Allelopathic Effect of *Plantago psyllium* on Germination and Growth Stages of Four Weed Species

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ABSTRACT

Field observations suggested that French psyllium *(Plantago psyllium)* probably exerts allelopathic effects, although there was no evidence in the literature to support this assumption. The main objectives of this study were to determine whether *P. psyllium* affects the germination and growth of some weeds by allelopathic function. To explore allelopathic responses of *P. psyllium* upon germination and growth stages of redroot pigweed (*Amaranthus retroflexus*), wild barley (*Hordeum leporinum*), black mustard (*Brassica nigra*), Lambsquarters (*Chenopodioum album* L.), a laboratory bioassay and three greenhouse experiments including root and above ground residues of *P. psyllium* effects and simultaneous growth of *P. psyllium* with weeds on target plants were conducted. Results showed that aqueous shoot extract, shoot residue and simultaneous growth of *P. psyllium* displayed the most consistent negative effects on germination and dry matter of target plants, respectively. Shoot residue and simultaneous growth significantly decreased height and dry matter of all target species except for wild barley. On the other hand, there were no significant effects of root residue of

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P.psyllium on dry matter and height of target plants. Results also showed that *P. psyllium* can decrease the ability of weeds to germinate, grow and survive especially in drought-prone environments and where water resources are limited.

Key words: allelopathy, germination, growth stages, weeds, *Plantago psyllium*

چکیده

مشاهدات مزرعه شواهدی را مبنی بر وجود خصوصیات اللوپاتیک کنترل علف‌های هرز، در گونه دارویی پسیلیوم مشخص ساخت اگر چه در بررسی منابع علمی، شواهدی برای تائید این نظریه یافت نشد. هدف این مطالعه تعیین وجود یا عدم وجود خصوصیات آللوپاتیک هرز در گونه پسیلیوم از خانواده بارهنگ (*Plantaginaceae*) برای کنترل علف های بود. برای حصول این هدف، چهار آزمایش زیست سنجی برای آزمون پتانسیل آللوپاتیک پسیلیوم روی چهار گونه علف هرزشامل تاج خروس (*Amaranthus retroflexus*)، جو وحشی (*Hordeum Leporinum*)، خردل سیاه (*Brassica nigra*) و سلمه تره (*Chenopodium album*) اجرا شد. آزمایشات گلخانه ای، شامل اثر بقایای ریشه پسیلیوم، بقایای خشک، و بقایای پسمانهای پسیلیوم (در حالت خاک آمیخته) روی خصوصیات رشدی چهار گونه علف هرز مورد نظر و نیز اثر رشد همزمان پسیلیوم با چهار گونه علف مذکور بودند. درآزمایش دیگری، اثر عصاره بقایای اندام های هوایی پسیلیوم روی خصوصیات جوانه زنی و گیاهچه‌ای چهار گونه علف هرز مورد نظر تعیین شد. اثر بقایای اندام‌های هوایی پسیلیوم، و رشد همزمان پسیلیوم با علف‌های هرز به طور معنی داری باعث کاهش رشد علف‌های هرز شدند ولی بقایای ریشه پسیلیوم اثر معنی‌داری روی کاهش رشد علف‌های هرز مذکور نداشت. از طرفی عصاره اندام‌های هوایی پسیلیوم، همه خصوصیات جوانه زنی علف‌های هرز مورد نظر را تحت تاثیر قرارداد، به طوری که درصد جوانه زنی بذور علف‌های هرز تا حدود ۷۰٪ کاهش یافت. به طور کلی، نتایج این مطالعات نشان داد که پسیلیوم دارای خصوصیات آللوپاتیک کنترل علف‌های هرز می باشد.

واژه‌های کلیدی : پسیلیوم، آللوپاتی، جوانه زنی، کنترل علف‌های هرز

INTRODUCTION

Weed management during growing season has been a serious problem for many years. Worldwide, a 10% loss of agricultural products can be attributed to competitive effect of weeds, despite their intensive control. Potential yield reductions caused by uncontrolled weed growth throughout growing season have been estimated to be 45 to 95%, depending on crop species, ecological and climatic conditions (Ampong-Nyarko & De Datta, 1991). Therefore, weed management is a key element of most agricultural systems. The application of herbicides has been a major factor enabling the intensification of agriculture in past decades. Indeed, three million tones of herbicides per year are used in most agricultural systems (Stephenson, 2000). There has been increasing herbicide resistance in weeds and widespread concern about adverse environmental effects from herbicide use (Stephenson, 2000). For this reason, the use of allelopathic varieties may provide an alternative to minimize the risk towards agroecosystems by serving in a complementary way with herbicides. The term allelopathy was coined by Molisch in 1937. His definition referred as a new method of weed control that could lead to reduced labor costs and increased efficiency. Numerous plants possess allelopathic properties, including many crops: Wheat (*Triticum aestivum* L.) (Wu *et al*., 2001), sorghum (*Sorghum bicolor* L. Moench) (Ben-Hammouda *et al.*, 1995), and rye (*Secale cereale* L.) (Raimbault *et al*., 1990) and also many weeds such as giant foxtail (*Setaria faberii* Herrm.) (Bell & Koeppe 1972), yellow nutsedge (*Cyperus esculentus* L.) (Drost & Doll, 1980) and *Amaranthus spp*. (Keilo *et al*., 2004). Rye and wheat residues can be managed to suppress weed emergence and seedling growth in the field (Blum *et al*. 1997). Aqueous extracts of oat (*Avena sativa* L.) and barley plants reduced germination and root growth of the winter annual weeds downy brome (*Bromus tectorum* L.), flexweed (*Descurainia sophia* L. Webb), and stinkweed (*Thlapsi arvense* L.) (Moyer & Huang .,1997). Water extracts of oat shoots contain phytotoxic concentrations of l-tryptophan that inhibits germination and radicle and hypocotyls growth of lettuce (*Lactuca sativa* L.) in laboratory bioassays (Kato-Noguchi *et al*., 1994). The allelopathic potential of maize (*Zea mays* L.) is attributed to the allelochemicals, benzoxazolinone, which inhibited root and shoot growth of oat and ryegrass (*Lolium multiflorum Lam.*) (Kato-Noguchi *et al*., 1998). Allelopathy can be used in weed management in two ways: by selecting an appropriate crop variety or incorporating an allelopathic character into a desired crop variety, and by applying residues and straw as mulches to grow an allelopathic variety in a rotational sequence that allows residues to remain in the field (Rice, 1995).

It is difficult to separate resource competition from allelopathy under field conditions. To overcome this problem, various laboratory screening techniques have been developed to measure allelopathy without the interference of resource competition (Macias, 1993; Moyer *et al*., 1997). *Plantago psyllium* L. is an important herb that has been used as medicinal plant for many centuries in South Asia and is now widely grown all over the world. *P. psyllium* can be grown under a wide range of agro-climatic conditions but it is mostly confined to arid areas due to its minimum water requirements (Zahoor *et al*., 2004). Psyllium is the common name used for several members of the plant genus *Plantago* whose seeds are used commercially for the production of mucilage. Herbalists use psyllium to help treat intestinal conditions such as colitis and dysentery, bladder problems, rheumatism, ulcers, and urinary tract infections. Psyllium was traditionally used in some cough remedies and is still used topically for the treatment of hemorrhoids, skin rashes, and insect bites and stings (Zahoor *et al*., 2004).

The primary chemical constituents of psyllium include mucilage (arabinoxylan), aucubine, protein, enzymes, xylose, galactose, oil (linolein, olein, palmitin), and starch. Psyllium seeds contain 10-30% mucilage. The laxative properties of psyllium are due to the swelling of the husk when it comes in contact with water. It passes through the small intestine undigested and lining the mucus membranes (demulsifying and lubricating) (Zahoor *et al*., 2004).

As field observations have suggested, *P. psyllium* probably exerts some allelopathic effects, although there was no evidence in the literature to support this assumption (Rahimi, 2007). Since allelopathy effects for *P. psyllium* have not been reported previously, the first step was to determine its potential as an allelopathic agent. For this reason, a bioassay was conducted in petri dishes to avoid soil and microbial interactions and in a controlled environment. If allelopathy was demonstrated at this level, further work could attempt to resolve interactions under greenhouse conditions to evaluate the effects of allelochemicals in natural environments. The objective of this research was to determine whether *P. psyllium* has allelopathic interaction with four major weeds species (wild barley, black mustard, pigweed and Lambsquarters).

MATERIALS AND METHODS

Laboratory Experiments

Preparation of extracts: Whole plants of *P. psyllium* were collected from field in 2005-2006 growing season and were dried for 2 days in an oven set at 70˚C. The dried tissues were ground in a mechanical grinder and dissolved in distilled water to concentrations of 20, 40, 60 and 80 g L^{-1}. Solutions were mixed for 12 h and centrifuged for 30 min at 1300 rpm and the supernatant was removed with a pipette. The lowest concentration of extract (20 g L^{-1}) was estimated to be similar to leachate produced by a plant residue in the field of about 2000 kg ha^{-1} dry matter, and the highest concentration of extract (80 g L^{-1}) to be equivalent to a field residue four times higher (8000 kg ha^{-1} dry matter) (Ahn & Chung, 2000). Supposedly, these values simulated the plant residue in a field after a low and high productive year, respectively. The bioassay was conducted as follows. Seeds of target species including pigweed, wild barley, mustard and Lambsquarters were sterilized, placed on double filter paper (Whatman No.2) in petri dishes and watered with 10 ml of aqueous extracts (0, 20, 40, 60 and 80 g L^{-1}) concentrations of shoot extracts). One hundred seeds were sowed in two petri dishes for each treatment. Treatments were arranged within the growth chamber in a completely randomized design. EC, pH and osmotic potential of aqueous extracts were measured on stock extracts 2 days after extraction (Chon & Boo, 2005). Osmotic potential of aqueous extracts was measured by thermocouple psychrometer (Boyer & Knipling, 1965; Chon & Boo, 2005). Germination was carried out in a germination maintained at regime of 12 h light at 25 °C and 12 h darkness at 15°C. The number of germinated seeds was counted every 2 days for 30 days. Germination rates were calculated according to the modification by Khan and Ungar (1997) of the Timson's germination velocity index: ΣG/t; where G is the percentage of seeds germinated after 2 days intervals, and t is the total time of germination (Vicente *et al.,* 2004). After 30 days, root and shoot length and root and shoot dry weight were measured.

Seed Recovery after Allelopathic Treatments

All seeds from the previous germination tests which did not germinate after 1 month at different aqueous extracts concentrations, were placed in new petri dishes with filter paper moistened with distilled water, and incubated under the same conditions for an additional 30 days. The recovery of germination was calculated following Pujol *et al.* (2000), using the relation:

The recovery of germination= {(a-b)/(c-b)}*100, where a is the total seed number germinated after being transferred to distilled water, b is the total seeds number germinated in aqueous solution and c is the total seed number which were sown in germination test.

Greenhouse Experiments:

1-Effects of Above Ground Dry Matter of *P. psyllium* on Target Plants Growth

This experiment was conducted in a greenhouse, from April to July 2006. Four weed species including redroot pigweed, wild barley, mustard and Lambsquarters were subjected to 3 different concentrations of shoot extracts of *P. psyllium* (0, 0.4 and 0.8 kg m^{-2}) and two watering regimes including (1) a well watered control (2) water withheld 30 days after sowing (DAS). The experiments were factorial arranged in completely randomized design with four replications. *P. psyllium* residues of 0.4 and 0.8 kg m^{-2} were estimated to be similar to the amount of *P. psyllium* residue after harvesting in the field. In total, 120 pots were filled with manure, sand, gravel and clay 2:3:3:2. Each pot was 20 cm in diameter and 30 cm in height. As drainage water might have allelopathic compositions, it was reversed to pot after watering. Two days before sowing, nitrogen (60 kg ha^{-1}), phosphorous (40 kg ha^{-1}) and potassium (40 kg ha^{-1}) were mixed with soil for each pot. Ten seeds were sown in each pot and were later thinned to 3 plants per pot. Water holding content was estimated by saturating the pots with water and weighing them after they had drained overnight. Pots were adequately watered at field capacity from emergence until the start of watering treatment. Height and dry matter of all target species were determined 90 DAS.

Effects of Simultaneous Growth of *P. psyllium* on Target Plants Growth

The experiment was conducted in a greenhouse. Four different weeds including pigweed, wild barley, mustard and Lambsquarters were grown with *P. psyllium* in the same pots simultaneously and separately as control in two watering regimes including (1) well watered control (2) withholding water after 30 DAS to 90 DAS. These experiments were conducted as factorial experiment arranged in completely randomized design with four replications. Seedlings were thinned to two plants of *P. psyllium* and two of the target plants at each pot at 30 DAS. Fertilizer application and watering treatment were the same as above. Height and dry matter of all target species were determined in 90 DAS. *P. psyllium* root residue had no significant effect on the above mentioned weed traits (data not shown).

Statistical Analysis

Germination and recovery of germination data were arcsin transformed before statistical analysis to ensure homogeneity of variance; a three two-way General Liner Model (GLM) ANOVA were used (SAS Institute Inc., 1989) for germination experiment, *P. psyllium* above ground dry matter effects experiment and *P. psyllium* simultaneous growth with target species experiment. Means were compared using Duncan multiple range test at $P \leq 0.05$.

RESULTS AND DISCUSSION

Effects of Aqueous Extracts on Weeds Seed Germination

The values of EC, pH and osmotic potential of *P. psyllium* extracts measured for each aqueous extraction ranged from 0.12 to 0.44 ds m^{-1}, from 6.1 to 6.85 and from 0.044 to 0.150 Mpa, respectively (Table 1). It was assumed that EC, pH and osmotic potential of *P. psyllium* extract did not affect seedling growth of target weeds, indicating that allelopathic effects of plant extracts override the effects of these parameters (Chon & Boo, 2005). Although it is often assumed that the response of seeds or seedlings to plant extracts is due entirely to allelopathy, the extract may also exert negative osmotic effects on the target plants (Bell & Koeppe, 1972). Osmotic potential less than 0.2 Mpa of PEG 8000 has little effect on root growth at the concentrations of extract normally used (Chon *et al*., 2004). The value of EC, pH and osmotic potential of *P.psyllium* extracts suggested that the reduction in root length can be explained, mainly by allelopathic effect from extracts. It was found that aqueous extracts significantly decreased seed germination, root and shoot elongation and root and shoot dry weight of target plants as compared with control (Table 2). Maximum inhibition was caused by 60 and 80 gL^{-1} of extracts in which germination reductions ranged between 25 and 68% (Figure 1). The degree of inhibition increased for all traits with increase in extract concentrations from 20 to 80 gL^{-1} of water. All extracts significantly reduced seedling root and shoot length which ranged between 51 to 83 and 17 to 59%, respectively (Table 2). It was observed that *P.psyllium* shoot extracts in 60 and 80 gL^{-1} of water had the greatest inhibitory effect on root and shoot dry weight which were ranged from 85 to 62%, respectively. On the average, root and shoot dry weight decreased by 25, 40, 48 and 42% in wild barley, black mustard, pigweed and Lambsquarters, respectively as compared with control. It seems that root length and dry weight have been significantly affected more than shoot length and dry weight. This may be attributed to the fact that roots are the first organs to come in contact with allelochemicals. Tawaha and Turk (2003) reported black mustard extracts reduced wild barley hypocotyl length, hypocotyl weight, radicle weight, seed germination, and radicle length by as much as 44, 55, 57, 63 and 75 %, respectively, when compared with a water control. Increasing the water extract concentrations from 4 to 20 g per 100 ml of water of all black mustard parts significantly increased the inhibition of wild barley germination, seedling length and weight.

The lowest shoot extract concentration did not affect the germination rate of target species seeds, but high concentration significantly decreased the germination rate

Table1: EC, pH and osmotic potential of aqueous shoot extracts of *P. psyllium* in four concentrations

extract concentration ($g L^{-1}$)	EC ($dS m^{-1}$)	pH	Osmotic Potential (Mpa)
Control	0.060	6.95	0.021
20	0.123	6.82	0.044
40	0.268	6.71	0.096
60	0.383	6.10	0.125
80	0.440	6.85	0.150

of all target species seeds. There were no significant differences in germination recovery rate and percentage in response to all extract concentrations (Table 2). Germination recovery rate was not affected by extracts at any concentration. For all treatments, reduction was greatest with 80 $g L^{-1}$ extract solution. Effects of *P. psyllium* shoot extract on shoot and root elongation and dry matter were variable among species. These extracts inhibited root and shoot elongation and dry matter production in

Lambsquarters, pigweed and mustard while the effects on wild barley were not significant (Figure 1). Eighty gL^{-1} of the extract concentration caused a marked reduction in root length of target species except, wild barley seedlings. The reduction rate was between 11 and 55% compared with control (Table 2). The degree of inhibition in each weeds species increased with increasing extract concentration. At the highest extract concentration, wild barley had the lowest reduction and pigweed had the highest reduction in all germination traits (Figure 1). It seems that *P.psyllium* extract concentrations have no significant effect on wild barley, while black mustard, pigweed but Lambsquarters was significantly affected in extract concentrations more than 40 gL^{-1} (Figure 1). Similar results were reported for high allelopathic activity of stem extracts of alfalfa (Guenzi *et al.*, 1964) and sorghum (Ben-Hammouda *et al.*, 1995).

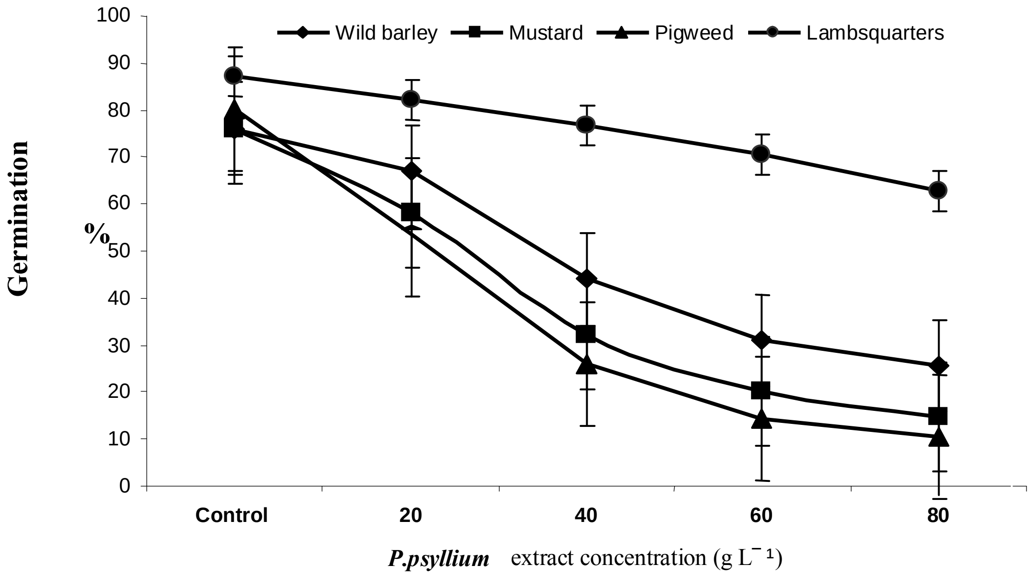

Figure 1: Effects of different *P.psyllium* extract concentrations on weed germination percentage. Bars represent standard errors.

Table 2. Mean comparison of *P. psyllium* shoot extract concentration on germination traits.

Main Effect		Seed germination (%)	Root length (cm)	Shoot length (cm)	Root dry weight (mg plant^{-1})	Shoot dry weight (mg plant^{-1})	Germination rate (day^{-1})	Recovery germination rate (day^{-1})	Germination recovery (%)
Extract concentration	g L^{-1}								
	Control	90 a*	6.1 a	5.37 a	89.3 a	65.50 a	0.38 a	0.36 a	
	20	68 b	2.9 b	4.4 b	50.63 b	54.52 b	0.41 a	0.34 a	84 a
	40	54 c	1.8 c	3.1 c	25.66 b	40.30 b	0.31 b	0.32 a	85 a
	60	43 d	1.3 d	2.1 d	23.09 c	30.26 c	0.25 c	0.35 a	77 a
	80	28 e	1.1 d	2.1 d	18.16 c	26.60 c	0.22 c	0.38 a	75 a
Weeds species									
	Wild barley	76 a	2.89 b	3.92 a	47.71 a	59.15 a	0.31 a	0.52 a	78 a
	Mustard	48 b	3.50 a	3.64 a	39.09 b	40.50 b	0.26 c	0.49 a	76 a
	Pigweed	42 b	2.38 c	2.42 b	26.95 c	26.90 c	0.21 c	0.46 ab	82 a
	Lambsquarters	45 b	2.82 b	2.40 b	28.14 c	27.74 c	0.34 ac	0.42 b	48 b

*Means within each column having the same letters are not significantly different (Duncan 5%)

Effects of *P. psyllium* above Ground Dry Matter on Weeds Growth

Growth of all target species, as indicated by plant height and dry matter per plant, 90 days after planting, were significantly reduced in pots with *P. psyllium* residue incorporation as compared with control (Table 3). *P. psyllium* residue incorporation of 0.4 and 0.8 kg m^{-2} reduced plant height and dry matter of target species, between 35 to 53% and 45 to 62%, respectively, compared with control (Table 2). *P. psyllium* residue incorporation under water stress condition caused a marked reduction in plant height and dry matter in all target species compared with well-watered treatment (Figure 2 and Table 3). *P. psyllium* residue incorporation at the rate of 0.4 and 0.8 kg m^{-2} reduced plant height and dry matter of target species, ranging between 20 to 44 %, 20 to 58%, respectively, compared with control in well watered treatment. In water stress condition, plant height and dry matter of target species were significantly reduced more in compared with control ranging between 32 and 65, 40 and 81%, respectively (Figure 2). It seems that drought can intensify the allelopathic effects of *P. psyllium* residue on all four target weeds (Figure 2). At the highest residue concentration, pigweed had the lowest and wild barley had the highest reduction in their height and dry matter as compared with control under both conditions (Figure 2). Tawaha and Turk (2003) reported growth of wild barley, as indicated by plant height and weight, was significantly reduced, when grown in soil previously cropped to black mustard compared with that cropped to wild barley and incorporation of fresh black mustard roots and both roots and shoots reduced wild barley germination, plant height and weight, when compared with a no-residue control. Effects of *P. psyllium* residue incorporation on height and dry matter were variable among target species, whereas 0.4 kg m^{-2} *P. psyllium* residue incorporation significantly inhibited dry matter in all target species except wild barley, while 0.8 kg m^{-2} *P. psyllium* residue incorporation significantly inhibited dry matter in all target species as compared with control in well-watered and water-stressed conditions. All target species dry weights were significantly affected by *P. psyllium* residue incorporation at 0.4 and 0.8 kg m^{-2} which was significantly lower than control in water stress condition as compared with well watered condition (Figure 2).

Effect of Simultaneous Growth of *P. psyllium* with Weeds

Height and dry matter of all target species were significantly reduced when they were simultaneously grown with *P. psyllium*. Dry matter of pigweed, mustard, wild barley and Lambsquarters were reduced by 46, 38, 20 and 44 % under well-watered conditions, compared with 61, 56, 42 and 62 % under water stress condition, respectively. Pigweed had the highest and wild barley had the lowest height and dry matter when growing simultaneously in the same pot with *P. psyllium* as compared with growing alone (control). Simultaneous growth of *P. psyllium* with target species under water stressed condition caused a marked reduction in their height and dry matter in Lambsquarters and pigweed. Wild barley and mustard simultaneous growth was not significantly different from control under well-watered regime, while this growth was significant by different for all target species at water-stressed condition (Figure 3). Simultaneous growth of *P. psyllium* with target species significantly inhibited dry matter in pigweed, black mustard and Lambsquarters in well watered and water stressed conditions, while wild barley was affected in water stressed condition as compared with its separate growth under the same condition (Figure 3).

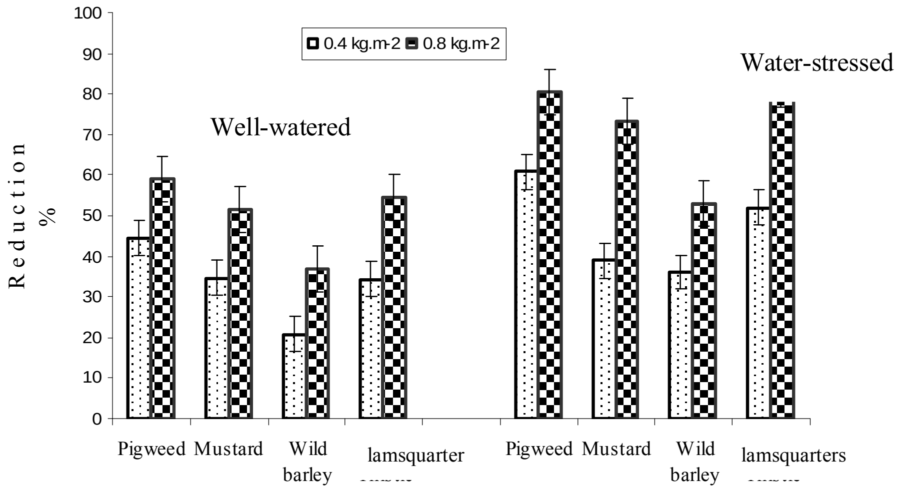

Figure2. Effects of different content of *P. psyllium* residue incorporation on weeds dry matter under well-watered and water-stressed conditions. Bars represent standard errors

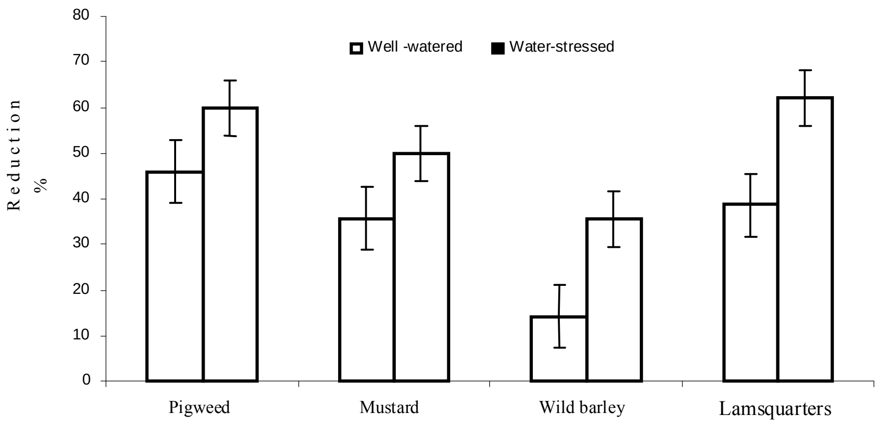

Figure3.Effects of simultaneous growth of *P. psyllium* with weeds on their dry matter under well-watered and water-stressed conditions. Bars represent standard errors

Table 3: Mean comparison of *P. psyllium* shoot residues and water regime on height and dry matter of four weed species.

	Shoot Residue (kg m^{-2})	Height (cm)	Dry Matter (g pot^{-1})
Shoot residues:			
	0	39.09 a*	9.09 a
	0.6	25.66 b	4.77 b
	1.2	18.63 c	3.40 b
Weeds:			
	Wild barley	34.06 a	6.68 b
	Mustard	24.31 b	7.96 a
	Pigweed	14.88 c	3.24 d
	Lambsquarters	16.59 c	5.14 c
Well- watered		26.34 a	7.30 a
Water-stressed		18.58 b	4.20 b

*Means within each column having the same letters are not significantly different (Duncan5%)

Table 4: Mean comparison of *P. psyllium* simultaneous growth with target species and water regime on height and dry matter of four weed species.

	Height (cm)	Dry Matter (g pot^{-1})
Control	27.67 a*	8.3 a
Simultaneous growth	22.09 b	5.5 b
Weeds		
Wild barley	31.81 a	8.36 b
Mustard	25.79 b	10.1 a
Pigweed	20.20 d	5.24 c
Lambsquarters	21.71 c	3.99 d
Well-watered	31.4 a	9.11 a
Water-stressed	18.34 b	4.73 b

Conclusion

This study demonstrated that *P. psyllium* displayed allelopathic activity and influenced emergence and growth of black mustard, pigweed, Lambsquarters and wild barley. Germination percentage was less sensitive than seedling growth to allelopathy, as it was illustrated in (Table 2). Shoot extract caused a slight delay in germination and final germination rates were affected by aqueous extract of *P. psyllium* (Table 2). Effects of *P. psyllium* shoot concentration on shoot and root elongations and dry matter were variable among species. The pattern observed suggests a high ability of *P. psyllium* to compete against weeds which can be an issue with potential agronomic consequences. The results indicate a different degree of sensitivity between target species, and suggest that if water resources are limited during plant growth, which is common in Mediterranean areas, poor germination percentage, root development and dry matter accumulation of weeds may restrict the ability of weeds to cope with a water deficit and impair their ability to compete with *P. psyllium*. This study is the first to demonstrate the allelopathic potential of *P. psyllium*, one of the most valuable medicinal plants in arid and semiarid areas, and the results can be the basis for establishment of long-term experiments to evaluate allelopathy under field conditions. These experiments will further help to verify the impact of allelopathy on cultivation and establishment of some drought and salt resistant medicinal plants in places where water restriction is an important issue. The inhibitory substances present in *P. psyllium* plants causing allelopathy could be used as a source of potential natural herbicide. However, they must first be identified and their modes of actions studied.

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