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Optimizing Sowing Date for the Productivity of Durum Wheat (*Triticum turgidum* L. var. Durum) in Central Highland of Ethiopia

Bizuwork Tafes Desta*, Almaz Meseret Gezahegn, Sisay Eshetu, Abuhay Takele

Department of Agronomy and Crop Physiology, Ethiopian Inistitute Agricultural Reseach, Debre Zeit Agricultural Research Center, Debre Zeit, Ethiopia

Email address:

b.tafes@gmail.com (B. T. Desta), almimeseret@gmail.com (A. M. Gezahegn), siscoeshetu23@gmail.com (S. Eshetu), kidumet94@gmail.com (A. Takele)

*Corresponding author

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Abstract: The field experiments were carried out at Debre Zeit Agricultural Research Center during the main cropping season between 2015 and 2017 to determine best sowing date for durum wheat productivity. The treatments were consisted of a factorial combination of four sowing date (late-June, mid-July, Late-July and mid-August) and two durum wheat varieties (Ude and Mangudo). The experiment was laid out in a randomized complete block design with three replication. Results showed that the main effect of sowing date had a significant effect on growth, yield and yield components of durum wheat. In contrast, main effect of variety and interaction effects of variety with sowing date had not a significant effect on growth, yield and yield components of durum wheat. The highest aboveground biomass yield (8990.7 kg/ha) and grain yield (3504.6 kg/ha) were obtained when durum wheat was sown in mid-July, but it was not significantly different yield from late-June. Based on 30 years rainfall data, the possibility of occurrence of dry spell is less during this period. Therefore, sowing of durum wheat from late-June to mid-July can be recommended for durum wheat production in the study area.

Keywords: Durum Wheat, Sowing Date, Yield, Varieties

1. Introduction

Durum wheat (*Triticum turgidum* L. var Durum) is the second most cultivated wheat species in the world, next to common wheat [1]. Ethiopia is considered a center of diversity for durum wheat (*Triticum turgidum* L var. durum). The crop has been under cultivation since ancient times. It covers 24% of the total cultivated lands used for durum wheat in Ethiopia. It is mainly grown on heavy black clay soils (*Vertisols*) of highlands with altitude range of 1800 to 2800 meter above sea lavel exclusively under rain fed conditions [2]. Durum wheat is the best wheat for pasta products due to its strong gluten, excellent amber color and superior cooking quality. It consumed traditionally in Ethiopia in the form of whole wheat, fermented and leavened local bread [3]. Although Ethiopia is the center of origin for durum wheat and the crop plays a significant role for the farmers and industries, the average yield which is 2.2 t/ha [4] is far below the yield potential of the crop. Lack of improved varieties, inadequate and erratic rainfall, poor agronomic practices, diseases and insect pests are among the principal limitations to wheat production in Ethiopia [5]

Sowing date is one of the most important agronomic factors which need great emphasis for maximum yield of crops. Durum wheat grain yield are dependent on the environment, genetic factors and the interaction between them [6]. Optimum sowing date positively affect grain yield of wheat and causing better adjustment to the physiology, phenology and environmental conditions [7, 8]. In addition, the appropriate sowing date also affects the water, temperature and solar radiation available for the crop. The highest values of some vegetative characters, yield attributes

and grain yields as well as enhancement in biological and economical yield occurred when wheat planted earlier [9].

A Sowing date trials at Debre Zeit Agricultural research center showed that the highest grain yield (2306 kg/ha), was obtained when improved durum cultivars planted on June 22 [10]. However, the optimum calendar date for sowing varied from year to year, presumably due to variation in rainfall. Moreover, each variety have their own specific requirements for sowing dates, seed rate and nutrients to determining crop growth and productivity [11]. To this end, it is worth to investigate appropriate sowing date for new released varieties to advance production and productivity of durum wheat. Therefore, the present study was designed with the objectives to determine appropriate sowing date that can increase productivity of durum wheat varieties.

2. Materials and Methods

2.1. Description of Experimental Site

The field experiments were conducted at DZARC (Debre Zeit Agricultural Research Center) during three consecutive (2015 to 2017) cropping seasons under rain fed condition. The site is located in East Shewa Zone of Oromia Regional State. It is found at 47 km away from South East of the capital city of Ethiopia, Addis Ababa. Its geographical location is 8°44′N latitude and 38°58′E longitude. The altitude is about 1900 meter above sea level. The soil type of the site is *Vertsiol* [12]. The total monthly rainfall of the experimental site during 2015 to 2017 is presented in Figure 1. The area received total rainfall of 433.2 mm, 459.6 mm and 596.3 mm during 2015, 2016 and 2017 cropping season (June to December) respectively.

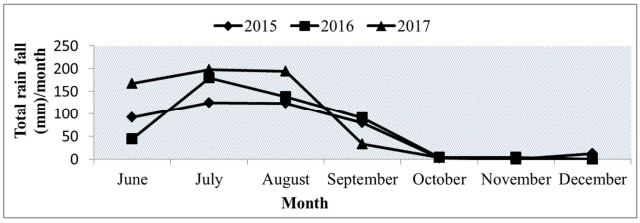


Figure 1. *In 2015-2017 total monthly rainfall during the cropping season (June to December) at DZARC.*

2.2. Experimental Design and Treatments

The experiment was laid out in a randomized complete block design with three replications. The treatments were consisted a factorial combination of four sowing date (late-June, mid-July, Late-July and mid-August) and two durum wheat varieties (Ude and Mangudo). The plot size of $9m^2$ (3m x 3m) was used for all treatments. The spacing between blocks and plots was 1m and 0.5 m, respectively. Each plot consisted of fifteen rows and spaced 20 cm apart. The net central unit areas of each plot consisting of eight central rows of 2.80 m long were harvested and used for yield determination, whereas the others two outer rows were kept as border plants.

2.3. Experimental Field Management

The field was ploughed and harrowed to fine the plot using a tractor. The seeds was sown with hand drilling at the rate of 150 (kg ha^{-1}) in 20 cm rows spacing. Recommended rate of 76 kg/ha N and 46 kg/ha P_2O_5 were applied. Urea (46% N) and Diammonium phosphate (DAP) (46% P_2O_5) were used as the source of N and P respectively. The full dose of P_2O_5 and one-third of N fertilizer were applied at the sowing time and remaining two-third of N fertilizer was applied at tillaring stage as a top dressing. Other agronomic practices were kept uniform for all treatments. The crop was harvested manually at physiological maturity, when the vegetative parts turned to yellow and samples were taken from a sample quadrat of 2 m x 2 m for each plot.

2.4. Data Collection

Data such as, plant height, spike length, number of productive tillers, number of seed per spike, aboveground biomass yield kg/ha, grain yield kg/ha, thousand kernels weight and harvest index were taken. Thirty yeas rain fall data were taken form DZARC to confirmed the onset, endset and length of growing period in the study area.

2.5. Data Analysis

The data subjected to combined analysis of variance (ANOVA) over years after confirmation of homogeneity of error variance using Gen Stat version 17th ed software program. The means were compared by LSD method at 0.05 probability level. The long year (1987-2017) historical rainy seasons and dry spells (within the rainy season) were analyzed based INSTAT soft ware years daily weather data.

3. Results and Discussion

3.1. Plant Height

The combined analysis of variance over years showed that the effect of sowing date was significantly ($P < 0.001$) affected the plant height. However, main effect of variety and their interaction effect with sowing date were not significant. The tallest plant height (77.19 cm) was obtained from sown in mid-July but it was at par with plant height recorded from sown in late-June. The shortest plant height (66.65cm) was recorded on delayed sowing (mid-August). In general, late-June to mid-July sowing increased plant height of durum wheat. This increment in plant height might be due to the fact that at early sowing crop may have enjoyed better environmental conditions especially soil moisture, temperature and solar radiation which resulted to tallest plants. In conformity with this result, [13] reported that increasing of plant height of wheat in early sowing.

3.2. Spike Length

Combined analysis of variance over three years (2015 and 2017) revealed that only main effect of sowing dates had a significant effect ($P<0.05$) on spike length of the crop (Table

1). In contrast, the main effect of variety and the interaction between variety and sowing dates did not affect spike length. Among different sowing dates, the longest spike length (7.06 cm) recorded when the crop was sown in mid-July, whereas the shortest of spike length (6.22cm) obtained when the crop sown in mid-August (Table 1). Generally, spike length was increased by about 13.83% when the crop was sown on mid-July as compared to that of delayed sowing (mid-August). These results are strongly supported by [14] who reported sowing date is significant influence on the spike length of wheat crop.

3.3. Number of Productive Tillers/Plant

Neither the main effect nor the interaction effect of variety and sowing date were significant on number of productive tillers per/plant (Table 1).

3.4. Number of Seeds per Spike

Number of seeds per spike was significant ($P<0.05$) effect was observed by main effect of variety and sowing date. However, the interaction effects of variety by sowing date were not significant (Table 1). Ude variety gave the higher (42.49) seeds per spike as compared to Mnagudo variety (39.42). Regarding on the sowing date, sowing of durum wheat on late-June gave the maximum number of seed per spikes (43.82) as compared to mid-August which showed the lowest (37.96) value for number of seeds per spike (Table 1). Similar observations are in line with those of [13].

Table 1. *Means of spike length, plant height, number of productive tillers and number of seed per spike of durum wheat as influenced by variety and sowing date at Debre Zeit in 2015 to 2017 cropping season.*

Treatments				
Variety	**PH (cm)**	**SL (cm)**	**NPT**	**NSP**
Ude	72.84	6.82	6.98	42.49a
Mangudo	71.72	6.70	6.86	39.42b
LSD (0.05)	ns	ns	ns	2.30
Sowing date				
Late –June (28-June)	76.73a	6.73b	7.13	43.82a
Mid-July (15-July)	77.19a	7.06a	7.05	43.00a
Late-July (30-July)	68.55b	6.52b	6.90	39.05b
Mid-August (15-August)	66.65b	6.72b	6.60	37.96b
LSD (0.05)	5.73	0.41	ns	3.26
CV (%)	9.60	7.35	17.82	11.95
Variety X Sowing date	ns	ns	ns	ns

PH= plant height; SL= spike length; NPT= Number of productive tillers; NSP= number of seed per spike; Means with the same letter in columns are not significantly different at 5% level of significance; LSD= least significant differences at 5%; CV (%) = Coefficient of variation

3.5. Aboveground Biomass Yield

Effect of variety and sowing date on aboveground biomass yield of durum wheat at Debre Zeit during 2015 and 2017 cropping season are presented in Table 2. The combined analysis of variance over three years revealed significant ($p<0.05$) difference among sowing dates for aboveground biomass yield. However, main effect variety and the interaction effects of the two factors (sowing date x variety) were not significant. The highest aboveground biomass yield (12806 kg/ha) was obtained when durum wheat was sown on mid-July, whereas lowest aboveground biomass yield (10222 kg/ha) in case of late sowing i.e. mid-August (Table 2). The total aboveground dry biomass yields obtained durum wheat was sown mid-July at Debre Zeit exceeded the lowest aboveground dry biomass yield produced by 25.28% compared to delay sown (mid-August). This yield advantage achieved in early sowing was mainly due to better stand establishment per meter of the crop, added more number of productive tillers/plant, longer spike length and plant height, cumulatively increased biomass yield. Previous research work indicated that at Debre Zeit Agricultural Research station, the highest aboveground biomass yield (12306 kg/ha) for improved durum cultivars was obtained with early sowing (June 22) [10].

3.6. Grain Yield

Sowing date is one of the major factors that influence growth and yield of crops. The combined analysis of variance over three years revealed that significant ($p<0.05$) difference among sowing dates for mean grain yield of durum wheat. However, the main effect of variety and the interaction effect of the two factors did not influence the grain yield (Table 2). The maximum grain yield (3504.6 kg/ha) was produced when the crop was sown in mid-July compared to sown in mid-August which produced minimum grain yield (2500.9 kg/ha). However, the mean grain yield of durum wheat produced when the crop was sown in mid-July, statistically at par with the grain yield obtained from late-June) (Table 2). In general, sowing on mid-July at Debre Zeit, of durum wheat gave 40.13% enhancements in grain yield compared to delay sowing (mid-August). This might be due to the fact that sowing earlier, produced maximum vegetative and reproductive components like more number of plants emerged/m^2, more number of productive tillers/plant with better survival, more number of kernels/spike, which in return yielded more grain yield. Similarly to this result, the highest yield (2306 kg/ha) for improved durum cultivars was obtained with early sowing (June 22); with late August sowing, an 83% yield loss was incurred at Deber Zeit station [10]. In contrast with the current result, earlier research result showed that late sowing dates (early-August sowing produced 30% higher grain yields than that of early sowing dates (sowing in late-June through July) on vertisol [15].

3.7. Thousand Kernels Weight and Harvest Index

The combined analysis of variance indicated non-significant effects of variety and sowing dates as well as the interaction of these two factors on the thousand kernels weight and harvest index of durum wheat (Table 2). Thousand kernels weight is more governed by genetics rather than the environments. Although, statistically not significant but numerically the heavier seeds (50.38 g) and highest present of harvest index observed, when the crop was sown at early sowing. There was a gradual decrease in grain weight and harvest index with each successive sowing and the minimum grain weight (48.13g) and harvest index (24.46) was observed in delay sown (mid-August).

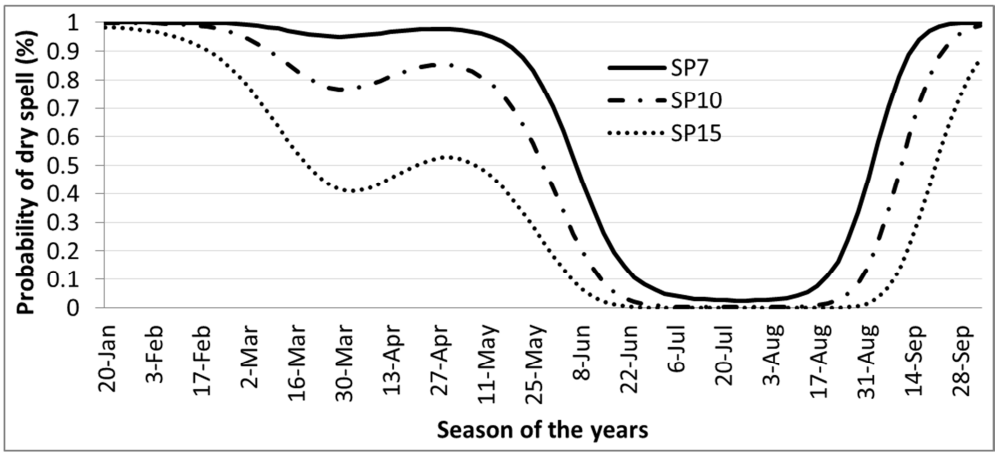
Table 2. *Means of aboveground biomass yield, grain yield and thousand kernels weight and harvest index of durum wheat as influenced by variety and sowing date at Debre Zeit in 2015- 2017 cropping season.*

Treatments				
Variety	**AGBY (kg/ha)**	**GY (kg/ha)**	**TKW (g)**	**HI (%)**
Ude	11560	3173.1	50.02	27.45
Mangudo	11472	2906.5	48.71	25.33
LSD (0.05)	ns	ns	ns	ns
Sowing date				
Late –June (28-June)	12556a	3347.2ab	50.38	27.35
Mid-July (15-July)	12806a	3504.6a	49.83	27.37
Late-July (30-July)	10481b	2806.5bc	49.13	26.77
Mid-August (15-August)	10222b	2500.9c	48.13	24.46
LSD (0.05)	1470.9	689.21	ns	ns
CV (%)	15.32	17.19	17.49	15.45
Variety x Sowing date	ns	ns	ns	ns

AGBY= aboveground biomass yield; GY= grain yield; TKW=thousands kernel weight; HI= harvest index; Means with the same letter in columns are not significantly different at 5% level of significance; LSD= least significant differences at 5%; CV (%) = Coefficient of variation

3.8. Percentile Description of Onset, End Date, Length of Growing Duration of the Season

The occurrence of rainy seasons and dry spells (within the rainy season) was carried out based on frequency analysis of 30 years (1987-2017) at DZARC daily weather data. The onset, end date and length of growing period are presented in Table 3. Onset of rainy seasons occurred before 1st dekad of June (2-Jun) was 25% while it occurred before 3rd dekad of June (24-Jun) in 75% with coefficient of variation (CV) of 7.96% at DZARC. On the other hand, the end date of rainy season occurred before 3rd dekad of September (26-Sep.) was 25% and occurred.



Source; (DZARC meteorology data)

Figure 2. *Probability of dry spell period over 30 (1987-2017) at DZARC.*

Table 3. *Summary of Onset, end rain season and LGP for 30 years (1987 to 2017) at DZARC.*

	Statistical parameter	**Onset**	**End date**	**LGP (No of days)**
Debre Zeit	Minimum	01-Jun	16-Sep	68
	Quartile 1 (25%)	02-Jun	26-Sep	100
	Median Quartile 2 (50%)	18-Jun	06-Oct	108
	Quartile 3 (75%)	24-Jun	07-Oct	109
	Maximum	19-Jul	23-Oct	131
	Mean	16-Jun	03-Oct	121
	SD	13.37	8.65	14.39
	CV (%)	7.96	3.12	13.32

3.9. Probability of Dry Spell Occurrence

As shown in figure 2, the probability of dry spell period of 7, 10 and 15 days of dry spell <10% occurrence are between 8-June to 10-August. The dry spell length occurred at seedling growth, flowering and grain filling stages more than 10% in the rain season of any of crop is most sensitive and potentially damaging [16]. The current result, also indicated that sowing of durum wheat between late June (28) to mid-July (15) less dry spell probability occurrence.

4. Conclusion

Based on the result, growth, yield components and yield of durum wheat were affected by the dates of sowing. Durum wheat sown in between late-June (28-June) to mid-July (15-July) had a significant yield difference compared to late sowing dates (28-July and 15-August). The thirty year rainfall data showed 75% of a relative frequency of the onset of rain was on June 24 and an offset on October 07. Moreover, less dry spell probability occurrence <10% was shown in between, 22-June to 8-August. Therefore, we conclude that sowing of late-June to mid-July can be recommended for the durum wheat productivity at Debre Zeit.

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