ABUNDANCE AND ALLELOPATHIC EFFECT OF *Parthenium hysterophorus* ON CROPS OF SOUTH-WESTERN REGION OF BANGLADESH

Mst. Sharmin Khatun

MASTER OF SCIENCE

IN

AGRONOMY

DEPARTMENT OF AGRONOMY

SHER-E-BANGLA AGRICULTURAL UNIVERSITY,
DHAKA-1207

DECEMBER, 2021

ABUNDANCE AND ALLELOPATHIC EFFECT OF *Parthenium hysterophorus* ON CROPS OF SOUTH-WESTERN REGION OF BANGLADESH

By

Mst. Sharmin Khatun
REGISTRATION NO. 19-10365

A Thesis
Submitted to the Faculty of Agriculture,
Sher-e-Bangla Agricultural University, Dhaka,
In partial fulfilment of the requirements
for the degree of

MASTER OF SCIENCE

IN

AGRONOMY

SEMESTER: JULY- DECEMBER, 2021

Approved by:

………………………………………….   ……………………………………
(Prof. Dr. Sheikh Muhammad Masum)   **(Prof. Dr. Parimal Kanti Biswas)**

Supervisor   **Co-supervisor**

…………………………………
(Prof. Dr. Tuhin Suvra Roy)
Chairman
Examination Committee

CERTIFICATE

This is to certify that the thesis entitled, "**ABUNDANCE AND ALLELOPATHIC EFFECT OF *Parthenium hysterophorus* ON CROPS OF SOUTH-WESTERN REGION OF BANGLADESH"** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in the partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE (M.S.) IN AGRONOMY,** embodies the result of a piece of *bona fide* research work carried out by **MST. SHARMIN KHATUN,** Registration No. **19-10365** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

I further certify that such help or source of information, as has been availed of during the course of this investigation has duly been acknowledged.

(Prof. Dr. Sheikh Muhammad Masum)

Department of Agronomy

Sher-e-Bangla Agricultural University

Dhaka-1207

Dated:

Place: Dhaka, Bangladesh

DEDICATED

TO

MY BELOVED

PARENTS

LIST OF ACRONYMS

AEZ	Agro-Ecological Zone
Agric.	Agriculture
Agril.	Agricultural
Agron.	Agronomy
ANOVA	Analysis of variance
@	at the rate of
BARI	Bangladesh Agriculture Research Institute
Biol.	Biology
cm	Centimeter
CRD	Complete Randomized Block Design
CV %	Percent Coefficient of Variation
df	Degree of Freedom
°C	Degree Celsius
e.g.	exempli gratia (L), for example
Environ.	Environment
et al.,	And others
etc.	Etcetera
Fig.	Figure
g	Gram (s)
g m^{-2}	Gram per square meter
ha^{-1}	Per hectare (s)
hrs.	Hour (s)
i.e.	id est (L), that is
Inst.	Institute
Intl.	International
J.	Journal
Kg	Kilogram (s)
LSD	Least Significant Difference
M.S.	Master of Science
m^2	Meter squares
mg	Miligram
ml	Mili Litre
No.	Number
ns	Non-significant
%	Percentage
SAU	Sher-e-Bangla Agricultural University
Sci.	Science
t ha^{-1}	Ton per hectare
Uni.	University
var.	Variety
viz.	Namely

LIST OF CONTENTS

CONTENTS (CONTD.)

ABUNDANCE AND ALLELOPATHIC EFFECT OF *Parthenium hysterophorus* ON CROPS OF SOUTH-WESTERN REGION OF BANGLADESH

ABSTRACT

Periodical weed surveys were conducted during 2020-21 at Jashore, Jhenaidah, Chuadanga, Meherpur, and Khustia of Bangladesh to observe the severity of parthenium and to identify how many crops were affected by this weed. Parthenium weed was identified using the visual method, and quadrates were used to determine the number of parthenium weeds. The densest infestations of parthenium weed were found along roadsides, in fallow land, grasslands, and in fields of various crops. Only one species of parthenium which affected rice, maize, lentil, chickpea, field pea, jute, cotton, mustard, sesame, groundnut, tomato, pointed gourd, brinjal, bean, okra, onion, garlic, turmeric, chili, ginger, potato, banana, sugarcane, napiergrass, marigold, etc. The highest (29.67 plants m^{-2}) abundance of parthenium weed occurred at border areas due to the proximity to routes connecting Bangladesh and India. Among 27 Upazilla studied sites, the relative density was highest at Sarsha, Jashore (33.5%) followed by Damurhuda, Chuadanga (29.8%). The allelopathic activity of *P. hysterophorus* was examined against the seed growth of twenty crop species including major cereals, pulses, oilseeds, spices, fiber, and vegetables. 5% aqueous leaf extract was used to investigate the allelopathic activity of *P. hysterophorus* to seeds and pre-germinated seeds (radicle protruded by at least 1 mm) of test species. The following three parameters were used in allelopathic screening methodologies (a) germination percentage (%), (b) radicle length (cm), and (c) plumule length (cm). Results of Petri dishes experiment had shown a complete failure of germination (0%) due to the treatment in sesame, jute, pumpkin, red amaranth, chili, radish, and tomato. Among the cereals, wheat had the greatest reduction in radicle and plumule length (96% and 94%, respectively) compared to the respective control. Therefore, an integrated parthenium management approach is urgently needed to control the spread of this invasive weed.

Chapter 1

Introduction

INTRODUCTION

Parthenium weed (*Parthenium hysterophorus* L.) family Asteraceae commonly called parthenium weed, congress weed, carrot weed or white top is an alien invasive herbaceous weed, native to the tropical and subtropical Americas but now with pan tropic distribution (Adkins and Shabbir, 2014) and has become a major weed in Australia, India, Ethiopia and many other parts of the world (Masum *et al*., 2013). The weed has been accidentally introduced in all cases. After introduction *Parthenium* weed expands its range rapidly and creates mono-specific thickets that threaten cropping land, rangeland, and the biodiversity of natural ecosystems. For example, the major introduction in India occurred in the 1950s and within a few years, it has speeded all most all over the country. Today it is present in all parts of the country (Kohli *et al*., 2006). By 1975 it was estimated that the weed had infested over a million ha of land and by 2010 this figure had risen to over 35 million ha of land (DWSR, 2011). Parthenium weed is capable of adapting to a variety of habitats (Adkins and Navie, 2006). It is an invader of cultivated and disturbed areas, as well as natural areas. This weed is also recognized as one of the leading threats to biodiversity and imposes tremendous costs on agriculture, forestry, fisheries, wetlands, roadsides, natural areas, and other human enterprises, including human health.

Parthenium weed infests several major crops including wheat (*Triticum aestivum* L.), maize (*Zea mays* L.), rice (*Oryza sativa* L.), and sugarcane (*Saccharum officinarum* L.) in different countries (Bajwa *et al*., 2016). In agricultural fields, the *Parthenium* weed has allelopathic chemicals mainly parthenin, which show a high competitive ability for soil moisture and nutrients. In addition, the allelochemicals produced by *Parthenium* weed were found to inhibit germination and growth of adjacent crops and other plant species (Gnanavel, 2013). For example, in India yield reductions in rice (by 40%), tomato (*Solanum lycopersicum* L., by 63%), sorghum (by 40 to 90%), and fodder (up to 90%) have been reported (Sushilkumar, 2014). Besides, the allelochemicals produced by parthenium weed, mainly *parthenin*, are known to inhibit germination, growth, and grain fill of adjacent crops and other plant species (Gnanavel, 2013). Moreover, the weed can quickly colonize disturbed land, including overgrazed or cleared areas where competition is less and thus establishes quickly to dominate pastures and crop fields. It also inflicts large losses to grazing land productivity, livestock production, and native biodiversity (Adkins and Shabbir, 2014). Thus, *Parthenium* is a weed of national significance.

Infestation is known to be present in Bangladesh (Akter and Zuberi, 2009; Adkins, 2009; Karim, 2009). Recently it has been introduced to Bangladesh presumably from India. The weed has also been identified in Jashore, Narail, Magura, Kushtia, Meherpur, Chuadanga, Faridpur, Rajbari, Rajshahi, Natore, Pabna, Sirajgonj, Manikgonj, Gazipur, Dhaka and Mymensingh districts (Karim and Forzwa, 2010, Masum *et al*., 2013). Nowadays many parthenium weed is being dispersed through vehicles and agricultural commodities. Bangladesh is one of the most victimized countries in the world due to Climate

Change. It has resulted in a measurable rise in global temperature, negative changes in rainfall patterns as well as other changes in the environment. Climate change is now an ongoing phenomenon globally and in Bangladesh in particular. Changes in temperature and rainfall are likely to change the distribution of plants, including weeds. In general, temperature, precipitation, and atmospheric CO_2 (carbon dioxide) are climatic variables that alter plant invasiveness (Bradley *et al*., 2010).

As a noxious and invasive species in numerous countries across Africa, Asia, Oceania, and Australasia, *Parthenium* weed is suggested to be physiologically adaptable and thereby tolerant to a wide range of temperature regimes, lower rainfall, and elevated CO_2. Besides this tolerance characteristic, *Parthenium* weed has been suggested to be more vigorous and prolific under a changing climate with an altered canopy architecture that may be associated with higher competitiveness (Navie *et al*., 2005) or in other words 'invasiveness'. Although many studies on the impacts of *Parthenium* weed have been done in other countries, no or very limited initiative has been taken to investigate the impacts of this notorious weed in Bangladesh. It is essential to know the critical analytical characteristics such as density, frequency, abundance, and allelopathic potential of the species if we want to know its dominance in a community. Weed density measures the number of species in a unit area, sometimes expressed as a percentage. Frequency is the number of times the species occur in the sampling unit, or it is the degree of dispersal of the species. The abundance of a species is the total number of the species present in the weed community and is a relative measure. The severity of weed infestation usually regards the percentage of area covered by the species (Maszura *et al*., 2018). Allelopathy plays an important role in agroecosystems by involving a wide range of plant-plant interactions and the effect of allelopathic chemicals tends to be highly species-specific (Masum *et al*., 2019).

Parthenium weed can invade a wide range of environments due to its vigorous growth habit, high seed production, and effective dispersal mechanisms. The date of the arrival of the weed into Bangladesh is still unknown but from the last 10 years of observation, it can be speculated that it has come from India as the larger populations of the weed are to be found in the border districts on the road systems connecting the two countries. Although several studies on the impact of *Parthenium* weed have been undertaken in many countries, very little work has been undertaken in Bangladesh. A few accounts of *Parthenium* weed in Bangladesh are available even though most of the people of Bangladesh never know anything about this emerging problem. To address this problem effectively it is important to investigate the parthenium weed outbreaks within Bangladesh, to determine the severity of these infestations, determine their impacts on crop production, and biodiversity, and then develop integrated weed management approaches for different infested districts of Bangladesh. Regular weed monitoring is needed to control the weed sustainably. Weed monitoring involves repetitive surveys to track weed populations over time. The comparisons between different periodic surveys can help to elucidate the effect of new weed control technologies on weed species shift. Therefore, it is essential to identify the parthenium-infested locations, that is, the geographical range of the weed, its abundance, and the severity of infestation in the study site.

Therefore, keeping all the points in mind mentioned above, the present piece of research work was carried out with the following objectives:

- Accurately identify the areas with *Parthenium* populations and quantify their abundance and severity of infestation in Bangladesh
- Find out the impacts of parthenium on crop production

Chapter 2
Review of Literature

REVIEW OF LITERATURE

Parthenium is a very noxious and invasive weed. It is a weed of global importance causing severe economic, environmental, human, and animal health problems in Asia, Africa, Australia, and the Pacific region. *Parthenium hysterophorus* is a quarantine pest for Bangladesh and is considered to be a potential hazard organism. Parthenium weed has ability to invade a wide range of environments due to its vigorous growth habit, high seed production, and effective dispersal mechanisms. It also infests a large number of crops across diverse range of cropping systems around the world. This chapter presents a comprehensive review of literature on the related works which have been done in the country and many other countries of the world with regards to the effect of parthenium on different crops.

2.1 Abundance of parthenium weed

Zareen *et al.* (2021) performed a survey to measure the distribution of invasive Parthenium (*Parthenium hysterophorus* L.) weed in the University Campus, Peshawar, the capital city of Khyber Pakhtunkhwa province. The University Campus comprised on; The University of Peshawar, Islamia College University, The University of Agriculture Peshawar, Pakistan Forest Institute and the New Developmental Research Farm. In these selected areas Parthenium weed distribution was measured in particular the academic, residential and research farm. Moreover, the survey also investigated the impact of parthenium weed upon native weeds flora inside the University campus. A 1m^2 quadrat was used to collect the data. During the survey, a total of 32 weeds species were recorded belonging to 18 different families and 32 genera, the life cycle of 23 weeds were annual while 9 weeds have a perennial. The data were recorded on absolute density (%), relative density (%), absolute frequency (%), relative frequency (%) and importance values (%) of parthenium weed and others flora. The collected data show that parthenium weed was the most dominant species having 76.8 m^{-2} plants density in the NDF and (32.0 m^{-2}) at Islamia College University. However, the highest frequency (100%) of parthenium was observed for The University of Agriculture, while minimum 80%) occurred in the Agronomy field. A More, the relative frequency of parthenium was maximum (25%) in Islamia College; whereas, it's minimum (12.9%) at Agronomy field. Finally, the Importance Value of parthenium indicates the highest (45.98%) at Dairy Farm followed by (40.33%) at the Horticulture field's area.

The distribution and abundance data of the weed were recorded at five km intervals following all accessible roads of the zone at Northwest Ethiopia. The result reveals that *P. hysterophorus* L. was less distributed in the area with a 4.95% frequency. However, it was found abundantly growing at roadsides, wastelands, around habitation, market place, and around Zeghibridge where it can rapidly spread to most economical lands like the arable and grazing lands. Moreover, it has aggressively invaded a nursery site, which enables the weed to enter agricultural fields directly. This suggests that the weed is on a fast move to agricultural lands in the zone. The regular active development activities such as agricultural investment, construction of roads, and factories are presumed to promote its spread. Therefore, a decisive and timely decision is needed to mitigate the weed when it is still sparse and small (Horo *et al*. 2020).

The distribution of *P. hysterophorus* was measured in the agricultural lands, road side, river side and fallow lands in Chitrakoot district, India. The study also investigated the harmful effect of parthenium upon native weeds and flora in the Chitrakoot district. Quadrates method (1m x 1m) was used to collect the data of distribution and population of this weed. In this investigation, total 14 weed species were recorded belonging to 8 different families and 14 genera. The data were recorded by absolute density (m^2), relative density (%), absolute frequency (%), relative frequency (%) and importance value (%) of parthenium and other associated weeds. The finding reveals that Parthenium weed is the most dominant species in comparison to other associated weeds. In conclusion, the parthenium weed become a serious problem and replaces the entire native flora in the non-crop area. Due to no proper management and high growth rate, nowadays it becomes as super weed in the Chitrakoot district. So, the management of parthenium weed requires the call attention from the Government Policy makers and proper quarantine inspection to conserve the native flora and fields crops to get maximum crop yield (Tripathi and Chandra, 2019).

Maszura *et al*. (2018) stated that parthenium hazard is a national agenda in Malaysia, and Kedah is the worst infested state in the country. Despite it, the distribution and abundance of the weed is not systematically documented. They conducted Periodical weed surveys at Kuala Muda, Kedah, during March and

September 2015 to identify infested locations, to determine density, abundance, and severity of infestation, and to do mapping of weed distribution of the area. Geographic locations were recorded using a GPS. Weed density was measured following the list count quadrat method. The mapping of weed infestation was done by the ArcGIS software using data of GPS and weed density. Different letters were used to indicate the severity of infestation. Results indicated that in Kuala Muda, sixteen sites are infested having average weed density of 10.6 weeds m^{-2}. The highest density was noted at Kg. Kongsi 6 (24.3 plants m^{2}). Relative density was highest at Semeling (27.25%) followed by Kg. Kongsi 6 (23.14%). The average severity of infestation was viewed as the medium. Parthenium abundance and relative density increased by 18.0% and 27%, respectively, in the second survey conducted. The intervention of concerned authority to tackle the weed problem using integrated weed management approach is emphasized.

Nguyen *et al.* (2017) examined the composition and dynamics of the soil seedbank was conducted at two locations in central Queensland between December 2007 and May 2009. These two grassland communities were infested with parthenium weed (*P. hysterophorus* L.), which had been present at both sites for at least 25 years. During the period of study, the seedbank varied between 5962 and 16206 seeds m^{-2} at the Clermont site and between 6795 and 24862 seeds m^{-2} at the Moolayember Creek site. Parthenium weed exhibited a very abundant and persistent seedbank, accounting for 80−87% of the seedbank at the Clermont site and 3−26% of the seedbank at the

Moolayember Creek site. The species richness and species diversity of the seedbank, as well as the seed abundance of several native and introduced species, were higher at the Moolayember Creek site than at the Clermont site.

Khan and Aneja (2016) carried out to see the status of *Parthenium* infestation and its effect on yield losses caused to various cereals, oil, pulse, forage, sugar, vegetable, agroforestry and flowering crops cultivated in Haryana and some parts of Punjab, Uttar Pradesh and Delhi. Of the total 25 crops surveyed in different seasons, *Parthenium* was recorded in three cereals *viz*. rice (*Oryza sativa*), wheat (*Triticum aestivum*) and sorghum (*Sorghum vulgare*). However, it was not recorded in maize (*Zea mays*) and pearl millet (*Pennisetum typhoides*), the other commonly grown cereals in the States. Among different crops, the severe infestation of *Parthenium* was recorded in *Saccharum officinarum* (64.15%) followed by *Eruca sativa* (63.35%), *Helianthus annuus* (57.85%), *Brassica campestris* (57.63%), *Trifolium alexandrinum* (56.91%) and *Populus* sp. (54.63%). The vegetable crop infested by *Parthenium* weed included lady’s fingers (*Abelmoschus esculentus*), onion (*Allium cepa*), garlic (*A. sativum*), carrot (*Daucus carota*), cucumber (*Cucurbita maxima*), potato (*Solanum tuberosum*) and leguminous fodder Eegyptian clover (*Trifolium alexandrinum*). Maximum losse due to *Parthenium* infestation was observed in *E. sativa* (55%) and sunflower (52.5%).

Field surveys were carried out at Njiro suburb, Arusha-Kilimanjaro border and Arusha Airport in Arusha region in Tanzania during January to February 2013. *Parthenium* weed was identified using visual method; and quadrates were used to determine number of parthenium weeds in the fields. The weed was found growing along the roadsides, near residential areas, crop land and grazing lands. The mean number of parthenium weeds were significantly among the three locations ($p<0.05$). The density, frequency and abundance of parthenium weeds were high at Njiro suburb compared to Arusha-Kilimanjaro border and at Arusha airport (Kilewa and Rashid, 2014). Similarly Khan *et al.* (2014) conducted field survey of four districts of the Peshawar valley, Khyber Pakhtunkhwa viz. Swabi, Mardan, Charsadda and Peshawar in Pakistan were carried out during May-June, 2009-2010 to study the distribution and invasion of parthenium weed. Twenty five locations were sampled from each district. Data regarding absolute and relative density, frequency, relative frequency, importance valve %, average importance value, constancy classes and importance value constancy index of parthenium weed and other weeds of the area were recorded by using (1x1 m^2) quadrate. The mean data across the surveyed districts reveals that the flora is predominated by parthenium weed with the highest relative density of 42.68% among all species. Mean distribution data showed that parthenium weed infestation was abundant and almost not uniform in all districts, however highest relative frequency of 26.14% was recorded for parthenium weed. Looking at the overall distribution of flora in Peshawar valley, parthenium weed is spreading rapidly along the roadsides, into agricultural fields and on wastelands. The dominance of parthenium weed is attributable to its invasive ability due to its allelopathic properties, higher growth rate, rapid flowering and higher fecundity.

Surveys of waste and grazing lands from 10 localities of the district Hafizabad were undertaken during March-April, 2009 to study the distribution of an alien invasive weed parthenium (*P. hysterophorus* L.) in comparison of the weeds of the area. A total of 67 weed species belonging to 25 angiospermic plant families were found growing in the district. Parthenium was found to be growing in nine out of ten studied sites exhibiting 90% prevalence. The absolute frequency of occurrence of parthenium was 51%. Out of 67 recorded weed species in the area, only 14 weeds showed absolute frequency of 50% or above including parthenium (Riaz, 2010).

2.2 Allelopathic effect of parthenium on crops

Putri (2022) examined the allelopathic effect of the leaf litter of parthenium weed under glasshouse conditions. Fresh leaves were oven dried and crushed to crude powder, hereafter referred to as leaf litter. The leaf litter were incorporated into the upper layer of the media of green fingers compost bark in pots. In to this were sown the seeds of the test plans then set to germinate. Another treatment without leaf litter was set up as a series of control. The treatments were arranged in simple randomized design in the glasshouse. After one week, any seedling produced were counted and thinned to five seedlings per pot. The plants produced from these seedlings were harvested after further 40 days of growth and the growth parameter including root length, shoot length, and dry weight were measured. The measurable growth reduction increased as the amount of parthenium weed leaf litter increased but variability between results existed. The uncontrollable factors and seasonal conditions may cause this variability, in addition to the seed quality. The chemicals contained within the parthenium weed leaf litter has been shown to affect crop growth presumably through allelopathic activity under natural field conditions. The uncontrollable factors and seasonal conditions may cause this variability, in addition to the seed quality. The chemicals contained within the parthenium weed leaf litter has been shown to affect crop growth presumably through allelopathic activity under natural field conditions.

A laboratory experiment was conducted by Bhuvaneshwari *et al*. (2019) during 2019 at Anbil Dharmalingam Agricultural College and Research Institute, Thiruchirappalli to evaluate the allelopathic effect of *P. hysterophrous* on germination and seedling growth of different field crops. Laboratory experiment was carried out in completely randomized design (CRD) with four replications and six treatments viz., control, 5, 10, 15, 20 and 25 % of *P. hysterophorus* whole plant extract. The results revealed that there was negative correlation observed between concentration of *P. hysterophorus* whole plant extract and germination percentage, seed length, root length, seedling length and seedling vigour index in all treatments. Increasing concentration of *P. hysterophorus* whole plant extract significantly inhibited the germination, shoot length, root length, seedling length and SVI of all tested crops. The highest seedling mortality percentage of various crops *viz*., sweet corn, groundnut, gingelly, cowpea and rice were registered at 25 % *P. hysterophorus* whole plant extract.

Amare (2018) conducted twice repeated experiment under laboratory conditions to investigate the allelopathic effects of aqueous extracts of *P. hysterophorus* L. shoot (stem + branch) and leaf, at 0, 5, 10 and 15 g L^{-1} (w/v) concentrations on maize (*Zea mays* L.) seed germination, seedling growth (shoot and root length) and biomass production. The treatments were laid out in completely randomized design with the factorial arrangement in four replications. Result indicated that the highest germination percentage (98.75%) was recorded from control whereas the lowest (43.75 %) was from stem extract at15 g L^{-1} concentration level. Similar trend was also observed by leaf extract. Root and shoot length of maize crop was reduced by 91.4 % and 70.8% leaf extracts hence the roots were more sensitive to allelopathic effect than shoot. Hassan *et al*. (2018) conducted laboratory and pots based studies during July-August and October- November, 2010 in Weed Research Laboratory, Department of Weed Science, The University of Agriculture Peshawar, Khyber Pakhtunkhwa Pakistan. The experiments were conducted to investigate the allelopathic effect of parthenium on crops *Triticum aestivum*, *Cicer arietinum* and *Brassica campestris*, and weeds including *Avena fatua*, *Asphodelus tenuifolius* and *Lolium rigidum*. The fresh leaves of *P. hysterophorus* were dried in shade and grinded. The desired quantity of powder was soaked for 16 hr. in the desired quantity of water to make the stock solution of the maximum concentration *viz*. 75 g L^{-1}. Five seeds of each species were placed in Petri dishes and in pots, extracts were applied when needed. Control (0 g L-1) was also included for comparison. Both experiments were laid out as Factorial in completely randomized design (CRD) with four replications and two runs each. Since the statistical differences between the runs were non-significant the data were pooled before subjecting it to ANOVA and mean separation. The differences among the test species and the rates of parthenium extracts were different statistically ($P \leq 0.05$) for all the traits examined, while for the species x parthenium concentration interaction, the differences were only significant ($P \leq 0.05$) for plant height in the pot experiment. The results showed that with the increasing concentration of *P. hysterophorus*, all the parameters studied in the six test species were significantly decreased. Hence, the present study suggests that *P. hysterophorus* affects the agro-ecosystem and needs to be properly managed, moreover, its allelopathy on weeds is an encouraging finding for the weed managers for the sustainable management of weeds. Shrestha and Thapa (2018) explored the allelopathic effects of *P. hysterophorus* on germination of two major cereal crops of Nepal, Rice (*Oryza sativa*) and Wheat (*Triticum aestivum*). The experiment was conducted at laboratory of Department of Botany, Prithivi Narayan Campus, Pokhara, Nepal during 2017. In laboratory, seeds of rice and wheat were treated with aqueous extracts of *P. hysterophorus* plant parts *viz*. root, stem, leaf, inflorescence and whole plant with concentration of 5, 10, 15 and 20%. The experiment was laid out in a complete randomized design (CRD) in a factorial arrangement with three replicates of each test. The result suggests that the effect was more on wheat than on rice. The maximum inhibition in seed germination of rice was recorded by the inflorescence extract however, in wheat seed germination was inhibited by leaf extract. In both rice and wheat, roots were highly affected than shoots because root first encounters the toxic allelochemicals and absorbs it. The highest concentration (20%) of leaf, inflorescence and whole plant extract was found to be most pernicious whereas root and stem were recorded to have little effects.

Anwar *et al*. (2016) examined allelopathic activity of *P. hysterophorus* against the seed growth of five test species i.e., *Avena fatua*, *Rumex dentatus, Helianthus annuus* (var., K.S.E 7777), *Z. mays* (var., Islamabad Gold 2010) and *T. aestivum* (var., Wafaq 2001). Two screening methods, i.e., aqueous extract method and plant sandwich method were used to investigate the allelopathic activity of *P. hysterophorus* to seeds and pre-germinated seeds (radicle protruded by at least 1 mm) of test species on filter paper and soil. Following three parameters were used in allelopathic screening methodologies. (a) germination percentage (%), (b) radicle length (cm) and (c) plumule length (cm). The STATISTIX 9 software was used for analysis of results. Means were separated by using Fisher's protected LSD test. Results of petri plate experiment had shown greatest decrease of 87.6% in sunflower followed by *Rumex dentatus* 83.6%, maize 78.7%, wheat 58.2 and 26.6% *Avena fatua* as compared to their respective control in aqueous extract. Plumule length of cereals wheat and maize were more drastically affected by aqueous extract of *P. hysterophorus* resulted 75.2 and 83.25% decrease as compared to their respective control. A significant decrease of 40, 49.37 and 52.2% was recorded in plumule length of *A. fatua*, *R. dentatus* and *H. annuus* as compared to their control plants. Germination of all the test species was suppressed with aqueous extracts.

Parthenium weed has been reported to cause serious growth suppression and yield reductions in several grain crops, including cereals, pulses and oilseeds in different parts of the world. A substantial literature exists that reports the growth and yield reduction caused in grain, fibre, horticultural, forage and cash crops due to parthenium weed in India and Ethiopia. Much of this research has been conducted under controlled conditions and has been directed to evaluate the effects of the weed on the early stages of crop establishment and growth. As a matter of fact, these early impacts play a vital role in the overall crop development and eventually grain yield losses. So, an inferential approach is often adopted by many researchers to predict the ultimate effect on grain yield by observing the reduction in seed germination and early vigorous growth. However, sometimes the results of such laboratory bioassays may not be pronounced and so cannot be used to provide meaningful ecological predictions (Belgeri and Adkins, 2015). Netsere (2015) carried out an experiment under laboratory conditions to investigate the allelopathic effects of aqueous extracts of *P. hysterophorus* L. shoot (stem + branch), leaf, inflorescence, root and whole plant (leaf + shoot+inflorescence + root) at 0, 5, 10 and 15% (w/v) concentrations on maize (*Z. mays* L.) and sorghum (*S. bicolor* L. Moench) seed germination, seedling growth (shoot and root length) and biomass production. The treatments were laid out in completely randomized design with factorial arrangement in four replications.

The trial was conducted twice. Results showed that significant ($p < 0.01$) differences between plant parts and whole plant except for stems and root length of maize, where the effect was significant ($p < 0.05$) and non-significant, respectively. Inflorescence and whole plant extracts at all concentration, shoot at 15% and leaf at 10 and 15%, completely inhibited seed germination of the crops. In contrast, aqueous extract of shoot and root at 5% proved to be lower deleterious effect, while at higher concentration greatly reduced the aforementioned parameters. Tahseen *et al.* (2015) conducted an experiment to appraise the allelopathic effects of *P. hysterophorus* L. leaf, stem and flower extracts on growth and seedling related traits of *Phaseolus vulgaris* L. The *P. hysterophorus* leaf extract showed inhibitory activity on germination, shoot length, root length, seed vigour, tolerance index, root length, shoot length, fresh and dry weight of bean seedlings. All the parameters were found to be decreased with increase in the concentration of aqueous leaf extract except phytotoxicity, when compared to control. The maximum and minimum value was observed for all these parameters in 2% and 10% concentration, except phytoxicity respectively, when compared to control. The result of the study showed that inhibitory effects of *P. hysterophorus* leaf extract that may be due to the presence of some allelochemicals.

Demissie *et al.* (2013) carried out to evaluate the effect of *P. hysterophorus* on germination and elongation of onion (*Allium cepa*) and bean (*Phaseolus vulgaris*). The plant extract prepared by the extractions of 1, 2, 4, 8, and 16 g powder in a 400ml of distilled water were tested for their effects on seed germination and elongation of the test species. In the experiment about 10 seeds were planted in Petri dish in duplicates. The replicate was repeated twice and distilled water was used as control. When compared with the control group, seeds germination rate at lower concentration of the aqueous extract of part of parthenium was slightly similar. At higher concentration (16mg $400ml^{-1}$); however, the rate of the germination as well as the rate of elongation was significantly decline. In a one most concentrated extract both seed germination and rate of elongation is not recognized at first day in this study. In addition, the study the biomass of the Bean and Onion at a concentration of 16gm 400 ml^{-1} was found to be about 50% lesser than the control. Hence they concluded that, the parthenium extracts contain allelopathic effect which could affect the seed germination and elongation of Onion and Bean. Devi *et al.* (2013) conducted experiments on allelopathic effect of the aqueous leaf, stem and root extracts of *P. hysterophorus* on the seed germination and growth of a cereal crop plant (i.e. *Oryza sativa* L.). Seed germination was observed when exposed to different concentrations i.e. 2%, 4%, 6%,8% and 10%, of leaf, stem and root extracts of *P. hysterophorus*. Higher inhibition was observed when exposed to the leaf extract compared to stem and root extracts. The higher inhibition was observed at 10% level of leaf extract followed by stem and root extract. Higher inhibition of radical and plumule growth of the cereal crop i.e. *Oryza sativa* was observed with the increase in concentration of the leaf, stem and root extracts.

Devi and Datta (2012) studied the allelopathic effect of the aqueous leaf extract of *P. hysterophorus* on the seed germination, radicle and plumule growth of the seedlings of *Zea mays* L. by applying five different treatments (2, 4, 6, 8 and 10%) of two plant leaf extracts. Results exhibited that seed germination on account of allelopathic inhibition was found in all levels of leaf extract. However, highest degree of inhibition in radicle and plumule growth of the test plant i.e., *Z. mays* (L.) was observed in 10% concentration i.e., 2.08 cm and 7.82 cm in *P. hysterophorus*, respectively. In laboratory experiments, Masum *et al.* (2012) investigated the impact of *P. hysterophorus* leaf extract on the seed germination and seedling growth of maize (*Z. mays* L.), soybean (*Glycine max* L.) and cotton (*Gossypium hirsutum* L.). They claimed that this invasive weed significantly inhibited the seed germination and seedling growth of test crops due to its allelopathic potential. Parthasarathi *et al.* (2012) studied allelopathic effect of *P. hysterophorus* L. on seed germination and seedling growth of two pulse crops (*Vigna radiata* (L.) R. Wilczek and *Vigna mungo* (L.) Hepper) and one oil seed crop (*Arachis hypogea* L.). The concentrations used were 20 g L^{-1}, 30 g L^{-1} and 50 g L^{-1} leaf extract of *P. hysterophorus*. Seed germination of greengram was completely inhibited at 30 g L^{-1} leaf extract of *P. hysterophorus* but in blackgram and ground nut, failure of seed germination was recorded only at 50 g L^{-1} leaf extract. The seed germination, plumule, radicle length and total biomass production were reduced with increasing concentration of aqueous solution. The study concluded that increasing concentration of leaf extract of *P. hysterophorus* has adverse effect on germination, radicle length, plumule length and biomass production of *Vigna radiata* followed by *Vigna mungo* and *Arachis hypogea* than the control. The leaf extract has strong inhibitory effect on radicle growth than the plumule growth. The tolerance level of parthenium allelopathy of crops represented as Groundnut > Blackgram > Greengram.

Biswas *et al.* (2010) made an investigation to assess the allelopathic effects of parthenium weed debris (*P. hysterophorus* L.) on the emergence and seedling development of rice. Parthenium fresh leaves and plants were air-dried for one week in the greenhouse. The cut samples (4-6 cm) were further dried in an electric oven at 70 °C for 3 days. The oven-dried plant samples were then cut into smaller pieces (0.5-1 cm) and mixed with field soil. Four concentrations of weed debris (e.g. 0, 0. 25, 0.5 and 1.0 g dry weight per 100g soil) were included. Twenty five non-dormant seeds of rice were put on the soil surface of pots. The pots were watered regularly with equal amount of water. The number of emerged seedlings was counted daily up to 12 days of seed placement. Plant height, leaf numbers and leaf area of rice were measured after 30 days of seed placement. The dry weight of randomly selected 10 seedlings was recorded after being dried at 72°C in an electric oven for seven days. The weed debris at different concentrations of parthenium reduced the seed emergence, plant height, leaf numbers, leaf area and seedling dry weight of rice. Seedling emergence, plant height, leaf number, leaf area, and dry weight were reduced by 25.40%, 20.98%, 20.02%, 33.85% and 22.78% respectively. Among all the parameters were considered, leaf area was most affected than other parameters.

The inhibitory effects on rice were positively related to the concentration of parthenium weed debris in soil. Gupta and Narayan (2010) investigated the effects of leaf biomass of *P. hysterophorus* L., *Cassia obtusifolia* L. and *Achyranthes aspera* L., weeds on seed germination and seedling growth of wheat and pea and changes in the soil organic carbon. Soils were amended with leaf biomass (1, 2 and 5 g/Kg soil) of these weeds and the mixtures of leaf biomass of *P. hysterophorus* (5 g/Kg soil) with *C. obtusifolia* or *A. aspera* (5 g/Kg soil). The leaf biomass of weeds significantly improved the soil organic C pool and influenced the crop growth. However, their impact was crop specific and depended on doses and quality of leaf biomass (weed type). The mixtures of *P. hysterophorus* had variable effects (additive, antagonistic and synergistic) on the crop growth, thus, weed biomass may have potential in weed management.

A laboratory based study was undertaken by Amin *et al.* (2007) during January 2007 in Weed Research Laboratory, Department of Weed Science, NWFP Agricultural University Peshawar, Pakistan to investigate the allelopathic potential of aqueous extracts of *P. hysterophorus* (L.) against wheat (*Triticum aestivum*), *Avena fatua* and *Lepidium* sp. The whole plants of *P. hysterophorus* were dried in shade and ground to a fine powder, which was dissolved at 10, 20 and 30 g l^{-1}. Ten seed of each test species were placed in Petri dishes and extracts were applied when needed. A control was also included for comparison. Increasing the concentration of *P. hysterophorus* reduced the germination percentage, seedling length and seedling weight of all the three species tested significantly. The tolerance order of the species against the extract concentration of *P. hysterophorus* were *Triticum aestivum* > *Avena fatua* > *Lepidium* sp. The present study suggests that *P. hysterophorus* (L.) affects the agro ecosystem and needs careful attention. However, these extracts can be used as a viable weed management technique, but further studies are needed to explore the full potential of parthenium as a bioherbicide. Maharjan *et al.* (2007) studied allelopathic effects of aqueous extract of leaves of *P. hysterophorus* on seed germination and seedling growth of three cereal crops (*O. sativa* L., *Z. mays* L. and *T. aestivum* L.), three cultivated crucifers (*Raphanus sativus* L., *Brassica campestris* L. and *Brassica oleracea* L.) and two wild species of family Asteraceae (*Artemisia dubia* Wall ex. Besser and *Ageratina adenophora* (Spreng) King and HE Robins). Seed germination of all crucifer species was completely inhibited at >2% leaf extract of *P. hysterophorus* but in other species, except maize, complete failure of seed germination was recorded only at >6% in *T. aestivum* and *A. adenophora*; at 10% in *O. sativa* and *A. dubia*. Seed germination of *Z. mays* was not completely inhibited but it was low at high concentration of the extract. The extract had strong inhibitory effect to root elongation of seedling in cereals and to shoot elongation in crucifers and wild Asteraceae. Leaves of *P. hysterophorus* may be a source of natural weedicide against *A. adenophora* which will help to control invasive plants.

Allelopathic effects of entire shoot extract, plant part extracts, and shoot residue of parthenium (*P. hysterophorus* L.) on corn (*Z. mays* L.), ryegrass

(*Lolium multiflorum* Lam.), wheat (*T. aestivum* L.), velvetleaf (*Abutilon theophrasti* Medik.), and soybean [*G. max* (L) Merr.] growth were examined. Parthenium shoot contained water-soluble materials that were toxic to root growth of velvetleaf and wheat. At 4% (w/ v) concentration, root growth of velvetleaf and wheat were reduced by 60 and 75 %, respectively. The order of increasing sensitivity to parthenium was ryegrass, corn, wheat, and velvetleaf (Mersie and Singh, 1987).

Kanchan and Jayachandra (1979) observed that association with *P. hysterophorus* L. caused retarded growth and nodulation (*P. vulgaris* var. 'Burpees Stringless') the inhibition decreasing with increasing distance the weed. Leachate collected from parthenium grown pots also caused similar inhibition growth. The inhibitory nature of the root exudate was confirmed under sterile cultural conditions its effect on wheat (*T. aestivum* var. 'UP301') seedling growth. At the rosette and stage of the weed there was maximum exudation of inhibitors which remained active for about days.

Based on the above research shows parthenium weed (*P. hysterophorus* L.) is one of the most destructive invasive plant species found in natural systems and agroecosystems which interferes with crop production directly through allelopathic growth inhibition.

Chapter 3

Materials and Methods

MATERIALS AND METHODS

This chapter presents a brief description of the experimental period, site description, climatic condition, treatments, experimental design and layout, data collection, and statistical analysis.

3.1 Experimental period

The experiment was conducted during the period from April 2020 to March 2022.

3.2 Location of weed survey

Field surveys were conducted in 27 Upazilas (administrative regions) at Jashore, Jhenaidah, Chuadanga, Meherpur, and Khustia Districts of Bangladesh during April 2020 to March 2021 (Appendix I). These areas, located in the Khulna Division of south-western region of Bangladesh, are commonly known as the Jashore hub. The Jashore hub includes the western part of the Ganges River floodplain that is predominantly high and medium high-land. Calcareous dark grey floodplain soils and calcareous brown floodplain soils are the principal soil types and are somewhat alkaline in nature. The organic matter content in the dark grey soils is high, but lower in the brown ridge soils. The whole area is relatively more arid than other areas of the country. This region is suitable for cereals and vegetable production. This region produces a variety of crops year-round and plays a vital role in agricultural production in Bangladesh (Dewan *et al.*, 2017).

3.3 Procedure of weed survey

The survey was taken along the roadside verges at intervals of 500 meters throughout the 27 Upazila of the south-western region of Bangladesh between April 2020 to March 2021. The crop fields were considered in the survey and using the list quadrat method (Khan *et al*., 2014; Mahajan and Fatima, 2017).

A photographic record was made while undertaking the field surveys, at sites where *Parthenium* weed infestations were significant. When *Parthenium* was found at a density of at least one plant per 10 m^2 the topographical integrates were listed using a hand-held GPS (Maszura *et al*., 2018).

.3.4 Determination of relative density and abundance of parthenium weed

The weed density was determined by placing a quadrat (1 m^2) at random onto the survey site and applying the list quadrat technique (Mahajan and Fatima, 2017). At each survey site, 10 quadrats were taken. Parthenium weed, along with other weed species were counted inside each quadrat. Density, frequency, and abundance of parthenium weed plants were determined by the following formula and as described in many earlier studies (Knox *et al*., 2011; Nkoa *et al*., 2015; Maszura *et al*., 2018).

$$D_i = (\sum Y_i) / S_a$$
$$F_i = (\sum Z_i) / n$$

Where: D_i = density of the species i; $\sum Y_i$ = number of individual plants of species i contained in a quadrat; S_a = Surface area of the sampling unit; F_i = frequency of species i; $\sum Z_i$ = number of sampling unit with species i; n = number of quadrats sampled (Nkoa *et al*., 2015).

$$R_i = (\sum N_i) / N_W$$
$$A_i = N_i / Q_w$$

Where: R_i = relative density of weed species I; $\sum N_i$ = total number of weed species i; N_w = total number of all weed species; A_i = abundance of species i; N_i = total number of weed species i in all quadrats; Q_w = total number of quadrats in which weed occurred.

3.5 Mapping the distribution of *parthenium* infestation and the percentage of area coverage (severity class)

The information on *Parthenium* distribution and severity of infestation was marked on the base maps of South-West region of Bangladesh. The mapping of *Parthenium* weed distribution was done by measuring the percentage of area coverage completed by visual estimate within the quadrat. All the data of infested areas were transferred into a digital map using Geographic Information System (GIS) software, ArcGIS. The distribution, density, and percentage of coverage by the *Parthenium* weed were considered in mapping the weed infestation.

3.6 Crop Infestation

Surveys were conducted between April 2020 to March 2021 during different crop seasons to see the infestation status of parthenium in various economically important agricultural crops cultivated in Jashore hub region of Bangladesh. A total of 26 different crops including cereal, oil, vegetable, fodder, sugar, agroforestry and flower yielding crops were surveyed to see the percent occurrence and percent infestation of parthenium weed. Surveys were also conducted in search of parthenium infestation in orchards of different fruits. The percent occurrence and infestation of parthenium was calculated as follows:

$$\% \text{ Occurrence} = \frac{\text{No. of field having parthenium}}{\text{Total number of fields surveyed}} \times 100$$

$$\% \text{ Infestation} = \frac{\text{Total no. of quadrates in which parthenium weed occurred}}{\text{Total number of quadrates used}} \times 100$$

The percent infestation of parthenium was determined by presence and absence of the weed in the selected crop fields. The crop fields were selected on the basis of seasons as well as commonly grown crops in that particular area. The no. of fields visited for different crops were ranged between 20 to 200. Quadrates were used to determine number of parthenium in each of the selected fields and 20 quadrates of 50 x 50 cm^2 were randomly located at approximately 2 meter intervals throughout the 50 meter length of the field.

3.7 Sample and test seeds collection

The sample of fresh parthenium biomass at maximum vegetative stage of the plant from different infested parts of the country was collected. The seeds of different test crops were collected from Siddque Bazar, Dhaka.

3.8 Extraction Procedure

The leaves were separated, cut into fine pieces and weighed. The sample of leaves were dried in an oven at a temperature of 60ºC till a constant dry weight obtained. The dried samples then after grind in a blender to fine uniform texture and stored in glass jars until use.

3.8.1 Extraction in aqueous solvent

The weighed sample of plant material was ground in sterilized mortar and pestle and mixed in the sterilized water at 48 h at room temperature. Stock aqueous extract was obtained by soaking 50 g air-dried plant material in 1000 mL of cold distilled water for the concentration of 5% at room temperature for 24 hours. This aqueous leachates was filtered through three layers of muslin cloth to remove debris. The filtrate was then refiltered through one layer of Whattman No. 1 filter paper and stored in dark cool place for use by the method of Masum *et al.* (2016). The extract was generally used within a week. The pH prepared solution was 5.74.

3.9 Treatments and Experimental Design

The experiment was conducted in the year 2021, at Central Laboratory, Department of Agronomy, Sher-e-Bangla Agricultural University, Bangladesh. There were two treatments including 5% aqueous of leaf extracts and control with three observations with three replications of each. The treatments were arranged in completely randomized design (CRD) with three replications. The treatments were adopted in natural room light condition homogenously to all the Petri dishes.

3.10 Bioassay

Ten seeds of each test crops were placed on Whatman 2 MM paper in a Petri dish (9 cm), and 6 mL of a treatment solution or control was added. Every 48 h, one milliliter of each solution was added per Petri dish. Germination was assessed (rupture of seed coats and the emergence of radicle, Mayer and Poljakoff mayber, 1963) every 12 h until no further seeds germinated. The total germinated seeds (%) were calculated from the cumulative germination data after 1 week (Weidenhamer *et al*., 1987). Treatments were replicated three times. The same data were then used to calculate and compare different indices. Then after the supernatant was taken for further experiment on the germination of test crop seeds. The respective rate of elongation of the seedling was also monitored.

3.11 Collection of data

Data were recorded on the following parameters:

- Germination (%)
- Germination Inhibition (%)
- Shoot and root length (cm)
- Seedling inhibition (%)

Germination inhibition (%)

Germination inhibition (%) of the receiver plant was measured by the following formula (Othman *et al*., 2006).

$$\text{Germination Inhibition (\%)} = 1 - \frac{\text{Germinated seed with treatment solution}}{\text{Germinated seed in control}} \times 100$$

Seedling Inhibition (%)

Percentage inhibition was determined by the following formula (Lin *et al*., 2004).

% Inhibition =

$$\frac{\text{Control plant radicle/ plumule length} - \text{Treated plant radicle/ plumule length}}{\text{Control plant radicle/ plumule length}} \times 100$$

3.12 Statistical Analysis

The treatment means were separated by using Fisher's Protected Least Significant Difference test with the help of a computer package program named Statistix 10 data analysis software. The Type I error was set at 0.01 for all the statistical comparisons. Standard Errors were calculated by using Microsoft Excel.

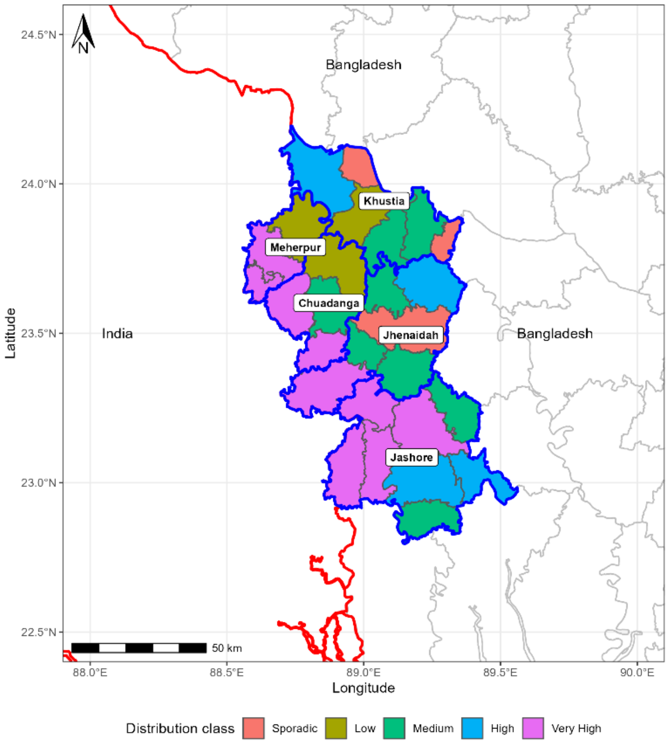
Chapter 4

Results and Discussion

RESULTS AND DISCUSSION

4.1 Distribution of *Parthenium hysterophorus* in south-western region of Bangladesh

Invasive alien plant species are becoming major threats around the world and parthenium weed is one of the most significant ones. The distribution of parthenium weed in 27 Upazilas of the five districts indicated severe infestation of the weed (Fig. 1 and Appendix II). *High* (5 to 7 plants in each m^2) to *very high* (> 8 plants in each m^2) infestations were found in 12 Upazilas among total 27 Upazilas. Whereas *medium* infestation was found in 8 Upazilas. Only one species of parthenium (*Parthenium hysterophorus)* was found affecting major crops in the studied areas. Therefore, according to the field survey, the results indicates that parthenium has already become a major pest of the agroecosystems of south-west region of Bangladesh. Both water and air are suspected to be the major vectors of parthenium spread in arable agroecosystems; while vehicular and mechanized farming responsible for long-distance dispersal (Navie *et al*. 1996). Thus, the weed can potentially spread all over the country. In Bangladesh, this weed has taken a relatively short time to become invasive, with introduction only 20 years ago. Because Zaker and Ahmed (1997) do not list it in their list of wildflowers in Bangladesh.



The Red line indicates the Bangladesh-India border, whereas the thick blue line indicates district boundaries. Distribution class: (i) Sporadic = 1 or more clusters within 100 m^2 (ii) Low = 1 to 2 plants in each m^2 (iii) Medium = 3 to 4 plants in each m^2 (iv) High = 5 to 7 plants in each m^2, and (v) Very High = more than 8 plants in each m^2. Country boundary layers source: GADM (https://gadm.org).

Figure 1. Distribution class of the parthenium spread across districts.

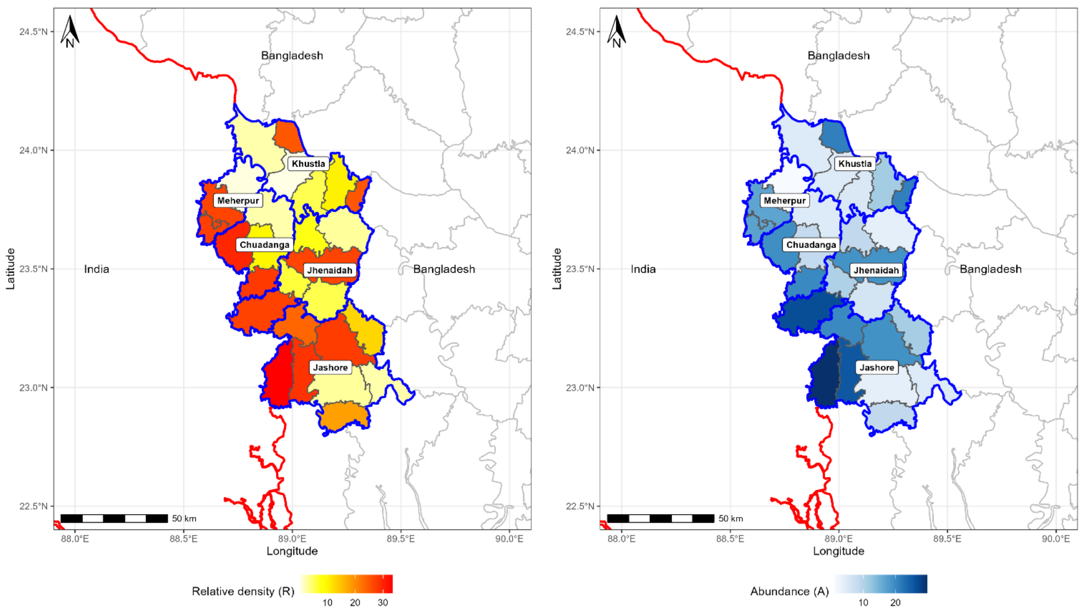
4.2 Density, frequency, and abundance of parthenium weed

The relative density (RD), frequency, and abundance of parthenium weed infestation in the southwestern region of Bangladesh are shown in Table 1. The data shows variation in the weed dynamics throughout the 27 Upazilas. In absolute weed density resultant data, the utmost distribution of parthenium weed (33.5 m^2) was confirmed at Sarsha Upazila, Jashore (Figure 2). The phytosociological survey of this region showed a high frequency of *P. hysterophorus* in general; however, the relative density (RD) (%) of the weed in different sectors of this region ranged from 0.48 –39.85%.

Table 1. Total number of quadrats used (NQ), other species found per quadrats (OS), number of all species found per quadrats (AS), number of quadrats with parthenium weed (QP), frequency of parthenium weed distribution (F), parthenium weed abundance (A), relative density (R; %), and symbol for severity class (SC)

No	Sites	District	NQ	OS	AS	QP	F	A	R	SC
1	Sarsha	Jashore	10	75.9	94.7	8	0.8	29.7	33.51	H
2	Jikargacha	Jashore	10	60.2	62.5	8	0.8	25.4	28.68	H
3	Chougacha	Jashore	10	61.4	67.4	8	0.8	20.0	23.74	H
4	Sadar	Jashore	10	54.3	67.7	7	0.7	19.1	27.79	H
5	Keshabpur	Jashore	10	59.6	64.9	6	0.6	8.8	18.17	M
6	Manirampur	Jashore	10	41.5	42.7	3	0.3	4.0	2.81	L
7	Abhaynagar	Jashore	10	65.5	67.0	3	0.3	5.0	2.24	L
8	Bagherpara	Jashore	10	53.0	60.9	7	0.7	11.3	12.97	M
9	Sadar	Jhenaidah	10	50.3	65.4	8	0.8	18.9	27.09	H
10	Maheshpur	Jhenaidah	10	56.6	77.8	8	0.8	26.5	27.25	H
11	Kaliganj	Jhenaidah	10	44.9	47.5	4	0.4	6.5	5.47	M
12	Kotchandpur	Jhenaidah	10	63	67.2	4	0.4	10.5	6.25	M
13	Shailkupa	Jhenaidah	10	41.5	42.7	3	0.3	4.0	2.81	L
14	Harinakunda	Jhenaidah	10	51.8	56.2	5	0.5	8.8	7.83	M
15	Alamdanga	Chuadanga	10	65.5	67.0	3	0.3	5.0	2.24	L
16	Sadar	Chuadanga	10	55.6	61.6	7	0.7	8.6	9.74	M
17	Damurhuda	Chuadanga	10	53.8	67.4	7	0.7	19.4	29.82	H
18	Jibannagar	Chuadanga	10	39.8	49.8	5	0.5	20.0	28.08	H
19	Gangni	Meherpur	10	83.1	83.5	3	0.3	1.3	0.48	T
20	Sadar	Meherpur	10	41.5	53.2	7	0.7	16.7	26.99	H
21	Mujibnagar	Meherpur	10	46.4	60	8	0.8	17.0	27.67	H
22	Bheramara	Khustia	10	49.2	64	7	0.7	21.1	25.13	H
23	Daulatpur	Khustia	10	65.5	67.0	3	0.3	5.0	2.24	L
24	Khoksa	Khustia	10	49.2	64	7	0.7	21.1	25.13	H
25	Kumarkhali	Khustia	10	49.7	55.4	5	0.5	11.4	10.29	M
26	Sadar	Khustia	10	39	41.2	4	0.4	5.5	5.34	M
27	Mirpur	Khustia	10	65.5	67.0	3	0.3	5.0	0.24	T

Symbol used Severity class Percent coverage: T = trace/rare less than 1%, L = low/occasional plants between 1 and 5%, M = moderate/scattered plants between 5 and 25%, H = high/fairly dense between 25 and 100%; Adopted from the U.S. Department of the Interior (2001) and Cooksey and Sheley (2002).



The Red line indicates the Bangladesh-India border, whereas the thick blue line indicates district boundaries. Country boundary layers source: GADM (https://gadm.org).

Figure 2. Relative density (left) and abundance (right) of parthenium plotted across all 27 Upazilas of the five districts of the southwestern part of Bangladesh.

McFadyen (1992), surveying central Queensland, Australia, reported that > 10% of the area was infested by weeds. A similar pattern of invasion was noticed by Oudhia (2000) in a phytosociological survey of weeds during the rainy season with special reference to parthenium in Raipur, India. He found that *P. hysterophorus*, *Senna tora* (L.) Roxb., and *Achyranthes aspera* L. dominated the vegetation. It was noticed during the survey that the weed prefers to invade areas that have been recently disturbed and where topsoil is removed. This, in turn, minimizes the competition from native species and enhances the chances of survival of the invading plants (Annapurna and Singh, 2003). It is also noticed that the weed has aggressively colonized the crop field, open land, pasture, and wasteland of our studied areas, indicating a severe infestation. Among our survey sites at Sarsha Upazila and Jikargacha Upazila of Jashore and Damurhuda Upazila of Chuadanga district, it was found that parthenium weed had a high degree of sociability, and these formed large stands under different habitats. Due to its aggressive nature and allelopathic impacts on nearby plants, *P. hysterophorus* has a high relative dominance (Kohli *et al.*, 1985; Adkins and Sowerby, 1996). The size and persistence of this weed's soil seed bank, the high viability of its seeds when buried, a high rate of germination, and the innate dormancy mechanism of its seeds are a few additional ecological characteristics that Navie *et al.* (1996) highlighted as contributing to this weed's aggressiveness. *P. hysterophorus*, which may generate up to 25000 seeds plant^{-1}, is a very prolific seed producer, according to Joshi (1991), and it is swiftly encroaching on other countries. It can be found in wastelands, decrepit places, rocky crevices, water channels, roadsides, and train tracks (Shabbir and Bajwa, 2006).

4.3 Parthenium infestation in crops

Results of the present study show that parthenium weeds were found growing and spreading rapidly in agricultural fields, alongside the road, residential areas, and grazing lands. The severity of abundance in different crop fields by parthenium weed was presented in table 2. Of the total 26 crops surveyed from 2020 to 2021, parthenium was recorded in three major cereals, *viz*. rice (*Oryza sativa*), wheat (*Triticum aestivum*), and maize (*Zea mays*). However, it was only in *aus* rice (upland rice) and the infestation was lower (8.75%). Parthenium weed was found in three pulse crops namely lentil (*Lens culinaris*), field pea (*Pisum sativum*), and chickpea (*Cicer arietinum*) where *P. sativum* was found severe infestation (57.85%). Among fiber crops tosaa jute (*Chorchorus olitorius*) was found most infested (57.63%) by parthenium weed. Parthenium weed was found in four oil yielding crops namely mustard (*Brassica campestris*), groundnut (*Arachis hypogaea*), sesame (*Sesamum indicum*), and sunflower (*Helianthus annuus*) where *B. campestris* fields were found extremely (63.85%) infested by this weed. Sugarcane (*Saccharum officinarum*), the sugar-yielding crop, tuber crop potato (*Solanum tuberosum*), spices crops onion (*Allium cepa*), garlic (*Allium sativum*) and turmeric (*Curcuma longa*), narcotic crop tobacco (*Nicotiana tabacum*), marigold (*Tagetes erecta*) a flowering crop and fruit orchards of banana (*Musa acuminate*), and mango (*Mangifera indica*) were also found infested by Parthenium. Among these different crops, a severe infestation of parthenium was recorded in *S. officinarum* (60.35%). Napier grass (*Pennisetum purpureum*) was the only fodder crop infested by this weed. Besides some vegetable crops were also found infested by this weed. The vegetables infested by parthenium weed include bottle gourd (*Lagenaria siceraria*), pumpkin (*Cucurbita maxima*), country bean (*Lablab purpureus*), and tomato (*Solanum lycopersicum*). Moreover, parthenium weed is also a serious weed of pastures and rangelands in different parts of the surveyed area (data not shown). Parthenium weed has been documented to have a detrimental effect on agricultural output through resource competition and allelopathy in many countries in Asia, Africa, and Australia. In most of these countries, the weed has already infested susceptible crops, while in other countries it is still in the

Table 2. Percentage occurrence and infestation of *P. hysterophorus* in various crops

Crops name	No. of fields visited	No. of fields having weed	% Occurrence of the weed	% Infestation in crops fields
Cereal crops				
Oryza sativa (*aus* rice)	180	6	3	8.75
Oryza sativa (*aman* rice)	50	3	sporadic	-
Zea mays	60	3	5	11.45
Triticum aestivm	45	2	4	22.32
Pulse crops				
Lens culinaris	20	1	5	12.45
Pisum sativum	25	6	24	57.85
Cicer arietinum	20	2	10	32.40
Fibre crops				
Chorchorus olitorius	35	15	43	57.63
Gossipium hyrsutum	12	1	8	13.45
Oil crops				
Brassica campestris	37	9	24	63.85
Arachis hypogaea	3	1	33	28.35
Sesamum indicum	10	1	10	17.50
Helianthus annus	6	1	16	10.00
Tuber crops				
Solanum tuberosum	20	7	35	38.75
Sugar crop				
Saccharum officinarum	70	45	64	60.35
Narcotic Crops				
Nicotiana tabacum	16	1	6	13.45
Spices crops				
Allium cepa	28	4	14	30.47
Allium sativum	26	2	8	26.35
Curcuma longa	14	3	21	17.5
Vegetables crops				
Lagenaria siceraria	22	3	14	11.50
Cucurbita maxima	14	2	14	8.45
Lablab purpureus	5	1	20	10.50
Solanum lycopersicum	20	4	20	17.75
Fodder crops				
Pennisetum purpureum	15	8	53	55.00
Fruit crops				
Musa acuminata	33	2	6	24.33
Mangifera indica	20	11	55	12.45
Flower yielding crops				
Tagetes erecta	6	1	16	11.25

process of moving from the areas that it originally colonized into the cropping lands. Tiwari and Bisen (1982) also reported infestation of parthenium in field crops like soybean, millets, and paddy. In North America, parthenium weed has been recorded in several crops including sugarcane, maize, cotton, sorghum, onion, and citrus orchards (Dale, 1981). Infestation of parthenium in sugarcane was much higher than in other crops recorded by Patil *et al.* (1997). Parthenium has been found to suppress the yield of sunflower and sorghum in sufficient amounts (Parsons and Cuthberston, 1992). In Tamil Nadu, crop losses due to heavy infestation of parthenium weed in cotton were found in the range of 300 kg of seeds ha^{-1}. A low infestation of parthenium in rice was recorded by Khan and Aneja (2016).

4.4 The inhibitory impact of *P. hysterophorus* on different crops

Allelopathy activity of leaf extract of *P. hysterophorus* was examined against the seed germination and radicle and plumule growths of twenty economically important crops including three major cereals *viz.* rice (*Oryza sativa* L.), wheat (*Triticum aestivum* L.), and maize (*Zea mays* L.), six pulse crops *viz.* chickpea (*Cicer arietinum* L.), cowpea (*Vigna unguiculata* L.), green gram (*Vigna radiata* (L.) R. Wilczek), black gram (*Vigna mungo* (L.) Hepper), field pea (*Pisum sativum* L.) and lentil (*Lens culinaris* Medik), two oilseed crops *viz.* mustard (*Brassica campestris* L.) and sesame (*Sesamum indicum* L.), one fiber crop *viz.* Tossa jute (*Corchorus olitorious* L.), one spice crop *viz.* onion (*Allium cepa* L.), and seven vegetable crops *viz.* bean (*Phaseolus vulgaris* L.), cucumber (*Cucumis sativus* L.), pumpkin (*Cucurbita pepo* L.), red amaranth (*Amaranthus cruentus* L.), chili (*Capsicum frutescens* L.), radish (*Raphanus sativus* L.) and tomato (*Solanum lycopersicum* L.). Tefera (2002) found that the inhibitory allelopathic impact of leaf extract was more powerful than of other vegetative parts. Anwar *et al*. (2016) stated that germination percentage, radicle length, and plumule length are the three major parameters to determine the allelopathic effect on the receiver plant.

4.5 Germination percentage

The process of germination, which is the restart of metabolic processes and growth by seed tissues, begins with the absorption of water through osmosis and imbibition, which activates enzymes and boosts metabolic activity. The treatment of different types of crops with 5% *P. hysterophorus* leaf extract registered a lower germination percentage compared to the control (Table 3). The failure of germination (0%) due to the treatment was found in sesame, jute, pumpkin, red amaranth, chili, radish, and tomato. Tefera (2002) reported that leaf aqueous extract of *P. hysterophorus* resulted in complete failure of seed germination in *Eragostis tef*. Among the major cereals, wheat had the minimum germination percentage (21%) followed by maize (33%) and rice (44%). The failure and minimum germination compare to control might be due to phenols, alkaloids, and allelochemicals present in parthenium (Pandey, 1997). The inhibitory effect of parthenium leaf extracts on seed germination might also be due to an imbalance in metabolism regulated by various enzyme activities (Oyun, 2006). However, the herbicidal activity of flavonoid compounds may be contributing to the further decline in the germination percentage (Javaid *et al*., 2010; Sorecha and Birhanu, 2017).

Table 3. Allelopathic effect of *P. hysterophorous* on germination percentage, radicle length, and plumule length of different crops

Name of the Crops	Germination (%)		Radicle length (cm)		Plumule length (cm)	
	Control	Aqueous extract	Control	Aqueous extract	Control	Aqueous extract
Cereal crops						
Rice	96.33 ± 0.88	44.33 ± 4.70	3.37 ± 0.11	0.85 ± 0.03	4.27 ± 0.15	1.04 ± 0.01
Wheat	97.43 ± 0.69	21.33 ± 2.03	4.47 ± 0.33	0.20 ± 0.06	8.83 ± 0.45	0.57 ± 0.17
Maize	94.57 ± 0.88	33.33 ± 3.28	12.42 ± 0.65	7.09 ± 0.21	12.72 ± 0.46	7.13 ± 0.51
Pulse crops						
Chickpea	87.33 ± 7.06	27.33 ± 4.67	10.46 ± 0.48	5.53 ± 0.70	3.54 ± 0.25	1.75 ± 0.19
Cowpea	92.00 ± 2.19	38.33 ± 4.41	6.68 ± 0.34	3.68 ± 0.26	9.32 ± 0.45	6.66 ± 0.29
Greengram	95.00 ± 1.15	70.60 ± 4.63	9.10 ± 0.35	4.33 ± 0.97	18.13 ± 0.64	13.33 ± 0.94
Blackgram	95.00 ± 1.82	81.33 ± 2.89	7.73 ± 0.33	5.13 ± 0.43	18.40 ± 0.36	15.60 ± 0.93
Fieldpea	94.20 ± 0.67	34.00 ± 3.21	63.78 ± 1.40	9.48 ± 0.52	59.00 ± 3.88	7.39 ± 0.66
Lentil	93.17 ± 1.73	37.00 ± 1.53	51.95 ± 8.50	6.54 ± 0.10	64.31 ± 3.12	6.43 ± 1.03
Oilseed crops						
Mustard	87.83 ± 4.04	38.96 ± 4.87	3.78 ± 0.12	2.08 ± 0.30	3.56 ± 0.81	1.21 ± 0.09
Sesame	85.33 ± 0.88	0.00 ± 0.00	3.22 ± 0.14	0.00 ± 0.00	3.64 ± 0.10	0.00 ± 0.00
Fiber crop						
Jute	80.67 ± 3.53	0.00 ± 0.00	1.32 ± 0.05	0.00 ± 0.00	2.64 ± 0.10	0.00 ± 0.00
Spices crops						
Onion	77.50 ± 1.73	14.67 ± 2.03	2.80 ± 0.70	0.67 ± 0.17	3.56 ± 0.80	0.98 ± 0.12
Vegetables crops						
Bean	79.33 ± 0.58	42.33 ± 2.96	18.33 ± 0.24	10.04 ± 0.88	33.45 ± 0.16	19.15 ± 2.29
Cucumber	86.00 ± 1.76	41.67 ± 2.03	46.79 ± 2.98	19.79 ± 0.63	62.77 ± 1.20	25.82 ± 1.57
Pumpkin	75.67 ± 2.40	0.00 ± 0.00	17.72 ± 0.40	0.00 ± 0.00	10.37 ± 1.12	0.00 ± 0.00
Amaranth	74.33 ± 0.58	0.00 ± 0.00	11.42 ± 0.66	0.00 ± 0.00	20.43 ± 1.42	0.00 ± 0.00
Chilli	76.33 ± 4.41	0.00 ± 0.00	3.12 ± 0.29	0.00 ± 0.00	3.38 ± 0.13	0.00 ± 0.00
Radish	92.33 ± 0.33	0.00 ± 0.00	8.33 ± 0.24	0.00 ± 0.00	16.45 ± 1.64	0.00 ± 0.00
Tomato	96.00 ± 1.73	0.00 ± 0.00	0.35 ± 0.03	0.00 ± 0.00	0.89 ± 0.03	0.00 ± 0.00

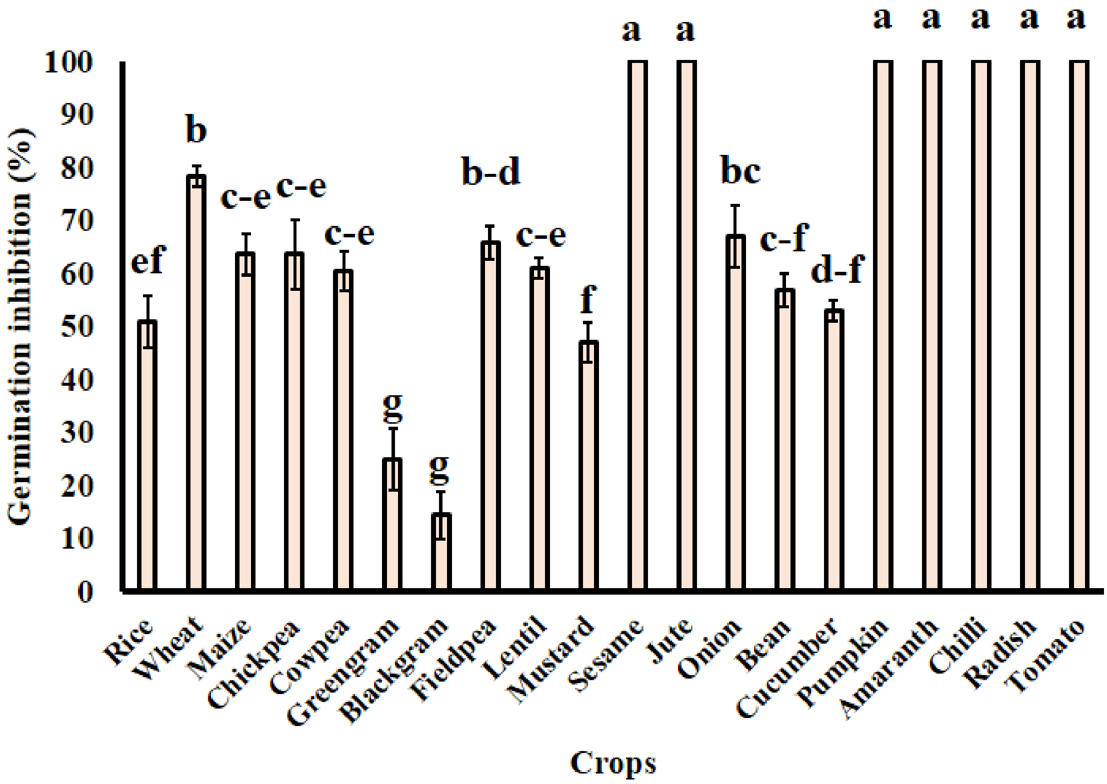
4.6 Effect of *P. hysterophorus* aqueous extract on radicle and plumule length of test species

Aqueous extract of *P. hysterophorus* drastically reduced the radicle and plumule length of germinated seeds of all test species (Table 3). Among the cereal species, there was the highest reduction in the radicle and plumule length of wheat. The results showed that radicle and plumule length of rice at 75 and 74%, respectively different from that of the control. The radicle and plumule length of wheat at 96% and 94%, respectively were different from that of the control. Whereas in maize, radicle length at 43% and plumule length 44% were different from that of the control. Among pulses, the radicle and plumule lengths of lentil were highly reduced (87 and 90%, respectively) as compared to the control. The germinated mustard seed's radicle and plumule were 45 and 66%, respectively different as compared to the mustard control seedlings. Similarly, the onion had 76 and 72% of radicle and plumule, respectively varying as compared to the onion control seedlings. Between the germinated vegetables of been and cucumber, cucumber had the higher reduction seedling growth (58 and 59%, radicle, and plumule, respectively different from control seedling), and been had 45 and 43%, radicle, and plumule, respectively different from control seedlings. Radicle appeared more sensitive to allelopathic effect than plumule in most cases of test species. Similar findings have been reported for tomato (Mersie and Singh, 1987), chickpea and sesame (Ashebir *et al*., 2012), maize, soybean, and cotton (Masum *et al*., 2012), black gram and green gram (Parthasarathi *et al*., 2012), onion and bean (Demissie *et al*., 2013), bean (Tahseen *et al*., 2015), maize (Anwar *et al*., 2016; Amare, 2018), wheat, chickpea and mustard (Hassan *et al*., 2018), rice and wheat (Shrestha and Thapa, 2018), cowpea and rice (Bhuvaneshwari *et al*., 2019). Dicotyledonous test plants demonstrated more inhibitory effects on seedling growth than monocotyledonous plants in this study. Khanh *et al*. (2006) also found that *Passiflora edulis* aqueous extracts strongly suppressed the growth of dicot plants, whereas the growth of monocot plants was less affected.

4.7 Inhibition percentage

The seeds imbibed with aqueous parthenium leaf extract delayed and inhibited the germination, radicle growth, and plumule growth (Figs. 3, 4, and 5, respectively and Appendix III) in comparison to the control which was highly significant ($p < 0.01$).

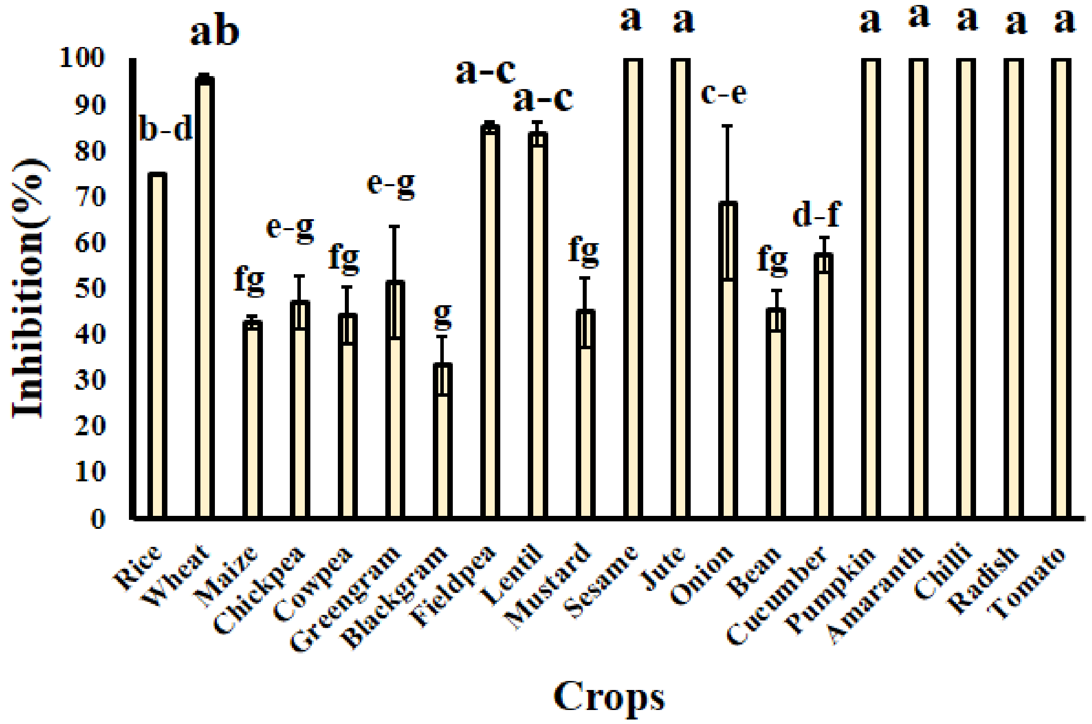
The highest inhibition (100%) in seed germination of sesame, jute, pumpkin, red amaranth, chili, radish, and tomato whereas the lowest (14%) inhibition was found in black gram which was statistically similar to green gram germination inhibition (25%).



Vertical bars represent the standard error at a 1% level of significance.

Figure 3. Germination inhibition potential of the aqueous extracts from parthenium weed on different agricultural seeds.

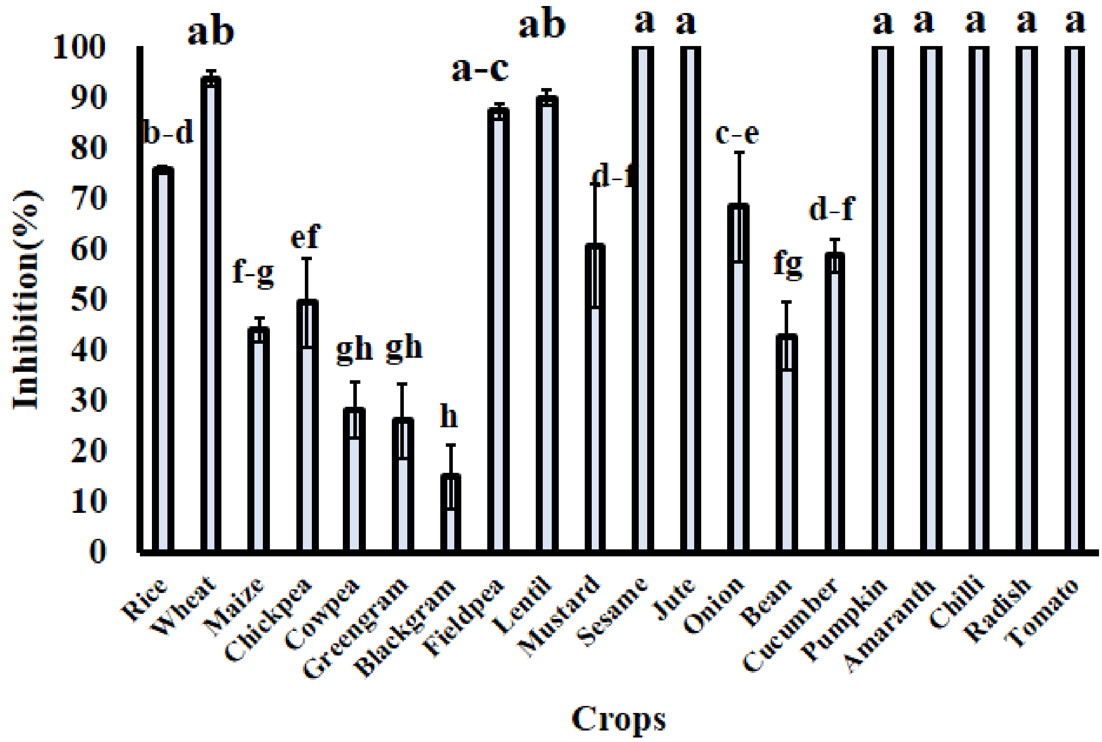
Results of Petri plate experiment had shown the greatest (96%) decrease of radicle in wheat other than full inhibited crops (i.e., jute, onion, pumpkin, red amaranth, chili, radish, and tomato) followed by field pea 85%, and lentil 84% as compared to their respective control. Whereas the radicle of black gram was less (33%) affected which was statistically similar to the many other crops like maize (42%), cowpea (44%), mustard (45%), been (45%), and green gram (51%).



Vertical bars represent the standard error at a 1% level of significance.

Figure 4. Radicle length inhibition potential of the aqueous extracts from parthenium weed on different agricultural seeds.

The highest (94%) drop in plumule was seen in wheat, according to Petri plate experiment findings other than full inhibited crops (i.e., jute, sesame, pumpkin, red amaranth, chili, radish, and tomato) followed by lentil 90% and field pea 87%, and as compared to their respective control. Whereas the plumule of black gram was less (15%) affected which was statistically similar to green gram (26%) and cowpea (28%).



Vertical bars represent the standard error at a 1% level of significance.

Figure 5. Plumule length inhibition potential of the aqueous extracts from parthenium weed on different agricultural seeds.

Many grain crops, including cereals, pulses, and oilseeds, have been documented to suffer severe growth suppression and yield decreases due to parthenium weeds in various parts of the world. Germination and early growth suppression are the most commonly affected stages due to the powerful action of allelopathy at this early stage of crop growth (Bajwa *et al.*, 2019). The emergence of rice seedlings and subsequent growth were significantly hindered by parthenium weed residues (Biswas *et al.*, 2010). Srivastava *et al.* (2011) reported the reduction of water uptake in germinating seeds as one mechanism of germination inhibition by parthenium weed. The subsequent crop growth was also severely affected because of poor germination and seedling vigor.

Chapter 5

Summary and Conclusion

SUMMARY AND CONCLUSION

Parthenium weed (*Parthenium hysterophorus* L.) family Asteraceae commonly called parthenium weed, congress weed, carrot weed or white top is an alien invasive herbaceous weed, native to the tropical and subtropical Americas but now with pan tropic distribution.

Periodical weed surveys were conducted during 2020-21 at Jashore, Jhenaidah, Chuadanga, Meherpur, and Khustia of Bangladesh to observe the severity of parthenium and to identify how many crops were affected by this weed.

The observation was made alongside the highways and major roads of the study sites with an interval of 500 meters. The farmland, wasteland, and riverbank around the survey spots were also considered in the survey following the list quadrat method. The geographical coordinates were recorded using a GPS. When parthenium was observed at a density of at least one plant per 10 m^2 area, it was considered the presence of the weed. The mapping of parthenium weed distribution was done by measuring the percentage of area coverage completed by visual estimate within the quadrat. All the data of infested areas were transferred into a digital map using Geographic Information System (GIS) software, ArcGIS. The distribution, density, and percentage of coverage by the parthenium weed were considered in mapping the weed infestation

The numbers of parthenium were noticeably among the twenty-seven locations. Results of the present study show that parthenium weeds were found growing and spreading rapidly in agricultural fields, alongside the road, residential areas, and grazing lands. Distribution of parthenium weed: rice, maize, mustard, onion, banana, turmeric, potato, blackgram, field pea, country bean, lentil, tomato, bottle gourd, sugarcane, napiergrass, etc. Maximum parthenium weed was found in Jashore and Chuadanga districts due to the Indian way from these districts. All districts of this region were affected by *Parthenium hysterophorus* but no other species were found in this region. The data in illustrates the variability in weed dynamics throughout the 27 studied sites. In absolute weed density resultant data, the utmost distribution of Parthenium weed (33.5 m^2) was confirmed at Sarsha Upazilla, Jashore.

Parthenium weed has been reported to be a strongly allelopathic species and this trait has been suggested to be important in invasion and persistence in a wide range of native and non-native ecosystems. Parthenium weed contains potential allelochemicals within its aerial parts (e.g. leaves). Subsequently, a laboratory experiment was conducted using a 5% aqueous concentration of Parthenium along with distilled water that served as a control. During the laboratory study, data were recorded on germination percentage (%), and root and shoot length per plant (cm). The study demonstrated that leaf aqueous extracts of *P. hysterophorus* exhibited significant inhibitory effects on seed germination and seedling growth of all tested crops including major cereals, pulses, oilseeds, fiber, spices, and vegetables.

The complete failure of germination (0%) due to the treatment was found in sesame, jute, pumpkin, red amaranth, chili, radish, and tomato. Among the major cereals, wheat had the minimum germination percentage (21%) followed by maize (33%) and rice (44%). Aqueous extract of *P. hysterophorus* drastically reduced the radicle and plumule length of germinated seeds. The results showed that radicle and plumule length of rice at 75 and 74%, respectively different from that of the control. The radicle and plumule length of wheat at 96% and 94%, respectively were different from that of the control. Whereas in maize, radicle length at 43% and plumule length at 44% were different from that of the control. Among pulses, the radicle and plumule lengths of lentil were highly reduced (87 and 90%, respectively) as compared to the control. The germinated mustard seed's radicle and plumule were 45 and 66%, respectively different as compared to the mustard control seedlings. Similarly, the onion had 76 and 72% of radicle and plumule, respectively varying as compared to the onion control seedlings. Between the germinated vegetables of been and cucumber, cucumber had the higher reduction seedling growth (58 and 59%, radicle, and plumule, respectively different from control seedling), and been had 45 and 43%, radicle and plumule, respectively different from control seedlings. Radicle appeared more sensitive to allelopathic effect than plumule in most cases of test species.

Parthenium weed is known to have drastic impacts on agricultural productivity and sustainability. However, little information is available on its direct impacts on agriculture, especially in Bangladesh. The information presented in this research demonstrates that parthenium is a very invasive weed species shown in the southwest region of Bangladesh. The adverse impacts of parthenium aqueous extracts on the growth of test crops could be attributed to the presence of various phytotoxic compounds in parthenium. Thus, the present findings suggest preventing parthenium infestation around the crop fields and pastures which could be affected by the allelochemicals released by parthenium. The agricultural impacts of parthenium weed are multilateral and therefore require dynamic broad-spectrum solutions. Preventive measures are important to check for new infestations in cropping areas. The integrated management strategies involving chemical, biological, and mechanical control methods are likely to be the most effective. However, proper legislation and policy-making, and coordination of management to help control parthenium weed in Bangladesh are necessary.

References

REFERENCES

Adkins (2009). Parthenium weed poses danger to crops. Published in Dhaka Mirror, December 30, 2009.

Adkins, S.W. and Navie, S.C. (2006). Parthenium weed: a potential major weed for agro-ecosystems in Pakistan. *Pakistan J. Weed Sci. Res*. **12**: 19–36.

Adkins, S.W. and Shabbir, A. (2014) Biology, ecology and management of the invasive parthenium weed (*Parthenium hysterophorus* L.) *Pest Manag. Sci*. **70**: 1023–1029.

Adkins, S.W. and Sowerby, M.S. (1996). Allelopathic potential of *Parthenium hysterophorus* L. in Australia. *Plant Prot. Q*. **1**: 20–23.

Akter, A. and Zuberi, M.I. (2009). Invasive alien species in Northern Bangladesh: Identification, Inventory and Impacts. *Intl. J. Bio. Con*. **1**: 129-134.

Amare, T. (2018). Allelopathic effect of aqueous extracts of parthenium (*Parthenium hysterophorus* L.) parts on seed germination and seedling growth of maize (*Zea mays* L.). *J. Agric. Crops*. **4**(12): 157-163.

Amin, A., Rahsid, H., Khan, M.A. and Khan, M.I. (2007). Allelopathic effects of *Parthenium hysterophorus* (L.) extracts on seed germination and growth of wheat and associated weeds. Proceedings of the 21st Asian Pacific Weed Science Society Conference (Editors: B. Marambe, U.R. Sangakkara, W.A.J.M. De Costa, and A.S.K. Abeysekara), 2-6 October 2007, Colombo, Sri Lanka.

Annapurna, C. and Singh, J.S. (2003) Variation of *Parthenium hysterophorus* in response to soil quality: Implications for invasiveness. *Weed Res.* **43**: 190–198.

Anwar, T., Khalid, S., Saeed, M., Mazhar, R., Qureshi, H and Rashid, M. (2016). Allelopathic interference of leaf powder and aqueous extracts of hostile weed: *Parthenium hysterophorus* (Asteraceae). *Sci. Int*. **4**(3): 86-93.

Ashebir B., Sharma, J.J. and Lisanwork, N. (2012). Allelopathic effects of aqueous extracts and plant residues of *Parthenium hysterophorus* L. on kabuli chickpea and sesame. *Eth. J. Weed Mgt.* **5**: 13-26.

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.

Bajwa, A.A., Shabbir, A. and Adkins, S.W. (2019). Interference and impact of parthenium weed on agriculture. *In*: Parthenium Weed: Biology, Ecology and Management (eds. Adkins, S., Shabbir, A. and Dhileepan K.). pp. 57- 78.

Belgeri, A. and Adkins, S.W. (2015) Allelopathic potential of invasive parthenium weed (*Parthenium hysterophorus* L.) seedlings on grassland species in Australia. *Allelopathy J*. **36**: 1–14.

Bhuvaneshwari, K., Muniyappan, C., Priyadharshini, D., Sathyapriya, P., Rathika, S. and Ramesh, T. (2019). Allelopathic effect of *Parthenium* *hysterophorus* L. on germination and seedling growth of different field crops. *The Pharma Innov. J.* **8**(7): 257-261.

Biswas, O., Paul, K.P., Ghosh, S. and Karim, S.R. (2010). Allelopathic effects of parthenium weed debris in soil on the emergence and development of rice. *J. Agrofor. Environ*. **4**: 193–196.

Bradley, B.A., Blumenthal, D.M., Wilcove, D.S. and Ziska, L.H. (2010). Predicting plant invasions in an era of global change. *Trends Ecol. Evol*. **25**: 310-318.

Cooksey, D. and Sheley, R. (2002). Montana Noxious Weed Survey and Mapping System, MSU Extension Service MT199613 AG 7, Bozeman, MT, USA.

Dale, I.J. (1981). Parthenium weed in Americas: A report on the ecology of *Parthenium hysterophorus* in South central and North America. *Australian Weeds* **1**: 8-14.

Demissie, A.G., Ashenafi A., Arega A., Etenash U., Kebede A. and Tigist A. (2013). Effect of *Parthenium hysterophorus* L. on germination and elongation of Onion (*Allium cepa*) and Bean (*Phaseolus vulgaris*). *Res. J. Chem. Environ. Sci.* **1**(2): 17-21.

Devi, O.I. and. Dutta, B.K. (2012). Allelopathic effect of the aqueous extract of *Parthenium hysterophorus* and *Chromolaena Odorata* on the seed germination and seedling vigour of *Zea mays* L. *In vitro*. *Aca. J. Plant Sci*. **5**(4): 110-113.

Devi, O.I., Dutta, B.K. and Choudhury, P. (2013). Effect of allelopathic plant extracts (i.e. *Parthenium hysterophorus* and *Chromolaena odorata*) on the seed germination and seedling vigour of rice (*Oryza sativa* L.) *in vitro*. *Int. J. Agri. Sci.* **3**(10): 766-774.

Dewan, M.M.R., Harun Ar Rashid, M., Nasim, M. and Shahidullah, S.M. (2017). Diversity of crops and cropping systems in Jessore region. *Bangladesh Rice J.* **21**(2): 185-202.

DWSR. (2011). Deadly parthenium weed invades India's farmlands. Directorate of Weed Science Research Institute, India. Available at: http://www.youtube.com/watch?v=HBS-ayXeiT4

Gnanavel, I. (2013). *Parthenium hysterophorus* L: a major threat to natural and agroecosystems in India. *Sci. Int.* **1**: 124-131.

Gupta, S. and Narayan, R. (2010). Effects of applied leaf biomass of *Parthenium hysterophorus, Cassia obtusifolia* and *Achyranthes aspera* on seed germination and seedling growth of wheat and pea. *Allelopathy J.* **26**(1): 59-70.

Hassan, G., Rashid, H.U., Amin, A., Khan, I.A. and Shehzad, N. (2018). Allelopathic effect of *Parthenium hysterophorus* on germination and growth of some important crops and weeds of economic importance. *Planta Daninha*. v36:e018176372.

Horo, J.T., Gudisa, T., Worku, E. and Tilahun, D. (2020). Distribution and Abundance of Parthenium hysterophorus L. in Metekel Zone, Northwest Ethiopia. *American J. Plant Sci.***11**: 1101-1110.

https://gadm.org

Javaid, A., Shafique, S. and Shafique, S. (2010). Herbicidal effects of extracts and residue incorporation of *Datura metel* against parthenium weed. *Nat. Prod. Res.* **24**: 1426-1437.

Joshi, S. (1991). Interference effects of *Cassia uniflora* Mill on *P. hysterophorus* L. *Plant Soil*. **132**: 113–118.

Kanchan, S.D and Jayachandra. (1979). Allelopathic effects of *Parthenium hysterophorus* L. I. exudation of inhibitors through roots. *Plant Soil* **53**(1&2): 27-35.

Karim, S. M. R. (2009). Parthenium agacha: Bangladesher Janno maraktok humki (Parthenium weed: A dangerous threat for Bangladesh). Krishi Projukti Barta. Published by BAURES, Bangladesh Agricultural University, Mymensingh. 3: 21-23.

Karim, S.M.R. and Forzwa, R. (2010). Allelopathic effects of parthenium weed on the seed germination and seedling growth of field crops. Abstracts, Annual Botanical Conference 2009, held at Chittagong University, Bangladesh during 9 to 10 January 2010, pp. 38-39.

Khan, H., Marwat, K. B., Hassan, G., Khan, M. A. and Hashim, S. (2014). Distribution of parthenium weed in Peshawar valley, Khyber Pakhtunkhwa-Pakistan. *Pak. J. Bot*. **46**(1): 81-90.

Khan, S.A. and Aneja, K.R. (2016). Parthenium infestation and yield losses in agricultural crops. *Indian J. Weed Sci.* **48**(4): 428–431.

Khanh, T.D., Chung, I.M., Tawata, S. and Xuan, T.D. (2006). Weed suppression by *Passiflora edulis* and its potential allelochemicals. *European Weed Res*. *Soc.* **46**: 296-303.

Kilewa, R. and Rashid, A. (2014). Distribution of invasive weed *Parthenium hysterophorus* in natural and agro-ecosystems in arusha Tanzania. *Int. J. Sci. Res.* **3**(12): 1724-1727.

Knox, J., Jaggi, D. and Paul, M.S. (2011). Population dynamics of *Parthenium hysterophorus* (Asteraceae) and its biological suppression through *Cassia occidentalis* (Caesalpiniaceae). *Turkish J. Bot*. **35**(2): 111-119.

Kohli, R.K., Batish, D.R., Singh, H. and Dogra, K.S. (2006). Status, invasiveness and environmental threats of three tropical American invasive weeds (*Parthenium hysterophorus* L., *Ageratum conyzoides* L., *Lanana camara* L.) in India. *Biol. Inv.* **8**: 1501–1510.

Kohli, R.K., Kumari, A. and Saxena, D.B. (1985). Auto and teletoxicity of *Parthenium hysterophorus* L. *Acta Univ. Agric. Brnol* (Czechoslovakia). **33**: 253–263.

Lin, D., Tsuzuki, E., Sugimoto, Y., Dong, Y., Matsuo, M. and Terao, H. (2004). Elementary identification of phenolic allelochemicals from dwarf lilyturf plant (*Ophiopogon japonicas* K.) and their growth inhibiting effects for two weeds in paddy rice field. *Plant Prod. Sci*. **7**: 260-265.

Mahajan, M. and Fatima, S. (2017). Frequency, abundance, and density of plant species by list count quadrat method. *Int. J. Multidisciplinary Res*. **3**(7): 1-8.

Maharjan, S., Shrestha, B.B. and Jha, P.K. (2007). Allelopathic effects of aqueous extract of leaves of *Parthenium hysterophorus* L. on seed germination and seedling growth of some cultivated and wild herbaceous species. *Sci. World* **5**(5): 33-39.

Masum, S.M., Ali, M.H., Mandal, M.S., Haque, M.N. and Mahto, A.K. (2012). Influence of *Parthenium hysterophorus*, *Chromolaena odorata* and PRH on seed germination and seedling growth of maize, soybean and cotton. *Bangladesh J. Weed Sci.* **3**: 83–90.

Masum, S.M., Hasanuzzaman, M. and Ali, M.H. (2013). Threats of *Parthenium hysterophorus* on agro-ecosystems and its management: a review. *Intl. J. Agri. Crop Sci*. **6**: 684-697.

Masum, S.M., Hossain, M.A., Akamine, H., Sakagami, J.I. and Bowmik, P.C. (2016). Allelopathic potential of indigenous Bangladeshi rice varieties. *Weed Biol. Manag*. **16** (3):119-131.

Masum, S.M., Hossain, M.A., Akamine, H., Sakagami, J.I., Ishii, T., Konno, T., Nakamura, I. Assaduzzaman, M and Bowmik, P.C. (2019). Performance of Bangladesh indigenous rice in a weed infested field and separation of allelopathy from resource competition. *Weed Biol. Manag*. **19**: 39-50.

Maszura, C.M., Karim, S.M.R., Norhafizah, M.Z., Kayat, F. and Arifullah, M. (2018). Distribution, density, and abundance of parthenium weed (*Parthenium hysterophorus* L.) at Kuala Muda, Malaysia. https://doi.org/10.1155/2018/1046214.

Mayer, A.M. and Poljakoff-mayber, A. (1963). The germination of seeds. Pergamon Press, New York.

McFadyen R.E. (1992). Biological control against parthenium weed in Australia. *Crop Prot*. **11**: 400–407.

Mersie, W. and Singh, M. (1987). Allelopathic effect of *Parthenium hysterophorus* extract and residue on some agronomic crop and weeds. *J. Chem Ecol*. **13**(7): 1739-1747.

Navie S.C., McFadyen R.E., Panetta F.D. and Adkins S.W. (1996). The biology of Australian weeds 27, *Parthenium hysterophorous* L. *Plant Prot. Q*. **11**: 76–88.

Navie, S. C., Panetta, F. D., McFadyen, R. E., and Adkins, S. W. (2005). The effect of CO_2 enrichment on the growth of a C3 weed (*Parthenium hysterophorus* L.) and its competitive interaction with a C4 grass (*Cenchrus ciliaris* L.). *Plant Prot. Q*. **20**: 61-66.

Netsere, A. (2015). Allelopathic effects of aqueous extracts of an invasive alien weed *P. hysterophorus* L. on maize and sorghum seed germination and seedling growth. *J. Biol. Agric. Healthca*. **5**(1): 120-124.

Nguyen, T.L.T., Bajwaa, A. A., Naviec, S. C., O'Donnella, C. and Adkins, S. (2017). The soil seedbank of pasture communities in central

Queensland invaded by *Parthenium hysterophorus* L. *Rangel. Ecol. Manag*. **70**(2): 244-254.

Nkoa, R., Owen, M.D. and Swanton, C.J. (2015). Weed abundance, distribution, diversity, and community analyses. *Weed Sci.* **63**(SP1): 64-90.

Othman, Y., Al-Karaki, G., Al-Tawaha, A.R. and Al-Horani, A. (2006). Variation in germination and ion uptake in barley genotypes under salinity conditions. *World J. Agric. Sci.* **2**: 11-15.

Oudhia P. (2000). Medicinal herbs and insects of Chhattisgarh India. *Insect Environ*. **6**: 138.

Oyun, M.B. (2006). Allelopathic potentialities of *Gliricidia sepium* and *Acacia auricliformis* on the germination and seedling vigour of maize. *American J. Agric. Biol. Sci*. **1**(3): 44-47.

Pandey, D.K. (1997). Inhibition of najas (*Najas graminea* Del.) by parthenium (*Parthenium hysterophorus* L.). *Allelopathy J*. **4**: 121-126.

Parsons, W.T. and Cuthberston, E.G. (1992). Noxious Weeds of Australia. Inkata Press, Melbourne. p. 292.

Parthasarathi, T., Suganya, V. and Sivakumar, R. (2012). Allelopathic effect of aqueous leaf extract of *Parthenium hysterophorus* L. on seed germination and seedling growth in greengram, blackgram and groundnut. *Madras Agric. J.* **99** (7-9): 514-517.

Patil, S.A., Jatti, P.D., Chetti, M.B. and Hiremath, S.M. (1997). Survey of parthenium in Bijapur district – A case study. pp 20-23. *In*: Proceedings

Ist International Conference on Parthenium Management (Eds. Mahadevappa M.P.V.C.) Vol. II University of Agricultural Sciences, Dharwad, Karnataka, India.

Putri, W.E. (2022). Allelopathic effect of parthenium weed (*Parthenium hysterophorus* L.) leaf litter on the seedling emergence and growth of wheat (*Triticum aestivum* L.). The 3rd International Conference on Agriculture and Rural Development. IOP Conf. Series: Earth and Environmental Science. p. 978.

Riaz, T. (2010). Prevalence of invasive parthenium weed in district Hafizabad, Pakistan. *J. Anim. Plant Sci.* **20**(2): 90-93.

Shabbir, A.and Bajwa, R. (2006). Distribution of parthenium weed (*Parthenium hysterophorus* L.), an alien invasive weed species threatening the biodiversity of Islamabad. *Weed Biol. Manag*. **6**: 89-95.

Shrestha, B. and Thapa, C.B. (2018). Allelopathic effects of invasive alien species *Parthenium hysterophorus* L. on seed germination of paddy and wheat. *Himalayan Biodiv*. **6**: 1-6.

Sorecha, E.M. and Birhanu, B. (2017). Allelopathic effect of *Parthenium hysterophorus* L. on germination and growth of peanut and soybean in Ethiopia. *Adv. Crop Sci. Technol*. **5**: 285.

Srivastava, J., Raghava, N. and Ragha va, R.P. (2011). Allelopathic potential of parthenium to reduce water absorption in germinating cowpea seeds. *Indian J. Sci. Res*. **2**: 59–65.

Sushilkumar (2014). Spread, menace and management of *Parthenium*. *Indian J. Weed Sci*. **46**(3): 205–219.

Tahseen, N.K., Kumar, H. and Jagannath, S. (2015). Assessment of allelopathic efficacy of *Parthenium hysterophorus* L. plant parts on seed germination and seedling growth of *Phaseolus vulgaris* L. *Brazilian J. Biol. Sci*. **2**(3): 85-90.

Tefera, T. (2002). Allelopathic effects of *Parthenium hysterophorus* extracts on seed germination and seedling growth of *Eragrostis tef* (Zucc.) Trotter. *J. Agron. Crop Sci*. **188**(5): 306-310.

Tiwari, J.P. and Bisen, G.R. (1982). Growth analysis of *Parthenium hysterophorus* L. *Indian J. Weed Sci*. **14**: 49-53.

Tripathi, P. and Chandra, R. (2019). Diversity of *Parthenium hysterophorus* and associated weeds in the Chitrakoot District. *Int. J. Biol. Innov*. **1**(2): 51-55.

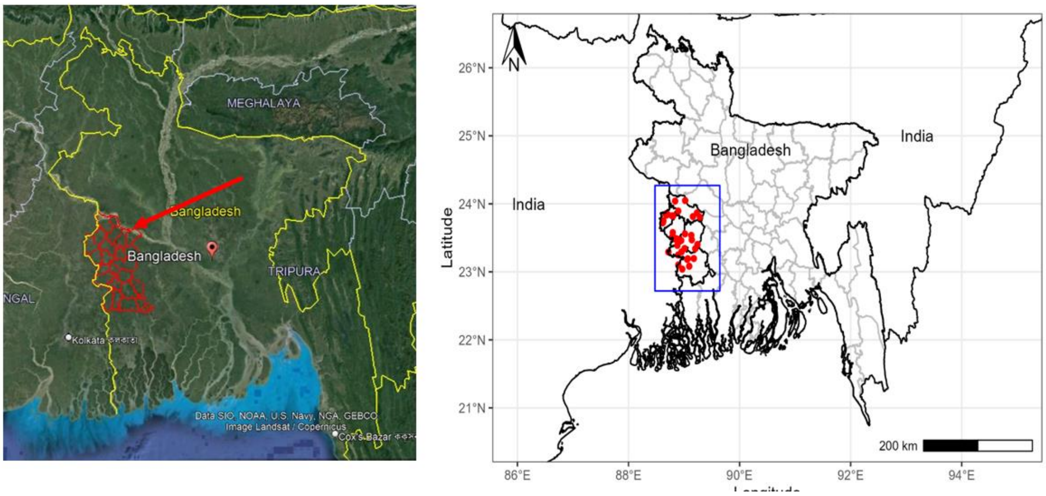
Weidenhamer, J.D., Morton, T.C. and Romeo, J.T. (1987). Solution volume and seed number: often overlooked factors in allelopathic bioassays. *J. Chem. Ecol*. **13**: 1481–1491.

Zaker, A. and Ahmed, N. (1997). Wild Flowers of Bangladesh. University Press.

Zareen, S., Khan, N. and Rahman, S. (2021). Distributions of invasive weed Parthenium (*Parthenium hysterophorus* L.) in the University campus Peshawar KPK. *Acta Ecol. Sin*. **41**(1): 10-17.

Appendices

APPENDICES



Appendix I. Map showing the Bangladeshi districts where field surveys were conducted. The red dots denote the occurrence points of parthenium weed.

Appendix II. Distribution of parthenium weed in 27 Upazilas within five districts of south-western Bangladesh

Districts	Upazila	Distribution of parthenium weed						
		Sporadic	Low	Medium	High	Very high		
Jashore	Sarsha					■		
	Jikargacha					■		
	Chougacha							■
	Sadar						■	
	Keshabpur					■		
	Manirampur		■					
	Abhaynagar		■					
	Bagherpara					■		
Jhenaidah	Sadar						■	
	Maheshpur							■
	Kaliganj					■		
	Kotchandpur					■		
	Shailkupa		■					
	Harinakunda					■		
Chuadanga	Alamdanga				■			
	Sadar					■		
	Damurhuda							■
	Jibannagar							■
Meherpur	Gangni				■			
	Sadar							■
	Mujibnagar							■
Khustia	Bheramara						■	
	Daulatpur		■					
	Khoksa						■	
	Kumarkhali					■		
	Sadar					■		
	Mirpur				■			

Note: sporadic = 1 or more clusters within 100 m^2, low = 1 to 2 plants in each m^2, medium = 3 to 4 plants in each m^2, high = 5 to 7 plants in each m^2, and very high = more than 8 plants in each m^2

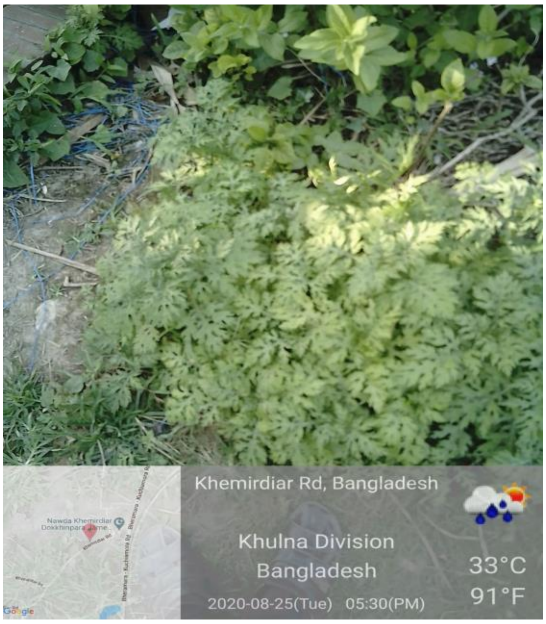
Appendix III. Analysis of variance of the data on crop germination, radicle and plumule inhibition percentage as affected by *P. hysterophorus* leaf extracts

Source of variation	DF	Means square values		
		Germination inhibition (%)	Radicle inhibition (%)	Plumule inhibition (%)
Treatment	19	2075.64**	1915.66**	2571.42**
Error	40	33.92	95.57	80.64
CV%		8.28	13.26	12.48

**Significant at 1% level

Appendix IV. Pictures of the survey

Parthenium infestation in road side

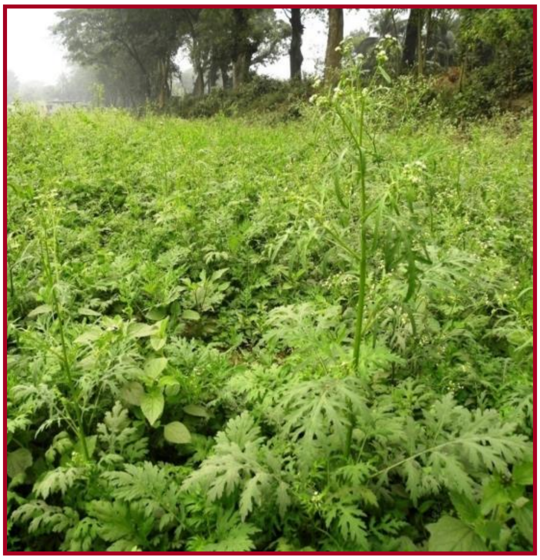


Parthenium infestation site with GPS location

Parthenium infestation in *aus* rice

Parthenium infestation in napiergrass

Parthenium infestation in sugarcane



Parthenium infestation in field pea

Parthenium infestation in Banana

Parthenium infestation in potato

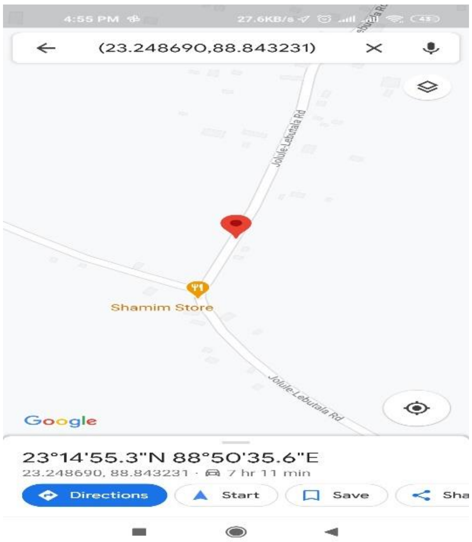
Parthenium infestation in jute

Parthenium infestation in grassland

Parthenium infestation in mustard

Parthenium infestation in wheat

Parthenium infestation in *aman* rice



Geographic location of the left side picture

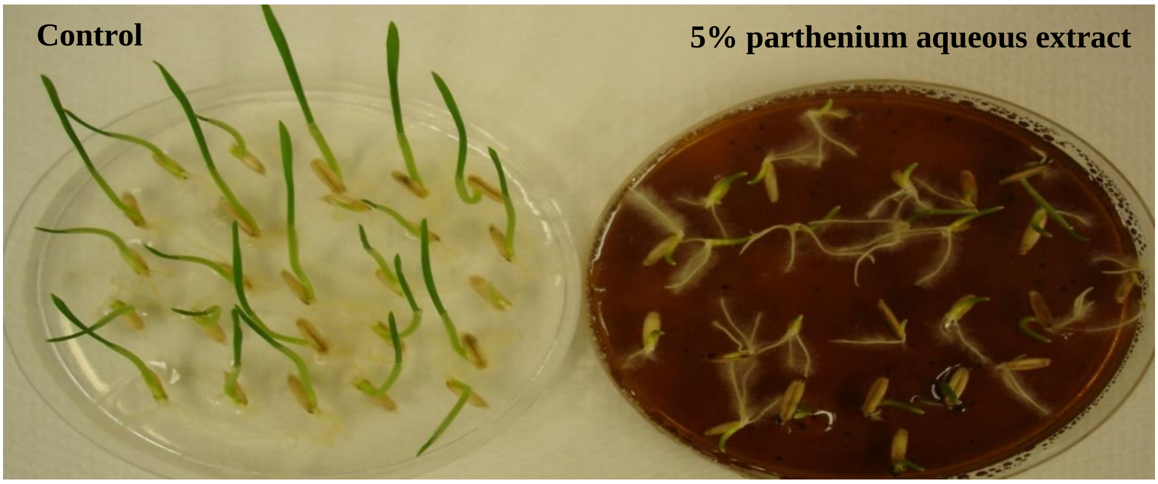


Plate 1. Effect of *P. hysterophorus* leaf extract on rice seedling growth

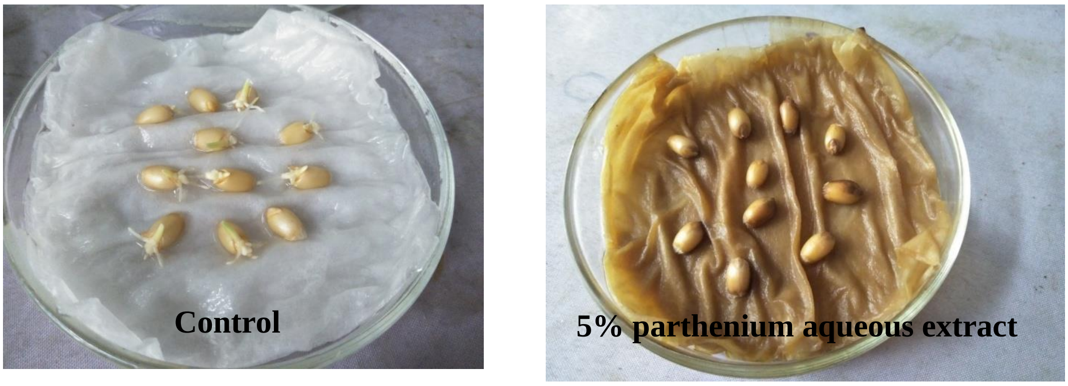


Plate 2. Effect of *P. hysterophorus* leaf extract on wheat germination

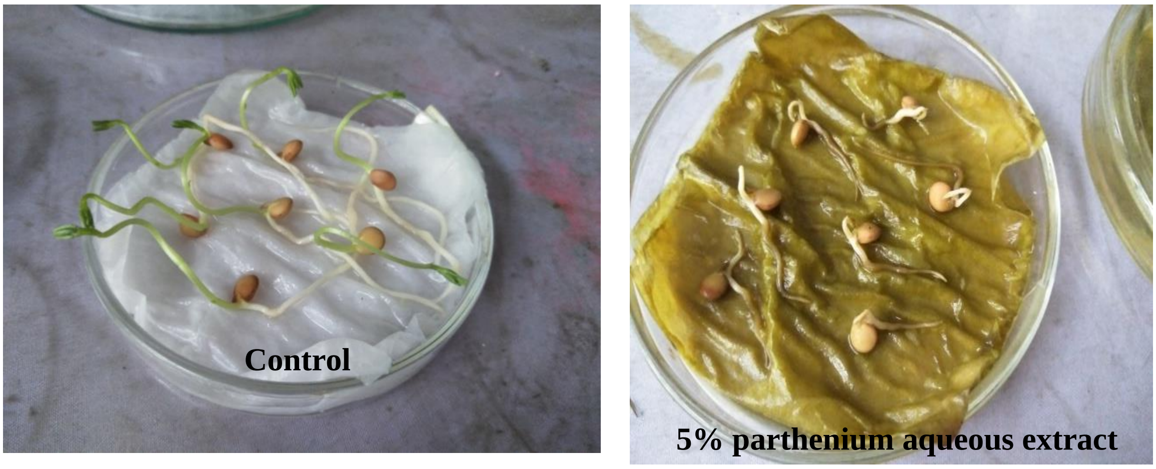


Plate 3. Effect of *P. hysterophorus* leaf extract on lentil seedling growth

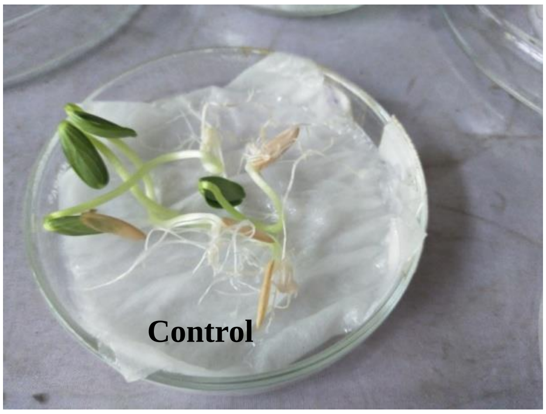


Plate 4. Effect of *P. hysterophorus* leaf extract on cucumber seedling growth