soil type vertisols and the most dominate land cover taken by cultivated land.

Description of Experimental Materials
The wheat variety ADEL-6 obtained from Werer Research center was used as test crop. It was released by WARC/EIAR in 2013. It is for irrigated lowlands possess high grain yield of 5-6 t ha^{-1} good end use quality and tolerant to heat and salinity (ICARDA, 2017). The seed is certified and its germination was (98%) with 99% purity. Diammonium phosphate (18% N and 46% P$_2$O$_5$) and Urea (46% N) were used as source of fertilizers.

Treatments and Experimental Design
The experiment was laid out on a split-plot design comprising two factors *viz.* irrigation intervals as main-plot factor and seed rate as sub-plot factor. The main-plot factor had four levels, namely; 5 days, 8 days, 11 days and 14 days interval and sub plot had four levels, namely; 75, 100, 125 and 150 kg ha^{-1}. The treatment combinations were sixteen (16) treatments with three replications.

Experimental Procedures and Field Management
Land preparation started at end of November, 2019. Tractor with conventional land preparation implements, were used for plowing and disking. Each treatment was applied to a plot area of 5.4 m^2 consisting of 6 rows of 3 m long and 1.8 m width with 0.3 m row spacing. The spacing between plots and blocks were 0.5 m and 1m, respectively. The one edge row at both sides and 0.3 m row length from both sides of row endings were left to be a border to avoid the border effects for the whole plot. Then, four rows with plot size 2.4 m by 1.2 m (2.88m^2) were used as net plot.

Wheat variety ADEL-6 seed was used from Werer research center. The seed were measured and bag for each seed rate treatments. Each sub plot was 6 rows plot^{-1} with 0.3m apart and 3cm hull length. Sowing was done by human labor with drilling two weeks after land preparation; at mid November 2019. DAP fertilizer were applied at sowing time at the rate of 50 kg ha^{-1} by human labor were broadcasted and Urea 150 kg ha^{-1} was also applied by split application; half 20 days after sowing (DAS) and the remaining half at booting stage uniform dose to the experimental plots.

Irrigation water was applied by furrow and two free irrigation were given for all treatments uniformly before starting irrigation intervals treatments. Irrigation water flow rate in to treatment plot was controlled by partial flume for each duration. With a head (Z) of 18 cm and it has 12.3 l/se discharge rate at field capacity level. Irrigation treatments were started 21days later after sowing or 14 days after emergence on this stage the wheat plant which were 15cm long of seedling at initial stage. Due to these facts irrigation treatment (application schedule) were started on reference evapotranspiration (ETo), the plant were at seedling stage namely grass cover. Hence; the treatment were treated as per schedule that were planed (5, 8, 11 and 14) days interval. During each application, it was treated to a best earthling level. Irrigation treatments was found that maximum irrigation water was applied for 5 days interval that received maximum of 11 irrigations when compared with the 14 days interval which was received a maximum of 4 irrigations. On the other hand, 8 days interval and 11 days intervals treatments in the study experiment others agronomic practices were applied uniformly except two treatment factors, received a maximum of 7 and 5 irrigations, respectively, within the growing period.

Crop Data Collected
Phenological and Growth Parameters
Days to 50% heading (DH): Days to heading was recorded by counting number of days from the date of sowing until when 50% of the plants in a plot produced spikes above the sheath of the flag leaf that was determined by visual observation.

Days to 90% physiological maturity (DPM): Days to physiological maturity was recorded by counting the number of days from date of sowing until when 90% of the plants changed green colour to yellowish, as indicated by senescence of the leaves as well as free threshing of seeds from the glumes when

pressed between the thumb and the forefinger.

Plant height (PH): It was measured in cm from ground level to the top of the spike excluding the awns from ten randomly pre-tagged plants in the net plot at maturity.

Spike length (cm): It was measured from the bottom of the spike to the tip of the spike excluding the awns from 10 randomly taken spikes from the net plot.

Yield Components and Yield
Number of tillers (NT): The number of tillers was counted from 0.5m length from two places in the net plot and then averaged

Number of productive tillers: The number of tillers bearing spikes was counted at the time of harvest per 0.5 meter length from two places of the net plot area and then averaged

Number of kernels per spike: The mean number of kernels per spike was computed as an average of 10 randomly taken spikes from the net plot area.

Thousand kernels weight (g): thousand kernels weight was determined based on the weight of 1000 kernels sampled from the grain yield of each net plot by counting using electronic seed counter and weighed with electronic sensitive balance. Then the weight was adjusted to 12.5% moisture content.

Aboveground dry biomass (t ha⁻¹): the aboveground dry biomass was determined from plants harvested from the net plot area after sun drying to a constant weight and converted to tons per hectare.

Grain yield (GY): grain yield was taken by harvesting, sun-drying and threshing the grain from the net plot area. The yield was adjusted to 12.5% moisture content.

Straw yield (StY): Straw yield was obtained as the difference of the total above ground dry biomass and grain yield.

Harvest index (HI): It was calculated on a plot basis as the ratio of grain yield to the aboveground biomass yield and expressed as a percentage

$$HI (\%) = \frac{Grain\ yield\ /plot}{Aboveground\ dry\ biomass\ /plot} \times 100$$

Data Analysis
All data collected were subjected to analysis of variance (ANOVA) procedure using GenStat 15th edition software (GenStat, 2012). Comparisons among treatment means with significant difference for parameter was done by using Fisher's protected Least Significant Difference (LSD) test at 5% level of significance.

Results and Discussion
Phenological and Growth Parameter of Wheat
Days to heading
Days to 50% heading was not significantly affected by the main factor of irrigation interval and seed rate and interaction effect of irrigation interval and seed rate. The longest days to 50% heading (49.33 days) was recorded for 5 day irrigation interval and at 75 kg ha⁻¹ seed rate (49.58) (Table 1). The dalliance in

days to heading with frequent irrigation interval may be due to excessive frequency of irrigation which was 11 times applied during the growth period which enhanced vegetative growth.. Moreover, the delayed heading with the lowest seed rate might be due to less competition for growth resources within plants.

Table 1: Main effect of irrigation interval and seed rate on plant phenology, growth parameters and yield components of bread wheat

Treatment		DM	PH	SLpS	KpS	SL
Irrigation Intervals (days)						
5	49.33	81.42	63.87	13.67	27.92	5.92
8	47.92	81.75	61.13	13.42	30.33	6.32
11	47.17	79.58	64.08	13.75	30.25	6.42
14	47.92	80.50	61.73	13.33	29.17	5.78
LSD (5%	NS	NS	NS	NS i,	NS	NS
Seed rate (kgha⁻¹)						
75	49.58	81.92	61.70	13.42	29.08	6.37
100	46.92	80.75	63.32	13.83	30.25	6.07
125	47.83	80.25	62.23	13.67	29.00	6.03
150	48.00	80.33	63.57	13.25	29.33	5.97
LSD (5%)	NS	NS	NS	NS	NS	NS
CV (519)_	5.79	2.52	6.71	5.90	15.68	6.46

LSD (5%) = least significant difference at 5% probability level, CV (%) = coefficient of variation in percent, NS = non significant, DH = day to heading, DM = day to maturity, PH = plant height (cm), SLpS = number of spikelets per spike, NKPS = number of kernels per spike and SL= spike length.

Days to 90% physiological maturity
The result showed that, irrigation intervals and seed rates had no significant influence on days to 90% physiological maturity. The result showed that delayed in physiological maturity (81.92 days) was recorded at 75 kg ha⁻¹ and when irrigation was applied at 8 days interval. The delayed day to physiological maturity with the lowest seed rate might be enhanced vegetative growth due to less intra specific competition.

Plant height
The analysis of variance revealed that the two main factors of irrigation intervals and seed rate and interaction of these two factors had no significant influence on plant height (Table 1). Even though the difference is non-significant, highest seed rate of 150 kg ha⁻¹ relatively gave increased plant height (63.57 cm) than 75 kg ha⁻¹ (61.70 cm). The possible reason for increased plant height with increased seed rate might be that plants become thinner and longer to compete the above ground resources specially the solar radiation at the highest seed rate.
In agreement with this result, Haile *et al*. (2013) [12] also reported in wheat that the height of plants grown at the lowest seed rate was significantly lower than the height of plants grown at higher seed rates.

Spike length
The statistical analysis results revealed that spike length was not significantly affected by main effects of irrigation interval and seed rate as well as by their interaction. Even though, spike length was not significantly affected by main and interaction effects, the 14 days irrigation interval and the highest seed rate (150 kg ha⁻¹) gave the lowest spike length (Table 1) which could be due to severe competition for growth resources especially for soil moisture.
The result of this study result was also in agreement with the findings of Gafaar (2007) [10] who stated that increasing sowing density from 200 up to 400 grains m⁻² significantly decreased spike length. Similarly, Seleiman (2010) [27] reported that the

longest spikes were obtained from 250 and 300 grains per m^2 while the shortest spikes were recorded by using the highest seeding rate (400 grains per m^2).

Similar result was also reported by Khokhar *et al.* (2010) [18] where spike length was significantly higher with five irrigations (shorter interval) in comparison with other irrigation treatments. Aslam *et al.* (2014) [3] also reported that the crop receiving five irrigations resulted in maximum spike length of 12.04 cm while the lowest spike length of 9.64 cm on average was recorded in plots given three irrigations.

Yield Components
Number of total tillers
The analysis of variance showed that both the main factors of irrigation interval and seed rate as well as the interaction effect had highly significant (*P*<0.01) effect on number of total tillers per 0.5 m length. In this regard, the highest number of total tillers (54.33) was obtained from the seed rate of 150 kg ha^{-1} with irrigation interval of 5 days while the lowest number of total tillers (24.67) was recorded at seed rate of 75 kg ha^{-1} and with irrigation interval of 14 days (Table 2). The highest number of total tillers with highest seed rate and frequent irrigation might be due to high frequency of irrigation and high plant population that leads to high moisture availability and maximum seed rate that had highest plant population and enhanced number of tillers per unit area. Aslam *et al.* (2014) [3] reported that wheat crop irrigated five times had maximum number of tillers (402.11 m^{-2}) while the minimum number of tillers (338.00 m^{-2}) was observed in wheat crop kept on three irrigations. Faruque (2002) [9] also reported that the plant growth which depends partly on turgor pressure to sustain cell enlargement, is more sensitive to water supply.

Table 2: Number of total tiller per 0.5 m row length of wheat as affected by the interaction of irrigation intervals and seed rate

Irrigation interval (days)	Seed rate (kg ha^{-1})			
	75	100	125	150
5	29.00gh	34.67f	44.67c	54.33a
8	27.67hi	37.00e	41.67d	50.00b
11	26.33i	35.00f	38.00e	44.67c
14	24.67j	29.33g	34.00f	40.33d
LSD (0.05)	1.520			
CV (%)	2.45			

Means with the same letter(s) in the same column and rows of each trait are not significantly different at 5% probability level, LSD (5%) = least significant difference at 5% probability level, CV (%) = coefficient of variation in percent and NT = number of tiller per 0.5m length.

Number of effective tillers
The number of effective tillers was significantly (*P*<0.01) affected by main effect of irrigation interval and seed rate and their interaction. The highest number of effective tillers (49.33 tillers per 0.5 m length row) was obtained from the seed rate of 150 kg ha^{-1} at five days irrigation interval while lowest number of effective tillers (19.67 tillers in per 0.5 m length row) was recorded at seed rate of 75 kg ha^{-1} and irrigation interval of 14 days (Table 3).

The highest number of productive tillers with the highest seed rate and frequent irrigation might be due to the highest plant population per unit area and availability of adequate soil moisture. Likewise, Geleta *et al.* (2002) [11]; and Gafaar (2007) [10] reported that, number of spikes m^{-2} were increased with increasing seeding rate in wheat. Khan *et al.* (2004) [16] also reported significantly maximum number of fertile tillers with three irrigation levels.

Table 3: Number of effective tiller per 0.5 m row length of wheat as affected by the interaction of irrigation intervals and seed rate

Irrigation interval (days)	Seed rate (kg ha^{-1})			
	75	100	125	150
5	28.00j	34.67fg	41.67c	49.33a
8	25.67k	34.00g	39.67d	45.00b
11	24.331	32.00h	37.33e	39.67d
14	19.67m	27.33j	31.00i	35.00f
LSD (0.05)	0.92			
CV (%)	1.61			

Means with the same letter(s) in the columns and rows are not significantly different at 5% probability level, LSD (5%) = least significant difference at 5% probability level, CV (%) = coefficient of variation in percent.

Number of kernel per spike
Analysis of the variance showed that the main effects of irrigation interval and seed rate as well as the interaction had no significant effect on the number of kernels per spike Its value ranged from 27.92 to 30.33 (Table 1).

In contrast with this result, Mehrvar and Asadi (2006) reported that by increasing seed rate the number of grains per spike was reduced.

Thousand kernels weight
The analysis of variance revealed that the interaction of irrigation interval and seed rate had significant (*P*<0.05) effect on thousand kernels weight. The highest thousand kernels weight (32.20 g) was recorded from seed rate of 100 kg ha^{-1} and 11 days irrigation interval whereas the lowest thousand kernels weight (27.99 g) was recorded at the seed rate of 125 kg ha^{-1} and 8 days irrigation interval (Table 4).

The lowest kernels weight recorded from higher seed rate might be due to high population density had resulted in competition and thereby might lead to insufficient grain filling. In addition, the presence of higher spike number per rows leads to lower number of kernels per spike and small sized kernels because of inter plant competition to limited resources in the soil.

This result was in agreement with reports of the higher seed rate in bread wheat resulted in decreased 1000 kernels weight (Baloch *et al.,* 2010) [4]. Also other authors emphasized the influence of seed rate and plant density on 1000-kernel weight that as seed rate increased also number of spikes m^{-2} increased, but 1000 kernel weight decreased (Hiltbrunner *et al.,* 2005) [13].

Table 4: Thousand kernel weight (g) of wheat as affected by the interaction of irrigation intervals and seed rate

Irrigation interval (days)	Seed rate (kg ha^{-1})			
	75	100	125	150
5	29.07de	30.17a-d	31.60abc	30.83a-d
8	32.00ab	31.67abc	27.99e	29.33de
11	30.60a-d	32.20a	30.07a-e	29.73cde
14	31.17a-d	30.77a-d	30.30a-d	29.93b-e
LSD	(0.05)	2.156		
CV (%)	4.20			

Means with the same letter(s) in the columns and rows are not significantly different at 5% probability level, LSD (5%) = least significant difference at 5% probability level and CV (%) = coefficient of variation in percent.

Yield and Harvest Index
Grain yield
Analysis of variance showed that irrigation interval and seed rate showed significant effect (*P* < 0.01) on grain yield. Likewise, interaction of irrigation interval and seed rate also high

significantly affected wheat grain yield. The highest grain yield (5.40 t ha⁻¹) was obtained from seed rate of 100 kg ha⁻¹ and irrigation interval of 11 days which was statistically at par with the seed rate of 100 kg ha⁻¹ and irrigation interval of 8 days (5.40 t ha⁻¹) (Table 5). On the other hand, the lowest grain yield (1.42 t ha⁻¹) was from the combination of seed rate of 75 kg ha⁻¹ and irrigation interval of 14 days. The lowest yield at the lowest seed rate might be due to sub-optimal population which could not efficiently utilize the available growth resources. while the lower yields at the highest density might be due to severe competitions among the plants. In very thick densities, falling rate of leaves would increase due to shade and much competition to sun light and environmental conditions, which possibly leading to decreasing rapid early growth, and decreasing grain yield in case of limiting environmental factors such as temperature and sun light. Moreover, the longest duration (14 days) decreased the yield the most due to the obvious moisture stress created.

In conformity with this result, Kumar *et al*. (2006) [19] and Otteson *et al*. (2007) [24] reported that increasing seed rate up to 150 kg ha⁻¹ with optimum fertilizer application resulted in increased grain yield of wheat. Similarly, Baloch *et al*. (2010) reported that the use of 150 kg seed ha⁻¹ produced higher grain yield of 5103.3 kg ha⁻¹ than other seeding rates (100, 125, 175, and 200 kg ha⁻¹).

The study result agreed with the result of Kanwar *et al*. (2008) [17] who observed that 5 times irrigation resulted in greater density, dry weight and nutrient uptake by wheat compared to twice or three times. Similarly, Wajid *et al.* (2002) [29] reported that wheat crop produced highest grain yield by applying irrigation at all definable growth stages. Khokhar *et al*. (2010) [18] also reported that wheat grain yield was higher with five irrigations followed with four and three irrigations. The result of this study has shown that grain yield was significantly reduced under longer irrigation intervals.

Table 5: Grain yield (t ha⁻¹) of wheat as affected by the interaction of irrigation interval and seed rate

Irrigation interval (days)	Seed rate (kg ha⁻¹)			
	75	100	125	150
5	3.60e	3.71de	3.49e	4.94ab
8	4.54abcd	5.11a	4.09bccie	3.95cde
11	3.70de	5.40a	3.60e	4.84abc
14	1.42f	4.05bccie	3.58e	3.28e
LSD	(0.05)	0.77		
CV (%)	11.53			

Means the same letter(s) in columns and rows are not significantly different at 5% probability level, LSD (5%) = least significant difference at 5% probability level and CV (%) = coefficient of variation in percent.

Aboveground dry biomass
Aboveground dry biomass was highly significantly affected by the main effect of irrigation intervals and seed rate and by their interaction. The highest biomass yield (13.34 t ha⁻¹) was obtained from the combination of 11 days irrigation interval and 100 kg ha⁻¹ seed rate while the lowest dry biomass yield (3.30 t ha⁻¹) was recorded with seed rate of 75 kg ha⁻¹ and 14 days of irrigation interval (Table 6).
Gafaar (2007) [10] reported the highest value of biological yield with increasing seed rate up to 400 grains m⁻² in wheat crop. However, the current result was in contrast with results reported by Allam (2003) [2] where in wheat higher seed rates, higher number of plants and tillers failed to produce higher biomass yield. With regards to the irrigation interval, the result is in line

with the findings of Aslam *et al*. (2014) [3] who reported that wheat crop irrigated five times resulted in significantly maximum biological yield (13732 kg ha⁻¹) while the minimum biological yield (8600 kg ha⁻¹) was recorded in three irrigations.

Table 6: Aboveground dry biomass (t ha⁻¹) of wheat as affected by the interaction of irrigation interval and seed rate

Irrigation Interval (days)	Seed rate (kg ha⁻¹)			
	75	100	125	150
5	8.67ef	8.95ef	8.21ef	12.13ab
8	11.08bcd	12.58ab	9.78de	9.69de
11	8.97def	13.34a	8.57ef	12.02abc
14	3.30g	9.96cde	8.62ef	7.50f
LSD	(0.05)	1.758		
C.V (%)	10.89			

Means with the same letter(s) in columns and rows are not significantly different at 5% probability level, LSD (5%) = least significant difference at 5% probability level and CV (%) = coefficient of variation in percent.

Straw yield
Analysis of variance showed that the main effects of irrigation interval and seed rate and their interaction showed highly significant (*P*<0.01) effect on grain yield. Like the aboveground dry biomass yield, the highest straw yield (7.95 t ha⁻¹) was obtained from the combination of 11 days irrigation interval and 100 kg ha⁻¹ seed rate while the lowest dry biomass yield (1.88 t ha⁻¹) was recorded with seed rate of 75 kg ha⁻¹ and 14 days of irrigation interval (Table 7). The highest straw yield with the intermediate seed rate could be that higher planting density within limit might produce more total dry matter per unit area. Similar results were obtained by Ali *et al*. (2004) [1] who found that biological yield was increased with increasing seeding rate in wheat.

Table 7: Straw yield (t ha⁻¹) of wheat as affected by the interaction of irrigation interval and seed rate

Irrigation interval (days)	Seed rate (kg ha⁻¹)			
	75	100	125	150
5	5.08de	5.24de	4.72de	7.18ab
8	6.53bc	7.47ab	5.69cd	5.74cd
11	5.27de	7.95a	4.97de	7.18ab
14	1.88f	5.91cd	5.04de	4.22e
LSD	(0.05)	1.01		
CV (%)	10.64			

Means with the same letter(s) in columns and rows are not significantly different at 5% probability level, LSD (5%) = least significant difference at 5% probability level, CV (%) = coefficient of variation in percent and t ha⁻¹ = ton per hectare.

Harvest index
Analysis of variance showed that interaction of irrigation interval and seed rate showed highly significant (*P* < 0.01) effect on harvest index. The highest harvest index (43.01%) was recorded from 14 days irrigation interval and 75 kg ha⁻¹ interaction while the lowest harvest index (40.29%) were recorded from the combination of irrigation interval of 11 days and seed rate of 150 kg ha⁻¹ (Table 8).
The lowest harvest index at the highest seed rate might be due to increased plant height and increased biomass yield rather than grain yield which lead to decrease of harvest index. The result of the current study was consistent with that of Zeng and Shannon (2000) [31] who showed that at high density, carbohydrate supply was limited because of shading among plants and the competition between shoot growth and panicle growth which

resulted in the reduction in harvest index with the increases in seeding densities. In contrast, Mollah *et al.* (2009) [23] reported that seed rate did not have significant effect on harvest index of wheat.

Table 8: Harvest index (%) of wheat as affected by the interaction of irrigation intervals and seed rate

litigation interval (days)	Seed rate (kg ha⁻r)			
	75	100	125	150
5	41.48def	41.47def	42.42b	40.77gh
8	41.03fghi	40.66ijk	41.85cd	40.78ghij
11	41.26efg	40.45ik	42.02bc	40.29k
14	43.01a	40.63ijk	41.58cde	41.23efgh
LSD	(0.05)	0.38		
CV (%)	0.54			

Means with the same letter(s) in the columns and rows are not significantly different at 5% probability level, LSD (5%) = Least significant difference at 5% probability level, CV (%) = Coefficient of variation in percent and HI= harvest Index.

Conclusion

Bread wheat is one of the most important world cereal crops and is a staple food for about one-third of the world's population. In Ethiopia, it is one of the major cereals grown mainly under rainfed conditions. Water is essential for crop production, and any shortage has an impact on final yields. In irrigation practice, over or under irrigation application affects plant growth and yield. A reasonable irrigation scheduling is a key factor to help farmers increase crop yield and save water regarding limited water resources. Moreover, optimum seed rate is one of the most important agronomic practices for maximum yield of crop.

Even though the production of wheat is practiced under irrigation in the study area, its productivity is low due to lack of recommendations on optimum irrigation interval and seed rate. Therefore, this study was conducted during 2019 cropping season to assess the effect of seed rates and irrigation intervals on yield component and yield related traits, and to identify economically feasible seed rate and irrigation interval for increased yield of wheat.

The treatments consisted of four irrigation intervals (5, 8, 11 and 14 days) and four seed rate (75, 100, 125 and 150 kg ha⁻¹) using wheat variety ADEL-6 as the test crop. The experimental design was split plot design with three replications using irrigation interval as the main plot factor and seed rate as sub-plot factor.

Results showed non-significant main and interaction effects of the factors on days to heading, days to maturity, plant height, spike length, spikelet's per spike, and number of kernels per spike. On the other hand, the interaction effect of irrigation interval and seed rate had highly significant effect on total tillers, effective tillers, grain yield, aboveground dry biomass yield, straw yield and harvest index. The highest number of total tillers and effective tillers were obtained from the seed rate of 150 kg ha⁻¹ with irrigation interval of 5 days while the lowest number of total tillers and effective tillers were recorded at seed rate of 75 kg ha⁻¹ and with irrigation interval of 14 days. In contrast, the highest grain yield (5.40 t ha⁻¹), the highest biomass yield (13.34 t ha⁻¹) and the highest straw yield (7.95 t ha⁻¹) were obtained from seed rate of 100 kg ha⁻¹ and irrigation interval of 11 days which were statistically at par with the seed rate of 100 kg ha⁻¹ and irrigation interval of 8 days while the lowest values for these parameters were recorded with seed rate of 75 kg ha⁻¹ and 14 days of irrigation interval. On the other hand, the list harvest index (43%) was record from combination of 150 kg

seed ha⁻¹ and irrigation interval of 14 day.

Thus, from the result of the study, it can tentatively be concluded that use of 100 kg ha⁻¹ seed rate and irrigation interval ranging from 8 to 11 days can improve the productivity of bread wheat in the study area.

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