The effects of parthenium weed density on yield attributes and yield of maize in Ethiopia

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Summary Parthenium weed is an invasive alien species in numerous countries around the world, including Australia. It has become a major weed species in tropical and sub-tropical cropping systems, in which it causes significant crop yield losses. However, information about economic thresholds of parthenium weed in different crops is currently lacking which is imperative for sustainable management of this species. The present study was conducted to determine the effects of different densities of parthenium weed (0, 5, 10, 15, and 20 plants m^{-2}) on growth and yield of maize in Ethiopia. A strong linear relationship was observed between density and biomass of parthenium weed. Parthenium weed biomass also had strong negative correlations with yield and yield related traits of maize. Density of parthenium weed had a significant negative effect on growth and yield of maize. The highest density of parthenium weed (20 plants m^{-2}) caused the highest reductions in maize leaf area index (15%), ears per plant (21%), thousand grain weight (12%), biological yield (15%) and grain yield (18%) as compared with the plots free from parthenium weed. However, parthenium weed densities of 5–15 plants m^{-2} only caused 8–10% losses in the grain yield of maize. Therefore, it is suggested to reduce the density of this weed species to below 15 plants m^{-2} to avoid substantial yield losses.

Keywords *Parthenium hysterophorus*, economic threshold, *Zea mays*, weed management, yield losses.

INTRODUCTION

Parthenium weed (*Parthenium hysterophorus* L.) is one of the most invasive species in the world. It is not only a major problem for native biodiversity and human and animal health but also an increasing threat to crop production in over 40 countries (Adkins and Shabbir 2014, Bajwa *et al.* 2016). It is also a Weed of National Significance in Australia where it causes huge losses to pasture and crop productivity and livestock production (Adkins and Shabbir 2014). Parthenium weed infestations in cropping systems have increased dramatically in many countries in Asia and Africa (Tamado *et al.* 2002, Bajwa *et al.* 2016). Ethiopia is one such country where this noxious weed species is seriously affecting crop yields (Tamado *et al.* 2002). It infests staple food crops such as grain sorghum (*Sorghum bicolor* L. Moench) and maize (*Zea mays* L.) in this part of the world (Tamado *et al.* 2002).

Parthenium weed competes strongly with these crops and causes significant reductions in crop yield. In Pakistan, Safdar *et al.* (2015) reported up to 50% grain yield losses in maize by different densities of parthenium weed under irrigated conditions. Another study reported that parthenium weed, at the densities of 2 to 16 plants m^{-2}, caused up to 25% loss in fresh fodder yield of sorghum crop (Asif *et al.* 2017). However, competition dynamics of parthenium weed in maize crops in Ethiopia are not well-studied. It is crucial to determine the economic thresholds of parthenium weed in different crops to devise suitable and timely management strategies. This study was conducted to assess the negative effect of different densities of parthenium weed on growth and yield of a maize crop in Ethiopia.

MATERIALS AND METHODS

A field study was carried out 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 loam. 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. Nitrogen (N) and phosphorus (P) fertilisers were applied at the rate of 87 and 46 kg ha^{-1}. The crop was grown under rainfed conditions (average annual rainfall in this region of Ethiopia is 827 mm). Seeds of parthenium weed were collected from local, naturally growing populations and uniformly broadcast at each experimental plot (ca. 10 g per plot) by hand just after sowing the crop except the control treatment (0 plants m^{-2}). Five different densities of parthenium weed (0, 5, 10, 15 and 20 plants m^{-2}) were established, then maintained throughout the duration of the study. More than required parthenium weed seedlings were removed manually as they appeared in the different treatments. Moreover, all other weeds were also removed by hand pulling in all the treatments throughout the crop season.

Aboveground plant biomass of parthenium weed was recorded from two different locations (each 1 m^2) in each experimental plot before harvesting the crop. Biomass was recorded after oven drying at 70°C for 3 days. Fresh leaves of maize were collected in the different treatments to measure the leaf area and to determine 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 sets were subjected to an analysis of variance using Statistix-8.1 software. Treatment means were separated by the least significant difference (LSD) test at P<0.05. The data on parthenium weed biomass and maize grain yield were plotted by regression analysis in Microsoft Excel.

RESULTS AND DISCUSSION

Different densities of parthenium weed significantly affected its own biomass (P<0.05), increasing linearly with increasing densities (Figure 1). Parthenium weed densities also had a significant impact on growth, yield-related traits and yield of maize crop (P<0.05). The highest values for leaf area index, ears per plant, 100-grain weight and biological yield were observed in the plots where no parthenium weed was present (Table 1). The highest density of parthenium weed (20 plants m^{-2}) caused the highest reductions in leaf area index (15%), number of ears per plant (21%), 100-grain weight (12%) and biological yield (15%) as compared with the parthenium weed-free control.

The grain yield of maize was also significantly affected by different densities of parthenium weed (Figure 2). A strong negative relationship was observed between parthenium weed density and maize grain yield ($R^2 = 0.88$). Parthenium weed densities of 5, 10, 15 and 20 plants m^{-2} caused 7.6, 8.5, 9.7 and 17.7% loss in maize grain yield, respectively, when compared to the treatment that had no parthenium weed plants present.

The results of this study show that parthenium weed negatively affects maize growth and yield. However, the negative impact is more pronounced at weed densities higher than 15 plants m^{-2}. These higher weed densities also produced more biomass per unit area, which caused crop growth and yield reductions.

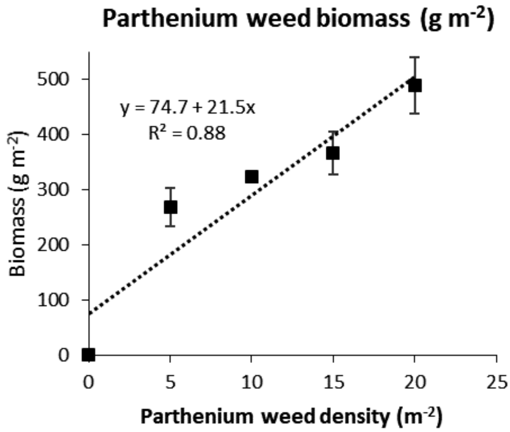

Figure 1. Effect of different densities of parthenium weed on its dry biomass when growing in a maize crop. Error bars represent ± standard errors of the mean.

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

Weed density (m^{-2})	Leaf area index	No. of ears per plant	100-grain weight (g)	Biological yield (t ha^{-1})
0	4.6 a[A]	1.4 a	45.0 a	22.0 a
5	4.5 ab	1.3 b	43.5 ab	20.4 b
10	4.3 bc	1.3 b	42.6 bc	19.9 b
15	4.0 cd	1.2 c	41.3 cd	19.6 bc
20	3.9 d	1.1 d	39.8 d	18.6 c
$LSD_{0.05}$	0.10	0.03	1.80	0.53

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

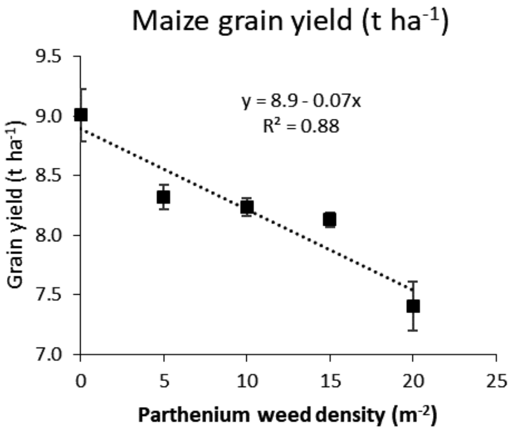

Figure 2. Effect of different densities of parthenium weed on grain yield of maize crop. Error bars represent ± standard errors of the mean.

The negative effects can be attributed to strong interference effects (competitive and allelopathic) provided by parthenium weed plants. It has been reported that parthenium weed efficiently acquires the essential resources such as moisture, nutrients and light, while growing alongside other plant species (Safdar *et al.* 2015, 2016). It has a tall stature, fast-growing habit, and the ability to tolerate harsh climatic conditions, which makes it highly competitive (Bajwa *et al.* 2016, 2018). Earlier studies have also shown similar negative effects of parthenium weed on maize and sorghum yields (Safdar *et al.* 2015, 2016, Asif *et al.* 2017).

Safdar *et al.* (2015) reported that parthenium weed attained more biomass at its higher densities and accumulated more N, P and potassium than maize plants. Parthenium weed interferes with crops not only through competition but it also suppresses crop growth through allelopathy (Singh *et al.* 2003, Bajwa *et al.* 2016). The plant can release potent allelochemicals like parthenin, and various phenolic acids and flavonoids 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.

In conclusion, different densities of parthenium weed can cause a substantial yield loss in maize crops grown in Ethiopia. Growth and yield losses increased with increasing parthenium weed densities. However, the weed density above 15 plants m^{-2} caused a significantly higher yield loss. Therefore, this weed species must be kept below this threshold to avoid substantial yield loss.

ACKNOWLEDGMENTS

This manuscript is part of the PhD research project of Ali Ahsan Bajwa who is thankful to the Australian Government and The University of Queensland, Australia for the provision of a Research Training Program Scholarship and University of Queensland Centennial Scholarship, respectively.

REFERENCES

Adkins, S. and Shabbir, A. (2014). Biology, ecology and management of the invasive parthenium weed (*Parthenium hysterophorus* L.). *Pest Management Science* 70, 1023-9.

Asif, M., Ayub, M., Tanveer, A. and Akhtar, J. (2017). Estimating yield losses and economic threshold level of *Parthenium hysterophorus* in forage sorghum. *Planta Daninha* 35, e017164158.

Bajwa, A.A., Chauhan, B.S. and Adkins, S.W. (2018). Germination ecology of two Australian biotypes of ragweed parthenium (*Parthenium hysterophorus*) relates to their invasiveness. *Weed Science* 66, 62-70.

Bajwa, A.A., Chauhan, B.S., Farooq, M., Shabbir, A. and Adkins, S.W. (2016). What do we really know about alien plant invasion? A review of the invasion mechanism of one of the world's worst weeds. *Planta* 244, 39-57.

Safdar, M.E., Tanveer, A., Khaliq, A. and Maqbool, R. (2016). Critical competition period of parthenium weed (*Parthenium hysterophorus* L.) in maize. *Crop Protection* 80, 101-7.

Safdar, M.E., Tanveer, A., Khaliq, A. and Riaz, M.A. (2015). Yield losses in maize (*Zea mays*) infested with parthenium weed (*Parthenium hysterophorus* L.). *Crop Protection* 70, 77-82.

Singh, H.P., Batish, D.R., Pandher, J.K. and Kohli, R.K. (2003). Assessment of allelopathic properties of *Parthenium hysterophorus* residues. *Agriculture, Ecosystems and Environment* 95, 537-41.

Tamado, T., Ohlander, L. and Milberg, P. (2002). Interference by the weed *Parthenium hysterophorus* L. with grain sorghum: influence of weed density and duration of competition. *International Journal of Pest Management* 48, 183-8.