Parthenium hysterophorus L. AS A SOURCE OF NUTRIENTS FOR MAIZE *(Zea mays)* AND SORGHUM *(Sorghum bicolor)*

Gul Hassan, Anees Amin, Haroon ur Rashid, Naqib Ullah Khan and Hussain Ali[1]

ABSTRACT

To evaluate the potential of the invasive alien weed; Parthenium hysterophorus L., as a source of nutrients for growth of maize and sorghum, experiments were conducted in pots at the Department of Weed Science under ambient conditions and subsequently repeated at the Institute of Biotechnology and Genetic Engineering, University of Agriculture, Peshawar, Pakistan under controlled environment. Fresh plants of Parthenium and berseem were collected before flowering stage, chopped into about 1 cm pieces, dried and then incorporated into soil 30 days before planting. The treatments included NPK at recommended dose alone and NPK + 1, 2, 3 and 4% dried parthenium (w/w of soil). For comparison, treatments like dried berseem 2% (w/w) and untreated (0 NPK and 0 Parthenium or berseem); were also employed. The experiments were replicated four times as factorial in completely randomized design (CRD). Eight seeds each of sorghum and maize were separately seeded in each pot ultimately thinned to 5 plants per pot. Since the statistical differences between the two experiments were non-significant, the data were pooled before subjecting it to ANOVA and mean separation. The statistical analyses of data exhibited significant differences for fertilizer treatments for all the parameters studied and the differences between maize and sorghum were also significant for all the parameters studied except fresh biomass, whereas the interaction was significant for the dry biomass only. The data showed that regardless of species the highest fresh and dry biomass plant^{-1} (9.52, 3.22 g), plant height (46.98 cm), leaf area (71.94 cm^{2}) and root length (10.27 cm) were recorded in the 2% parthenium + NPK recommended dose, but for all the parameters differences were non significant from 3% parthenium + NPK and the NPK alone. These treatments ranked higher than 2% berseem + NPK and the untreated check, where berseem is a conventional green manure crop. Incorporation of 4% parthenium along with NPK adversely affected all the parameters studied, which perhaps was due to its allelopathic effect at higher concentration. Berseem also showed allelopathy to maize and sorghum even greater than parthenium, as it inhibited all the parameters studied. Further research is suggested to confirm these findings.

Keywords: Allelopathy, maize, nutrients, *Parthenium*, *Sorghum bicolor*, *Zea mays.*

Citation: Gul Hassan, Anees Amin, Haroon ur Rashid, Naqib Ullah Khan and Hussain Ali. 2019. Parthenium hysterophorus L. as a source of nutrients for maize *(Zea mays)* and sorghum *(Sorghum bicolor)*. Pak. J. Weed Sci. Res., 25 (2):161-172.

[1] University of Agriculture, Peshawar 35130, Khyber Pakhtukhwa, Pakistan.
Corresponding Author's E-mail:hassanpk_2000pk@yahoo.com

INTRODUCTION

Parthenium hysterophorus L. belonging to family Asteraceae is an aggressive upright herb of 30-200 cm. It is native to subtropics of North and South America and is fast-maturing annual (or, under certain conditions, a short-lived perennial) with a deep tap root and an erect stem that becomes woody with age (Hassan and Amin, 2009). Its leaves are pale greesn, branched and covered with soft fine hairs. The small white flowers (4 mm across) have five distinct corners and grow on the stem tips. Each flower produces four or five black wedge-shaped seeds that are 2 mm long with thin white scales (Nguyen and Adkins, 2011).

Parthenium hysterophorus has emerged as one the top most worst weeds of world including Pakistan. It is spreading rapidly like wild fire in many parts of Pakistan and elsewhere in the world (Hassan and Amin, 2009; Javaid and Anjum, 2005; Khan *et al.,* 2014; Hassan *et al.,* 2018), Ethiopia (Zuberi *et al.*, 2014), Nepal (Timsinaa *et al.*, 2011) and Australia (Nguyen *et al.*, 2017). Its nuisance has been reported from the 40 countries of the world (Nguyen *et al.*, 2017). The weed is rapidly replacing the local flora along the roadsides, around the agricultural fields and on wastelands. It starts growing in February and remains dominant species in wastelands till winter. In Pakistan, it has been observed that it stays dormant during winter and restarts growing in early spring and flowering rapidly (Hassan and Amin). The allelopathic grasses like *Desmostachya bipinnata* Stapf. and *Imperata cylindrica* (L.) Beauv. restrict the spread of this weed (Personal observation). However, it has been observed infesting the allelopathic grass like *Sorghum bicolor* (L.) Moench. (Hassan and Amin, 2009) . So far, this weed is not a problem of in common crops like rice, wheat, maize and others. Nevertheless it invades the fields of some vegetables like *Citrullus vulgaris* where crop density is low especially when cropping is done on ridges. Scarce infestation of parthenium has also been observed in maize, sorghum and sugarcane (Hassan and Amin, 2009). The major cause of its spread like wild fire is that it is not relished by cows, buffalos, camels, goats and sheep. However, its worth as a nutrient source has been reported (Raju and Gangwar, 2004; Javaid and Riaz, 2005; Javaid and Shah, 2008, 2010; Saini *et al.*, 2014, Hussain *et al.* 2016).

Parthenium infestation has been noticed more in rainfed than in irrigated agriculture. In India, Parthenium weed causes yield losses of up to 40% in several crops (Khosla and Sobti, 1979) and it is reported to reduce forage production up to 90% (Nath, 1981). In Pakistan, the *Parthenium* is likely to become a serious problem in perennial grasslands, wastelands around communities and summer crops (Javaid and Anjum, 2005).

Fertilizers as a source of plant nutrients and pesticides as plant protection measures are being used to increase the crop production. However, imbalanced and non-judicious use of these agrochemicals has polluted the environment to a great extent. Concern is growing that food produced under such a crop management may not be safe or of good quality. This has shifted the scientific approach towards some alternative measures (Ferron and Deguine, 2005; Shaxson, 2006). Organic farming offers an alternative that can eliminate many of the environmental problems of conventional agriculture. It accounts for over 24 million ha worldwide (Willer and Yussefi, 2004), but recently it has reached to 70 million ha in the world (IFOAM Organics International, 2019) and has become a mainstream practice for at least some crops (Anonymous, 2004). Bajwa *et al.* (2004a,b) have also reported the allelopathic potential of parthenium weed. The competitive ability is attributed to the presence of various phytotoxic compounds in parthenium residues e.g. water-soluble phenolics acids and sesquiterpene lactones including parthenin (Picman and Picman, 1984; Reinhardt *et al.,* 2004, 2006; Singh *et al.,* 2005; Belz, 2016). Kishor *et al.* (2010) have reported that the nutrient composition of composted *Parthenium* was even higher than FYM. Hence recycling of *Parthenium* plants by composting and *Parthenium* extract seems to be an efficient way for utilizing the tremendous agricultural weeds. Recently Mainali *et al.* (2015) have offered a novel approach to species distribution for *P. hysterphorus.*

Keeping in view the ever increasing significance of organic nutrients sources in agriculture, experiments were undertaken with the objectives, a) to figure out the possibility of *P. hysterophorus* L as a manure, and b). to monitor the growth response of maize and sorghum to the decomposed biomass of *P. hysterophorus* L. at various levels.

MATERIALS AND METHODS

Pot experiment was conducted in March 2009 at the Department of Weed Science under ambient conditions, and subsequently repeated at the Institute of Biotechnology and Genetic Engineering, University of Agriculture, Peshawar, Pakistan under greenhouse conditions during Spring 2009. Peshawar lies between 71°-27' and 72°-47' east longitude and 33°-40' and 34°-31' north latitude.

Chemical composition of parthenium

Proximate analysis of *Parthenim* was done at The Undergraduate Laboratory, Department of Agricultural Chemistry, University of Agriculture, Peshawar, Pakistan. Moisture, ash content, percent nitrogen and crude protein content were determined by standard analysis method. The analysis revealed nitrogen content as 1.5 % which is an ample value to be supplied to the succeeding crop. The crude protein content was 8 % which also shows a great potential of parthenium to be used as green manure. Similarly, ash content amounted to 17 % which further exhibits an enormous potential for the supply of minerals to the crops.

Treatments and Design

Fresh plants of parthenium and berseem were collected from the New Development Farm, University of Agriculture, Peshawar, Pakistan at vegetative growth stage were chopped into 1 cm pieces, dried under shade and incorporated into soil 30 days prior to sowing of crops. The plastic pots measuring 15 cm, 6″ diameter and 22.5 cm depth were filled with silty loam soil and slightly pressed. At both the locations, pot experiments comprised of seven treatments viz. recommended dose of NPK (alone), NPK+1%, NPK+2%, NPK+3% and NPK+4% (w/w) of dried parthenium biomass, NPK+2% (w/w) berseem clover (*Trifolium alaxandrinum*) and standard check (no NPK and parthenium or berseem). Pots were irrigated with good quality tap water and left for decomposition of plant material. The fertilizers used were urea, triple superphosphate (TSP) and potassium sulphate (K_2SO_4) at 100:75:45 kg NPK ha^{-1}. All the fertilizers were added at the time of planting. NPK fertilizers were mixed in the soil at the time of sowing of seeds and pots were watered thereafter. Eight seeds of maize and sorghum each were planted in each pot and after emergence, 5 uniform seedlings were maintained for each test species. Each treatment comprised of two pots. The experiment was laid out as factorial in completely randomized design (CRD).

For both the experiments, the data were recorded on germination (%), fresh and dry biomass plant^{-1}, plant height (cm), leaf area plant^{-1} (cm^2) and root length (cm). Standard procedures were adopted for recording all the data. Leaf area was recorded with the leaf area meter (LI-3100, LI-COR, USA). Data on all characteristics in both experiments were recorded on all 5 plants in each treatment and means computed thereof. Germination percentage was computed on the basis of all emerged plants. The experiment was terminated 45 days after sowing.

Statistical Analyses

Data recorded for both the experiments were pooled as the differences between the two runs of experiment were non-significant statistically, the data were subjected to Analysis of variance technique using MSTATC computer software to establish differences among the treatments and the significant means were subjected to LSD test to decipher the statistical differences among the treatment means (Steel *et al*., 1997).

RESULTS AND DISCUSSION

Germination percentage

Statistical analysis of the data (Table-1) revealed that various treatments and species significantly affected the germination percentage of maize and sorghum, while the species × treatments interaction was found non-significant. Statistically similar germination was recorded in 3% parthenium + NPK (95.5%), 2% parthenium + NPK (92.5%), 1% parthenium + NPK and NPK alone (82.5% each). Lowest germination (57.65%) was recorded where the highest amount of parthenium was incorporated into the pots of test species. Incorporation of berseem gave germination of 72.5%. For the species, the higher germination (88.57%) was recorded in maize as compared to 67.85% germination in sorghum (Table-1). In interaction the highest numerical germination was recorded in maize under the untreated control. Composting parthenium with other plant materials reduced its allelopathic effects on lettuce emergence rate and radicle and plumule length than composting parthenium alone (Wakjira *et al.,* 2009). The release of parthenin during decomposition of leaf material has a potential to play a leading role for allelopathy in *P. hysterophorus*, however its significance in a natural setting very much relies on the amount of leaf material accumulated on soil surfaces and concentration of parthenin in residues (Belz *et al.,* 2007). Similar adverse impact of parthenium residues has also been reported by Batish *et al*. (2002) on growth of *Cicer arietinum* and *Raphanus sativus.* Growth of the *Triticum aestivum, Avena fatua and Lepidium* spp*.* was inhibited at higher concentration of parthenium extracts (Amin *et al.,* 2007).

Fresh biomass (g) plant^{-1}

The perusal of data (Table-2) revealed that different treatments applied to add nutrients for growth of maize and sorghum had significant effect statistically on fresh biomass, however species and treatments × species interaction means were non significant statistically. Treatment means indicated that 2% parthenium + NPK (9.52 g), 3% *Parthenium* + NPK (9.45 g) and NPK alone (8.01 g) had the highest fresh biomass, while the lowest biomass of merely 4.14 g, even less than half of the top ranking treatments was recorded in 4% *Parthenium* + NPK which was probably due to allelopathic effects of *parthenium.* The biomass produced by berseem (6.09 g) was also comparable statistically with the highest dose of parthenium along with NPK and untreated check (5.82 g). The data in Table-2 further exibit the drastic difference in biomass was visible in maize and sorghum which perhaps is due to the inherent differences in biomass accumulation in the two test species. The interaction effect also showed a vast difference in the treatments involving maize as compared to the treatments involving sorghum (Table-2).

Composting parthenium with other plants resulted in lower inhibition of emergence rate and radicle and plumule lengths compared to composting parthenium alone (Wakjira *et al.,* 2009). The stimulatory effect of *parthenium* aqueous extracts at low doses has been reported as a result of process known as hormesis, where there is stimulatory effect on sub-lethal doses and inhibitory effect at higher concentrations (Haroon ur Rashid *et al.,* 2008). The sesquiterpene lactone parthenin produced by certain populations of the invasive weed *P. hysterophorus* L. is another example for the stimulation/inhibition properties of some allelochemicals. The compound is biosynthesized during the entire life cycle of the plant, reaching maximum values during generative stages (Reinhardt *et al.,* 2006). It is sequestered in capitate-sessile trichomes on leaves, stems, and the achene-complex of *P. hysterophorus* (Reinhardt *et al.,* 2004). Parthenin might be released from plant material by being washed from ruptured trichomes or from decomposing tissues and may contribute to the plant's interference with the surrounding neighbours. *P. hysterophorus* L. leaf residue (LP, leaf powder) inhibited salvinia (*Salvinia molesta* Mitchell*)* biomass and the number of healthy fronds at 0.25% (w/v) and killed the treated plants at and above 0.75% (w/v) in about 5-15 days (Pandey, 1994). The recent findings of Javaid and Shah (2010), Krishna Murthy *et al.* (2010), Kishor *et al.* (2010) and Hussain *et al.* (2016) also suggest the worth of parthenium as a green manure in increasing yield in wheat and rice, respectively. The present findings also suggest that *Parthenium* in low concentration can be effectively utilized along with the synthetic fertilizers to enhance the productivity of field crops.

Table-1. Effect of parthenium on germination percentage of maize and sorghum.

Species tested	Treatments							Means
	NPK alone	1% Parth. +NPK	2% Parth +NPK	3% Parth. +NPK	4% Parth. +NPK	2% Bers. +NPK	Control	
Maize	95.00	95.00	95.00	100.00	70.00	85.00	100.00	88.57 a
Sorghum	70.00	70.00	90.00	90.00	45.00	60.00	50.00	67.85 b
Means	82.50ab	82.50ab	92.50a	95.00a	57.50d	72.50bc	75.00cd	

$LSD_{0.05}$ for concentration means = 13.68; Values followed by similar letters are non significantly different by LSD at α = 0.05.

Table-2. Effect of *Parthenium* on fresh biomass (g) of maize and sorghum.

Species tested	Treatments							Means
	NPK alone	1% *Parth,* + NPK	2% *Parth.* + NPK	3% *Parth.* + NPK	4% *Parth.* + NPK	2% *Bers.* + NPK	Control	
Maize	14.87	13.37	17.56	17.03	7.64	11.27	10.48	13.17
Sorghum	1.17	1.32	1.48	1.86	0.64	0.91	1.17	1.22
Means	8.01abc	7.34bcd	9.52a	9.45ab	4.14e	6.09cde	5.82de	

$LSD_{0.05}$ for concentration means = 2.143
Values followed by similar letters are non significantly different by LSD Test at α = 0.05.

Dry biomass (g) plant^{-1}

Statistical analysis of the data depicted that different species, concentrations of parthenium and their interaction had significant effect on dry biomass of the test species (Table-3). The higher concentrations of *Parthenium* inhibited dry biomass of the test species as compared to lower concentrations. The highest dry biomass (3.22 g) was recorded in 2% *Parthenium* along with NPK, which was however statistically at par with NPK alone (2.74 g). The lowest dry biomass (1.31 g) was recorded in 4% *Parthernium* and NPK, which was also statistically comparable with the untreated check (1.8 g). For the species, about 5 times more photosynthate was accumulated by maize as compared to sorghum. For the interaction, the highest (5.63 g) biomass was recorded in 2% parthenium +NPK in maize crop, while the lowest biomass was recorded in untreated in both test species and all the treatments involving sorghum crop (Table-3).

The early growth of crops, measured in terms of seedling length and dry weight was significantly reduced when grown in soil amended with varying amounts of parthenium residues (Singh *et al.,* 2005). *Parthenium hysterophorus* extracts significantly inhibited germination and establishment in *Cassia tora*, and the effect increased with extract concentration. The leaf extract had the greatest effect (Acharya and Rahman, 1997). Comparing the values in control, with the treated plots, there are convincing evidences of the presence of allelochemicals in parthenium extracts that can selectively affect weeds and crops. However, more meaningful results could be obtained if parthenium is used in other combinations of fertilizers under various environmental conditions.

Plant height (cm) plant^{-1}

Data in Table-4 revealed that species and treatments had significant effect on the plant height of maize and sorghum, while their interaction was non-significant statistically. The data showed that for the main effects, highest plant height (46.98 cm) was found in 2% *Parthenium* + NPK, 3% *Parthenium* + NPK (45.76 cm) and NPK alone (42.53 cm), while the lowest plant height was measured in 4% *Parthenium* + NPK (26.55 cm), 2% berseem + NPK (29.34 cm) and the untreated check (26.73 cm). For the species the taller plants were recorded in maize (46.09 cm) as compared to 27.45 cm in sorghum. The interaction of species × treatments revealed the taller plants involving maize as compared to the treatments involving sorghum crop (Table-4).

Laboratory studies depicted parthenin's phytotoxic properties against a broad range of plant species, including weeds and crops *e.g. Ageratum conyzoides* L., *Amaranthus viridis* L., *Avena fatua* L., *Cassia tora* L., *Chenopodium murale* L., *Phaseolus aureus* Roxb., and *T. aestivum* (Batish *et al.* 1997, 2002; Datta and Saxena, 2001). The focus of these studies was adverse effects and, thus, recognition of parthenin hormesis was often constrained by the lack of doses below inhibition range. Earlier, Sudhakar (1984) has reported enhanced growth of rice due to application of parthenium green leaf manure. The plant height was decreased as the parthenium concentration increased. Sorghum was more prone to the higher concentrations of parthenium which might be due to the differential response of crops to allelochemicals released by the parthenium after decomposition.

Table-3. Effect of Parthenium on dry biomass (g) of maize and sorghum.

Species tested	Treatments							Means
	NPK alone	1% Parth, + NPK	2% Parth. + NPK	3% Parth. + NPK	4% Parth. + NPK	2% Bers. + NPK	Control	
Maize	4.23 b	4.00 b	5.63 a	4.46 b	2.09 d	3.16 c	3.04 c	3.80 a
Sorghum	1.24 e	0.91 e	0.81 e	0.73 e	0.53 e	0.56 e	0.57 e	0.76 b
Means	2.74 ab	2.45 b	3.22 a	2.60 b	1.31 d	1.86 c	1.80 cd	

$LSD_{0.05}$ for concentration means = 0.5373, $LSD_{0.05}$ for concentration means = 0.7598.

Values followed by similar letters are non significantly different by LSD Test at α = 0.05

Table-4. Effect of *Parthenium* on plant height (cm) of maize and sorghum.

Species tested	Treatments							Means
	NPK alone	1% *Parth,* + NPK	2% *Parth.* + NPK	3% *Parth.* + NPK	4% *Parth.* + NPK	2% *Bers.* + NPK	Control	
Maize	52.15	50.20	57.45	52.34	34.04	39.37	37.09	46.09 a
Sorghum	32.91	28.81	36.50	39.19	19.06	19.32	16.36	27.45 b
Means	42.53ab	39.50b	46.98a	45.76ab	26.55c	29.34c	26.73c	

$LSD_{0.05}$ for concentration means = 7.362.

Values followed by similar letters are non significantly different by LSD Test at α = 0.05

Leaf area (cm^2) plant^{-1}

Statistical analysis of the data manifested the significant differences among the treatments and the two species tested, whereas their interaction was found non significant statistically (Table-5). The concentration means indicated that slight concentration of *Parthenium* had stimulated the growth of maize and sorghum. The highest leaf area was measured in 3% *Parthenium* + NPK (74.53 cm^2), 2% *Parthenium* + NPK (71.94 cm^2) and NPK alone (64.07 cm^2). The highest concentration (4%) adversely affected the leaf area development and produced statistically comparable leaf area with 2% beseem + NPK and the untreated check. Regardless of fertilizer treatments, the higher leaf area (75.81 cm^2) was recorded in maize as compared to 27.91 cm^2 in sorghum (Table-5).

Species-specific difference in sensitivity to aqueous leaf extracts of fresh and dry leaf material of *P. hysterophorus* were reported in previous studies (Meirsie and Singh, 1987; Kohli *et al*, 1996). Similar adverse impact of *Parthenium* residues has also been reported by Batish *et al*. (2002) on growth of *Cicer arietinum* and *Raphanus sativus.* Our findings suggest that *Parthenium* is potential weed that can be utilized for crop production safely if it is used in adequate amount before seed setting in order to discourage the propagules while keeping in view the invasive nature of parthenium weed.

Root length (cm) plant^{-1}

The data in Table-6 shows that different concentrations of *Parthenium* treatments and the species tested had significant effect on the root length of test species, while their interaction was statistically non-significant. The treatment means indicated that the higher root length was measured in 2% *Parthenium* + NPK (10.27 cm), 3% *Parthenium* + NPK (9.07 cm), 1% *Parthenium* + NPK (8.77 cm) and NPK alone (8.47 cm). The lower root length in berseem; being statistically comparable with untreated check also exhibits the higher allelopathic effect of berseem even higher than parthenium. The data in Table-6 further exhibits the higher root length in maize (10.38 cm) as compared to sorghum (5.47 cm), regardless of fertilizer applied.

The release of parthenin during decomposition of leaf material has a potential to play a leading role for allelopathy in *P. hysterophorus;* however its significance in a natural setting will very much rely on the amount of leaf material accumulated on soil surfaces and concentration of Parthenin in residues (Belz *et al.,* 2007). A slight promotion in root length at low parthenin concentration was previously found for *Triticum aestivum* (Batish *et al*., 1997). Parthenin, the major allelochemical causing the bioactivity is the question of the ecological significance and possible impacts of hormesis. Parthenin can be released by leaching from living plant parts or by decomposition of plant residues (Kanchan and Jayachandra, 1980; Reinhardt *et al.* 2004). Present findings suggest that *Parthenium* can be used to enhance the productivity of the crops. Javaid and Shah (2010) also recorded the highest root biomass in 3% parthenium application wheat crop. Likewise, Hussain *et al.* (2016) tested vermicompost on the germination and early growth of green gram *(Vigna radiata)*, ladies finger *(Abelmoschus esculentus)* and cucumber *(Cucumis sativus)* and concluded no adverse allelopathy of parthenium and enhanced the growth of test species. Previously, Saini *et al.* (2014) were of the view that in order to meet the parthenium hazard its large scale utilization is a holistic approach for its control such as either as green manure or after composting. Raju and Gangwar (2004) successfully used parthenium for nutrients addition in rice production.

CONCLUSIONS

From the above findings, it is concluded that in order to cope with the parthenium menace, it may be used as nutrient supplement in maize and sorghum cultivation with a caution that higher concentration of parthenium may lead to its adverse allelopathic effects which could hamper the growth of the referred crops. Moreover, it was also contemplated that berseem clover is also allelopathic to sorghum and maize.

ACKNOWLEDGEMENTS

The authors are highly indebted to the Higher Education Commission, Islamabad, Pakistan for providing funds to undertake this Research under International Linkages Project with the University of Queensland, Australia

Table-5. Effect of Parthenium on leaf area (cm^2) per plant of maize and sorghum.

Species tested	Treatments							Means
	NPK alone	1% *Parth,* + NPK	2% *Parth.* + NPK	3% *Parth.* + NPK	4% *Parth.* + NPK	2% *Bers.* + NPK	Control	
Maize	95.65	73.09	105.56	102.10	49.89	58.92	45.45	75.81 a
Sorghum	32.49	26.76	38.31	46.97	19.67	22.09	9.32	27.91 b
Means	64.07ab	49.93bc	71.94a	74.53a	34.78cd	40.51cd	27.39d	

$LSD_{0.05}$ for concentration means = 21.04.

Values followed by similar letters are non significantly different by LSD Test at ɑ = 0.05

Table-6. Effect of Parthenium on root length (cm) of maize and sorghum.

Species tested	Treatments							Means
	NPK alone	1% *Parth,* + NPK	2% *Parth.* + NPK	3% *Parth.* + NPK	4% *Parth.* + NPK	2% *Bers.* + NPK	Control	
Maize	12.24	11.30	13.30	9.67	7.21	8.95	10.03	10.38 a
Sorghum	4.70	6.16	7.25	8.47	2.84	4.30	4.21	5.42 b
Means	8.47abc	8.73ab	10.27a	9.07ab	5.02d	6.62cd	7.12bc	

$LSD_{0.05}$ for concentration means = 2.084.

Values followed by similar letters are non significantly different by LSD at $\alpha = 0.05$

REFERENCES CITED

Acharya S.S. and A. Rahman, 1997. Allelopathic effect of *Parthenium hysterophorus* on seed germination and seedling growth of *Cassia tora* Linn. Environ. Ecol., 15(2): 335-337.

Amin A., Haroon ur Rashid, M.A.Khan and M.I.Khan, 2007. Allelopathic effect of *Parthenium hysterophorus* L. extracts on germination and growth of wheat and associated weeds. Proc. 21st Asian Pacific Weed Science Society Conference, 2-6 Oct, 2007 Colombo, pp. 14-18.

Anonymous. 2004. Organic farming enters the mainstream. Nature (London) 428: 783p.

Bajwa, R., S. Shafique, S. Shafique and A. Javaid, 2004a. Effect of Foliar Spray of Aqueous Extract of *Parthenium hysterophorus* on growth of sunflower. Int. J. Agric. Biol. 6 (3):474–478.

Bajwa, R., S. Shafique, T. Anjum and S. Shafique, 2004b. Antifungal activity of allelopathic plant extracts IV: Growth response of *Drechslera hawaiiensis, Alternaria alternata* and *Fusarium monilifrome* to aqueous extract of *Parthenium hysterophorus*. Int. J. Agric. Biol., 6 (3)511-516.

Batish, D.R, R.K. Kohli, H.P. Singh and D.B. Saxena, 1997. Studies on herbicidal activities of parthenin, a constituent of *Parthenium hysterophorus*, towards billgoat weed (Ageratum conyzoides). Current Sci., 73(4): 369-371. Batish, DR, H.P. Singh, R.K. Kohli, B.D. Saxena and S. Kaur, 2002. Allelopathic effects of parthenin against two weedy species, *Avena fatua* and Bidens pilosa. J. Envir. Exp. Bot., 47: 149-155.

Belz. R.G., C.F. Reinhardt, L.C. Foxcroft and K. Hurle, 2007. Residue allelopathy in Parthenium hysterophorus L. Does parthenin play a leading role? Crop Prot., 26: 237- 245.

Belz R.G. 2016. Investigating a potential auxin-related mode of hormetic/inhibitory action of the phytotoxin parthenin. J. Chem. Ecol., 42:71-83.

Datta, S. and D.B. Saxena. 2001. Pesticidal properties of parthenin (from *Parthenium hysterophorus*) and related compounds. Pest Manag Sci.57(1):95-101.

Ferron, P. and J.P. Deguine, 2005. Crop protection, biological control, habitat management and integrated farming- A review. Agron. Sustain. Dev., 25: 17- 24.

Haroon ur Rashid, M.A. Khan, A. Amin, K. Nawab, N. Hussain and P.K. Bhowmik, 2008. Effect of *Parthenium hysterophorus* L., root extracts on seed germination and growth of maize and barley. The Americas J. Plant Sci. Biotechnol. 2(2): 51-55.

Hassan, G. and A. Amin, 2009. First Annual Technical Report. Higher Education Commission's International Linkage Project on Parthenium Weed. Department of Weed Science, University of Agriculture, Peshawar, Pakistan.

Hassan, G., H.U. Rashid, A. Amin, I.A. Khan and N. Shehzad. 2018. allelopathic effect of *Parthenium hysterophorus* on germination and growth of some important crops and weeds of economic importance. Planta Daninha, 36:e018176372.

Hussain, N., T. Abbasi and S.A. Abbasi. 2016. Vermicomposting transforms allelopathic parthenium into a benign organic fertilizer. J Environ Manage. 180:180-9. doi: 10.1016/j.jenvman.2016.05.013. Epub 2016 Jun 1.

Javaid, A. and T. Anjum, 2005. *Parthenium hysterophorus* L. – A noxious alien weed. Pak. J. Weed Sci. Res., 11(3-4): 81–87.

Javaid, A. and T. Riaz, 2008. Effects of application of green leaf manure on growth and mycorrhizal colonization of maize. Allelopathy J., 21(2):339-347.

Javaid, A. and M.B.M. Shah, 2008. Use of parthenium weed as green manure for maize and mungbean production. Philippines Agric. Sci., 91 (4): 478-482.

Javaid, A. and M.B.M. Shah. 2010. Growth and yield response of wheat to EM (effective microorganisms) and parthenium green manure. Afr. J. Biotechnol., 9 (23):3373-3383. IFOAM Organics International, 2019. https://www.ifoam.bio/en/news/2019/02/13/world- organic-agriculture-2019. Accessed on May 10, 2019.

Kanchan, S.D. and Jayachandra, 1980. Allelopathic effects of Parthenium hysterophorus L. Part IV. Identification of inhibitors. Plant Soil, 55 (1): 67–75.

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

Khosla, S.N. and S.N.Sobti, 1979. Parthenium - a national health hazard, its control and utility a review. Pesticides, 13: 121-127.

Kishor, P., A.K. Ghosh, Surendra Singh and B.R. Maurya. 2010. Potential use of parthenium (*Parthenium hysterophorus* L.) in agriculture. Asian J.Agric. Res., 4 (4): 220-225.

Kohli, R.K., D. Rani, H.P. Singh and S. Kumar, 1996. Response of crop seeds towards the leaf leachates of *Parthenium hysterophorus* L. Indian J. Weed Sci., 28: 104-106.

Krishna Murthy, R.K., H.R. Raveendra, and T.B.M. Reddy, 2010. Effect of *Chromolaena* and parthenium as green manure and their compost on yield, uptake and nutrient use efficiency on Typic Paleustaff. EJBS 4 (1):41-45.

Mainali, K.P., D. L. Warren, K. Dhileepan, A. McConnachie, L. Strathie, G. Hassan, D. Karki, B.B.Shrestha and C. Parmesan. 2015. Projecting future expansion of invasive species: comparing and improving methodologies for species distribution modeling. Glob. Change Biol. 21(12):4464-80. doi: 10.1111/gcb.13038.

Meirsie, W. and M. Singh, 1987. Allelopathic effects of Parthenium (*Parthenium hysterophorus* L.) extracts and residue on some agronomic crops and weeds. J. Chem. Ecol., 13: 3111-3122.

Nath, R., 1981. Note on the effect of Parthenium extract on seed germination and seedling growth in crops. Ind. J. Agric. Sci., 51: 601-603.

Nguyen, T., A.A. Bajwa, A. Belgeri, et al. 2017. Impact of an invasive weed, *Parthenium hysterophorus*, on a pasture community in south east Queensland, Australia. Environ. Sci. Pollut. Res. 24: 27188. https://doi.org/10.1007/s11356-017-0327-1.

Nguyen, T L. T. and S.W.Adkins. 2011. PhD Dissertation University of Queensland, Brisbane Australia.

Pandey, D.K. 1994. Inhibition of salvinia (*Salvinia molesta* Mitchell) by Parthenium (*Parthenium hysterophorus* L.). II. Relative effect of flower, leaf, stem, and root residue on salvinia and paddy. J. Chem. Ecol., 20(12): 3123-3131.

Picman J. and A.K.Picman, 1984. Autotoxicity in *Parthenium hysterophorus* and its possible role in germination. Biochem. System. Ecol., 12: 287-292.

Prasad, C. and S. Priyadarshani. 2006. Effect of *Parthenium hysterophorus* L. extracts on cultivated turnip (*Brassica rapa* L.). Allelopathy J., 17 (1):97-104.

Raju, R.A. and B. Gangwar. 2004. Utilization of potassium-rich green-leaf manures for rice (*Oryza sativa*) nursery and their effect on crop productivity. Indian J. Agron., 49 (4): 244-247.

Reinhardt, C., S. Kraus, F. Walker, L. Foxcroft, P. Roberts and K. Hurle, 2004. The allelochemical parthenin is sequestered at high level in capitate-sessile trichomes on the leaf surface of *Parthenium hysterophours.* J. Plant Dis. Prot., (Special Issue). 19: 253– 261.

Reinhardt, C., M. Van der Laan, R.G. Belz, K. Hurle and L.C. Foxcroft, 2006. Production dynamics of the allelochemical parthenin in leaves of *Parthenium hysterophorus* L. J. Plant Dis. Prot., (Special Issue) 20: 427-433.

Saini, A., N. K. Aggarwal, A. Sharma, M. Kaur and A. Yadav. 2014. Utility potential of *Parthenium hysterophorus* for its strategic management. Adv. Agric., http://dx.doi.org/10.1155/2014/381859.

Shaxson, T.F., 2006. Re-thinking the conservation of carbon, water and soil: a different perspective. Agron. for Sust. Dev. 26: 9-19.

Singh, H.P., D.R. Batish, N. Setia and R.K.Kohli,. 2005. Herbicidal activity of volatile oils from *Eucalyptus citriodora* against *Parthenium hysterophorus*. Annals Appl. Biol., 14(6): 89-94.

Singh , H.P., R.B.Daizy, K.P.Jasvir and K.K.Ravinder, 2005. Phytotoxic effects of Parthenium hysterophorus residues on three Brassica species. Weed Biol. Manage., 5: 105–109.

Steel, R.G.D., J.H.Torrie, and D.A. Dickey. 1997. Principles and procedures of statistics: a biological approach. McGraw Hill Book Co. New York.

Sudhakar, P., 1984. Substitute of fertilizer nitrogen through green manure in lowland rice. M.Sc. Thesis, Tamil Nadu Agriculture University, Madurai, Coimbatore, India.

Timsinaa, B., B. B. Shrestha, M. B.ur Rokayac and Z. Münzbergová. 2011. Impact of *Parthenium hysterophorus* L. invasion on plant species composition and soil properties of grassland communities in Nepal. Flora 206:133-240.

Wakjira, M., G. Berecha and S. Tulu, 2009. Allelopathic effects of an invasive alien weed *Parthenium hysterophorus* L. compost on lettuce germination and growth. Afr. J.Agric. Res., 4 (11): 1325-1330.

Willer, H. and M. Yussefi, 2004. The world of organic agriculture: Statistics and Emerging trends, International Federation of Organic Agriculture Movements, Bonn, Germany p. 167.

Zuberi, M.I., T. Gosaye and S. Hossain. 2014. Potential threat of allien invansive species: *Parthenium hysterophorus* L. to subsistence agriculture in Ethiopia. Sarhad. J. Agric. 30(1): 117-125.