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Effect of Seed Type, Water Regime and Partial Cutting on the Growth Performance of *Emex* Spinosa (L.) Campd in Egypt

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Abstract: *Emex spinosa* (L.) Campd (Little jack) is an annual plant of family Polygonaceae, which is native to the Mediterranean region. It is a monoecious species, develops aerial and subterranean propagules; the subterranean propagules are large, heavy, and hardly spinescent, positioned at the base of the plant near its root neck, do not disperse and germinate out of the dead mother plant. The aerial propagules are smaller, spiny, develop at the nodes of the above ground stem and are freely dispersed. The present study aims at evaluating the state of *Emex spinosa* to adapt different environmental conditions in Egypt, assessing the adaptive significance of the production of subterranean and aerial seeds with different sizes and estimating the compensation of this plant to different intensities and frequencies of stimulated grazing. Two experiments were carried out in the Experimental Farm of Faculty of Science, Tanta University, Tanta, Egypt. In the first experiment, three factors which affect the seed germination and seedlings growth, were tested: seed type (subterranean seeds, aerial heavy and aerial light seeds), water regime (wet, medium and dry) and partial cutting (0 % and 50 %). The second experiment was carried out using the aerial heavy seeds subjected to medium water regime and three cut levels (25, 50 and 75 %). The results indicated that the subterranean seeds gave the highest percentage of seed germination compared with the aerial heavy and light seeds. All organs of the plants generated from the subterranean seeds and grown under the wet gave the highest growth parameters regime. The uncut treatment gave the highest values of most of the vegetative and reproductive characters at different growth stages. 25 % cut treatment had the highest vegetative and reproductive characters for all organs. These results were discussed and compared with the other related studies.

Key words: aerial seeds,subterranean seeds,partial grazing, seed germination,water stress

INTRODUCTION

Emex spinosa (L.) Campd (Little jack) is an annual plant of family Polygonaceae, which is native to the Mediterranean region. It was found in two varieties: *E. spinosa* var. *spinosa* and *E. spinosa* var. *minor* Zoh. et Waisal [11]. In Egypt, it is commonly known as Dirs el-Agooz [56]. Its distribution in Egypt includes Nile Delta, Eastern Desert, Western Desert and its Oases, Mediterranean Coast and Sinai. It plant inhabits fields, orchards, gardens, waste ground and canal banks[12].

Emex spinosa (L.) Campd. is a monoecious species, only female flower are obviously dimorphic. It develops aerial and subterranean propagules; the subterranean propagules are large, heavy, and hardly spinescent, positioned at the base of the plant near its root neck, do not disperse and germinate out of the dead mother plant [23,65]. The aerial propagules are smaller, spiny, develop at the nodes of the above ground stem and are freely dispersed. The perianth of the aerial propagules is thick, very hard and woody, that of the subterranean ones is thinner and softer. Four to eight large subterranean achenes with large embryos and endosperm are produced, while the plant is still in the rosette stage. If growing conditions permit, about two weeks, later, small, spined aerial achenes are produced, with enhanced dispersal characteristics. They occur at successive nodes up the stems, which grow out from the rosette. They occur in much greater numbers than the subterranean achenes under favorable growing conditions, but only the latter may be produced under dry conditions [22].

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Growth and reproductive ability of *Emex spinosa* in relation to temperature and photoperiod have a wider range of possible environments than its present distribution. The subterranean achenes are less dormant, have a higher viability percentage, germinated at a faster rate, less temperature dependent in germination and produce larger seedling than aerial achenes. Subterranean achenes germinate equally well in light or dark, but aerial achenes have a strong light requirement [64]. The germinating propagules develop a rosette of leaves. The first female flower appears about a month after germination in the axils of the rosette leaves; where the male flowers are formed on an inflorescence arising out of the center of the leaf rosette. This constitutes the first flowering [22]. After pollination, when the fruits formed in the axils of the rosette leaves start to develop, the contractile fleshy taproot pulls the young fruits into the soil where they develop into the mature subterranean propagules. The aerial propagules develop much later from sessile female flowers The present study aims at: 1- evaluating the state of *Emex spinosa* to adapt different environmental conditions in Egypt (e.g. growing in field crops as a weed, and in the desert as drought escaping), 2- assessing the adaptive significance of the production of subterranean and aerial seeds with different sizes, and 3- estimating the compensation of this plant to different intensities and frequencies of stimulated grazing (i.e. partial cutting at different phenological stages.

MATERIALS AND METHODS

Aerial and subterranean seed samples of *Emex spinosa* were collected from Al-Arish, North Sinai. The aerial seeds were divided into two categories depending on the weight of seeds: the seeds of weight $\geq$ 0.2 mg were called aerial heavy seeds, and the seeds of weight < 0.2 mg were called aerial light seeds. Seeds were weighted and soaked in distilled water for 48 hours, and then put in Petri dishes on one layer of Whatman filter paper. The germinated seeds were transplanted in pots of 12 cm diameter and 20 cm height. Two experiments were carried out in the experimental farm of Faculty of Science, Tanta University, Tanta, Egypt. In the first experiment, the effect of three factors on the seed germination and seedlings growth, were tested: seed type (subterranean seeds, aerial heavy and aerial light seeds), water regime (wet, medium and dry) and partial cutting (0 % and 50 %). For each treatment, 6 pots were used, in each pot three individuals were planted, the total numbers of the experimental units (i.e. pots) were 108 pots. The water regime was carried out as follows: irrigation every two days (wet), irrigation every four days (medium) and irrigation every twelve days (dry); while the water regime and partial cutting were carried out as follows: irrigation every two days and cut level 50 % (wet), irrigation every four days and cut level 50 % (medium) and irrigation every twelve days and cut level 50 % (dry). The experimental design followed the complete random block design. The second experiment was carried out on the aerial heavy seeds subjected to a medium water regime and three cut levels (25, 50 and 75 %). For each cut level, 6 pots were used, in each pot three individuals had been planted. The total number of the experimental units (i.e. pots) was 18 pots. The experimental design followed the complete random design.

For each treatment, the following measurements were carried out for each individual in each pot at each time: number of leaves (leaf $plant^{-1}$), leaf length (cm $leaf^{-1}$), leaf width (cm $leaf^{-1}$), number of male and female flowers (flower $plant^{-1}$), number of subterranean and aerial seeds (seed $plant^{-1}$), root weight (g $plant^{-1}$), stem weight (g $plant^{-1}$), leaf weight (g $plant^{-1}$) and seed weight (g $plant^{-1}$). The significance of variation in the population variables such as number of leaves, root length, leaf length, leaf width, number of subterranean seeds, female and male flowers, aerial seeds, weight of subterranean and aerial seeds, fresh and dry weights of roots, stems and leaves in different stages in relation to the different treatments (seed type, water regime and partial cutting) were assessed using three-way analysis of variance technique (ANOVA-3) in the first experiment, and one way analysis of variance (ANOVA-1) in the second experiment. The applications of these techniques were according to SPSS program [7].

RESULTS AND DISCUSSION

Subterranean seeds gave the highest germination percentage (83.9 %) compared with the aerial heavy seeds (75.5 %) and the aerial light ones (67.5 %). The germination in all seed types increased exponentially during the first 6 days, then increased gradually till the 12th day, after that there was no more germination till the end of the experiment (Fig. 2). The germination percentage of the subterranean seeds was 8.5 % in the 1st day, 71.5 % in the 6th day and 83.3 % in the 12th day; while the aerial heavy seeds had 0.3 %, 63.6 % and 75 %; and the aerial light seeds had 3.5 %, 62.3 % and 67.3 % in the same days, respectively.

Number of leaves, leaf length and width with time of the seedlings originated from the three seed types, under the three water regime and partial cutting treatments increased gradually with time (Table 1). The seedling from subterranean seeds had the highest average number of leaves, leaf length and width (11.1 leaf, 13.4 and 3.4 cm, respectively), but those of aerial light seeds had the

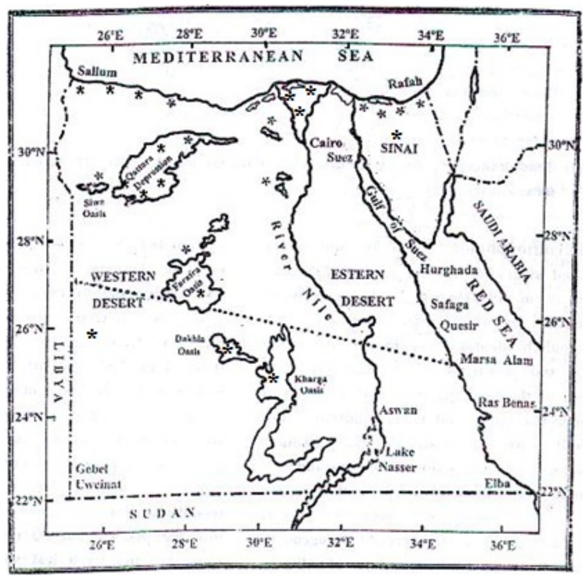

Fig. 1: Distribution of *Emex spinoisa* L.Campd. in Egypt (*).

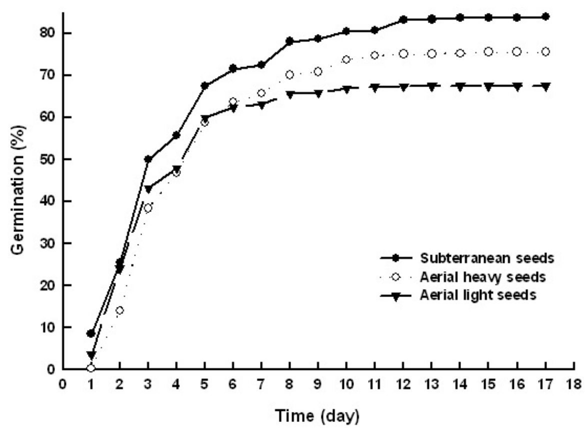

Fig. 2: Effect of seed type on seed germination of *Emex spinosa.*

lowest (9.9 leaf, 10.6 and 2.7cm, respectively). Regarding the water regime, the plants growing under wet regime had the highest number of leaves, leaf length and width (7.5 leaf plant^{-1}, 12.5 and 3.3 cm, respectively) compared with the plants growing under medium regime (5.1 leaf, 10.3 and 2.6 cm, respectively). In general, the uncut treatment had higher values than that of the cut one. The uncut treatment had the highest number of leaves (8.8 leaf), leaf length (12.4 cm) and leaf width (3.1 cm), while the cut one had the lowest values of the same variables (8.4 leaf, 11.4 and 2.9 cm, respectively). For most measuring times, the three-way analysis of variance indicated that the number of leaves is significantly different according to seed type, water stress and partial cutting (Table 1). On the other hand, and in most cases, leaf length and width are significantly different according to the different treatments of the three factors, but not for their interactions.

During the vegetative stage, the plants generated from the subterranean seeds had the highest root length (8.8 cm), leaf number (6.2 leaf) and leaf dry weight (0.2 g), but the aerial light seeds had the lowest values (7.6 cm, 5.4 leaf and 0.1 g, respectively). On the other hand, the wet regime had the highest of leaf number (6.5 leaf) and leaf dry weight (0.2 g), while the medium one had the highest root length (8.6 cm). The dry weight of root had the same value (0.1 g) for the three seed types and water regime treatments (Fig. 3).

During the flowering stage, the plants generated from the subterranean seeds had the highest root length, leaf number , root and leaf dry weights

Table 1: Overall effect of the seed type, water stress and partial cutting on the leaf variables of Emex spinosa. *: P≤ 0.05, **: P≤ 0.01 and ***: P≤ 0.001 according to three-way analysis of variance (ANOVA-3).

Treatment		Time (day)							
		30	45	60	75	90	105	120	135
a- number of leaves (leaf plant-1)									
Seed type (s)	A. small	3.1	4.6	5.3	5.9	6.8	7	8.2	9.9
	A. large	2.9	4.2	4.8	5.8	6.9	7.5	8.7	10
	Sub.	3.6	4.8	5.1	5.9	7.1	7.7	9.2	11.1
Water stress (w)	Wet	3.6	5.4	6.4	7.4	9.5	13.2	15.6	12.1
	Medium	3.1	4.2	4.6	5.4	6.3	8.1	6.3	7.5
	Dry	3.1	4.2	4.3	4.8	4.6	3.8	4.4	5.1
Partial cutting (c)	Uncut	3.3	4.6	5.6	6.2	7.4	8.1	9.4	8.8
	Cut	3.3	4.6	3.5	4.5	5.2	5.6	6.9	8.4
F-ratio	Fs	7.5***	3.2*	0.3	0.1	0.4	6.3**	8.8***	4.6*
	Fw	5.9**	11.5***	15.0***	14.0***	27.7***	83.0***	103.3***	49.9***
	Fc	-	-	44.6***	26.0***	21.7***	31.1***	28.2***	4.3*
	Fsxw	-	-	0.5	0.4	1.8	9.7***	12.7***	6.5***
	Fsxc	-	-	0.2	0.4	1.1	1.7	1.7	1.8
	Fwxc	-	-	0.1	0.6	1.3	33.7***	28.2***	7.5***
	Fsxwxc	-	-	0.7	0.8	2.7	2.3	3.0*	3.2*
b- leaf length (cm leaf-1)									
Seed type (s)	A. small	4.3	5	5.1	5.6	6.3	8.8	9.4	10.6
	A. large	4.9	5.8	5.8	6.6	7.3	9.2	10.4	11.4
	Sub.	5.7	7	7.2	8.3	9.7	11.6	12.4	13.4
Water stress (w)	Wet	5.5	6.5	6.5	7.3	8.1	10.7	11.9	13.1
	Medium	5.3	6.4	6.5	7.3	8.1	10.7	11.3	12.5
	Dry	4.4	5.4	5.6	6.3	7.2	9.1	9.8	10.3
Partial cutting (c)	Uncut	4.8	5.8	6.6	7.3	8.1	10.4	11.2	12.4
	Cut	6.1	7.2	4.8	5.9	7.1	9.5	10.5	11.4
F-ratio	Fs	28.4***	3.2*	22.5***	29.3***	40.0***	32.8***	34.9***	23.7***
	Fw	13.0***	11.5***	9.1***	5.8**	2.1	5.8**	7.6***	14.6***
	Fc		-	50.7***	22.6***	6.5	3.5	3.1	2.8
	Fsxw	-	-	0.5	1.6	0.9	1.2	1.5	1.2
	Fsxc	-	-	2.7	1.9	0.8	0.2	0.3	0.8
	Fwxc	-	-	0.5	0.2	1.3	1.9	2.5	1.3
	Fsxw&c	-	-	0.3	0.2	0.2	0.7	1.0	1.9
c- leaf width (cm leaf-1)									
Seed type (s)	A. small	0.9	1.2	1.3	1.4	1.7	2	2.5	2.7
	A. large	1	1.3	1.4	1.7	1.9	2.2	2.6	2.9
	Sub.	1.4	1.7	1.8	2.1	2.4	2.8	3.1	3.4
Water stress (w)	Wet	1.2	1.5	1.6	1.9	2.2	2.6	3	3.3
	Medium	1.2	1.5	1.6	1.8	2.1	2.5	3	3.3
	Dry	1.1	1.3	1.5	1.7	1.8	2.2	2.3	2.6

Table 1:Continue

Partial cutting (c)	Uncut	1.1	1.4	1.6	1.8	2.1	2.5	2.8	3.1
	Cut	1.3	1.6	1.3	1.6	1.8	2.3	2.6	2.9
F-ratio	Fs	83.4***	66.8***	59.5***	44.0***	42.6***	27.5***	5.7**	12.5***
	Fw	6.1**	8.1***	6.0**	2.5	4.8**	4.5*	8.1***	10.0***
	Fc	-	-	55.4***	20.4***	6.1*	0.8	0.1	2.2
	Fsxw	-	-	0.9	1.2	0.9	1.2	1.1	0.8
	Fsxc	-	-	1.0	0.7	0.0	0.5	0.7	0.1
	Fwxc	-	-	0.4	1.6	2.3	0.5	1.9	1.1
	Fsxwxc	-	-	0.9	0.9	1.0	1.4	0.6	1.5

(12.1 cm, 13.1 leaf, 0.2 and 1.6 g). In contrast, the plants generated from the aerial light seeds had the lowest number of leaves and leaf dry weight (12.0 leaf and 1.6 g). The plants generated from the aerial heavy seeds had the lowest root length (10.9 cm) and root dry weight (0.1 g). Generally, the wet regime had the highest values of all vegetative and reproductive attributes except the root length (Fig. 3). During the fruiting stage, the plants generated from the subterranean seeds had the highest root length (18.6 cm), number of leaves (13.9 leaf), and root, stem and leaf dry weights (2.5 g each); while the plants generated from the aerial light seeds had the lowest (17.5 cm,12.9 leaf plant^{-1}, 0.3, 0.3 and 2.0 g, respectively).

During the flowering stage, the plants generated from the subterranean seeds had the lowest number of male and female flowers (29.9 and 28.1 flower), while the plants generated from the aerial light seeds had the highest number of subterranean seeds, male and female flowers and (6.1 seed, 34.7 and 33.1 flower). On the other hand, during the fruiting stage the plants generated from the aerial heavy seeds had the highest number of aerial seeds (14.4 seed) and aerial seed weight (0.2 g). In addition, the plants generated from the aerial light seeds had the highest number of subterranean seeds (13.5 seed). Generally, the wet regime had the highest values of all vegetative and reproductive attributes compared with the medium regime during fruiting stage (Fig. 4). The uncut treatment led to higher root length (19.4 cm), numbers of leaves (16.3 leaf), subterranean seeds (13.4 seed), aerial seeds (14.9 seed), and weights of aerial seed (0.2 g), dry root (0.5 g), dry stem (0.4 g) and dry leaf (2.4 g) compared with the cut treatment (16.5 cm, 10.4 leaf, 10.6 seed, 10.2 seed, 0.1 g, 0.4 g, 0.3 g and 2.0 g, respectively) (Fig. 5).

The results indicated a gradual increase in number of leaves, leaf length and width with time for the three cut levels (Fig. 6). The plants under 25 % had the highest number of leaves, length and width (11.3 leaf, 11.9 cm and 3.2 cm), while that under 75% had the lowest (6.7 leaf, 11.1 cm and 3.0 cm). The number of leaves ranged from 2.7 leaf after 60 days for plants under 75 % cut level to 11.3 leaf plant^{-1} after 135 days for plants under 25 % cut level. Similarly, the leaf length had the same trend with different cut levels: it ranged from 6.3 cm to 11.9 cm and leaf width ranged from 1.5 cm to 3.2 cm.

During the fruiting stage, the plants under 25 % cut treatment had the highest number of leaves (9.2 leaf), subterranean seeds (5.2 seed) and aerial seeds (13.2 seed), and the highest weights of aerial seeds (0.2 g), and dry leaf (0.6 g); but the lowest root length (7.1 cm). On the other hand, those under 75 % had the lowest number of leaves (5.2 leaf) and aerial seeds (7.2 seed), and the highest weights of aerial seeds (0.1 g), and dry leaf (0.3 g); but the highest root length (8.0 cm), subterranean seed number (4.7 seed) and subterranean seed weight (0.2 g). The plants under 50 % cut treatment had the smallest stem dry weight (0.04 g each). The one-way analysis of variance indicated that the number of leaves and leaf dry weight were significantly different according to the cut levels ($P \leq 0.05$) (Table 2).

During the vegetative stage, the analysis of variance indicated no significant variation in the growth attributes in relation to seed type and water regime, except the leaf dry weight in relation to seed type ($P \leq 0.01$). During the flowering stage, the root length, number of leaves and female flower number had significant variation in relation to water regime ($P \leq$ 0.01, 0.01 and 0.05, respectively). On the other hand, during the fruiting stage, the dry weights of the plant organs (root, stem and leaf) are highly significant according to seed type ($P \leq 0.001$) and the interactions between seed type and other treatments (Table 3). Number of leaves and subterranean seeds, weights of subterranean seeds, root, stem and leaves had significant variation in relation to water regime. Also, the number of leaves, dry weights of root and leaf had significant variation in relation to partial cutting and the interactions between partial cutting and seed type.

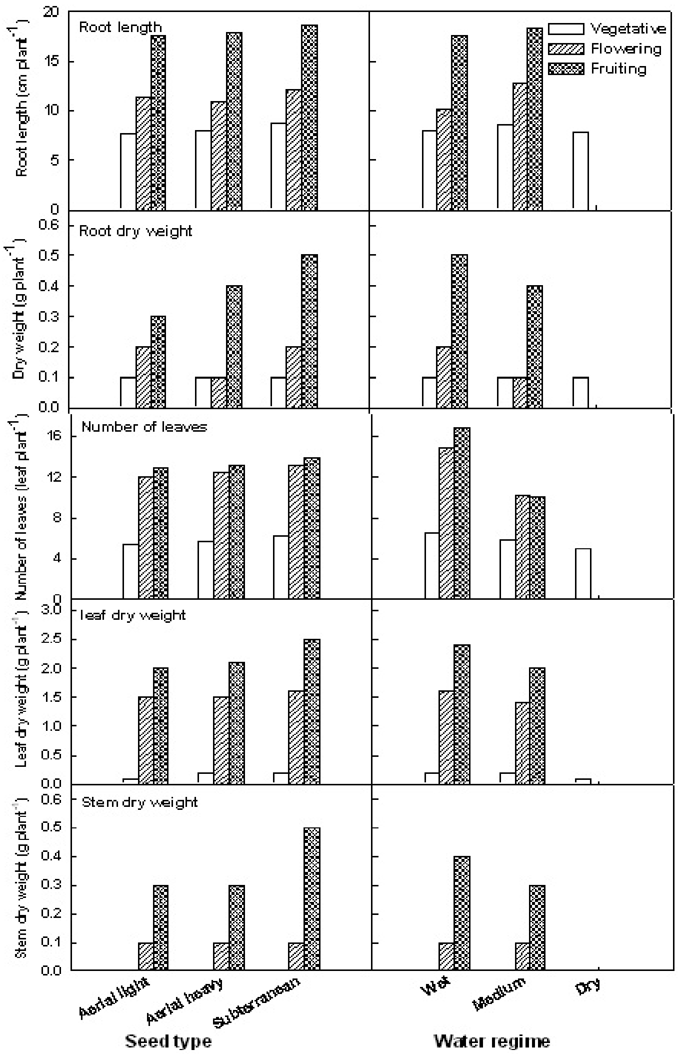

Fig. 3. Effect of seed type and water regime on the vegetative organs of *Emex spinosa*.

Discussion: Germination characteristics are important in establishment, and the presence of two or more mechanisms of germination may increase the number of safe–sites a species can exploit [27]. The ecological importance of these mechanisms is shown in the adaptation of the subterranean seeds of *Emex spinosa* for persistence *in situ* of the species since they are left in safe-sites occupied by their parents. The results of the present study indicated that, the subterranean seeds gave the highest germination percentage compared with the aerial heavy and light seeds. These results are similar to those obtained by Weiss [64]. and Evenari *et al.*[21]. who reported that the subterranean seeds of *Emex spinosa* were less dormant, had a higher percentage of viability, and germinated at a faster rate than the aerial seeds. The perianth of subterranean propagules is thin and soft, while the perianth of the aerial propagules is thick, hard and woody. These advantages of subterranean seeds, especially in habitats and seasons where time and energy become critical resources, would reinforce the interference effects. The germination site of the subterranean propagules is predetermined by the position of the mother plant. It is therefore, a comparatively safe-site because it limits to the uncertainly factor inherent in the pattern of desert rainfall and uncertainly factor associated with random distribution [21]. The mother plant has succeeded to establish itself in a run on microsite and the chances are that because of the microtopography- runoff will collect there also in later years. On the other hand, the small aerial propagules are telechoric and consequently very few germinate in the immediate vicinity of their mother plant. Also, they had a strong light requirement for germination [64]. It was interesting to compare the germination percentage in the present study with the other studies on the same species:

Seed type	Present study	Evenari *et al.* (1977)	Weiss (1980)
Subterranean. seeds	83.9	80	90.0
Aerial seeds	71.5	80	70.1

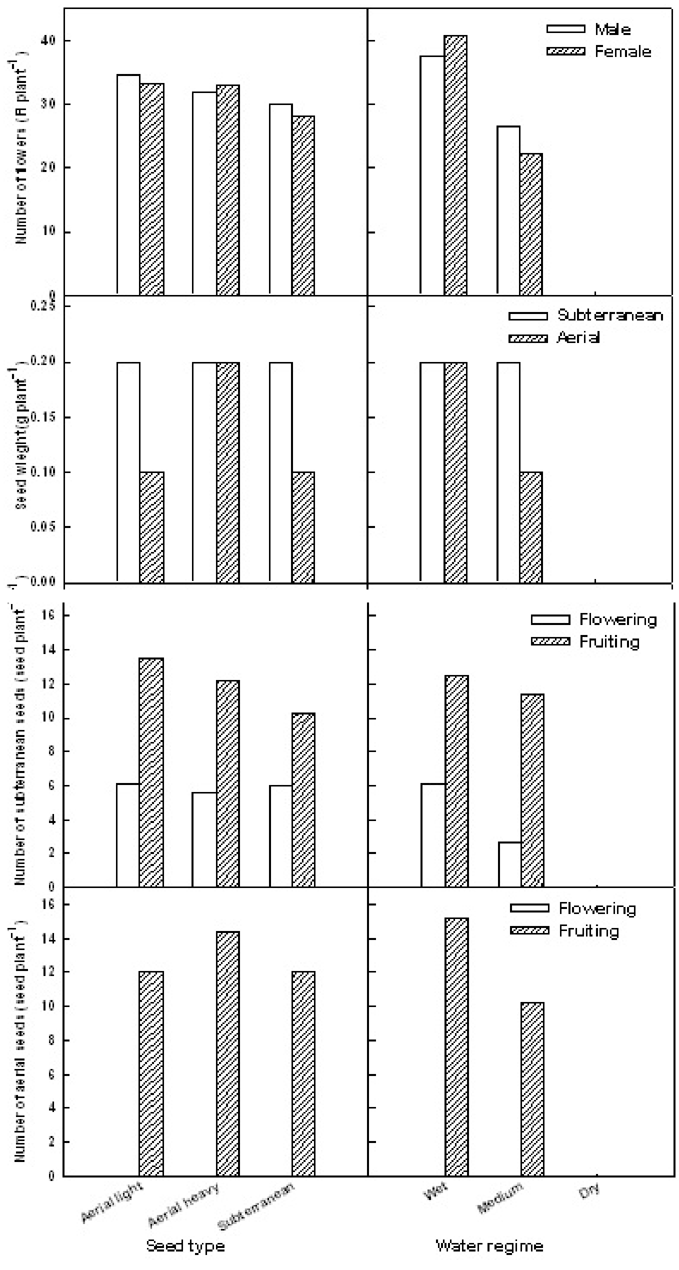

Fig. 4: Effect of seed type and water regime on the reproductive organs of *Emex spinosa*

In the present study, the seed germination rate was highest during the first 6 days in the subterranean seeds, which indicates that heavier seeds (presumably having larger food reserves) germinated better and faster. A similar observation was made by Tripathi and Khan [60]. on the subtropical forest tree species *Quercus dealbata* and *Quercus griffithii*, and Arunachalam *et al.* [5]. on *Mesua ferrea*. Greater plant length and dry mass in the seedlings generated from the subterranean seeds are attributed to larger carbon reserves that confer a competitive reproductive advantage on plants. In addition, it leads to the hypothetical conclusion that the ecological fitness of *Emex* species under study is linked to greater maternal carry-over effects. In another sense, the following could be viewed as some of the indicators of the increased tolerance of *Emex spinosa*

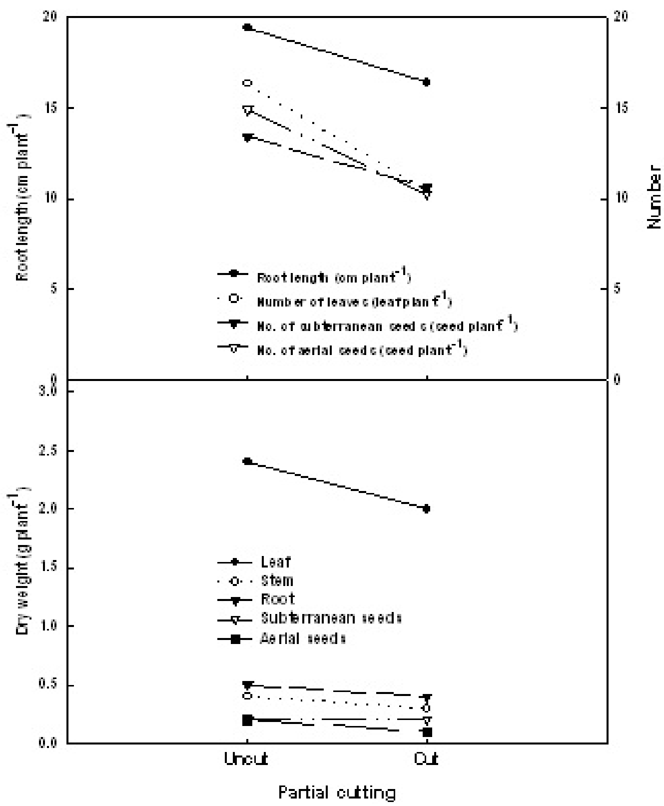

Fig. 5: Effect of partial cutting on the growth variables of *Emex spinosa* at the fruiting stage.

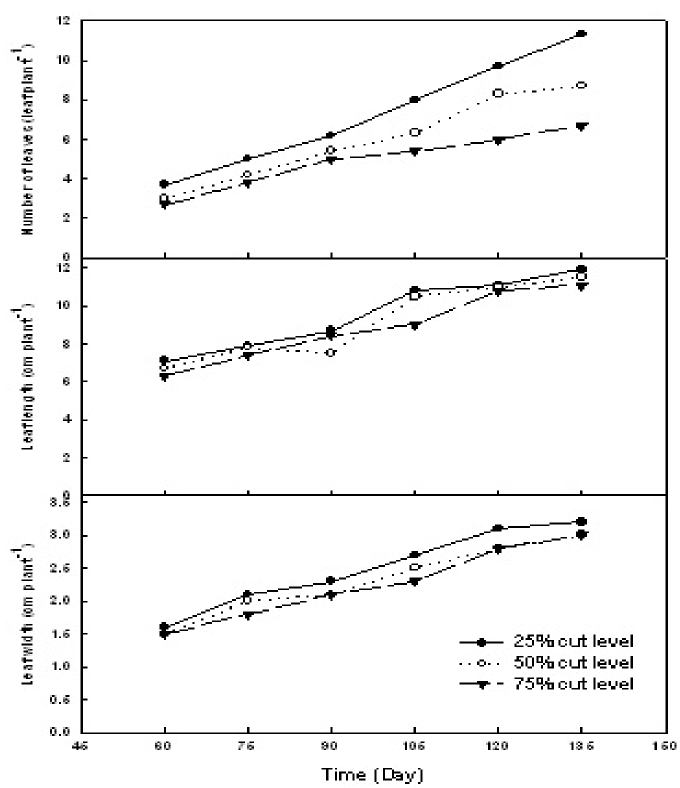

Fig. 6: Effect of three cut levels (%) and time after sowing (day) on leaf variables of *Emex spinosa*.

Table 2: Overall effect of the three cut levels on the growth variables of *Emex spinosa* during the fruiting stage. *: P ≤ 0.05 according to one way analysis of variance (ANOVA).

Variable	Cut level			F-Value
	25%	50%	75%	
Root length (cm $plant^{-1}$)	7.1	7.1	8.0	0.4
Number of leaves (leaf $plant^{-1}$)	9.2	8.7	5.2	4.0*
Number of Subterranean seed (seed $plant^{-1}$)	5.2	5.2	4.7	0.6
Number of Aerial seed (seed $plant^{-1}$)	13.2	13.2	1.7	1.7
Leaf dry weight (g $plant^{-1}$)	0.6	0.4	0.3	5.4*
Stem dry weight (g $plant^{-1}$)	0.1	0.04	0.1	0.3
Root dry weight (g $plant^{-1}$)	0.1	0.1	0.1	1.6
Subterranean seed weight (g $plant^{-1}$)	0.1	0.1	0.2	0.1
Aerial seed weight (g $plant^{-1}$)	0.2	0.1	0.1	0.8

Table 3: F-values of the overall effect of seed type (Fs), water regime (Fw) and partial cutting (Fc) on growth variables of *Emex spinosa* of different stages. *: P≤ 0.05, **: P≤ 0.01 and ***: P≤ 0.001 according to three-way analysis of variance (ANOVA-3)..

Variable		Fs	Fw	Fc	Fsxw	Fsxc	Fwxc	Fsxwxc
Vegetative stage								
Root length (cm plant-1)		1.2	0.6		0.5			
Number of leaves (leaf plant-1)		0.7	2.8		0.5			
Dry Weigh (g plant-1)	Root	2.3	0.5		0.4			
	Leaf	6.8**	1.2		0.8			
Flowering stage								
Root length (cm plant-1)		0.6	7.7**		1			
Number of leaves (leaf plant-1)		0.3	7.3**		1.7			
Dry Weight (g plant-1)	Root	0.1	1.7		0.4			
	Leaf	0.2	3.2		0.6			
	Stem	0.5	1.6		1.5			
No. of subterranean seed(seed plant-1)		0.4	0.5		0.9			
No. of female flowers(flower plant-1)		0.2	5.1*		0.1			
No. of male flowers(flower plant-1)		0.2	0.1		0.2			
Fruiting stage								
Root length (cm plant-1)		0.9	1.5	18.4***	8.0***	3.1*	0.2	1.4
Number of leaves (leaf plant-1)		0.3	47.4***	37.4**	2.8	3.9*	12.7***	1.1
Dry Weight (g plant-1)	Root	19.9***	24.2***	25.5***	21.2***	30.5***	5.7*	15.3***
	Leaf	11.4***	12.4***	16.5***	12.8***	12.1***	9.6**	10.1***
	Stem	10.3***	8.4***	1.2	1.7	10.8***	2.5	4.2*
No. of subterranean seed(seed plant-1)		1.2	5.0*	0.6	1	0.7	0.3	0.5
No. of aerial seeds(seed plant-1).		0.2	2.6	2.7	1.5	0	1.1	1.6
Subterranean seed weight (g plant-1)		0	5.0**	2.4	0.4	0.7	1.1	0.1
Aerial seed weight (g plant-1)		0.3	2.7	3.7	1.1	0.3	1.6	1

seedlings: 1- possession of subterranean seeds with sufficient resources for initial seedling establishment, 2- relatively greater allocation of vegetative biomass in favour of leaf components, and 3- low root/shoot ratio [26]. Similar conclusion was made by Arunachalam *et al*. [5].

The aerial achenes are however adapted for dispersal, since they are small, spiny and float easily in water. Their dispersal in time to open or pioneer sites requires a degree of dormancy related to the degree of intermittent availability of such sites [12]. The greater dormancy of aerial compared with subterranean seeds is compatible with this concept. On the other hand, increased seed size may increase the percentage of germinating seeds and the rate at which germination occurs [2,50]. Seed size also affects growth and survivorship in the seedling phase of the life cycle, where heavier seeds usually germinate faster than lighter seeds of the same species [61]. This may be due to the ability of heavy seeds to provide higher energy and nutrients for greater germination capacity [62]. Also, an increase in the size of seedlings with increased size or weight of seeds has been reported in a variety of agricultural species such as: soybeans [17] wheat [4] lettuce [48] tall fescue [25] and subterranean clover [6]. Seed size and seedling vigor are similarly correlated for a number of naturally occurring species [3].

Empirical studies have shown that seed size can affect seedling survival, growth and establishment [30,67,29,41.20,40]. Harper *et al.* [27] claimed that seed size is such an important life-history trait for life prospects of seedlings that stabilizing selection, canalizes it to be quite constant within species. This view was later questioned when field studies showed is considerable variation in seed size at the within-individual, within-population and within-species levels [42,61]. For all seed types, the present results indicated that there is a gradual increase in number of leaves, leaf length and leaf width of *Emex spinosa* with time. The plants originated from the subterranean seeds had the highest average number of leaves, leaf length and leaf width compared with the aerial heavy and light ones. These results are in agreement with the study of Evenari *et al.* [21] on the same species. Seed size affects growth and survivorship in the seedling phase of the life cycle [50] Various measures of growth vigor (including germination rate, cotyledon area, leaf area of seedlings, rate of shoot growth and rate of increase in biomass) were positively correlated with each other, as well as with seed size [64].

The effect of water stress, in the present study, had the same trend as the seed type, where there is a gradual increase in the number of leaves, leaf length and leaf width with the time for all levels of water stress. The wet regime had the highest number of leaves, leaf length and leaf width compared with the medium and dry regimes. These results are in accordance with the study of Evenari *et al.* [21]. on the same species. The depression of vegetative growth of *Emex spinosa* plants under drought treatment could be resulted from a reduction in chlorophyll content and consequently the plant photosynthesis efficiency (see the studies of [1,13]). Under dry conditions, this has advantages because of the increased moisture availability leading to a better chance of germination. Any water that is available may be channeled into the space left by desiccation and shrinkage of the roots of the dead parents which themselves may still contain some moisture. In fact, under such conditions, plants of *Emex spinosa* do emerge mostly in clumps from the subterranean seeds [23].

The present study indicated that the uncut treatment had higher values of growth variables than the cut treatment. These results are in accordance with those obtained by Lehtila and Syrjanen [36] on *Melampyrum* species. The importance of leaves may be the result of either the photosynthates they produce or their transpiration [47] The defoliation will differ in its effects according to the initial leaf area, the severity of the defoliation and the climatic conditions. If the leaf area is higher than that of the optimum canopy for dry matter production, then any defoliation reducing the leaf area towards the optimum will increase the rate of dry matter production and, more especially, the rate of leaf production. On the other hand, if the leaf area is reduced from the optimum canopy to a lower leaf area, the rate of leaf and dry matter production will be heavily curtailed.

During the vegetative stage, the present study indicated that the subterranean seeds had the highest root length, number of leaves, fresh and dry weight of leaves as compared with the aerial seeds. Evenari *et al.* [21] demonstrated that, the small seedlings were derived from the aerial propagules, while the large seedlings were derived from the subterranean propagules. Also, the present study comparable to the study of Lehtilä and Ehrlén [35] on *Primula veris* that has shown a positive relationship between the seed size and seedling performance, i.e. a larger seed size is associated with higher seedling establishment [40].

During the flowering and fruiting stages of *Emex spinosa*, the present study indicated that the seedlings originated from the subterranean seeds had the highest root length, number of leaves, fresh and dry weight of leaves compared with aerial heavy and light seeds. The seedlings derived from the subterranean propagules had larger root system, cotyledons and leaves. On the other hand, the number of female and male flowers had an opposite trend to that of the number of leaves for all seed types. The plants originated from the light aerial seeds had the highest number of female and male flowers compared with those originated from the aerial heavy and subterranean seeds. In general, heavier seeds tend to yield larger and more vigorous seedlings [64], but studies with results opposite to this generalization exist [19]. Heavy seeds also have been shown to provide seedlings with a competitive advantage in relation to seedlings from light seeds [19,68,29], but there are other results not confirming the competitive disadvantage of low seed weight [15]. Several investigators have found that the advantages derived from high seed weight are limited to early stages of seedling growth and do not contribute to increased reproductive output [15,34].

One of the objectives of the present study is to investigate the effects of drought stress on dry matter production and plant performance during soil drying. During the vegetative stage, the wet regime led to the highest average number of leaves and fresh weight of leaf compared with the medium and dry regimes. The depression of vegetative growth of *Emex spinosa* plants under drought treatment could be resulted from a reduction in chlorophyll content and consequently efficiency of the plant photosynthesis [1,13]. During the flowering and fruiting stages, the present study indicated that the wet regime had the highest number of leaves, subterranean seeds, female and male flowers, leaf and stem fresh weights, leaf and root dry weights.

In the present study the increased root to shoot ratio under drought stress during the flowering and fruiting stages in the present study is in accordance with the study of Liu and Stützel [37]. on *Amaranthus* species. It is well known that, as the soil water availability is limited, plant growth is usually decreased. This was previously considered to be due to turgor loss in expanded cells. However, the studies have shown that stem and leaf growth may be inhibited at low water potential despite complete maintenance of turgor in the growing regions as a result of osmotic adjustment. This suggests that the growth inhibition may be metabolically regulated, possibly serving an adaptive role by restricting the development of transpiring leaf area in the water-stressed plants [51]. Drought stress, in the present study, did not affect root to shoot ratio during vegetative stage. This result is in agreement with the finding of Sobrado and Turner [53] who recorded that a similar trend in well-watered and droughted plants of *Helianthus petiolaris* and *Helianthus annuus*. Conservative shoot growth during drought could be advantageous, especially if root growth is promoted, but genotypes that sustain shoot growth during drought may have greater marketability, which is particularly important for leafy vegetable crops. A high root dry mass ratio could reflect an increased capacity of water uptake, thereby maintaining the shoot in a well-hydrated condition [10].

Among the stages of *Emex spinosa* growth, as indicated in the present study, leaf area (represented by leaf length and width) per root dry mass was least affected by drought stress. This could be ascribed to its low stomatal conductance [37] which enables the plants to control water status restrictively when water uptake by the root was curtailed as the soil dried. Previous studies have shown that water use efficiency of *Emex spinosa* is related to the morphological characteristics of leaves. Wright *et al.* [67], proposed that under field conditions, and moderate temperatures, there is a close negative relationship between water use efficiency and specific leaf area. In the present study, water use efficiency was negatively correlated to specific leaf area over the plant under well-watered conditions. This relationship between water use efficiency and specific leaf area may be due to the fact that plants with low specific leaf area (thicker leaves) have high nitrogen content and more mesophyll cells per unit area, both leading to higher rates of CO_2 assimilation, and consequently, higher biomass production [59]. Drought stress, which reduces specific leaf area, may also increase water use efficiency. This is probably part of an adaptive mechanism to reduce leaf area and transpiration [18].

Generally, the present study indicated that the shoot growth is more sensitive than root growth to soil drying. These results agree with that of Kirnak *et al.* [31,32]. Shoot growth can be inhibited prior to the development of decreased water potentials in the aerial parts of the plant [49]. This response may be attributed to the action of non-hydraulic regulatory signals from those roots exposed to dry soil, while at the same time the remainder of the root system supplies adequate water to maintain the shoot water status [52]. On the other hand, the present study showed significant reduction in the fruit yield of the water-stressed plants, compared with unstressed plants. A number of other workers have reported similar effects of water stress on fruit yield and/or biomass reduction for a range of other agricultural and horticultural crops including sorghum [16], tomato [57], peach [58], strawberry [31], and eggplants [32].

During the fruiting stage, the uncut treatment had higher root length, number of leaves, subterranean seeds, and aerial seeds, aerial seed weight, root, stem and leaf fresh weights, root, stem and leaf dry weights than the cut treatment. These results are in accordance with those of Lehtila and Syrjanen [36], who concluded that, the leaf removal of *Melampyrum* could decrease the plant growth and reproduction. The importance of leaves may be the result of either the photosynthates they produce or their transpiration [47]. However, the present results showed that seed size is adjusted according to the availability of resources, as a part of a plastic response to environmental variation [39,28]. Seed size increase could thus be a part of the plant strategy to tolerate herbivory [55,54].

The 25% cut treatment had the highest number of leaves, leaf length and leaf width compared with 50% and 75% cut treatments during the vegetative and fruiting stages. Several authors have reported that defoliation-induced yield reduction was caused by reduced seed or pod number per area [14,10]. However, other studies indicated that the seed size, as the yield component, is affected by defoliation [43]. Earlier defoliation studies have indicated that soybean yield is affected by the extent of defoliation and the time at which defoliation occurred during the growth of the crop. Defoliation during the vegetative growth period of soybean showed little effect on yield because of the potential of the soybean canopy to accelerate leaf growth rate during its vegetative growth period. Pickle and Caviness [46] reported no yield loss when 100% defoliation was imposed at mid vegetative development. Weber [63] indicated a 20% yield loss when complete defoliation was done between vegetative and full bloom stages. They reported only a little effect on yield when 50% defoliation was applied during the same period. Several authors reported different mechanisms of recovery by soybean after defoliation had occurred: e.g. delayed lower leaf senescence after defoliation [33] and reduced transpiration by the canopy after defoliation [44]. Yield compensation after 75% defoliation at full-bloom period was reported under favorable conditions of good rainfall [24]. On the other hand, defoliation will differ in its effects according to the initial leaf area, the severity of defoliation and the climatic conditions [45].

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