Research Article

Response of Maize (*Zea mays* L.) to *Parthenium hysterophorus* Mixed Soil Under Climatic Condition of Dera Ismail Khan, KP, Pakistan

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Abstract | Parthenium (*Parthenium hysterophorus* L.) is one of the most aggressive herbaceous weeds of the Asteraceae family. It is widely distributed, almost across the world and has become the most important invasive weed throughout the globe. The infestation of parthenium has been reported to reduce grain and forage yields about by 40-90%. The spread of parthenium has been attributed to its alllelopathic potential. Allelochemicals released from parthenium have been reported to decrease germination and growth of agronomic crops, vegetables, trees and many other weed species. Growth promoting effects of parthenium extracts at low concentrations have also been reported in certain crops. A laboratory experiment was carried out to evaluate the germination and germination indices of maize with estimation of maize growth infested with parthenium allelopathy. This trial was conducted Completely Randomized Design with 3 replications. Parthenium dry powder (5, 10, 15, and 20 %) mixed with soil produced variable responses regarding seed germination and seedling growth. Emergence index, mean germination time and vigour index were significantly affected by various parthenium dry powder percentages. The smaller amount of parthenium powder (5, 10 and 15%) promoted the maize germination and seedling growth. The highest parthenium dry powder (20%) negatively affects the maize germination and seedling growth. Germination %, time to start germination and the time taken to 50% germination were not be affected by parthenium dry powder. Growth parameters like plant, root, shoot lengths and their respective weights were also adversely influenced by contaminated soil. Whole photosynthetic efficiency and plant physiological characters were also severely affected. 25% to 50% germination physiology was disturbed by 15% and 20% parthenium mixed soil respectively. Similar trend of decrease is found in plant biomass and photosynthesis. In light of our findings from this study, it is recommended that smaller amount of parthenium dry powder percentage (5, 10 and 15%) promoted the maize germination and seedling growth positively. Therefore' the maize can be planted in the field infested with parthenium weed to some extent and its planting should be avoided where the higher population of parthenium precedes the maize planting.

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Introduction

Weeds are the undesired plants and volunteer in nature, which enter into fields and compete with economic crops at the farm, garden, pastures or forests and utilize the all-available resources and decrease the quality and quantity of crops. Some weeds are invasive, lethal and allergic in nature.

Gajarbooti or parthenium (*Parthenium hysterophorus* L.) is a noxious weed of the family Asteraceae. It belongs to the subtropics of North and South Americas, but now also found in Asia as well as Africa and Australia. In the current scenario, this weed has become troublesome in Pakistan, spreading rapidly in forest, pastures, agriculture and fallow fields as well Tanveer *et al*. (2015). There are many studies on parthenium crop competition with different crops to predict economic losses and to calculate optimum level or time of effective weed control (Das, 2008). Allelopathy is a phenomenon that describes a general association among different plants growing in the same habitat which may be beneficial for some and harmful for the other plant species. Allelochemicals are different metabolites which are released in by different ways to the natural growth ecology of a plant (Geimadil *et al*., 2015).

Parthenium has a strong potential to affect plant growth through phytotoxity (Allelopathy) (Knox *et al*., 2011). Parthenium aqueous leaf extract has more phytotoxicity than other plant parts in cereal seedlings (Maharjan *et al*., 2007). Species respond differently in their sensitivity to the water extracts of parthenium in germination, growth and development (Gupta and Narayan, 2010). Although concentrated solution of parthenium having allelochemicals influences the process of germination, seedling growth and grain yield of cereals, Lower concentrations are considered to have positive impact and stimulate plant growth (Tefera, 2002). Maize (*Zea mays* L.) is one of the most economic crop throughout the globe in rainfed and irrigated areas. It is a multipurpose crop used as food, fodder, oil seed and also utilized in industry as raw material especially food industry. It was cultivated on 1653 thousand hectares and gave production of 10.653 million tonnes during the year 2021 in Pakistan (GoP, 2022). Maize is an important crop for the economy, adding 3.0 percent to the agricultural value and 0.7 percent to the GDP. In 2022-23, farmers planted maize on 1,720 thousand hectares, 4.1 percent more than the previous year. This resulted in a 6.9 percent increase in production, reaching 10.183 million tonnes. The main factors behind this growth were the expanded cultivation area and the higher yield per hectare (GoP, 2023).

Seed germination is the activity of embryo to start within moistened seed, which is susceptible to water contamination of allelopathic materials (Farooq *et al*., 2013). Biotic stress through allelopathy caused by weeds is considered a major threat to crops by decline in germination, reduced growth of seedlings and biomass of plants by affecting enzymes and cell division. The increase in production was due to improved technology and proper weed management. In order to improve the crop economic production and weed management in sustainable agriculture, farmers use several strategies. Use of aqueous extracts of some plants as growth promoter or inhibitor, significantly impact on the yield of crops. The continued invasion of parthenium across the globe requires a thorough understanding about it. Thus, it is necessary to determine the compatibility, interaction and interference of parthenium with maize germination prior to its planting in the field, where parthenium is already established. The objective of this research is to explore the parthenium positive or negative impact on maize germination, seedling growth and development with variation in the concentrations mixed directly into the soil. Such information would facilitate the farmer and scientists to undertake weed management of parthenium. This research will also help to evaluate the impact of parthenium mixed soil on the indices of maize germination and its seedling growth.

Materials and Methods

An experiment was laid out in the laboratory to evaluate the allelopathic effect of parthenium weed on germination and growth of maize crop. The trial was laid out in completely randomized design (CRD) with three replications. The soil sample of 1.5 kg were taken in pots and the required amount of parthenium powder was mixed in each pot to make the mixture on w/w basis, having 5, 10, 15 and 20 % of parthenium powder in the respective pot.

Parthenium weed was collected from the different fields from various location of Gomal University,

Dera Ismail Khan, KPK., Pakistan. Parthenium plants were cut into small pieces, dried into oven and the grinded into powder by grinding machine. The powder of parthenium was mixed into soil in the following percentages.

Treatment	Percentage of parthenium powder
T 1	Control
T 2	5 %
T 3	10 %
T 4	15 %
T 5	%

The pots after mixing parthenium and soil were filled. Irrigation with the tap water to wet the soil in the pot completely. The extra water was allowed to drain freely for 48 hrs. After that when the pots reached at field capacity levels, the 15 seeds of maize were sown in each pot to a depth of 2.5cm. Then the pots were kept in open air to allow the maize seeds to germinate and grow in natural environment. Standard procedures were adopted to record the results of each parameter of germination physiology, growth and photosynthetic efficiency of maize.

Experimental soil characteristics

Soil features	Unit	Value
pH	-	8.5
Sodium adsorption ratio (SAR)	-	11.6
Electrical conductivity	ds m^{-1}	1.75
Sand	%	36.40
Silt	%	24.80
Clay	%	40.8
Soil texture	-	Clay loam
Organic matter	%	0.41

Results and Discussion

Germination physiology

Parthenium weed is troublesome, unwanted and toxic to neighboring plants grown in similar habitat. Maize seed germination and its germination physiology (G %, TSG %, MGT, EI, VI) was depressed in a differential way by contamination of soil with parthenium powder. In comparison with control, Distilled water treated (DWT) only, maximum decline in germination % (77.78), Emergence index and vigor index were determined for the Germination (%) in T5 (20% mixture of soil). Time taken to 50 % germination (days) was found non-significant by application of control to 20 % of parthenium mixed soil. It is clear from the data presented in Table 1 could not impact statistically on above mentioned parameters. Results indicate that later on seedling growth of maize was inhibited by contaminated soil. This might be due to the presence of allelochemicals in soil contaminated with parthenium as compared to control. After decomposition of parthenium parts in the soil released allelochemicals which affected the metabolism, respiration, cell division and photosynthesis of maize (Zohaib et al., 2016). Bhuvaneshwari *et al.* (2019) determined negative relationship on germination and seedling growth of maize by applying parthenium extract at varying concentrations. Maize is less sensitive to the allelopathic impact of parthenium as compared to other cereals like wheat, rice, barley (Pandey *et al.*, 2011).

Growth parameters

The result about maize seedling growth and development in contaminated soil with parthenium presented in Table 2. Allelochemicals released from parthenium affected the growth of maize adversely.

Table 1: *Parthenium mixed soil influence on germination physiology of maize.*

Treatment	TSG (days)	Germination %	Time taken to 50% germination (days)	Mean germination time	Emergency index	Vigor index
T1	5.33	86.67	9.33	0.30b	1.83b	2600.0ab
T2	4.67	91.09	8.67	0.37b	2.13ab	3426.0a
T3	4.00	93.33	7.17	0.46ab	2.35ab	2873.3ab
T4	4.67	93.33	6.83	0.87a	2.70a	2920.0ab
T5	5.67	77.78	9.00	0.35b	1.70b	1768.9b
LSD	NS	NS	NS	0.25	0.81	1598.4

TSG, Time start the germination of maize. NS= Non-significant; The variation in alphabets with in columns and rows are significantly different @ p 144= 0.05

All parameter of growth recorded in Table 2 i.e., plant length (cm), Root length (cm), shoot length (cm), plant fresh weight (g), dry weight (g), and root-shoot ratio significantly affected except dry weight and root-shoot ratio. A clear trend of declined in growth is found in above mentioned parameter as concentration increased. The impact of parthenium is concentration dependent: An increase in concentration of parthenium body parts in the soil associated with decline in growth parameter. Seedling growth inhibition was great with high concentration in T5 (20 % parthenium). Similar types of results were reported by Tanveer *et al.* (2015).

Table 2: *Parthenium mixed soil influence on seedling growth of maize.*

Treatment	Plant length (cm)	Root length (cm)	Shoot length (cm)	Plant fresh weight (cm)	Dry weight (g)	Root shoot ratio
T1	18.3a	7.3a	11.0a	1.27a	0.16	0.67
T2	16.5b	7.2a	9.3a	0.96ab	0.09	0.78
T3	16.3b	6.3ab	10.0a	0.87ab	0.08	0.63
T4	13.2c	5.5ab	7.7b	0.76b	0.05	0.71
T5	10.3d	4.6d	5.9c	0.51a	0.46	2.24
LSD 0.03	2.93	0.97	1.34	0.57	NS	NS

The variation in alphabets with in columns and rows are significantly different @ p= 0.05

They stated that the order of increasing sensitivity to parthenium correlated with number of plants present in the field. The decomposing residues of parthenium have been registered to modify the rhizosphere, this way seedling growth of maize is affected by releasing phenolics and cause inhibition in uptake of nutrients (Batish *et al.*, 2005). The soil incorporation of parthenium after decomposing caused inhibition in roots more as compared to shoot (Tanveer *et al.*, 2015). Golatkar and Ambiye (2010) suggested different types of allelochemicals to be released from decomposition of parthenium in soil i.e., Tannins, saponins, glycosides and phenolic compounds.

Interference of these allelochemical released from parthenium in process of nutrient absorption, respiration and photosynthesis could reduce plant growth by altering physiological process such as changes in all membrane and dehydrogenase enzyme (Geimadil *et al.*, 2015).

Plant physiology and photosynthesis

Plant physiology and photosynthetic parameters of fodder maize differed significantly with contamination rate of parthenium in the soil (Table 3). Except number of leaves which is a genetic character of specie and variety. Tallest plants of maize and high number of leaves were recorded in control. However, any incorporation of parthenium having different concentration showed non-significant variation in number of leaves plant^{-1} of maize seedlings. A clear trend of decline was found in SPAD value, crop growth rate (g m^{-2} day^{-1}), plant height and number of leaves from control to T5 (20% mixture soil with parthenium). Plant height was measured from base of the plants to growing apex of stem and expressed in cm. Number of leaves of 5 plants are recorded and averaged, plant SPAD value was determined by SPAD photometer (Minolta, 2015) photosynthetic efficiency (%) and crop growth rate were calculated on dry weight basis (Sinha, 2014). Chlorophyll are green pigment matter absorbs radiant energy and converts into chemical energy measured by spad meter is the key factor for photosynthesis. Its reduction from control to T5 also declined the photosynthesis efficiency, crop growth rate and plant height in maize. Hussain *et al.* (2021) described the results of parthenium concentration in the field. They reported that parthenium extracts keep on increasing, plant height might get negative impacted. Hassan *et al.* (2018) also observed that parthenium stubbles may cause soil toxicity and therefore suppress the growth of sorghum. Parthenium may change the anatomy of maize in the stem and leaves.

Table 3: *Parthenium mixed soil influence on plant physiology and photosynthetic efficiencies.*

Treatment	Plant height (cm)	No. of leaves	Spade value	Crop growth rate (gm^{-2} day^{-1})	Photosynthetic efficiency (%)
T1	7a	5	16.71 a	0.63 a	0.57
T2	5b	4	13.92 b	0.53 b	0.56
T3	5b	4	12.72 b	0.45 b	0.42
T4	4b	4	8.9 c	0.47 b	0.43
T5	4b	4	6.9 d	0.39 c	0.42
LSD 0.05	1.67	NS	2.3	0.21	NS

The variation in alphabets with in columns and rows are significantly different @ p = 0.05

Seedling exposed to parthenium allelochemicals undergoes altered the cell wall, process of cell division and osmosis (Hallak *et al.*, 1999). Tamado *et al.* (2002) determined the critical threshold density of parthenium in the maize field. In maize crop, 3 plants

per $m^{-2}$of parthenium resulted in 69% reduction in grain yield. Wakjira *et al*. (2009) suggested that soil incorporation of parthenium inhibited not only plant growth, ultimately resulted low grain and fodder yield of maize.

Conclusions and Recommendations

It is concluded for the present study that parthenium dry powder % mixed with soil produced variable responses regarding seed germination and seedling growth. Emergence index, mean germination time, vigor index, growth parameters and photosynthetic parameters were significantly affected by various parthenium dry powder percentages. The smaller amount of parthenium powder (5, 10, and 15 %) promoted the maize germination and seedling growth.The highest parthenium dry powder (20 %) negatively affects the maize germination and seedling growth. Germination %, Time to start germination, time taken to 50% could not be affected by parthenium dry powder.

In light of above conclusions, it is recommended that smaller amount of parthenium dry powder percentage (5%) promoted the maize germination and seedling growth positively. Therefore, the maize can be planted in the field infested with parthenium weed to some extent and its planting should be avoided where the higher population of parthenium precedes the maize planting.

Novelty Statement

In corporation of *Parthenium hysterophorus*, dried leaves powder into soil and determination of this mixture on maize is a new work for the weeds scientists.

Author's Contribution

Iqtidar Hussain: Principal Investigator.
Muhammad Inam Ullah Qaisrani: M.Phill scholar.
Abdul Aziz Khakwani: Co-investigator.
Zuhair Hasnian: Statistical analyst.
Umar Khitab Saddozai, Muhammad Naeem and Hadia Gul: Laboratory management and helped in data collection.
Moneeza Abbass: Laboratory management, helped in data collection and recorded photosynthetic data.

Conflict of interest

The authors have declared no conflict of interest.

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