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Appropriation, occurrence, seriousness and impact of the rust (Puccinia abrupta var. partheniicola) on Parthenium hysterophorus L. in Western Hararghe Zone, Ethiopia

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Abstract

Parthenium is an exotic invasive weed that originated in South America, and has formed severe infestations in Ethiopia. This weed is known to be host to various micro-organisms such as the rust pathogen *Puccinia abrupta* var. *partheniicola* that may be used as a component of integrated parthenium weed management. Field surveys were conducted in 2008 and 2009 cropping seasons in eastern Ethiopia to determine distribution, incidence, and severity of the rust (*P. abrupta* var. *partheniicola*) on this weed. In addition, the effect of this pathogen on morphological parameters of parthenium was studied both in the field and in the greenhouse at the Plant Protection Research Center, Ambo. A total of 218 fields were surveyed in four districts (Chiro, Gemechis, Kuni and Tullo) of Western Hararghe Zone, eastern Ethiopia. All the fields surveyed were infected with the pathogen, indicating that the disease was widely distributed in the zone. The incidence of rust in the surveyed area ranged from 25 to 74% while severity ranged from 18 to 55%. The highest (74%) and the lowest (25%) disease incidence were recorded in Tullo and Chiro, respectively, while the highest (55%) and the lowest (18%) disease severities were encountered at Gemechis and Chiro, respectively. Altitude had significant effect on both disease parameters ($p \leq 0.05$). The effect of this pathogen on morphological parameters of parthenium under field conditions was found to be significant ($p \leq 0.05$) at all locations. The effect of the rust on parthenium dry matter and seed production was significant ($p \leq 0.05$) at all locations. Also, the effect of the rust on morphological parameters of parthenium in the greenhouse was significant ($p \leq 0.05$). In addition, there was significant variation in the number of rust pustules per leaf, leaf senescence, and number of leaves attacked per plant, disease incidence and severity both at 14 and 21 days after inoculation. In the greenhouse, comparison of isolates from Ambo, Kuni, and Tullo showed significant effect while isolates from Chiro and Gemechis performed poorly for all the studied morphological parameters of parthenium. This study indicated that *P. abrupta* var. *partheniicola* has the potential to reduce morphological parameters as well as dry matter and seed production capacity of parthenium weed. It also elucidated the presence of variation in aggressiveness of the isolates. However, more extensive studies need to be undertaken at molecular level to utilize this pathogen in combination with other host-specific insects and pathogens after importation and release, as a component of integrated parthenium weed management in Ethiopia.

Keywords: *Parthenium hysterophorus*, *Puccinia abrupta* var. *partheniicola*, aggressiveness, biological control, disease incidence, disease severity, epidemiological factors.

INTRODUCTION

In Ethiopia, disease, insects and weeds contribute to a loss of 42% yield reduction in field crops (Tamado et al., 2002). Especially, weeds are one of the biotic stressors which have contributed to the low level of grain yield, quality of fruits, vegetables, cereals, and incurred high level of herbicide cost. Hence, they have a strong share in the stagnation of the country's national economy (Taye et al., 2004). One of the weed species which is becoming serious in Ethiopia is *Parthenium hysterophorus L.*, which affects range lands, forest lands, crop lands, gardens, orchards, and has a significant role in yield reduction (Taye et al., 2004).

Parthenium, an invasive herbaceous weed that is believed to have originated in tropical Americas, now occurs widely in Asia, Australia Southern and east Africa. It is an annual procumbent, leafy herb, 0.5 to 2 m tall, bearing alternate, pinnatified leaves, belonging to the family Compositae. The major ecological and morphological characteristics that contribute to severe invasiveness might be its adaptability to wide climatic and soil conditions, production of allelopathic chemicals and the ability to produce large number of seeds (10,000 to 25,000 per plant) which are small in size (1 to 2 mm diameter) and light in weight (50 ∝g) to travel long distances through wind, water and other means (Navie et al., 1996).

It is believed to have been introduced into Ethiopia in the 1970s during the Ethio-Somali war and has become a serious weed both in arable and grazing lands (Berhanu, 1992; Fasil, 1994; Frew et al., 1996; Tamado, 2002). Parthenium can cause severe crop yield losses. In India, a yield reduction of 40% in agricultural crops (Khosla and Sobti, 1981) and 90% reduction in forage production were reported. In eastern Ethiopia, parthenium is the second most frequent weed (54%) after *Digitaria abyssinica* (63%) (Tamado and Milberg, 2000) and sorghum grain yield was reduced from 40 to 97% depending on the year and the location (Tamado et al., 2002). Other than direct competition with crops, parthenium poses allelopathic effect on different crops and other plants (Mersie and Singh, 1988; Evans, 1997a; Adkins, 2002; Wakjira et al., 2005; Adkins and Naive, 2006).

Although several methods have been developed for the control of parthenium, each has its own limitations. For instance, removing parthenium by slashing or mowing as soon as or before it flowers, though it prevents seed production, results in regeneration of new shoots leading to a repeated operation. Manual and mechanical uprooting also prove to be of limited value owing to enormous amount of labour and time required (Berhanu, 1992) and vulnerability of workers engaged in the operation to the various kinds of allergies caused by the weed (Kololgi et al., 1997). Chemical control, though effective, is temporary and needs repeated application, besides it has problems of residues, selectivity, availability and cost of application (Singh, 1997). Hence, the use of biocontrol agents including insects, pathogens and strong interfering smoother crops are recommended for the long-term management of parthenium (Adkins, 2002).

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Parthenium management through biological method can be made by using different pathogens (fungal and bacterial agents) and insects *(Zygogramma bicolorata).* Use of fungal species especially *P. abrupta* var. *partheniicola* helps in reducing parthenium morphological parameters, seed production capacity and biological aging or leaf senescence (Evans, 1987b; Evans 1997a; Parker et al., 1994). Except the investigation made by Taye (2002), so far, comprehensive study on parthenium biological control using the rust was not made in Ethiopia. Also, the presence of variation in aggressiveness of the isolates of this pathogen was not studied. Therefore, the objective of this study was to evaluate the distribution, incidence, severity and effect of parthenium rust on parthenium morphological parameters under field and greenhouse conditions in Western Hararghe Zone, Oromia Regional State, Ethiopia.

MATERIALS AND METHODS

Field study

Description of the study area

Field surveys were conducted in major parthenium infested areas of Western Hararghe Zone in four districts (Chrio, Gemechis, Kuni and Tullo) during September to December 2008 and October to December 2009. West Hararghe is located between 7° 55′ N to 9° 33′ N latitude and 40° 10′ E to 41°39′ E longitude. The major crops grown in the study area are sorghum, maize, chat, field beans, potato and tef. The area is characterized by Charcher Highlands having undulating slopes and mountainous in topography. The mean annual rainfall ranges from 850 to 1200 mm/year with minimum and maximum temperatures of 12 and 27°C, respectively.

Survey on the distribution, incidence and severity of rust on parthenium

Field surveys from September to December 2008 and October to December 2009 were made in four districts (Chrio, Gemechis, Kuni and Tullo) of Western Hararghe Zone, where parthenium infestation was found to be high and exhaustive inventory of parthenium infestation with rust was made (Taye, 2002).

Assessment of rust on parthenium was conducted in different habitats: cultivated (80%), vacant (10%) and grass lands (10%), to study the distribution, incidence, severity and effect of the rust (*P. abrupta* var. *partheniicola*) on morphological parameters of parthenium. Rust incidence and severity were recorded and its effect on morphological parameters was evaluated by comparing diseased and healthy parthenium plants.

Assessment of rust disease incidence

Percentage of parthenium plants with disease symptoms over the total plants in a 1 m × 1 m (1 m^2) was assessed. In each locality, five counts were taken per field and 3 to 5 fields per location were assessed at an interval of 8 to 10 km per location as indicated on the car speedometer. Rust incidence was calculated using the following formula:

$$\text{Rust incidence} = \frac{\text{Number of parthenium plants with disease}}{\text{Total number of parthenium plants/m}^2} \times 100$$

Assessment of rust disease severity

Rust severity (% leaf area covered by rust) was assessed on twenty plants per field by moving in each field in a zigzag manner. The 1 to 5 disease scoring scale suggested by Ambo (PPRC, 2000) was used to assess the rust severity level.

Assessment of parthenium dry matter production

Dry matter production was assessed at flowering stage on five diseased and five healthy plants. The plants were harvested, weighed and kept in an oven dry at a temperature of 105°C for 72 h. Then the proportion of the weight loss was assessed:

$$\text{\% Dry matter production} = \frac{\text{Weight of dry parthenium plants}}{\text{Weight of fresh parthenium plants}} \times 100$$

Determination of the effects of rust on parthenium morphological parameters and seed production

Effect of rust on parthenium morphological parameters and seed production capacity were studied under field condition by comparing healthy and rust infected plants. Samples were collected from parthenium infested areas at flowering stage. The morphological parameters considered were plant height, number of leaves per plant, leaf length, leaf width, leaf area, number of branches per plant and dry matter weight. Two separate samples were collected; one for the determination of the effects of rust on morphological parameters, and the other for the determination of its effects on seed production.

Effect on morphological parameters

Forty plants (20 healthy and 20 diseased) were observed by moving diagonally in crop fields and non-crop lands in Chiro, Gemechis, Kuni and Tullo districts in 2008 and 2009 main crop seasons. Morphological data and sample collection were made late in the evening to avoid drying of plants. Finally, data from different locations were analyzed using Chi-square (x^2) test, and percentage proportion of the effect were used to test the presence of significant difference within locations and among districts (Gomez, 1984; Taye et al., 2004).

Effect on seed production

Forty matured plants (20 healthy and 20 diseased) were collected by diagonally moving in the fields at Chrio, Gemechis, Kuni and Tullo districts, and comparison on the effect of the pathogen on seed production was made between Chrio and Tullo districts representing mid altitude and high land areas, respectively. The dried plants were threshed and clean seeds were weighed.

Laboratory and greenhouse studies

Greenhouse studies

Greenhouse studies were conducted at Ambo PPRC located 125 km west of Addis Ababa. Seeds were collected from matured parthenium plants in September 2009 from western Hararghe zone and seedlings were raised. To avoid surface contaminants, seeds were disinfected with 5% NaOCl for 2 min and soaked in a sterile distilled water to remove excess NaOCl. Pots having 25 cm × 15 cm × 30 cm volume were filled with garden soil, sand and manure in the ratio of 2:1:1. Seeds were sown on this prepared media.

Assessment of aggressiveness of rust isolates

Collection of spores: Rust spores were collected from different districts of West Hararghe Zone from September to October 2009 from leaves and stems of diseased parthenium plants. Collected plants were pressed, sun dried and transported to Ambo PPRC. Rust pustules were scratched off from these materials and kept in vials and placed in refrigerator at 4°C until used for aggressiveness test. Fresh spores were collected from Ambo and used as a reference test because their pathogenecity was already known (Taye et al., 2004).

Multiplication of rust on parthenium seedlings: Isolate viability was tested by carrying out spore germination test in the laboratory. Briefly, spores were thinly spread over a wet filter paper in a Petri dish and incubated at room temperature and germination percentage was determined after 24 h and inoculated to parthenium seedlings for mass multiplication.

Inoculation of spores

Inoculum was prepared by mixing rust spores in sterile distilled water and a drop of 0.01% Tween 80, and the concentration was adjusted to approximately 10^5 spores per ml using haemocytometer. The suspensions were sprayed with hand sprayer on the leaves at 4 to 6 leaves stage (Parker et al., 1994).

Inoculated plants were sprayed with fine droplets of water to create dew and kept in plastic chamber to maintain maximum humidity (≥85%). The plants were maintained at about 17°C for 24 h. After inoculation, the plants were placed in standard greenhouse condition. Multiplied spores were inoculated to fresh seedlings on pots to assess aggressiveness of each isolate.

Comparison of aggressiveness of rust isolates

Studies on aggressiveness of four rust isolates collected from western Hararghe Zone and a reference isolate from PPRC area were carried out in greenhouse at Ambo during October to December 2009 using a randomized block design (CRD).

Data collected in the greenhouse and analysis of data

Data on the number of leaves on each plant attacked by rust and number of pustules developed on each leaf were recorded. Effect of the disease on plant height, leaf length, leaf width, leaf area, number of leaves per plant, disease incidence, and disease severity were assessed. And, analysis of variance was made using SAS software version 9.0.

RESULTS AND DISCUSSION

Distribution, incidence and severity of the rust (*Puccinia abrupta* var. *partheniicola*) in Western Hararghe Zone

Field surveys on the distribution, incidence and severity

Table 1. Incidence and severity (mean value) of *P. abrupta* var. *partheniicola* on parthenium at Chiro, Gemechis, Kuni and Tullo districts of West Hararghe Zone, under field condition.

Location	Altitude (m.a.s.l)	Mean of disease incidence (%)	Mean of disease severity (%)
Chiro	1850 - 2300	30.00 (25.0)[a]	25.10 (18.0)[a]
Gemechis	1700 - 1950	56.17 (69.0)[b]	47.8 (55.0)[b]
Kuni	2150 - 2460	50.77 (60.0)[c]	40.40 (42.0)[c]
Tullo	1850 - 2200	59.34 (74.0)[d]	45.57 (51.0)[d]
Mean		49.02 (57.0)	39.82 (41.0)
CV		26.30	32.30
LSD		15.47	14.00

Table 2. Effect of *Puccinia abrupta* var. *partheniicola* on morphological parameters of parthenium at flowering at Chiro, Gemechis, kuni and Tullo districts, Western Hararghe Zone.

No.	Parameters	Percentage reduction in size of morphological parameters			
		Chrio	Gemechis	Kuni	Tullo
1	Mean plant height (cm)	10	11	8	15
2	Mean number of leaves per plant	10	12	8	23
3	Mean leaf length (cm)	31	34	26	50
4	Mean leaf width (cm)	19	21	14	40
5	Mean leaf area (cm^2)	32	36	28	26
6	Mean number of branches/plant	40	46	32	33

of parthenium rust were conducted in Western Hararghe Zone. A total of 218 fields were surveyed in four districts (Chiro, Gemechis, Kuni and Tullo). In all the surveyed fields parthenium weed was affected by rust and the pathogen was widely distributed in the fields. Mean rust incidence varied from a minimum of 25% at Chiro to maximum of 74% at Tullo. Similarly severities of 18 and 55% were noted at Chiro and Gemechis, respectively (Table 1). The pathogen was found to be infecting leaves, stems, and floral parts of parthenium plants in the studied area. Also the disease was distributed in all parts of the studied locations ranging from an altitude of 1700 to 2460 m.a.s.l (Table 1).

The analysis of variance for both disease incidence and severity showed that there is no significant difference within location; but there existed a significant difference among locations (Table 1). This might be due to the variation in epidemiological factors (environmental conditions, stages of the parthenium plants and differences in aggressiveness of rust isolates) as well as the variation in time of sampling during the survey ($p \leq 0.05$). Similarly, an investigation conducted by Taye et al. (2004) showed the presence of a significant difference in the level of rust disease incidence and severity in different parts of Ethiopia. Location effects were highly significant ($p \leq 0.05$) for mean plant height, number of leaves per plant, leaf width, leaf length, leaf area and number of branches per plant. This is owing to the fact that spore dispersal, germination and the response of the plant to the disease vary with location and meteorological parameters (Chemeda, 2001). Similar studies undertaken by Parker et al. (1994) and Taye et al. (2004), showed the existence of a significant difference among locations both in Australia and Ethiopia, respectively.

Effect on morphological parameters

The effect of rust disease on morphological parameters of parthenium was assessed by comparing healthy and diseased plant samples collected from Chiro and Tullo districts under field condition. The result showed the disease has reduced mean plant height, number of leaves per plant, leaf length, leaf width, leaf area and number of branches per plant by 10, 10, 31, 19, 32 and 40%, respectively for Chrio, and 15, 23, 50, 40, 26 and 33%, respectively for Tullo (Table 2). Similarly, the results from the Chi-square (x^2) analysis of variance for parthenium morphological parameters showed the presence of significant difference among locations ($p \leq 0.05$). This might be owing to the existence of variation in the epidemiological factors of the locations which has a profound effect on the amount of the disease and its effect (Appendix Tables 1 and 2).

Similarly, rust infected parthenium plants were subjected to stress which can reduce the competitive ability of the weed. Similar study undertaken by Parker et al. (1994) and Taye et al. (2004), showed closer results in utilizing this pathogen as a classical biological control agent which is eco-friendly and economically feasible.

Table 3. Effect of *Puccinia abrupta* var. *partheniicola* on dry matter and seed production capacity of parthenium plant in Western Hararghe Zone.

No	Parameter	Percentage reduction in size of morphological parameters			
		Chiro	Gemechis	Kuni	Tullo
1	Dry matter	35.0	45.0	38.0	36.3
2	Seed weight	50.0	42.0	42.0	72.0

In the study area, the effect of *P. abrupta* var. *partheniicola* was more severe at Tullo than Chrio for all parameters. This might be due to the temperature and relative humidity variations at Chiro and Tullo as well as the variation in the level of aggressiveness between the isolates from both locations. That is, Tullo is cooler than Chiro which is highly favorable for the epidemics of parthenium rust. In an investigation conducted by Taye et al. (2004), it was demonstrated that rust has reduced plant height and leaf area by 11 and 25%, respectively at Debrezit and Ambo. Thus, the present finding is in line with their report.

As Tamado et al. (2002) reported, parthenium has severely invaded the eastern parts of Ethiopia. Currently, the status of the weed in both east and west Hararghe Zones of Oromia Regional State is highly severe and its impact has caused tremendous yield reduction and economic loss. No matter how, there exists a varied distribution among different locations the invasiveness of parthenium at high altitude areas is low this might be due to the presence of *P. abrupta* var. *partheniicola* which has limited its further expansion in those high land areas.

Effect of rust on dry matter and seed production

The result from the Chi-square (x^2) analysis of variance for dry matter production and seed weight in the study area showed, there is a significance difference among locations for all parameters. This is owing to the difference in epidemiological factors of the locations (environmental factors, level of aggressiveness of the pathogen and the growth stage of parthenium plant).

Dry matter production at maturity and mean seed weight per plant were significantly reduced at Tullo resulting in 36 and 72% reduction, respectively as compared to diseased plants at Chrio. Similarly, 35% reductions in dry matter production as well as 50% reduction in seed weight were observed at Chrio, Table 3. In 2008, as the meteorological data showed, the monthly rainfall and temperatures in the months of October and November at the study areas were favorable for the rust epidemics than similar study in 2009 (Appendix Table 3).

Comparison of aggressiveness of *P. abrupta* var. *partheniicola* isolates

In the greenhouse study, nine days after inoculation, the symptom of rust and development of pustules were observed on Ambo, Kuni, Gemechis and Tullo isolates, and the area and number of pustules were relatively increased from the 9th day till the 23rd day. After the 23rd day, all the infection has stopped and the progress of the disease was localized. Starting from the 14th day to 23rd day, all the leaves infected by uredinio spores of *P. abrupta* var. *partheniicola* were subjected to rapid leaf senescence and total defoliation was observed after 28 days. In addition, it was observed that all the leaves which emerged after the inoculation were found to be healthy.

In comparison to the field study, in the greenhouse, the dispersal and auto-infection capacity of *P. abrupta* was limited, owing to the absence of wind and other dispersal agents in the greenhouse as compared to the wide exposure of parthenium plants to many spore dispersal agents which help in increasing the cyclic infection of the plant. In the field study, the effect of the rust on all morphological parameters was found to be severe than the greenhouse study and as a result the biological age of the weed was so short. This is owing to the landing of larger number of spore population carried by wind to the plant parts which can attack all organs simultaneously and cyclically.

In the greenhouse, 14 days after inoculation the effect of *P. abrupta* var *partheniicola* isolates showed marked variation on morphological parameters of parthenium (Table 4) in which the effect of Ambo isolate on plant height, leaf length, leaf width, number of leaves per plant and leaf area was superior to other isolates followed by Kuni isolate. In Tullo and Gemechis isolates, there was no significant variation for all parameters and the isolate from Chiro showed poor performance for all parameters ($p \leq 0.05$).

Similarly, at 21 days after inoculation, the effect of *P. abrupta* isolates showed significant difference on morphological parameters of parthenium (Table 5). Under all parameters, the effect of Ambo isolate showed a significant effect followed by Kuni ($p \leq 0.05$). At this day, disease severity for Ambo, Kuni, Gemechis and Tullo isolates have showed a marked increase which is in line with the fact that disease development and effect advance for certain period of time and relapses when the affected areas are totally consumed (Van der Plank, 1963). From the analysis of variance, it can be seen that the Ambo isolate was found to be the most aggressive one while the aggressiveness of the Chiro isolate was found to be the poorest ($p \leq 0.05$).

Table 4. Effect of *Puccinia abrupta* var. *partheniicola* at 14 days after inoculation on parthenium weed. Plant height, leaf length, leaf width, number of leaves per plant and leaf area (mean value), were evaluated in greenhouse at Ambo, 2009.

Isolate (treatments)	Plant height (cm)	Leaf length (cm)	Leaf width (cm)	Number of leaves per plant	Leaf area (cm^2)
Ambo	13.33^{a}	12.50^{a}	5.50^{a}	2.34^{a}	12.00^{a}
Kuni	14.16^{ab}	12.66^{a}	5.50^{a}	2.44^{a}	12.00^{a}
Gemechis	14.83^{b}	13.46^{b}	6.83^{b}	2.61^{b}	12.83^{b}
Tullo	14.80^{b}	13.50^{b}	7.16^{b}	2.78^{b}	12.83^{b}
Chiro	14.96^{c}	13.83^{bc}	7.50^{c}	2.74^{b}	13.46^{c}
Control	15.00^{c}	13.85^{bc}	7.83^{c}	2.80^{bc}	13.50^{c}
CV	4.44	3.51	7.25	3.57	4.44
LSD	1.10	0.72	0.89	0.16	0.96

*Means with same letter are not significantly different.

Table 5. Effect of *Puccinia abrupta* var. *partheniicola* at 21 days after inoculation on parthenium weed. Plant height, leaf length leaf width number of leaves per plant and leaf area (mean value), were evaluated at Ambo, 2009.

Isolate (treatments)	Plant height (cm)	Leaf length (cm)	Leaf width (cm)	Number of leaves per plant	Leaf area (cm^2)
Ambo	15.00^{a}	15.00^{a}	7.50^{a}	2.74^{a}	12.13^{a}
Kuni	15.00^{a}	15.00^{a}	7.56^{a}	2.75^{a}	12.5^{a}
Tullo	16.60^{b}	15.00^{a}	7.80^{b}	2.78^{b}	12.50^{a}
Gemechis	17.33^{b}	15.66^{ba}	7.80^{b}	2.78^{b}	12.83^{c}
Chiro	18.66^{c}	16.66^{b}	8.00^{bc}	2.83^{c}	13.00^{c}
Control	20.66^{d}	16.66^{b}	8.33^{c}	2.88^{c}	13.50^{c}
CV	6.29	6.77	9.75	5.08	4.30
LSD	1.96	1.87	1.35	0.25	0.97

P. abrupta in the experiment was observed colonizing the whole leaf and stem surface of parthenium (Figure 1) which hinders gaseous movement and light interception which are helpful in undertaking carbohydrate production (photosynthesis) and also helps in increasing the rapid oxidation of carbohydrate reserve in the plant body, thus the parthenium plant growth will be suppressed, its competitive ability is reduced, its seed production capacity is reduced and the overall impact of the weed on native plants and soil resource (growth resource) will be reduced and hence, the present finding is in line with Evans (1987b).

Conclusions

Parthenium is an exotic invasive weed that originated in South America now causing severe infestation in Ethiopia. This weed is known to be infected by various micro organisms such as the rust pathogen that may be used as a component of integrated weed management. A total of 218 fields were surveyed in 2008 and 2009 cropping seasons in four districts (Chiro, Gemechis, Kuni and Tullo) of west Hararghe zone. And result from the present study showed that *P. abrupta* var. *partheniicola* was widely distributed in all of the surveyed areas covering different altitudes which range from 1700 to 2460 m.a.s.l. During the study, it was found that the distribution of rust varied among locations, and higher rust incidence and severity were observed in areas where the altitude is higher and the temperature was cooler.

Rust disease incidence varied from 25 to 74% at Chiro and Tullo, respectively. And 18 to 55% severities were noted for Chiro and Gemechis, respectively. From the analyzed result, there was no significant difference within location but significant differences were observed among locations ($p \leq 0.05$). Similar study conducted by Parker et al. (1994) in Australia and Mexico showed the same result. The effect of rust on plant height, leaf area, leaf length and leaf width was significant, and the pathogen has reduced the morphological parameters significantly under field conditions ($p \leq 0.05$). The effect of *P. abrupta* on leaf senescence was also significant and the pathogen had a potential in reducing the photosynthetic part of the parthenium weed. With regard to seed production, it was noted that the pathogen also had a potential in minimizing the seed producing capacity of parthenium and a reduction of 0.015 to 0.04 g was recorded during the study at Chiro and Tullo, respectively.

In the greenhouse study, at 14 and 21 days after inoculation, it was found that the isolates had different degree of aggressiveness in which Ambo isolate became the most aggressive followed by Kuni for all parameters.

Figure 1. The effects of *Puccinia abrupta* var. *partheniicola* on parthenium weed under greenhouse condition 21 days after inoculation at Ambo Plant Protection Research Center, 2009. The leaves were subjected to rapid leaf senescence as a result of the disease (Ambo isolate, the most aggressive one).

In the study, it was observed that there is no significant difference between Gemechis and Tullo isolates but Chiro isolate showed poor degree of aggressiveness ($p \leq 0.05$). With regard to disease severity and leaf senescence all the inoculated leaves were severely infected and the leaves were subjected to rapid leaf senescence 21 days after inoculation. From this finding, it can be concluded that *P. abrupta* var. *partheniicola* isolates had different degrees of aggressiveness. However, further studies have to be conducted to confirm the presence of genetic diversity among the population of this pathogen at molecular level.

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APPENDIX

Table 1. Element monthly mean maximum temperature of Chiro Station.

Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
2003	28.0	29.4	28.7	28.9	30.6	29.8	27.0	27.2	28.5	29.6	29.2	27.4
2004	28.4	27.5	28.3	28.7	30.5	29.3	29.3	29.5	29.5	29.3	27.2	24.9
2005	28.3	30.1	29.4	28.7	29.0	29.3	29.3	29.5	29.3	29.3	27.2	21.9
2006	28.5	29.5	28.6	28.1	29.0	29.1	28.2	27.4	27.9	28.5	27.1	25.2
2007	25.0	29.5	30.4	28.1	28.7	29.4	28.5	27.2	26.8	27.8	27.3	NA
2008	27.2	28.4	29.3	28.4	27.5	28.3	28.2	28.8	25.8	27.4	28.0	26.4
2009	28.4	30.5	30.0	29.4	28	28.5	28.5	28.6	25.5	27.6	28.5	26.4

Table 2. Element monthly mean minimum temperature (°C) of Chiro Station.

Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
2003	16.5	17.6	15.4	16.1	16.2	16.8	15.1	15.9	16.6	17.1	15.7	13.8
2004	14.3	14.0	14.0	15.2	16.4	15.2	13.2	14.1	15.2	15.1	14.9	15.8
2005	15.8	16.4	16.3	15.7	15.8	16.3	15.9	16.0	15.8	16.4	15.0	10.4
2006	15.4	18.1	12.4	15.8	16.6	15.5	14.9	14.9	15.1	14.7	13.8	13.0
2007	13.0	17.2	16.4	14.8	15.0	16.0	14.9	15.6	14.8	13.3	11.0	NA
2008	14.5	17.0	16.2	14.4	15.2	16.0	14.6	15.0	15.2	15.0	14.8	14.2
2009	15.4	17.6	15.5	15.7	15.0	16.5	14.5	15.0	15.5	15.0	14.0	14.5

Table 3. Element monthly total rainfall (mm) of Chiro Station.

Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
2003	3.2	29.4	74.7	111.6	25.2	96.6	215.4	225.0	141.4	0.0	40.8	15.8
2004	51.5	0.0	73.4	164.8	2.4	36.1	125.6	145.9	446.8	99.0	17.0	28.0
2005	0	14.8	107.6	173.6	208.8	98.4	215.6	87.6	171.0	4.8	12.4	0
2006	12.0	33.4	130.0	88.0	63.4	47.0	140.8	243.3	103.1	133.0	0	73.2
2007	18.2	0	150.0	285.4	43.4	96.8	186.3	195.9	147.2	16.2	0	NA
2008	15.0	15.6	130.0	264.8	40.4	82.8	168.4	214.0	105.0	112.0	128	65.0
2009	12.0	6.5	108.0	182.0	26.0	15.0	120.0	108	120.0	96.0	85.0	90.0