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EVALUATION OF THE EFFECT OF PARTHENIUM (*Parthenium hysterophorus* L.) WEED DENSITY ON THE VEGETATIVE GROWTH AND GRAIN YIELD OF TEFF (*Eragrostis tef* Zucc. Trotter*) IN SHEWA-ROBIT DISTRICT, NORTH SHEWA, ETHIOPIA*

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Abstract
Parthenium weed (*Parthenium hysterophorus* L.), is one of the top alien invasive weed species in more than 40 countries, including Ethiopia. It infests several crops and causes significant yield losses, the extent of which depends, among others, on the density of weed and characteristics of crop species. Therefore, the objective of this study was to evaluate the effect of Parthenium (*Parthenium hysterophorus L.*) weed density on vegetative growth and grain yield of teff (*Eragrostis tef* Zucc. Trotter) using field experiment. Factorial combination of two traditional teff landraces namely *Nech* and *Seregegna*; and three levels of weed density (0, 5% and 10%) were used in the study. The experiment was arranged in randomized complete block design (RCBD) with four replications. To determine the extent of growth and yield loss caused by weed treatment, the differences between the means recorded for each trait at each treatment and weed free control plot were compared using Two-way ANOVA and the Tukey`s significant difference test. The results obtained in the study revealed that there was statistically significant difference ($P \leq 0.05$) on the effect of Parthenium weed density on vegetative growth and grain yield of the two landraces of teff studied. However, the difference between landraces was not significant. The mean maximum grain yield/plot (738.5 ± 49.2 gram) was obtained from control plot and the lowest grain yield/plot (482.2 ± 57.8 gram) was recorded from 10% Parthenium weed density treatment plot, which makes percent yield loss of 34.6% compared to the control plot. This in turn corresponds to a yield loss of 640.75 kg/ha. In general, the observed yield loss with increasing density of weed might attribute to reduction in availability of moisture, soil nutrients and light. Thus, there is a need for proper management of Parthenium weed starting from early period of seedling emergence of the test crop.

Key Words: Eragrostis teff, Grain yield, *Parthenium hysterophorus*, vegetative growth, Weed density

1. Introduction

Among the biotic barriers of crop production, weeds take the foremost position in affecting crops more than agricultural pests in the world (Maskey, 1997). They cause a loss of agriculture productivity, primarily through crop growth and yield reduction that occurs due to their competitiveness and in the second place by raising the financial and labor input to control them (Agrow, 2003). Swanton *et al*. (2015) reported that the annual economic loss caused by noxious weeds at a global level has been estimated to be more than $100 billion.

Like other parts of the world, weed infestation is the chief production constraint in Ethiopia. Especially in recent years the problem has been exacerbated by the arrival of various alien noxious weed species (Kebede, 2000; EIAR, 2011). Among which, Parthenium weed (*Parthenium hysterophorus* L), is one of the top disastrous weed species reported to be introduced to the country accidentally in the 1980’s through grain food aid for famine relief. Today, the weed infests many agricultural fields and causes severe yield losses in major food crops and has become a major problem for sustainable crop production (Tamado *et al*. 2002, Safdar *et al*. 2016). Tamado *et al.* (2002b) reported 40 to 90% sorghum grain yield reduction in eastern Ethiopia, due to Parthenium weed competition from plots which were left uncontrolled throughout the cropping season. Mitiku (2011) reported a grain yield loss 18.5% to 86.5% of common bean due to Parthenium weed in eastern Ethiopia. Asresie *et al*. (2010) also reported 79.5% yield loss of sorghum crop due to Parthenium invasion northeastern Ethiopia indicating the extent of damage caused by this weed species. More recently, Ali *et al* (2018) reported 3, 6, 8 and 15% yield loss of maize from Parthenium weed competition study conducted 2, 4, 6 and 8 weeks after crop emergence, respectively as compared with the season long weed-free treatment.

Teff (*Eragrostis tef* L.) is one of the most staple grain crops for more than 50 million people in Ethiopia (CSA, 2010). The grain of teff is ground to flour that can be fermented and made into the Ethiopian flat sour dough bread known as ‘*injera’*, which is the Ethiopian staple food(Gilbertson, *et al*.,1993). Abebe *et al*.(2007) also documented that teff grain has many important nutritional value, and it leads all of the other food crop grains by being vital source of dietary minerals (such as iron, calcium phosphorus and copper),and the essential amino acids needed for the body’s growth and repair. Gilbertson, *et al.* (1993), documented that teff grain has two other important health related nutritional values. First, since teff grain lacks gluten, it can be used to produce gluten-free food products for people who are allergic to gluten. Secondly, whole teff grain is rich source of dietary fiber (bran), which is important in blood sugar management to prevent diabetes and in maintaining colon health. Besides to its high quality nutritional values for human consumers, teff has other significant economic importance for the farming community such as a profitable cash crop with a rewarding market value (Berhane *et al*. 2011), crop residue with high quality nutritional value for livestock feed (Tesfaye, 2001).

Although teff is adaptable to wide range of environmental conditions and highly tolerant to moisture stress and water logging conditions (Seifu, 1997), it is intolerant to weed infestations such as Parthenium (Rezene and Zerihun, 2001). However, so far quantitative information on the effect of Parthenium weed on growth and yield of teff is scanty. This study therefore, stems from this understanding and aimed at examining the growth and yield response of teff to varying densities of Parthenium weed treatment using a field experiment.

2. Materials and Methods

2.1 Description of the study area

The field experiment was carried out in Shewa Robit district situated between $39^0$52’ to $39^0$58’ E & $09^0$57’ to $10^0$03’ N at edge of the Great Rift Valley at an altitude of 1280 masl. It is found 225 Kms north east of Addis Ababa (Figure 1). The soil of the study area is clay loam with pH= 8.3, organic matter =3.7%, total nitrogen = 0.20% and available phosphorus= 5.3 ppm (Andargie *et al*., 2013). The mean maximum and minimum temperature is 31.23 ^oC and 13.3 ^oC respectively (North Shewa Agricultural office). The area receives an average annual rainfall of 851.7 mm, and the main rainy season is July to (North Shewa Agricultural office).

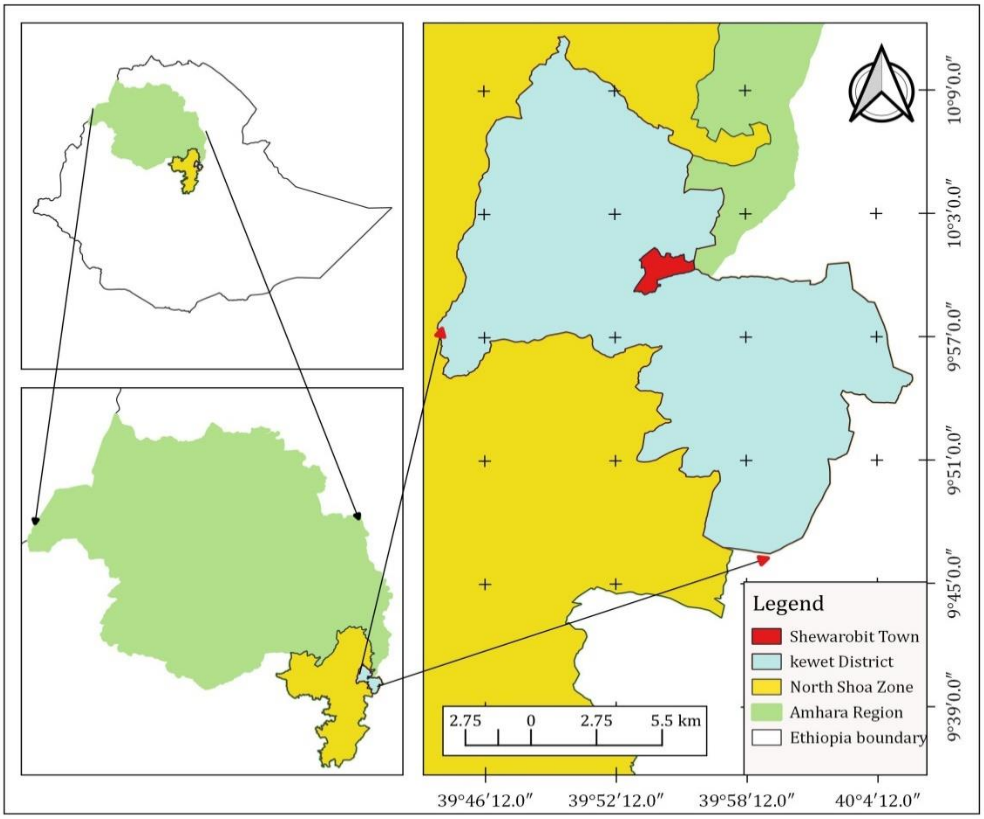

Figure 1 Location Map of the study area

2.2 Agricultural practices of the study area

The study area is characterized by cereal based cropping system and teff *(Eragostis tef)* and Sorghum *(Sorghum bicolor)* are the two major crops that are widely cultivated. However, teff is the most dominant and widely grown crop relative to sorghum.

2.3 Site Selection, Experimental Design and Treatments

Shoa Robit district-was selected as study site because it is heavily infested by Parthenium weed and known by teff production. The field experiment consisted of three weed densities (0, 5% and 10%) and two landraces of teff locally called *Nech* and *Seregegna teff*, which were arranged in randomized complete block design with four replications. The experimental plot of 2m by 2m was used for the study. In each treatment plot 2 gram of seed of test crop was sown with varying seed mass of Parthenium weed keeping the seed mass of the test crop constant following Rejamanek *et al*., (1989). Accordingly, a mixture of 2g seed of teff and 0.1g seed of Parthenium weed was sown in rows for 5 % of Parthenium weed density treatment plot. Similarly, a mixture of 2g seed of teff and 0.2g seed of Parthenium weed was sown in rows for 10 % of Parthenium weed treatment plot. Throughout the experiment other weeds, other than the experimental weed, were regularly removed by hand. The experiment was conducted during the main teff cropping season of the study area that is from July 2016 to October, 2016.

2.4 Data collection and measurement

2.4.1 Growth parameters

Data on vegetative growth such as height, leaf length and width and number of tillers were collected after 40 days of crop emergence. Measurement of stem height was made from the ground level to the tip of the longest and recently expanded leaf. Leaf length was measured from the base of leaf sheath to the tip and leaf width was taken at the broadest point of the lamina. Leaf area was estimated as a product of leaf length, leaf width, and 0.75 (shape factor). Measurement of plant height and leaf length and width was done using a ruler. On the other hand, tiller number on each plant was counted. Growth data were taken from 20 plants which were located at the central row of the experimental plot to avoid what so called “marginal effect”.

2.4.2 Grain yield

Grain yield data were collected and recorded following harvesting. Harvest was carried out 114 days after seedling emergence when the plant reached physiological maturity. Harvest of plants of all experimental treatment was carried out on the same day by using a sickle. The harvested crop from each plot was stacked into piles separately and kept intact for air drying. After seven days of air drying, the harvested crop from each plot were placed on a plastic sheet and the seed heads were threshed vigorously by hands, until all the seeds had been dislodge. Then, the seeds collected were carefully separated from the stubble and cleaned by sieving and winnowing. The cleaned seeds from each experimental plot were then weighed by using a precise laboratory beam balance which has a sensitivity of 0.01 g.

2.4.3 Estimation of yield loss

The magnitude of crop loss that occurred due to weed treatments was computed and described as a percent of the respective weed free control group, using the formula developed by Panda (2010):

$$\mathrm{YL} \quad = \frac{\mathrm{Y1} - \mathrm{Y2}}{\mathrm{Y1}} \times 100$$

Where YL is percent of grain yield loss or the reduction that occurred on the growth parameter, $Y_1$is the average value of each measured trait obtained from the weed free control plots, and Y_2 is the average value of the respective trait recorded at each treatment level (5%& 10%) of Parthenium weed.

2.5 Statistical analysis

To determine the extent of crop damage caused by weed treatment (whether it is significant or not), the differences between the means recorded for each trait at the weed free control plot and each of the treatment type were evaluated using ANOVA, and the Tukey`s significant difference test, with the help of statistical software.

3. Results

3.1 Effect of Parthenium weed on vegetative growth

3.1.1 Height

The effect of Parthenium weed density on height growth of two varieties of teff was presented in Figure 2. In both varieties, plant height decreased with increased density of weed. The mean maximum height of 23.6 and 23.7 cm for V1 and V2, was recorded respectively from a control plot and the mean minimum height of 21.9 and 21.8 for V1 and V2, was recorded respectively from a plot receiving 10% weed density treatment. The ANOVA test also showed the observed variation in height between treatments is statistically significant at $P \leq 0.05$. However, the difference in height between varieties and variety by weed density interaction was not significant.

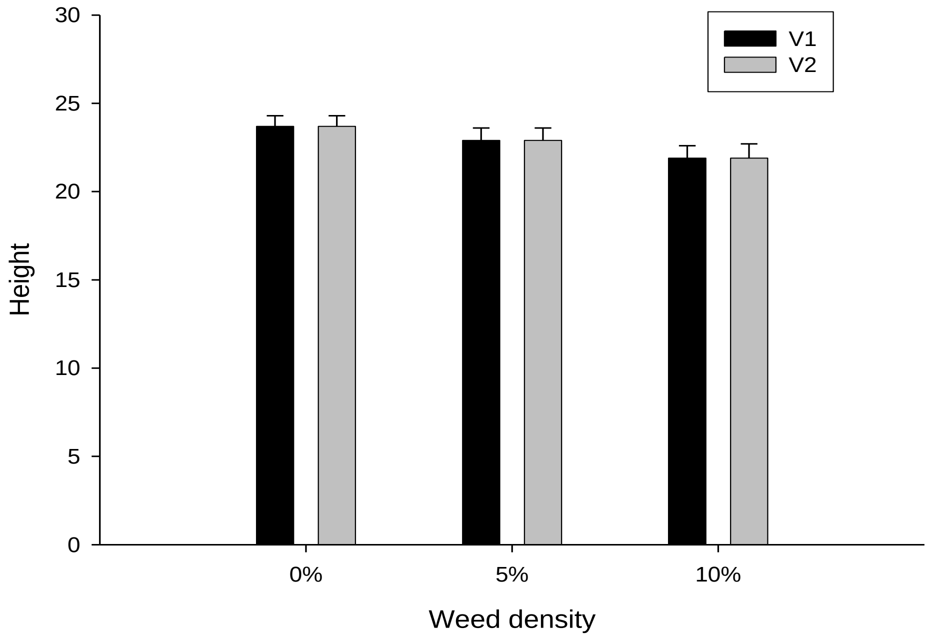

Figure 2 Height (cm) of two varieties of teff as influenced by weed density

3.1.2. Leaf area

The effect of varying weed density of *Parthenium* on leaf area growth of two varieties of teff is presented in Fig 3. The maximum leaf area of 13.4 and 13.6 in V1 and V2, was recorded respectively from control plot, whereas the minimum of 11.7 and 11.8 in V1 and V2 was recorded at a plot with 10% weed density. Results of ANOVA showed the presence of significant ($P \leq 0.05$) effect of weed density on leaf area. However, the effect of variety and variety by weed density interaction on leaf area was not significant

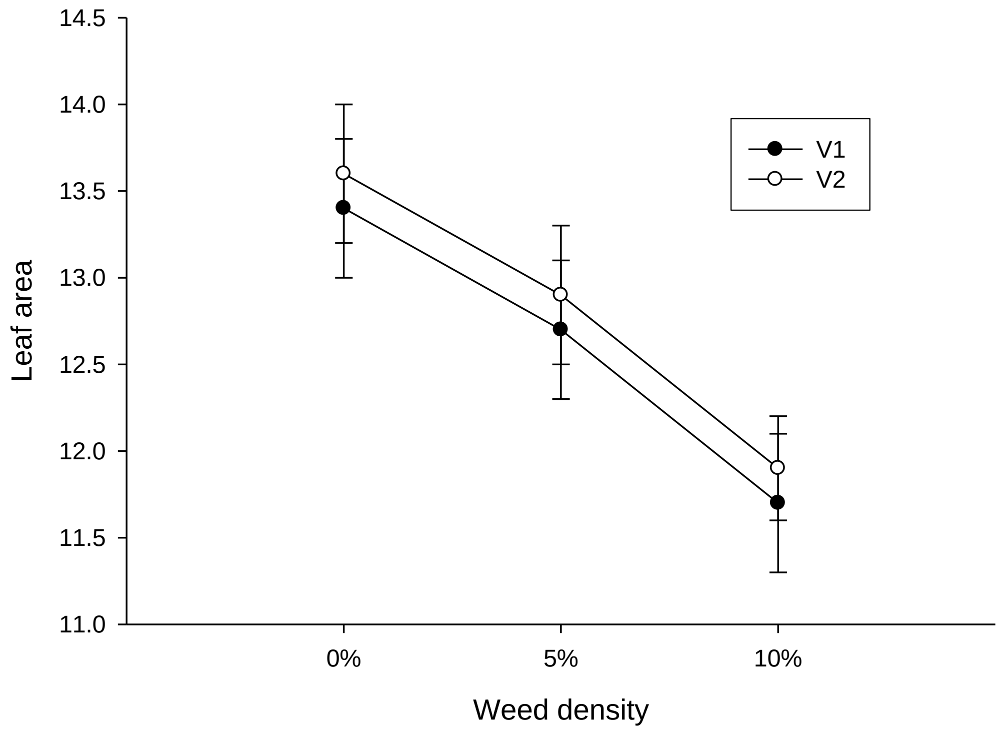

Figure 3. Leaf area (Cm2) of two varieties of teff as influenced by weed density

3.1.3 Tiller number

The effect of varying weed density of *Parthenium* on tiller production of two varieties of teff is presented in Table 1. The maximum number of tillers, 5.7 $\pm$ 0.07 and 5.8 $\pm$ 0.1, in V1 and V2, was recorded respectively from control plot, whereas the minimum of 5.5 $\pm$ 0.1 and 5.4 $\pm$ 0.2 in V1 and V2, was recorded respectively at a plot with 10% weed density. Analysis of variance (Appendix 2) showed statistically significant ($P \leq 0.05$) effect of weed density and variety on number of tillers/plant though the interaction was not significant.

Table 1. Mean leaf area of two varieties of teff in relation to different levels of Parthenium weed density

	Weed density		
Variety	0	5%	10%
V1	5.7 ± 0.07^{a}	5.6 ± 0.02^{ab}	5.5 ± 0.1^{b}
V2	5.8 ± 0.1^{a}	5.6 ± 0.1^{ab}	5.4 ± 0.2^{b}
Overall mean	5.75 ± 0.08^{a}	5.6 ± 0.06^{ab}	5.45 ± 0.15^{b}

Means in the same column represented by same letter are not significantly different at $P \leq 0.05$

3.2 Effect of Parthenium on crop yield

The effect of varying density of weed of *Parthenium* on grain yield of two varieties of teff is presented in Table 2. The mean maximum and minimum grain yield obtained in the study ranges from 764.4 ± 49.2 to 490.2 ± 52.2 and 712.6 ± 49.2 to 474.2 ± 63. 2 in variety one and variety 2 respectively (Table 2). Analysis of variance (Appendix 2) also showed statistically significant ($P \leq 0.05$) effect of weed treatment level on grain yield of teff though weed treatment by variety interaction was not significant. Moreover, the yield loss caused by 5% and 10% Parthenium weed treatment level was found to be 14.9 and 38.9 respectively in variety one and 13.9 and 33.4, respectively in variety two. In general, ANOVA showed that the level of Parthenium weed treatment can result in significant grain yield loss on teff crop.

Table 2. Effect of weed density on yield of two varieties of teff

	Weed density		
Variety	0	5%	10%
V1	764.5 ± 49.2[a]	650.3 ± 39.9[b]	490.2 ± 52.5[c]
V2	712.6 ± 49.2[a]	613.6 ± 59.5[b]	474.2 ± 63.2[c]
Overall mean	738.5 ± 49.2[a]	631.9 ± 49.9[b]	482.2 ± 57.8[c]

Means in the same column represented by same letter are not significantly different at $P \leq 0.05$

4. Discussion: Effect of Parthenium weed on vegetative growth and grain yield of teff

Irrespective of the difference in varieties, Parthenium weed treatment decreased the height growth of teff compared to the control. At 10% weed density treatment, the reduction in height computed to be 7.2% and 8% in variety one and variety two respectively. Since height of a plant is an effective component of competitive struggle for light, the observed reduction in height growth of the test has a significant impact on crop productivity mainly by affecting crop's competitive ability for resources such as light. In similar studies, the effect of Parthenium weed on vegetative growth and dry matter production of crop plants such as soy bean and haricot bean was well documented (Masum *et .al.* 2013). Parthenium weed was also reported to reduce vegetative growth on a wide range of cereal crops such as rice (*Oryza sativa L.*), wheat (*Triticum aestivum* L.), maize (*Zea mays* L.), and sorghum *(Sorghum bicolor* L.) in different parts of the world (Adkins and Shabbir, 2014).

The study showed the presence of statistically significant ($P \leq 0.05$) effect of Parthenium weed density on leaf area. In general, in both varieties of teff, the leaf area was reduced with increased density of weed treatment. Accordingly, at 10% weed density treatment, the percent reduction was 12.8 and 13.2 in V1 and V2 respectively. Verities in duration, intensity and quality, light regulates many aspects of plant growth and development. Leaves are the sites of light interception and plants with large leaf area have a great competitive advantage over plants with smaller leaf area. Thus, the observed reduction in leaf area in response to increased density of weed definitely affects plant growth and development not only by reducing the amount of light intercepted but also the surface area for photosynthesis.

The result of the present study showed statistically significant ($P \leq 0.05$) effect of weed treatment level on grain yield of the two varieties of teff studied. Moreover, the yield loss caused by 5% and 10% Parthenium weed treatment level was found to be 14.9 and 38.9 respectively in V1 and 13.9 and 33.4, in V2. However, direct comparison of the results of the present study with other similar studies is not possible for a number of reasons mainly due to the fact that the extent of yield loss due to weed competition against a given crop depends on several factors, mainly on the type of weed species and its population density (Gallandt, 1997; Schonbeck, 2013). Nevertheless, yield loss caused by Parthenium weed has been documented for a wide range of other cereal crops such as rice (*Oryza sativa* L.), wheat (*Triticum aestivum* L.), maize (*Zea mays* L.), and sorghum *(Sorghum bicolor* L.) in different parts of the world. In such crops, Parthenium weed has been shown to reduce yields by as much as 40% in India (Adkins and Shabbir, 2014).

Moreover, previous studies have confirmed that vegetative growth parameters such as stem height, leaf length and tillering are positively correlated with grain yield of teff (Solomon, 2010).However, the negative impact of the experimental weed at the 5% treatment level on such yield related traits of the test crop varieties was not consistent with the extent of grain yield loss that occurred due to its competition under the same treatment level. The Tuky's SD test indicated that the means of the vegetative growth features under the 5% treatment were not statistically significant from the weed free control, whereas with regard to grain yield at harvest, the data indicated that grain yield was significantly lower than that of the weed free control group. While there may be a number of possible factors, the reason for such disparity can be hypothetically attributed to the fact that the relatively lower population density (5%) of the experimental weed might have delayed the critical period of weed interference and thus did not exert marked impact on the growth of the test crop varieties during their early growth period. On the other hand, relatively severe weed competition, which resulted in grain yield loss could have occurred during the late growing season of the experimental crop. In line with this assumption Hall *et al*. (1992) reported that the beginning of the critical period of weed interference for a given crop can vary with several factors and weed density is one of the major factors, which determine the beginning of the critical period. It has been indicated by the same author that at conditions of relatively lower weed density, the critical period of weed- crop tends to start late and vice versa.

5. Conclusions and recommendations

The present study showed significant effect of Parthenium weed density on vegetative and grain yield of teff varieties. The extent of crop yield loss that occurred due to weed competition at each treatment level was assessed by comparing with the weed free control group. A relatively higher (between the 10% & 0%weed treatment levels) and moderate(between the 5% & 0% weed treatment levels) differences were observed in all of the measured traits of the experimental teff varieties, indicating that both weed treatment levels had an impact on the growth and grain production of the experimental crop varieties. Nevertheless, the impact of Parthenium weed competition at the 5% treatment level on the growth parameters of the test crop varieties was not statistically significant , whereas with regard to grain yield at harvest, the result indicated that grain yield was significantly affected at both treatment levels (5% and 10%).The possible cause of this disparity can be attributed to the relatively lower density of the experimental weed and its late emergence relative to the crop that might have delayed the onset of the critical period of weed–crop competition, so that the weed did not cause significant crop loss during their early growth period (at least until 40 DAE the crop). On the other hand, relatively severe weed competition which caused the recorded grain yield loss could have occurred during the late growing season of the test crop varieties.

Based on the result of this experiment, it seems to be reasonable to conclude tentatively that under relatively lower levels of infestation (< 5%) Parthenium weed competition may not affect teff plant during the crop's early growth period and the subsequent risk of grain yield loss can be minimal. The basis for this suggestion is the delayed onset of the weed's critical period of competitiveness and its late emergence relative to the crop.

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Conflicts of interest

The authors declare no conflicts of interest.

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