Effect of parthenium weed on maize yield at different competition durations in Ethiopia

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Summary Parthenium weed (*Parthenium hysterophorus* L.) is an invasive weed species in more than 40 countries, including Australia. It infests several major crops and causes substantial yield losses. It is important to determine its critical competition duration in different crops to devise a suitable management strategy. A field study was conducted to evaluate the effect of parthenium weed on maize at different weed-crop competition durations in Ethiopia. Six treatments applied included: season-long weed-free; weed-free after 2, 4, 6 and 8 weeks of crop emergence; and season-long weedy. Parthenium weed biomass increased with increasing competition duration. Parthenium weed negatively affected the growth, yield and yield related traits of maize at all competition durations; however, more reductions in all these parameters were observed at longer parthenium weed competition durations. The highest and lowest values for leaf area index, ears per plant, thousand grain weight, grain yield and biological yield were observed in season-long weed-free and season-long weedy treatments, respectively. Parthenium weed competition for 2, 4, 6 and 8 weeks after crop emergence caused 3, 6, 8 and 15% losses in maize grain yield, respectively, when compared with the season-long weed-free treatment. It is important to note that the yield reductions in plots which were kept weed-free after 8 weeks were similar as in those kept weedy throughout the season. The results suggest that management strategies should be devised to control parthenium weed in maize during the critical competition period of 4–8 weeks after crop emergence.

Keywords *Parthenium hysterophorus*, weed-crop interference, *Zea mays*, weed management, yield losses.

INTRODUCTION

Parthenium weed is an invasive alien species which infests non-cropped areas, pastures, diverse cropping systems and forest ecosystems in more than 40 countries around the world (Adkins and Shabbir 2014, Bajwa *et al.* 2016). It is also a Weed of National Significance in Australia and a Class-2 declared pest in Queensland (Adkins and Shabbir 2014). Parthenium weed causes substantial losses to pasture and crop productivity, livestock production and native biodiversity (Adkins and Shabbir 2014). It is also notorious as a source of allergies, respiratory problems and other health complications in humans and animals.

Parthenium weed infests many field crops in countless countries of Asia and Africa (Tamado *et al.* 2002, Safdar *et al.* 2016). It causes severe yield losses in major food crops and therefore, poses serious threat to regional and global food security. It interferes with crop production directly through competition and through allelopathic interactions (Bajwa *et al.* 2016). Parthenium weed infests a large area in Ethiopia where it has become a major problem for sustainable crop production. For instance, sorghum (*Sorghum bicolor* L. Moench) is one of the most important grain crops in dry low-land areas of Ethiopia and suffers significantly from parthenium weed infestation (Tamado *et al.* 2002). In eastern Ethiopia, grain yield losses in sorghum were up to 97% at 100 parthenium weed plants m^{-2} (Tamado *et al.* 2002). Even at the density of three plants m^{-2}, parthenium weed caused up to 69% yield reductions. The critical period for parthenium weed management to avoid the substantial yield loss was up to 60 days after crop emergence.

Parthenium weed infestation in maize (*Zea mays* L.) crop is also very troublesome in different regions. Maize is an important grain crop in Ethiopia along with sorghum and both suffer from heavy parthenium weed infestations. However, information on the parthenium weed critical competition period in the Ethiopian maize system is lacking. Such information is very important to understand the dynamics of parthenium weed competition with maize and to devise management strategies. This field study was conducted to evaluate the impact of parthenium weed on maize growth and yield at different competition durations in Ethiopia.

MATERIALS AND METHODS

A field study was conducted at Haramaya, eastern Ethiopia (latitude of 9°26′ N, longitude of 42°03′ E and an altitude of 1980 m above sea level). The soil of the experimental site was a well-drained deep alluvial with a sub-soil stratified with loam texture. The total average annual rainfall was 827 mm, and the average temperature was 16.8°C. The experiment was laid out in a randomised complete block design with three replications per treatment. Maize cultivar Melkassa-2 was planted at 75 × 25 cm spacing. Phosphorus (P) fertiliser in the form of triple super phosphate at 46 kg P_2O_5 ha^{-1}, and half of the nitrogen (N) fertiliser in the form of urea (87 kg N ha^{-1}) were applied uniformly in all plots by band application method at the time of planting and the remaining half of N-fertiliser was applied at the knee height stage (50 cm) of seedlings.

Seeds of parthenium weed were collected from local, naturally growing populations. About 10 g parthenium weed seed was uniformly broadcasted over each experimental plot just after sowing the crop to ensure a dense population of parthenium weed; except in the season-long weed-free treatment. Six different parthenium weed competition treatments were used:

- season-long weed-free;
- weed-free 2 weeks after crop emergence;
- weed-free 4 weeks after crop emergence;
- weed-free 6 weeks after crop emergence;
- weed-free 8 weeks after crop emergence; and
- season-long weedy.

The season-long weedy and weed-free treatments were established as controls. A uniform parthenium weed density of 15 plants m^{-2} was maintained in all treatments except the weed free treatment. All the other weeds were removed by hand pulling in all the treatments throughout the crop season. For parthenium weed biomass, plants were harvested from two different locations from within the crop (each 1 m^2) and from different treatments just before starting the parthenium weed control in the respective treatments. Biomass was recorded after oven drying at 70°C for 3 days. Leaves were collected from all treatments to measure the leaf area index 10 weeks after crop emergence. The number of ears per plant was recorded before harvesting from 20 plants in each treatment. The 100-grain weight, biological and grain yield were recorded after harvesting the crop. All the data were subjected to analysis of variance using Statistix-8.1 software. Treatment means were separated by the least significant difference (LSD) test at P<0.05. The graph was prepared in Microsoft excel.

RESULTS

Parthenium weed competition duration had significant impact on parthenium weed biomass and maize growth and yield (P<0.05).

The highest parthenium weed biomass was observed in the season-long weedy treatment which was statistically similar to the treatment which was kept free from parthenium weed 8 weeks after crop emergence (Figure 1). The lowest parthenium weed biomass was obtained from plots where parthenium weed grew for only 2 weeks. Parthenium weed competition duration significantly (P<0.05) affected the leaf area index, number of ears per plant, 100-grain weight and biological yield of maize (Table 1). The highest leaf area index, number of ears per plant, 100-grain weight and biological yield were observed in the season-long weed free treatment. The lowest values for all these parameters were recorded for the season-long weedy treatment. Parthenium weed competition for 2–8 weeks caused the reductions of 4–29%, 5–16%, 4–18% and 2–16% in leaf area index, number of ears per plant, 100-index and biological yield, respectively, as compared with the season-long weed-free treatment.

Grain yield of the maize crop was also significantly reduced with increasing duration of parthenium weed competition (Table 2). The highest grain yield was obtained in the season-long weed-free treatment (9.4 t ha^{-1}) followed by the treatment which was kept weed-free 2 weeks after crop emergence (9.1 t ha^{-1}).

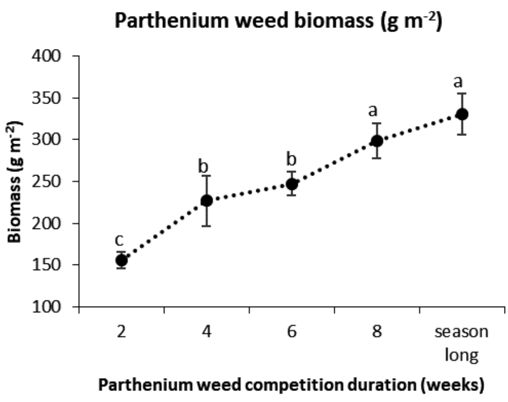

Figure 1. Effect of competition duration on parthenium weed biomass when growing in a maize crop. Error bars represent ± standard errors of the mean. Means sharing the same letter, do not differ significantly according to the least significant difference (LSD) test at P<0.05.

The lowest grain yield was recorded in the season-long weedy treatment. The grain yield in the 4 and 6-weeks competition treatments was statistically similar (Table 2). The season-long weedy and 8-weeks competition treatments provided the lowest grain yields (7.9 and 8.0 t ha^{-1}, respectively) which were statistically similar (Table 2). Overall, different competition durations caused 2.5–15.5% grain yield loss compared to the season-long weed-free treatment.

Table 1. Effect of parthenium weed competition duration on different growth and yield attributes of maize.

	Leaf area index	No. of ears per plant	100-grain weight (g)	Crop biomass (t ha^{-1})
T1[A]	5.1 a[B]	1.37 a	45.2 a	23.5 a
T2	4.9 ab	1.30 ab	43.2 b	23.1 a
T3	4.6 abc	1.29 ab	40.0 c	21.9 b
T4	4.4 bc	1.24 bc	39.0 c	20.9 c
T5	4.3 c	1.24 bc	38.6 cd	20.1 cd
T6	3.6 d	1.15 c	37.0 d	19.8 d
LSD at P<0.05	0.49	0.09	1.68	0.96

[A] T1 = Season-long weed-free, T2 = Weed-free after 2 weeks, T3 = Weed-free after 4 weeks, T4 = Weed-free after 6 weeks, T5 = Weed-free after 8 weeks, T6 = Season-long weedy

[B] Means sharing the same letter, in a column, do not differ significantly according to the least significant difference (LSD) test at P<0.05.

Table 2. Effect of parthenium weed competition duration on maize grain yield.

	Grain yield (t ha^{-1})	Yield loss (%)[C]
T1[A]	9.4 a[B]	–
T2	9.1 ab	2.5
T3	8.8 bc	5.7
T4	8.7 c	7.5
T5	8.0 d	14.5
T6	7.9 d	15.5
LSD at P<0.05	0.32	

[A] T1 = Season-long weed-free, T2 = Weed-free after 2 weeks, T3 = Weed-free after 4 weeks, T4 = Weed-free after 6 weeks, T5 = Weed-free after 8 weeks, T6 = Season-long weedy.

[B] Means sharing the same letter, in a column, do not differ significantly according to the least significant difference (LSD) test at P<0.05.

[C] Yield loss compared season-long weed-free treatment.

DISCUSSION

Weed-crop competition balance determines the crop growth and yield. Parthenium weed competition for longer periods negatively affected maize growth and yield. This may be mainly due to enhanced competition for water, nutrients and space (Bajwa et *al.* 2016, Safdar *et al.* 2016). The fast-growing habit and efficient resource acquisition of parthenium weed might have given it a competitive advantage over the crop (Bajwa *et al.* 2016). It has been reported that parthenium weed can germinate under a wide range of environmental conditions and it can grow very quickly by establishing a long tap root, extensive branching, large number of well-expanded leaves and a stiff, erect stem (Bajwa *et al.* 2016, 2017, 2018). These attributes are helpful for rapid canopy development, space acquisition and overall plant growth. In addition, parthenium weed uptakes water and nutrients from the rhizosphere very efficiently as compared with most crop plants. For instance, Safdar *et al.* (2016) reported that N, P and K uptake by parthenium weed increased with increasing competition period in the maize crop. Parthenium weed growth increased with the passage of time and it had higher biomass production in the treatments where it grew for the longer durations. This is possibly due to the continuous supply of moisture through irrigations and nutrients by fertiliser application (Safdar *et al.* 2016).

Parthenium weed competes strongly with neighbouring plants by not only resource competition but also by releasing allelopathic chemicals in its rhizosphere and aerial surroundings. Several earlier publications support the view that parthenium weed can suppress the growth of other plants through allelopathy (Singh *et al.* 2003, Belgeri and Adkins 2015). The plant can release potent allelochemicals like parthenin, and various phenolic acids and flavonoids (Bajwa *et al.* 2016) which are phytotoxic to growth of certain plants. So, the allelopathic potential of parthenium weed might also play an important role in the interference with maize growth.

The higher biomass production of parthenium weed at longer competition durations (4–8 weeks) caused a decline in growth and yield-related traits of maize, which ultimately led to grain yield losses. Lower yield losses in the 2-week competition treatment might be due to less competition of parthenium weed with crop growth. The critical competition period is between 4 and 8 weeks where the crop suffered heavy yield losses. Safdar *et al.* (2016) reported 21–44% yield losses in maize due to 5–8 weeks of parthenium weed competition. Earlier, Tamado *et al.* (2002) reported huge yield losses (40 to 95%) caused by parthenium weed competing with sorghum crop for 2–9 weeks. Yield losses in the 8-week competition treatment were equal to the unweeded control which indicates that any weed control after 8 weeks of competition may not provide economic benefits. Our results also show significant yield declines at prolonged parthenium weed competition durations; however, the magnitude of yield loss is comparatively less. This may be due to good rainfall during the crop growth season which benefited crop growth.

In conclusion, parthenium weed can cause a substantial yield loss in maize crops grown in Ethiopia. Growth and yield losses increased with increasing parthenium weed competition duration. The critical competition period was between 4–8 weeks. Any management strategy should target parthenium weed in maize during this period to enhance crop yield and profitability. Given the parthenium weed infestation in north and central Queensland cropping systems, this recommendation is also valid for maize growers of those areas. Similar studies should be carried out in Australia with focus on other major crops.

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