African Journal of Biotechnology Vol. 8 (22), pp. 6162-6167, 16 November, 2009
Available online at http://www.academicjournals.org/AJB
ISSN 1684–5315 © 2009 Academic Journals

Full Length Research Paper

Effects of sowing date and nutsedge removal time on plant growth and yield of tef [*Eragrostis tef* (Zucc.) Trotter]

Abdul Shukor Juraimi[1], Mahfuza Begum[2], Ahmed M. Sherif[1] and A. Rajan[3]

[1]University Putra Malaysia (UPM), Faculty of Agriculture, 43400 Serdang, Selangor, Malaysia.
[2]Institute of Tropical Agriculture, UPM, Faculty of Agricultural Sciences and Food, 97000 Bintulu Campus, Sarawak, Malaysia.
[3]UPM, Faculty of Agricultural Sciences and Food, 97000 Bintulu Campus, Sarawak, Malaysia.

Accepted 21 July, 2009

Tef [*Eragrostis tef* (Zucc.) Trotter] is an annual C_4 grass crop that originated in Ethiopia. The average grain yield of this crop is low; averaging < 0.8 Mg ha^{-1} in farmer's fields of the semi arid conditions. Productivity can be increased to a considerate extent through the improvement of management practices alone, particularly sowing time with appropriate weed control. The objective of this study was to identify the growth and yield performance of tef as affected by cultural manipulation of date of sowing and weed removal time at semi arid region in Alem tena in Ethiopia. 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 two weeks (W2), four weeks (W3), six weeks (W4) after crop emergence and weed-free check (W5). All data were subjected to analysis by ANOVA, principal component analysis (PCA) and correlation/regression analysis. Weed removal time played a minor role compared to sowing time. Irrespective of weeding dates, delayed tef sowing time was very critical. Plant height reduced by 23 to 32%, panicle length by 45.51 and 55.11% crop biomass by 34.39 and 35.53% and grain yield 60 to 68%, when sowing was delayed for 7 and 15 days, respectively. The relationship between plant height and grain yield and crop biomass and grain yield of tef was very strong and quadratic, 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. Nutsedge competition during the first 6 weeks after crop emergence reduced tef biomass by more than 30%. Keeping the tef field free of weeds for at least six weeks for early and late sown tef is essential to give the crop advantage of growing faster to enhance crop yields.

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

INTRODUCTION

Tef, [*Eragrostis tef* (Zucc.) Trotter] is an important species belongs to the family *Poaceae* (Gugsa et al., 2001). About 50% of more than 300 *Eragrostis* species are native to Africa and Ethiopia is the center of origin of tef (Vavilov, 1951). Tef is the most important indigenous cereal of Ethiopia. It is grown for both human food and animal feed (Telda et al., 1999). Tef comprises high iron and calcium (Mengesha, 1966), on average 9.5% of crude protein and two prominent sources of amino acids metionine and cysteine which are mostly lacking in common Ethiopian crops (Asrat and Frew, 2001). In addition, it is culturally deep entrenched in the food habit of the Ethiopian population. Tef flour is fermented and made a spongy flatbred "injera" that is staple food in Ethiopia and is also used to brew alcoholic drinks such as teta and katikaka (Ketema, 1996). It is mainly a cash crop and occupies more than 31% of the total farmland area of the country (Tefera et. al., 2001).

One of the most important characteristics that make tef an efficient crop is its CO_2 assimilation efficiency as a C_4 species (Takele et al., 2000). Physiological advantages of C_4 photosynthesis include higher rates of CO_2 fixation,

*Corresponding author. E-mail: mzap_27@yahoo.co.uk.

reduced photorespiration and decreased transpiration (Raghavendra and Das, 1993). But tef produces very low yield, averaging only 0.8 Mg ha^{-1} on a country wide basis and its yield is below this average value in the drier parts of the country (Balesh et al. 2005). More over, Belay et al. (2008) reported that the grain yield gap between on-station and farmer managed on-farm trials are very wide. It might be a cause of low fertility level of phosphorus and lesser attention of farmers to control weed in on farm trials than on-station fields.

On the other hand purple nutsedge (*Cyperus rotundus* L.) is a noxious weed present in varying abundance in practically all crops including tef. It also possesses the highly efficient C_4 dicarboxylic acid photosynthetic pathway, which enhances their potential as a serious weed. Yield loss in agronomic crops due to nutsedge alone could be as high as 42% (Bendixen and Stoube, 1977). Countrywide yield losses in Ethiopian tef due to weeds in general vary from 23-65% (Fissehaie et. al., 2001). But information about losses due to nutsedge alone in any crop is lacking. According to farmers' opinion, nutsedge control in tef is the most time consuming, tedious and difficult job among the control measure activities in tef fields.

During cultivation, farmers uproot and take out all plant materials from the field. However, since the rhizomes of nutsedge are broken into many small pieces by the plowing process, the fragments in the soil readily germinate as soon as conditions become favorable. No single control measure has been found to be effective in controlling nutsedge. Gesaten and Primagram herbicides were tried in tef by Knife and Unger (1985) against diverse weed species. Both were non-effective against purple nutsedge. Nevertheless, specific research on nutsedge removal time in tef as well as on other crops has not been attemped in Ethiopia.

Studies on competitive ability of tef with improved cultural practices would provide more effective weed suppression and economic benefits to famers in Ehiopia, where chemical control is economically not feasible. In addition, the competitive effect between tef and purple nutsedge, both C_4 species, has not been studied. Effects of date of sowing and other cultural practices in relation to weed interference also have not been studied.

Being a cash crop, productivity of tef may be increased to considerable extent through the adoption of cultural management practices. Hence, this paper deals with the effects of tef sowing date and nutsedge removal time on growth, yield components and yield of tef.

MATERIALS AND METHODS

The experiment was conducted at Alem Tena in Ethiopia from July to December 2004. Alem Tena is a semi arid area situated at an altitude of 1200 m above sea level. The area has erratic rainfall that could reach up to 900 mm per year. The temperature ranges from 8°C to 31°C (National Meteorological Services Agency, *Pers Comm*). The soil type was clay composed of 13% sand, 14% silt and 73% clay.

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 four weeks after crop emergence (W3); weeded six weeks after crop emergence (W4); and weed-free check (W5).

The weedy-check was left weedy with purple nutsedge (that is, 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 plot size was 3 × 3 m with harvestable area of 2.5 × 2.5 m and footpaths of 1 m between plots and 2 m between replications. 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 to 4 and together with yield data. Tukey's studentised range test (Tukey Grouping) was used for means comparison to compare treatment means.

RESULTS AND DISCUSSION

Principal component Analysis carried out on growth and yield parameters of tef showed that biomass had the highest share of 62.83% in terms of contribution to grain yield along with other parameter; tef density (18%), plant height (8%) and panicle length (10%).

Treatment effect of tef sowing dates or weed removal times had no significant difference on tef density (data not shown). However, 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 22.80 and 32.06% due to delayed sowing for 7 and 15 days, respectively irrespective of weeding dates (Table 1).

Similarly, panicle length in early sown plants was significantly longer than in the delayed sown plants, respectively (Table 2). There was reduction in panicle length by 45.50 and 55.11% due to delay in sowing by 7 and 15 days, respectively. That is, the 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. There was also significant differences between weed removal times, whereby, weed-free check was significantly different and

Table 1. Effect of delayed sowing and weed removal time on plant height (cm).

Weed removal	Delayed sowing *			Weed removal mean**
	0 Day (S1)	7 Days (S2)	15 Days (S3)	
Weedy check (W1)	(1) 78.25a	(6) 53.25abc	(11) 58.25abc	63.25e
Weeded 2 wae* (W2)	(2) 62.00abc	(7) 60.00abc	(12) 44.25bc	55.42e
Weeded 4 wae (W3)	(3) 77.50a	(8) 67.25abc	(13) 38.75c	61.17e
Weeded 6 wae (W4)	(4) 74.25ab	(9) 47.00abc	(14) 45.00bc	55.42e
Weed-free check (W5)	(5) 80.75a	(10) 60.25abc	(15) 67.00abc	69.33e
Delayed Sowing Mean***	74.55f	57.55g	50.65g	
CV%		10.72		

*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 letter 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 panicle length (cm).

Weed removal	Delayed Sowing *			Weed removal mean**
	0 Day (S1)	7 Days (S2)	15 Days (S3)	
Weedy check (W1)	(1) 36.00a	(6) 17.50def	(11) 16.00def	23.17gh
Weeded 2 wae* (W2)	(2) 27.25bc	(7) 18.75de	(12) 10.75f	18.92h
Weeded 4 wae (W3)	(3) 32.75ab	(8) 18.75de	(13) 11.75ef	21.08gh
Weeded 6 wae (W4)	(4) 32.25ab	(9) 14.50def	(14) 13.00ef	19.92gh
Weed-free check (W5)	(5) 33.25ab	(10) 18.50de	(15) 21.00cd	24.25g
Delayed Sowing Mean***	32.00j	17.60k	14.50k	
CV%		12.89		

*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 letter in rows are not significantly different (HSD, p<0.05).
Figures in parentheses (1-15) are treatment numbers. *Wae=weeks after crop emergence.

produced higher panicle length than the weeding two-weeks after emergence.

There were 34.39 and 35.53% reductions in tef biomass due to delay in sowing dates by 7 and 15 days, respectively (Table 3). In timely sown plots, the crop emerged early and occupied the space, whereas in delay sowing for 7 and 15 days, weeds emerged earlier than the crops and caused reduction in biomass. Crop biomass in the weed-free-check was significantly higher than the crop biomass in plots weeded 6-weeks-after-crop-emergence. This showed that nutsedge competition during the first 6 weeks reduced the biomass by more than 30%. This is in line with Weaver and Tan's (1983) idea that the longer weeds are allowed to remain in the plots before removal, the higher the effect on crop dry weight. The interaction effect between tef sowing delayed by 7 and 15 days, and weed removal 6 and 4 weeks-after-crop-emergence are clearly seen in treatment 9 and 13 respectively, where tef biomass was significantly lower (>50%) than the early planted treatment combination 4 and 3. Cotton planted three weeks later than nutsedge emergence experienced severe growth retardation, and at 10 weeks the crop plants weighed only 15% of those growing without weeds (Horowitz, 1975).

The differences in grain yield between timely sowing tef (S1) and the two other delayed sowings (S2 and S3) were highly significant (Table 4). Hence the reductions in tef yield due to delaying of sowing by 7 and 15 days was very high by 60 and 68%, respectively. Firbank and Watkinsson (1990) 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., (2001) reported that a delay in tef sowing date beyond the second week of July to the first week of August would reduce yield by 30%. There was strong linear correlation between plant height and crop biomass ($y = 0.02x + 23.07$, R^2=0.70 Figure 1) indicates that there was both intra as well as inter-specific competition, whereby, about 70% of the variation in height was contributed by crop biomass. In line with this, the relationship between plant height and grain yield, and between crop

Table 3. Effect of delayed sowing and weed removal time on biomass (kg ha^{-1}).

Weed removal	Delayed Sowing *			Weed removal mean**
	0 Day (S1)	7 Days (S2)	15 Days (S3)	
Weedy check (W1)	(1) 2966ab	(6) 1608cd	(11) 1978bcd	2183ef
Weeded 2 wae* (W2)	(2) 2214bc	(7) 2007bcd	(12) 1903cd	2041ef
Weeded 4 wae (W3)	(3) 3324a	(8) 2617abc	(13) 1196d	2379ef
Weeded 6 wae (W4)	(4) 2617abc	(9) 1106d	(14) 1703cd	1809f
Weed-free check (W5)	(5) 3262a	(10) 2099bcd	(15) 2493abc	2618e
Delayed Sowing Mean***	2876.4g	1887.3h	1854.5h	
CV%		13.51		

*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 letter in rows are not significantly different (HSD, p<0.05).
Figures in parentheses (1-15) are treatment numbers. *Wae=weeks after crop emergence.

Table 4. Effect of delayed sowing and weed removal time on grain yield (kg ha^{-1}).

Weed removal	Delayed Sowing *			Weed removal mean**
	0 Day (S1)	7 Days (S2)	15 Days (S3)	
Weedy check (W1)	(1) 193.50a	(6) 32.00b	(11) 62.00ab	95.83c
Weeded 2wae* (W2)	(2) 28.50b	(7) 71.25ab	(12) 17.25b	39.00c
Weeded 4wae (W3)	(3) 96.75b	(8) 62.75ab	(13) 3.00b	54.17c
Weeded 6wae (W4)	(4) 103.50ab	(9) 10.25b	(14) 17.00b	43.58c
Weed-free check (W5)	(5) 178.00a	(10) 61.25ab	(15) 90.50ab	109.95c
Delayed Sowing Mean***	120.05d	47.50e	37.95e	
CV%		50.82		

*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 letter in rows are not significantly different (HSD, p<0.05).
Figures in parentheses (1-15) are treatment numbers. *Wae=weeks after crop emergence.

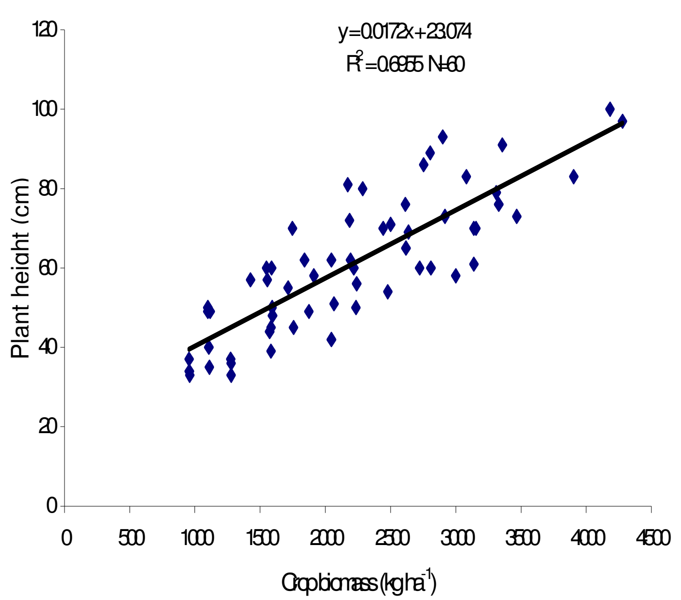

Figure 1. Relationship between crop biomass and plant height of tef.

biomass and grain yield were also very strong and quadratic ($y = 0.1x^2 - 8.21x + 190.1$, R^2=0.68, Figure 2; $y = 3.0 \times 10^{-5}x^2 - 0.08 + 59.341$, R^2=0.61, Figure 3). As the crop biomass increased, plant height increased and as plant height increased grain yield of tef also increased. A closer look at the relationship between plant height and grain yield of tef and between biomass and tef grain yield showed that early sowing was superior to late sowing whereby the variation R^2=0.77 and R^2=0.65 were attributed to plant height and crop biomass, respectively (Figures 4 and 5).

According to the literature, higher photosynthetic rate of C_4 species also results in more dry matter production per unit of input utilization. Ebba (1969) had reported that tef plants produced more than 5,000 kg ha^{-1} of green material within a period of three months. Under favorable environmental conditions and ample inputs, tef could produce 6,355 to 19,630 kg ha^{-1} of total biomass (Asefa et al., 2001). That is, as contemplated by the PCA, the relationship between biomass and grain yield of tef was very close. Tef produces more biomass and taller plants due to inter and intra-specific competition, which results

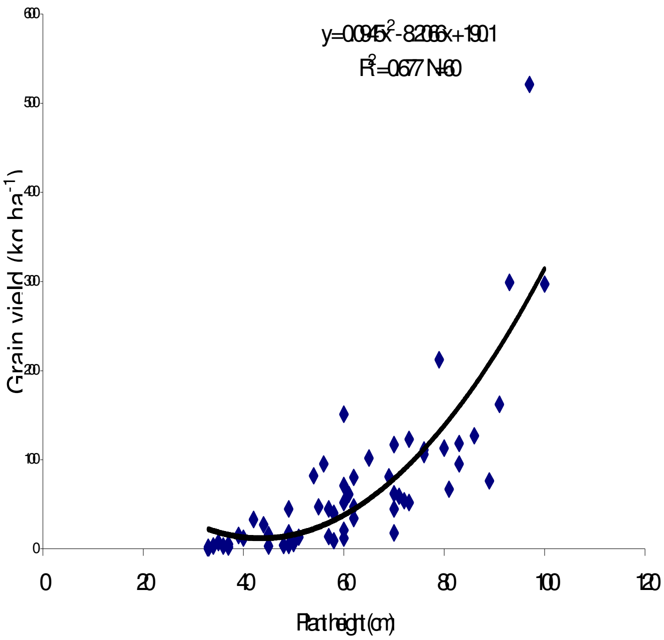

Figure 2. Relationship between plant height and grain yield of tef.

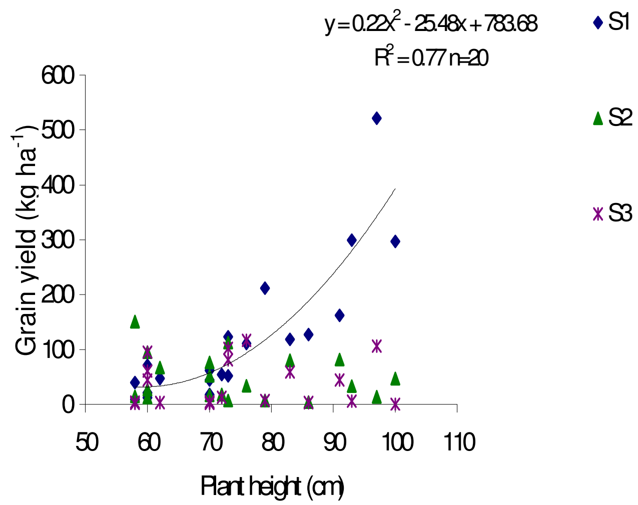

Figure 4. Closer look at the relationship between plant height and grain yield with respect to sowing date of tef.

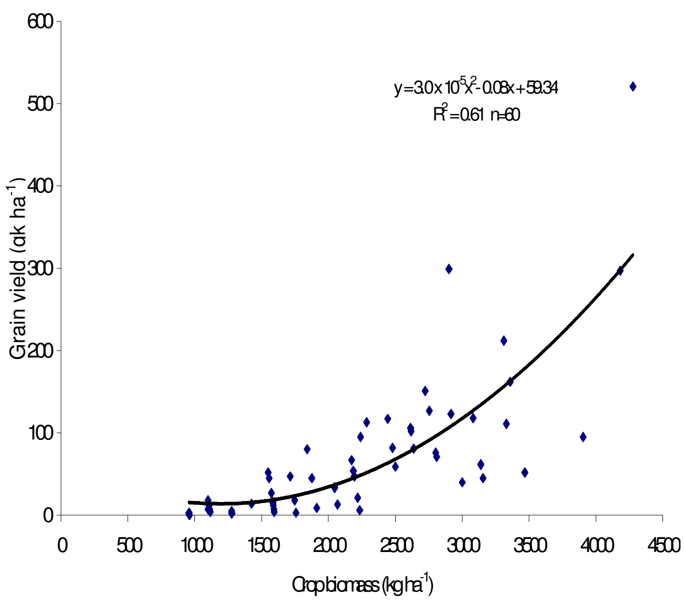

Figure 3. Relationship between crop biomass and tef grain yield.

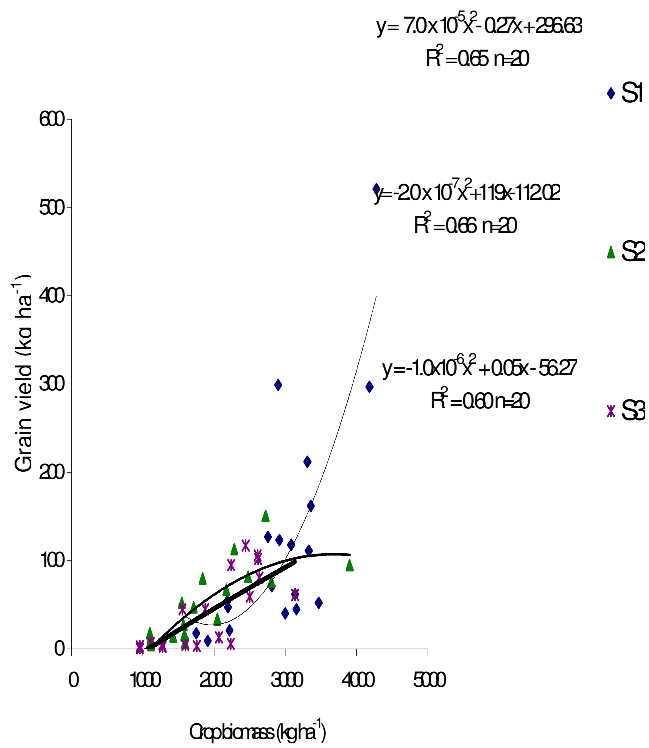

Figure 5. Relationship between crop biomass and tef grain yield with respect to delay in sowing date.

in higher grain yield.

Conclusion

Delayed sowing of tef by 7 and 15 days had resulted in reduction of plant height by 22.80 and 32.06%, panicle length by 45.51 and 55.11%, crop biomass by 34.39 and 35.53% and grain yield by 60 and 68%, respectively. Delayed weeding at 6 weeks after crop emergence caused more than 30% crop biomass reduction. There were strong relationship between plant height and grain yield of tef (R^2 = 0.68) as well as between biomass and grain yield (R^2 = 0.61). Hence plant height and grain yield were not affected by nutsedge. In other words, tef was more competitive than nutsedge. Early sowing of tef is essential to increase crop growth and yield.

REFERENCES

Asefa K, Ketema S, Tefera H, Hundera F, Kefyalew T (2001). Genetics diversity for agronomic traits in tef. In Narrowing the Rift: Tef Research and development. (Eds Tefera H, Belay G and Sorrells M). Proceedings of the International Workshop on Tef Genetics and Improvement held at Debre Zeit, Ethiopia.

Asrat W, Frew T (2001). Utilization of tef in the Ethiopian diet. In Narrowing the Rift: Tef Research and development. (Eds H. Tefera. Belay G, Sorrells M. Proceedings of the International Workshop on Tef Genetics and Improvement, DebreZeit, Ethiopia, pp. 239-244.

Balesh T, Zapta F, Aune J, Situala B (2005). N fertilization, soil type and cultivars effects on N use efficiency in tef (Eragrostis tef (Zucc.) Trotter). Nutr. Cycl. Agroecosyst. 71: 203-211

Belay G, Tafera H, Getachew A, Assefa K, Metaferia G (2008). Highly client-oriented breeding with farmer participation in the Ethiopian cereal tef [*Eragrostis tef* Zucc. Trotter]. Afr. J. Agric. Res. 3(1): 22-28.

Bendixen LD, Stoube ES (1977). Yellow and purple nut sedges: two weeds species of world wide significance. Weeds Today, 9(1): 9-15.

Ebba T, Mersie W (1969). Tef (*Eragrostis tef*). The cultivation, usage and some of the known diseases and insect pests. Study on the tolerance of tef [*Eragrostis tef* Zucc. Trotter]. MCPA and other herbicide, M.Sc. Thesis, University of Reading, England. 2: p. 4.

Firbank LG, Watkinsson AR (1990). On the effect of competition: from monoculture to mixture. In: Grace JB and Tilman D (eds) Perspective on plant competition. Academic Press, Inc. San. Diego p. 484.

Fissehaie R, Tadele Z, Tefera H, Belay G, Sorrells M (2001). Weed Research in Tef. In Narrowing the Rift: Tef Research and development. Proceedings of the International Workshop on Tef Genetics and Improvement held at Debre Zeit, Ethiopia.

Gugsa L, Belay G, Ketema S, Tefera H, Belay G, Sorrells M (2001). The cytogenetics of tef. In Narrowing the Rift: Tef Research and development. Proceedings of the International Workshop on Tef Genetics and Improvement held at Debre Zeit, Ethiopia.

Horowitz M (1975). Competition effects of three perennial weeds, *Cynodon dactylon* (L), *Cyperus rotundus* (L) and *Sorghum halepense* (L) Pers. On young citrus. In Zimdahl RL (ed). Weed Competition. A review-International Plant Protection Centre Document. 31: p. 80.

Hundera F, Bogale T, Tefera H, Asefa K, Kefyalew T, Debelo A, Ketema S, Tefera H, Belay G, Sorrells M (2001). Agronomy research in tef. In Narrowing the Rift: Tef Research and development. Proceedings of the International Workshop on Tef Genetics and Improvement held at Debre Zeit, Ethiopia.

Ketema S (1996). Promoting the Conservation and Use of Underutilized Crops. Biodiversity Institute, Addis Ababa, Ethiopia. 7(11): 35-41.

Knife B, Unger J (1985). The effect of soil acting herbicides versus hand weeding in tef [*Eragrostis tef* Zucc. Trotter] under Ethiopian conditions. Beitrage Zur Tropischen Landwirtschaft und Veterinarmedizin (German DR). 23(3): 295-299.

Mengesha MH (1966). Chemical composition of tef (*Eragrostis tef*) compared with that of wheat, barley, and grain sorghum. Econ. Bot. 20: 268-273.

Raghavendra AS, Rama Das VS (1993). C_4 photosynthesis and C_3-C_4 intermediacy: adaptive strategies for semiarid tropics. In: Abrol et al. (eds). Academic Publishers, Dodrecht, Netherlands, pp. 317-338.

Tefera H, Ketema S, Tefera A, Belay G, Sorrells M (2001). Production and importance of tef in Ethiopian agriculture. In Narrowing the Rift: Tef Research and development. Proceedings of the International Workshop on Tef Genetics and Improvement held at Debre Zeit, Ethiopia.

Telda A, Mamo T, Klaij M C, Diedhiou M L (1999). Effects of cropping system, seed bed management and fertility interactions on biomass of crops grown in the central highlands of Ethiopia. J. Agron. Crop Sci. 183: 205-211.

Vavilov NI, Mersie W (1951). The origin, variation, immunity and breeding of cultivated plants. Study on the tolerance of tef [*Eragrostis tef* (Zucc.) Trotter] to MCPA and other herbicides. M. Sc. Thesis, University of Reading, Eng. 2: p. 4.

Weaver SE, Tan CS (1983). Critical peiod of weed interference I transplanted tomatoes (*Lycopersicum esculentum*): Growth analysis. Weed Sci. 31: 476-481.