Original Research Article

Seed Germination and Seedling Emergence of Shepherd's needle *(Scandix pecten-veneris)* as Affected by Seed Weight or Burial Depth.

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ABSTRACT

Shepherd's needle (*Scandix pecten-veneris* L.) is a very common broadleaf weed of winter cereals in Greece. Knowing the behavior of the weed seeds in the soil may help in designing its management strategy. Field and laboratory experiments were conducted to evaluate the effect of seed weight or burial depth on seed germination and seedling emergence in 2008 and 2010. For seed weight effect on germination and seedling emergence light and heavy seeds were tested by Petri dish assay and in the field (sowing depth 4 cm). For burial depth study six depths- 2.5, 5, 7.5, 10, 12.5 and 15 cm - were examined in field trials made in two periods of time: 25 November and 15 March for two years. Percentage of seed germination, seedling emergence and mean emergence time were measured. Results showed that light seeds germinated better (74±2.2-95±2.2%) and earlier (20.5±0.64-31.0±0.45 days) than heavy seeds (34±3.2-58±5.1% and 25.4±0.57-33.8±0.46 days respectively). The burial depth influenced seedling emergence and mean emergence time (MET) in most cases. Low emergence percentage (1.7±1.1-33.8±7.2%) was found at the depth of 15cm and high at depth of 2.5, 5, 7.5 cm. Seeds sowed 15 cm deep had higher MET (27.0±0.9-55.1±1.1 days) than those sowed at 2.5 cm (20.9±0.9-41.6±0.5 days).

Keywords: seedling emergence; burial depth; seed weight; germination; Scandix pecten-veneris.

1. INTRODUCTION

Nowadays, concerns for environmental protection and the demand for less use of chemicals in agriculture have increased considerably. Scientists aim at more efficient, sustainable and economical alternative methods in weed control such as integrated weed management systems. However, the development of effective integrated weed management systems depends on a thorough understanding of weed seed biology [1]. Seedling emergence is a key event in determining the success of some weeds in an agroecosystem [2]

Shepherd's needle (*Scandix pecten-veneris)* is a very common annual broadleaf weed of Apiaceae family of winter cereals in Greece [3] and is controlled mainly by chemical methods. To improve its control where this weed is a problem, it is important and useful to know about its germination behavior. However, studies on factors affecting seed germination and emergence of this weed, such as seed weight and burial depth, are scarce. The weight of seed is known to play a major role in plant population dynamics and community structure [4]. Heavy seeds are considered to have better adaptation in competitive conditions [5] while lighter seeds show often high dispersal and much persistence in the seed bank [6]. Another factor that alters the weed seed emergence is burial depth and species-specific emergence responses to this have already been well-documented [7]. Generally, with increasing burial depth plant seed emergence decreases. Carefully chosen cultivations, tailored to the weed species composition in the reservoir of seeds in the soil, can alter seed behavior. This could be achieved by encouraging emergence and hence the premature depletion of the seed bank or by burying weed seeds to depths from which they cannot germinate and successfully emerge [8].

The objective of this research was to reveal the influence that seed weight or burial depth have on germination, seedling emergence, and mean emergence time of *Scandix pecten-veneris* thus, expanding our knowledge into managing the population of this weed species.

2. MATERIALS AND METHODS

2.1 Plant material

All needed weed fruits were harvested, in a random way, from the natural population that exists at the research farm Velestino, University of Thessaly, in the middle of July in 2007 and 2009 (in central Greece Shepherd's needle seedling emergence occurs from October to April [10] and maturity at the end of spring-May). Each flower produces a fruit (mericarp) consisting of two seeds which remain joined until they ripe. Each seed has a long scabrid needle-like appendage (beak) up to 6cm in length, which acts as a spring dispersal mechanism as the seed ripens. Only fruits with both well developed seeds were selected and stored in paper bags in laboratory temperature. The field experiments were carried out in a field where *Scandix pecten-veneris* had never been seen emerged before. The soil texture (depth 0-30 cm) was Sand 47%, Silt 30%, Clay 23% (Loam). Irrigation was applied after sowing and during the tests at any time it was necessary. For the laboratory tests, the amount of soil used was collected from the above field. For seed weight trials, selected fruits were divided into two classes, small-light and big-heavy, based on the size of the fruit. Seeds derived from them had mean weight 8±2.9 or 15±3.2 mg, made up the small-light class, and 35±3.6 or 53±4.3 mg made up the big-heavy class in 2008 or 2010 trials respectively. Heavy seeds had a beak about 1/3 to 1/4 bigger in length compared to light seeds and also bigger and heavier the lower reserve part. In seed burial depth tests, all the selected fruits were of medium size-weight (to avoid possible interactions between light or heavy seed weight and burial depth) and derived seeds had mean weight 25±2.1 mg.

2.2 Mean emergence time and seed weight trial

Forty seeds of each class were sowed in the field at a depth of 4 cm in a randomized complete block design (RCB), with plot size 0.5 x 0.5 m, block size (including space between plots) 1.2 x 0.5 m and four replications per treatment (weight class) on 24 March 2008 and 12 February 2010. The number of emerged seedlings (cotyledons completely unfolded) was recorded daily until no more seedlings were observed. Mean emergence time (MET) was calculated according to the equation of Ellis & Roberts [9] as follow:

$$MET = \sum Dn \,/\, \sum n$$

where n is the number of seeds, which were emerged on day D, and D is the number of days counted from the beginning of the test.

2.3 Seed germination and seed weight trial

The effect of seed weight on seed germination was evaluated in laboratory tests carried out in June 2008 and 2010. Twenty seeds of each heavy and light class (described above) were placed in a plastic 9 cm diameter Petri dish (5 dishes-replications per treatment-class, in completely randomized design). Then, dishes were filled with 50 mL of dry sieved soil (2 mm size sieve) and irrigated with 20 mL distilled water. The applied temperature and photoperiod inside the incubator was 15^{o}C/ dark 24 h. Temperature selection was based on previous laboratory experimentation of the authors on the effect of temperature on Shepherd's needle seed germination (unpublished findings). Petri dishes were left at these conditions for 35 days, then the germinated seeds were carefully removed, counted and the final germination percentage was calculated. Germination was recorded only once (end of experiment) and not daily to avoid the risk of breaking the radicles by digging into soil to check germinated seeds.

2.4 Seedling emergence and seed burial depth trial

Six burial depths were examined: 2.5, 5, 7.5, 10, 12.5 and 15 cm in field trials carried out during two different periods of time - 25 November and 15 March (sowing dates) for two years 2008-09 and 2010-11. Forty seeds were sowed at each depth in a RCB design with plot size 0.5 x 0.5 m, block size (including space between plots) 2 x 1.5 m and 4 replications per treatment-depth. Emergence of seedlings was recorded every day until no more seedlings were observed. Mean emergence time (MET) was also calculated as mentioned before. Soil temperature at a depth of 5 cm was recorded (1 record/30 min) by a data logger (type i-button Dallas Semiconductor) placed near the plots. Values on Fig. 1 showed that there was a difference in mean soil temperature between years 2008-09 and 2010-11 during these trials. In March trials the temperature was lower in 2010-11 than 2008-09 (difference of 0 to 5-6^{o}C) from sowing date (15 Mar.) to the end of April. In November 2010-11 test the mean soil temperature for about 10 days (10 to 20 Dec.) was very low and ranged between 1 to 5^{o}C.

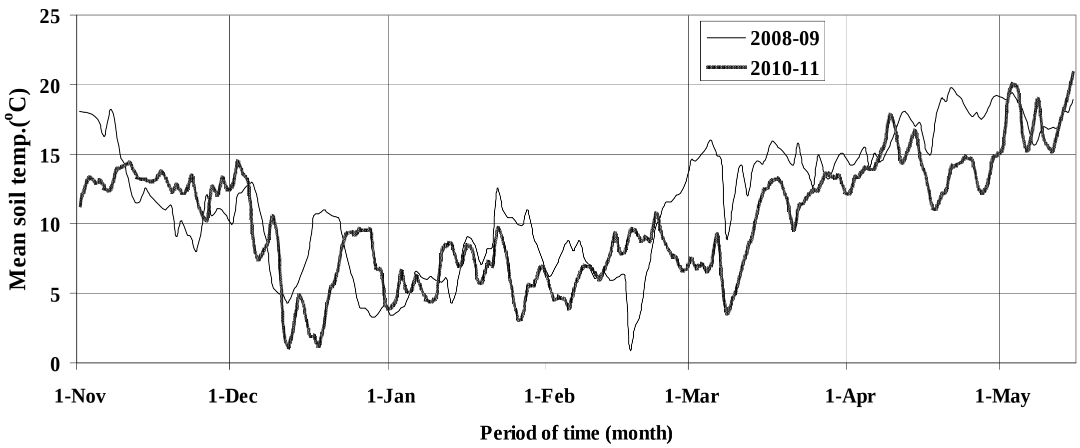


Fig. 1. Mean soil temperature at 5 cm depth in field trials 2008-09 and 2010-11

2.5 Statistical analysis

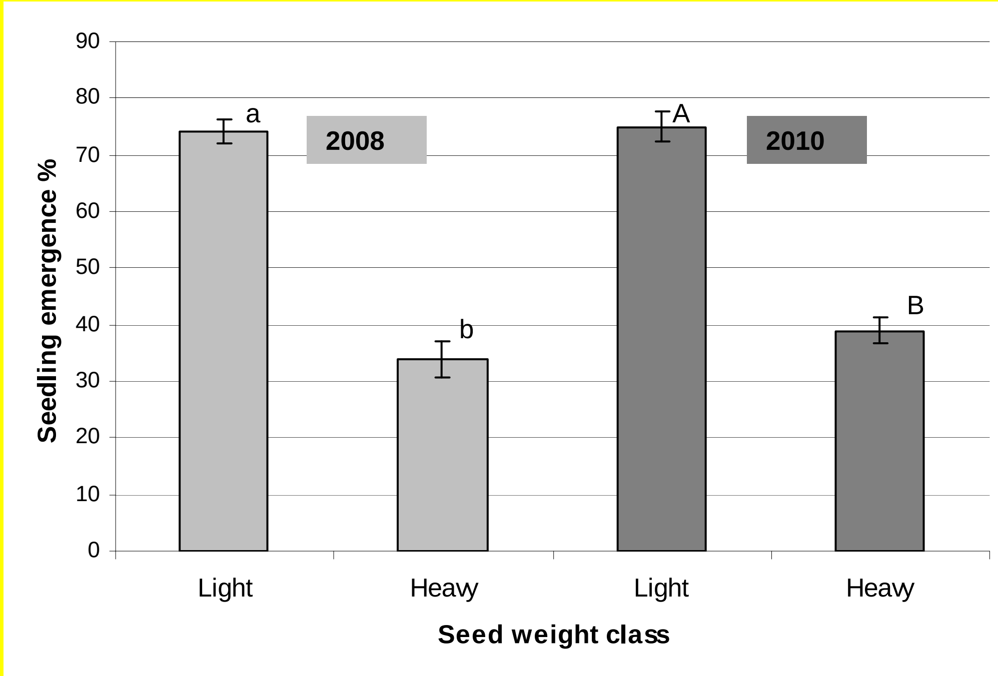
Data from trials which examined the effect of seed weight on germination and mean emergence time of Shepherd's needle were analyzed by an ANOVA. Regression analysis was performed for data from seedling emergence and seed burial depth tests. SPSS software (v13.0 for Windows) was used for all statistics. Where F test was significant treatment means were given with their ±SE.

3. RESULTS

3.1 Seed weight effect on seedling emergence – seed germination

Emergence of seedlings was found to be affected by seed weight significantly in both field experiments, in 2008 and in 2010 (Fig. 2 and Table 1). The final percentage of light seeds emerged (74±2.2-75±2.7%) was almost double than that of heavy seeds (34±3.2-39±2.3%).

In 2008 mean emergence time of light seeds was lower (20.5±0.64 days) compared to that of heavy seeds (25.4±0.57 days). Also in 2010 trial, light seeds emerged earlier (31.0±0.45 days) than heavy seeds (33.8±0.46 days) (Fig. 2).



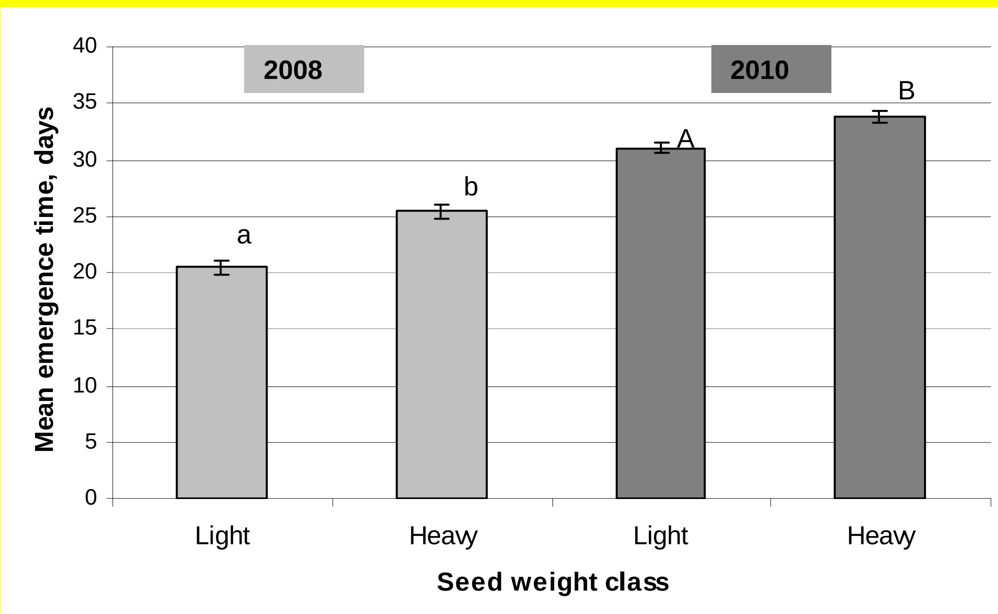


Fig. 2. Seedling emergence as % (above) and mean emergence time in days (below) of Shepherd's needle as affected by seed weight.

For each year, different letters above bars indicate significant difference at P =.05. Error bars are standard error of means of four replications

Table 1. Two-way ANOVA for the effect of seed weight on seedling emergence and mean emergence time (field trials 2008, 2010)

	Source of var.	Sum of Squares	df	Mean Square	*F-value*	*P*-value
Seedling emergence 2008	Treatments	3200	1	3200	738.462	.000
	Replications	164.5	3	54.833	12.654	.033
	Error	13	3	4.333		
	Total	3377.5	7			
Seedling emergence 2010	Treatments	2556.125	1	2556.125	78.751	.003
	Replications	55.375	3	18.458	0.569	.673
	Error	97.375	3	32.458		
	Total	2708.875	7			
Mean emergence time 2008	Treatments	48.020	1	48.020	21.631	.019
	Replications	2.260	3	0.753	0.339	.801
	Error	6.660	3	2.220		
	Total	56.940	7			
Mean emergence time 2010	Treatments	15.680	1	15.680	13.876	.034
	Replications	1.590	3	0.530	0.469	.725
	Error	3.390	3	1.130		
	Total	20.660	7			

Results derived from laboratory tests were similar to those of field experiments. Light seeds had a statistically significant higher level of germination percentage, 78±4.6-95±2.2%, than heavy seeds, 35±3.5-58±5.1% in both years 2008 and 2010 (Fig. 3 and Table 2).

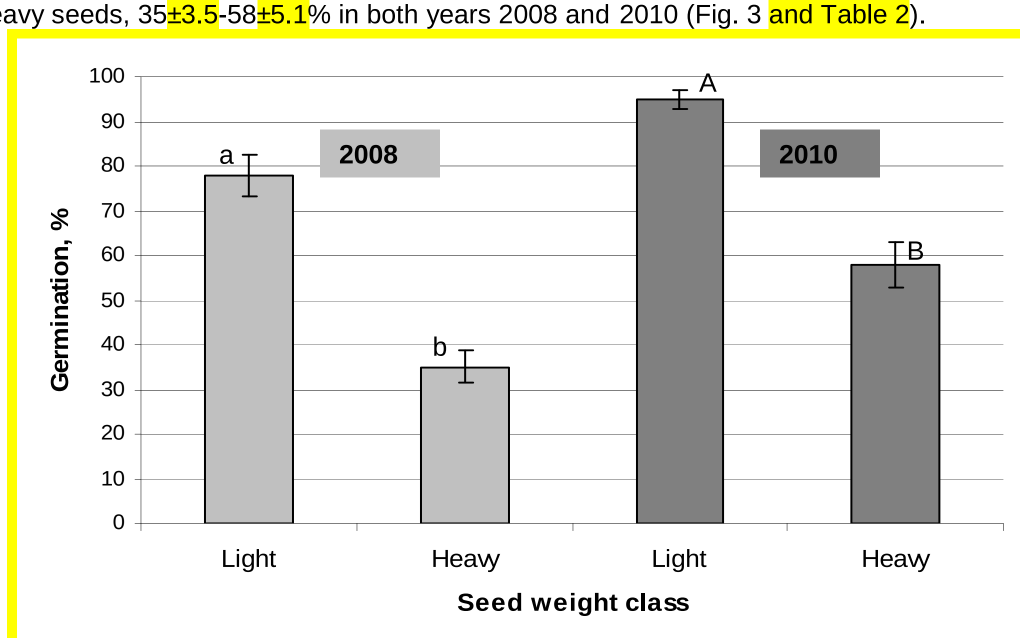


Fig. 3. Seed germination (%) of Shepherd's needle as affected by seed weight.
For each year, different letters above bars indicate significant difference at P =.05. Error bars are standard error of means of five replications

Table 2. One-way ANOVA for the effect of seed weight. on seed germination (laboratory trials 2008-2010)

	Source of var.	Sum of Squares	df	Mean Square	*F-value*	*P*-value
Germination 2008	Between Groups	4622.5	1	4622.5	54.38	.00
	Within Groups	680	8	85		
	Total	5302.5	9			
Germination 2008	Between Groups	3422.5	1	3422.5	43.46	.00
	Within Groups	630	8	78.75		
	Total	4052.5	9			

3.2 Seed burial depth effect on seedling emergence

Significant influence of burial depth on Shepherd's needle emergence was measured in 2008-09 and 2010-11 trials in both periods of time 25 November and 15 March (except Nov. 2010) as shown in Table 3. Emergence percentage generally decreased as burial depth increased. The lowest percentage 1.7±1.1 to 33.8±7.2% was found at the depth of 15 cm. Emergence above 70% was measured in all trials where seeds were sowed 2.5 to 10 cm deep in soil except in March 2011 test where the highest percentage (51.7±7.7%) was observed only in 2.5 cm depth.

Table 3. Seedling emergence (%) of Shepherd's needle as affected by burial depth in two periods of time in 2008-09 and 2010-11 trials

	2008-09		**2010-11**		
Depth (cm)	**25 Nov.**	**15 Mar.**	**25 Nov.**	**15 Mar.**	**Grand Mean**
2.5	86.3±5.2	75.0±5.4	68.3±9.6	51.7±7.7	**70.3**±7.2
5	90.0±4.6	81.3±4.7	65.0±10.8	41.7±6.6	**69.5**±10.6
7.5	85.0±2.0	87.5±4.3	80.0±7.4	45.0±9.4	**74.4**±9.9
10	72.5±12.7	78.8±5.5	70.0±5.4	26.7±6.6	**62.0**±11.9
12.5	51.3±14.3	61.3±2.4	66.7±1.2	10.0±5.0	**47.3**±12.8
15	26.3±10.5	33.8±7.2	66.7±3.1	1.7±1.1	**32.1**±13.4
Grand mean	**68.5**±10.2	**69.6**±8.0	**69.4**±2.2	**29.4**±8.2	**59.2**

Means in each column are followed by ± standard error

Part of data of Table 3 (six grand means) were also examined by regression analysis. The observed means plotted in Fig. 4, show that seeds in depth between 2.5 and 9 cm had an emergence of about 70% but deeper than 9 cm emergence decreased significantly. Regression analysis (Table 4) indicated that there was a significant (*P*= .004) quadratic trend with R^2 = 0.975 of seedling emergence response to burial depth whereas, these parameters were minimized for the linear trend (*P*=.021 and R^2=0.775)

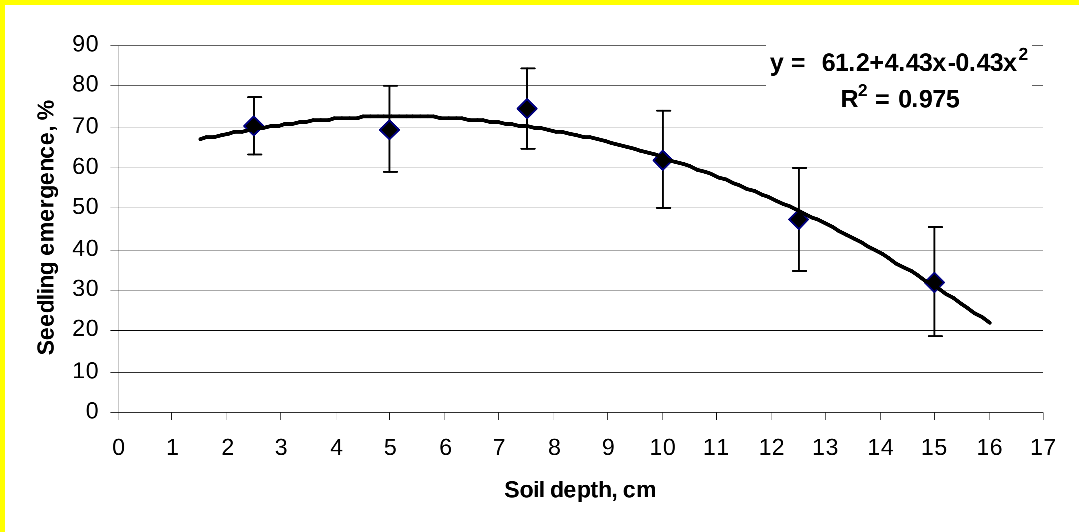


Fig. 4. Response curve of seedling emergence to burial depth according to regression equation. *Error bars are standard error of observed grand means.*

Table 4. Regression analysis for seedling emergence and burial depth

Equation	Model Summary					Parameter Estimates		
	R^2	***F*-value**	**df1**	**df2**	***P-value***	**Constant**	**b1**	**b2**
Linear	0.775	13.76	1	4	.021	86.267	-3.086	
Quadratic	0.975	58.764	2	3	.004	**61.2**	**4.434**	**-0.43**

Mean emergence time (MET) of Shepherd's needle was also affected by burial depth in all trials in both years. When seeds were sowed deeper in the soil, seedling emergence was delayed. MET in 15cm treatments (Nov: 54.1±3.4, Mar: 27.0±0.9 days) during the year 2008-09 was higher than that in 2.5 cm (31.8±2.1, 20.9±0.8 days, respectively) as shown in Table 5. Similar results were taken in 2010-11 study (Table 5).

Table 5. Mean emergence time (days) of Shepherd's needle as affected by burial depth in two periods of time in 2008-09 and 2010-11 trials

	2008-09		2010-11		
Depth (cm)	**25 Nov.**	**15 Mar.**	**25 Nov.**	**15 Mar.**	**Grand Mean**
2.5	31.8±2.1	20.9±0.9	41.6±0.5	25.4±0.7	**29.9**±4.5
5	29.0±1.8	20.1±0.6	47.8±1.9	30.7±2.0	**31.9**±4.5
7.5	35.6±0.9	21.7±0.3	48.1±1.8	35.6±1.2	**35.2**±5.4
10	39.5±5.7	24.7±0.9	48.5±1.3	35.4±3.0	**37.0**±4.9
12.5	45.0±4.5	23.7±0.4	50.5±1.2	32.3±0.8	**37.9**±6.0
15	54.1±3.4	27.0±0.9	55.1±1.1	47.0±1.2	**45.8**±6.5
Grand mean	**39.2**±3.8	**23.0**±1.06	**48.6**±1.8	**34.4**±2.9	**36.3**

Means in each column are followed by ± standard error

The six grand means of MET (Table 5) were also analyzed by regression and results (Table 6) revealed that there was a significant linear trend (*P*= .003 and R^2 = 0.91) of mean emergence time response to burial depth. Curve estimation showed also a significant quadratic trend (*P*= .015) with higher value of R^2 = 0.94 and this equation was used in Fig. 5

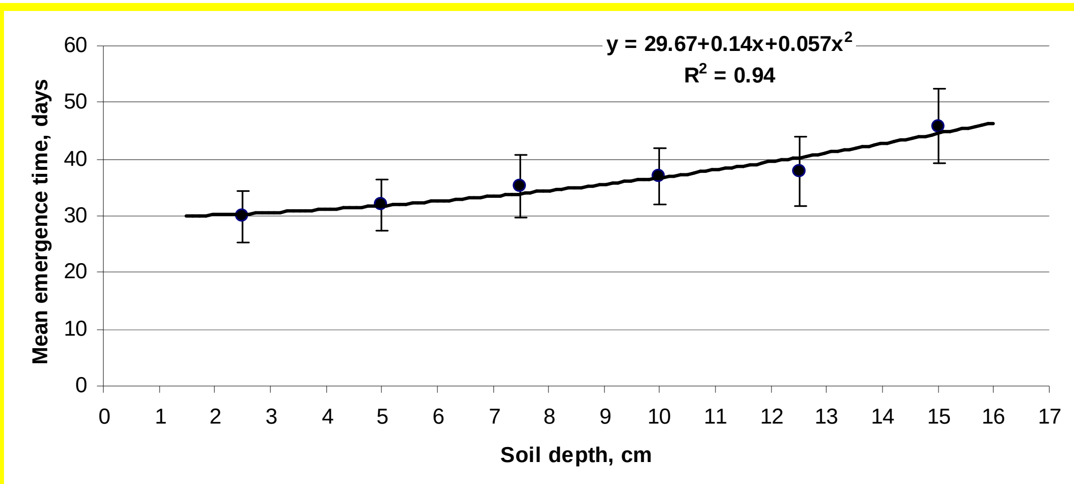


Fig. 5. Response curve of mean emergence time to burial depth according to regression equation. *Error bars are standard error of observed grand means.*

Table 6. Regression analysis for mean emergence time and burial depth

Equation	Model Summary					Parameter Estimates		
	R^2	***F*-value**	**df1**	**df2**	***P-value***	**Constant**	**b1**	**b2**
Linear	0.91	40.35	1	4	.003	26.353	1.135	
Quadratic	0.94	23.608	2	3	.015	**29.670**	**0.14**	**0.057**

4. DISCUSSION

Seed weight had a strong influence on Shepherd's needle seed germination and seedling emergence as derived from the experimental results. Larger-heavier seeds had significantly lower percentage of germination-emergence as compared to small-lighter seeds. Similar results to these findings have been observed for *Erodium brachycarpum* [11]. Contrary to this, it has been reported that heavier seeds of *Abutilon theophrasti* [12], *Lithospermum arvense* [13] and *Panicum racemosum* [14] had greater germination. However, for other species like *Ambrosia artemisiifolia* [15], *Dactylis glomerata* [16], *Andropogon tectorum* [17], *Rumex obtusifolius* [18] weight of seed had no any effect on their germination. Baskin and Baskin [19] suggested that this effect is species dependant and different seed sizes may have low, high or same germination percentage. Shepherd's needle light seeds had lower mean emergence time than heavy seeds and that means earlier germination in soil. Earlier germination of light seeds had also been found in *Pastinaca sativa* [20], *Cakile edentula* [21], *Erodium brachycarpum* [11], *Alliaria petiolata* [22] and *Senna obtusifolia* [23]. However, Stanton [24] found that seed size of *Raphanus raphanistrum* had no effect on emergence time. Stamp [11] attributed the earlier germination of small seeds to their greater access to water as a result of their higher surface to volume ratio. Hence, small seeds imbibed water faster and broke dormancy sooner. Susko and Lovett-Doust [22] stated that more rapid uptake of water, as well as thinner seed coats, may be responsible for the earlier loss of dormancy in small seeds of *Alliaria petiolata.* In a previous germination study of Shepherd's needle seeds carried out by the authors of this article (unpublished data) it was found that seeds of same size treated with a 98% sulphuric acid solution had higher germination percentage than those of seeds treated with distilled water. It means that sulphuric acid made the seed coats thinner, therefore quick water uptake become easier. So, thinner seed coat of light Shepherd's needle seeds may be one reason for their earlier germination compared to heavy seeds.

Many studies have reported the negative effect of increasing burial depth on emergence of several weeds species such as *Amaranthus spinosus and A. viridis* [1], *Phalaris paradoxa* [25], *Xanthium strumarium, Abutilon theophrasti, Pharbitis purpurea* [26], *Plantago lanceolata, Digitaria sanguinalis, Portulaca oleracea, Stellaria media* [27], *Ambrosia artemisiifolia* [15]. Burial depth also influenced Shepherd's needle emergence percentage and MET in our study. In most cases, as seeds were sowed deeper in soil the total emergence percentage decreased and MET increased. It seemed that the 12.5 cm was the critical depth (for the given soil type) for emergence of this weed, below which the seeds poorly could give seedlings and their emergence was too delayed. In the burial tests carried out during March, mean emergence time generally was smaller than that of November trials (independently of burial depth). Differences in mean soil temperature at this period of time could explain this.

Benvenuti and Macchia [28] suggested that affections of burial depth on weed seed germination could be attributed to variation of different soil's layer characteristics, water holding-capacity and gas environment conditions. Although no retrieval of buried seeds was made in this study to check germination afterwards, suicide seed germination or induced secondary seed dormancy could probably also has been another reason for low emergence at deep sowing depths. In November 2010 trial, statistically significant difference in total emergence percentage between treatments was not observed (although there was for MET measurements). During field experiment installation soil moisture was very close to saturation due to extended rainfall and the soil used to cover the buried seeds was not compressed properly as in the other trials in order to avoid excessive soil compaction. This may have altered soil's layer characteristics and, perhaps, the results that were observed.

5. CONCLUSION

To summarize, seed weight of Shepherd's needle influenced its germination and emergence characteristics, light seeds germinated and emerged quicker and in higher percentage than heavy seeds. It seems that the variable seed size is a biological trait that could allow this weed like other weed species to cope with the variable soil environment conditions found in different fields. Also, the fact that seedling emergence is limited and delayed considerably where seeds sit 12.5 cm or deeper below soil surface could make soil tillage at a depth of 15 cm or more with moldboard plough a useful tool in controlling this weed where it is a problem.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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