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Impact of Grazing Intensity and Human Disturbance on the Population Dynamics of *Alkanna orientalis* Growing in Saint Catherine Mountains, South Sinai, Egypt

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Abstract: The present study aimed to investigate the effect of grazing intensity on dynamics of *Alkanna* populations that grow in Saint Catherine mountains. Seventy plots (4x4 m^2) were selected to represent variation of *Alkanna orientalis* population under different degrees of grazing and human disturbances. The results showed that four main groups of *Alkanna* population can be recognized. These groups differ significantly in the percentage of coverage, average of flower buds, flowers, fruits, plant height and grazing intensity and soil organic content.
Insignificant variation in the soil moisture content, natality, and mortality were indicated. The impact of grazing and fencing was seen through the comparison between fenced and unfenced populations. The results revealed that the vegetation cover, average of plant height and reproductive organs (floral buds) increased for unfenced population as compared to fenced while percentage of dryness and average number of fruits was higher in fenced population. The results of natality and mortality showed that the four groups of *Alkanna* populations have different rates of natality occurring at third and fourth groups of populations (heavily grazed), whereas the mortality rate of first group was very high as compared to a very low rate in the fourth group.

Key words: Natality, mortality, fencing, *Alkanna orientalis*, grazing impact.

Introduction

To the local Bedouins of Saint Catherine, grazing is considered as one of the main jobs traditionally practiced by young girls. In the last ten years, nevertheless, grazing has become as one of the main threats to natural vegetation of Saint Catherine area, (Moustafa and Ktopateck, 1995). Continuous overgrazing, over cutting, and uprooting of plants used for fuel purposes and trading have resulted in the paucity of trees, shrubs and the disappearance of pastoral plants.

Overgrazing has also caused a significant change in plant communities marked with the appearance of some species, indicative of overgrazing such as *Alkanna orientalis, Peganum harmala, Phlomis aurea* and *Fagonia mollis* (Moustafa and Kamel, 1996).

Boraginaceae is a relatively large family comprised of varied annuals, perennial herbs, shrubs and trees. About 30 genera are used as ornamentals and trees. Several species are also used for medicinal purposes or as dyes or herbs, (Heywood, 1978). Members of this family are widely distributed throughout temperate and subtropical areas of the world but they are less frequently observed in cool, temperate and tropical regions. Fifty two species of Boraginaceae pertaining to 19 genera are recorded in Egypt, in which 27 species from 17 different genera are observed in Sinai.

In Saint Catherine area six genera are distributed commonly in wadis and slope habitats, (for example, *Alkanna sp., Trichodesma sp., Paracaryum sp., Anchusa sp., Echium sp.*, and *Myosotis sp.*; Zaghloul, 1997). Two species of *Alkanna* are recognized in Egypt, namely *A. orientalis* and *A. tinctoria*. In fact, most of the previous studies about *Alkanna* were concerned mainly with insects-plant pollination interactions. For example, Gilbert *et al.* (1996) studied the spatial difference in phenotypic reproductive characters of *Alkanna orientalis* flowering in early spring and its pollinator *Anthophora pauperata*. Wolff *et al.* (1997) were concerned mainly with population sub structure and its relation to pollinators behaviour. The aim of present study is to investigate the effect of grazing intensity on the dynamics *of Alkanna* population, as well as changes in soil conditions and *Alkanna* population caused by grazing and fencing, respectively.

Materials and Methods

Selection of plots: The area of (Saint Catherine) was subjected to a great variation of grazing, human disturbance, cutting, uprooting plants and soil disturbance due to activities of Bedouins and tourists. Four wadis were selected to survey different populations of *Alkanna:* wadis of El-Arbaie'en, Garagnia, Deir and Tala'a, (Fig.1).

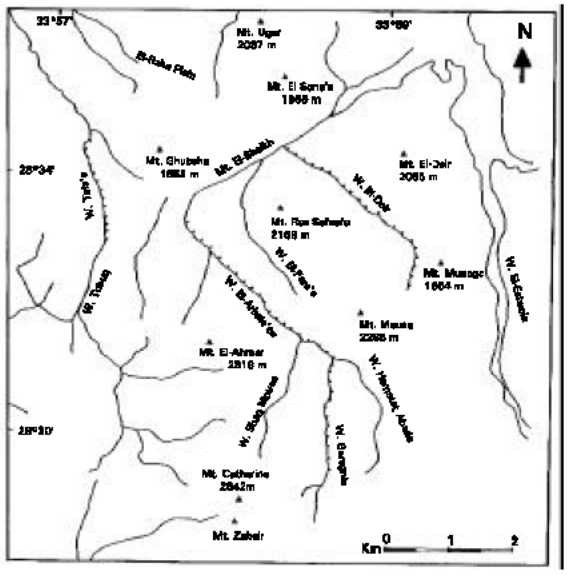

Fig. 1: Map of the study area (Saint Catherine mountains)

Seventy (4x4 m^2) plots were located as permanent plots representing variation of *A. orientalis* population under different degrees of grazing and human disturbance. From these 70 plots, 47 plots were located at W. El-Arbaie'en (of which 33 unfenced, and 14 fenced), seven plots located at W. Garagnia (unfenced), eight plots at W. Talah (unfenced), and

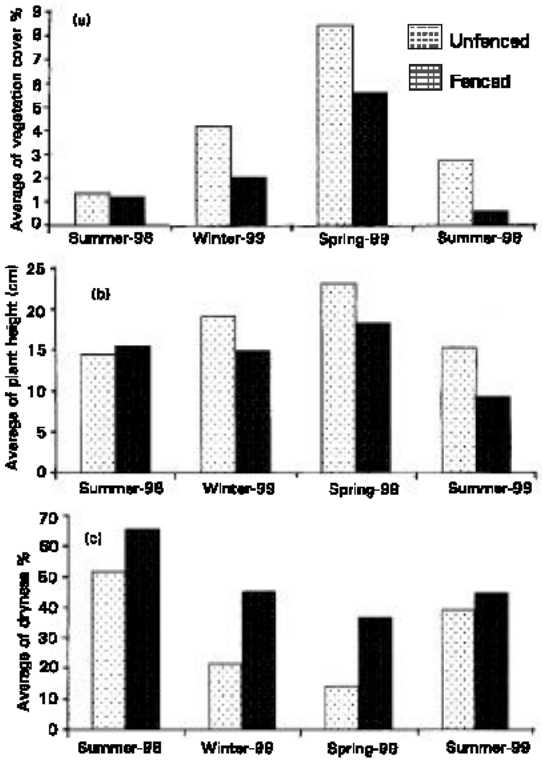

Fig. 2: Comparison between fenced and unfenced population of *Alkanna orientalis* showing the average of (a): vegetation cover (b) plant height, and © percentage of dryness in *Alkanna* vegetation during four main seasons of the year 1998 to 1999.

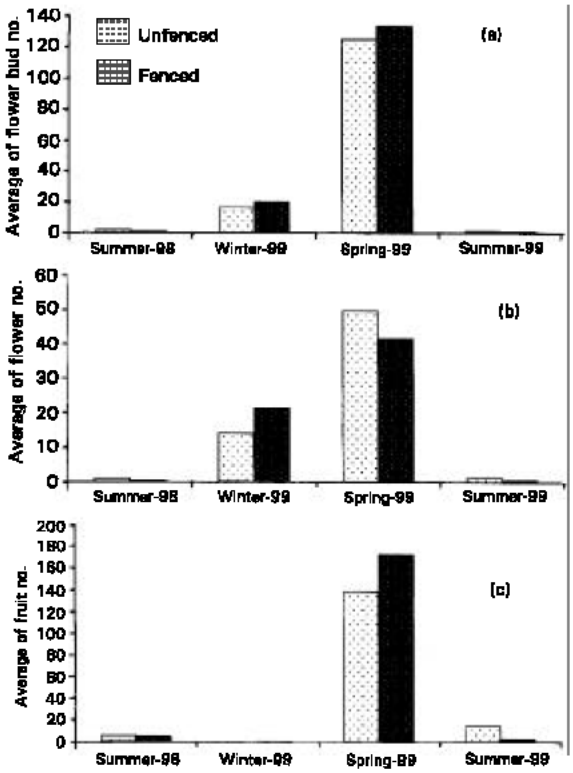

Fig. 3: Comparison between fenced and unfenced populations of *Alkanna orientalis* (a) number of flower buds, (b) number of flowers and © number of fruits, during four main seasons of the year 1998 to 1999.

eight plots were at W. Deir (unfenced). Three areas were chosen and constructed as fenced population of *Alkanna*.

Soil sampling and analysis: Three replications of soil samples were collected from each plot to determine their physical and chemical characteristics. Gravimetric methods were used to determine moisture content of selected soil samples, whereas organic matter content was determined by loss-on-ignition (LOI), where loss was calculated in percent of the oven-dried sample (Wilde *et al.*, 1972).

Record of vegetation and population parameters: In each of the selected seventy permanent plots, a number of *A. orientalis* individuals were recorded where the following parameters were measured: (a) the number of *Alkanna* individuals in each plot, (b) the list of species associated with *Alkanna*, © the percent of plant cover of *Alkanna* in each plot, (d) the number of floral buds, flowers, and fruits, seed shedding, and dryness percent, *etc.*, and (e) the natality and mortality during different seasons.

Quantification of grazing and human disturbance: Each plot is scored according to grazing intensity index based on following points: (a) the number of browsed branches; (b) the number of grazed individuals; © the number of visits by animals during different seasons of the year; (d) the number of animals grazing in each area and their type (sheep, goats, feral donkeys, and camels), (e) number of dung in each plot and (f) rate of cutting and uprooting of plants by Bedouins.

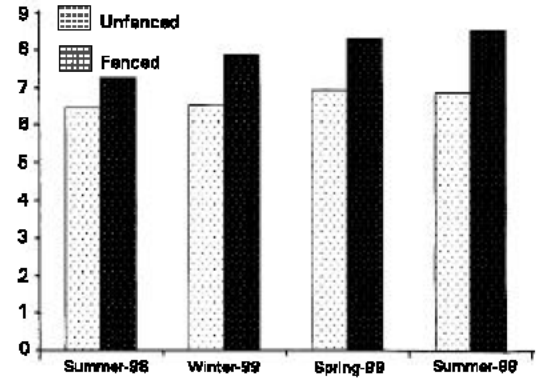

Fig. 4: The difference in total number of *Alkanna* individuals between fenced and unfenced populations.

Data treatment The data were analyzed using two-tailed paired-sample (t-test), one way Analysis of Variance (ANOVA) and Pearson correlation test according to Zar (1984).

Study area: Saint Catherine area represents the highest part of the southern Sinai mountainous terrain. It is characterized by high and rigid mountains that range in height between 1500 and 2641 meters above sea level. The study area includes the highest mountain peaks in Egypt, such as Gebel Catherine (2641m) and Gebel Mousa (2285m). Four main wadis are chosen for surveying the populations of *Alkanna orientalis;* they are El-Arbaie'en, Tala'a, El-Deir, and Garagnia. These wadis represent the most common habitats for *Alkanna orientalis* and they show the most available variation in physiographic and geomorphological formation (Fig. 1).

Danin (1983) described the study area as predominately smooth-faced granite outcrops forming mountains such as Gebel Serbal, Ras Sefsafa and Gebel El-Rabah. In general, these mountains contain the very deep gorge (W. El-Arbaie'en and W. El-Sheikh). The geomorphology of Saint Catherine area form a part of highly rugged mountains with acid plutonic and volcanic rocks belonging to Precambrian basement complex of the southern part of Sinai peninsula.

The landscape of the study area is distinguished by four different types of land forms; namely slopes, gorges, terraces, and ridges. Mountains are dissected by faults and joints which play an important role in controlling the movement of ground water (Moustafa and Klopatek, 1995).

Climate: Sinai lies in the arid belt of North Africa and belongs to Saharan Mediterranean area with a true desert climate (Migahid *et al.*, 1959, and Logan, 1968). The seasonal pattern of temperature, precipitation and relative humidity is similar to those in the Mediterranean region. In the study area, the climate is extremely arid with long, hot, and rainless summers and cool winters. The climate of the study area is quite different for rest of the South Sinai due to its high elevation (1500-2624 m). The mean annual precipitation in Saint Catherine area over 25 years (1970-1994) is 45 mm per year, the high mountains receive more precipitation (100 mm/year) as rain and snow (Danin, 1983). In some parts of this area, floods resulting from convective rains have been observed during the winter and spring. The extremes of the mean air temperature range from 5.4 to 25.1°C with the lowest temperature in January and February and the highest in July and August (Moustafa and Kamel, 1996).

Results

Types of *Alkanna* populations: Based on the total plant coverage of *Alkanna orientalis* at each plot, the populations are grouped into four main clusters (Table 1). The first group is represented by twenty-eight populations and it is subjected to low grazing practices. The second group included 13 populations characterized by higher *Alkanna* coverage and higher percentage of reproductive organs than the first group. The populations of the group are subjected to moderate degree of grazing practices. The third group has only 10 populations characterized by high plant coverage ranging between 10-15%, which is significantly high for plants growing in arid zone environments.

The fourth group comprised of 5 populations, the third and fourth groups are subjected to heavy grazing and human interference (Table 1).

The results of statistical evaluation showed that these four groups of *Alkanna* are significantly varied in percentage of coverage, average of flower buds, flowers, fruits, height and grazing intensity index. There is also an insignificant variation in values of total moisture contents of the studied soil samples, particularly between samples of the first and second groups, in one hand, and those of the third and fourth groups, on the other (Table 1). The fourth group has the highest organic content due to high coverage percentage and grazing intensity. Insignificant variation in the natality and mortality percentages are indicated among different groups of *Alkanna* populations.

Impact of grazing and fencing: To investigate the effect of grazing on *Alkanna*, 14 populations of *Alkanna* were fenced and compared with the nearest unfenced 14 populations in the same area (W. El -Arbaie'en). It is noticed that the vegetation cover was the highest for unfenced populations during three seasons; namely the winter, spring and the summer of 1999. Consequently, the average plant height was considerably higher in unfenced populations compared to the fenced ones, except in the first summer of 1998 where the plant height was slightly greater in the fenced populations. On the other hand, the percentage of dryness recorded in the fenced populations during seasons of the study was greater than that of the unfenced populations, (Fig. 2 a, b, & c).

Table 1: The mean values of vegetation parameters, grazing intensity, soil factors, species richness and demographic parameters (including natality and mortality) in the four main types of *Alkanna orientalis* populations growing study area

	Population group				F-ratio	P-value
	1	2	3	4		
No. of plots	28.0	13.0	10.0	5.0		
Vegetation cover %	2.5	7.9	14.7	23.7	263.1	0.000
No. of flowers	218.1	792.8	1436.9	2656.6	51.9	0.000
No. of flowers buds	117.1	380.0	537.1	730.8	41.5	0.000
No. of fruits	293.1	954.2	1291.3	1646.6	21.6	0.000
Plant height (cm)	14.1	18.3	15.3	21.8	4.0	0.013
Grazing intensity	1.7	2.4	3.5	4.2	9.8	0.000
Moisture contents %	0.3	0.3	0.4	0.4	1.9	0.137
Organic matter %	3.1	2.4	3.3	4.8	3.8	0.016
species richness	7.0	58.8	4.4	3.2	4.7	0.005
Natality %	24.6	30.9	41.9	33.3	2.0	0.130
Mortality %	32.6	20.1	19.7	14.9	1.5	0.217

Table 2: The comparison between fenced and unfenced populations of *Alkanna orientalis* including the difference between each two means, t-values and their significance.

Season		Summer 98	Winter 99	Winter 99	Summer 99
No. of individuals	Differences	-1.000	-1.357	-1.357	-1.643
	T-Value	-0.699	-1.124	-0.707	-0.944
	P-Value	0.497	0.281	0.492	0.362
Flower buds	Differences	0.431	-10.508	8.165	0.595
	T-Value	0.862	-1.060	0.363	0.744
	P-Value	0.404	0.308	0.723	0.470
Flower	Differences	1.086	-3.669	-8.774	0.438
	T-Value	0.803	-0.189	-0.0977	0.843
	P-Value	0.436	0.853	0.825	0.436
Fruits	Differences	0.600	-0.008	-33.735	11.932
	T-Value	0.272	-0.023	-0.329	3.804
	P-Value	0.790	0.982	0.747	0.002
Alkanna coverage	Differences	5.225	698.727	411.222	504.713
	T-Value	-0.058	1.614	0.563	0.247
	P-Value	0.950	0.131	0.583	0.028
Plant height	Differences	-1.154	3.850	4.870	5.901
	T-Value	-0.621	1.277	1.117	1.967
	P-Value	0.545	0.224	0.284	0.071
Dryness (%)	Differences	-12.974	-20.680	-2.627	-5.418
	T-Value	-2.812	-4.612	-0.367	-0.719
	P-Value	0.015	0.000	0.720	0.485

It is noticed that floral buds have increased during the spring for unfenced populations. The number of flowers in the fenced and the unfenced populations are not significantly different. On the other hand, the average number of fruits was higher in fenced populations than in unfenced ones. This is due to browsing of sheep and goats where they eat the flowers and young branches (Fig. 3a, b, & c).

The differences between fenced and unfenced populations are statistically evaluated using t-test on the means of vegetative and reproductive parameters, during four seasons of the study, (Table 2). It is indicated in Table (2) that the summer of 1999 (which is the last monitored season) represents the most appropriate period of time to discern the differences between fenced and unfenced populations. The number of fruits, coverage percentage, and plant height display significantly high values in the fenced populations as compared to unfenced ones.

Natality, mortality and grazing effect: Natality is simply defined as the production of new individuals in a population. It has a great influence in the increase of population size and its distribution. The natality of *Alkanna orientalis* is expressed as the percentage of new seedlings of *Alkanna* divided by the total number of *Alkanna* during different seasons (Fig. 4).

Results of the study have revealed that the natality rates of the first and second groups attain maximum values during spring but decline to their lowest values during the following summer owing to grazing and drought effects. These two groups are also affected by low to moderate intensities of grazing. In the third and fourth groups, where grazing intensity is considerably high, the natality rate declines in the former but attains a state of stability (equilibrium) in the latter group during spring. *Alkanna* population of the fourth group tends to display a slight increase in the number of individuals during summer.

Mortality is an estimate of a population expressed as the loss in their numbers recorded throughout successive seasons. The rate of mortality in the four main groups of *Alkanna* populations shown in Fig. 2 declines during spring season. Mortality rate is relatively high in all populations due to grazing and drought. Generally, the results revealed a strong relationship between natality and mortality data (Fig. 4). It is observed that the change in the number of individuals of the first and second groups are dynamic during the monitored seasons. It, however, attains a state of equilibrium in the third and fourth groups despite of intensive grazing.

The relationship between vegetative factors, grazing intensity, soil condition, and demographic parameters are tested and evaluated statistically, as shown in Table 3. The total cover of *Alkanna* is strongly correlated with the average of reproductive organs such as the number of flower buds, flowers, and fruits. The number of flowers increases significantly with increases in the number of flower buds and fruits. Grazing intensity is usually correlated with two vegetative factors; they are the total coverage and the number of flowers (Table 3). Furthermore, the organic content of soil samples is positively correlated with grazing and with their total moisture content. The species richness is negatively correlated with total coverage and number of flowers. Natality did not show any significant correlation with any of the studied factors contrary to mortality that showed a highly significant correlation with the number of fruits and a slightly negative correlation with the number of flower buds (Table 3).

Discussion

The vegetation of Saint Catherine area is subjected to two main categories of threats affecting the vegetation structure of the area. The first group includes natural threats such as aridity and floods. Floods, for example, occur every seven years destroying the vegetation cover of most wadis. The second group of threats includes human-induced impacts, such as overgrazing, over collection of plants, construction works, and quarries in addition to the deterioration of

Table 3: Pearson correlation test showing test relationship between vegetation parameters of *Alkanna orientalis* grazing intensity and soil factor

Parameters	Natality	Vegetation cover %	No. of flower buds	fruits	No. of intensity	No. of content%	Grazing matter %	Moisture	Organic	Species %
No. of flower buds		0.860***								
No. of flower		0.892***	0.824***							
No. of fruits		0.794***	0.836***	0.757***						
Grazing intensity		0.459**	0.838	0.601***	0.089					
Moisture content %		0.261	0.322	0.341	0.184	0.377				
Organic matter %		0.205	0.099	0.386	-0.052	0.565***	0.588***			
Species richness		-0.443	-0.415	-0.418	-0.319	-0.253	-0.176	-0.233		
Natality %		-0.010	-0.084	-0.012	0.045	-0.070	0.027	0.009	-0.089	
Mortality %		-0.301	-0.411*	-0.164	-0.479**	-0.004	-0.004	0.166	-0.820	0.085

*** p <0.001, ** p <0.01, *p <0.05.

vegetation cover attributed to feral donkeys. These dangerous threats would eventually lead to the depletion of plant cover and to the disappearance of plant communities in addition to other changes in the make-up of plant communities threatening, in particular, medicinal, endemic, and rare species. Grazing has become one of the most serious problems affecting vegetation in the last twenty years, (Moustafa and Klopateck, 1996).

A great number of *A. orientalis* populations are flourished by overgrazing in the wadi systems of Saint Catherine. As *A. orientalis* is regarded as incomplete palatable species, animals tend therefore to graze only on flowers and young branches, and on dry shoot system at the end of the season (burned leaves). Field observations indicate that *Alkanna* and many other species such as *Ascelipias sinaicus* and *Teucrium polium* are the products of overgrazing.

Although, *Alkanna* is not a complete edible plant and is not usually collected by Bedouins, the variation in coverage, and the production of reproductive organs are distinguished into four main groups according to grazing pressure. Results of the study indicate that the abundance of *Alkanna* is closely connected to grazing practices. It is well known that plant population in arid lands is highly sensitive to changes in climate (Turner, 1990) and domestic livestock grazing (Chambers and Norton, 1993). Although climatic changes greatly alter the distribution of plant species in the study area, particularly *Alkanna,* the selected sites are not located very far apart to objectively ascribe any perceptible variation to a specific change. It is therefore emphasized that variation in plant population is caused only by grazing and is strongly related to its intensity. Results of this study are comparable to those of West (1983) who demonstrated that grazing by domestic livestock in arid shrub land causes widespread changes in species abundance.

The actual moisture content of the soil fluctuates depending on soil composition, topography, and climatic variations. Organic matter content influences physical, chemical, and biological properties of soil. It provides nutrients and energy materials, and exerts a strong influence on the formation of structural aggregates, retention of moisture, and adsorption of nutrient ions (Wilde *et al.*, 1972). Despite the importance of moisture content on the distribution of plant species, (Moustafa and Zayed, 1996), the present study revealed that there is no variation between groups of *Alkanna* that could be related to changes in soil moisture content.

Plant population in arid regions is not only influenced by low precipitation but it is also greatly affected by unpredictable nature of its distribution (Chambers & Norton, 1993).

Total amount of precipitation in arid ecosystems is usually very low. Type of precipitation, intensity of annual variations, soil topography, and the nature of vegetation cover greatly influence the availability of moisture provided by precipitation to different plants (Moustafa & Zaghloul, 1996).

Bartolome (1993) also indicated that in semi-arid rangeland environments, differential plant response linked to selective grazing is not an important factor regulating the structure and function of an ecosystem. Studies of Bartolome (1993) are compatible with the results of present study. In addition to that, species respond to grazing depending not only on their palatability to livestock but also on their life history and physiological characteristics (Chamber & Norton, 1993).

Crawley (1997) found that it is difficult to generalize the impact of herbivory on plant diversity, some studies have shown increased plant species richness under herbivory (Belsky, 1992; Pandy and Singh, 1992; Montalvo *et al.*, 1993), a few have shown reduced species richness (Milton, 1940), and several studies have shown no effect of herbivory on species richness at all. The present study shows that species richness is significantly varied between the four populations where the overgrazed populations found with lowest species richness. This is true because animals graze plants and leaves of *Alkanna* as desert or sweet after the main meal. The other reason, that animals graze the very young and soft branches of *Alkanna* that do not have spines or not sticky, so the Alkanna exhibit overcompensation of coverage under high grazing intensity under most favorable environmental conditions (Belsky, 1986 and 1987).

The impact of herbivory on plant performance depends on its timing (phenology) location (the tissue attached and how old it is), intensity (how much is eaten) and frequency (how often the plants are attacked). Crawley, (1997) emphasized that season and intensity of grazing in relation to a species phonological development is an important factor influencing rates of change.

The palatability in present study is very difficult to be estimated in numbers because every plant could be attacked from at least one type of domestic animals at a specific time where specific organs of the plant would be grazed, (e.g. flower's, fruits or branches). Only six species of the twenty eight species recorded in all plots are completely unpalatable (21%). These species have different defense mechanisms that prevent the animals from attacking them (e.g. *Ascelipias sinaicum, Origanum syriacum, Andrachne purpura, Onopordom mulpigam,* and *Verbascum sinaicum).* Other palatable species are eaten with different percentages during different seasons according to their phenological stage.

This study indicates that protecting *Alkanna* populations has reduced the total coverage of *Alkanna,* which in its turn decreases the average production of reproductive organs, such as flower buds and fruits. On the other hand, grazing practices tend to increase coverage, plant height, and flower buds of unfenced populations. Fenced and unfenced populations have almost the same number of flowers. It is clearly evident that in unfenced population, plant response acts at a compensating equal rate to grazing pressures by herbivores.

Crawley (1997) and Trenbath (1993) have indicated that the net effect of single or repeated grazing events on the cumulative growth of plants can be zero, or negative or positive. This depends on the availability of leaf area, meristems, stored nutrients, soil resources, and the frequency and intensity of defoliation.

Alkanna is in fact the first plant species commencing its vegetative stage at early fall (October). It is also the first plant in the whole area to bloom at early spring (March). When animals attack *Alkanna* branches and flowers the plant responsive action is capable of compensating strongly the action of overgrazing.

Based on the results of natality and mortality, all groups of *Alkanna* populations (unfenced) have different rates of natality. On the other hand, the mortality rate of the first group is very high as compared to a very low rate in the fourth group. The mortality rates of the second and the third groups are very close to each other. Low natality rates of low grazed populations is related to a decrease in the total plant cover and to browsing the flower buds, flowers that contain nectars and young branches. At heavily grazed populations, the coverage is generally very high giving rise to chances of producing more flowers and more seeds, more coverage *of Alkanna* help to

create long palatability season that is basically related to the compensation rate of each plant, (Chambers and Norton, 1993).

The present study indicates that unfenced plots are distinguished by a significant increase in plant coverage and in the number of *Alkanna* individuals compared to fenced plots. In fenced plots, the increase in the number of individuals is ascribed to the protection of flowers that would otherwise be eaten by animals and thenceforth increasing the chance of producing more and more new individuals. However, the observed decrease in the total plant cover of fenced plants where grazing stress is negligible is caused by compensation rates of negative or near zero values (Crawley, 1997).

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