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Research Article

Distribution and Impact of Parthenium (*Parthenium hysterophorus L.*) on Weed Species Diversity in Maize Fields in Western Gojjam Zone, Amhara National Regional State, Ethiopia

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An investigative weed flora survey was conducted in parthenium-infested maize fields in West Gojjam Zone in 2019/2020. The objective was to investigate the distribution and impact of parthenium on species diversity. A survey was conducted on 90 fields using $2\,m \times 2\,m$ ($4\,m^2$) quadrats (totally 270). A total of 110 weed species belonging to 27 families were identified out of these families. Asteraceae with 26 species (23.36%) and Poaceae with 18 species (16.36%) were abundant. The highest importance value (IV) was recorded by *Ageratum conyzoides, Amaranthus hybridus*, and *Bidens pilosa*, with 28.05, 19.18, and 13.16%, respectively, in no parthenium infestation level. The highest IV of 27.08, 17.71, and 16.44%, respectively, was shown by *Ageratum conyzoides, Bidens pilosa*, and *Galinsoga parviflora* with 27.08, 17.71, and 16.44%, respectively, in very low parthenium infestation level. *Ageratum conyzoides* (29.38%), *Bidens pilosa* (24.10%), and *Parthenium hysterophorus* (22.68%) had the highest IV in low parthenium infestation level. *Parthenium hysterophorus* (91.32%), *Ageratum conyzoides* (17.19%), and *Echinochloa colona* (16.34%) had high IV in moderate parthenium infestation level. It is concluded that *Ageratum conyzoides*, *Bidens pilosa*, *Echinochloa colona*, and *Galinsoga parviflora* were competitive over parthenium based on importance value, and this indicates to suggest parthenium as a biological management option.

1. Introduction

Parthenium (*Parthenium hysterophorus* L.) is native to regions across the Gulf of Mexico and has spread to more than 40 countries across five continents [1–3]. Parthenium was first discovered in 1980 near food assistance distribution centers in Ethiopia around Dire-Dawa in 1980 [4, 5]. Parthenium weed entered the country through military vehicles during the Ethio-Somali war of 1976/77 [5, 6]. The presence of weed in Kenya and Somalia [7] and the ability of the seed to migrate long distances from these neighboring countries by wind, water, and other means also suggested possible entry into Ethiopia. After its introduction, the weed has spread rapidly through farmlands, forests, orchards, poorly controlled arable croplands, and rangelands in Ethiopia [8].

Parthenium affects crop production, livestock production, natural ecosystem production, biodiversity, and human and animal health, according to Karim [1, 9]. Singh et al. [10] and Mirza et al. [11] have reported that parthenium damage results not only in direct competition but also in a decrease in the quantity and quality of a crop created by an allelopathic effect that can inhibit the growth of other plants. Information on the spatial distribution of weeds for a farmer can, therefore, provide a better understanding of the expected benefit and a way to minimize input costs by applying weed-specific control [12]. The economic and environmental benefits of documenting the spatial variation of weeds have been recognized and used for some time in conventionally controlled systems to apply site-specific inputs [13].

Because of its recent introduction, there is little understanding and documentation of parthenium distribution and invasion in the West Gojjam District, Amhara National Regional State, Ethiopia. To know its supremacy in a group, it is important to know the characteristics such as density, frequency, and abundance of the species. Consequently, this field survey was planned to investigate the distribution and effect of parthenium on the diversity of weed species in maize fields.

This research was carried out in order to resolve the hypothesis that the frequency, density, abundance, importance value, and diversity of weed species would be greatly influenced by parthenium infestation.

2. Materials and Methods

2.1. Description of the Weed Survey Area. This study was carried out in the Jabitenah and Burie districts of West Gojjam Zone. Jabitenah district is found at 10° 42′ 14′′ N latitude and 37° 03′50′′ *E* longitude, with an altitude of 1350–2090 meters above sea level, and Burie district is also at 10° 42′ 00′′ N latitude and 37° 16′ 00′′E longitude, with an altitude of 1500–2300 meters above sea level. The total annual rainfall and maximum and minimum annual temperature of the Jabitenah district were 900–1467 mm, 30°C, and 13°C, respectively, whereas the total annual rainfall and maximum and minimum annual temperature of the Burie district were 1000–1500 mm, 29°C, and 19°C, respectively [14]. The soils in the survey site have the textural class of clay to sandy clay and pH of 6.5–6.8 (slightly acid to neutral), and the soil type was Nitosol and Vertisol.

2.2. Sampling of Weed Flora. Weed survey was conducted in the 2019/2020 main cropping season in Jabitenah and Burie districts. From each district, three farmers' associations were identified. In addition to this, three large-scale private farms, namely, Upper Bir, Lower Bir, and Amhara Seed Enterprise were included. Ten fields from each farmers' association (a total of 60 fields) and three private farms (a total of 30 fields) were selected. Three $2\,m \times 2\,m$ ($4\,m^2$) quadrats (totally 270) were used following a cross-diagonal line in maize fields [15].Most of the farmers use monocropping and fertilizers but not herbicides with minimum tillage, whereas private farms practice the usage of fertilizer, herbicides, crop rotation, and conventional tillage.

2.3. Identification and Collection of Weed Flora. The distribution of parthenium in the districts was carried out in maize fields when most of the weed species were found flowering (September and October 2019/2020). According to the framework defined by Chellamuthu et al. [16] and Ayele et al. [17], the sample sites were classified into five parthenium infestation levels based on the density proportion, no (0 percent), very low (1–10 percent), low (11–25 percent), moderate (26–50 percent), and high (>50 percent), of all plants' total percentage density. In each of the sample quadrates of the parthenium infestation stages, the identity and quantity of the weed species were determined and registered. In the field, most of the species of weed collected from the quadrats were described. For proper identification, unclear sample specimens of the weed species were collected, numbered, dried, and transported to Haramaya University herbarium. Regarding the flora of Ethiopia and Eritrea, the nomenclature of the weed plant species was carried out [18–20].

2.4. Data Analysis. During the course of studies, the data were recorded on the following parameters as adopted from [21, 22]:

$$\begin{aligned}
\text{Relative frequency (RF)} &= \frac{\text{The frequency value } (\mathbf{F}) \text{ for species } \mathbf{I}}{\text{Total sum of all frequency for all species surveyed}} \text{x}\,100,\\
\text{Relative Density (RD)} &= \frac{\text{Mean Field Density for an individual } (\mathbf{I}) \text{ (all fields)}}{\text{Sum of the densities for all weed species}},\\
\text{Relative Abundance (RA)} &= \frac{\text{Abundance of a particular weed species}}{\text{Total abundance of all weed species}},\\
\text{Importance value (IV)} &= \text{RD} + \text{RF} + \text{RA},\\
\text{Similarity Index (SI): SI} &= \frac{(\text{Epg})}{\text{Epg} + \text{EPa} + \text{Epb}} \times 100,
\end{aligned} \tag{1}$$

where SI = similarity index; Epg = number of species found in both; EPa = number of weed species found only in the farmer's maize crop fields; and Epb = number of species found in private and seed enterprise maize crop farms.

2.5. Regression and Correlation. The analysis was carried out using the abundance of parthenium as an independent variable and species and Shannon diversity index and richness as the dependent variables. The analysis was performed using Excel software.

3. Results and Discussion

3.1. Weed Flora Composition. The weed flora of maize fields was comprised of 110 species including *Parthenium hysterophorus* from 90 parthenium-infested sampled fields in the 2019/2020 main cropping season. These weed species were distributed within 27 families. The predominant families were Poaceae and Asteraceae with 26 (23.36%) and 18 (16.36%) species, respectively, whereas Boraginaceae, Papaveraceae, Plantaginaceae, Portulacaceae, Primulaceae, Ranunculaceae, Rubiaceae, and Scrophulariaceae were represented by a single species (Figure 1). The greater number of species in Poaceae and Asteraceae might be due to their adaptability under a wider range of environment and soil types, aggressive behavior, enormous seed production, efficient seed dispersal, long-lasting dormancy, and spectacular competitive ability of weed species present in these families. This finding conforms with the findings of Tana and Milberg [23] on sorghum in eastern Ethiopia, Nigatu et al. [24] on sorghum fields of eastern Amhara, Million et al. [25] in Gambella, and Ayele et. al. [17] in Jijjiga.

3.2. Frequency and Relative Frequency of Weed Species. From 90 sampled fields, no parthenium infestation level (NPIL) was found on 24 fields, very low parthenium infestation level (VLPIL) not only on 25 fields, low parthenium infestation level (LPIL) not only on 30 fields, and moderate parthenium infestation level (MPIL) not only on 11 fields. A reference to the data in Table 1 exhibits that *Ageratum conyzoides, Amaranthus hybridus*, and *Amaranthus hybridus* with 1.00, 1.00, and 0.96 showed the highest frequency and 31 species showed the least frequency with 0.04 in NPIL. In VLPIL, *Parthenium hysterophorus* (1.00), *A. conyzoides* (0.92), and *A. hybridus* (0.88) showed the highest frequency and the other 22 species had the least frequency (0.04). The highest frequency (0.00, 0.80, and 0.57) was recorded by *P. hysterophorus, A. conyzoides*, and *Bidens pilosa,* respectively, whereas the least frequency (0.03) was recorded by 21 species in LPIL. Among the frequently occurring species, *P. hysterophorus* (1.00), *A. hybridus* (0.73), and *A. conyzoides* (0.64) had the highest weed frequency and 18 species showed the least with 0.09 frequency in MPIL (Table 1).

The relative frequency shows the distribution of weed flora in maize fields. The relative frequency of *A. conyzoides, Echinochloa colona,* and *A. hybridus* was the uppermost than others with 4.35, 4.35, and 4.17%, respectively, whereas 29 species showed the least relative frequency with 0.18% in NPIL. Among the weed species, *P. hysterophorus, A. conyzoides,* and *A. hybridus* were recorded to have the highest relative frequency with 5.95, 5.48, and 5.24%, respectively, in VLPIL, while the least was a record by 22 species with 0.24%. Among the recorded weeds species, the highest relative frequency of 9.07, 7.25, and 5.14% were found for *P. hysterophorus* followed by *A. conyzoides* and *B. pilosa*, respectively, whereas the least was recorded by 21 species with 0.30% in LPIL. In MPIL, *P. hysterophorus* (11.45%), *A. hybridus* (8.33%), and *A. conyzoides* (7.29%) showed the highest relative frequency, while the least was recorded by 18 species with 1.04% (Table 2).

As the degree of infestation increased, the relative frequency of parthenium was increased. Ayele et al. [17] also stated that when the degree of infestation increased from no to high parthenium infestation, the relative frequency of parthenium increased from 0.00 to 66.98%. Similarly, Nigatu et al. [24] found that the relative frequency between low and high levels of parthenium infestation was 8.22 to 56.38 per cent. In Eastern Ethiopia, Tamado [5] stated that the parthenium is the most frequent weed (54 %) after *Digitaria abyssinica* (63%).

3.3. Mean Field Density and Relative Density of Weed Species. The mean field density ranged from 0.03 to 28.83, 0.03 to 18.03, 0.04 to 12.70, and 0.09 to 53.06 m$-^{2}$ in NPIL, VLPIL, LPIL, and MPIL, respectively (Table 1). In NPIL *A. conyzoides, A. hybridus,* and *B. pilosa* showed the highest mean field density (28.83, 24.11, and 9.97 m^{-2}, respectively), while the least was in *Pennisetum sphacelatum* with 0.03 m^{-2}. Among the weeds species, the maximum mean field density was recorded by *A. conyzoides, B. pilosa,* and *G. parviflora* with 18.03, 9.93, and 9.35 m^{-2}, respectively, whereas the minimum was observed in *Brachiaria eruciformis* with 0.03 m^{-2} in VLPIL.

The highest mean field density was recorded by *A. conyzoides* (12.70 m^{-2}), *B. pilosa* (10.76 m^{-2}), and *P. hysterophorus* (6.76 m^{-2}), and the lowest was recorded by *Eragrost paniciformis* (0.04 m^{-2}) in LPIL. *P. hysterophorus, A. conyzoides,* and *E. colona* showed a maximum mean field density with 53.06, 5.64, and 5.39 m^{-2}, respectively, whereas the minimum was by *Leucas martinicensis* with 0.09 m^{-2} in MPIL. Parthenium had 0.00, 5.93, 6.76, and 53.06 m^{-2} mean field density in NPIL, VLPIL, LPIL, and MPIL, respectively. The data in Table 2 exhibit the highest relative density by *A. conyzoides, A. hybridus,* and *B. pilosa* with 16.75, 14.00, and 5.79%, respectively, whereas the least was by *A. arvensis, C. ambrosioides,* and *P. sphacelatum,* all with 0.02% in NPIL. The maximum relative density in VLPIL was recorded by *A. conyzoides* (16.31%), *B. pilosa* (8.99%), and *G. parviflora* (8.46%), although the minimum was recorded by *B. eruciformis* (0.02%).

The results revealed that *A. conyzoides, B. pilosa,* and *P. hysterophorus* were found to be the most dominant species with a relative density of 16.50, 13.98, and 8.78%, respectively, while *E. paniciformis* was found to be the least with 0.06 m^{-2} in LPIL. In MPIL, *P. hysterophorus, A. conyzoides,* and *E. colona* revealed the highest relative density with 56.57, 6.01, and 5.75%, respectively, while the least was by *L. martinicensis* with 0.10%. In NPIL, VLPIL, LPIL, and MPIL, the relative parthenium density was 0.57, 5.01, 9.05, and 56.59 %. Maszura et al. [26] recorded that, at different study locations in Malaysia, the relative density of parthenium ranged from 23.09 to 27.25%. Likewise, Ramadhan and Amzath [27] reported that parthenium had a relative frequency, density, and abundance of 53.3 to 80%, 1.2 to 6.4 plants/m^2, and 2.3 to 8 plants, respectively, in crop fields in Tanzania.

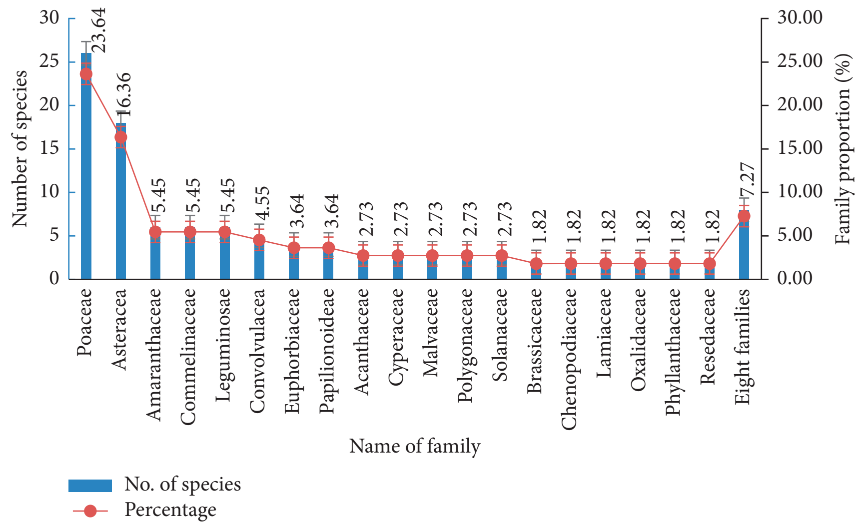

Figure 1: Number and proportion of weed species within the families.

Table 1: Highest and least weed frequency, mean field density, and abundance in different parthenium infestation levels in maize fields.

Name of species	Weed frequency				Mean field density (m^{-2})				Abundance			
	NPIL	VLPIL	LPIL	MPIL	NPIL	VLPIL	LPIL	MPIL	NPIL	VLPIL	LPIL	MPIL
Ageratum conyzoides	1.00	0.96	0.80	0.64	28.83	18.03	12.70	5.64	86.50	49.70	47.71	
Amaranthus hybridus	1.00	0.88		0.73	24.11							
Amaranthus hybridus	0.96											
Parthenium hysterophorus	0.00	1.00	1.00	1.00	0.00	5.93	6.76	53.06	0.00	24.00	41.03	159.18
Bidens pilosa			0.57		9.97	9.93	10.76		42.09	43.82	42.24	46.50
Galinsoga parviflora						9.35			39.11			52.00
Echinochloa colona								5.39				
Phyllanthus maderaspatensis										58.00		
Pennisetum sphacelatum					0.03				2.00			
Brachiaria eruciformis						0.03						
Eragrost paniciformis							0.04					
Leucas martinicensis								0.09				
Brachiaria eruciformis , *Hygrophila auriculata*, and *Justicia heterocarpa*										2.00		
Oxygonum sinuatum											1.00	
Trifolium steudneri												1.33

NPIL= no parthenium infestation level; VLPIL= very low parthenium infestation level; LPIL = low parthenium infestation level; MPIL = moderate parthenium infestation level.

3.4. Abundance and Relative Abundance of Weed Species. The result showed (Table 1) that the highest abundance was recorded by *A. conyzoide*s, *B. pilosa,* and *G. parviflora* with 86.50, 42.09, and 39.11 plants, respectively, in NPIL, while *Pennisetum sphacelatum* with 2 plants was recorded the least abundant weed. According to the results, *Phyllanthus maderaspatensis* (58.00 plants), *A. conyzoides* (49.70 plants), and *B. pilosa* (43.82 plants) were found to be the most abundant and *B. eruciformis* , *Hygrophila auriculata,* and *Justicia heterocarpa* were represented with the least abundance (2 plants) in VLPIL. The highest abundance value (47.71, 42.24, and 41.03 plants) was recorded by *A. conyzoides*, *B. pilosa,* and *P. hysterophorus*, respectively, in LPIL, whereas the least abundance value (1 plant) was recorded for *Oxygonum sinuatum* (Table 1). In MPIL, *P. hysterophorus, G. parviflora,* and *B. pilosa* recorded the highest abundance value of 159.18, 52.00, and 46.50 plants, respectively, and *Trifolium steudneri* showed the least abundance of 1.33 plants in maize fields.

The study in Table 2 showed that high relative abundance in NPIL was itemized by *A. conyzoide*s, *B. pilosa,* and *G. parviflora* with 6.96, 3.38, and 3.15%, respectively, whereas the least was by *Pennisetum sphacelatum* with 0.16%. The highest relative abundance was registered by *P. maderaspatensis* (6.18%), *A. conyzoide*s (5.29%), and *B. pilosa* (4.67%), while the least was by *B. eruciformis, H. auriculata,* and *J. heterocarpa* in VLPIL with 0.21%. Among the weed species, *A. conyzoides, B. pilosa,* and *P. hysterophorus* displayed the maximum relative abundance of 5.63, 4.98, and 4.84%, respectively, and *O. sinuatum* had the minimum value of 0.12% in LPIL. *Parthenium hysterophorus* (23.30%), *G. parviflora* (7.61%), and *B. pilosa* (6.73%) weeds showed the highest relative abundance, whereas *T. steudneri* (0.20%) showed the least in MPIL.

Overall, the majority of weed species showed positive associations between frequency, density, and abundance. The higher the frequency of the species, the greater the density and abundance of the weed, and vice versa. Nkoa et al. [28] reported that weed abundance is related to the number (density) or frequency of weeds, which may have positively affected the abundance. The higher frequency, density, and abundance values of the weed species indicate that these species may grow in competition with parthenium. In addition, the competitiveness of these with parthenium may be greater in the long term and may serve as a substitute method for parthenium management with in a similar agroecological condition.

3.5. Importance Value of Weed Species. By using the addition of relative frequency, density, and abundance to get importance value in Table 2 for each species revealed that the highest importance value was recorded by A. *conyzoides*, *A. hybridus,* and *B. pilosa*, with 28.05, 19.18, and 13.16%, respectively, and the least was by *Pennisetum sphacelatum* with 0.36% in NPIL. Among the weed species, the highest importance value of 27.08% was for *A. conyzoides* followed by *B. pilosa* and *G. parviflora* with 17.71 and 16.44%, respectively, and the lowest was found for *B. eruciformis* with 0.48% in VLPIL. The results of this study revealed that *A. conyzoides* (29.38%), *B. pilosa* (24.10%), and *P. hysterophorus*, (22.68%) had the highest importance value and the least was recorded by *Commelina albescena* (0.62%) in LPIL. *Parthenium hysterophorus* was the most dominant weed species with the highest importance value (91.32%), followed by *A. conyzoides* and *E. colona* with an importance value of 17.19% and 16.34%, respectively, whereas the minimum was by *Leucas martinicensis* (1.58%) in MPIL.

Generally, *A. conyzoides, A. hybridus, B. pilosa, E. colona, G. parviflora,* and *P. hysterophorus* had the highest importance value from all parthenium infestation levels. These species with significant importance could have adapted to the agricultural exploitation of unused resources produced by the current system of maize cultivation in the study region. The value of parthenium in NPIL, VLPIL, LPIL, and MPIL was 0.00, 13.88, 22.68, and 91.32%, respectively (Table 2). After its introduction in a few years, parthenium weed has acquired a value increase of 91.32%, which is by far greater than the value of all native species in MPIL. Shabbir and Bajwa [29] reported that *P. hysterophorus* had the highest relative frequency (24.1%), relative density (45.8%), and importance value (109.0%).

3.6. Impact of Parthenium on Species Diversity. Maximum species richness was reported in NPIL with 98, followed by VLPIL, LPIL, and MPIL with 72, 68, and 37, respectively (Figure 2). The richness of the species decreases as the sample infestation increases. Nigatu et al. [24] observed similar outcomes, with 48, 46, and 37 weed species present at low, medium, and high levels of parthenium infestation, respectively. In NPIL, the highest species equality was observed, followed by VLPIL, LPIL, and MPIL with 0.94, 0.93, 0.93, and 0.72, respectively (Figure 2). The evenness index in MPIL was similarly found but comparatively lower. This means that, in distribution, the species in MPIL are patchy. The maximum Shannon diversity index was obtained in NPIL (4.32), VLPIL (3.89), and LPIL (3.94), and the lowest was in MPIL (2.61).

The decline in diversity index with the successive increase in the infestation level of parthenium indicated that the variation in the type of weed species and the heterogeneity in the community decreased with the increase in parthenium infestation. Likewise, the evenness index was relatively higher in low infested areas, indicating the weed species were more equitably distributed at NPIL than the others do. Parthenium is an invasive weed that poses a serious threat to the environment and biodiversity due to its high invasion and allelopathic impact, which quickly replaces native vegetation [30].

The diversity of the aboveground plant community was the lowest ($H' = 2.61$) when parthenium was present at its maximum mean field density (i.e., 53.06 plants m−2), while the index was the highest ($H' = 4.30$) when parthenium was present at zero mean field densities (Table 1 and Figure 2). Therefore, as the diversity of the aboveground plant community increases, the mean field density of the parthenium decreases, and vice versa. This indicates that parthenium greatly decreases the density and diversity of other species. Similarly, Getachew [31] recorded a decline in species diversity due to the high abundance of parthenium in Ethiopia. Studies in Australia (Grice [32]) and India (Kohli et al. [33]) have also observed a decline in plant diversity because of parthenium invasions.

Due to the effect of parthenium, the species richness, evenness, and Shannon diversity index of other weeds were decreased by 62.24, 39.30, and 23.40%, respectively. In general, the present study showed that there was a sharp decline in the diversity index as parthenium density increased. This result validates the results of Kohli et al. [33] that the Shannon index showed great plant diversity in the uninfested region, while in the parthenium-infested areas, the index was reduced by 9.95 to 33.80%. The higher value of the diversity index shows the difference in the species type and the heterogeneity of the community, whereas the lower value points to the homogeneity of the community. Similarly, studies by Sakai et al. [34] and Grice [32] have shown that parthenium adversely affects the composition and diversity of species, resulting in displacement and imbalance in natural and agricultural systems.

3.7. Weed Similarity in Parthenium Infestation Levels. The result in Table 3 showed that the highest similarity (63.46%) was between NPIL and VLPIL followed by NPIL and LPIL (58.10%) and the least was between NPIL and MPIL (32.35%). The greater dissimilarity in species composition was observed between the NPIL and MPIL (32.35%). In NPIL and VLPIL, a total of 104 species were found out, of which 66 species were common, 32 species were only in NPIL, and 6 species were only in VLPIL. As described by Tesema and Lema [35], if the similarity index is below 60%, it is said that the two infestation levels have different weed communities. Since the similarity

Table 2: The relative frequency, density, and abundance of aboveground weed species at different parthenium infestation levels in maize fields.

No.	Name of species	Relative frequency (%)				Relative density (%)				Relative abundance (%)			
		NPIL	VLPIL	LPIL	MPIL	NPIL	VLPIL	LPIL	MPIL	NPIL	VLPIL	LPIL	MPIL
1	*Abutilon figarianum*	0.36	0.00	0.00	0.00	0.48	0.00	0.00	0.00	0.80	0.00	0.00	0.00
2	*Acayranthes aspera*	0.18	0.24	0.30	0.00	0.06	0.10	0.07	0.00	0.56	0.85	0.59	0.00
3	*Aeschynomene virginica*	1.27	0.71	0.30	0.00	1.50	0.94	0.43	0.00	0.61	0.92	0.71	0.00
4	*Ageratum conyzoides*	4.35	5.48	7.25	7.29	16.75	16.31	16.50	6.01	6.96	5.29	5.63	3.89
5	*Agrostis alba*	0.18	0.00	0.00	2.08	0.04	0.00	0.00	0.48	0.40	0.00	0.00	1.10
6	*Alternanthera repens*	0.36	0.00	0.00	0.00	0.15	0.00	0.00	0.00	0.76	0.00	0.00	0.00
7	*Alysicarpus* Spp.	0.91	0.48	0.00	0.00	0.44	1.99	0.00	0.00	0.87	1.01	0.00	0.00
8	*Amaranthus graecizans*	2.90	3.33	3.63	2.08	1.54	2.29	1.73	1.42	0.96	1.45	1.18	1.90
9	*Amaranthus hybridus*	4.17	5.24	4.84	8.33	14.00	3.72	1.79	2.84	1.01	1.14	0.87	1.88
10	*Amaranthus spinosus*	0.18	0.00	0.00	1.04	0.04	0.00	0.00	0.19	0.40	0.00	0.00	0.88
11	*Anagallis arvensis*	0.18	0.48	0.60	0.00	0.02	0.19	0.16	0.00	0.24	0.85	0.65	0.00
12	*Argemone mexicana*	0.36	0.24	0.00	0.00	0.04	0.11	0.00	0.00	0.36	0.53	0.00	0.00
13	*Aspilia kotschyi*	0.18	0.00	0.00	0.00	0.16	0.00	0.00	0.00	1.61	0.00	0.00	0.00
14	*Bidens biternata*	0.72	0.95	1.21	1.04	1.01	1.17	1.57	1.36	2.51	2.90	2.86	6.15
15	*Bidens pilosa*	3.99	4.05	5.14	1.04	5.79	8.99	13.98	1.49	3.38	4.67	4.98	6.73
16	*Brachiaria eruciformis*	0.54	0.24	0.00	0.00	0.44	0.02	0.00	0.00	1.45	0.21	0.00	0.00
17	*Brassica carinata*	0.54	0.71	0.30	0.00	0.46	0.54	0.30	0.00	0.51	0.53	0.83	0.00
18	*Caylusea abyssinica*	2.36	2.62	1.21	0.00	2.77	3.31	1.66	0.00	2.12	2.65	2.86	0.00
19	*Celosia trigyna*	3.44	2.14	2.42	0.00	4.80	2.67	3.96	0.00	2.52	3.24	2.39	0.00
20	*Chenopodium album*	0.18	0.00	0.30	0.00	0.05	0.00	0.12	0.00	0.72	0.00	0.94	0.00
21	*Chenopodium ambrosioides*	0.18	0.00	0.00	1.04	0.02	0.00	0.00	0.29	0.24	0.00	0.00	1.32
22	*Chloris radiota*	0.18	0.24	0.00	0.00	0.22	0.76	0.00	0.00	0.72	2.24	0.00	0.00
23	*Commelina albescens*	0.00	0.00	0.30	0.00	0.00	0.00	0.09	0.00	0.00	0.00	0.24	0.00
24	*Commelina benghalensis*	1.99	1.67	2.12	1.04	0.47	0.46	1.44	0.29	0.73	0.58	0.98	1.32
25	*Commelina diffusa*	0.36	0.24	0.00	0.00	0.24	0.11	0.00	0.00	1.21	0.96	0.00	0.00
26	*Commelina forskalaei*	0.36	0.00	0.00	0.00	0.13	0.00	0.00	0.00	0.64	0.00	0.00	0.00
27	*Commelina latifolia*	2.90	2.38	2.72	5.21	1.04	1.13	1.05	1.78	0.65	1.00	0.96	1.61
28	*Commelina subulata*	0.18	0.24	0.00	0.00	0.05	0.14	0.00	0.00	0.48	1.28	0.00	0.00
29	*Convolvulus arvensis*	0.18	0.24	0.00	0.00	0.04	0.07	0.00	0.00	0.40	0.64	0.00	0.00
30	*Corchorus olitorius*	0.72	0.48	0.91	1.04	0.65	0.40	1.29	1.36	1.43	2.40	1.30	2.05
31	*Corchorus trilocularis*	0.72	0.00	0.91	1.04	0.71	0.00	0.87	1.00	1.77	0.00	2.36	4.54
32	*Crassocephalum rubens*	1.81	1.90	0.30	0.00	0.76	0.74	0.13	0.00	0.76	0.81	1.06	0.00
33	*Crotalaria filipes*	0.91	0.24	0.00	0.00	0.92	0.29	0.00	0.00	0.85	0.85	0.00	0.00
34	*Crotalaria recta steud*	0.18	0.00	0.00	0.00	0.31	0.00	0.00	0.00	1.05	0.00	0.00	0.00
35	*Crotalaria spinosa*	0.18	0.00	0.00	0.00	0.19	0.00	0.00	0.00	0.64	0.00	0.00	0.00
36	*Cynodon dactylon*	0.36	0.00	0.60	0.00	0.12	0.00	0.48	0.00	1.01	0.00	0.77	0.00
37	*Cynodon nlemfuensis*	0.72	0.24	0.30	0.00	0.57	0.14	0.07	0.00	1.43	1.28	0.59	0.00
38	*Cynoglossum lanceolatum*	0.18	0.00	0.30	0.00	0.08	0.00	0.16	0.00	0.64	0.00	1.18	0.00
39	*Cyperus alopeouraides*	0.18	0.00	0.30	0.00	0.18	0.00	0.33	0.00	0.20	0.00	2.95	0.00
40	*Cyperus esculentus*	0.36	0.00	0.60	0.00	0.14	0.00	0.59	0.00	0.68	0.00	2.42	0.00
41	*Cyperuse rotundes*	0.18	0.00	0.00	0.00	0.08	0.00	0.00	0.00	0.80	0.00	0.00	0.00
42	*Dactyloctenium aegyptium*	0.00	0.24	0.00	0.00	0.00	0.11	0.00	0.00	0.00	0.96	0.00	0.00
43	*Datura stramonium*	0.18	0.00	0.91	0.00	0.04	0.00	0.20	0.00	0.40	0.00	0.55	0.00
44	*Digitaria velutina*	0.36	0.95	0.91	0.00	0.24	1.48	0.52	0.00	0.40	1.09	0.47	0.00
45	*Digitaria ternata*	2.17	1.67	1.81	0.00	2.86	2.39	1.57	0.00	2.38	3.01	2.14	0.00
46	*Dinebra retroflexa*	2.36	3.33	0.91	4.17	1.94	4.95	1.08	4.94	2.44	1.83	1.97	0.91
47	*Echinochloa colona*	4.35	4.52	4.23	6.25	4.17	4.15	7.62	5.75	1.73	2.96	2.90	4.34
48	*Eleusine indica*	3.99	3.10	2.12	2.08	5.39	3.99	2.61	1.97	1.83	2.71	3.05	4.46
49	*Elusine Jaegeria*	0.00	0.24	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.96	0.00	0.00
50	*Eragrostis cilianensis*	0.72	0.71	0.30	0.00	0.74	1.05	0.35	0.00	1.85	3.09	2.83	0.00
51	*Eragrostis ciliaris*	0.36	0.00	0.91	0.00	0.31	0.00	0.71	0.00	1.57	0.00	1.93	0.00
52	*Eragrostis paniciformis*	0.54	0.00	0.30	0.00	0.38	0.00	0.06	0.00	1.26	0.00	0.47	0.00
53	*Eragrostis schweinfurthii*	0.18	0.00	0.00	0.00	0.29	0.00	0.00	0.00	0.97	0.00	0.00	0.00
54	*Eriochloa fatmensis*	0.36	0.24	0.00	0.00	0.44	0.27	0.00	0.00	2.17	2.34	0.00	0.00
55	*Erocastrum arabicum*	0.00	0.00	0.60	0.00	0.00	0.00	0.17	0.00	0.00	0.00	0.71	0.00
56	*Euphorbia heterophylla*	1.27	1.90	0.60	2.08	0.38	0.63	0.25	0.45	0.54	0.69	1.00	1.02
57	*Euphorbia hirta*	1.99	0.48	1.81	0.00	0.68	0.21	0.74	0.00	0.61	0.91	1.00	0.00
58	*Euphorbia hypericifolia*	0.18	0.48	0.00	0.00	0.22	0.51	0.00	0.00	0.72	0.75	0.00	0.00

Table 2: Continued.

No.	Name of species	Relative frequency (%)				Relative density (%)				Relative abundance (%)			
		NPIL	VLPIL	LPIL	MPIL	NPIL	VLPIL	LPIL	MPIL	NPIL	VLPIL	LPIL	MPIL
59	*Euphorbia indica*	0.72	0.48	0.30	0.00	0.25	0.14	0.13	0.00	0.62	0.64	1.06	0.00
60	*Fallopian convolvulus*	0.00	0.48	0.00	0.00	0.00	0.23	0.00	0.00	0.00	1.01	0.00	0.00
61	*Flaveria trinervia*	0.00	0.00	0.60	0.00	0.00	0.00	0.35	0.00	0.00	0.00	1.42	0.00
62	*Galinsoga parviflora*	3.26	3.81	2.72	1.04	5.06	8.46	5.24	1.68	3.15	4.17	4.76	7.61
63	*Galium spurium*	0.36	1.19	0.30	0.00	0.27	0.31	0.35	0.00	0.24	0.55	0.59	0.00
64	*Guizotia scabra*	1.27	1.19	2.12	1.04	1.18	1.41	1.79	0.29	1.68	2.49	2.09	1.32
65	*Guizotia villosa*	0.36	0.00	0.00	0.00	0.11	0.00	0.00	0.00	0.56	0.00	0.00	0.00
66	*Hygrophila auriculata*	1.45	1.19	1.81	0.00	0.17	0.18	0.25	0.00	0.21	0.21	0.33	0.00
67	*Hypochaeris radicat*	0.00	0.00	0.00	2.08	0.00	0.00	0.00	0.29	0.00	0.00	0.00	0.66
68	*Ipomea cairica*	0.36	0.24	0.00	0.00	0.24	0.29	0.00	0.00	0.40	0.85	0.00	0.00
69	*Ipomea cordofana*	0.18	0.00	0.60	0.00	0.05	0.00	0.12	0.00	0.48	0.00	0.47	0.00
70	*Ipomea eriocarpa*	0.36	0.95	0.60	0.00	0.10	0.36	0.20	0.00	0.48	0.80	0.83	0.00
71	*Ipomea purpurea*	1.09	0.48	0.91	0.00	0.21	0.13	0.22	0.00	0.40	0.59	0.59	0.00
72	*Justicia flava*	0.18	0.00	0.60	0.00	0.20	0.00	0.20	0.00	2.65	0.00	1.36	0.00
73	*Justicia heterocarpa*	0.72	1.19	0.00	0.00	1.48	0.87	0.00	0.00	0.50	0.21	0.00	0.00
74	*Lactuca saligna*	0.18	0.48	0.00	0.00	0.24	0.65	0.00	0.00	0.80	0.96	0.00	0.00
75	*Lactuca serriola*	1.81	1.90	2.12	0.00	0.55	0.65	0.78	0.00	0.55	0.72	0.91	0.00
76	*Launaea cornuta*	1.09	0.95	0.00	3.12	0.35	0.37	0.00	1.10	0.58	0.83	0.00	1.66
77	*Leucas deflexa*	0.00	0.00	0.30	0.00	0.00	0.00	0.09	0.00	0.00	0.00	0.71	0.00
78	*Leucas martinicensis*	1.45	1.19	1.81	1.04	0.48	0.47	0.66	0.10	0.60	0.83	0.90	0.44
79	*Medicago polymorpha*	0.36	0.00	0.30	0.00	0.14	0.00	0.09	0.00	0.68	0.00	0.71	0.00
80	*Melinis repens*	0.00	0.00	1.51	1.04	0.00	0.00	0.69	0.48	0.00	0.00	0.38	0.73
81	*Nicandra physalodes*	3.62	4.29	3.63	1.04	3.26	4.10	4.38	1.23	1.62	2.01	2.98	5.56
82	*Nigella sativa*	0.36	0.24	0.30	0.00	0.29	0.22	0.35	0.00	0.48	0.64	0.94	0.00
83	*Oxalis latifolia*	0.36	0.24	0.00	0.00	0.11	0.12	0.00	0.00	0.56	1.07	0.00	0.00
84	*Oxalis stricta*	0.18	0.00	0.30	1.04	0.10	0.00	0.07	0.19	0.97	0.00	0.59	0.88
85	*Oxygonum sinuatum*	0.72	1.19	1.81	1.04	0.26	0.37	0.68	0.29	0.64	0.26	0.12	1.32
86	*Parthenium hysterophorus*	0.00	5.95	9.07	11.45	0.00	5.37	8.78	56.57	0.00	2.56	4.84	23.30
87	*Pennisetum sphacelatum*	0.18	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.16	0.00	0.00	0.00
88	*Phalaris paradoxa*	1.99	2.38	0.91	5.21	0.75	0.24	1.17	1.23	0.65	0.86	0.79	1.11
89	*Phyllanthus fraternus*	0.36	0.95	0.60	0.00	0.31	2.10	0.69	0.00	2.33	0.35	0.94	0.00
90	*Phyllanthus maderaspatensis*	0.00	0.24	0.30	0.00	0.00	0.36	0.39	0.00	0.00	6.18	1.89	0.00
91	*Plantago lanceolata*	0.36	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.68	0.00	0.00	0.00
92	*Portulaca oleracea*	0.18	0.00	0.30	1.04	0.11	0.00	0.12	0.26	1.13	0.00	0.94	1.17
93	*Reseda luteola*	0.00	0.24	0.00	1.04	0.00	0.22	0.00	0.87	0.00	0.64	0.00	1.32
94	*Rottboellia cochinchinensis*	0.36	0.24	1.51	0.00	0.31	0.07	0.81	0.00	1.53	0.64	1.32	0.00
95	*Rumex bequaertii*	0.72	0.24	0.00	2.08	0.53	0.40	0.00	0.29	0.20	1.17	0.00	0.66
96	*Setaria pumila*	0.18	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.72	0.00	0.00	0.00
97	*Solanum nigrum*	0.18	0.48	0.00	0.00	0.29	0.59	0.00	0.00	0.97	1.33	0.00	0.00
98	*Sonchus asper*	2.17	1.19	2.42	1.04	0.57	0.37	0.82	0.29	0.48	0.66	0.84	1.32
99	*Sonchus oleraceus*	0.91	1.90	0.00	0.00	0.31	0.39	0.00	0.00	0.34	0.51	0.00	0.00
100	*Sorghum arundinaceum*	1.81	2.62	2.42	2.08	0.61	0.94	0.72	0.87	0.61	0.76	0.74	1.98
101	*Sorghum halepense*	0.18	0.00	0.30	0.00	0.19	0.00	0.17	0.00	0.64	0.00	0.47	0.00
102	*Striga hermonthica*	1.63	2.14	1.21	1.04	0.73	0.68	0.52	0.65	0.81	0.66	1.06	2.93
103	*Tagetes minuta*	0.54	0.71	0.30	4.17	0.13	0.17	1.00	0.29	0.43	0.50	2.71	0.33
104	*Tridax procumbens*	0.18	0.00	0.00	0.00	0.22	0.00	0.00	0.00	0.72	0.00	0.00	0.00
105	*Trifolium rueppellianum*	3.80	3.81	1.51	4.17	1.02	0.63	1.16	0.29	0.48	0.35	1.89	0.33
106	*Trifolium semipilosum*	0.18	0.24	0.00	0.00	0.05	0.08	0.00	0.00	0.48	0.75	0.00	0.00
107	*Trifolium steudneri*	0.18	0.00	0.00	3.12	0.06	0.00	0.00	0.13	0.56	0.00	0.00	0.20
108	*Urochloa panicoides*	0.36	0.24	0.91	0.00	1.16	0.36	0.91	0.00	1.85	2.13	0.47	0.00
109	*Vicia sativa*	0.18	0.24	0.00	0.00	0.15	0.22	0.00	0.00	0.48	0.64	0.00	0.00
110	*Xanthium strumarium*	3.44	1.90	3.32	4.17	1.64	0.80	1.47	0.97	0.86	0.88	1.09	1.10
	No. of fields for each infestation level found	26	20	37	**7**								

NPIL= no parthenium infestation level; VLPIL= very low parthenium infestation level; LPIL = low parthenium infestation level; MPIL = moderate parthenium infestation level.

indices for NPIL and VLPIL were greater than 60%, it can be concluded that both parthenium infestation levels exhibited similar weed communities and, thus, require similar management options, whereas the remaining parthenium infestation level requires different weed management options because it had less than 60% similarity index.

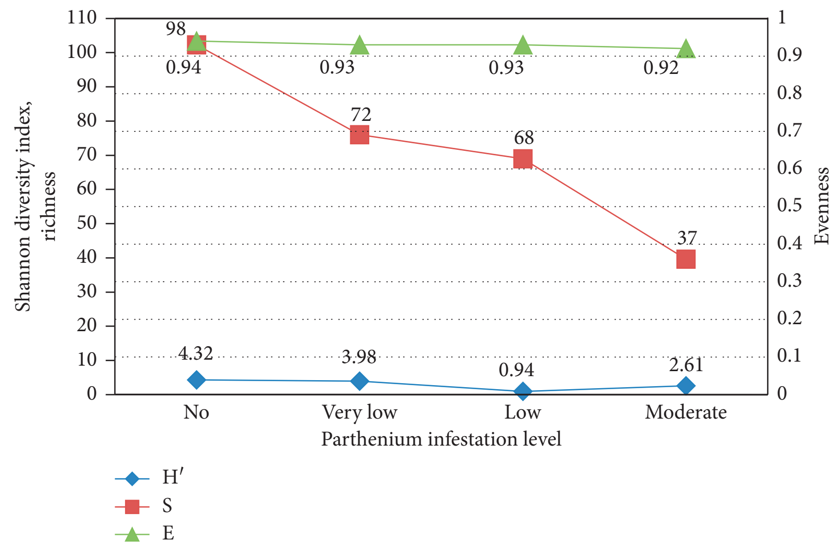

Figure 2: The Shannon diversity index (H), Richness (S), and Evenness (E) of weed species at different parthenium infestation levels.

Table 3: Similarity index of aboveground weed species among parthenium infestation levels.

Similarity	Number of weed species			Similarity index (%)
	On both infestations	1st infestation	2nd infestation	
NPIL vs. VLPIL	66	32	6	63.46
NPIL vs. LPIL	61	37	7	58.10
NPIL vs. MPIL	33	65	4	32.35
VLPIL vs. LPIL	48	24	20	52.17
VLPIL vs. MPIL	28	44	9	34.57
LPIL vs. MPIL	29	39	8	38.16

NPIL=no parthenium infestation level, VLPIL=very low parthenium infestation level, LPIL = low parthenium infestation level, MPIL = moderate parthenium infestation level.

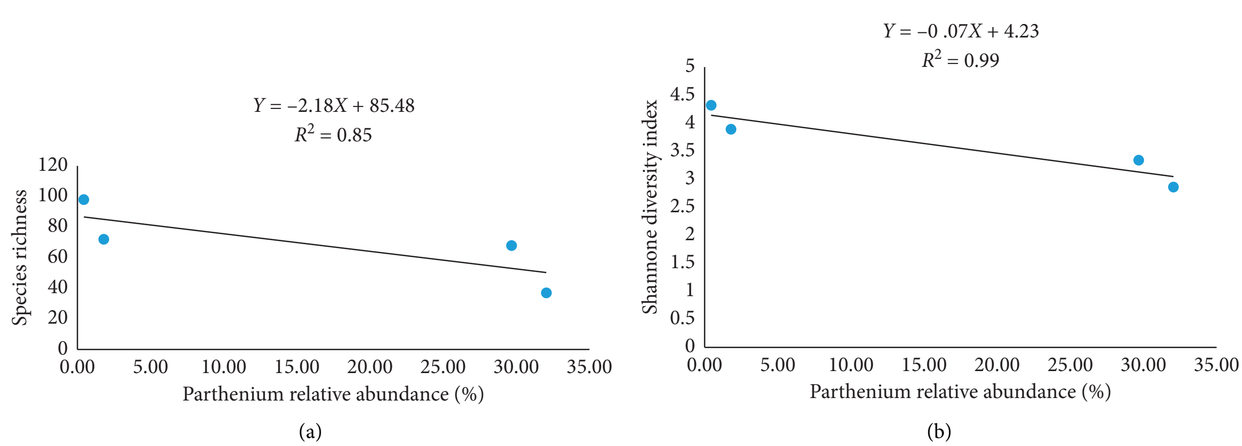

Figure 3: The regression and correlation analysis of parthenium relative abundance with species richness (a) and Shannon diversity index (b).

3.8. Regression and Correlation. The parthenium relative abundance was a strongly negative relationship with species richness ($Y = -2.18X + 85.48$) and Shannon diversity index ($Y = -0.07x + 4.23$) (Figure 3). The R^2 value indicates that 85% and 99% of the total variation in species richness and Shannon diversity index were explained by the regression equation estimated by parthenium relative abundance, respectively. There was a negative association between the relative abundance of parthenium with species richness and the index of Shannon diversity with $r = -0.92$ and

$r = -0.99$, respectively. Similarly, Nigatu et al. [24] also state that a clear negative association between the degree of parthenium coverage and species diversity ($R^2 = 73\%$) and evenness ($R^2 = 69.5\%$) was shown by the regression study.

4. Conclusions

The study showed that 110 weed species belonging to 27 families were identified in the study area. In LPIL and MPIL, *P. hysterophorus* had high frequency, relative frequency, mean field density, relative density, abundance, relative abundance, and importance value, but the other species of weeds were reduced. Similarly, as the parthenium infestation level increased, the weed species richness, Shannon diversity index, and evenness were reduced.

In general, *A. conyzoides, A. hybridus, B. pilosa, E. colona, G. parviflora,* and *N. physalodes* had relatively the highest relative frequency, relative density, relative abundance, and importance value in all parthenium infestation levels. This suggests that these weed species had a stronger relationship and were growing in competition with parthenium. There is an urgent need for intensive management efforts directed at parthenium in the study area. Finally, these data are recommended to provide the government, scientists, ecologists, policymakers, importers of herbicides, and other stakeholders with knowledge on the level of parthenium invasiveness in the study areas of maize. In the future, more survey work is needed regularly on different crops at different cropping seasons to identify possible problematic weed and weed population shifts. Using of *A. conyzoides, A. hybridus, B. pilosa, E. colona, G. parviflora,* and *N. physalodes* will be suggested to other researchers to do biological control on parthenium in the future.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare no conflicts of interest.

Authors' Contributions

Dinberu Million apprehended the ideas of the document, performed the research, collected data, analyzed the data, and wrote the original manuscript. Lisanework Nigatu, Zelalem Bekeko, and Hirpa Legesse advised all the research activities and data analysis, as well as review and editing of the manuscript. All authors have read and agreed to the published version of the manuscript.

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