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EFFECTS OF SIMULATED GRAZING (CLIPPING) ON PLANT POPULATION RESPONSES AND RESOURCE ALLOCATION PATTERNS IN A SEMI-ARID ENVIRONMENT

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Abstract

Surra rangeland reserve is a Steppe rangeland, located in the northwest part of Jordan. The vegetation composition of Surra semi-arid rangeland slopes (North and South facing slopes) were studied. In addition, the study focuses some population aspects of *Salsola vermiculata* at the reserve under natural conditions. Moreover, the effect of clipping (simulation of grazing) on the regrowth of *S. vermiculata* plants were studied in order to promote the conservation and sustainable use of this important forage plant. Randomly transects on each site to sample vegetation at 10 m intervals along each transect were delineated. For each sampling point, quadrates of 1 m^2 were placed and coverage, species composition, plant density and life form were assessed. The vegetation inside each quadrat was clipped and separated into forage and non-forage components. Fresh and dry weights for each component and relative density and dry biomass for *S. vermiculata* were determined. The overall shrub species recorded at the site showed a higher species richness at the south facing slopes of 15 shrub species. Density of shrubs (plant/ quadrates) were almost similar except for *S. vermiculata* where it was more frequent at the north facing slopes (7.5 P/Q) with high relative density (1.2 P/ Q). Moreover, a detailed vegetation analysis (herbs and shrubs) for north facing and south facing slopes showed higher values of plant densities at the south facing slopes and mostly attributed to herbaceous vegetation. Shrubs were more abundant at the north facing slopes. In general, forage plants constituted more than 90% of the vegetation present in the reserve. Plant cover and vegetation dry biomass was higher at the south facing slopes and mostly was forage vegetation. Herbaceous forage (grass and non-grass) vegetation had the highest densities in the north facing slopes, while only forage grass had the maximum density overall in the south facing slopes. The average *S. vermiculata* plant size was 0.026 m^3 with average biomass of 34 gm. Relative growth rate (RGR) were positive for the unclipped and 30% clipped plants and showed no difference indicating that 30 % clipping could be tolerated by these plants and could be classified as moderate grazing. However, the 60% treatment showed a negative RGR indicating a severe grazing effect of this clipping treatment, emphasizing that native shrubs constituted important forage for the livestock since they tolerate moderate grazing, in addition to soil conservation and reduction of non-forage plant species.

Key words: Rangelands, Surra rangeland reserve, *Salsola vermiculata*, Relative growth rate.

Introduction

Most rangelands in WANA (West Asia and North Africa) countries are degraded because of poor vegetation cover and accelerated soil erosion (Le Houerou, 1992; Abu-Zanat, 1995; Abu-Zanat *et al*., 2003). The degradation could be attributed to the uprooting of ligneous species for fuel, cultivation of barley as a fodder source and overstocking of sheep and goats on these lands (Al-Shawaheneh *et al*., 1998; Al-Tabini *et al.*, 2012). Large areas of arid and semi-arid zones fall within the Mediterranean region, where evapotranspiration exceeds the amount of rainfall and inadequate to support the crop production. Rangelands of the eastern desert, where annual rainfall is less than 200 mm, are characterized by low vegetation productivity (Abu-Zanat *et al*., 2004). Cultivation and plowing and of these rangelands with barely to feed grazers and removal of woody plants has resulted in degradation of these rangelands (Juneidi & Abu-Zanat, 1993). To protect these rangelands, the Ministry of Agriculture has established several range reserves, one of which is the Surra rangeland reserve.

The accelerated degradation of rangelands in arid areas and in Jordan has necessitated implementation of rehabilitation programs to these rangelands. Re-vegetation of fodder shrubs is one of the mainly used management approaches of rangelands in arid and semi-arid zones including Jordan to improve forage production and ensure sustainability of small ruminant production systems in the region (Le Houerou, 1992; Juneidi & Abu-Zanat, 1993; Abu-Zanat, 1995; Al-Shawaheneh *et al*., 1998; Abu-Zanat *et al.*, 2003). This approach depends primarily on both native and introduced plant species. The establishment costs of fodder plantations from direct seeding are less than transplanting techniques and so plants easily established by seeding are recommended for rehabilitation programs (Abu-Zanat *et al.*, 2003).

The saltbushes are commonly used as fodder shrubs for re-vegetation and many species are considered valuable forage plants. Native species including *S. vermiculata* have been reported to perform well in rehabilitation programs, than other species, since it can be established from direct seeding and more importantly, are capable of self-sowing (Osman & Ghassali, 1997; Louhaichi *et al*., 2014). *S. vermiculata* is an excellent forage plant and grazed by sheep, goats as well as camels since it contains high crude protein, minerals and low crude fiber with high digestible and metabolizable energy (Heneidy, 2002). The ability of this species to establish itself from direct seeding and its capacity of self-sowing have both dictated research toward the better understanding of the seed germination. Transplanting and sowing of *Atriplex* species and *S. vermiculata* at Jelfa degraded rangelands in Algeria were monitored from 1995-2001 (Anon., 2002). The survival percentage of seedlings was high for both shrub types (90 %). A natural regeneration of S. *vermiculata* was noticed in the seasons following transplanting. Direct seeding of fodder shrubs is a cheap method and effective to rehabilitate the degraded rangelands. The growth of plants grown from seeds was weak in the first four years (1998 – 2002) compared with those of the transplants. However, after four years of establishment no difference was detected between shrubs grown by the two methods (Anon., 2002). Studies on the impact of grazing on *S. vermiculata* are lacking. Simulated grazing experiments have been instrumental tools to study the impact of grazing on various plant traits such as relative growth rate, biomass and reproduction (Damhoureyeh & Hartnett, 2002). Therefore, it is only appropriate along with this study to demonstrate *S. vermiculata* responses to varied grazing/ clipping intensities.

The genus *Salsola* belongs to the goosefoot family, Chenopodiaceae, which entails a large number of halophytic perennial plants. Important genera of the family include *Atriplex*, *Salsola*, *Anabasis*, *Haloxylon* and *Suaeda* (Heywood, 1978). The four genera do occur in Jordan. and *S. vermiculata* is common in the desert and marginal lands; Eastern desert, Mafraq, Zarka, Madaba, Karak, Tafila, Shaubak, Wadi Rum, Wadi Araba, Dead Sea, Wadi Shuaib and Jordan Valley (Al-Eisawi, 1985; 1998). *S. vermiculata* is a bushy plant to low shrub, with woody, basal stems and young green branches. Leaves 0.5-1.5 cm, very narrow with pointed tips, densely covered by soft, long hairs. Flowers are minute at the axils of the leaves, producing fruits 5-8 mm in diameter with membranous wings (Al-Eisawi, 1998). Flowering occurs between April and October. The habitat of *S. vermiculata* is calcareous stony steppes and also somewhat saline soils of the Saharo-Arabian and Irano-Turanian bio-climatic regions. Zohary (1966) indicated that *S. vermiculata* is a glabrous perennial species 15-30 cm in height, stems ascending, and woody branching especially at base White glossy. Branches are alternate or at the lowermost almost opposite, with leaves (0.5-3 cm), arising from hairy axils. Mandaville (1990) identified the species as a shrublet, 15-60 cm in height, much branched with stems glabrous below, pubescent toward extremities. Leaves are minute and become longer in spring. Spring flowers are axillary, forming somewhat loose spikes up to c. 1.5-12 cm, autumn flowers often in shorter more congested spikes. Fruiting perianth is wide. It inhabits rocky slopes with little sand cover or silty bottoms of basins and the larger wadis. The plant is preferred by grazing animals and Bedouin often use it as firewood.

The main objectives of this study are to study the vegetation composition of semi-arid rangelands and to investigate some population aspects of *S. vermiculata* in semi-arid grasslands under natural conditions and to determine the effect of clipping (simulation of grazing) on the regrowth of *S. vermiculata* plants to promote the conservation and sustainable use of this important forage plant.

Study site: Surra rangeland reserve, a Steppe rangeland is located in the northwest part of Jordan at latitude 36˚10'E and longitude 32˚24'N (Fig. 1), with a mean annual rainfall of 220 mm (a 20-year mean) which mostly occurs in winter between December and March. Elevation ranges from 670 m to 690 m with a south-north slope. Soils of lithic xeric torriorthents, xerochrept calciorthids and camborthids dominate the reserve (Anon., 1994). Dominant vegetation includes *Stipa* spp., *Avena* spp., *Poa* spp., *Bromus* spp., *Hordeum* spp., *Aegilopes*, *Artemisia herba alba*, *Achillea fragrantisimia* and *Salsola vermiculata*. In the year 2000, substantial numbers of *Atriplex halimus* and *A. nummularia* seedlings were planted in the reserve to increase biomass production. Barham & Menscching (1988) indicated that the grazing capacity of rangelands in Jordan is far below the existing number of grazers. Consequently overgrazing and degradation of the rangelands are increasing. Although the rangelands area shrunk because of encroachment of other land uses, the number of grazing animals is constantly growing; the number of sheep and goats has risen dramatically in the past fifty years.

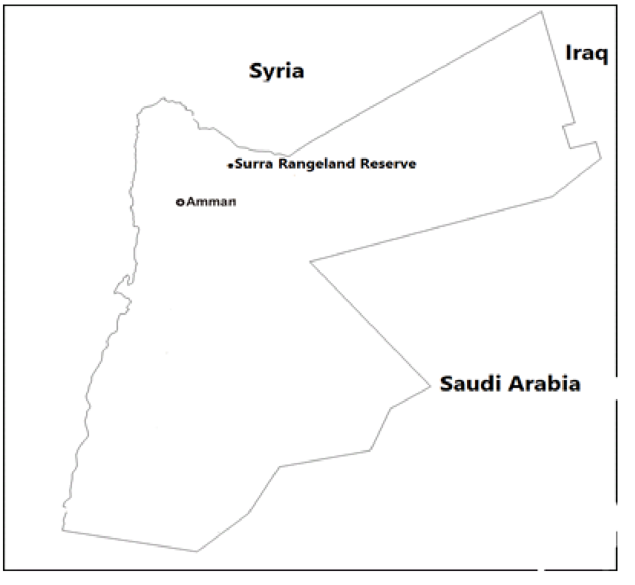

Fig. 1. The Hashemite Kingdom of Jordan, Surra Rangeland Reserve.

Sheep and goats, used the reserve for grazing purpose during spring and early summer. Without assessing the grazing capacity, it was observed that subsequently many parts of the reserve were overgrazed and degraded. Between the years 2000 and 2003 grazing animals were excluded from the reserve in a recovery effort to conserve genetic biodiversity of wild relatives. All range reserves in Jordan are now fenced and protected. However, some areas at the edges of fence might be damaged by intruders (owners of grazing herds) during summer and drought periods.

Materials and Methods

Vegetation sampling method: Four transects, 100 m each, were delineated randomly at each of the selected sites. The vegetation were systematically sampled at 10 m intervals along each transect (9 samples per transect, 36 samples per site), and 2 sites where selected (North facing site and South facing site). For each sampling point, quadrates of 1 m^2 were placed alternatively along each transect. Coverage, species composition, plant density and life form were recorded for each quadrat. The following dimensions were recorded for each *S. vermiculata* plant encircled within the quadrate: i.e., height, longest and shortest diameters of canopy, and number of branches. The vegetation inside each quadrat were clipped by hand shears at ground level and the severed material were separated into forage and non-forage components. Fresh and dry weights for each component were determined. Relative density and dry biomass for *S. vermiculata* were determined. Plant samples were oven dried to determine dry biomass.

Annex 1. Shrub composition of the selected sites at Surra Rangeland Reserve, Jordan.

S.No.	Plant species	Density (Plant/Quadrate)
1. North facing slopes		
1.	*Salsola vermiculata*	7.5 mainly in the upper parts
2.	*Artimisia herba-alba*	0.4 mainly in the upper parts
3.	*Anthemis* sp.	1.7 mainly in the upper parts
4.	*Achelia santolina*	0.5 mainly in the upper parts
5.	*Noaea mucronata*	0.8 mainly in the upper parts
6.	*Varthemia iphionoides*	0.4 mainly in the upper parts
7.	*Atriplex numularia*	0.8 mainly in the lower parts
8.	*Atriplex leucoclada*	0.3 mainly in the lower parts
9.	*Lactuca* sp.	0.6 mainly in the lower parts
2. South facing slopes		
1.	*Salsola vermiculata*	3.2 randomly distributed all over the site
2.	*Artimisia herba-alba*	0.6 randomly distributed all over the site
3.	*Anthemis* sp.	2.3 mainly in the upper parts
4.	*Achelia centulina*	0.5 mainly in the upper parts
5.	*Noeae macronata*	0.6 mainly in the upper parts
6.	*Varthemia iphionoides*	0.3 mainly in the upper parts
7.	*Atriplex numularlia*	1.0 mainly in the lower parts
8.	*Atriplex leucoclada*	0.2 mainly in the lower parts
9.	*Lactuca* sp.	0.8 mainly in the lower parts
10.	*Anabasis syriaca*	0.3 randomly distributed all over the site
11.	*Hypoecum*	0.2 randomly distributed
12.	*Astragalus* sp.	rare
13.	*Verbascum*	rare

Simulated grazing: A standard correlation curve of size and weight was used to estimate the biomass of the tested plants. Biomass production of shrubs was estimated non-destructively. Shrub biomass of *S. vermiculata* was estimated by dimensional method at the reserve (Sarfraz *et al*., 2012: Yousfi & Azzouzi, 2015). For a 20 randomly marked plants, canopy dimensions, short width (SW) and long width (LW) and plant height (H) were recorded. After recording data, each plant was harvested; fresh weights were recorded immediately, and then dry biomass of plants. The canopy volume was calculated by using the formula: Canopy Volume=1/6π LW*SW*H. (Sarfraz *et al*., 2012), then correlating it to standing dry biomass. The simulation of grazing was applied in the field. Forty five enclosures (1 m^2) were established around selected *S. vermiculata*, 3 clipping intensities were conducted once (0, 20, 40% of plant height) early in the growing season. Measurements of (H, SW and LW) of each selected plant were taken (Dry Biomass initial; "Wi"). Measurements of (H, SW and LW) of each selected plant were recorded at the end of the season (dry biomass final; "Wf") to determine their response to the different clipping intensities. The initial dry biomass and final dry biomass of the tested *S. vermiculata* were estimated using the above correlation curve. Relative growth rate (RGR) was calculated using the following equation;

$$RGR = \frac{(\log Wf - \log Wi)}{\text{Growth period}} = \text{Gram per gram per day (Hunt 1978)}$$

Results

In general, visual observation of the area during the study indicates that Surra rangeland reserves constituted a high vegetation cover, biomass, density and diversity compared to the adjacent unprotected land.

Overall shrub species composition recorded at Surra rangeland reserve revealed a higher richness of shrub plant species at the south facing slopes (15 shrubs) but a nearly high similarity of the main shrubs (9) existed in both sites (North facing and south facing slopes). Shrub plant density was almost similar except for *S. vermiculata* where it was denser at the north facing slopes. Vegetation analysis (Table 2) listed the different parameters measeured, plant densities showed higher values (plant/ quadrates) at the south facing slopes and mostly attributed to herbaceous vegetation, while shrubs were more abundant at the north facing slopes. In general, forage plants dominated the vegetation structure (visual observation). Plant cover was higher (57%) at the south facing slopes compared to the north facing slopes (36%). Plant dry biomass was also higher at the south facing slopes and mostly was forage vegetation. Herbaceous forage (grass and non-grass) vegetation had the highest densities in the north facing slopes, while only forage grass had the maximum density overall in the south facing slopes. Relative density of *S. vermiculata* was higher at the North facing slopes compared to South facing slopes (1.2 and 0.2 P/ Q).

The average *S. vermiculata* plant size was ({1/6*3.14(43*31.5*36.5)}) 0.026 m^3 and the average plant dry biomass was 34 gm. Size measurments and correlation calculation (Table 1), shows the different dimensions of the selected plants and the calculated plant size and estimated weight of the different treatments (Wi), the final dry biomass (Wf) and the relative growth rate (RGR) for 60 days duration. RGR were positive for the unclipped and 30% clipped plants and showed no difference indicating that 30 % clipping could be tolerated by these plants and could be classified as moderate grazing, however, the 60% treatment showed a negative RGR indicating a severe grazing effect of this clipping treatment.

To fully understand the dynamics of the *S. vermiculata* populations under the semiarid conditions of the rangelands, the field studies should be accompanied with a controlled greenhouse experiments (Damhoureyeh & Hartnett, 2002).

Table 1. Size measurement and correlation of dry biomass of the selected *S. vermiculata* plants.

Plant No.	Clipping %	SW (cm^2)	LW (cm^2)	H (cm^2)	Size (m^3)	Initial dry Biomass (gm.)	Final dry biomass (gm.)	RGR ($gm*gm^{-1}*d^{-1}$)
1.	0%	30.00	40.00	39.00	0.024	40.00	50.00	0.0016
2.	0%	27.00	39.00	38.00	0.021	35.00	45.00	0.0018
3.	0%	31.00	39.00	40.00	0.025	36.00	43.00	0.0013
4.	0%	29.00	35.00	36.00	0.019	25.00	31.00	0.0016
5.	0%	35.00	45.00	45.00	0.037	50.00	65.00	0.0019
6.	0%	27.00	39.00	40.00	0.022	27.00	37.00	0.0023
7.	0%	33.00	36.00	35.00	0.022	29.00	36.00	0.0016
8.	0%	36.00	47.00	43.00	0.038	40.00	50.00	0.0016
9.	0%	30.00	40.00	40.00	0.025	30.00	37.00	0.0015
10.	0%	30.00	45.00	42.00	0.030	33.00	44.00	0.0021
11.	0%	25.00	35.00	31.00	0.014	20.00	25.00	0.0016
12.	0%	28.00	32.00	35.00	0.016	20.00	20.00	0.0000
13.	0%	29.00	36.00	33.00	0.018	25.00	35.00	0.0024
14.	0%	33.00	40.00	32.00	0.022	25.00	36.00	0.0026
15.	0%	36.00	48.00	39.00	0.035	42.00	55.00	0.0020
Average		***30.60***	***39.73***	***37.87***	***0.025***	***31.80***	***40.60***	***0.0017***
16.	30%	30.00	40.00	35.00	0.022	30.00	35.00	0.0011
17.	30%	31.00	45.00	36.00	0.026	28.00	33.00	0.0012
18.	30%	32.00	47.00	34.00	0.027	34.00	41.00	0.0014
19.	30%	35.00	48.00	37.00	0.033	39.00	43.00	0.0007
20.	30%	36.00	51.00	40.00	0.038	45.00	50.00	0.0008
21.	30%	39.00	55.00	41.00	0.046	36.00	42.00	0.0011
22.	30%	21.00	35.00	32.00	0.012	32.00	40.00	0.0016
23.	30%	35.00	39.00	35.00	0.025	29.00	40.00	0.0023
24.	30%	30.00	39.00	36.00	0.022	29.00	40.00	0.0023
25.	30%	31.00	39.00	32.00	0.020	25.00	33.00	0.0020
26.	30%	37.00	46.00	46.00	0.041	50.00	60.00	0.0013
27.	30%	26.00	40.00	40.00	0.022	31.00	38.00	0.0015
28.	30%	28.00	40.00	34.00	0.020	29.00	36.00	0.0016
29.	30%	28.00	42.00	32.00	0.020	31.00	36.00	0.0011
30.	30%	36.00	49.00	37.00	0.034	42.00	45.00	0.0005
Average		***31.67***	***43.67***	***36.47***	***0.027***	***34.00***	***40.80***	***0.0014***
31.	60%	34.00	55.00	39.00	0.038	45.00	40.00	-0.0009
32.	60%	31.00	50.00	39.00	0.032	44.00	40.00	-0.0007
33.	60%	39.00	52.00	43.00	0.046	52.00	45.00	-0.0010
34.	60%	25.00	45.00	35.00	0.021	25.00	20.00	-0.0016
35.	60%	26.00	36.00	32.00	0.016	22.00	20.00	-0.0007
36.	60%	29.00	32.00	30.00	0.015	20.00	15.00	-0.0021
37.	60%	32.00	40.00	30.00	0.020	24.00	20.00	-0.0013
38.	60%	35.00	45.00	32.00	0.026	34.00	30.00	-0.0009
39.	60%	30.00	39.00	31.00	0.019	23.00	20.00	-0.0010
40.	60%	36.00	51.00	37.00	0.036	49.00	40.00	-0.0015
41.	60%	31.00	48.00	31.00	0.024	35.00	29.00	-0.0014
42.	60%	25.00	32.00	35.00	0.015	26.00	20.00	-0.0019
43.	60%	36.00	49.00	40.00	0.037	58.00	51.00	-0.0009
44.	60%	34.00	52.00	38.00	0.035	45.00	38.00	-0.0012
45.	60%	35.00	50.00	32.00	0.029	35.00	30.00	-0.0011
Average		***31.87***	***45.07***	***34.93***	***0.027***	***35.80***	***30.53***	***-0.0012***

Short width (SW), Long Width (LW), Plant Height (H), Relative Growth Weight (RGR)

Table 2. Vegetation analysis of the surveyed sites at Surra Rangeland Reserve, Jordan. Overall average.

North facing slopes							
Palatability	**Plant form**	**Relative density %**	**Dominant vegetation**	**Number of species**	**Dry biomass gm**	**Plant cover %**	**Density P/Q**
1) Palatable 2) Palatable	1) Forage grass 2) Forage shrub	41.6 1.2	1) *Poa Bulbosa* 2) *Salsola vermiculata*	6.5	72.3	36.25	202
South facing slopes							
Palatability	**Plant form**	**Relative density %**	**Dominant vegetation**	**Number of species**	**Dry biomass gm**	**Plant cover %**	**Density P/Q**
1) Palatable 2) Palatable	1) Forage grass 2) Forage shrub	87 0.2	1) *Stipa barbatus* 2) *Salsola vermiculata*	3.3	113.8	57	495

Discussion

The results of this study are consistent with previous studies on rangeland vegetation and grazing effects (Yousfi & Azzouzi, 2015; Al-Bakri & Abu-Zanat, 2007; Damhoureyeh & Hartnett, 2002). Since rangelands in arid environments are generally characterized by sparse vegetation and hence low vegetation cover. Moreover, Plant species responses to environmental conditions vary according to edaphic factors (Urooj *et al.,* 2016), However, protection and properly managed counterparts contain moderate vegetation cover and biomass (Al-Bakri & Abu-Zanat, 2007). This study indicated that native shrubs constitute important forage for the livestock since they tolerate moderate grazing (Table 1) in addition to soil conservation and reduction of non-forage plant species (Table 2).

S. vermiculata, as a native shrub in this rangeland exhibited high tolerance to drought as a result of natural selection, in addition to moderate grazing throughout this habitat and high relative density amongst other shrubs. Also, these result coincides with other recent population studies under similar conditions (Al-Tabini *et al.*, 2012; Sarfraz *et al*., 2012; Louhaichi *et al*., 2014; Yousfi & Azzouzi, 2015).

Conclusions

There is an urgent need to establish and properly manage rangelands within the arid and semiarid areas of Jordan since these zones are highly degraded and considered marginal lands. More controlled research under greenhouse conditions is needed to better understand the population dynamics of drought and grazing tolerant forage shrubs associated with the field experiments. These studies will provide a good tool for decision makers to better plan for and manage rangeland preserves.Some major concerns regarding the health of semiarid rangelands in Jordan could be highlighted as the following: Firstly, livestock grazing puts a great pressure on the arid and semiarid rangelands of the Eastern Desert. Moreover, the government strategies and practices in the rangelands (cultivation of barley as a fodder source and overstocking of sheep and goats) plus the uprooting of native shrubs by the locals, resulted in the degradation of these zones; Secondly, Utilization of rangelands without any grazing management plan and extraction of vegetation for fuel wood are the major causes of rangeland degradation. Finally, Most of arid and semi-arid zones fall within the arid Mediterranean climate, where evapotranspiration exceeds the amount of rainfall is inadequate to support the crop production.

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