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## The Effects of Sowing Date and Variety on Yield and Yield Components of Teff under Irrigation in Northwestern Amhara, Ethiopia

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### ABSTRACT

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Teff cultivation under irrigation is emerging as a new practice in Amhara region, Ethiopia. Thus, teff production under an irrigation environment necessitates optimization of agronomic practices including the sowing dates. Therefore, the experiment was carried out to determine the optimal sowing date for teff production in Koga irrigation scheme during the 2021-2022 seasons. A field experiment was designed with treatments consisting of two varieties (*Quncho* and *Tsedey*) having different maturity periods and seven planting dates (November 1<sup>st</sup>, November 15<sup>th</sup>, December 1<sup>st</sup>, December 15<sup>th</sup>, January 1<sup>st</sup>, January 15<sup>th</sup>, and February 1<sup>st</sup>). The treatments were arranged in a split-plot design with three replications. Variety was considered as the main plot factor and the sowing date as the sub-plot factor. Data of plant height, days to maturity, panicle length, grain yield, and biomass yield were collected and subjected to analysis of variance. The combined analysis of variance over the years showed a significant difference in response to varieties and sowing date on grain yield. However, the interaction effect was not significant. The long maturing variety, *Quncho*, had a higher grain yield than the medium maturing variety, *Tsedey*. Concerning the sowing dates, treatments sown on December 1<sup>st</sup> recorded the highest grain yield (2528 Kg ha<sup>-1</sup>) which was statistically similar with December 15<sup>th</sup> sown treatment. Therefore, December 1 to 15<sup>th</sup> could be recommended as optimum sowing dates for late maturing teff varieties like *Quncho* in Koga irrigation scheme and similar agro-ecologies. However, if double cropping is a target, the early maturing variety, *Tsedey*, could be a better alternative using the aforementioned sowing dates.

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## 1. INTRODUCTION

Teff (*Eragrostis tef* L) has been grown in Ethiopia for thousands of years and is one of the country's most important crops. Teff can be produced both by irrigation and rain-fed systems in Ethiopia. Nevertheless, the majority of produce comes from rain-fed production systems. Teff production in the main season exceeds over 3.1 million hectares annually in Ethiopia. Ethiopian has the largest harvest in the world, with 5.8 million tons and a productivity of 1.843 tons per hectare (CSA, 2020). The crop cultivated mainly for the preparation flat bread locally called *Injera*. *Injera* is the most favorite food in Ethiopia and consumed in their daily meal as Asian do for rice. Straw is a multipurpose material that is primarily used for livestock feed and the preparation of home bricks (Minten *et al.*, 2018).

Recently teff production under irrigation is become popular in Amhara region. Low water demand during the growing period associated with the high price of teff grain could be the reason for wider expansion of the crop under irrigation. As a C4-plant, only two to three irrigations are enough throughout the growing season in Vertisols of Fogera district while the number of irrigations increased in Nitosols of Mecha. As a new crop under the irrigation system, most of the agronomic practices of teff are not optimized. Among all the management aspects, the sowing date imposes an urgent challenge to be resolved immediately. Compared to the main rainy season, there is a change in temperature and light conditions during the winter season.

According to said *et al.* (2013) planting date determines the quality and yield performance of many crops. It regulates the kind of environmental conditions to which the various phenological stages of the crop to be exposed. Plants adapted to hot summer show injury when experiencing non-freezing cool temperature (David *et al.*, 1990). Studies indicated that temperature is a major environmental agent that determines the rate of plant growth and development (Mohammed *et al.*, 2021). Nevertheless, the temperature of the area distinctly varies from month to month. This implies that determining of sowing date is definitely important in teff production especially under irrigation condition. Planting date determines the temperature received at growth, flowering, and fruiting stage of the

crops. Changing the sowing time directly affects both the thermos and photoperiod, which largely affects the phenological development and biomass accumulation of crop plant (Patel, 2019). Crop sown late is usually affected by hot temperature prevailing in March and April in the west Amhara region. Overall, timely planting of crops generally ensures sufficient time for root development, vegetative growth, and yield. There are also cases to escape peak periods of weed infestation, temperature, and disease damage through proper manipulation of planting time. Like planting date, the variety used is also a major factor to achieve higher yield. Teff showed long, short, and medium maturing periods. It has not yet been determined which variety of teff should be planted under irrigation conditions. There are opinions that late maturing variety may show difficulties in land preparation, harvest, and post-harvest management practices with the main season crop. Early showers of rainfall adversely affect harvesting and lead to teff shattering. Over 30 percent of yield loss recorded in teff is due to shattering. Early set variety is believed to be best suited for irrigation. It increases the number of harvestings per season. Therefore, this experiment was conducted with the objective of determining the optimum sowing date for teff varieties under irrigation conditions in Mecha district.

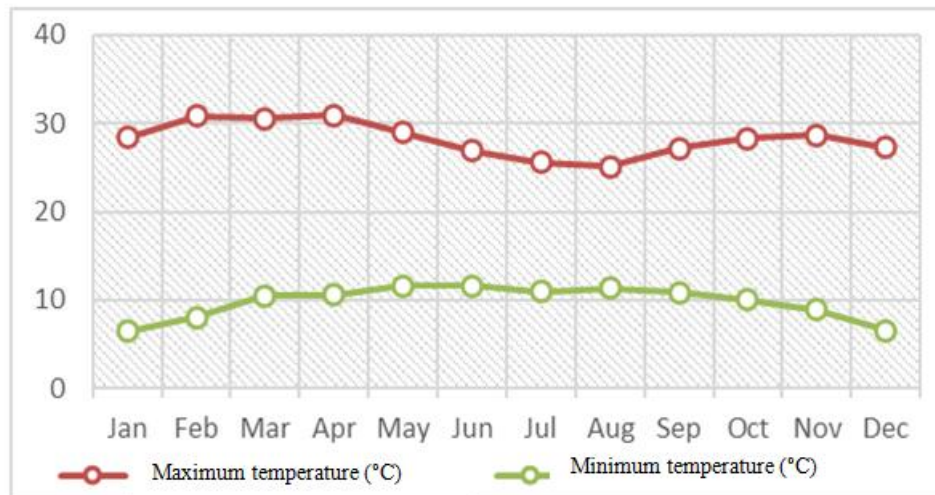
## 2. MATERIALS AND METHODS

### 2.1. Description of the Study Area

The experiment was carried out on station and farmers field from 2021-2022 in Mecha districts of northwestern Ethiopia, where over 7,000 hectares of modern irrigation scheme constructed and have been operating (Ayalew *et al.*, 2008). Mecha district is located at 11° 24' 12" to 11° 30' 12" north latitude and at 36° 51' 12" to 37° 24' 12" east longitude. The altitude ranges from 1500 to 23000 meters above sea level and one of the minor producers of teff in the region during the main rainy season (Densaw *et al.*, 2016). Mecha area had mean annual minimum and maximum temperatures of 12 °C and 28 °C, respectively (IWMI, 2011). However, the average mean minimum and maximum temperatures from November to March were 7.4 °C and 29.1 °C, respectively (Figure 1). Well-drained Nitosols is the dominant soil type of the study area. A

mixed farming system is a common practice where the majority of crops are grown mainly under rainfall conditions (Yenesew et al., 2011). Maize, finger millet, and lupine are the major crops grown in the main season. Wheat, onions, pepper, cabbage, and potatoes are the major crops produced under irrigation

conditions (Densaw et al., 2016). The district experiences four distinctly varied seasons namely summer from June to August, autumn from September to December, winter from December to February, and spring from March to May (Legese et al., 2008).



**Figure 1:** Average monthly minimum and maximum temperature of the study area (2013-2022)

## 2.2. Treatment Setup

The treatment consisted of two varieties (Quncho and Tsedey) (Table 1) having different maturity periods and seven sowing dates (November 1st, November 15th, December 1st, December 15th, January 1st, January 15th, and February 1st). Tsedey is an early-maturing variety, whereas Quncho is a long-maturing one (Tobe et al., 2013; Woldeyohannes et al., 2022). The treatments were arranged in a split-plot design with variety as the main plot factor and planting date as the sub-plot factor, with three replications. Teff sowing was done every 15 days' interval starting from November 1st to February 1st. The spacing between blocks and plots was 1.5 and 1 meter, respectively. The gross plot size was 3.2 x 2 m in width and

length and with a net plot size of 2.8 x 1.6 m. To ease the irrigation, the plots were further sub-divided into three mini-beds of 0.8 x 2 meters in size with a furrow width of 40 cm. Teff sowed at a seeding rate of 15 Kg ha<sup>-1</sup> with a 20 cm row distance. Fertilizers were applied at the rate of 40/60 kg ha<sup>-1</sup> of N and P2O5 in the form of urea and NPS respectively. All P2O5 and ½ of N were applied at planting and the rest 1/2 of N was applied at tillering. Weeding was applied at 20 and 45 days after sowing. Water was applied through the furrow irrigation system every three days from sowing to emergence and every ten days from emergence until maturity. Insect pest (Trips) appeared at the seedling stage and protected with insecticide (Diazinon 60%) at 1 liter ha<sup>-1</sup> spray.

**Table 1:** Characteristics of tested varieties

Variety	Altitude (meter)	Rainfall (mm)	Yield (t ha <sup>-1</sup> )		Maturity (days)
			Research site	Farmers field	
DZ-Cr-37( <i>Tsedey</i> )	1800-2700	500-1200	1.8-2.8	1.4-1.9	82-90
DZ-Cr-387( <i>Quncho</i> )	1800-2500	800-1200	2.5-2.7	2.0-2.2	80-113

Source (Molalign, 2020)

### 2.3. Data Collection and Analysis

Data of plant height, days to maturity, panicle length, grain yield and biomass yield were collected and subjected to analysis of variance (SAS, 2002). Biomass and grain yield was measured from the central rows excluding the border rows. Other data were measured from central rows of randomly selected ten plants. Homogeneity of error of variance analyzed by dividing larger mean square of error to smaller mean square of error as suggested by Gomez (1984). Combined analysis of variance over years done so as to obtain stable recommendation in spite of year variation.

### 3.1. Analysis of Variance

A combined analysis of variance was performed for each trait measured. Grain yield was significantly ( $P < 0.05$ ) affected by variety and sowing date whereas straw yield was highly significantly ( $P < 0.01$ ) affected by variety and sowing date (Table 2). None of the growth parameters were significantly affected by variety and sowing date interaction. The difference in days to maturity in response to variety was due to the genetic variations of the two varieties. The result is in line with Melle & Tesfaye, (2020), who reported *Quncho* matures later than *Tsedey* in high potential areas where moisture is not limiting.

## 3. RESULT AND DISCUSSION

**Table 2:** Mean squares of the combined analysis of variance of grain yield and growth parameters response of teff to sowing date and varieties at Mecha district under irrigation (2021 - 2022)

Source of Variation	Degree of freedom	Days to maturity (days)	Plant height (cm)	Panicle length (cm)	Grain yield (kg ha <sup>-1</sup> )	Straw yield (t ha <sup>-1</sup> )
Blocks (Rep)	2	302.2ns	39.60ns	21.14ns	36810.82ns	0.15ns
Year	1	300.40ns	38.28ns	3.57ns	437044.50*	4.03*
Main plot factor (Varieties = A)	1	1030.31*	1021.20*	2098.09*	3044904.02*	4.16**
Error (a)	2	226.21	36.45ns	57.19ns	13836.08ns	0.13
Sub plot factor (Sowing date = B)	6	185.61**	1775.73**	528.35**	5235462.35*	5.49**
Interaction effect (A*B)	6	321.47ns	272.57ns	45.33ns	197463.52ns	0.0ns5
Error (b)	24	612.1ns	70.80ns	21.14ns	36810.82ns	0.15ns
Total	41	4492.1	3254.63			

Note: \*\*=highly significant at  $P < 0.01$ ; \*=significant at  $P < 0.05$ ; ns = not significant at  $P \geq 0.05$

### 3.1. Growth and Grain Yield Response Teff to Sowing Date and Variety of Each Year

The analysis of variance for individual years showed that plant height, panicle length, grain and straw yield were significantly ( $P < 0.05$ ) affected by main the effects of variety and sowing date (Tables 3 and 4). None of the parameters were significantly ( $P \geq 0.05$ ) affected by the interaction of variety and

sowing date. In both years, plant height, panicle length, grain and straw yield were higher in the long-maturing variety, *Quncho*, than the medium-maturing variety, *Tsedey*. At the same time, the very early to early planting period improved the growth variable and yield of the teff cropping systems compared to the late and very late planting period in all years (Tables 3 and 4).

Table 3: Growth parameter and grain yield response of teff to varieties and sowing date at Mecha district in 2021

Source of variation	Days to maturity (days)	Plant height (cm)	Panicle length (cm)	Grain yield (kg ha <sup>-1</sup> )	Straw (t ha <sup>-1</sup> )	Harvest index
<b>Variety(A)</b>						
Quncho	108a	87.8	41.05	2190.91	3.56	0.38
Tsedey	101b	84.7	36.37	2008.97	3.20	0.37
	**	Ns	ns	*	*	ns
CV %	3.48	8.6	11.68	11.06	12.7	10.10
Means	104.9	86.29	38.71	2099.94	3.38	0.37
SE(a)	3.2	3.17	2.49	9.08	0.10	0.01
<b>Sowing date(B)</b>						
November 1 <sup>st</sup>	107a	89.88bc	39.57bc	2302.13b	3.55bc	0.37a
November 15 <sup>th</sup>	106ab	90.45b	40.81ab	2373.1b	3.85ab	0.37a
December 1 <sup>st</sup>	104bab	97.08a	44.03a	2684.4a	3.99a	0.41a
December 15 <sup>th</sup>	105ab	92.75ab	43.01a	2606.2a	3.90ab	0.40a
January 1 <sup>st</sup>	105ab	84.38c	36.53c	2051.78c	3.35bc	0.37a
January 15 <sup>th</sup>	102b	76.51d	33.86d	1451.63d	2.70d	0.37a
February 1 <sup>st</sup>	102b	72.98d	33.13d	1230.38e	2.33e	0.32a
Sig	**	*	*	**	**	**
C.V. %	2.1	10.81	13.40	17.04	11.3	13.04
Means	104.9	86.29	37.53	2099.94	3.48	0.37
SE(b)	2.2	3.1	2.05	151	0.16	0.02

Note: CV=coefficient of variation; SE= standard error; \*\*highly significant at P<0.01; \*significant at P<0.05; means followed with the same letter are not significantly different

### 3.2. Growth and Grain Yield Response Teff to Sowing Date and Variety In Combined Over Locations and Years

As depicted in Table 5, the longest days to maturity (108 days) were recorded for *Quncho* variety, while the shortest days to maturity (102 days) on *Tsedey* variety. The highest plant height (88.28 cm), panicle length (42.09), grain (2183.56 kg ha<sup>-1</sup>), and biomass (3.38 t ha<sup>-1</sup>) yield was recorded on variety *Quncho*, whereas the lowest yield and growth parameters recorded on *Tsedey*. *Tsedey* had a lower plant height (83.35 cm), panicle length (35.01 cm), grain (1914.31 kg ha<sup>-1</sup>), and biomass (3.17 t ha<sup>-1</sup>) yield compared to *Quncho*. Sowing of *Quncho* had 14.06 and 6.62% grain and biomass yield advantage over *Tsedey*.

The longer days to maturity of *Quncho* than *Tsedey* is due to the genetic variability of each variety (Table 5). In most scenarios and under optimal conditions long maturing varieties

enjoyed more temperature and light to accumulate more dry matter and grain yield over short maturing variety (Van Dobben, 1962). This suggested that, as far as the water availability is granted long maturing *Quncho* variety gave better yield than *Tsedey*. The study is in line with Melle & Tesfaye (2020) who confirmed in good rainfall amounts and distribution seasons, *Quncho* had more yield than *Tsedey*. Likewise, Yazachew Fikre (2021) indicated that *Quncho* demonstrated higher yield in higher potential area where moisture and other climate variables are less likely limiting. However, there are reports that *Tsedey* performed better in the moisture stress area than *Quncho* (Molalign, 2020). In other similar studies, *Tsedey* recommended in moisture stress area of Belessa and other similar areas (Bakala et al., 2018; Fentie et al., 2012). In addition, Basha (2018) reported that

in drought prone area of Guji zone, *Tsedey* gave a reasonably higher yield to be recommended for the area and other similar agroecologies. In general water shortage in Koga irrigation scheme is very unlikely as the area is facilitated with moder irrigation scheme. As a result, the late maturing and

high-yielder *Quncho* is undoubtedly the preferred variety of Koga irrigation schemes. However, there is some level of moisture stress in the downstream area of the scheme where an early maturing variety might be preferable.

**Table 4:** Growth parameter and grain yield response of teff to varieties and sowing date at Mecha district in 2022

Treatments	Days to maturity (Days)	Plant Height (cm)	Panicle Length (cm)	Grain yield (kg ha <sup>-1</sup> )	Straw (t ha <sup>-1</sup> )	Harvest index
Variety(A)						
Quncho	109a	88.75a	43.15a	2176.21a	3.20	0.40
Tsedey	102b	81.92b	33.68b	1819.65b	2.93	0.39
Sig.	*	*	*	*	*	*
CV %	3.49	7.29	10.27	13.9	14.73	11.23
Means	106	85.33	38.41	1997.93	3.07	0.40
SE(a)	0.31	3.3	0.94	124	0.02	0.02
Sowing date(B)						
November 1 <sup>st</sup>	108.5a					
November 15 <sup>th</sup>	106.83ab	87.68b	37.13b	2012.0c	3.18ab	0.41a
December 1 <sup>st</sup>	107.1ab	91.481b	38.65b	2154.0bc	3.30a	0.41a
December 15 <sup>th</sup>	105.8abc	98.13a	45.96a	2373.2a	3.34a	0.42a
January 1 <sup>st</sup>	105bc	91.48a	44.68a	2326.4ab	3.25a	0.42a
January 15 <sup>th</sup>	102 dc	79.98c	36.63b	2012.0c	3.12ab	0.40ab
February 1 <sup>st</sup>	101.75d	77.35cd	33.2c	1742.6d	2.85b	0.39ab
February 15 <sup>th</sup>	108.5a	74.11d	32.6c	1278.8e	2.44c	0.36b
Sig	**	*	*	**	**	**
C.V. %	2.3	9.2	14.15	12.97	16.7	11.68
Means	106	85.33	38.41	1997.93	3.07	0.40
SE(b)	0.10	1.9	1.1	59.01	0.01	0.01

Note: CV=coefficient of variation; SE= standard error; \*\*highly significant at P<0.01; \*significant at P<0.05; means followed with the same letter are not significantly different

**Table 5:** Growth parameter and grain yield response of teff to varieties and sowing date at Mecha district in combined over locations

Treatments	Days to maturity (Days)	Plant height (cm)	Panicle Length (cm)	Grain yield (kg ha <sup>-1</sup> )	Straw (t ha <sup>-1</sup> )	Harvest index
Variety(A)						
Quncho	108a	88.28a	42.09	2183.56	3.386	0.39
Tsedey	102b	83.35b	35.01	1914.31	3.176	0.38
Sig.	**	*	*	*	*	
CV %	3.2	9.30	13.2	13.89	14.13	12.4
Means	106	85.81	38.56	2048.93	3.28	0.53
SE(a)	0.21	3.20	2.41	48.36	0.22	0.01
Sowing date(B)						
November 1 <sup>st</sup>	108a	88.78b	38.35bc	2200.34b	3.36b	0.41a
November 15 <sup>th</sup>	106ab	89.53c	39.73b	2263.54b	3.57ab	0.39abc
December 1 <sup>st</sup>	106ab	97.61a	45.00a	2528.07a	3.66a	0.41a
December 15 <sup>th</sup>	105b	92.12b	43.85a	2466.30a	3.57ab	0.42a
January 1 <sup>st</sup>	105 b	82.18c	36.58c	2031.90c	3.23b	0.38bcd
January 15 <sup>th</sup>	102c	76.92d	33.53d	1597.11d	2.77c	0.38cd
February 1 <sup>st</sup>	101c	73.55d	32.9d	1254.58E	2.38c	0.36d
Sig	*	*	*	**		**
C.V. %	2.8	9.60	14.15	12.97	16.76	10.30
Means	0.18	85.81	38.56	2048.93	3.28	0.53
SE(b)	3.0	1.83	13.21	13.2	62.76	0.10

Note: \*\*=highly significant at  $P<0.01$ ; \*=significant at  $P<0.05$ ; ns=not significant at  $P\geq 0.05$ ;

CV=coefficient of variation; means followed with the same letter are not significantly different

The grain yield and biomass yield were significantly ( $P<0.05$ ) affected by sowing date. Compared to late and very late planting, very early to early planting improved the growth variables and yield of teff (Table 5). December 1<sup>st</sup> sowing date showed maximum plant height (97.61 cm) and panicle length (45.00 cm) followed by December 15<sup>th</sup> sowing date. The highest grain (2528.07 kg ha<sup>-1</sup>) and biomass yield (3.66 kg ha<sup>-1</sup>) was recorded on December 1<sup>st</sup> sowing date followed by December 15<sup>th</sup>, November 15<sup>th</sup>, November 1<sup>st</sup>, January 1<sup>st</sup>, January 15<sup>th</sup>, and February 1<sup>st</sup> sowing date in decreasing order. February 1<sup>st</sup> sowing date had the smallest plant height (73.5 cm), panicle length (32.9cm), grain yield (1254.38 kg ha<sup>-1</sup>), and straw yield (2.38t ha<sup>-1</sup>). December 15<sup>th</sup> sowing date gave comparable and statistically identical grain and biomass yield compared with December 1<sup>st</sup> planting time. Sowing at November had higher grain

and biomass yield following December planting dates. The lowest grain and biomass yield was recorded in January and February planting dates.

The results generally showed that every early and late planting had a huge yield penalty on teff in Mecha district (Table 5). Planting too early (November sowing) coincides most of teff phenology with the coolest months (December and January) of the year and adversely affect teff growth. November sowing teff reaches a tillering stage in late December which is the coolest season in Ethiopia. This low temperature at early-stage results in a relatively low yield in very early November planting dates. This situation adversely affects the growth capacity of teff. Similar to this result cool temperature during tillering stage adversely affects tiller formation and other subsequent phenology of wheat (Meleha et al., 2020). The result is in conformity to Yadav (2010), who indicated that cold stress adversely affect emergence, and vegetative growth in most crops. In

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addition, David (1990) indicated that growth inhibition in plants occurs when temperature drops from 0 to 15 °C. Tobe et al. (2013), reported that early sowing of canola before hot weather appeared to delay flowering and boost seed yield of canola. In other similar studies, Odireleng & Sylvia (2018) showed that sowing of beans in December found optimum for winter season planting. Delay in planting also contribute huge yield penalty as the temperature become very hot during flowering and seed setting stages. Research indicated that elevated temperature in maize showed shortening of the vegetative and reproductive periods, and reduction in pollen viability and kernel numbers (Lizaso et al., 2018). The too high temperature at flowering led to flower abortion and poor seed setting in brassica napur (Lester et al., 2004). In other similar studies, Shaheen et al. (2016) showed that high temperature in tomato modifies plant structure and enhance cell membrane permeability and stomata conductivity. According to David et al. (2007) hot temperature encourage high vegetative growth but limited nutrient partitioning encounter when coincided with grain filling stage. Bita & Gerats (2013) confirmed that high temperature induces high evapotranspiration that leads to water starvation in plants. Rasul et al. (2011) Approved high temperature increases net respiration in plant and finally reduces grain yield in crops. In general, every crop has its own sowing date due to its specific photoperiod and temperature requirements. In most scenarios, late planting aligned grain filling stage with the hottest months (March and April) while very early planting aligns

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tillering stage with coolest month (December and January) of the year in Ethiopia.

## 4. CONCLUSION AND RECOMMENDATION

Long-maturing, Quncho varieties produced more grain and biomass yield than early-maturing, Tsedey varieties. Teff performed best when planted on December 1st, followed by planting on December 15th. When compared to early and late sowing times, December sown teff produced the highest grain yield. This showed that the teff growth stage coincides with the average temperature required by the crop in December, January, and February which could be considered as optimum for teff productivity. Early and late sowing times are not optimal for teff. Early planting is prone to cool temperatures, whereas late planting is prone to hot temperatures. Both cool and hot temperatures above or below the optimal level adversely affect crop physiology and, ultimately, the grain yield of the crops. Therefore, it is recommended that the Quncho variety and sowing date interval of December 1st to 15th be the optimum sowing dates for teff in the Mecha district during the irrigation season. However, if double cropping is a target, Tsedey is the earliest than Quncho and could be an alternative variety with the same planting date to Quncho at Koga irrigation scheme.

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