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Full Length Research Paper

Growth and yield response of wheat to EM (effective microorganisms) and parthenium green manure

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Parthenium weed (*Parthenium hysterophorus* L.) is rapidly spreading in many countries around the world and has become a serious threat to nature as well as managed ecosystems. The present pot experiment was conducted in 2005 -2006 to study the effect of parthenium green manure (1, 2, 3 and 4% on fresh weight bases) and EM (effective microorganisms), a biofertilizer, on the growth and yield of wheat (*Triticum aestivum* L.). EM application was carried out by applying 1 L of 0.2% dilution of the commercial stock EM solution per pot at fortnight intervals throughout the experimental period. Plants were harvested at flowering and maturity stages. Shoot length and dry biomass were gradually increased by increasing the quantity of green manure. There was 272% increase in shoot dry biomass over control at maturity due to 4% green manure application as compared to 137% increase due to recommended dose of nitrogen-phosphorus-potassium (NPK) fertilizer. Highest root biomass was recorded in 3% green manure amended treatment. Spike length, number of grains per spike and grains yield was also gradually increased by increasing the quantity of green manure. There was 43 to 253% increase in grain yield over control due to various green manure treatments as compared to 96% increase due to NPK fertilizers over control. EM application in un-amended control, NPK fertilizers as well as in various green manure treatments either exhibited insignificant effect or significantly reduced various studied parameters. The present study concludes that parthenium weed has the potential to be used as green manure for wheat.

Key words: Effective microorganisms, green manure, parthenium, wheat.

INTRODUCTION

The excessive use of agrochemicals has polluted the environment to a great extent and the food produced under such farm management may not be safe or of good quality. Public awareness to these problems has shifted the approach towards some alternative measures (Shaxson, 2006). Organic farming offers an alternative that can eliminate many of the environmental problems of conventional agriculture. In comparison with conventional farming, organic farming has potential benefits in improving food quality and safety (Giles, 2004), promoting soil structure formation (Pulleman et al., 2003), alleviating environmental stresses (Macilwain, 2004), and enhancing soil biodiversity (Oehl et al., 2004). Organic mulching directly provides organic C inputs to soil that reduces soil erosion and is also effective in conserving soil moisture and buffering drastic changes in soil temperature (Pinamonti, 1998). Forage legumes are widely used as green manure crops to improve soil fertility (Turgut et al., 2005). However, there is need to investigate the potential of other plant species especially weeds that produce huge amounts of plant materials, to be used as green manures.

Parthenium (*Parthenium hysterophorus* L.), an invasive weed of family Asteracea, is native to the subtropics of North and South America but now has invaded Asia, Africa and Australia during the last 50 years and is spreading at an alarming rate (Navie et al., 1996). A lot of available data highlights its impact on agriculture as well as on natural ecosystems (Chippendale and Panetta,

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Table 1. Environmental data during different months of the experimental period.

Months	Mean daily temperature (°C)	Total precipitation (mm)	Relative humidity (%)	Total bright sunshine (h)	Solar radiation MJ/MF/day
November	21.1	9.0	67	203.5	12.42
December	15.1	30.8	71	195.1	9.28
January	14.1	18.9	64	199.8	9.92
February	20.7	4.9	61	200.4	12.28
March	21.5	42.1	57	237.5	15.84
April	29.2	0.01	29	288.0	20.25

Source: Pakistan Meteorological Department, Islamabad, Pakistan.

1994; Singh et al., 2003). There are reports of total habitat change in native Australian grasslands, open woodlands, river banks and floodplains due to parthenium invasion (Chippendale and Panetta, 1994). Similar invasions of national wildlife parks have also been reported in southern India (Evans, 1997). The sesquiterpene lactone parthenin that is biosynthesized by this species is thought to play a role in its allelopathic interference with surrounding plants (Belz et al., 2007). In spite of its many harmful effects, this noxious weed has many properties to be used as a green manure to enhance soil fertility and crop growth. It has sufficient amount of nutrients, easily available, produces succulent tops, capable of growing on poor soils and produces huge biomass (Javaid and Shah, 2008; Javaid et al., 2009).

Effective microorganisms (EM) technology of nature farming was introduced by Higa (1989) who isolated some beneficial microorganisms from the soil and called them EM. EM culture consists of co-existing beneficial microorganisms, the main being the species of photosynthetic bacteria viz. *Rhodopseudomonas plastris* and *Rhodobacter sphacrodes*; lactobacilli viz. *Lactobacillus plantarum*, *Lactobacillus casei* and *Streptococcus lactis*; yeasts (*Saccharomyces* spp), and *actenomycetes* (*Strptomyces* spp.), which improve crop growth and yield by increasing photosynthesis, producing bioactive substances such as hormones and enzymes, controlling soil diseases and accelerating decomposition of lignin materials in the soil (Higa, 2000). In Pakistan, this technology of nature farming was introduced in 1990 by the Nature Farming Research Centre, University of Agriculture, Faisalabad. Numerous field and green house trials are indicative of the benefits of this technology for crop production, as a probiotic in poultry and livestock rations, and to enhance the composting and recycling of municipal / industrial wastes and effluents (Hussain et al., 1999, Javaid, 2006, 2009; Javaid and Mahmood, 2010). At present Nature Farming Research and Development Foundation is disseminating this technology throughout the country. The present study was carried out to investigate the effect of parthenium green manure and EM application on growth and yield of wheat.

MATERIALS AND METHODS

Soil characteristics

The soil used in the present experiment was sandy loam in texture with pH 7.5, organic matter 0.87%, N 0.045%, available P 6.5 mg kg^{-1} and exchangeable K 100 mg kg^{-1}. The micronutrients, viz., boron, manganese, iron, copper and zinc were 1.08, 23.8, 10.8, 1.8 and 1.6 mg kg^{-1}, respectively.

Environmental characteristics

Experiment was conducted during November 2005 to April 2006 in the University of the Punjab, Lahore, Pakistan. The city of Lahore is located on latitude 31.57 N and longitude 74.31 E. The climate of the region presents extremes of heat and cold. There are four well defined seasons viz., winter (December - February), spring (March - April), summer (May - September) and autumn (October - November). The area receives the highest rainfall during monsoon months of July and August. Data regarding various environmental characteristics viz., temperature, light intensity, rain fall and humidity during various months of experimental period is given in Table 1.

Soil amendments

There were six treatments without EM application viz. control, nitrogen-phosphorus-potassium (NPK) fertilizers, and 1, 2, 3 and 4% parthenium green manure on fresh weight bases equivalent to 0.22, 0.44, 0.66 and 0.88% on dry weight bases, respectively. Succulent shoot top and leaves of 30 - 35 days old parthenium were collected prior to flowering stage and cut into 1 cm pieces. Parthenium shoot material contained 2.15% N, 0.11% P, and 2.25% K on dry weight bases (Singh et al., 2007). The cut fresh material was mixed in the pot soil at 1, 2, 3 and 4%. Pots were irrigated with tap water and left for 30 days for decomposition of manure. In NPK fertilizers treatments, 60 mg N kg^{-1} as urea, 50 mg P_2O_5 kg^{-1} as triple super phosphate and 40 mg K_2O kg^{-1} as sulphate of potash were applied as basal to the respective pot soil three days prior to sowing of seeds (Rashid et al., 1993). Pots were irrigated with tap water, a similar set of treatments was also prepared for EM application.

Sowing of Seeds

Seeds of wheat var. Inqalab 91 were sown in all the pots and after one week of germination two uniform seedlings per pot were maintained. Each treatment was replicated thrice. Pots were arranged in a completely randomized manner in a wire netting house under natural environmental conditions.

EM application

EM cultures under the commercial name of EM Bioaab was obtained from Nature Farming Research and Development Foundation Faisalabad, Pakistan. The stock culture was diluted to prepare 0.2% solution by adding tap water. The fresh solution was used immediately after preparation. The respective pots of EM treatment were irrigated with 1 L of 0.2% dilute solution after mixing of parthenium green manure in the soil. Each pot received 1 L of dilute EM solution. These pots were further supplemented with 1 L of 0.2% EM solution at fortnight intervals throughout the experimental period (Javaid, 2006).

Data collection and statistical analysis

Plants were harvested at flower initiation and ripening stages. Data regarding shoot length, number of tillers per plant, root and shoot dry biomass, spike length, number of grains per spike, grain yield per plant, weight of 100 grains and harvest index were recorded. Data regarding the effect of NPK fertilizers and parthenium green manure were subjected to one-way analysis of variance (ANOVA) and means were compared using Duncan's Multiple Range Test (Steel and Torrie, 1980). The statistical difference between two corresponding treatments with and without EM application was calculated by applying t - test.

RESULTS

Effect of NPK fertilizers and parthenium green manure on shoot growth

Generally, there was a gradual increase in shoot length with the increase in parthenium green manure. All the parthenium amendments significantly enhanced the shoot length at both the harvest stages except 1% manure at the flowering stage. There was 9–47% and 26–30% increase in shoot length at flowering stage and maturity, respectively, due to various parthenium green manure treatments. NPK fertilizers enhanced shoot length by 27% and 38% over control at flowering and maturity stages, respectively. The effect of 3% and 4% parthenium green manure amendments was at par with the recommended dose of NPK fertilizers (Figure 1A and 2A). Number of tillers per plant was increased both by NPK fertilizers and parthenium green manure. At flowering stage, the effect of 4% green manure was significant where 100% increase was recorded over the control. However, at later growth stage, the effect of both NPK fertilizers and green manure was not significant (Figure 1B and 2B).

NPK fertilizers significantly increased shoot dry biomass by 80% and 137% at the flowering and maturity stages, respectively. Application of 1% green manure failed to affect the studied parameter significantly. However, the rest of the green manure treatments significantly enhanced shoot biomass. Generally, there was a gradual increase in shoot biomass as the quantity of green manure was increased. There was 88 -154% and 166–272% increase in shoot biomass at flowering and maturity stages, respectively, due to 2–4% parthenium green manure application (Figure 1C and 2C).

Effect of NPK fertilizers and parthenium green manure on root growth

The effect of NPK fertilizers on root growth was not significant at the flowering stage. However, at maturity, a significant increase of 202% in root dry biomass was recorded over control. All the applied doses of parthenium green manure significantly enhanced root biomass at both harvest stages except 1% manure at flowering stage. There was a gradual increase in root biomass with increase in quantity of green manure up to 3% and a decline was recorded thereafter. There were 144 and 242% increase in root biomass at flowering and maturity stages, respectively, due to 3% parthenium green manure (Figure 1D and 2D).

Effect of NPK fertilizers and parthenium green manure on yield

A gradual and significant increase in spike length was recorded as the quantity of parthenium green manure was increased from 1-4%. There was 12–36% increase in spike length over control due to various parthenium green manure amendments. NPK fertilizers enhanced spike length by 31% over control. Spike length in 3 and 4% green manure amendments was comparable to that of spike length in NPK treatment (Figure 3A). Similarly, a gradual increase in number of grains per spike was evident in different green manure amended treatments. Highest increase of 179% in number of grains per spike over control was recorded in 4% green manure treatment as compared to only 78% increase due to NPK fertilizers application (Figure 3B). The effect of parthenium green manure and NPK fertilizers on grain yield was similar to that of effect on spike length and number of grains per spike. The highest increase of 253% in grain yield over control was obtained in 4% green manure treatment while only 96% increase was recorded in NPK fertilizers treatment (Figure 3C). Data regarding 100 grains weight reveals that NPK fertilizers failed to affect this parameter significantly. In contrast, 2 and 4% parthenium green manure treatments significantly enhanced the weight of 100 grains over control (Figure 3D). Highest harvest index (23%) was recorded in 4% green manure amendment. However, difference among the various treatments

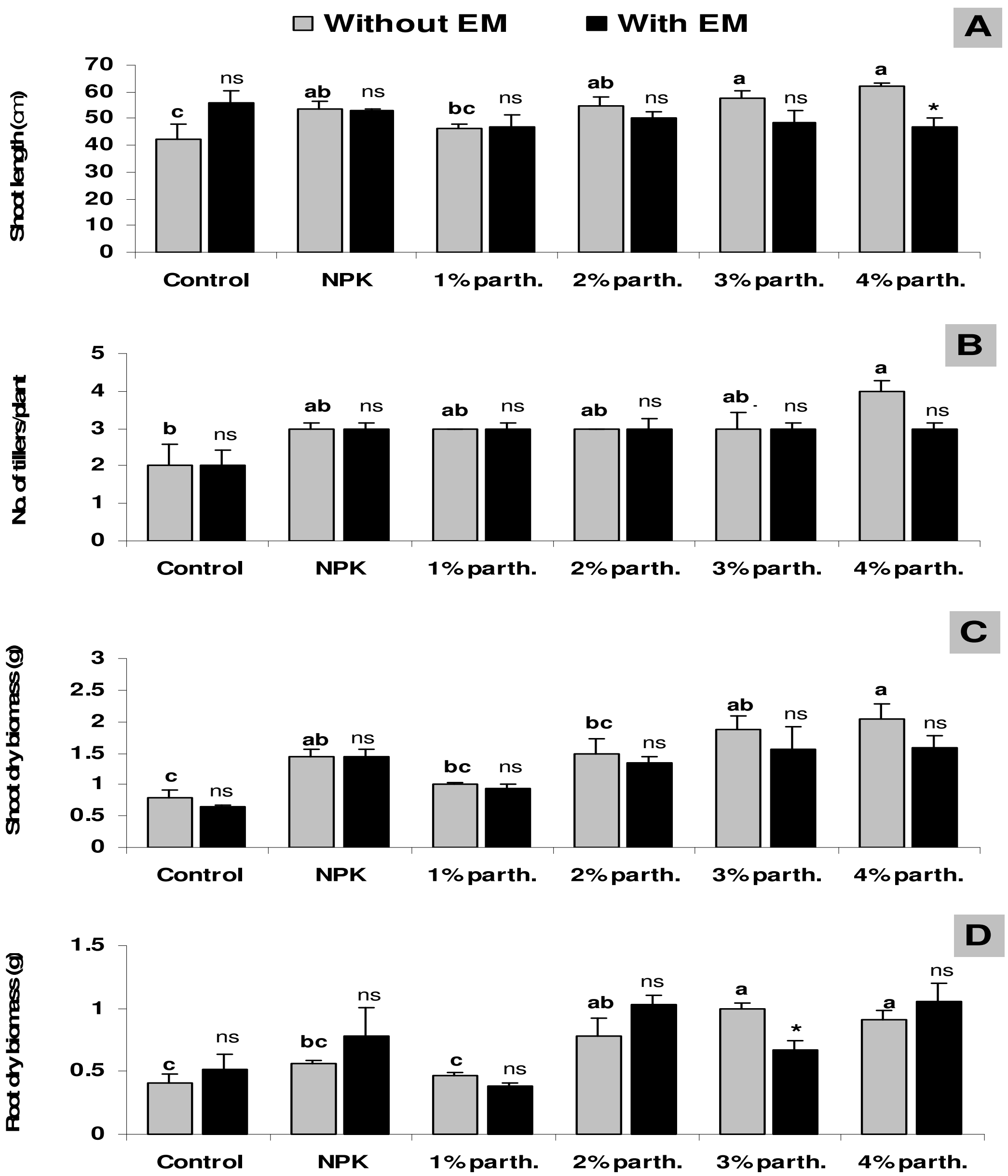

Figure 1. Effect of *Parthenium* green manure and EM application on root and shoot growth of wheat at flowering stage. Vertical bars show standard error of means of three replicates. Values with different bold letters at their top show significant difference (P = 0.05) between different non-EM treatments as determined by DMR Test. *, ** show significant difference between two corresponding treatments with and without EM application at 5% level of significance as determined by t-test. ns = Non significant difference between two corresponding treatments with and without EM application.

was not significant statistically (Figure 3E).

Effect of EM application on growth and yield of wheat

EM application effect was either not significant or adversely affected the various plant growth and yield parameters. Shoot length response to EM in all the treatments was not significant at both the harvest stages except in 4% green manure treatment where a significant reduction was recorded at flowering stage. Similarly, the effect on number of tillers was not significant in all the treatments at both harvest stages. Shoot biomass exhibited a variable response at the two harvest stages. At flowering stage, the effect of EM was not significant in all the treatments. At maturity, a significant reduction in shoot

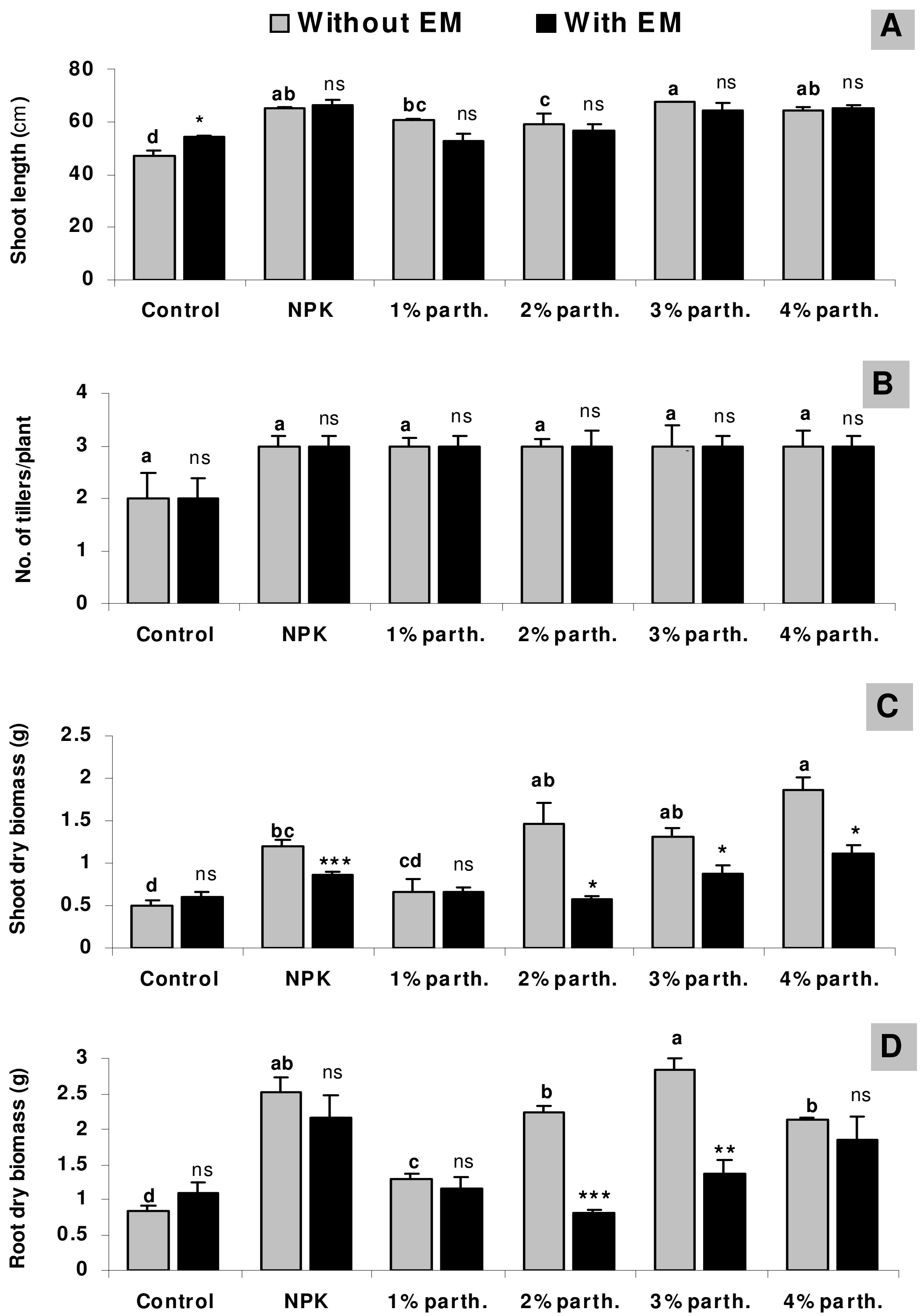

Figure 2. Effect of *Parthenium* green manure and EM application on root and shoot growth of wheat at maturity. Vertical bars show standard error of means of three replicates. Values with different bold letters at their top show significant difference (P = 0.05) between different non - EM treatments as determined by DMR Test. *,** show significant difference between two corresponding treatments with and without EM application at 5, 1 and 0.1% level of significance, respectively as determined by t-test. ns = Non significant difference between two corresponding treatments with and without EM application.

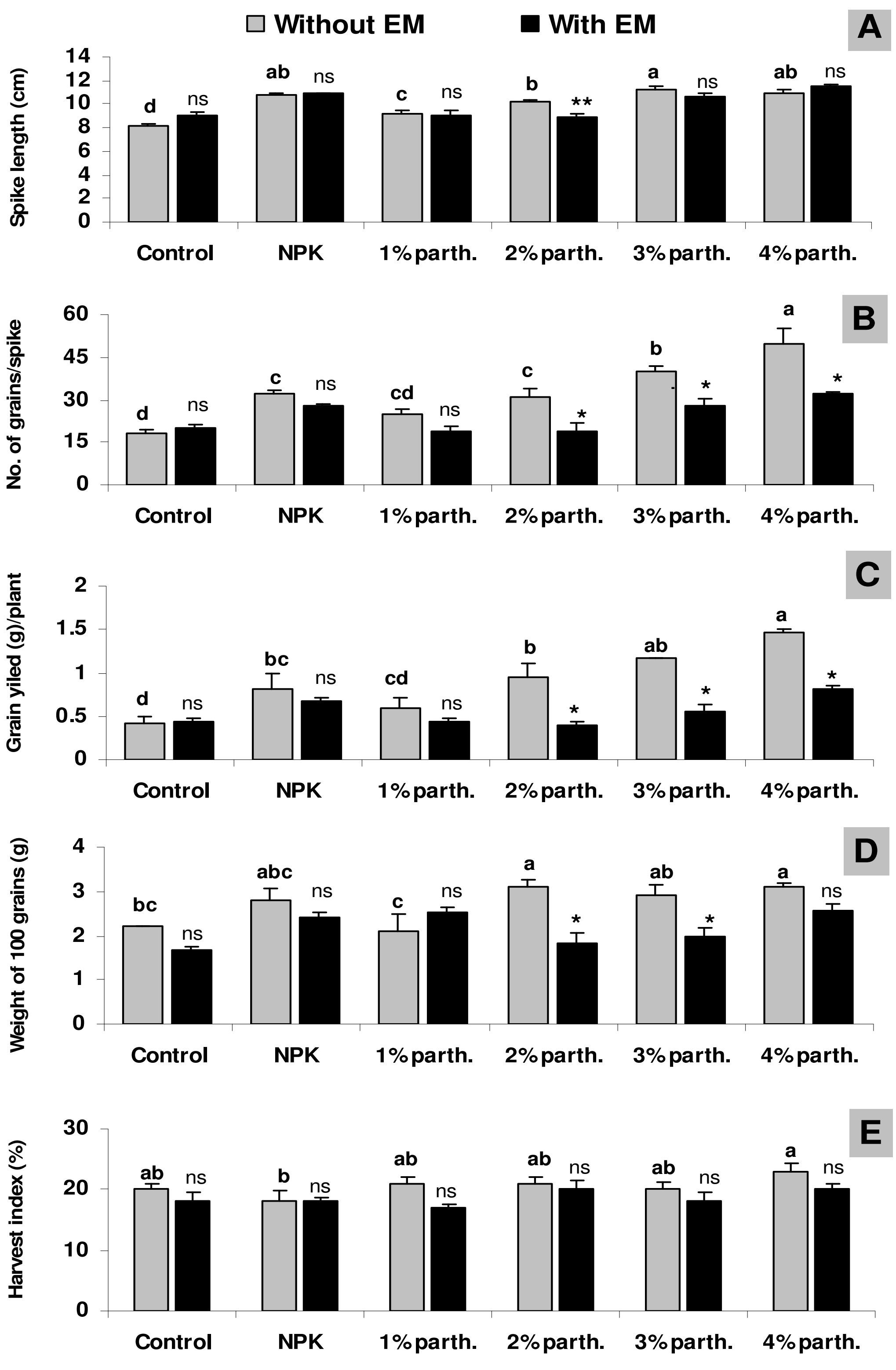

Figure 3. Effect of Parthenium green manure and EM application different yield parameters of wheat. Vertical bars show standard error of means of three replicates. Values with different bold letters at their top show significant difference (P = 0.05) between different non - EM treatments as determined by DMR Test. *, ** show significant difference between two corresponding treatments with and without EM application at 5 and 1% level of significance, respectively as determined by t-test. ns = Non significant difference between two corresponding treatments with and without EM application.

biomass was evident in NPK fertilizers as well as in various green manure treatments. Similarly, root biomass was significantly declined by EM application in 2% green manure at flowering stage and in 3% green manure at both the harvest stages (Figure 1and2). Number of grain per spike and grain yield were also affected adversely and significantly by EM application in various green manure treatments. Similar adverse impact of EM application was also recorded on 100 grains weight in 2 and 3% green manure treatments (Figure 3).

DISCUSSION

In the present study, green manuring potential of aggressive weed parthenium was evaluated for wheat crop. Generally, shoot growth and grain yield was gradually enhanced by increasing the manure dose from 1- 4% (on fresh weight bases). Similarly, root growth was increased up to 3% green manure dose. Similar effects of parthenium green manure have also been reported on maize and rice growth (Sudhakar, 1984; Javaid and Shah, 2008; Javaid et al., 2009). Addition of parthenium green manure to the soil enhanced organic matter (Singh et al., 2003) and nutrient availability (Singh et al., 2007), consequently root and shoot growth of wheat was increased. The gradual increase in plant growth by increasing amount of parthenium green manure may be attributed to the greater availability of nutrients such as nitrogen, phosphorus and potassium. It seems probable that 3 and 4% parthenium green manure treatments contain these nutrients especially nitrogen equivalent to that of recommended dose of chemical fertilizers. However, in contrast to the findings of the present study, Singh et al. (2005) reported adverse effects of parthenium residues on growth of *Brassica campestris, Brassica oleracea* and *Brassica rapa.* Similar adverse impact of parthenium residues has also been reported by Batish et al. (2002) on the growth of *Cicer arietinum* and *Raphanus sativus.* The different effects of parthenium green manure on crop growth in these earlier and the present study could be due to the following reasons. Firstly, in studies by Singh et al. (2005) and Batish et al. (2002) higher amounts of parthenium residue viz. 1- 4% were used as compared to 0.22- 0.88% (on dry weight bases) used in the present study. It is likely that sufficient quantities of allelochemicals viz. phenolic acids and parthenin (Jarvis et al., 1985; Belz et al., 2007) were released from greater amounts of parthenium residue in the earlier studies that exhibited allelopathy and thus the benefits of green manure were not apparent in those studies. Secondly, in the present study, pots were left for 30 days after mixing the parthenium green manure. It seems probable that phytotoxic compounds were degraded to some extent during this time period. Thirdly, low concentrations of parthenin, the main allelopathic constituent in *P. hysterophorus,* are known to promote growth in many plant species including wheat, *Ageratum conyzoides* L., *Echinochloa crus-galli* (L.) P. Beauv., *Eragrostis curvula* (Schrad) Nees, *Eragrostis tef* (Zucc.) Trotter and *Lactuca sativa* L. (Batish et al., 1997; Belz et al., 2007). Fourthly, in earlier studies, different test crops were used belonging to Brassicaceae and Papilionaceae families as compared to wheat (Poaceae) in the present study. In one of our previous study, parthenium green manure was found beneficial for maize but not for mungbean (Javaid and Shah, 2008). Species specificity of allelochemicals has been reported in many earlier studies (Noor and Khan, 1994). Toxicity is associated with the presence of strong electrophilic or nucleophilic systems. Action by such systems on specific positions of proteins or enzymes would alter their configuration and affect their activity (Macías et al., 1992).

In the present study, EM application effect was either not significant on plant growth and yield of wheat or significantly reduced the various studied parameters. Earlier, there were contradictory reports regarding the effect of EM application on crop growth and yield. Many workers have reported increase in crop growth and yield by the application of EM (Daly and Stewart, 1999; Yan and Xu, 2002; Javaid, 2006; Khaliq et al., 2006). However, the investigations of other workers have revealed that the effect of EM on crop growth and yield was usually not evident or even negative especially in the first test crop (Bajwa et al., 1999; Daiss et al., 2007; Javaid et al., 2008) possibly because introduced effective microorganisms have to face a competition with soil indigenous microflora (Bajwa et al., 1995). Studies have shown that these constrains can be overcome through periodic repeated applications of EM at least during the first few years (Sangakkara et al., 1998; Javaid et al., 2000, 2002; Javaid, 2010). According to Kinjo et al. (2000) the lack of consistency in results of the experiments regarding EM application may be due to variable cultural conditions employed in previous studies. Imai and Higa (1994) stated that the observed decline in crop yields could often be attributed to the fact that soils, where conventional farming is practiced, have become disease-inducing or putrefactive soils from long-term use of pesticides and chemical fertilizers. Consequently, it takes time to establish a disease-suppressive or zymogenic soil. Until this conversion process is completed, it is virtually impossible to exceed crop yields that were obtained with conventional farming methods.

Conclusion

The present study concludes that the parthenium weed has the potential to be used as a green manure to improve the growth and yield of wheat. Amendment of the soil with 4% green manure one month prior to the sowing of wheat gave crop growth and yield better than the recommended dose of NPK fertilizer. However, before its recommendation to farmers, further field studies are required. Moreover, the toxicity of the parthenium may be reduced to a remarkable extent by using it after composting as this process reduced the phenolic content of parthenium up to 41.4% (Ramaswami, 1997). EM application is not suitable along with parthenium green manure during the first year of application. Further research work is required to study the effect of EM application in the succeeding years.

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