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Determination of sowing date for irrigated wheat in Metema and Belesa areas of Amhara region, Ethiopia

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ABSTRACT

The sowing date is one of the most important factors in determining irrigated wheat yield. Appropriate sowing dates provide favorable temperatures for obtaining the maximum yield of wheat. Wheat sowing date experiment under irrigation was conducted at Metema (on station) from 2021 to 2022 and at Belesa (on farm) during the 2022 irrigation seasons, to determine the appropriate sowing date for irrigated wheat. Six sowing dates (November 10, November 25, December 10, December 25, January 9, and January 24) were tested in a randomized complete block design (RCBD) with three replications. The combined analysis of variance over years at Metema showed that the sowing date was highly significant ($P<0.01$) for all parameters, whereas at Belesa all parameters were significantly affected by sowing date except days to heading, days to maturity, and spikelets per spike. Early sowing date delayed days to heading and maturity in Metema. Most yield-related traits showed the highest value when wheat was sown on November 10th and the lowest values, when wheat was sown on January 24th in both locations this was due to a higher temperature in delayed sowing caused forced maturity of the crop, which increased respiration, reduced photosynthesis, and accelerated phasic development and resulted in lower yield parameters and final yield of wheat crop. Maximum grain yield (5000 kg ha^{-1}) and above-ground biomass (11164 kg ha^{-1}) were recorded when wheat was sown on November 25 at Metema, whereas at Belesa the maximum grain yield (2737 kg ha^{-1}) and above ground biomass yield (6191 kg ha^{-1}) obtained in the early sowing date (November 10). The minimum grain yield (489 kg ha^{-1}) and above ground biomass yield (2633 kg ha^{-1}) at Metema and the minimum grain yield (1326 kg ha^{-1}) and above ground biomass yield (3873 kg ha^{-1}) at Belesa were obtained as sowing date delayed to January 24th. Therefore, early sowing from November 10 up to November 25 for Belesa and Metema and similar agroecologist recommended as the appropriate sowing dates for irrigated wheat production.

1. Introduction

Bread wheat (*Triticum aestivum* L.) is the second essential cereal crop after rice in the world (Falola et al., 2017). Ethiopia is the largest producer of wheat in Sub-Saharan Africa with an estimated annual production of 6.7 million tones from an area of 2.1 million hectares (1.7 million hectares rain-fed and 0.4 million hectares irrigated) with average productivity of 3 and 4 t ha^{-1} under rain-fed and irrigated conditions, respectively (CSA, 2022). Amhara Region is the second major wheat growing area, accounting for about 1.82 million ton production from a 0.64 million-hectare area with an average productivity of 2.83 t ha^{-1} (CSA, 2021). Wheat occupies a central position in attaining national food self-sufficiency in Ethiopia (Jemal et al., 2015). However, the growing population has affected the existing resources, the problem is also aggravated due to limited cultivated areas almost all wheat is produced under rain-fed conditions (CSA, 2018). Because of this, the country is still a net importer of wheat to meet the demand for food (Anteneh and Asrat, 2020). On the other hand, Ethiopia has extensive irrigation potential estimated to exceed 5.3 million hectares for crop production (Seleshi et al., 2010). The irrigation potential for wheat production in the lowland areas of the country is high, which helps to make the country self-sufficient in wheat within a short period (EIAR, 2020). Changing the current low level of wheat production is the key issue for the Ethiopian government (Gebreselassie et al., 2017). In this regard, more than 400,000 hectares of wheat were cultivated under irrigation in the year 2021/22 production season across the entire country (Gedifew, 2022).

The wheat productivity <2.5 t ha^{-1} under irrigation in the country as well as in the region is far below the average yield obtained at the research stations (7 t ha^{-1}) and on a farm (6 t ha^{-1}) and the potential productivity of the crop (7.5 t ha^{-1}) (EIAR, 2020). So, increasing wheat productivity under irrigation through a quick crop management practices trial like sowing date, seed rate, improved variety, soil management, and other agronomic practices have the key role in increased wheat yield. According to Meleha et al. (2020), sowing date is the least-cost technology and the top problem for wheat productivity. The sowing date is a factor that affects the yield of irrigated wheat. It is different in various climatic conditions of each region and it is temperature dependent (Abbas et al., 2019). Proper sowing date creates suitable environmental conditions (optimum temperature) for growth duration, phenological condition, yield, and yield-related parameters (Yusuf et al., 2019; Meleha et al., 2020). Late sowing exposed to low temperatures at the germination causes delayed emergence and low plant population and higher temperature at the reproductive stage leads to forced maturity and results in a reduction of yield of wheat (Gupta, 2017). Delay sowing date reduced wheat grain yield by 16% (Ouda et al., 2005). Too early wheat sowing produces weak seedlings with poor root systems and prolongs the duration of tillering due to injury in low temperatures that ultimately affects the yield (Ibrahim and Kittani, 2009b). According to Coventry et al. (2011), wheat yield increased from 10 to 80% with the management of the sowing dates and environmental conditions. Hence, proper sowing time is a basic factor for deciding the crop performance and achieving a higher yield (Tahir et al., 2019).

Amhara region especially Gondar is representative of low and middle-altitude, high-irrigated lands and water potential with the availability of some irrigation facilities and had good cropping system (EIAR, 2019). Sesame-soybean and teff-mung bean crop rotation is commonly practiced in Metema and Belesa, respectively where the sowing of wheat crop is determined by the harvesting time of thus precursor crops. A change in temperature and rainfall patterns on the globe and regional aspects due to climate effects have exerted a consequential impact on irrigated wheat production (Meleha et al., 2020). Ethiopia is one of the most vulnerable countries in terms of climate change. Sowing time is varied in different locations depending on the weather, topography, agronomic and genetic factors (Murungu and Madanzi, 2010; Silva et al., 2014). It is temperature dependent; the optimum temperature requirement of the crop in different stages should be optimized for higher yield and productivity (Meleha et al., 2020). Negassa et al. (2013) stated that the minimum, optimum, and maximum average temperatures at which the plant will grow optimally is 15°C, 23°C and 27°C, respectively. This indicates that optimum sowing date is the most important for irrigated wheat yield. However, there is no recommended sowing date for bread wheat production under irrigation conditions based on the local climatic conditions. Therefore, it is important to understand the optimum sowing date of irrigated wheat for enhancing yield in the context of the Metema and Belesa districts of Amhara region. Therefore, this study was conducted to identify the appropriate sowing date for irrigated wheat production under the furrow irrigation technique in Metema and Belesa areas of Amhara region.

2. Materials and Methods

2.1 Description of the study area

The field experiments were conducted in the lowland of West Gondar at Metema for two consecutive years (2021-2022) irrigation seasons and in the mid-land of Central Gondar at Belesa for one year (2022) irrigation season. Metema is located at 12° 20' and 13° 10' N latitude and 36° 5' and 36° 45' E longitude (Figure 1) at an altitude of 681 meters above sea level (NMSAB, 2022). The Belesa area is located with a latitude of 12° 19' to 12° 46' N and a longitude of 37° 37' to 38° 29' E at an altitude of 1500 meters above sea level (NMSABB, 2022). The weather data (temperature and relative humidity) of both locations were collected from the National Meteorology Station Agency Bahir Dar Branch as shown in Figure 2.

2.2. Experimental Treatments, Design and Management

The treatment consists of 6 sowing dates (November 10, November 25, December 10, December 25, January 9, and January 24) and is conducted using a randomized complete block design (RCBD) with three replications. Wheat variety (Kekeba) with a seed rate of 150 kg ha^{-1} drilled in rows at its recommended inter-row spacing of 0.2 m. The gross plot size was 2.8 x 3.5 m (9.8 m^2). The net plot area was 1.2 x 3.5 m (4.2 m^2). The distance between adjacent plots and blocks was 1 and 1.5 m wide, respectively. The total number of rows in the gross and net plots was 8 and 6, respectively. The total number of beds in a plot was four and the total number of rows in one bed was two. The wheat crop was harvested from the center of six rows of the net plot area by excluding the one-row left and one-row right border rows right as border rows. Irrigation was done in-furrow (0.4 m wide) using furrow irrigation technique at the frequency of 7-day intervals. Each plot was fertilized with 92 kg ha^{-1} N in the form of 200 kg ha^{-1} urea and 46 kg ha^{-1} P_2O_5 in the form of 121 kg ha^{-1} NPS. All the recommended amounts of P_2O_5 and 1/2 of N were applied at the time of sowing, while the remaining 1/2 N was applied at the tillering stage. The experimental field land preparation was plowed two times using a tractor at different intervals starting from the first of October and the third plowing was done using oxen and leveled manually for sowing.

2.3. Data Collection and Analysis

Heading and maturity day's data were taken where the plot reaches 90 % of its heading and 85 % maturity period. Data like plant height (cm), spike length (cm), number of spikelets per spike, and kernel per spike were measured at the physiological maturity of the crop from ten randomly selected plants in central 6 rows. Thousand seed weight (g) was recorded by direct weighing of 1000 grain samples from bulked grains of each plot. Grain yield, above-ground biomass yield, and straw yield (kg ha^{-1}) were collected from the central 6 rows.

The homogeneity of variances was tested using the F test as described by Gomez and Gomez (1984). According to the homogeneity test, all traits were homogenous. Following examining the homogeneity of variances all the data were subjected to Analysis of Variance (ANOVA) using Proc Glm of SAS statistical software. The least significant difference (LSD) at a 5% level of significance was used for mean comparisons, whenever the analysis of variance results showed differences among the treatments for traits.

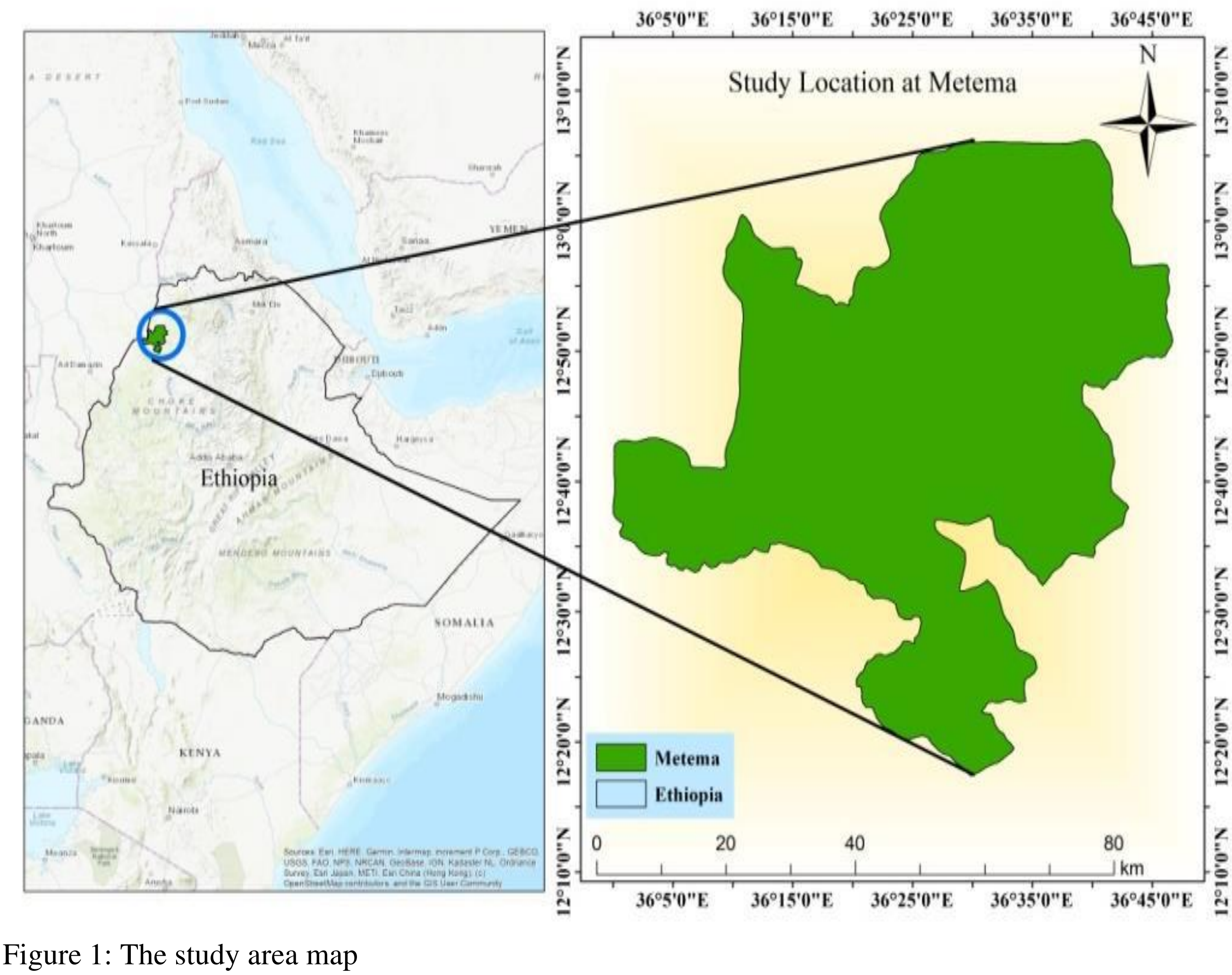

Figure 1: The study area map

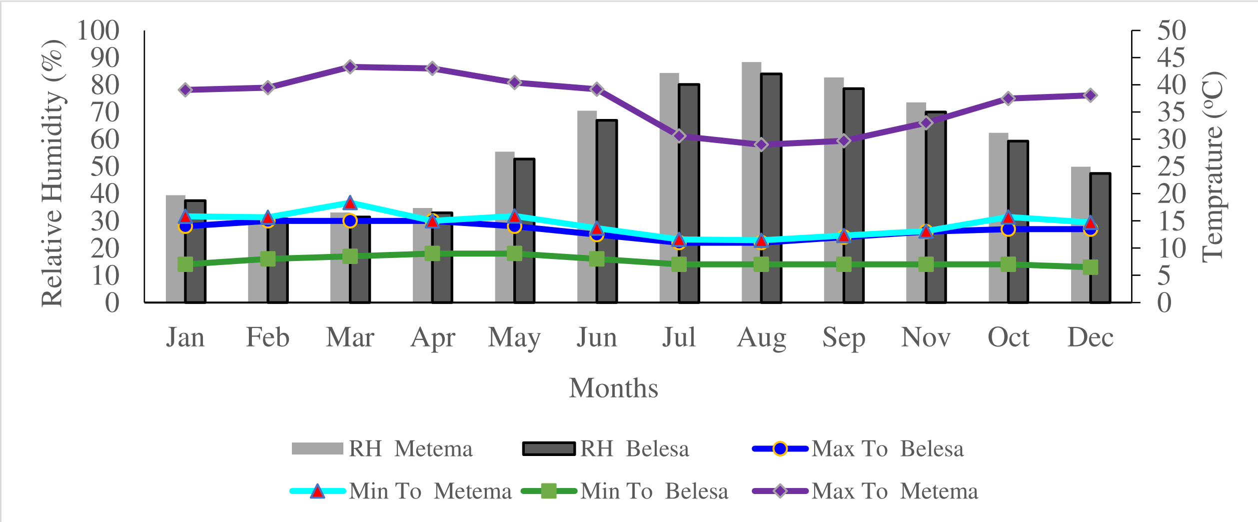

Figure 2: Annual monthly minimum and maximum temperature and relative humidity of Metema and Belesa in 2022 (Data source: NMSABB, 2022)

Table 1: The combined mean square values of ANOVA on wheat in Metema, 2021 and 2022

SoV	DF	DH	DM	PH	SL	SPS	KPS	GY	SY	AGBY	TSW	HI
Year	1	13.4^{*}	10^{**}	9.8^{ns}	3.5^{**}	1^{ns}	0.01^{ns}	5062725^{**}	839239^{ns}	1001923^{**}	21.3^{ns}	568^{**}
Rep (Year)	4	1.5^{ns}	1.2^{ns}	6.9^{ns}	0.3^{ns}	0.2^{ns}	2.6^{ns}	273540^{ns}	720622^{ns}	1314949^{ns}	5.3^{ns}	13.2^{ns}
Tre	5	115^{**}	156^{**}	671.5^{**}	2^{**}	2.7^{**}	337^{**}	17346738^{**}	14237426^{**}	59101339^{**}	114^{**}	613.9^{**}
Year *Tre	5	2^{ns}	21.2^{**}	112^{**}	2.3^{**}	2^{**}	23^{*}	281290^{ns}	2008713^{ns}	2240354^{ns}	20^{*}	157.8^{**}
Error	20	3	0.9	10	0.2	0.5	7.8	140375	829215	1305339	5.4	10.5

*SoV= Source of Variation; DF= Degree of Freedom; Rep= Replication; DH= Day to Heading; DM= Day to Maturity; PH= Plant Height; SL= Spike Length; SPS= Spikelets per Spike; KPS= Kernel per Spike; TSW= Thousand Seed Weight; GY= Grain yield; AGBY= Above Ground Biomass Yield; SY= Straw Yield and HI= Harvest Index.

Table 2: The mean square values of ANOVA on wheat in Belesa, 2022

SoV	DF	DH	DM	PH	SL	SPS	KPS	GY	SY	AGBY	TSW	HI
Rep	2	5.2^{ns}	0.4^{ns}	37.2^{ns}	0.1^{ns}	1.6^{ns}	2.6^{ns}	71802^{ns}	39749^{ns}	112970^{ns}	2.3^{ns}	12.1^{ns}
Tre	5	37.2^{ns}	54.5^{ns}	136.9**	0.9**	2^{ns}	55.7**	922802**	469388**	2362262**	51**	65**
Error	10	45.6	45.3	10.6	0.11	0.7	5.6	34651	17758	89797	2.9	12.7

*SoV= Source of Variation; DF= Degree of Freedom; Rep= Replication; Tre= Treatments; DH= Day to Heading; DM= Day to Maturity; PH= Plant Height; SL= Spike Length; SPS= Spikelets per Spike; KPS= Kernel per Spike; TSW= Thousand Seed Weight; GY= Grain yield; AGBY= Above Ground Biomass Yield; SY= Straw Yield and HI= Harvest Index.

Table 3: The combined effect of sowing date on phenological, growth and yield and yield related traits of wheat in Metema, 2021 and 2022

Treatments	DH	DM	PH (cm)	SL (cm)	SPS	KPS	GY (kg ha^{-1})	SY (kg ha^{-1})	AGBY (kg ha^{-1})	TSW (g)	HI (%)
10-November	59^{a}	89^{a}	81.2^{a}	8.4^{a}	13.5^{a}	38.7^{a}	3637^{b}	6395^{a}	10032^{ab}	34.9^{a}	36.7^{b}
25- November	56^{b}	86^{b}	73.9^{b}	7.9^{b}	13.3^{a}	38^{a}	5000^{a}	6165^{a}	11164^{a}	36.6^{a}	44.7^{a}
10-December	52^{c}	85^{c}	71b^{c}	7.3^{c}	13.2^{a}	34.7^{b}	3612^{b}	5468^{ab}	9079^{b}	34.8^{a}	40^{b}
25- December	52^{c}	82^{d}	68.3^{cd}	8.7^{a}	13.5^{a}	32^{c}	2261^{c}	4894^{b}	7154^{c}	30^{b}	31^{c}
9-January	51^{c}	78^{e}	66.3^{d}	8.4^{a}	12.7^{a}	28^{d}	1158^{d}	4549^{b}	5706^{d}	27.5^{bc}	20^{d}
24-January	47^{d}	76^{f}	49.6^{e}	8.7^{a}	11.8^{b}	22.5^{e}	489^{e}	2144^{c}	2633^{e}	26.2^{c}	21^{d}
LSD%	2	1.1	3.8	0.5	0.8	3.4	451	1097	1376	2.8	3.9
CV	3.2	1.2	4.6	5	5.3	9	14	18	15	7.4	10
Mean	53	83	68.4	8.3	13	31.2	2693	4936	7628	31.6	32.3

3. Results and Discussion

The combined analysis of variance over years at Metema showed that the sowing date was highly significant ($P<0.01$) for all recorded parameters (Table 1). The variance analysis at Belesa in 2022 showed sowing dates had highly significant ($P<0.01$) for all parameters except days to heading, days to maturity, and spikelets per spike (Table 2).

3.1. Days to heading and maturity

The maximum number of days to heading (59) and days to maturity (89) in Metema were recorded when sowing was done on November 10th. The minimum number of days to heading (47) and days to maturity (76) recorded as sowing was delayed to January 24th (Table 3). Early sowing took 12 and 13 additional days to full heading and maturity compared with late sowing dates, respectively. The flowering in plants is delayed with a timely sown crop because the crop is exposed to favorable weather during the whole life cycle and thus the different phases of plant life could be completed at appropriate timing. Under later sown conditions the plants were forced to early flowering because of a sudden temperature rise coupled with hot wind (Singh et al., 2022).

3.2. Plant height

The tallest (81.2 cm) and the shortest (49.6 cm) plant heights were recorded in 10-November and in January 24 sowing date at Metema, respectively (Table 3). The tallest (64 cm) and the shortest (45.8 cm) plant heights were recorded on 25 November and January 24 sowing date at Belesa, respectively. However, there was no significant difference between the November 10th and November 25th sowing dates for plant height in Belesa (Table 4). The difference in plant height in different sowing dates might be due to late sowing shorter growing periods for vegetative growth and starting the reproductive phase earlier, while early sowing gets suitable environmental conditions (temperature and solar radiation) that encourage the tallest plants.

The results are in harmony with those obtained by Sharma (2003) who stated that sowing earlier seemed to be more favorable for producing the tallest plants compared to later sowing dates.

3.3. Spike length

The longest spike length (8.7) obtained at the sowing date of December 25 and January 24 statically no difference with November 10 and January 9 while, the shortest spike length (7.3) at the sowing date of December 9 at Metema (Table 3). This research result had no significant difference between the early and late sowing date for spike length might be due to the poor interaction between temperature and spike length. On the other hand, the significantly longest spike length (7.5) was obtained at the sowing date of November 10, whereas the shortest spike length (6) at the sowing date of December 25, which had no significant difference with other sowing, dates at Belesa (Table 4). These findings were strongly supported by Kabir et al. (2019) who reported that the highest spike length was recorded on 13th November while the minimum spike length was recorded on 3rd December.

3.4. Number of kernels per spike

Sowing wheat on 10th November obtained the highest number of kernels per spike (38.7) at Metema and (41.6) at Belesa. The lowest kernel per spike (22.5) at Metema and (28.7) at Belesa was recorded as the sowing date was delayed to January 24 (Tables 3 and 4). The maximum number of kernels per spike early sowing may be due to the available weather conditions during plant life that helped rapid growth and formation of a good canopy able to make good photosynthesis. These results matched with research done by Kalatearabi et al. (2011) who reported that the number of grains per spike was affected by planting date because of delayed planting, plants encounter thermal stresses at the end of their growing season. These results are also in line with Tamiru Dejen et al. (2024) who observed that the maximum number of kernels per spike was obtained when wheat was sown on the optimum date of 30th and 15th October respectively, compared with late sowing dates of 30th and 15th December.

3.5. Number of spikelets per spike

The maximum (13.5) and the minimum (11.8) spikelets per spike were obtained at the sowing date of November 10 and January 24, respectively, but there was no significant difference in November 10 results with the remaining sowing dates (Table 3). The results about the spike length of wheat as significantly influenced by various sowing dates in the findings of Vahid et al. (2010). In contrast to this result, Kabir et al. (2019) reported that the number of spikelets per spike did not vary significantly due to different dates of sowing.

3.6. Grain yield

The highest grain yield (5000 kg ha^{-1}) was obtained when wheat was sown on 25th November, and the lowest value (489 kg ha^{-1}) was obtained at the sowing date on 24th January (Table 3) at Metema. A grain yield of 2737 kg ha^{-1} was obtained when wheat was sown on 10th November and decreased to 1326 kg ha^{-1} when wheat was sown on 24th January (Table 4) at Belesa. The result revealed that sowing from 10-25st November gave maximum yield might be due to the presence of higher spike length and grains per spike as well as a 1000-grain weight while the lowest yield obtained under late sowing dates might be due to the lowest value of all these yield attributes which may be result for lesser grain yield. Moreover, the decline in grain yield with delayed sowing may be due to high temperatures (in December 38.1℃ and in January 39.1℃) that caused forced maturity of the crop and resulted in lower yield parameters and final yield of irrigation wheat. Similar results have been reported by Singh et al. (2022) who obtained that wheat sown on November 20, displayed more grain yield (4146 kg ha^{-1}) and under late sowing (20th December) lesser grain yield (3611 kg ha^{-1}). This result was in line with Mitasha et al. (2022) who stated that higher grain yield in early sowing was mainly due to higher germination count, number of tillers, and number of grains per spike and 1000-grain weight. Habibi and Fazily (2022) reported that higher temperatures during anthesis in delayed sowing caused forced maturity and a decrease in the carbohydrate accumulation that produces smaller grains and limits grain yield. Furthermore, these results in accordance with those of Tamiru Dejen et al. (2024) who reported that late sowing results in less grain yield per hectare.

3.7. Straw yield and Biomass yield

Like that of grain yield maximum (6395 kg ha^{-1}) and minimum (2144 kg ha^{-1}) straw yield at Metema (Table 3) and the maximum (3453 kg ha^{-1}) and minimum (2314 kg ha^{-1}) straw yield at Belesa (Table 4) recorded at 10th November and 24th January, respectively. The maximum above-ground biomass yield (11164 kg ha^{-1}) in Metema and (6191 kg ha^{-1}) in Belesa were recorded on 25th and 10th November, respectively (Table 3 and 4). The minimum above-ground biomass yield (2633 kg ha^{-1}) at Metema (Table 3) and (3873 kg ha^{-1}) at Belesa (Table 4) was recorded on 24th January. Abdel-Nour et al. (2011) found that all studied characters were significantly highest in the optimum date compared to the late and early dates of planting. These results are in line with Tamiru Dejen et al. (2024) who reported that early sowing resulted in higher straw yield due to a greater number of tillers and plant height.

3.8. Thousand seed weights

The highest 1000-grain weight (36.6 g) was recorded wheat sown on 25th

November, whereas the lowest (24.4 g) 1000-grain weight was recorded when wheat sown on 24th January at Metema (Table 3). The highest (33.2 g) and the lowest (22.7 g) value 1000-grain weight was recorded on November 10th and January 24th at Belesa (Table 4). Thousand seed weights increased early sowing date might be due to the suitable and longer environmental conditions for vegetative growth, which resulted in the active photosynthesis and maximum translocation of assimilates to the grains and thus had heaviest grains. These results are in agreement with those obtained by Tamiru Dejen et al. (2024) who reported that the grain weight decreased significantly with each day delay in sowing. Delayed sowings produced the lowest test weight due to windy conditions that prevailed during the milking and grain-filling stages; the drop in test weight caused by the delay in seeding was mostly the result of a shorter growth period (Mitasha et al., 2022).

3.9. Harvest index

The highest (44.7%) and lowest (20%) harvest index at Metema was obtained at the 25th November sowing date and the 9th January sowing date, respectively. The lowest (20%) harvest index in 9th January similar to the 24th January sowing date harvest index (21%) at Metema (Table 3). At Belesa the highest (45.3%) and the lowest (34.3%) harvest indexes were obtained on November 25 and January 24, respectively, however there was no significant difference between the first and second sowing date and between January 24 and January 9 sowing date (Table 4). These results are in agreement with those of Ali et al. (2015), who reported that the maximum harvest index was observed in early sowing (November 16th), while the minimum was noted in late sowing (1st January).

Table 4: The main effect of sowing date on phenological, growth and yield and yield related traits of wheat in Belesa, 2022

Treatments	DH	DM	PH (cm)	SL (cm)	SPS	KPS	GY (kg ha^{-1})	SY (kg ha^{-1})	AGBY (kg ha^{-1})	TSW (g)	HI (%)
10-November	56.0	96	58.6^{ab}	7.5^{a}	13.7	41.6a	2737a	3453^{a}	6191^{a}	33.2^{a}	44^{a}
25-November	55.0	94	64^{ab}	6.4^{b}	11.8	35.1^{b}	2221^{b}	2645^{b}	4865^{b}	30.2^{ab}	45.3^{a}
10-December	53.7	91	59^{ab}	6.1^{b}	11.7	35^{b}	2080^{b}	2641^{b}	4794^{b}	29.2^{b}	43.3^{ab}
25-December	50.7	89	55.4^{b}	6^{b}	11.5	34.7^{b}	1504^{c}	2548^{bc}	4018^{c}	28.3^{b}	37.3^{bc}
9-January	50.0	88	$49.^{c}$	6.3^{b}	11.5	31.7^{bc}	1433^{c}	2508^{bc}	3941^{c}	23.2^{c}	36.3^{c}
24-January	46.7	84	45.8^{c}	6.2^{b}	11.9	28.7^{c}	1326^{c}	2314^{c}	3873^{c}	22.7^{c}	34.3^{c}
LSD (%)	NS	NS	5.9	0.7	NS	4.3	339	242	545	3.1	6.5
CV (%)	13	7.5	6	6	7	7	10	5	6.5	6.2	9
Mean	52	90	55.3	6.4	12	34.5	1884	2685	4614	27.8	40

*NS= non-significant

4. Conclusions

In conclusion, the sowing date November 25 gave the highest yield of 5000 kg ha-1 in the case of Metema and November 10 gave the highest yield of 2737 kg ha-1 in the case of Belessa. The yield obtained from the highest yield-giving sowing dates for Metema is better than Belessa. Results confirmed that inherent genetic yield potential is not enough to obtain a high wheat yield. Overall, at Metema, with the same varieties, the highest wheat yield was around 5000 kg ha-1 wheat sown on November 25 higher than at Belesa which gave 2737 kg ha-1 when wheat sown on November 10. The effect of sowing date on the grain yield traits was more open. Irrigated wheat sown on 25 November showed superior performance with a higher grain yield of 5000 kg ha^{-1} at Metema while wheat sown on 10 November showed superior performance with a higher grain yield of 2737 kg ha-1 at Belesa. While delayed sowing to late December and January showed adverse effects on the growth and yield parameters in all test locations. Therefore, early sowing from November 10 up to November 25 for both Metema and Belesa areas and similar agro-ecologies are recommended to enhance wheat productivity and similarly, other wheat trials are also sown under this range.

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