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Article

Parthenium hysterophorus Herbage Mulching: a Potential Source of Weeds Control in Soybean (*Glycine max*)

Cobertura Vegetal com Forragem de ***Parthenium hysterophorus****: Uma Fonte Potential de Controle de Plantas Daninhas na Cultura da Soja (****Glycine max****)*

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ABSTRACT - Weeds have indirect effects on crop plants. Crop development is affected by allelopathy from certain weed species. Allelochemicals from allelopathic weeds can disturb the root and shoot growth of emerging crop seedlings, as well as cause several other types of damage. A study was carried out to investigate the allelopathic potential of *Parthenium hysterophorus* for weed response in soybean. The experiment was laid out in Randomized Complete Block Design (RCBD) with split plot arrangements and replicated thrice. Sowing methods (broadcast and line sowing) were kept in the main plot and mulching treatments (surface mulching and soil incorporation) were kept in the sub-plots. Mulching of *Parthenium hysterophorus* was applied at the rate of 1.0 t ha^{-1}, 2.5 t ha^{-1}, 5 t ha^{-1} with control (no parthenium). Manual weed control was also used as treatments. The results revealed that significantly higher shoot length, shoot fresh weight, shoot dry weight, root length, root fresh weigh, root dry weight, number of nodules per plant, nodules fresh and dry weight, number of branches, number of pods per plant, thousand seed weight biological yield, economic yield, dry matter yield and harvest index were recorded with the soil incorporation of *Parthenium* herbage at the rate of 2.5 t ha^{-1}. Maximum weed density and weed dry biomass were recorded in control plots while weed control efficiency was seen greater in plots where *Parthenium* herbage was applied to surface at the rate of 5 t ha^{-1}. The results suggested that the use of *Parthenium hysterophorus* herbage mulching can reduce infestation of weeds by its allelopathic effects and increase the yield of soybean under sub-humid agro-climatic conditions.

Keywords: parthenuim weed, ground cover, allelopathy.

RESUMO - As plantas daninhas têm efeitos indiretos no cultivo de plantas. O desenvolvimento das culturas é afetado pela alelopatia de certas espécies dessas plantas. Os aleloquímicos de plantas daninhas alelopáticas podem perturbar o crescimento da raiz e da parte aérea de mudas emergentes das espécies cultivadas, além de causar vários outros danos. Foi realizado um estudo para investigar o potencial alelopático da espécie ***Parthenium hysterophorus*** *em resposta às plantas invasoras da cultura da soja. O experimento foi conduzido em um Delineamento de Blocos Completos e Casualizados (DBCC), em esquema de parcelas subdivididas e com três repetições. Os métodos de semeadura (semeadura a lanço e em linha) foram mantidos na parcela principal, e os tratamentos com cobertura vegetal (cobertura de superfície e incorporada ao solo) foram mantidos nas subparcelas. A cobertura vegetal de* ***Parthenium hysterophorus*** *foi aplicada a 1,0 t* ha^{-1}*, 2,5 t* ha^{-1}*, 5 t* ha^{-1} *e com controle (sem* ***Parthenium****). O controle manual de plantas daninhas*

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também foi utilizado como tratamento. Os resultados revelaram aumento significativo do comprimento, peso fresco e peso seco da parte aérea, comprimento, massa fresca e peso seco das raízes, número de nódulos por planta, peso fresco e seco dos nódulos, número de ramos, número de vagens por planta, rendimento biológico do peso de mil sementes, rendimento econômico, rendimento da matéria seca e índice de colheita devido à incorporação ao solo da forragem de ***Parthenium*** *a 2,5 t ha^{-1}. A densidade máxima de plantas daninhas e a biomassa seca delas foram registradas nas parcelas de controle, enquanto a eficiência do controle de plantas daninhas foi maior nas parcelas onde a forragem de* ***Parthenium*** *foi aplicada na superfície a 5 t ha^{-1}. Os resultados sugeriram que o uso da cobertura vegetal com forragem de* ***Parthenium hysterophorus*** *pode reduzir a infestação de plantas daninhas devido aos efeitos alelopáticos dessa planta e aumentar o rendimento de soja em condições agroclimáticas subúmidas.*

Palavras-chave: losna-branca, cobertura morta, alelopatia.

INTRODUCTION

Parthenium (*Parthenium hysterophorus*) of the family Asteraceae, an invasive weed native to Central America, is now widely distributed in Kenya, India, China, Asia, Africa and Australia (Khosla and Sobit., 1981; Aneja et al., 1991). *P. hysterophorus* is considered as a noxious weed because of its prolific seed production and fast spreading ability, allelopathic effect on other Plants, strong competitiveness with crops and health hazards to human as well as animals. *Parthenium* competes with other crops, plant species and various pasture species (Singh et al., 2003; Batish et al., 2005a, b). Studies on its chemical analysis indicated that *Parthenium hysterophorus* contains bitter glycoside parthnin, a major sesquiterpene lactone, in all of its parts, including trichome and pollens. Other allelochemicals that are present are hysterin, ambrosin, quercelagetin 3-7- dimethyl ether, 6 hydroxylkaemptrol 3-0 arabioglucoside, chlorogenic acid, flavonoids such as fumaric acid, caffeic acid, anisic acid, p-anasic acid, chlorogenic acid, ferulic acid and some other undefined alcohols (Maishi et al., 1998).

Weed control is one of the most important management practices for optimum soybean production. Weeds compete for nutrients, moisture and light and cause more yield reduction than any other factor in soybean (James et al., 2008). Soybean (*Glycine max*) belongs to the family Fabaceae, and it is one of the most valuable crops in the world. It is used as an oil seed crop and a rich source of protein for human diet (Tadayoshi et al., 2009). In 2011-2012, the world's soybean production was 238.7 million tons (James, 2013). It is known as the "GOLDEN BEAN" of the 20th century. Soybean contains about 30% of soluble and insoluble carbohydrates. Soybean seed oil is one of the most preferred oil for a healthy diet. The reasons for people's choice are quality, functionality, the fact that it is a precursor of Omega-3, Omega-6 and Vitamin E, and low price of soybean oil (Mounts et al., 1988).

As a result of weed competition, soybean yield reductions could be as high as 75%. Modern agriculture is productivity-oriented and mostly depends on synthetic inputs to tackle weeds and other pest problems (Sadeghi et al., 2010). However, intensive use of herbicides to control weeds over the last few decades is posing serious threats to the ecosystem and to the whole planet. Ground water contamination, associated health hazards and evolution of resistant weed bio-types resulting from continuous use of herbicides have diverted the attention of researchers to discover and establish alternative weed management strategies. There is an increasing thrust for organically produced commodities worldwide (Jamil et al., 2009). Hence, allelopathy can create interference among plants through biochemical pathways that can be manipulated to manage weeds in agro-ecosystems; also, allelopathic properties of native plants can be exploited for this purpose (Khanh et al., 2005; Chou and Lee, 1991). Allelopathic crop residues can be exploited for weed suppression, and they can thus be helpful in reducing reliance on herbicides (Weston, 1996). Therefore, the present study was conducted to evaluate various methods of sowing to optimize soybean yield. The second objective was to check the allelopathic effect of *Parthenium* herbage mulching on weed suppression, physiological, biochemical, growth and yield traits of soybean.

MATERIAL AND METHODS

The experiment was conducted on the farm of the Faculty of Agriculture, The University of Poonch, Rawalakot in North East of Pakistan under the foothills of the Great Himalayas. The research area lies at 33.51° N and 73.45 °E with an altitude of 1,638 m. The climate of this area is sub-humid with annual rainfall ranging from about 500 to 2,000 mm. Rainfall is irregular with intense storms during monsoon and winter. The mean monthly temperature ranges from a minimum of -3 °C to a maximum of 38 °C accompanied by severe cold and snowfall during winter. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications in a split-plot arrangement. Methods of sowing (broadcast and line sowing) were kept in the main plot and mulching treatments (surface mulching and soil incorporation) were kept in the sub-plots. *P. hysterophorus* herbage mulching was applied at the rate of 1.0 t ha^{-1}, 2.5 t ha^{-1} and 5 t ha^{-1}. Manual weed control and control were also used as treatments. The net plot size in use was 1.8 m x 3 m. The soybean variety NARC-1 was sown as a test crop.

Collection of *P. hysterophorus* herbage

Fresh plant parts including shoots and leaves of *P. hysterophorus* were collected from roadsides and fallow land of Rawalakot and in the vicinity. Herbage was brought to the laboratory and air dried in the shade for a week, then chopped in small pieces and used as surface mulch and sub-surface mulch.

Weeds were counted from the experimental area and weed density was calculated. The weeds of each experimental unit were cut manually from ground surface at the time of crop harvest with the help of a sickle, packed in polythene bags and brought to the laboratory. The weeds were dried in oven at 65 °C until constant weight. Weed dry weight was measured by a digital balance and the average was calculated. Weed control efficiency was recorded by using the formula of Balasubramaniyam and Planiappan (2016).

$$\text{WCE}\,(\%) = \frac{\text{Weed biomass in control plots} \;\; \text{Weed biomass in treated plots}}{\text{Weed biomass in control plots}} \times 100$$

Shoot length was measured and then averaged for five randomly selected crop plants of each treatment. The shoots were separated from the roots and weighed on an electric balance for fresh weight. Then the shoots were dried in an oven at 70 °C for 24 hours to calculate shoot dry weight. Root length was measured for each treatment with the help of a meter rod and then averaged. After collecting fresh samples of crop plants from each treatment, the roots were washed, cleaned, air dried and weighed on electric balance for measurement of fresh weight. The weighed roots were dried in an oven at 70 °C for 24 hours to measure root dry weight. Root stumps were dug up with the help of a spade and washed under running water. Then, the nodules were collected and counted for individual plant, and average per plant was calculated. The collected nodules were placed in petri dishes and weighed for fresh weight and then kept in an oven at 70 °C for 24 hours to measure dry weight. The number of branches of five selected plants was individually counted and then averaged. Number of pods from randomly five selected plants was counted at full pod stage and then averaged; 1,000 seeds were weighed at random from the grain lot of each plot with the help of an electronic balance. The crop was harvested and dried for 10 days. After drying, total biomass yield of each plot was measured with the help of a balance. Seed yield was measured by weighing the seeds of ten randomly selected plants of each treatment after harvest, and it was computed on a hectare basis. Dry matter yield was calculated in grams by using the following formula:

Dry matter yield = Biological yield – Seed yield

Harvest index was calculated by using the following formula:

$$\text{Harvest index}\,(\%) = \frac{\text{Seed yield}}{\text{Biological yield}} \times 100$$

"Residual transpiration" was measured according to Clarke et al. (1991). Residual transpiration on leaf area basis was determined as given below:

$$RT = (W_1 - W_2)/(LA.180)$$

Relative water content (RWC) was calculated using the formula proposed by Ritchie et al. (1990).

$$RWC (\%) = (FW\text{-}DW_2)/(TW\text{-}DW_2) \times 100$$

Osmotic adjustment was determined by the formula:

$$OA = TW - FW$$

Chlorophyll content was determined on a spectrophotometer at two wavelengths by the method of Arnon (1949).

Total chlorophyll = (8.02)(O.D. at 663 nm) + (20.2)(O.D. at 645 nm)

Statistical analysis

The data collected for various growth and yield parameters were analyzed statistically using Fisher's analysis of variance technique, and the least significant difference (LSD) test at 5% probability level was applied to test the significant difference among treatment means (Steel et al., 1997).

RESULTS AND DISCUSSION

Allelopathic effect of *Parthenium* on weeds

Weeds can be suppressed down by the use of various allelopathic compounds; for such a purpose, some allelopathic plants may be helpful in reducing weed density. Alleochemical plants such as sunflower, *P. hysterophorous* can be used as mulch or residues or can be incorporated in soil in order to get rid of weeds. Soil incorporation or surface mulching of allelochemicals systematically delays weed growth and germination, thus reducing weed density. Allelochemicals released from mulches of *Parthenium* can have a synergistic and/or a stabilizing effect on target species (Matloob et al., 2010). Better weed control can be achieved by incorporating plant residues that release a greater portion of allelochemicals in the soil (Elijarrat and Barcelo, 2001). The allelopathic effect of *P. hysterophorous* herbage mulching on weed density and weed dry biomass in soybean is shown in Table 1, with significant differences at various levels. Maximum weed density was recorded in control plots as compared to treated plots. Minimum weed density was recorded in case of *Parthenium* herbage surface mulching at the rate of 5 t ha^{-1}. In the case of the broadcast sowing method, higher weed density and greater weed crop competition were noticed as compared with line sowing. It can be inferred from the data that with increasing concentrations of *Parthenium*, weed density was decreased which shows the alellopathic property of the plant. *P. hysterophorus* showed pronounced reduction in weed density by inhibiting the germination of various weeds (Regina et al., 2007), or by limiting their growth by allelochemical compounds, which results in better crop production because of reduced competition. Allelopathy can reduce weed growth, leading to a reduction in weed dry biomass. Weeds cause a great reduction in crop yield; in some cases, weeds cause crop failure. Xuan et al., (2004) suggested that a great deal of agronomic significance can be achieved if allelopathy is exploited for agricultural production. Tefera et al. (2002) have documented the importance of *Parthenium* as a potential source of herbicides. The perusal of the data indicates that weed dry biomass was decreased by increasing the concentration of *Parthenium* extracts. Maximum weed dry biomass was recorded in control plots and minimum weed dry biomass was recorded where *Parthenium* was applied as surface mulch at the rate of 5 t ha^{-1}. Overall data indicated that higher concentrations were more effective in decreasing weed dry biomass as compared with lower concentrations. Reduction in weed dry biomass is noticed due to the fact that vegetative growth of weeds was restricted by *Parthenium* mulching (Daizy et al., 2002). Comparing the values in control with those in the treated plots, there are substantial indications of the presence of allelochemicals in *Parthenium* that can

Table 1 **-** Allelopathic effect of *Parthenium hysterophorus* mulching on mean values of broadcast and line sowing for the weed and crop attributes

Treatment	Weed density (m^{-2})	Weed dry biomass ($g\ m^{-2}$)	Weed control efficiency (%)	Root length (cm) of soybean	Root fresh weight (g) of soybean	Root dry weight (g) of soybean	Shoot length (cm) of soybean	Shoot fresh weight (g) of soybean	Shoot dry weight (g) of soybean
T_1	74.00 b	1.36 c	21.33 f	26.31 d	1.414 d	1.188 d	34.51d	40.35 d	23.08 d
T_2	50.50 d	1.10 e	36.52 d	32.88 b	2.225 b	1.965 b	65.45 b	58.35 b	32.93 b
T_3	9.66 h	0.75 g	56.82 b	10.14 h	0.078 g	0.006 g	6.83 h	5.25 gh	3.45 h
T_4	60.50 c	1.25 d	27.68 e	30.24 c	1.793 c	1.478 c	46.11 c	49.35 c	28.00 c
T_5	17.83 g	0.96 f	44.77 c	37.52 a	2.713 a	2.422 a	81.56 a	67.35 a	37.95 a
T_6	29.50 f	0.55 h	68.26 a	14.47 g	0.335 g	0.157 g	12.98 g	13.35 g	8.31 g
T_7	40.16 e	1.54 b	10.99 g	22.29 e	0.998 e	0.677 e	26.73 e	31.35 e	18.40 e
T_8	92.66 a	1.73 a	0.00 h	18.28 f	0.650 f	0.386 f	18.81 f	22.35 f	13.63 f
LSD	2.351	0.098	8.922	2.209	0.128	0.178	6.407	3.023	1.467

T_1 = Surface mulching at the rate of 1 t ha^{-1}, T_2 = Surface mulching at the rate of 2.5 t ha^{-1}, T_3 = Surface mulching at the rate of 5 t ha^{-1}, T_4 = Soil incorporation at the rate of 1 t ha^{-1}, T_5 = Soil incorporation at the rate of 2.5 t ha^{-1}, T_6 = Soil incorporation at the rate of 5 t ha^{-1},T_7 = Manual weed control, T_8 = Control.

selectively affect weeds. Weed control efficiency is the ratio between crop yield and the amount of weeds that are killed. In comparison with control, the highest weed control efficiency was recorded where *Parthenium* herbage was applied as surface mulch at the rate of 5 t ha^{-1}. It can be inferred that the allelopathic compounds in *P. hysterophorus* can suppress weeds before crop establishment to avoid weed crop competition. These effective mulching strategy can be used to manage weeds in crops such as soybean. Similar results were reported by Panwar and Malik (1991), who suggested that the allelopathic extract increased weed control efficiency compared with the weedy plots. In mulching of *P. hysterophorous*, higher weed control efficiency is due to the alelopathic effect of *Parthenium* at earlier stages; surface mulches not only reduce weed establishment but also inhibit the germination of various weeds.

Allelopathic effect of *Parthenium* on soybean

The root system plays an important role in the anchorage of plants in soil, and helps in the uptake of water and various nutrients. If a plant can maintain a good root system during stressed conditions, it may give good yield. But if a plant cannot maintain its root system in stressed conditions, it may fail to flourish. As shown in Table 1, a decrease in root length was clearly due to increased stress. Overall, T_5 shows the highest values for root length, root fresh weight, root dry weight, shoot length, shoot fresh weight and shoot dry weight and the lowest results were seen for T_3, followed by T_6 (Table 1). The plants failed to promote a good and healthy root system in case of T_6 and T_3, because of weed competition and stress. Reduction in root length, root fresh weight and root dry weight is also seen in control (T_8) because of weed competition. T_5 performed best; because of the application of *Parthenium hysterophorous* at the rate of 2.5 t ha^{-1}, there were great reductions in weed density and more weed control efficiency.

The present study suggested that root length, root fresh weight and root dry weight in T_5 and T_2 is increased as compared to T_3 and T_8 (control) probably because of the release of allelochemical at much higher rates, which significantly reduced the weeds in T_3 but also showed bad impact on the root system of soybean. Severe weed crop competition in control plots was also a reason for reduction in root length. Better weed control was achieved in treated plots at a reasonable rate, which resulted in higher root length, root fresh and dry weight. These results were followed by Patil et al., (1992) who noted that a significant increase in root length of green gram was due to the release of allelopathic compounds in a specific amount. Reduction in shoot length was due to higher weed density as in control plot T_8. Manual weed control was also performed (T_7) but it did not achieve good results, because weeds were not controlled properly. Decreases in shoot fresh and dry weight were caused by reduced shoot length, while increased shoot fresh and dry weight were due to the increasedin shoot length as a result of good weed control by *Parthenium* herbage applied to soil (Shehzad et al., 2016). At much higher rates of *Parthenium*, there was good weed control but it has a profound effect on the crop as well, i.e., the crop will show reduced growth. At the rate of 2.5 t ha^{-1}, phenolic compounds released from *Parthenium* enhanced and stimulated shoot growth of soybean, resulting in increased shoot length, shoot fresh weight and shoot dry weight. These results are comparable to the findings of Ja et al. (2011), who reported significant increases in shoot length after application of phenolics at a specific rate. Allelopathic chemicals released from *Parthenium* showed significant differences in nodulation, nodule fresh weight and nodule dry weight (Table 2). Because of lower weed crop competition by the application of *Parthenium* herbage at the rate of 2.5 t ha^{-1}, soil incorporation performed better than control and other treatments. The highest nodulation was found in the case of T_5 and the smallest nodules were recorded in T_3 where *Parthenium* herbage was applied to surface as mulch at the rate of 5 t ha^{-1}. Nodule fresh and dry weights were also positively increased by soil incorporation of *Parthenium* herbage at the rate of 2.5 ha^{-1} while it is negatively affected by the higher rates of *Parthenium* applied to soil and surface. Control also showed minor nodulation. Because of effective nodulation, more nitrogen was fixed and the crop performed better and gave good yield. Higher number of branches was noticed where *Parthenium* herbage was applied to soil at the rate of 2.5 t ha^{-1}. A greater number of branches was seen in this case because lower weed density and lower competition allow the crop to make a good stand. A greater number of branches resulted in higher biological yield. The lowest number of branches was found where *Parthenium* was applied at the rate of 5 t ha^{-1}. In this case, due to the application of *Parthenium* at a much higher rate, the plant limit their vegetative growth and hence there was a decrease in the number of branches, whereas T_8, T_6 and T_3 were at par with each other. Table 2 shows the data on the allelopathic effect of *Pathenium* on number of pods per soybean plant. Number of pods is an important determinant of yield. Number of pods per plant for each treatment showed statistically significant differences among various treatments. The highest number of pods was seen where *Pathenium* herbage was applied in soil at the rate of 2.5 t ha^{-1}. Overall, the lowest number of pods was noticed in T_3 where *Parthenium* herbage was applied at 5 t ha^{-1} and it was at par with T_6 and T8 (Table 2). It can be associated with better crop establishment and *P. hysterophorus* herbage incorporation to soil is proved positively allelopathic which killed weeds. Hence, it reduced competition and ultimately increased the number of pods per plant. Seed weight is a genuine scale that standardizes crop development. It is one of the main factors contributing towards overall seed yield. The assessment of the data in Table 2 illustrated the effect of various *P. hysterophorus* herbage mulching treatments and showed statistically differential responses of the different concentrations and methods of application. The lowest seed yield was produced by T_3 where *P. hysterophorus* was applied as surface mulch at the rate of 5 t ha^{-1}, while T_5 where *P. hysterophorus* was incorporated to soil at the rate of 2.5 t ha^{-1} showed best results. It is due to the fact that *P. hysterophorus* herbage soil incorporation at the rate of 2.5 t ha^{-1} enhanced the grain size and ultimately increased grain weight by reducing weed-crop competition and increasing utilization of nutrients and water by the crop. Table 2 shows the data on biological yield as influenced by various *P. hysterophorus* mulching. The data showed statistically significant

Table 2 **-** Allelopathic effect of *Parthenium hysterophorus* mulching on mean of broadcast and line sowing for the measured variables

Treatment	Nodules per plant of soybean	Nodules fresh weight (g) of soybean	Nodules dry weight (g) of soybean	Number of branches per plant of soybean	Number of pods per plants of soybean	1,000 seed weight (g) of soybean	Biological yield (kg ha^{-1}) of soybean	Economic yield (kg ha^{-1}) of soybean	Dry matter yield (kg ha^{-1}) of soybean	Harvest index (%) of soybean
T_1	78.83 c	2.121 c	1.475 c	26.00 cd	36.50 d	63.66 cd	1834.7 d	465.1 d	1369.5 b	25.34 d
T_2	108.00 a	2.471 ab	1.695 b	38.83 ab	63.66 b	76.66 ab	2235.2 b	725.1 b	1510.0 ab	33.48 ab
T_3	31.50 e	1.331 f	1.108 f	14.50 e	19.16 e	42.66 e	1053.3 g	246.3 g	665.9 e	23.21 d
T_4	93.00 b	2.373 b	1.568 c	31.83 bc	52.16 c	68.50 bc	2050.3 c	549.8 c	1499.0 ab	32.09 ab
T_5	118.83 a	2.653 a	1.843 a	44.00 a	82.00 a	86.00 a	2477.2 a	896.5 a	1580.7 a	36.08 a
T_6	37.50 e	1.636 e	1.153 ef	16.00 e	20.83 e	45.83 e	1096.2 g	325.3 f	770.8 de	29.81 bc
T_7	66.67 c	1.881 cd	1.35 d	21.00 de	28.67 de	58.00 d	1604.0 e	413.5 de	1190.5 c	32.09 cd
T_8	52.83 d	1.796 de	1.245 de	18.83 de	25.83 e	47.00 e	1214.0 f	386.6 e	827.0 d	25.75 cd
LSD	11.287	0.102	0.063	2.760	2.412	5.558	58.600	38.635	43.896	3.898

T_1 = Surface mulching at the rate of 1 t ha^{-1}, T_2 = Surface mulching at the rate of 2.5 t ha^{-1}, T_3 = Surface mulching at the rate of 5 t ha^{-1}, T_4 = Soil incorporation at the rate of 1 t ha^{-1}, T_5 = Soil incorporation at the rate of 2.5 t ha^{-1}, T_6 = Soil incorporation at the rate of 5 t ha^{-1}, T_7 = Manual weed control, T_8 = Control.

differences among the treatments. In case of T_5, higher biological yield was noticed where *P. hysterophorus* was applied to soil at 2.5 t ha^{-1} followed by T_2 , where *P. hysterophorus* was applied to surface at the rate of 2.5 t ha^{-1} and minimum biological yield was noticed in T_3, where *P. hysterophorus* was applied to surface at the rate of 5 t ha^{-1}. Control also showed lower biological yield as compared with manual weed control and some other treatments.

It can be attributed to better weed management by the allelopathic effect of *P. hysterophorus* and good crop establishment. These results supported the idea of reducing weeds with allelopathic effects of weeds (Awan et al., 2009). In soil and surface mulching of *Parthenium* at the rate of 5 t ha^{-1}, biological yield was reduced because at initial stages of crop establishment, the crop was negatively affected by allelopathy because of an increase in allelopathic compounds. Grain yield is at the interplay of various yield components, and it is also called economic yield, for which a crop is grown in terms of grain, root, stem etc. A careful examination of the data in Table 2 illustrated the allelopathic potential of *P. hysterophorus* herbage mulching on the economic yield of soybean. It showed a statistically differential effect of various treatments. The treatment which showed significantly higher results is T_5, where *P. hysterophorus* herbage was applied to soil at the rate of 2.5 t ha^{-1}, followed by T_2, where *P. hysterophorus* herbage was applied to surface at the rate of 2.5 t ha^{-1}. The lowest result was noticed in T_3, where *P. hysterophorus* herbage was applied to surface at the rate of 5 t ha^{-1}. A great reduction of economic yield was also noticed in case of control, where no *P. hysterophorus* herbage was applied. It is due to the fact that moderate rate of allelochemicals delays and stops the germination of some specific weeds of soybean and allows soybean plants to flourish. In the case of soil application of *Parthenium hysterophorous* at the rate of 2.5 t ha^{-1}, maximum dry matter yield results were noticed while the lowest yield was recorded in the case where *P. hysterophorous* was applied as surface mulch at the rate of 5 t ha^{-1} (Table 2). The data on the allelopathic effects of *Parthenium hysterophous* mulching at various levels and methods are shown in Table 2. The leading treatment was T_5, where *Parthenium hysterophous* herbage was applied to soil at the rate of 2.5 t ha^{-1}, while the lowest harvest index was noticed in T_3, where *Parthenium hysterophous* herbage was applied to surface at the rate of 5 t ha^{-1}. It is due to the fact that at higher concentrations of *Parthenium*, more allelochemicals were released, which significantly reduced weed density but also had a negative effect on the crop. Control also showed reduced harvest index because of high weed crop competition, hence the crop could not perform better. Residual transpiration is the loss of water at minimum stomatal aperture. Data on the residual transpiration in soybean are shown in Table 3. Maximum amount of residual transpiration was seen in the control plots, while the minimum amount of residual transpiration was exhibited by T_5, where *Parthenium* herbage was incorporated to soil at the rate of 2.5 t ha^{-1}. It shows that in control plots, more water was lost than in the treatments where *Parthenium* was applied as surface or soil mulch. Its mean that with the application of *Parthenium*, water loss by the transpiration can also be minimized. Table 3 shows data on osmotic adjustment,

Table 3 - Allelopathic effect of *Parthenium hysterophorus* mulching on physiological and biochemical parameters mean of broadcast and line sowing

Treatment	Residual transpiration (mg $H_2O/min/cm^2/10^5$) of soybean	Osmotic adjustment (mg) of soybean	Relative water content (%) of soybean	Chlorophyll content (mg g^{-1}) of soybean
T_1	12.13 f	1988.7 d	62.16 d	5.83 d
T_2	1.91 g	2304.7 b	82.00 b	7.19 b
T_3	18.51 d	1307.8 h	13.83 h	3.034 h
T_4	5.81 e	2151.7 c	73.16 c	6.55 c
T_5	0.37 h	2502.7 a	90.16 a	58.17 a
T_6	24.66 c	1486.2 g	24.66 g	3.72 g
T_7	30.50 b	1819.2 e	51.00 e	5.09 e
T_8	37.65 a	1650.5 f	37.50 f	4.39 f
LSD	1.026	4.240	10.983	0.472

T_1 = Surface mulching at the rate of 1 t ha^{-1}, T_2 = Surface mulching at the rate of 2.5 t ha^{-1}, T_3 = Surface mulching at the rate of 5 t ha^{-1}, T_4 = Soil incorporation at the rate of 1 t ha^{-1}, T_5 = Soil incorporation at the rate of 2.5 t ha^{-1}, T_6 = Soil incorporation at the rate of 5 t ha^{-1}, T_7 = Manual weed control, T_8 = Control.

which showed the highest value of osmotic adjustment by the treatment where *P. hysterophorus* was incorporated to soil at the rate of 2.5 t ha^{-1}. Minimum adjustment was performed where *P. hysterophorus* was applied to soil at the rate of 5 t ha^{-1}. As a result of higher stress, soybean cannot maintain its solute properties and cannot withstand high stress. Maximum relative water content was measured where *P. hysterophorus* was applied at the rate of 2.5 t ha^{-1} while minimum amount of relative content was seen in T_3 where *P. hysterophorus* was applied at the rate of 5 t ha^{-1}. This is because soybean maintains its water content at an appropriate level of *P. hysterophorus*. In control, the relative water content of plots were lower than that of manual weed control and various *P. hysterophorus* treatments (Table 3). Chlorophyll content plays an important role in photosynthesis. Maximum amount of chlorophyll content was noticed in T_5 where *P. hysterophorus* was applied to soil at the rate of 2.5 t ha^{-1}, followed by T_2 where *P. hysterophorus* was applied to surface of soil at the rate of 1 t ha^{-1}. Minimum amount of chlorophyll content was seen in T_3. This was because under high stress conditions, the plant cannot maintain its chlorophyll contents.

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