

Competition Effects of Date of Sowing and Nutsedge Removal Time on Yield and Yield Contributing Characters of Tef [*Eragrostis tef* (Zucc.) Trotter]

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Abstract: Problem statement: Tef [*Eragrostis tef* (Zucc.) Trotter] is a C₄ grass, most important indigenous cereal crop in Ethiopia. The average grain yield of this crop is low; averaging <0.8 Mg ha⁻¹. Under appropriate cultural practices such as the right sowing date, sowing rate, weeding time and fertilizer application, tef could produce grain yields of 2200-4599 kg ha⁻¹. A delay in planting beyond recommended date a substantial yield reduction might be occurred. On the other hand, surveys showed that purple nutsedge (*Cyperus rotundus* L.) is a noxious weed present in varying abundance in tef. Yield loss due to nutsedge alone could be as high as 42% in agronomic crops. In addition, tef as well as purple nutsedge possesses the highly efficient C₄ dicarboxylic acid photosynthetic pathway, which enhances their potential as high yielding crops or serious weeds. Studies on competitive ability of tef with improved cultural practices would provide more effective weed suppression and economic benefits to famers in Ethiopia, where chemical control is economically not feasible. The competitive effect between tef and purple nutsedge, both C₄ species, has not been studied yet. Hence, this paper deals with the effects of delay in tef sowing date and nutsedge removal time on growth and yield of tef.

Approach: Tef was planted at three sowing dates, recommended sowing date, 7 and 15 days delay after the recommended date. The five weed removal time were included as weedy check (W1), weeded 2 weeks (W2), 4 weeks (W3), 6 weeks (W4) after crop emergence and weed-free check (W5). All data were subjected to analysis by SAS, correlation/regression analysis and treatment means were compared using Tukeys Test. **Results:** Weed removal time played a minor role compared to sowing time. Irrespective of weeding dates, delayed tef sowing was very critical. When sowing was delayed for 7 and 15 days, reduction of plant height by 6.97 and 11.53%, panicle length by 8.21 and 12.32% and grain yield by 15 and 16%, respectively. There was relationship among plant height, biomass and grain yield, where by grain yield responds positively to taller plants and higher biomass when the crop is sown early in the season. Hence, tef was more competitive than nutsedge. Early sowing of tef is essential to increase crop growth and yield. **Conclusion/Recommendations:** Increase in plant height, panicle length and a corresponding increase in tef grain yields, provided that there was no delay in sowing of tef at all.

Key words: *Cyperus rotundus*, debre zeit, sowing time, tef [*Eragrostis tef* (Zucc.) trotter], weeding regime

INTRODUCTION

Tef, [*Eragrostis tef* (Zucc.) Trotter] is the only cultivated cereal in the genus *Eragrostis* under the family Poaceae. Ethiopia is the center of origin of tef^[9, 18] and is the only country in the world that uses tef as a cereal crop^[6]. Ethiopian farmers prefer tef, because the grain and straw bring good prices. Tef is also culturally deep entrenched in the food-habit of the Ethiopian

population. Tef occupies 31% of the total farmland area of that country^[14]. Its production area is increasing at unprecedeted scale due to increased market-demand both local and foreign. One of the most important characteristics that make tef an efficient crop in arid and semi arid areas is its CO₂ assimilation efficiency as a C₄ species^[10]. Physiological advantages of C₄ photosynthesis include higher rates of CO₂ fixation, reduced photorespiration and decreased transpiration.

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Therefore, C₄ plants grow faster, become larger and are more competitive than C₃ plants^[12].

Adaptation of diverse biotic and abiotic stresses has made tef a low risk crop for cultivation^[14]. Tef performs well above any other crops under unfavorable circumstances such as drought and water logging^[1,11]. In addition, adaptation of tef to different climatic and soil conditions has exposed it to grow in association with a diverse weed flora. Most surveys indicate that weed control in tef remains to be one of the most expensive, as well as time and energy consuming operation with little success in increasing tef productivity. As regards yield losses in tef, Fissehaie and Tadele^[5] have reported that countrywide yield losses due to weeds varied from 23-65%. Ketema, 1997^[11] reported that a yield loss of tef due to weeds in Ethiopia was 17.8%. It is believed that delay in removing weeds beyond 2-4 weeks after sowing may result in crop losses exceeding 10% and the majority of the highland crops yield 5 or 10% below than attainable yields. Weed counts at 4 weeks after planting showed significantly higher weed densities in the zero tillage compared to minimum, conventional and broad bed furrows tillage treatments^[17]. Under conditions where weeding is less and perennial weeds are a problem, crop losses due to weeds range from 10-50%, with a conservative estimate of 20%. Analysis of all surveys and investigations indicate, an over all realistic estimate of 25% yield loss due to weeds, which should be regarded as a serious loss to the farmer as well as the country as a whole^[12]. Being a cash crop, the little tef yield increment contributes a significant role in the striving of food deficit towards food security^[15].

Under appropriate cultural practices, it is possible for farmers to produce up to 2200-4599 kg ha⁻¹ tef grain yield^[16]. However, under ideal research conditions, Asefa *et al.*^[2] and Habtegebrial and Singh^[7] have found that tef could produced grain yield 32-61% higher than the farmers yield. Therefore, the study of the competitive effect of purple nutsedge on different yield components and yield of tef was necessary in order to determine feasible cultural control measures. Hence, this paper deals with the relationship between yield and yield contributing characters of tef with respect to time of sowing date and nutsedge removal time.

MATERIALS AND METHODS

The experiment was conducted at Debre Zeit Agricultural Research Center during the period July to December 2004. It is situated at an altitude of 1960 meters above sea level. It is one of the major tef

growing areas in the country. It has a warm climate with temperatures ranging from 7°C to a maximum of 30°C. The rainfall is more-or-less stable ranging from no-rain around November to as high as 750 mm month⁻¹ during the rainy season from June to October. It has black-clay soil (sand 10, silt 16 and clay 74), with high water holding capacity.

The plot size was 3×3m with harvestable area of 2.5×2.5 m and footpaths of 1m between plots and 2 m between replications. The experiment was laid down in a 3×5 factorial in randomized complete block design with four replications. Three dates of sowing and five dates of weeding were used as treatments. The three dates of sowing were: recommended date of planting tef (first sowing date S1, second week of July), sowing delayed by seven days after the first sowing date (S2) and sowing delayed by 15 days after the first sowing date (S3). The five weeding treatments were: Weedy check (W1); weeded two weeks after crop emergence (W2); weeded 4 weeks after crop emergence (W3); weeded 6 weeks after crop emergence (W4); and weed-free check (W5). The weedy-check was left weedy with purple nutsedge (i.e., all other weeds were uprooted and only nutsedge remained) for the whole season. The naturally occurring high infestations of purple nutsedge were considered for competition. In contrast, the weed-free-check was clean of all weeds, including purple nutsedge. Hence, weeding in this experiment means weeding the nutsedge; weeds other than nutsedge were regularly rouged out to make the competition only between tef crop and purple nutsedge.

The tef variety used was DZ-1-354 at 30 kg ha⁻¹. Sowing of tef was carried out manually by broadcasting because tef is not yet a mechanized crop. DAP and urea fertilizers at the rate of 100 kg ha⁻¹ of each were applied at sowing and during mid-season of the crop on all plots, respectively. All data were subjected to ANOVA, Principal Component Analysis (PCA) and correlation/regression analysis. PCA can be used to reduce a large amount of data into a manageable size. Among the parameters taken, those that contributed more, based on Principal Component Analysis, were considered here. The number of parameters was reduced from 12-4 and together with yield data. Tukey's studentised range test (Tukey Grouping) was used for means comparison to compare treatment means.

RESULTS

Principal component analysis carried out on yield and yield contributing parameters of tef showed that plant height, panicle length, spikelet number and biomass had contributed 30, 27, 13 and 9%, respectively to grain yield of tef.

Table 1: Effect of delayed sowing and weed removal time on tef height

Delayed sowing*				
Weed removal	0 day (S1)	7 days (S2)	15 days (S3)	Weed removal mean**
Weedy check (W1)	(1) 89abc	(6) 84abc	(11) 78c	83.41d
Weeded 2wae* (W2)	(2) 89abc	(7) 89abc	(12) 77c	85.00d
Weeded 4wae (W3)	(3) 91ab	(8) 89abc	(13) 84abc	87.83d
Weeded 6wae (W4)	(4) 93ab	(9) 86abc	(14) 79bc	85.67d
Weed-free check (W5)	(5) 93ab	(10) 77c	(15) 86abc	86.25d
Delayed sowing mean***	91.05e	84.70f		80.55f
CV (%)		8.99		

*: Means of treatment combinations followed by the same letter are not significantly different (HSD, p<0.05); **: Means of weed removal treatments followed by the same letter in a column are not significantly different (HSD, p<0.05); ***: Means of delayed sowing followed by the same letters in rows are not significantly different (HSD, p<0.05); Figures in parentheses (1-15) are treatment numbers. Wae: Weeks after crop emergence

Table 2: Effect of delayed sowing and weed removal time on tef panicle length

Delayed sowing*				
Weed removal	0 day (S1)	7 days (S2)	15 days (S3)	Weed removal mean**
Weedy check (W1)	(1) 34.25a	(6) 30.25abc	(11) 30.00abc	31.50d
Weeded 2wae* (W2)	(2) 31.25ab	(7) 26.00bc	(12) 29.25abc	29.08dc
Weeded 4wae (W3)	(3) 30.50ab	(8) 28.50ab	(13) 30.000abc	29.66dc
Weeded 6wae (W4)	(4) 31.25ab	(9) 30.75ab	(14) 25.25bc	29.08d
Weed-free check (W5)	(5) 3100ab	(10) 29.75abc	(15) 23.75c	28.16d
Delayed sowing mean***	31.65e	29.05ef	27.75f	
CV (%)	13.60			

*: Means of treatment combinations followed by the same letter are not significantly different (HSD, p<0.05); **: Means of weed removal treatments followed by the same letter in a column are not significantly different (HSD, p<0.05); ***: Means of delayed sowing followed by the same letters in rows are not significantly different (HSD, p<0.05); Figures in parentheses (1-15) are treatment numbers. Wae: Weeks after crop emergence

Table 3: Effect of delayed sowing and weed removal time on grain yield

Delayed sowing*				
Weed removal	0 day (S1)	7 days (S2)	15 days (S3)	Weed removal mean**
Weedy check (W1)	(1) 1600abc	(6) 1320bc	(11) 1280c	1400d
Weeded 2wae* (W2)	(2) 1580abc	(7) 1375abc	(12) 1440abc	1465d
Weeded 4wae (W3)	(3) 1800a	(8) 1250c	(13) 1220cabc	1423d
Weeded 6wae (W4)	(4) 1740ab	(9) 1520abc	(14) 1600abc	1620d
Weed-free check (W5)	(5) 1760abc	(10) 1480abc	(15) 1320bc	1420d
Delayed sowing mean***	1636e	1389f	1372f	
CV (%)	17.47			

*: Means of treatment combinations followed by the same letter are not significantly different (HSD, p<0.05); **: Means of weed removal treatments followed by the same letter in a column are not significantly different (HSD, p<0.05); ***: Means of delayed sowing followed by the same letters in rows are not significantly different (HSD, p<0.05); Figures in parentheses (1-15) are treatment numbers. Wae: Weeks after crop emergence

Weed removal time had no significant influence on above mentioned yield and yield contributing characters of tef. Sowing dates also had no significant difference on spikelet numbers and tef biomass (data not shown). However, in plant height, timely sown tef (S1) was more competitive against nutsedge than tef sown at second (S2) and third (S3) sowing dates, since plant height in timely sown tef was significantly higher than the delayed sown tef at second (S2) and third (S3) sowing dates. Plant height reduction was 6.97 and 11.53% due to delayed sowing for 7 and 15 days, respectively irrespective of weeding dates (Table 1). The average panicle length in early sowing date (S1)

was significantly different and longer from third sowing date (S3), but there was no significant difference between the first and second sowing dates as well as between the second and third sowing dates (Table 2). The reduction in panicle length due to delay in sowing for 15 days was 12.32%. In case of grain yield the plants produced significantly higher grain yield in the first sowing date compared to the second and third sowing dates (Table 3). Hence, there were yield reductions of 15 and 16% due to sowing delay of 7 and 15 days, respectively.

Regarding the relationship between crop biomass and plant height, there was slightly positive relationship

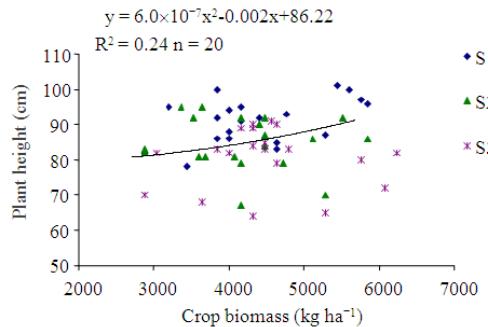


Fig. 1: Relationship between crop biomass and plant height with respect to sowing date of tef

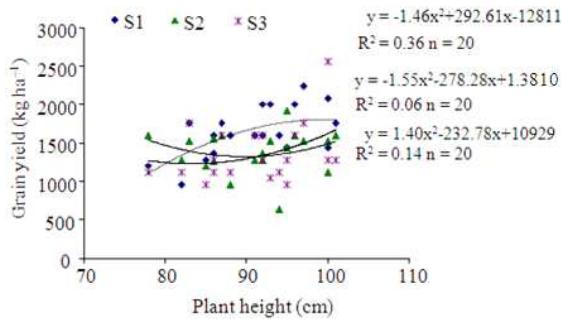


Fig. 2: Relationship between plant height and grain yield with respect to sowing date of tef

between crop biomass and plant height with respect to early sowing. As the biomass increased the height also increased (S1 $y = 6.0 \times 10^{-7} x^2 - 0.001x + 86.22$, $R^2 = 0.24$, Fig. 1). The relationship between panicle length and grain yield in the early sowing date (S1) showed as panicle length increased grain yield was also increased at first and then decreased and quadratics relationship was weak ($R^2 = 0.16$). At that sowing date relationship between spikelets number and grain yield of tef was positive (S1, $y = 4.52x^2 - 96.50x + 1688.4$, $R^2 = 0.39$, data not shown). However, the relationship between plant height and grain yield was stronger with respect to first sowing date compared to late sowing (S1 $y = -1.46x^2 + 292.61x - 12811$, $R^2 = 0.34$, Fig. 2). The response of grain yield to crop biomass in general was quadratic and positive but the attribute was not high ($y = -6.0 \times 10^{-5} x^2 + 0.73x - 521.04$, $R^2 = 0.22$, Fig. 3). The predicted biomass for a maximum grain yield of 1700 kg ha⁻¹ was 6000 kg ha⁻¹. Partitioning the data for sowing dates showed a positive linear relationship between crop biomass and grain yield for early sowing (S1, $y = 0.31x + 281.16$, $R^2 = 0.66$, Fig. 4). Early sowing resulted in higher grain yields largely due to reduced weed competition.

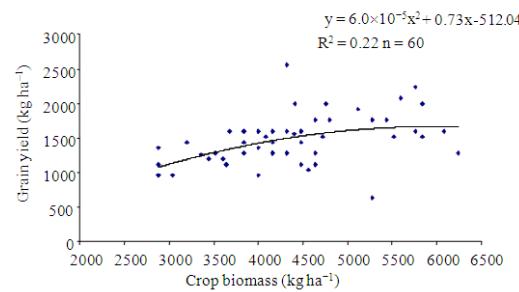


Fig. 3: Relationship between crop biomass and tef grain yield

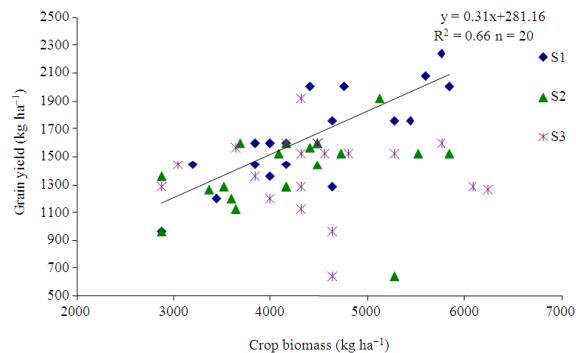


Fig. 4: Relationship between crop biomass and tef grain yield with respect to tef sowing date

DISCUSSION

An increase in panicle length was associated with increase in spikelets number and a corresponding increase in grain yields of tef, provided sowing is carried out without delay. In this experiment longer the delay in sowing the shorter the panicle length. This implies that leaving weeds to grow before crop sowing, will have effect on different parts of the plants and subsequently negatively affects the grain yield of tef. Firbank and Watkinson^[4] mentioned that even the slightest variation in emergence time could affect grain yield, either by altering the time available for growth or by giving earlier emerging plants a competitive advantage. Hundera *et al.*^[8] reported that a delay in tef sowing date beyond the recommended time would reduce yield by 30%.

In this study, among the four characteristics plant height and panicle length contributed 57% to grain yield, whereas spikelet number and tef biomass together contributed 22% to grain yield. According to Tefera *et al.*^[13] these above mentioned traits exhibited high and positive direct effects on grain yield. While Teklu and tefera^[16] observed that improved plant

height, panicle length and kernels per panicle were a feature of most modern acceptable genotypes. They found that stepwise regression analysis of grain yield on selected yield components revealed that number of spikelets and biomass yield were the most important attributes, which accounted for 56.7% of the variation in grain yield. According to the literature, higher photosynthetic rate of C₄ species also results in more dry matter production per unit of input utilization. Ketema^[1] had reported that tef plants produced more than 5,000 kg ha⁻¹ of green material within a period of three months. In favorable environmental conditions and ample inputs, tef could produce 6,355-19,630 kg ha⁻¹ of total biomass^[2]. In line with these findings, in the present experiment, the predicted biomass for a maximum grain yield of 1700 was 6000 kg ha⁻¹ tef biomass.

In this study, timely sown tef produced 17.78 and 19.24% higher yield compared to sowing in delay at 7 and 15 days respectively. Belay *et al.*^[3] opined that by any standards, a 13.5% yield advantage is quite high. Adnew *et al.*^[1] observed that diversity within the regions was found to be significant and, hence an opportunity for exploitation of tef improvement by proper management.

CONCLUSION

Delayed sowing of tef by 7 and 15 days had resulted in reduction of plant height by 6.97 and 11.53%, panicle length by 8.21 and 12.32% and grain yield by 15 and 16%, respectively. The relationship between plant height and grain yield and crop biomass and grain yield of tef was positive, whereby, as the plant height as well as crop biomass increased, the yield also increased. All these relationships clearly indicate the high competitive ability of tef against nutsedge.

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