WEED SUPPRESSING ABILITY OF PARTHENIN – A SESQUITERPENE LACTONE FROM *PARTHENIUM HYSTEROPHORUS*

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ABSTRACT

To find alternate chemicals with novel mode of action, allelochemicals which are natural plant products, are being investigated. This study was undertaken to explore the effect of parthenin (chemically a sesquiterpene lactone from *Parthenium hysterophorus* L.) on two weed species viz. *Amaranthus viridis* and *Chenopodium murale*. In a laboratory bioassay, germination, seedling growth and dry weight accumulation of the weeds were significantly reduced by treating with parthenin. The chlorophyll content and the respiratory activity were also significantly affected in the treated plants. The study concluded that phytotoxicity of parthenin could be useful as a natural herbicide for future weed management programmes.

Keywords: phytotoxicity, *Amaranthus viridis*, *Chenopodium murale*, weed management, natural herbicide.

INTRODUCTION

Use of synthetic chemicals has no doubt improved crop yields quantitatively as well as qualitatively but has created undesirable side effects in the form of health hazards, deterioration of environment quality and development of resistance and cross resistance. Due to these problems, efforts are being made to find alternatives to these chemicals. Among the various alternatives, use of natural plant products, called allelochemicals, offers a new approach for the management of noxious weeds and pests in a sustainable manner (Macias et al. 2001). These are biodegradable, and rarely contain halogenated atoms. They possess novel target sites that are different from synthetic chemicals, and can thus be explored as lead chemicals for the synthesis of new herbicides. They also exhibit a large degree of novelty and structural diversity and are highly sought after for the discovery of new agrochemicals (Duke et al. 2000). Moreover, the discovery of novel modes of action would lead to the development of new weed management tools.

Sesquiterpene lactones are one of the very important groups of natural plant products known for their biological activities, including allelopathic properties (Macias et al. 2001). Little has been done to explore their herbicidal potential, although there have been some studies (Batish et al. 1997, 2002; Macias et al. 2001). Among sesquiterpene lactones, parthenin is a natural component of *Parthenium hysterophorus* known for its phytotoxicity towards other plants including aquatic species (Pandey 1996; Batish et al. 1997, 2002). Recently, it has been observed to also possess pesticidal and nematicidal properties (Datta & Saxena 2001). In order to substantiate its weed suppressing properties, a study was undertaken to explore the effect of different concentrations of parthenin on the germination, growth and development of nettle-leaved goosefoot (*Chenopodium murale* L.) and amaranth (*Amaranthus viridis* L.).

MATERIALS AND METHODS

Parthenin was extracted from the locally collected shade-dried leaves of *Parthenium hysterophorus* L. following the method of Saxena et al. (1991). For growth experiments, solutions of parthenin were prepared by dissolving the requisite amount of parthenin in approximately 2 ml absolute alcohol and the final volume was adjusted with distilled water to get a stock solution of 500 µM. The stock solution was further diluted to 50, 100 and 300 µM. For bioassay studies, seeds of amaranth and nettle-leaved goosefoot were collected locally from the wild stands in the campus of Panjab University, Chandigarh, India.

To study the effects of parthenin on the early growth of test weeds, 25 seeds of each weed species were allowed to germinate and grow in a 15 cm diameter Petri dish lined with a Whatman no. 1 filter paper moistened with 10 ml of the respective parthenin solution. Treatment in a similar manner with distilled water instead of parthenin served as the control. For each treatment there were five replicates. Petri dishes were placed in a growth chamber at 25±2°C temperature, a 16:8 h light:dark photoperiod and relative humidity of around 75%. After 8 days, the number of seeds that germinated and the seedling length were measured and chlorophyll content was determined.

Chlorophyll was extracted in dimethyl sulphoxide (DMSO) following the method of Hiscox & Israelstam (1979). The amount was determined spectrophotometrically using the equation of Arnon (1949) and expressed in terms of dry weight as suggested by Daizy & Kohli (1991). Cellular respiration was measured indirectly using 2,3,5-triphenyl tetrazolium chloride salt (TTC) as per the method of Steponkus & Lanphear (1967). The data are presented as percent inhibition with respect to control and analysed by one-way ANOVA.

Furthermore, in a greenhouse experiment, the effect of spray treatment of parthenin was determined on 4-week-old plants of both weeds which had been raised in 100 mm diameter earthenware pots. For this, each plant was sprayed with 10 ml of the respective parthenin concentration. There were four replicates for each treatment on each weed species. Treatment in a similar manner with distilled water served as the control. On the second day after treatment, leaves were plucked from the treated plants, surface cleaned and subjected to estimation of chlorophyll content and cellular respiration.

RESULTS AND DISCUSSION

The results indicate that different concentrations of parthenin significantly reduced the germination of both *A. viridis* and *C. murale*. With increasing concentration of parthenin, a greater reduction in germination was observed indicating a dose-response relationship (Table 1). A complete inhibition in germination was observed at 500 µM concentration. The seedling growth and the chlorophyll content in the seedlings of both the test weed species were also significantly reduced (Table 1). In general, the inhibitory effect was more pronounced for *C. murale* than *A. viridis*.

TABLE 1: Percent inhibition of seed germination, seedling length and chlorophyll content of *A. viridis* (*A. v.*) and *C. murale* (*C. m.*) in response to parthenin.[1]

Concentration (µM)	Germination		Seedling Length		Chlorophyll Content	
	A. v.	*C. m.*	*A. v.*	*C. m.*	*A. v.*	*C. m.*
50	22.4*	20.3*	29.3*	25.7*	21.7*	15.3*
100	42.6*	40.2*	52.4*	50.4*	43.4*	52.7*
300	72.1**	73.3**	69.7**	80.3**	67.2**	75.4**
500	100**	100**	-	-	-	-

[1]Data presented as percent inhibition with respect to the control; * and ** represent significant difference at P<0.01 and 0.05, respectively.

Further, the plants sprayed with varying concentrations of parthenin were found to possess significantly less chlorophyll than the control. Here also, more inhibitory effect was observed on *C. murale* compared to *A. viridis*. In general, a concentration based dose-response relationship was observed in all the experiments. With 500 μM parthenin treatment, chlorophyll content was reduced by nearly 70% in *A. viridis*, whereas nearly 80% reduction was observed for *C. murale* ($P<0.01$). Likewise, the cellular respiration was greatly reduced in response to the parthenin treatment and at the highest concentration (500 μM), cellular respiration was reduced by around 60% and 78% in *A. viridis* and *C. murale*, respectively (Table 2).

TABLE 2: Effect of parthenin spray treatment on the chlorophyll content and cellular respiration of 4-week-old plants of *A. viridis (A. v.)* and *C. murale* (*C. m.*)[1].

Concentration (μM)	Chlorophyll Content		Cellular respiration	
	A. v.	*C. m.*	*A. v.*	*C. m.*
50	19.7*	27.3*	10.3*	5.3*
100	28.6*	38.4*	24.4*	35.2*
300	50.7*	59.2*	42.7*	50.8*
500	70.2**	82.2**	62.8**	78.1**

[1]Data presented as percent inhibition with respect to control; * and ** represent significant difference at $P<0.01$ and 0.05, respectively.

It is evident from the results presented above that parthenin exhibited a growth inhibitory effect on the two test weeds, although the reasons for this impaired growth could not be determined through these experiments. Possibly, it may be acting through a reaction with the ~SH groups of amino acids and proteins, a pathway utilised by sesquiterpene lactones in general. The effect is to interfere with normal plant functioning, resulting in impaired growth (Picman 1986). Parthenin also has a unique carbon skeleton backbone with two rings viz. α-methylne-γ-lactone and α,β-unsubstituted cyclopentenone, around a 7-membered ring which enables it to react with a wide variety of nucleophiles. Parthenin is also known to bring about some physiological changes such as damage of cellular membrane, loss of dehydrogenase activity in roots and decreased water content in leaves of the target plants (Pandey 1996). The phytotoxic activity of parthenin is known to persist for about 4 weeks under outdoor conditions (Pandey 1996).

From the present study, it is clear that it reduced the amount of chlorophyll in the treated plants. What is not clear is whether the observed loss in chlorophyll was due to the degradation of the already present chlorophyll or due to inhibition of its biosynthesis. Nevertheless, loss of chlorophyll is likely to interfere with the photosynthetic ability of the plants. Similar observations have been made by other workers in response to treatment with allelochemicals (Daizy & Kohli 1991; Dayan et al. 1999). Likewise, cellular respiration, measured through the use of TTC salt, which is known to trap oxygen released through the respiratory chain and form water insoluble red formazan, was also impaired with parthenin treatment. Such an observation has also been made by Kohli et al. (1993) who reported that parthenin affects respiration in the embryos of germinating mung bean seeds.

Therefore, it can be concluded from the present study that parthenin is a promising phytotoxin possessing weed suppressing ability and is worth exploiting as a natural herbicide for the management of noxious weeds. It also possesses species-selectivity in its phytotoxicity. Batish et al. (1997) reported that with the concentrations at which

parthenin affects the germination of bill goat weed (*Ageratum conyzoides* L.), no effect is seen on wheat. However, from the present data nothing definitive can be said about parthenin's mode of action and further studies in this regard are needed.

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