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Effects of Grazing Intensity by Sheep on the Production of *Atriplex nummularia* and Sheep Live Weight in Jordan

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EFFECTS OF GRAZING INTENSITY BY SHEEP ON THE PRODUCTION OF ATRIPLEX NUMMULARIA AND SHEEP LIVE WEIGHT IN JORDAN.

by

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A dissertation submitted in partial fulfillment
of the requirements for the degree

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Dedicated to the memory
of my parents,
whose silent presence
guided my effort

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ABSTRACT

Effects of Grazing Intensity by Sheep on the Production of *Atriplex nummularia* and Sheep Live Weight in Jordan.

by

Kamal I. Tadros, Doctor of Philosophy
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Major professor: Dr. Philip J. Urness
Department: Range Science

Rangelands in Jordan are deteriorated due to a combination of harsh environmental conditions and human misuse. Jordan is importing increasingly large quantities of meat and animal products to meet the demand from its growing population. Sheep are supplementarily fed during the dry season and large quantities of grain supplements are imported every year.

Significant success has been attained in the establishment of *Atriplex nummularia* Lindl. (ATNU) in Jordan. There is, however, a general lack of adequate research to determine if ATNU is effectively utilized by local sheep, to what extent it is utilized and to what extent it tolerates grazing. The objectives of this research were to determine the effects of grazing ATNU at two intensities (moderate and heavy) on subsequent production of ATNU browse, and on sheep live weight.

Results of this research showed that ATNU shrubs are grazing tolerant, they are stimulated by grazing to produce more forage than the non-grazed shrubs. When heavily grazed in the fall, they showed greater compensatory growth than moderately grazed shrubs, but the moderately grazed shrubs gave sustained production better than those heavily grazed in both good and bad years.

Sheep grazing ATNU shrubs with native forage (grasses and forbs) in the fall gained more weight at the moderately grazed treatments. The amount of sheep-live-weight gain was positively affected by the amount of food intake per sheep metabolic body weight and inversely affected by the percentage of ATNU browse in the diet. ATNU although less preferred by sheep than grasses and forbs, could probably be used up to 40% of the diet and still maintain sheep live weight.

ATNU is a good source of forage especially during the dry season, it provides (with native grasses and forbs) a high-quality forage and may considerably reduce the amount of costly supplements imported to Jordan.

(115 pages)

INTRODUCTION

The East Bank of Jordan (Figure 1) which occupies 9.26 million hectares, has a mediterranean climate characterized by wet cold winters and hot dry summers. About 92% of this area is desert and semi-desert rangelands with annual rainfall (Figure 2) less than 200 mm (National Planning Council 1976) and generally shallow, rocky yellow or grey desert soils. Rainfall comes mainly during December-March with some thunder showers in late November and early April; the rest of the year is dry.

Rangelands in Jordan are generally deteriorated due to a combination of harsh environmental conditions and human misuse. Overgrazing, uprooting of shrubs for firewood, plowing rangelands for cereal grain production (especially after the introduction of tractors) and to establish land claims, and random movement of vehicles all contribute to this misuse (Min. of Agric. 1977; Tadros 1979).

Animal production in Jordan comprises about 40% of the total agricultural production and about 6% of the gross national product. Animal production fluctuates radically among seasons and years (Siam 1985). Jordan produces only about 24% of its consumption of red meat and is importing increasingly large quantities of meat and animal products to meet the demand from its growing population. Such imports amounted to about $15 million in 1975 (Min. of Agric. 1977). In 1983, local production of red meat was about 10,190 tons and 32,637 tons were imported (Siam, 1985). This amount imported in 1983 was estimated at about $90 million.

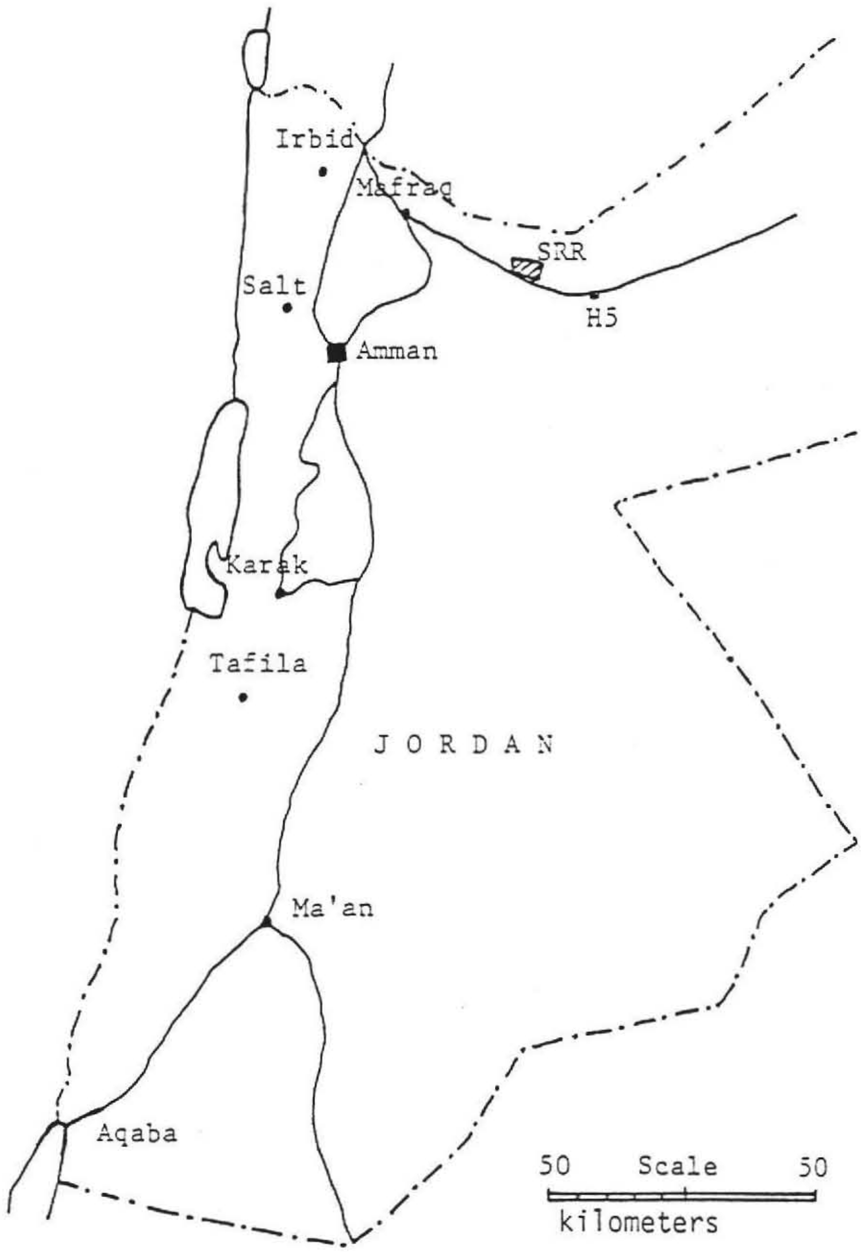

Figure 1: Map of East Bank of Jordan showing the location of the study area at Sabha Range Reserve (SRR).

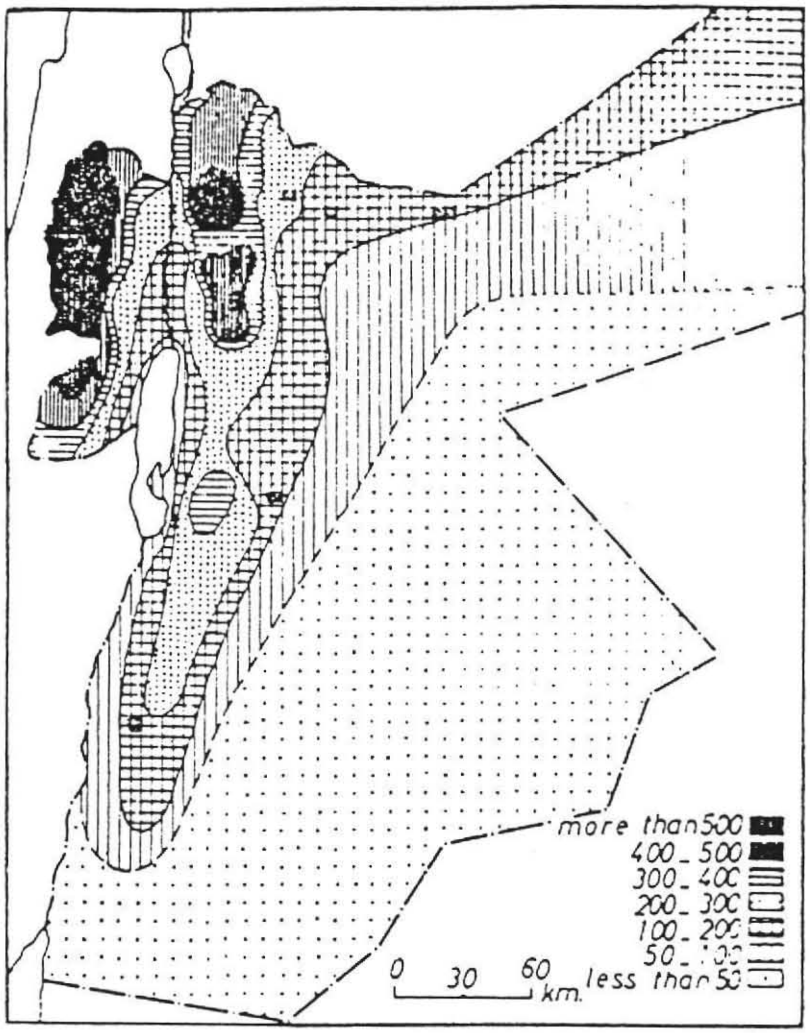

Figure 2. Mean annual rainfall in Jordan.

Sheep and goats, especially sheep, are by far the most important livestock resource in production of red meat followed by cattle and camels (Siam 1985). The main breed of sheep raised in Jordan is the fat-tail Awasi that depends mainly on range as a source of feed. Sheep are supplementally fed during the dry season (late summer and fall), and in winter if condition of the range is poor due to drought which is expected every other year (Duayfi and Tadros 1981).

In late fall when it starts to get cold in the western mountainous areas, sheep herds traditionally move east to the desert where the warm and early rainfall promotes growth of ephemeral vegetation. Herds move back westward in late spring, after the grasses mature and there is a shortage of water in the desert ranges, to graze fallow fields and cereal grain aftermath. During this traditional cycle, herds occupy rangelands with annual rainfall between 100-200 mm twice a year: in late spring on their way to the western mountainous areas and in fall on their way east to the desert.

One way that immediate results could be obtained to secure feed requirements and reduce the amount and cost of supplementation is the creation of green feed reserves on rangelands with 100-200 mm rainfall (Min. of Agric. 1977), by planting and protection of fodder shrubs to be grazed during the dry seasons when very little native feed would otherwise be available. Apart from the direct benefit to the pastoralists involved, there is a multiplier effect that the availability of feed would have on animal production. It would also serve as protection for the forested areas which invariably, especially during very dry years, tend to be invaded by flocks of sheep (Min. of Agric. 1977). Moreover, these shrubs could be of value in the reallocation and restoration of grazing rights in vast rangeland areas and as a source of fuel wood (Draz 1979). Huss (1979) recommended establishment of browse plantations in the Near East to be used as dry-season supplemental pastures in an overall management scheme because (1) rangelands are the region's largest renewable natural resource, (2) they provide the bulk of the forage consumed by the region's livestock, and (3) their destruction is a major cause of desert creep.

The results of experimental plant introduction trials from 1968-1972 in Syria indicated high adaptability of the Australian old-man saltbush, Atriplex nummularia Lindl. (ATNU), to local dry conditions of the steppe region (Draz 1980). Experience in other middle-eastern countries has shown that, under conditions equivalent to those existing in Jordan, it is possible to obtain from atriplex and grass a combined production of between 1,100 to 1,500 Scandinavian feed units per ha. That is many times more valuable than potential grain production on these marginal sites.

Significant success has been attained in the establishment of ATNU in Jordan (Gunn Rural Mgt. Pty. Ltd. 1978). It was introduced in 1975 and since 1981 more than 1.5 million seedlings have been planted every year on the range reserves that belong to the Ministry of Agriculture and on pilot projects with cooperatives through the World Food Programme Project No. 2422. Urness (1985) suggested that the work to determine the best approaches to shrub establishment in

Jordan appears to be largely completed, and that it is now time to consider animal-use aspects. There is, however, a general lack of adequate research on utilization of fodder shrubs. Many of the problems are peculiar to the area and the findings of research carried out elsewhere may be of limited application (FAO 1962). Until now no research has been done to find if ATNU is effectively grazed by local sheep (i.e. to what extent it is utilized, the best time of use, and to what extent it tolerates grazing).

The objectives of this research, therefore, were:

1. To determine the effect of fall grazing on ATNU at moderate and heavy intensities on subsequent production of ATNU browse.
2. To determine the effect of spring grazing of forbs and grasses at moderate and heavy intensities on production of ATNU. Grasses and forbs are presumably more palatable than ATNU in spring.
3. To study effects of moderate and heavy grazing intensities on ATNU in the fall in terms of their effects on sheep live weight.

The hypotheses to be tested were:

H_{01}: There is no difference in production of ATNU in response to moderate and heavy grazing intensities in the fall.

H_{02}: There is no difference in production of ATNU in response to moderate and heavy grazing intensities on grasses and forbs in the spring.

H_{03}: There is no effect of moderate and heavy grazing intensities on ATNU in the fall on sheep live weight.

LITERATURE REVIEW

IMPORTANCE OF SHRUBS

Rangelands in Jordan were degraded in a process whereby perennial grasses, forbs and shrubs were replaced by annuals. Misuse of water resources led to desertification and high salinity in the soils. Drought is considered one of the most important hindrances to animal production in the Middle East. In the dry season (June-October), the native range resources are scarce or very low in nutritive value. The shortage of feed for livestock is met by grazing the animals on crop residues or by providing them with supplements of cereal grain.

Introduction of drought and salinity-resistant fodder shrubs such as chenopods is one solution to the scarcity of feed resources during the dry season. They can provide feed as well as shelter for domestic livestock and wildlife and at the same time reduce soil salinity and erosion, which will help restore the integrity and productivity of these degraded rangelands. They also provide firewood and help stabilize animal production (Masri 1978, Hassan et al. 1984, Malcolm and Doney undated, DeMontgolfier-Kouevi and Le Houerou undated).

Nutritional qualities of shrubby vegetation are good, particularly when other types of vegetation are scarce seasonally or during drought. Shrubs not only furnish emergency forage during drought, but provide a relatively high quality feed as well. Although the carbohydrate percentages may be less than the desirable level for a single-feed-source, other factors often outweigh the lack of carbohydrates. Shrubs generally contain more protein than grasses and forbs, also shrubs retain their protein, carotene and carbohydrates better during drought than either grasses or forbs. Shrub use is relatively light as long as herbaceous vegetation is available, but they are useful to grazing animals in two ways: 1) as a source of protein to supplement the high fiber, moderate to high-energy diet provided by grasses during the dry part of a normal season; and 2) as reserves of fodder sufficient to maintain at least some of the animals during drought after the ground vegetation has died or become nonproductive (Merrill 1972, Everist 1972, McKell and Goodin 1973, Stanley 1978, Clarke 1982).

IMPORTANCE OF ATNU

Origin, characteristics and nutritional value

ATNU (old man saltbush) is a species of the genus *Atriplex*, which consists of halophytic (salt tolerant) plants in the family Chenopodiaceae. They occur widely in most arid and semi-arid areas of the world (Sharma et al. 1972). ATNU is an erect ramified shrub that may reach 3 m in height. The species originated in Australia where its native area corresponds to an arid to sub-humid Mediterranean climate with warm to temperate winter. It is found on clay, marl, hydromorphic, saline or calcareous soils. In reasonably deep soils, it is found in areas with 150 mm of annual rainfall. In shallow soils an average of 250-375 mm of annual precipitation is required. However, it can survive in a dormant stage with only 50 mm of rain annually (Baumer 1983).

Trumble (1932), as revised by Jones (1970), reported that Atriplex shrubs are of considerable value to livestock in areas subject to summer drought because 1) the capacity for production during feed shortage is high, 2) the water requirement is low, indicating a high efficiency of production in terms of rainfall, 3) the root system is deeply penetrating and capable of using moisture that has reached the subsoil during winter, 4) the protein and phosphoric acid contents are high, and 5) several species produce considerably higher yields than lucerne under field conditions.

ATNU has a large extensive root system. The main horizontal roots have been traced for more than 10 m while vertical extent exceeds 3.5 m (Jones and Hodgkinson 1970). The occurrence of an extensive root system in ATNU may explain its ability to survive rainless periods under semi-arid climatic conditions.

ATNU is capable of producing new leaves along the main stems and branches following complete defoliation and even from the base of the plant after being cut almost to ground level (Leigh and Wilson 1970, Hodgkinson and Becking 1978). Leigh and Mulham (1971) attributed the death of some ATNU shrubs after complete defoliation to the death of roots. ATNU shrubs are persistent perennial shrubs that keep their foliage throughout the year and provide good quality fodder as well as fire wood, erosion control and also serves as windbreaks (Sharma et al. 1972, Ruigrok 1985).

The establishment costs associated with planting ATNU seedlings are still rather high. In Tunisia, it is estimated at about US $500 ha-1 (El Hamrouni 1986). In Jordan, it may be about US $400-500 ha-1, because of the expensive hand labor. If machinery is used the costs are much less.

The logic for investigating Atriplex species as potential introductions to improve rangelands lies in their perennial habit, deep root systems, salt and drought tolerance, high nutritive value and tolerance to grazing (Sharma 1976, Masri 1978, Hyder 1981). They need little attention once established and can be grazed without incurring any specific management problems. Wood yields are broadly similar in terms of dry weight to the leaf production used for browse (Ruigrok 1985, DeMontgolfier-Kouevi and LeHouerou undated).

Atriplex shrubs show much diversity in form, production, and dispersion according to many factors including microtopography, soil type, soil water, degree of salinity and other environmental factors (Anderson 1970, Hassan et al. 1984). ATNU has many ecotypes, some grow very large, others stay dwarfed, and also they differ in drought resistance (Masri 1978). ATNU seedlings vary widely in such characteristics as leaf shape, leaf number, total leaf area, and tolerance of extreme levels of salinity, well above the concentration of sea water. Under drought conditions, its capacity to recover from wilting was enhanced by salinity rather than retarded (Gates 1972, Sharma 1976). ATNU is frost and salinity resistant (Le Houerou 1972, Ruigrok 1985, Leigh 1986). ATNU achieves salt tolerance by accumulating ions in the trichomes against a concentration gradient. The increased growth at high electrolyte concentrations (mainly sodium chloride), might be due to the rapid ion uptake, and that increased cell wall expansion would increase the leaf area, provide a greater photosynthetic surface, and therefore further increase growth (Jones 1970, Greenway and Osmond 1970, Goodin and Mozafar 1972, Hodgkinson and Becking 1978). Atriplex operates most efficiently at high concentration of chloride (Jones 1970). The salt percentage in the leaves may reach 20% of the dry matter. Atriplex plants may reduce the soil content of sodium chloride by about 1200 kg ha-1 year-1 (Masri 1978); and thus plants might be grown and harvested to remove excess salts and thereby reclaim land too saline for agricultural production (Goodin and McKell 1970).

ATNU is a high-producing species. Comparison of field grown ATNU with the performance of Hordium vulgare and Triticum aestivum crop plants on the basis of unit dry weight of above-ground material, indicated that ATNU was quite superior to the other species (Jones et al. 1970). Yields and crude protein contents have been comparable to or better than alfalfa (Goodin and McKell 1970, Krieg et al. 1977).

Proximate analysis of ATNU leaves revealed crude protein 26%, fat 1%, crude fiber 10%, ash 24% and nitrogen free extract 39%. Na was 4.9%, K 2.5%, Ca 1.4% and P 0.24%. Predicted digestible dry matter was 77% (Khalil et al. 1986). Digestible crude protein intake was 8.4 g/kg body weight $^{.75}$ for sheep. The corresponding total digestible nutrients intake was 21 g/kg body weight $^{.75}$. The above digestible crude protein provided 235% of the requirement, whereas the energy supplied by saltbush satisfied 78% of the requirement. It seems that ATNU leaves as a range forage for livestock would have good nutritive value with a digestible protein content reaching 12%

of the dry matter, that is almost identical to alfalfa in this respect. Died ATNU leaves fed to sheep and goats, yielded a digestibility of 69%. It can, therefore, be important in support of livestock during dry seasons in pastoral regions because nitrogen content and moderate organic matter digestibility are retained throughout dry periods in contrast to the low value of mature annual grasses (Wilson 1966b, Wilson 1977). Better energy value may be achieved either by mixing the saltbush with grasses that are characterized by high soluble carbohydrates or by supplementing it with a reasonable level of cereal grains (Masri 1978, Hassan et al. 1979, EMASAR 1983, Khalil et al. 1986).

Management of _A. halimus_ stands was studied by Ziani (1970). The shrubs were cut back to keep them within reach of livestock and ensure a maximum production of soft young leaves. Unless these cuts are made, wood production increases while leaf production decreases as the shrub gets older. Cutting _A. halimus_ at 50 cm above ground level increased leaf production over wood, compared with uncut shrubs. Utilization of _Atriplex_ shrubs should not exceed 60% of available forage in order to ensure regeneration and uniform forage production in following years (Zaroug 1985).

ATNU feed and animal performance

ATNU is one of the most palatable salt bushes. Leaves are consumed by all livestock. ACSAD studies (1983) showed that preference of _Atriplex_ species was in descending order; _A. halimus_, _A. nummularia_ and _A. canescens_. However, there are selected strains of ATNU of higher palatability (El Hamrouni and Sarson 1975, EMASAR

1983, Hassan 1984). Acceptance of Atriplex by animals increases in summer and fall seasons. As long as Atriplex is eaten in addition to natural range it can be a very useful supplement during the dry season when the range is of low nutritive value (Masri 1978, Kessler 1985), and may be an alternative to costly grain feeding (Leigh 1986). It is recommended for managing improved range sites in Jordan, so that sheep utilize native herbaceous forage species during the spring and fodder shrubs (mainly ATNU) during the fall (Zaroug 1985). Results from experiments of feeding Atriplex to sheep elsewhere show a good nutritive value of Atriplex, but yield variable data regarding parameters such as intake and growth of sheep (Jacobs and Smit 1977, Wilson 1977, Hassan and Abdel-Aziz 1979, Ruigrok 1985). For example, the digestible-dry-matter intake of ATNU was sufficient for maintenance of sheep according to Wilson (1966b), but Hassan and Abdel-Aziz (1979) found that rams given saltbush as the sole diet continued to lose weight. Adding 150 g of barley per head/day yielded a positive weight gain; moreover, saltbush intake increased significantly with barley supplementation. Voluntary dry-matter intake of the saltbush (30.6 g/kg body weight $^{.75}$) was within the normal range given by Wilson (1966a, 1977), namely, 26 - 34 g/kg body weight $^{.75}$, yet Hassan (1984) indicated that sheep feeding on ATNU consumed 64.2 g dry matter/kg body weight $^{.75}$.

The lack of a suitable level of readily available carbohydrates in saltbush seemed to be the main defect. In Australia, significant increase in body weights and a slightly higher wool yield were obtained from sheep flocks grazing ATNU reserves over that of the control plots of grassland that contained no ATNU (Leigh and Wilson 1970). Botanical analysis of the diet of the sheep showed that in winter and spring the saltbush provided only 10% of the forage eaten, the sheep were concentrating on the herbaceous plants growing between the bushes. In summer and autumn, the diet contained 25-90% saltbush depending on the presence of other plants and the stocking rate. With increasing stocking rate much higher weight losses occurred and the plots were unable to carry the sheep. In a grazing trial with local sheep in the Yemen Arab Republic in the dry season, Atriplex shrubs were readily eaten, almost all shrubs were completely defoliated up to 1 m height after the grazing trial (Kessler 1985). Sheep fed on a 55% ATNU, 45% sorghum stover diet showed weight gain during 6 weeks (Ruigrok 1985). Plots of ATNU grazed by sheep in South Africa maintained live weight without additional feeding (Jacobs and Smit 1977).

Water intake by sheep fed ATNU

Water intake was significantly higher for sheep fed ATNU compared to A. canescens (Hassan 1984). Water intake increased with increasing ratios of Atriplex in the diet (Ruigrok 1985). Sheep feeding on saltbush may increase their water consumption three-fold over that when feeding on grasses (Wilson 1966a, EMASAR 1983, Ruigrok 1985). Free-water intake by sheep fed ATNU increased significantly on the higher levels of barley supplementation, maybe as a result of increased feed intake (Hassan and Abdel-Aziz 1979). Water consumption was directly related to sodium content of the diet for sheep fed Atriplex; sodium content was high in summer diets and lower in winter diets. Feed intake of ATNU decreased to less than half when the drinking water was replaced by water containing 0.9-1.2% sodium chloride (Wilson 1966a). Thus, water quality available to grazing animals can affect performance significantly.

Salt content of ATNU

Atriplex parts consumed by animals contain a high percentage of salts (16-30%). This limits the consumption of ATNU because a sheep may consume up to 280 grams of salt per day (Wilson 1966a). Sodium may range from 0.9-6.3% and potassium from 1.4-40.5% of the dry matter of Atriplex. The high level of these elements in the feed or in the drinking water reduces feed digestion, causes diarrhea, and decreases animal weight due to depressed appetite (Pierce 1963, 1966; Wilson 1966a,b; Baumer 1983; Hassan et al. 1984). Therefore, one cannot depend on Atriplex alone as a diet for animals; it must be mixed with other plants, otherwise animals have to be supplemented with high carbohydrate feed.

Because of the high salt content of Atriplex it is necessary to find to what extent it can be used as a forage for sheep (Ruigrok 1985). There seems to be a range of palatability within an Atriplex population. Individual bushes of ATNU differ in their acceptability to sheep. Differences in salt concentrations between individual plants may be the cause of this varying palatability and important in management of the plant as fodder (Jones 1970, Lawton 1984, Kessler 1985, Leigh 1986). Salt content of Atriplex varies among different localities (soil, rainfall, evaporation, etc.), season, and individual shrubs at the same locality (Davis 1981). There exists also considerable variation in salt tolerance between different breeds of sheep. Sheep can be expected to automatically adjust their diet to the correct salt intake where possible by shifting to plant species of low salt content (CSIRO 1966 as revised by Kessler 1985, Ruigrok 1985).

Secondary compounds in Atriplex species

Most Atriplex species are regarded as excellent fodder plants, but potentially toxic amounts of oxalates have been reported in several (Everist 1974). Some ecotypes of Atriplex synthesize less oxalate than others, and selection of those ecotypes may be a very important factor in extending their future use (McKell and Goodin 1973). Some species of Atriplex have been reported to contain saponins which exert irritant effects to mammals (Sanderson et al. 1987) and the seeds produce haemalysis.

EFFECTS OF DROUGHT AND GRAZING ON SHRUBS

Many different features contribute to drought tolerance of shrubs, including leaf, stem and root adaptations. If plants do not obtain enough water to balance unavoidable losses they often shed their leaves. Generally the shedding begins with the oldest leaves and progresses toward the apical meristems; large winter leaves are often replaced by small summer leaves (Kozlowski 1972).

The main feature of Atriplex species is that soon after water stress occurs, leaf drop follows which reduces the photosynthetic surface and water-loss (Jones 1970, Rixon 1970). The relative rate of reduction in transpiration (the decrease in weight of the transpiring body during summer expressed as a percentage of the maximal weight in spring) was 70 and 96% for desert chamaephytes in mediterranean countries when rainfall was 178 and 32 mm in 1957 and 1958, respectively. Weights of the desert plants in 1958 were only 47 to 76% of the corresponding values for 1957 (Orshan 1972).

Although the year-to-year survival of annual plants depends on their ability to produce seeds, many perennial species survive adverse conditions by maintaining a reservoir of dormant meristems or buds, because dormant buds can survive conditions that would damage actively growing shoot tips. The plant can begin new growth after cold or drought or regenerate after damage to the top growth (Berg and Plumb 1972). Removal of terminal buds or twigs generally stimulates twig production. This vegetative growth is often to the detriment of flower and fruit production. Fall and winter seasons are the least detrimental periods for utilization, late spring and the middle of the growing season are the most damaging periods of use (Shepherd 1971, Garrison 1972).

Studying the responses of blackbrush (Coleogyne ramosissma), goats and cattle to a biological manipulation program, Provenza et al. 1983 found that increased utilization led to increased twig production. Browsing also improved the nutritional quality of blackbrush by stimulating current season's twig production. Heavy stocking intensities generated the greatest twig production. Studying some factors affecting twig growth in blackbrush, they indicated that as precipitation doubled, production increased by a factor of 1.9. Heavily browsed plants increased twig production by a factor of 3.6 relative to control plants. Annual twig production declined with rest from browsing. Browsing stimulated production of current season growth (CSG) by blackbrush and even after 4 years, heavily browsed plants (greater than 95% of the CSG removed) still outproduced unbrowsed plants.

Nitrogen and phosphorus are the major nutrient deficiencies limiting productivity in much of the semi-arid and arid regions of the world. Both these nutrients, particularly nitrogen, are associated with organic matter. In grazed rangelands, organic matter is derived from the plant residues and from feces and urine voided by grazing animals. Fecal pellets of sheep have a high concentration of nitrogen and phosphorus that may stimulate forage production in grazed compared to ungrazed areas (Rixon 1970).

Animals benefit plants by pollinating flowers, dispersing seeds, fertilizing soil with dung and reducing the size of competing plants. It has also been suggested over the last ten years that animals also benefit some plant species by grazing on them. Increased forage productivity caused by grazing has been reported by many studies in support of the hypothesis that plant communities overcompensate for tissue removed by grazers (Belsky 1986).

VEGETATION MEASUREMENT METHODS

In a study of Merino sheep grazing a bladder saltbush (*A. vesicaria*)-cottonbush (*Kochia aphylla*) community at three stocking rates, Wilson et al. (1969) estimated the amount of each of the major species present within the quadrats by eye, using a weight-estimate method. The mortality of A. vesicaria bushes in the plots was assessed at intervals by counting the number of live shrubs along permanent transects.

Studying the effect of grazing horses as manipulators of big game winter range, Reiner and Urness (1982) used the calibrated weight-estimated method (Tadmor et al., 1975) to estimate above-ground production of vegetation in treatment and control pastures immediately before and after each grazing period.

Uresk et al. (1977), sampling big sagebrush for biomass, employed a double sampling procedure for obtaining more reliable weight estimates. The relative-weight-estimate method was used for determining herbage production, where herbage yield is estimated as a percent of yield from a base plot rather than to estimate yields directly in grams or pounds. Hutchings and Schmautz (1969) used a double-sampling procedure to check and correct field estimates. Tadmor et al. (1975) applied a double sampling technique of visual weight estimates calibrated by harvesting to estimate production in grazed and ungrazed semiarid annual grasslands. They mentioned that a good level of accuracy can be achieved in such vegetation with a time expenditure significantly lower than by harvesting only, and that the method is highly successful when the sampled field is fairly homogeneous in species composition and phenological stage, even though it may be highly variable in biomass, cover and height. It seems that in these conditions the estimator can use his visual impression of cover, height or a combination of the two as good correlates of yield.

A visual estimate method was developed by Andrew et al. (1979) for estimating the weight of forage of chenopod shrubs. He called the method the Adelaide technique. Forage is estimated per individual shrub. A reference unit is selected. This is a leafy branch of the species to be estimated and typical of the predominant habit, leaf shape and leaf density. It is usually 10-20% of an average shrubs forage. Each shrub is then scored for the number of equivalent units contained in it, the number of unit equivalents then converted to forage value (g dry weight). The Adelaide technique gives accurate and precise estimates of shrub forage weights. It is quick and simple to use in the field, and requires no expensive equipment. The Adelaide technique (Reference-Unit-method) offers a reliable and standard method for shrub forage measurement.

Andrew et al. (1981) compared three methods for estimating shrub forage production (the capacitance probe, shrub dimension measurement, and the Adelaide technique) that were applied to a common set of chenopod shrubs. All methods had linear relationships between forage and method of measurement, but the Adelaide technique was best overall, i.e. the regressions were the most precise. The Adelaide technique coped well with differently-grazed shrubs (Andrew et al., 1979) and is an accurate, practical and simple method for shrub forage measurement.

Comparing the reference unit and dimensional-analysis methods for estimating large shrub foliage biomass in northeast Brazil, Kirmse and Norton (1985) indicated that both methods provided good estimates of foliage weight. The coefficients of determination for the reference-unit approach ranged from 0.890 to 0.985. Improved estimates with the reference-unit method were obtained when 1) a branch unit of 19% of total plant foliage was used versus a unit of only 7%. 2) the branch unit resembled the appearance of the branching of the plant being estimated and 3) estimations of 3 judges were averaged.

Indirect and non-destructive estimates are especially desirable where vegetation is sparse and slow-growing on permanent plots. Cabral and West (1986) quantitatively related the indirect non-destructive approach developed in Australia, the reference unit method, to clipped weights of winterfat (Ceratoides lanata) browse in Curlew Valley, Utah. The reference unit method was quite precise, accurate and efficient in predicting browse weights even though size and form of the shrubs differed greatly. The only major disadvantage was mental fatigue created by the requirement of greater sustained concentration.

DESCRIPTION OF THE STUDY AREA

The experiments were carried out on Sabha Range Reserve (SRR) in Jordan. The total area of this reserve is about 1154 ha, and it is located approximately 30 km east of Mafraq on the main road to H_5 (Fig. 1). It lies at latitude 32 N and longitude 36 E. Elevation of the site is approximately 680 meters above sea level. The actual area used for the experiments is about 4 hectares. The site, fenced in 1979 and planted to seedlings of ATNU in winter 1980, was chosen because of the homogeneity of the terrain and vegetation and the availability of sheep needed for the experiments. *Atriplex nummularia* forms a pure shrub stand on this site, where the seedlings were planted at a spacing of about 4m.

CLIMATE

The area has a semi-arid, Mediterranean climate. Moderate winds dominate most of the time, with a prevailing direction of west or northwest during summer and south or southeast during winter. Temperatures are high in summer and moderately low in winter. Mean maximum temperature is 33C with an absolute maximum of 44C. Mean minimum temperature drops to 2C in January with an absolute low value of -10C (JLDC 1986). Monthly mean temperatures range between 1C in January and 24C in July and August. Relative humidity rises from 40% in June to about 77% in January. Table 1 shows the average daily mean temperatures, average daily relative humidity and amount of rainfall at Mafraq during the time of the fall experiments in 1984

Table 1: The average daily mean temperature, the average relative humidity%, and the amount of rainfall at Mafraq, during the time of the experiment in fall, 1984 and fall, 1985.

Experiment	Util. treatment	Plot No.	Average daily Mean Temp. °C	Average Relative humidity	Rainfall MM.
Fall-A&B, 1984	U1*	1	15.55	64.65	40.00
	U1	4	15.55	64.65	40.00
	U1	9	15.55	64.65	40.00
	U2**	2	16.19	59.80	36.30
	U2	6	16.19	59.80	36.30
	U2	8	16.19	59.80	36.30
Average			15.87	62.23	38.15
Fall-A&B, 1985	U1	1	20.02	59.00	00.40
	U1	4	19.39	60.66	00.40
	U1	9	20.29	60.24	00.40
	U2	2	21.30	57.69	00.00
	U2	6	22.07	54.59	00.00
	U2	8	22.07	54.59	00.00
Average			20.86	57.80	0.20

* Treatment U1 = 80% utilization of *A. nummularia.*
** Treatment U2 = 40% utilization of *A. nummularia.*

and 1985.

The average annual rainfall is about 150mm. The rainy season at SRR before starting the experiments was poor (95mm). In 1984/1985 it was a relatively good rainy season (144mm or close to the average annual rainfall). In 1985/1986 it was again a poor rainy season (65mm). Table 2 shows the rainfall distribution and total amount of rainfall at SRR for the seasons 1982/1983 - 1985/1986.

SOILS

The soils of SRR are torriorthents-calciorthids with haplargids-natrargids-clayey complex. These soils were formed from basalt. The haplargid clayey soils are 50 to 150 cm deep with silty-clay-loam to clay-loam texture; hydraulic conductivity is slow; water retention is high; reaction is moderately alkaline; salinity is moderate; and gypsum is low. The natrargid clayey soils are 100 to 150cm deep, with clay-loam to clay texture; hydraulic conductivity is slow; water retention is high; reaction is moderately to very strongly alkaline; salinity is high; and gypsum is moderate (USAID 1986).

The study site is nearly flat; slope is about 1 to 3% with south exposure. The soil texture is a silty loam with depths exceeding 130 cm. Sheet and rill erosion by water is limited by gentle slopes (USAID 1986). The subsoil contains stones of different sizes. Field observations indicate the formation of surface crusts which normally form in the presence of high calcium carbonate, low organic matter and high silt content. When the soil dries, these crusts behave as a mechanical barrier to seedling plants as they reach the surface. The

Table 2: Rainfall distribution and total amount of rainfall at Sabha Range Reserve for the seasons 1982/1983 - 1985/1986.

Distribution\Rainy season	82/83 mm.	83/84 mm.	84/85 mm.	85/86 mm.
16/10 - 25/10	7	--	4	--
26/10 - 5/11	--	--	22	--
6/11 - 15/11	7	18	4	--
16/11 - 25/11	5	--	6	--
26/11 - 5/12	6	--	--	--
6/12 - 15/12	--	--	10	--
16/12 - 25/12	6	--	12	20
26/12 - 5/1	10	20	--	--
6/1 - 15/1	8	--	--	6
16/1 - 25/1	11	--	7	2
26/1 - 5/2	17	--	13	--
6/2 - 15/2	--	10	12	27
16/2 - 25/2	43	--	22	--
26/2 - 5/3	8	--	32	--
6/3 - 15/3	--	--	--	--
16/3 - 25/3	4	35	--	--
26/3 - 5/4	--	12	--	10
Total	132	95	144	65

soil structure is generally weak, and the basic infiltration rate is about 1cm/hr. Soil specific gravity ranges between 1.3 and 1.4. The water-holding capacity of the soil profile is between 160 to 180 mm/m (JLDC 1986). This site is fairly extensive in the northern one third of Jordan; it occurs on toe slopes and may receive additional water as run-on from upper slopes during periods of heavy rainfall. Such additional water is not of frequent occurrence in this precipitation zone. Table 3 shows the soil chemical analysis at a profile close to the study site.

VEGETATION

The past history of SRR as well as most of the rangelands in Jordan is one of long-term human misuse. SRR was fenced and protected in 1979. Plantation of fodder shrubs started in 1980; by 1986 about 700 hectares had been planted mainly to *Atriplex nummularia* and *A. halimus*. Protection from grazing, plowing and uprooting of the plants led to recovery of the vegetation, but the amount of vegetation production is variable and dependent mainly on rainfall amount and seasonal distribution.

Relative composition of vegetation by weight is estimated to be about 30% grasses and grasslike plants, 10% forbs, and 60% shrubs. The estimated annual production varies from 500-600 kg/ha in an average year (USAID 1986). In 1986, which was a below-average precipitation year, annual vegetation production was estimated at 400 kg/ha.

Table 3: Soil chemical analysis at a profile close to the study site at Sabha Range Reserve.

Horizon	Depth (cm)	EC (mmhos /cm)	pH	O.M (%)	Total Carb- onate (%)	Extractable cations Meq/100g				Micro Nutrients				Available P (ppm)
						Ca	Mg	Na	K	Mn	Fe	Cu	Zn	
AP	0-26	0.44	8.16	0.53	24.4	15.0	3.6	1.3	2.2	3.8	3.3	2.0	0.44	2.6
B_{21}	26-59	2.12	8.08	0.37	25.8	14.6	3.6	3.8	0.9	2.4	4.2	1.9	0.40	4.0
B_{22}^{ca}	59-110	-	-	-	60.0	-	-	-	-	-	-	-	-	-

Source: JLDC (1986).

The following native plant species are present on SRR:

Grasses and Grasslikes:	Forbs:	Shrubs:
Carex stenophylla	*Salsola volkensii*	*Salsola vermiculata*
Stipa capensis	*Salsola inermis*	*Anabasis setifera*
Hordeum murinum	*Plantago albicans*	*Halogeton alopecuroides*
Bromus tectorum	*Scenecio vernalis*	
Phalaris minor	*Anthymus syriaca*	
Poa sinaica	*Erucaria boveana*	
Stipa barbata		

METHODS AND MATERIALS

EXPERIMENTAL DESIGN

Design of the experiments (Fig. 3) was set up for three different objectives as follows:

Fall-A experiment

Effect of grazing intensities on production of ATNU: The purpose of this experiment was to study the effect of fall grazing at moderate and heavy intensities on the production of ATNU. This experiment consisted of 9 plots divided by fences, so that there are 3 treatments (80%, 40%, and 0% intensity of grazing on ATNU) and 3 replicates of each treatment (treatments were assigned randomly for each replicate Fig. 3). Each plot (Fig. 4) has 5 rows of shrubs, and each row has 8 shrubs, i.e., 40 shrubs in each plot. However, because the survival rate of these shrubs was less than 100% and dead ones were not replaced, and also because the Jordan Livestock Development Company dug up some of the shrubs while preparing the area adjacent to the plots for irrigated fodder production, the number of shrubs in each plot ranged from 23-38.

Spring experiment

Effect of grazing grasses and forbs at two intensities during spring on the production of ATNU: This experiment has the same number of plots, treatments and replicates as the Fall-A experiment, each plot has nearly the same number of shrubs, figure 3i.e., about 40 shrubs. The only difference is that these plots were utilized in

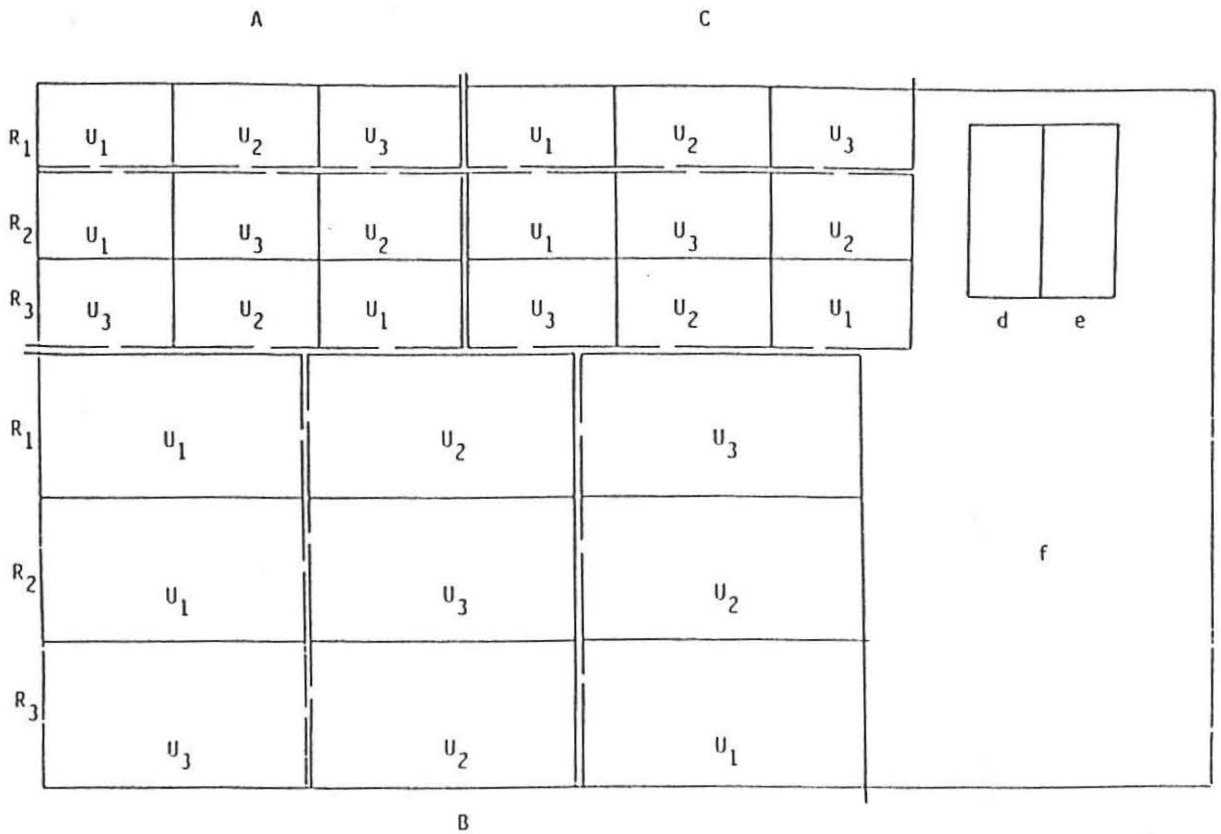

Figure 3. Experimental layout for the different experiments where: A = Fall-A experiment, B = Fall-B experiment, C = Spring experiment, d = plot where ATNU shrubs were cut in Fall 1984, e = plot where ATNU shrubs were cut in Spring 1985, f = plot used for training on vegetation estimation and providing the reference units, U_1 = heavily grazed treatment, U_2 = moderately grazed treatment, U_3 = ungrazed treatment (control), R_1, R_2, R_3, = the three replicates in each treatment.

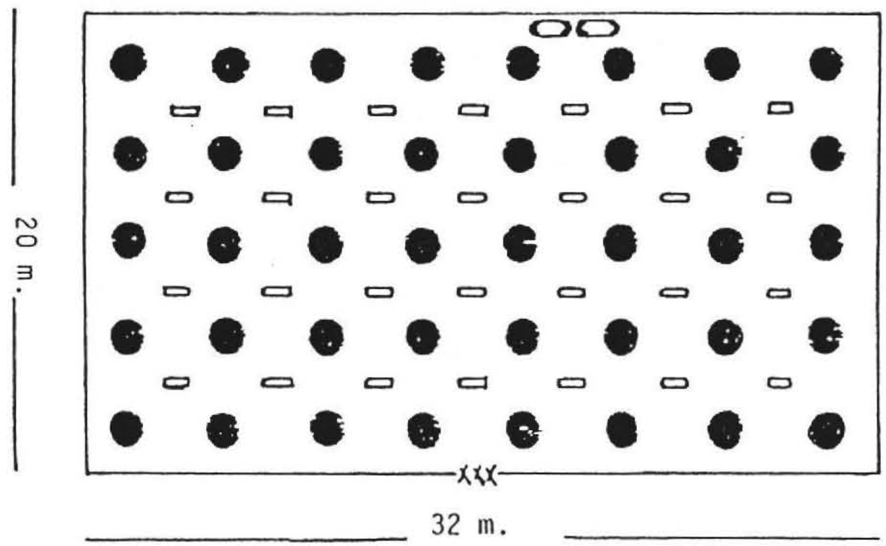

Figure 4. Representative plot of the Fall-A experiment where ● = the location of each of the 40 ATNU shrubs, ▭ = the location of each of the 28 quadrats used to sample grasses and forbs, ⬭ = the location of the watering points, xxx = the gate.

spring instead of fall and the focus of grazing is on forbs and grasses instead of shrubs because green forbs and grasses are available in spring and are presumably preferred to shrubs. At the intended grazing intensities of 80%, 40% and 0% on forbs and grasses, the forage weight of Atriplex shrubs was estimated to find whether or not shrubs were utilized in spring and if there was any effect on subsequent production of ATNU.

Fall-B experiment

Effect of grazing intensities on sheep live weight: This experiment has the same number of plots, treatments and replicates as in Fall-A experiment, but each plot was approximately 3 times larger and had 3 times the number of shrubs (i.e., each plot has 8 rows of shrubs and each row has 15 shrubs, a total of 120 shrubs) to give the sheep enough time on experimental plots to estimate sheep live-weight responses to grazing ATNU. Besides these three experiments, the experimental layout included the following:

1. One plot of about 40 shrubs outside the experimental area was selected to study the relation between actual and estimated forage weights of shrubs and the effect of cutting Atriplex shrubs at about 10 cm above soil surface in the fall season on their survival and regrowth. Another plot of about 40 shrubs outside the experimental area was chosen to provide the same information for the spring season.
2. An area outside the experimental plots but inside the fenced study area was chosen for training to estimate forage production

of shrubs, forbs and grasses and for obtaining a reference unit branch when needed.

3. An angle-iron stake 10-12 cm in length was driven into the soil in the interspace among each of four Atriplex shrubs in the experimental plots so that only 2 cm appeared above the soil surface. This permitted the quadrat used in estimating the production of grasses and forbs to be set exactly at the same place each time forage weight of grasses and forbs was estimated.
4. Thirty-six sheep (about 10 months old) were used in the Fall- A experiment then transferred to the Fall - B experiment. Another 36 sheep were used in the spring experiment, so that there were 6 sheep in each plot except the control.
5. Two plastic basins (each of 35-liter capacity) were placed in each treatment plot in each experiment to estimate water intake by each group of sheep. One basin full of water was put in one of the control plots to measure evaporation, and another empty basin was put in the control plot to measure precipitation to correct for water additions.
6. Soil samples were taken from each plot in each experiment at two depths (i.e. 0-30 cm and 30-60 cm) to determine if there was any effect of the treatments in each experiment on soil moisture content. Soil cores at each depth were mixed thoroughly, subsamples of 250 cm3 each were collected in standard air-tight soil cans and weighed before and after drying at 105oC for 24 hours.

METHODS USED TO ESTIMATE FORAGE WEIGHTS OF SHRUBS, GRASSES AND FORBS

1. The reference unit method, as described by Andrew et al. (1979, and 1981) and field tested by Kirmse and Norton(1985) and Cabral and West (1986), was applied to estimate the dry forage weight (leaves, fruits and young twigs) of ATNU shrubs. For this method a leafy branch, the reference unit, of ATNU was cut from a shrub outside the experimental plots that comprised about 10-20% of the average shrub size and resembled the predominant growth form and leaf shape of the shrubs in the experimental plots. The cut branch was compared with each shrub to be sampled, and the number of equivalent units in each shrub sample was recorded. After each use of a reference unit branch, its leaves, young twigs and fruits were stripped, oven dried at 105oC for 24 hours, and weighed. The dry forage weight of each shrub sample was estimated by multiplying the number of equivalent units for each shrub sample by the reference unit dry weight. From 23-38 shrubs in each plot in each experiment were sampled (Fig. 4).

2. An ocular-estimation method, as described by Tadmor et al. (1975), was applied to estimate the dry forage weights of grasses and forbs combined. A 50 x 20 cm plot frame was laid in the interspace among each four shrubs in each plot, so that 28 quadrats (Fig. 4) were estimated. Six of the 28 quadrats were chosen at random and estimated each year. Grasses and

forbs in these 6 quadrats were clipped, dried at 105oC for 24 hours and weighed. A regression equation was developed between the actual and estimated weights for each experiment, each time an experiment was performed to correct for personal bias.

METHODS OF CONDUCTING THE EXPERIMENTS

This research was conducted in fall 1984, spring 1985, summer 1985, and was repeated the second year in fall 1985, spring 1986, and summer 1986. For each experiment, 36 sheep were brought from Khanaseri Range Reserve to SRR at least one week before introducing them to the study plots to allow for adaption to grazing at the SRR. Apart from Atriplex shrubs the vegetation at Khanaseri is about the same as that at Sabha.

Fall-A experiment

1. Each of the 9 plots in this experiment had an area of about 640 m2.

   Dry forage weight of each ATNU shrub in each plot was estimated (using the reference unit method) before applying the treatments (i.e., 80%, 40% and 0% intensity of grazing). The same method was used immediately after the treatments to calculate the percent of forage utilized, and again in summer at the end of the growing season to evaluate forage production. This experiment was repeated the second year on the same plots to study the cumulative effect of one-and two-year's utilization on the production of ATNU.

2. Dry forage weight of grasses and forbs was determined using the ocular estimation method from 28 quadrats in each plot before grazing; 6 randomly chosen quadrats were clipped at the soil surface, and oven dried while forage weight from the remaining 22 quadrats was estimated after grazing. The forage weight estimates were corrected by the regression equation based on actual and estimated forage weights obtained from the 6 clipped quadrats. These estimates were repeated in the second-year experiment except the quadrats clipped the first year were excluded.
3. Each of the 6 sheep in each group assigned for each treatment was weighed immediately before and after the treatment to detect sheep live weight gain or loss.
4. Water intake by each group of sheep (i.e., 6 sheep assigned for each treatment) was measured and corrected for evaporation and rainfall.
5. At the beginning of the experiment in the fall and at the end of the growing season in summer, soil sample cores were collected to detect any difference in soil moisture content due to the treatments. Two soil sample cores, one at 0-30 cm depth, and the other at 30-60 cm depth, were taken at each plot in the experiment near a randomly chosen shrub in the first year. Four soil sample cores were taken the second year near 2 randomly chosen shrubs (i.e., 2 samples at 0-30 cm depth and 2 samples at 30-60 cm depth).

Spring experiment

Each of the 9 plots had an area of about 640 m2. The same data as in the Fall-A experiment were collected except that:

1. The focus of grazing in spring was on how the utilization of grasses and forbs (i.e. 80%, 40% and 0% utilization) affected shrub production. The forage weight of shrubs was estimated before and after grazing and evaluated in summer at the end of the growing season.
2. Since the time that sheep spent in the experimental plots was too short (1 to 3 days) to detect any changes in sheep live weight or water intake, these data were not collected.

Fall-B experiment

Each of the 9 plots in the Fall-B experiment had an area of about 1920 m2. The same data as in the Fall-A experiment were collected except that:

1. The number of shrubs in each plot was about 120. To estimate the dry forage weight of 40 of them, shrubs numbered 1, 4, 7, 10 and so on, were systematically sampled.
2. There were 98 interspaces among the 120 shrubs in each plot. To estimate the dry forage weight of grasses and forbs in 28 quadrats, interspaces numbered 1, 5, 9, 13 and so on (i.e., 25 interspaces) plus interspaces 2, 6, and 10 were systematically selected.
3. Two soil sample cores, one at 0-30 cm depth, and the other at 30-60 cm depth, were collected at each plot in the experiment

near a randomly chosen shrub in the first year and in the second year.

SHRUBS CUT IN FALL 1984 AND SPRING 1985:

Forage weights of 34 shrubs in fall 1984 and 33 shrubs in spring 1985 were estimated using the reference unit method. Then, each shrub was cut (using a hand-saw) at 10cm above the soil surface. Forage on each shrub was stripped, oven dried at 105C for 24 hours and weighed to study the correlation between actual and estimated dry weight forage using the reference unit method. A second objective was to study the effect of complete defoliation by cutting *Atriplex* shrubs at 10cm above soil surface in the fall or in the spring on their regrowth and survival.

CHEMICAL ANALYSES OF PLANT SAMPLES

While conducting the experiments mentioned above, I noticed that some of the *Atriplex* shrubs were grazed heavily, others were very lightly grazed, or even untouched. To investigate the causes, 2 samples (leaves and young twigs) were collected from some grazed male shrubs, ungrazed male shrubs, grazed female shrubs and ungrazed female shrubs in the plots of the experiments. These samples were analyzed qualitatively for saponin (Sanderson et al. 1987) and chemically for saponin (Li-Chun 1969), oxalates (Dye 1956), chloride (Chapman and Pratt 1961), and sodium and other cation electrolytes (using Inductively Coupled plasma, ICP). Other samples of ATNU and forbs and grasses were chemically analyzed for macro-nutrient content (crude protein, crude fiber, ether extract, ash, and nitrogen-free extract) on a dry matter basis (Horwitz 1980).

STATISTICAL ANALYSES

The statistical design was a split-plot design with 3 replicates of 3 treatments over time. The program RUMMAGE was used to analyze the data to detect significant differences among the grazing treatments for utilization and production of ATNU, grasses and forbs, sheep live weight, water intake by sheep, or salts and secondary-compound concentrations.

The general model used in these analyses was:

Y(RUTP) = R (R) + U (U) + RU + P(RUT) + T(T) + TU + TR + TRU + E, where

Y = the dependent variable, i.e., the dry forage weights of shrubs, the dry forage weights of grasses and forbs, the sheep live weight, or amount of water intake.

R = Replicates

U = Treatment or utilization, i.e., 80%, 40%, or 0% intensity of grazing.

RU = Interaction (Error A).

P(RUP) = Sub-samples within RU.

T = Time, i.e., before grazing, after grazing, and summer evaluation at the end of the growing season.

TU = Interaction between time and utilization.

TR + TRU = Interaction (Error B)

E = Sub-samples within RUT.

For soil moisture content, depth (D) at which the soil samples were collected was added to the model:

Y(RUDT) = R(R) + U(U) + RU + P(RUP) + D(D) + DU + DP + DR + DUR + T(T) + TU + TD + TUD + TUR + TR + TDR + TDRU + E where,

Y = Soil moisture percentage.

R = Replicates.

U = Utilization.

RU = Interaction Replicates x Utilization (Error A).

P(RUP) = Sub-samples within RU.

D = Depth at which soil moisture samples were taken.

DU = Interaction of depth x utilization.

DP = Interaction of depth x samples.

DR + DUR = Interaction (Error B).

T = Time of collecting samples.

TU = Interaction of time x utilization.

TD = Interaction of time x depth.

TUD = Interaction of time x utilization x depth.

TR + TUR + TDR + TDUR = Interaction (Error C).

E = Sub-samples within RUT.

A T-test was used to compare the mean of dry forage produced or the sheep-live-weight loss or gain between the different treatments.

The least significant difference (LSD) method was used to compare treatment means. Probabilities $\leq$ 0.05 were considered significant.

Regression analysis using the SPSS program was used to study the correlation between actual and estimated dry forage weights of ATNU shrubs in the fall or in the spring seasons. Also regression analysis was used to correct the estimated dry forage weights of grasses and forbs by building regression equations between the actual dry forage weights (obtained from clipped quadrats) and the estimated dry forage weights of the 6 randomly-chosen quadrats.

RESULTS

FALL-A EXPERIMENT

Utilization and production of ATNU

The actual utilization levels of shrubs in treatments (U_1, U_2, and U_3) were 73%, 42% and 0% in the first year and 80%, 53% and 0% in the second year. Table 4 shows the mean dry forage weights of ATNU in these treatments as estimated at T1 (before grazing), T_2 (after grazing), T_3 (the end of the growing season), and the mean amount of dry forage produced in response to utilization ($T_3 - T_2$).

Analysis of variance (Appendix table 12) showed that differences in the dry forage weights among different grazing intensities were not significant while they were significant ($P<0.05$) among different times of the treatments. The interaction TU was significant in the second year.

Comparing the different treatments for regrowth (Table 4), that produced in response to the heavy utilization (U1) was significantly higher than that produced in response to the control treatment (U_3). Regrowth produced in response to the moderate utilization U_2 was numerically intermediate but not significantly different from either U_3 or U_1 in the first year. In the second year regrowth following moderate utilization was significantly higher than the control.

Utilization of grasses and forbs:

Table 5 shows the mean dry forage weights of grasses and forbs in U_1, U_2 and U_3 as estimated at T_1 and T_2.

Table 4: Mean dry forage (g/shrub) produced by ATNU shrubs in the treatments at different times of the year.

Experiment	Utilization	First Year				Second Year			
		Before Grazing T_1	After Grazing T_2	At the end of growing season T_3	Regrowth $T_3 - T_2$	Before Grazing T_1	After Grazing T_2	At the end of growing season T_3	Regrowth $T_3 - T_2$
Fall-A	Heavy(U_1)	273^{a}	73^{a}	456^{a}	383^{a}	519^{a}	104^{a}	268^{a}	164^{a}
	Moderate(U_2)	226^{a}	132^{ab}	474^{a}	342^{ab}	461^{a}	217^{a}	339^{a}	123^{a}
	Control(U_3)	192^{a}	179^{b}	427^{b}	248^{b}	437^{a}	395^{b}	313^{a}	-83^{b}
Spring	Heavy(U_1)	208^{a}	189^{a}	266^{a}	77^{a}	205^{a}	159^{a}	172^{a}	13^{a}
	Moderate(U_2)	273^{b}	261^{b}	377^{b}	116^{a}	291^{c}	224^{b}	226^{b}	2^{a}
	Control(U_3)	222^{a}	220^{ab}	346^{b}	126^{a}	232^{b}	231^{b}	229^{b}	-2^{a}

[1]: Means followed by different letters are significantly ($P<0.05$) different within each time by treatment combination.

Table 5: Mean dry forage (g/0.1 m^2) produced by grasses and forbs in the treatments at different times of the year.

		First Year		Second Year	
Experiment	Utilization	Before Grazing T_1	After Grazing T_2	Before Grazing T_1	After Grazing T_2
Fall-A	Heavy (U_1)	2.44[a1]	0.00[a]	1.59[a]	0.00[a]
	Moderate (U_2)	3.36[b]	0.00[a]	2.27[a]	0.00[a]
	Control (U_3)	2.68[a]	2.37[b]	2.71[a]	2.67[b]
Spring	Heavy (U_1)	5.95[a]	0.53[a]	0.87[a]	0.24[a]
	Moderate (U_2)	7.29[ab]	3.28[c]	0.53[a]	0.22[a]
	Control (U_3)	8.92[b]	8.09[b]	1.47[b]	1.42[b]

[1]: Means followed by different letters are significantly ($P<0.05$) different within each time by treatment combination.

Analysis of variance (Appendix table 13) showed that the dry forage weights were not significantly different among different ($P<0.05$) utilization treatments but significantly different between the two times. The interaction TU was significant in the first year.

Soil moisture:

Appendix table 14 shows soil moisture percentages in the treatments at the two times (T_1, T_3) and the two depths (D_1,D_2). Analysis of variance (Appendix table 15) showed that soil moisture percentages were not significantly different ($P<0.05$) among the utilization treatments, but significantly different between depths. They were significantly different between times in the second year only.

Sheep live weight

Table 6 shows mean sheep live weight in U_1 and U_2 at T_1 and T_2. Analysis of variance (Appendix table 16) showed that sheep live weight was not significantly different ($P<0.05$) between the two treatments, but it was significantly different between the two times of the experiment. Comparing the two treatments for sheep-live-weight loss (Table 6), U_1 was not significantly different from U_2.

SPRING EXPERIMENT

Utilization and production of ATNU

The actual utilization levels on shrubs in treatments (U_1, U_2, and U_3) were 9%, 5%, and 0% in the first year and 23%, 23%, and 0% in the second year. Table 4 shows the mean dry forage weights of shrubs

Table 6: Mean sheep live weight (kg.) in the treatments of the Fall-A and B experiments in 1984 and 1985.

Experiment	Utilization	1984			1985		
		Before grazing T_1	After grazing T_2	Gain or loss T_2-T_1	Before grazing T_1	After grazing T_2	Gain or loss T_2-T_1
Fall-A	heavy(U_1)	27.0[1]	25.5	-1.4[a]	29.8	27.2	-2.7[a]
	moderate(U_2)	27.4	26.9	-0.5[a]	31.9	30.2	-1.7[a]
Fall-B	heavy(U_1)	25.5[a2]	26.0[a]	0.5[a]	27.2[a]	25.7[b]	-1.5[a]
	moderate(U_2)	26.9[b]	28.6[c]	1.7[b]	30.2[c]	31.1[c]	0.9[b]

1: Sheep live weight was not significantly different between utilization treatments, but was significantly different between times for Fall-A 1984 (27.2 vs. 26.2) and Fall-A 1985 (30.9 vs. 28.7)

2: Means followed by different letters are significantly ($P<0.05$) different within each time and within each treatment combination.

in these treatments as estimated at T_1, T_2, T_3 and the mean amount of dry forage produced in response to utilization (T_3-T_2).

Analysis of variance (Appendix table 12) showed that the dry forage weights of shrubs were significantly different among grazing intensities in the first year but not in the second year. The interaction TU was significant in the second year. They were also significantly different ($P<0.05$) among times of the treatments. Comparing the different treatments for dry forage produced (Table 4), that produced in response to U_1 was not significantly lower than U_3 nor was U_2 significantly lower than U_3.

Utilization of grasses and forbs

The actual utilization levels on grasses and forbs in treatments (U_1, U_2, and U_3) were 91%, 55% and 0% in the first year and 72%, 42% and 0% in the second year. Table 5 shows the mean dry forage weights of grasses and forbs in these treatments as estimated at T_1 and T_2.

Analysis of variance (Appendix table 13) showed that the dry forage weights were significantly different among utilization treatments in the second year only, while they were significant ($P<0.05$) between the two times of the treatments (T_1 and T_2) in both years. The interaction TU was significant ($P<0.05$) in the first year.

Soil moisture:

Appendix table 14 shows the soil moisture percentages in the treatments at the two times (T_1, T_3) and the two depths (D_1, D_2). Analysis of variance (Appendix table 15) showed that soil moisture percentages were not significantly different among the utilization treatments, but were significantly different ($P<0.05$) between times and between depths.

FALL-B EXPERIMENT

Sheep live weight

Table 6 shows the mean sheep live weights in U_1 and U_2 (77% vs. 47% utilization of ATNU in the first year and 79% vs. 51% utilization in the second year, Appendix table 16)) at T_1 and T_2. Analysis of variance (Appendix table 17) showed that sheep live weight was not significantly different between the two treatments. It was significantly different between the two times of the experiment ($P<0.05$) only in the first year. The interaction TU was also significant ($P<0.05$) in both years. Comparing the two treatments for sheep live-weight gain or loss (Table 6) showed that U_1 was significantly different from U_2 ($P<0.05$).

WATER INTAKE BY SHEEP

The mean water intake per sheep per day was averaged for Fall-A and B experiments together for each of U_1 and U_2 treatments (Table 7). Analysis of variance (Appendix table 18) showed that mean water intake per sheep per day was significantly different between the two treatments U_1 and U_2, and between the two years ($P<0.05$). Introducing average mean temperature, average relative humidity and amount of rainfall during the experiment as co-variates, analysis of variance showed no significant difference ($P<0.05$) between treatments.

EFFECTS OF CUTTING ATNU
AT 10CM HEIGHT

Table 8 shows the survival rate, actual and estimated mean dry forage weights, and estimated mean dry forage weights at the end of first and second growing seasons following the treatments of ATNU shrubs cut at 10 cm above soil surface in fall, 1984 and spring, 1985. Regressing the actual dry forage weight against the estimated dry forage weight of ATNU shrubs cut in Fall 1984 gave the following regression equation:

Actual dry forage weight = - 17.2 + 0.933 X Estimated dry forage weight ($r2$ = 0.951).

After cutting and complete defoliation, the survival and the dry forage weight of each shrub was estimated at the end of the growing season in summer, 1985. The survival rate or the percentage of shrubs that showed regrowth was 47% (16 out of the 34 shrubs); 18 of them died or at least did not show any regrowth. The mean dry forage weight of regrowth on the 16 shrubs was 46g. Evaluating these shrubs at the end of the second growing season after cutting, the survival rate stayed the same (47%), and the mean dry forage weight of regrowth on the 16 shrubs was 73g. i.e., the same shrubs that showed regrowth at the first growing season continued to grow at the end of the second growing season and none of the others showed any regrowth.

Regressing the actual dry forage weight against the estimated dry forage weight of ATNU shrubs cut in spring 1985 yielded the following regression equation:

Table 7: Mean water intake per sheep per day (liter) for Fall-A and B experiments in 1984 and 1985.

Experiment	utilization	First year	Second year
Fall- A&B	Heavy (U_1)	2.97[a1]	3.79[b]
	Moderate (U_2)	3.43[a]	4.24[b]

[1]Means followed by different letters are significantly ($P<0.05$) different with each time and within each treatment combination.

Table 8: The survival rate, actual mean dry forage weight, estimated mean dry forage weights at the time of the experiment, and at the end of the first and second growing seasons of ATNU shrubs cut at 10 cm above the soil surface in fall 1984 and spring 1985.

Type	Fall 1984	Spring 1985
Survival rate at the end of first growing season	47%	73%
Survival rate at the end of second growing season	47%	70%
Actual mean dry forage weight	251	321
Estimated mean dry forage weight	288	281
Estimated mean dry forage weight at the end of first growing season	46	25
Estimated mean dry forage weight at the end of second growing season	73	93

Actual dry forage weight = 0.59 + 1.14 X estimated dry forage weight ($r2 = 0.996$).

The survival rate or the percentage of the shrubs that showed regrowth was 73% at the end of the first growing season. Nine shrubs died or at least did not show any regrowth. The mean dry forage weight of regrowth on the 24 shrubs was 25g. The survival rate was 70% by the end of the second growing season; one more shrub had died. The mean dry forage weight of regrowth on the 23 shrubs was 93g.

CHEMICAL ANALYSES OF FORAGE SAMPLES

The eight samples of ATNU forage (2 male and 2 female grazed, 2 male and 2 female ungrazed) were chemically analyzed to try to explain the difference among the different samples in terms of their acceptability to sheep. Table 9 shows the percentages of crude saponin, soluble oxalates, total oxalates, chloride, sodium and total cation electrolytes (Na + K + Ca + Mg) in grazed (male and female) and ungrazed (male and female) ATNU forage samples on a dry matter basis. Analysis of variance (Appendix table 19) did not show any significant difference among the various parameters, except for total oxalates. The concentration of total oxalates was significantly higher ($P<0.05$) in male (5.63%) than female (4.87%) samples, but not significantly different ($P>0.05$) between the grazed and ungrazed samples. Table 10 shows the mean values for crude protein, ether extract, crude fiber, ash and nitrogen-free extract on a dry matter basis for ATNU, grass and forb samples. Samples were collected in the fall 1984 and spring 1985.

Table 9: The percentages of crude saponins, soluble oxalates, total oxalates, chlorides, sodium and total electrolyte cations on a dry matter basis in grazed and ungrazed, male and female ATNU forage samples.

ATNU forage sample	Crude saponins %	Soluble oxalates %	Total oxalates %	chloride %	sodium %	Total caton electrolytes (Na+k+Ca+Mg)%
ungrazed	1.7[a]	2.4[a]	5.1[a]	8.2[a]	7.1[a]	10.3[a]
grazed	2.3[a]	2.7[a]	5.4[a]	8.5[a]	7.1[a]	10.0[a]
male	1.7[a1]	2.6[a]	5.6[a]	8.0[a]	7.0[a]	10.1[a]
female	2.3[a]	2.6[a]	4.9[b]	8.8[a]	7.2[a]	10.1[a]

[1]: Means followed by different letters are significantly different ($P<0.05$) within each compound combination.

Table 10: Chemical analyses for macro-nutrients of ATNU (leaves and young twigs) and grass and forb samples collected at different times of the experiments.

Type of sample	Season	Crude protein %	Ether extract %	Crude fiber %	Ash %	Nitrogen-free extract %
ATNU	spring	14.2	1.3	5.2	26.4	53.0
	fall	12.3	3.1	10.3	28.8	45.5
grass & forb	spring	11.2	1.9	6.5	14.5	65.9
	fall	7.9	3.2	9.7	21.4	57.8

DISCUSSION

FALL-A EXPERIMENT

Prior to grazing in 1984, dry forage weights of ATNU in the heavy grazing U_1, moderate grazing U_2 and the control U_3 treatments were not significantly different. After ATNU shrubs were utilized by sheep, U_1 was significantly lower than U_3, U_2 was slightly but not significantly lower than U_3 at T_2 (Table 4) but at T_3 they were not significantly different. This means that, although shrubs in U_1 or U_2 were heavily or moderately grazed compared to the ungrazed shrubs in U_3, through more vigorous growth they were able to compensate for grazing, possibly through removal of apical dominance, and fertilization from dung. Actually there was an important difference between U_1 and U_3, and between U_2 and U_3 (Table 4) in the amount of current-season's growth produced in response to the treatments. I think shrubs were stimulated by grazing to produce more forage than shrubs in the control, thus to rendering the difference between them at the end of the first growing season insignificant.

In U_1, the mean dry forage weight of shrubs at T_3 was 1.67 and 6.25 times those at T_1 and T_2, respectively. Similar values for U_2 were 2.10 and 3.60; and for U_3 2.22 and 2.39 (Table 4). Because the amount of rainfall during the growing season following the treatments was relatively good (144mm) and close to average (150mm), shrubs in all treatments showed good growth. Although the compensatory growth (T_3 compared to T_2) was higher in U_1 than U_2 with regard to T_2, it was the opposite with regard to T_1. This means that although heavy grazing stimulated forage production more than moderate grazing, the latter resulted in more dry forage weight at T_3 compared to T_1.

In fall 1985, U_1, U_2 and U_3 were not significantly different. Although U_1 and U_2 (Fig. 5 and 6) were significantly different from U_3 at T_2, as 80% and 53% of forage weight was removed by sheep, respectively, at T_3 they were not significantly different (Table 4). This again may be explained as compensatory growth by grazed shrubs in U_1 and U_2 compared to the ungrazed shrubs in U_3, such that they were not significantly different at T_3. Actually there was an important difference between U_1 and U_3, and between U_2 and U_3, in the amount of current-season's growth produced in response to the treatments. I think here also as in fall 1984, shrubs were stimulated by grazing to produce more forage than shrubs in the control plots, that lost some forage through shedding leaves due to drought, to render the difference between them at T_3 insignificant.

In U_1, the mean forage weight of shrubs at T_3 was 0.52 and 2.58 times those at T_1 and T_2, respectively. Similar values for U_2 were 0.74 and 1.57; and for U_3, 0.72 and 0.79. Because the rainfall season following the treatments was poor (63mm, which was less than half the average annual rainfall for this site) and because of the effect of grazing for two successive seasons, the forage weights of shrubs in all the treatments at T_3 were less than that at T_1. Although the compensatory growth of shrubs in U_1 was higher than U_2 with regard to T_2, it was the opposite with regard to T_1. U_2 was less affected by grazing for the second season than U_1, and forage

Figure 5:, A plot in Fall-A, 1985 experiment before grazing (A), after being heavily grazed (B), and at the end of the following growing season (C).


9
A


9
B


9
C

Figure 6: A plot in Fall-A, 1985 experiment before grazing (A), after being moderately grazed (B), and at the end of the growing season (C).


A
B
C

production was similar to that of the control U_3, even though 53% of U_2 was utilized by sheep.

The mean dry forage weights of grasses and forbs were not significantly different. Although grasses and forbs in U_1 and U_2 were totally grazed compared to the control, the amount of forage estimated in each quadrat was low in both years and was affected in the second year by previous grazing. Thus no significant difference occurred among the treatments (Table 5). It is clear from this experiment that grasses and forbs, even as standing dead material, were preferred to ATNU browse and were grazed first; only after they become scarce did sheep shift to ATNU. Forage weights of grasses and forbs in U_1 and U_2 were similar to or higher than the forage weight in U_3 at T_1 in 1984. However, although the 1984/1985 rainy season following the treatments was relatively good, the forage weights of grasses and forbs of U_1 and U_2 at T_1 in Fall 1985 were much less than those of the previous year, while control (ungrazed) forage weight was higher. This means that grazing grasses and forbs heavily, even in the dormant season, affected their production the following year, possibly because grazing at this intensity reduced the number of seeds. Sheep were observed digging (Fig. 7) for roots of some grasses and forbs. Forbs such as Salsola inermis start growth in the fall, so heavy grazing may have affected their photosynthetic activity.

The soil moisture percentages in Fall-A, 1984 and 1985 were not significantly different among treatments U_1, U_2 and U_3. Probably because soil is poor in organic matter content, the first rain

Figure 7: A sheep digging for the roots of grasses.

compacted the soil and caused crust formation. The vegetation cover was sparce. The infiltration rate of moisture was not improved sufficiently to detect any changes among the treatments. Another explanation is that soil sample cores were taken near the shrubs, where there was some run-on water accumulation due to the slight slope of the area, that confounded the effect of the treatments.

SPRING EXPERIMENT

In the spring 1985 experiment, dry forage weights of ATNU shrubs in U_1, U_2 and U_3 were not significantly different, because they were lightly grazed (9%, 5%, and 0%, respectively). Forage weights of shrubs in U_1 and U_2 and U_2, and U_3 were significantly different at T_1 ($P<0.05$), i.e., before applying the treatments. This difference carried through to T_2 and T_3 (Table 4). Although the current season growth produced in response to treatments (i.e., $T_3 - T_2$) was not significantly different between any two treatments, it was noticed that regrowth in U_1 was less than that in U_2 which was less than that of U_3. In U_1, the mean forage weight of shrubs at T_3 was 1.28 and 1.41 times those at T_1 and T_2, respectively. Similar values for U_2 were 1.38 and 1.45, and for U_3, 1.56 and 1.57. Because the 1984/1985 rainy season was relatively good, shrubs in all the treatments showed good growth and forage weight at T_3 was more than that at T_1 or T_2. Growth of ATNU shrubs starts early in winter when moisture is available, so grazing these shrubs in spring reduced the current season growth by the amount grazed. In addition, spring grazing affected the photosynthetic tissues and growth points with the result that browsed shrubs produced less regrowth (T_3 - T_2) compared to controls.

In the spring 1986 experiment, intensity of grazing on ATNU shrubs was 22%, 23% and 0% in U_1, U_2 and U_3, respectively. Because the rainy season 1985/1986 was poor, less grass and forb forage was available so sheep grazed ATNU forage more than in spring 1985. Dry forage weights of ATNU were not significantly different among treatments (Table 4). The interaction TU was significant ($P<0.05$). Means of treatments over different times (Fig. 8) were close, because the slope of the control treatment was different from slopes of the grazing treatments. Because the rainy season just before applying the treatments was poor, growth of ATNU shrubs was suppressed. ATNU shrubs were utilized to the same degree in U_1 and U_2; because grasses and forbs were poorer in U_2 than in U_1, sheep shifted earlier to shrubs in U_2 and as a result consumed the same amount as in U_1.

In U_1, the mean forage weight of shrubs at T_3 was 0.84 and 1.08 times those at T_1 and T_2, respectively. Similar values for U_2 were 0.78 and 1.01, and for U_3 0.99 and 0.99 (Table 4). Because the rainy season 1985/1986 was poor, the forage weight of shrubs in the grazed treatments was reduced by the amount grazed at T_2 and those shrubs showed very little or no regrowth at T_3. ATNU shrubs were browsed very lightly in spring when grasses and forbs, which are preferred by sheep, were available. In a poor year (1986) when grasses and forbs were scarce, ATNU shrubs were browsed more than in a good year (1985).

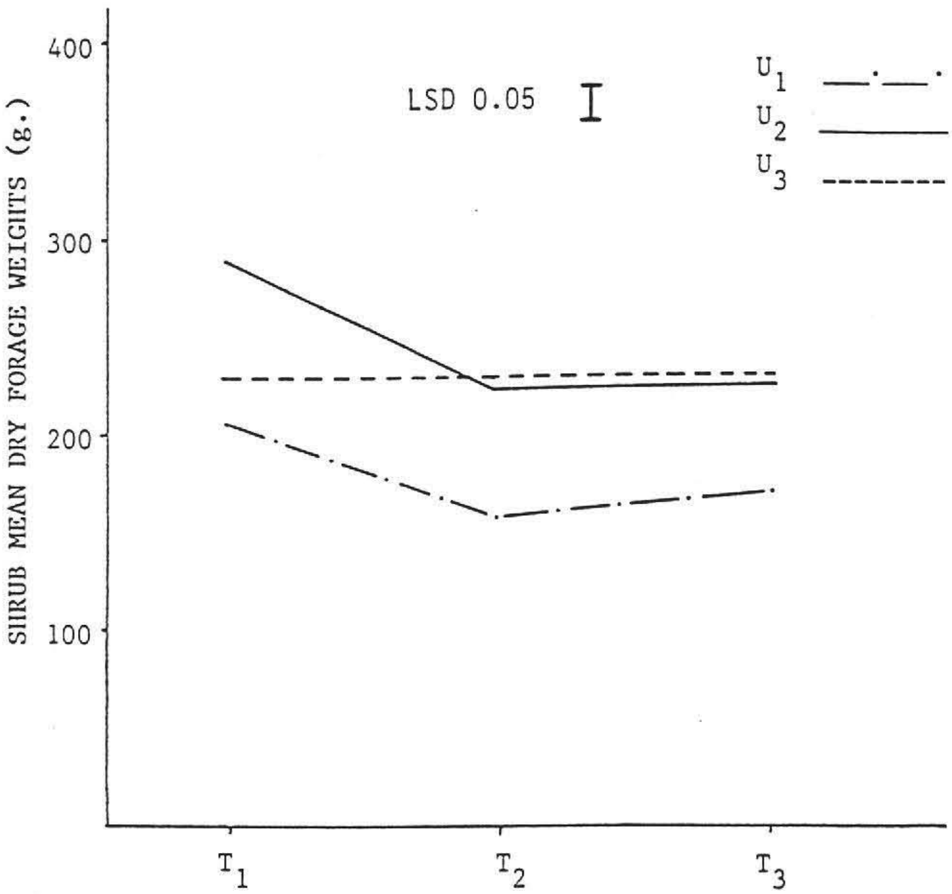

Figure 8 . Mean dry forage weights of ATNU shrubs in the different treatments at different times of the Spring 1986 experiment, showing the slope interaction TU.

Figure 9: Shows the heavily grazed grasses and forbs in U_1 compared to the ungrazed control U_3 in the Spring 1985 experiment. ATNU was slightly grazed.

Although grasses and forbs were utilized 91% and 55% in U_1 and U_2, respectively, compared to the ungrazed control (Fig. 9) in spring 1985, none of the treatments were statistically different, because the interaction TU was significant ($P<0.05$). Each treatment had a different slope between T_1 and T_2. The amount of forage utilized ($T_2 - T_1$) was significantly different among the treatments.

Poor growing conditions in 1986 yielded very low production of grasses and forbs. There were significant differences among treatments and between times because of the significant use on these grasses and forbs: 72%, 42%, 0% in U_1, U_2 and U_3, respectively.

Soil moisture percentages were not significantly different among treatments in either spring 1985 or spring 1986 experiments, probably for the same reasons explained in the Fall-A experiment.

FALL-B EXPERIMENT

In the Fall-A 1984 (started on Oct. 23) and 1985 (started on Sept. 18) experiments sheep live weight was not significantly different between the two treatments (U_1 and U_2) but was significantly different between the two times (before and after grazing). Sheep in both treatments showed significant loss in live weight between the two times of the experiment. Sheep in both treatments lost weight because they were used to grazing in large areas and to selecting their diet freely from a wider array of vegetation than was possible in the Fall-A experiment. It was the first time the sheep were confined in small plots and also it was the first time they intensively browsed ATNU shrubs. Because the same sheep used in the Fall-A experiment were transferred at the end of that experiment to the Fall-B experiment, the Fall-A experiment was considered as an adaptation period. The Fall-B experiment was considered the main experiment to study the effect of intensity of grazing ATNU on sheep live weight.

In Fall-B 1984, sheep in the U_1 treatment gained some weight but much less than in the U_2 treatment (Table 6). The mean sheep live-weight gain in U_1 (0.5 kgs) was significantly ($P<0.05$) less than that of U_2 (1.7 kgs) because in U_2 the total forage utilized daily per kg body weight $^{.75}$ was more than that in U_1 and the percentage of ATNU to the total forage utilized was less than that in U_1 (Table 11). A higher percentage of grasses and forbs in the diet in U_2 probably provided more available energy in U_2 than in U_1. U_1 was not significantly different between T_1 and T_2, while U_2 was significantly ($P<0.05$) higher at T_2 than at T_1.

In the Fall-B 1985 experiment, sheep in the U_1 treatment lost weight while those in U_2 gained weight (Table 6). The sheep live-weight loss in U_1 (-1.5 kgs) was significantly different from sheep live-weight gain in U_2 (0.9 kgs) during the time of the experiment. In the U_2 treatment total forage utilized daily per kg sheep live weight $^{.75}$ was more than that in U_1, and the percentage of ATNU to the total forage utilized was less than that in U_1 (Table 11). U_1 was significantly lower ($P<0.05$), while U_2 was not significantly higher at T_2 than at T_1. Actually, sheep in treatment U_1 were performing similarly to those in U_2 at the beginning of the experiment in both years (fig. 10). Towards the end of the

Table 11: Number of days sheep spent in the treatments, mean sheep live-weight gain or loss, total forage utilized per kg metabolic body weight per day and % of ATNU in the total forage utilized in Fall-B, 1984 and 1985 experiments.

Experiment	treat-ment	No. of days	gain or loss per sheep per day kg.	total forage (g) utilized per $kg^{.75}$ per day	ATNU % of forage utilized
Fall-B,	U_1	13	0.037	61.8	31.6
1984	U_2	9	0.188	73.0	15.4
Fall-B,	U_1	24	-0.063	28.4	54.5
1985	U_2	13	0.070	51.7	27.6

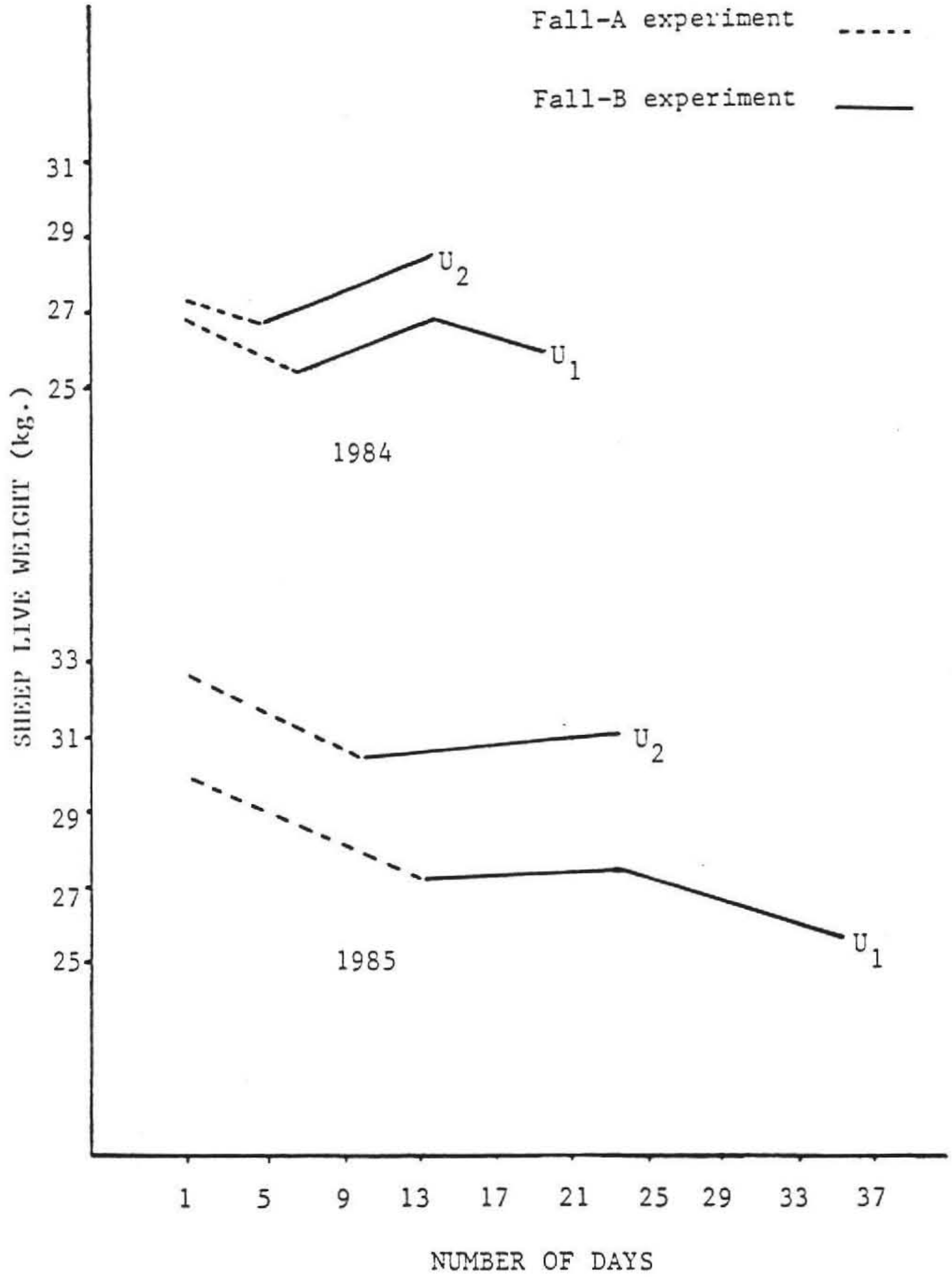

Figure 10: Mean sheep live weights in the Fall-A and B, 1984 and 1985 experiments showing the reponse to heavy (U_1) and moderate (U_2) intensities of grazing.

experiment, sheep started to lose weight, probably because ATNU was the only forage available after all grasses and forbs were consumed and because of reduced feed intake.

Sheep spent more time in the 1985 experiment than in the 1984 experiment (Table 11) to graze the required amount of forage from treatments U_1 and U_2. Sheep in treatment U_1 lost about 63g per sheep per day in 1985 compared to a gain of about 37g per sheep per day in 1984. In U_2, sheep gained about 70g per day in 1985 compared to a gain of about 188g per day in 1984. Performance of sheep was better in 1984 than 1985 for both U_1 and U_2 treatments because: 1) the total amount of forage utilized per kg sheep live weight .75 per day was more in 1984 for each of U_1 and U_2; 2) the percentage of ATNU to the total forage utilized was less (the percentage of grasses and forbs was more) in 1984 for each of U_1 and U_2 (Table 11) than in 1985 [grazing ATNU in 1984 followed by a good rainy season increased its production in 1985, while grazing grasses and forbs totally in 1984 reduced their production in 1985 (Tables 4 and 5)]; and 3) average percentage of relative humidity and amount of rainfall were lower and average daily mean temperature was higher during the time of the experiment in 1985 than in 1984 (Table 1). This may have affected the forage intake generally, and the acceptability of ATNU forage to sheep in particular due to its high salt concentration (Leigh, 1986). In 1984 the rainfall that came during the experiment may have washed the salt off the leaves of ATNU and rendered it more palatable (Davis, 1981) so that sheep finished the experiment in less time than in 1985.

WATER INTAKE BY SHEEP

Sheep consumed more water in U_2 than in U_1. It was expected that sheep in U_1 would consume more water because the percentage of ATNU they utilizaed was higher than U_2. In this experiment, feed intake by sheep in U_1 was less than that in U_2. The U_1 treatment took a longer time than U_2 and the trend in the fall is increasing relative humidity, decreasing temperature and increasing chances of rain. These factors probably affected water intake. This matter should be more thoroughly investigated in the future by fixing the time of the experiment and varying the area of plots or the number of sheep.

Water intake was significantly different between the two years of the experiment. Sheep in both treatments consumed more water in fall 1985 than in 1984, presumably because in 1985 1) sheep consumed more ATNU in their diet and 2) average relative humidity and amount of rainfall were less and average daily mean temperature was higher at the time of the experiment than in 1984. There were, however, not enough replicates or data to separate these effects.

EFFECT OF CUTTING ATNU

The survival rate of shrubs cut in spring was higher than those cut in fall, maybe because in spring shrubs had more carbohydrate reserves and readily activated meristems than those in fall. Possibly shrubs died because cutting caused the loss of above-ground meristems and maybe the death of the roots. This was a heavy treatment and, after two successive growing seasons, shrubs could not recover more than 25 or 33% of their original forage weight in fall or spring, respectively.

The reference unit method gave a good estimate of the dry forage weights of ATNU shrubs. R2's were high in both Fall-1984 and spring 1985. It is recommended for estimation of dry forage weights of ATNU in future studies and should be tested for other shrubs.

CHEMICAL ANALYSES OF FORAGE SAMPLES

The chemically analyzed samples for saponin, total oxalates, soluble oxalates, chloride, sodium and total cation electrolytes (Table 9) showed significant differences between grazed-ungrazed and male-female samples only for total oxalates. Total oxalates were significantly higher in male samples. Soluble oxalates and not total oxalates are the most effective as a poisonous component (which was very low; less than 3%). Oxalates did not affect grazing. Both male and female shrubs were grazed heavily.

Chemical analyses (Table 10) showed that ATNU is high in crude protein and could be a good supplement to native forages. It is moderate in carbohydrates compared to grassses and forbs, but the carbohydrates from an ATNU source may not be as easily digested as those from grasses and forbs.

CONCLUSIONS

From the data collected and analyzed at the Sabha Range Reserve, it is concluded that:

1. ATNU shrubs are a very important source of feed in the fall. Under conditions similar to those prevailing at SRR each shrub could provide 0.25 to 0.50kg dry weight forage in poor to average rainfall years, to supplement the poor native ranges.
2. This study (that covered two years), supported by other works such as Leigh and Wilson 1970, Sharma 1976, Masri 1978, and Hyder 1981, showed that ATNU shrubs are grazing tolerant. They were stimulated by grazing to produce more forage than the non-grazed shrubs. In a good rainy season following grazing of ATNU shrubs in the fall, both grazed and non-grazed shrubs, showed good growth. The amount of forage produced by the grazed shrubs was enough to compensate for the amount grazed and to show total forage weight equivalent to, or even greater than, forage weight of the ungrazed shrubs. In a poor rainy season following grazing of ATNU the grazed shrubs showed a good amount of growth, even though they were not able to compensate for the total amount of forage grazed. The non-grazed shrubs showed a decline in forage weight at the end of the growing season due to leaf drop. So it appears that grazing is necessary to keep ATNU shrubs productive in both good and bad years.
3. When heavily grazed, ATNU shrubs showed greater compensatory growth than moderately grazed shrubs, but the moderately grazed shrubs had higher forage weights at T_3 compared to T_1. The

moderate grazing of ATNU gives better sustained production than the heavy grazing in both good and bad years.

4. Grasses and forbs when available are preferred by sheep to ATNU both when green in spring or when dry in fall. Grasses and forbs were heavily grazed under treatments that imposed heavy and moderate grazing intensities on ATNU. When production of grasses and forbs was poor in spring following a poor rainy season, more ATNU forage was browsed compared to a good rainy season when ATNU shrubs were lightly grazed.
5. Grazing grasses and forbs heavily in the fall reduced their production, probably by uprooting perennial plants and reducing seed production on annual plants.
6. Soil moisture content was not affected by different intensities of grazing ATNU, probably because of crust formation, sparce vegetal cover, and accumulation of some run-on water near ATNU shrubs.
7. Grazing ATNU shrubs in spring reduced their summer forage weights by the amount of forage grazed. ATNU shrubs start growth in late fall after the first rains. When spring grazing was preceded by a good rainy season, grazed and ungrazed shrubs showed good growth, but the amount of forage weight at the end of the growing season compared to that before grazing was in descending order from the more grazed to the non-grazed treatments. When spring grazing was preceded by a poor rainy season, grazed shrubs did not show much growth after treatments to compensate for the amount of forage browsed. It is concluded

here that ATNU shrubs are more affected by spring grazing than fall grazing.

8. Sheep grazing ATNU shrubs with native forage (grasses and forbs) at SRR in fall gained more weight at the moderately grazed treatments. At the heavily grazed treatments sheep either gained slightly or lost some weight. The amount of sheep live-weight gain was positively affected by amount of food intake per sheep live weight $^{.75}$ and inversely affected by high percentage of ATNU browse in the diet.

9. When ATNU was used up to 32% of the total diet, sheep still gained some weight. When it contributed up to 55% of the diet, sheep lost some weight (Table 11). Probably ATNU could be used up to 40% of the diet and still maintain sheep live weight. However, sheep weight gains in fall are not critical because energy demand is low (i.e. non-lactating, early gestation).

10. Amount of water intake by sheep was positively related to the ATNU percentage in the diet and daily mean temperatures at the time of the experiment; found inversely related to the amount of rainfall and relative humidity. Comparing water intake by sheep between the moderately and heavily grazed treatments within the same year, it could be concluded that water intake was higher in the moderately grazed treatment. Sheep spent a longer time in the heavily grazed treatment when daily mean temperatures were dropping, relative humidity was increasing and there was some rain. Because of this, sheep in the moderately grazed treatment consumed a little more water than in the heavily grazed one,

even though the ATNU percentage in the diet was less. Water intake by sheep under different intensities of grazing ATNU needs to be more thoroughly investigated under fixed time for the different treatments.

11. The survival rate of ATNU shrubs cut at 10cm above soil surface in spring was better than those cut in the fall by the end of the second growing season. Probably because in spring they have active meristems and some carbohydrate reserves and available soil moisture to initiate growth.
12. Sodium and chloride ions are high in ATNU forage, saponins and oxalates are low. There were no apparent biologically important differences among ATNU samples that were chemically analyzed for these substances.

RECOMMENDATIONS

1. It is recommended that ATNU shrubs be planted in rows 4-5 meters apart to allow for growth of native grasses and forbs. Because ATNU forage is high in protein content, and native grasses and forbs even when dry are considered a good, easily digestible energy source, so ATNU together with native grasses and forbs may provide a diet sufficient to maintain sheep weight or even to allow some live-weight gain if properly managed. It is recommended also to plant ATNU shrubs in alternate strips to properly manage the intensity of grazing on shrubs and grasses and forbs.
2. *Atriplex nummularia* is an evergreen shrub that provides a good amount of forage which is also of high quality (except maybe for energy). It is recommended that rangelands that have ATNU plantations plus native grasses and forbs be used for about 6-8 weeks in the fall (Sept. - Oct.) in order to graze ATNU and the dry grasses and forbs concurrently. These rangelands could also be used in spring (April - May) for about 4-6 weeks to graze green grasses and forbs and to graze ATNU lightly. The use of rangelands between 100-200mm annual rainfall in this way is compatible with and complementary to the traditional grazing cycle of sheep in Jordan.
3. *Atriplex nummularia* is considered a good source of forage especially during the dry season and may considerably reduce the amount of supplements imported to Jordan at high cost. It is recommended to continue programs in range development using ATNU

seedlings, but also to try other suitable fodder species. One hectare planted to 1500 ATNU seedlings is estimated to cost $450 using hand labor (when machinery is used the cost will be much less). DeMontgolfier-Kouevi and LeHouerou (undated) evaluated internal rates of return of ATNU in Tunisia over 20 years period. If we consider that the useful life time of ATNU shrubs is 15 years and each shrub produces a sustained dry forage weight of 0.35 kg (the mean of dry forage weight of the two years of the experiments), the cost of production of 1kg dry forage weight of ATNU will be $0.06. I think if planted areas are properly managed, production will be much more and cost will be much less than this figure. The market price for 1kg of barley in Jordan is $0.24. The price of 1kg of barley subsidized by the government is $0.16. I think plantations of Atriplex are cheaper in the long run. Also forage will be available during the drought and does not need to be imported. Beside benefits to livestock production, other benefits include rangeland reclamation, soil and moisture conservation, combating desertification through site rehabilitation, and finding job opportunities for low-income people in rural desert areas.

4. To make the cost of shrub establishment lower, it is recommended that mechanized equipment (chisel plows, subsoilers, drills, etc.) be used for soil preparation and direct seeding with light soil preparation be tried in addition to transplanting seedlings.

5. It is recommended that the effect of grazing intensity on ATNU production be studied using goats to compare the effect on their live-weight gain or loss with sheep.

6. To study the effect of intensity of grazing on sheep live weight or production, with elimination of probable effects of environmental factors on sheep feed intake or water intake, it is recommended to fix the time of the experiment and vary the size of the plots or the number of animals.

7. For future research, it is recommended that sheep live weight and percent utilization of grasses, forbs and shrubs be estimated at shorter intervals (3-4 days) to determine more accurately the utilization level of grasses, forbs and shrubs at which sheep are maintained or start to gain or lose weight.

8. It is recommended that ATNU productivity, acceptability and effect on sheep live weight, be compared with other promising shrubs in Jordan such as *Atriplex halimus*, *A. leucoclada* and *Salsola vermiculata*.

9. It is recommended that the effect of cutting ATNU shrubs at different heights on its forage production be studied.

10. *Atriplex nummularia* gives more sustained forage production and more sheep live weight gain when moderately grazed and followed by a good or poor rainy season. Based on results of this study it is recommended that ATNU be moderately grazed. During drought or shortage of feed, ATNU still has the potential to be heavily grazed without being much affected, or much affect sheep live weight.

11. In view of the wide variability in genotypes and ecotypes of Atriplex, it is recommended that a plant selection program be undertaken to select the most palatable and productive strains to be propagated and utilized under controlled use.

12. There has been some good work done in Jordan in range improvement and shrub plantation, but there is a need to start range management and to introduce animal production as a component in range management. I hope the results of this research may give some direction to range management and further research on rangelands and animal production.

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APPENDIX

Table 12: Analyses of variance of mean dry forage weights for ATNU shrubs and the level of significance in the different experiments in 1984 and 1985.

Experiment	S.V.	d.f.	M.S.	F Value	Significance level of
F-A, 84	Rep.(R)	2	967555		
	Util.(U)	2	25962	0.154	
	Err.A.(RU)	4	168344		
	Time (T)	2	7650492	87.163*	0.05
	Interact.(TU)	4	220160	2.508	
	Err.B	12	87772		
F-A, 85	R	2	1066312		
	U	2	604022	2.465	
	RU	4	245061		
	T	2	3971750	76.639*	0.05
	TU	4	863526	16.663*	0.05
	Err.B	12	51824		
F-B, 84	R	2	173629		
	U	2	1279219	5.538*	0.10
	RU	4	231006		
	T	2	2497887	83.526*	0.05
	TU	4	173181	5.791*	0.05
	Err.B	12	29906		
F-B, 85	R	2	473404		
	U	2	2739915	6.924*	0.10
	RU	4	395713		
	T	2	1615458	104.043*	0.05
	TU	4	398905	25.691*	0.05
	Err.B	12	15527		
Spring, 85	R	2	137558		
	U	2	462432	6.949*	0.05
	RU	4	66548		
	T	2	965080	50.789*	0.05
	TU	4	30916	1.627	
	Err.B	12	19002		
Spring, 86	R	2	183652		
	U	2	336509	3.868	
	RU	4	87006		
	T	2	119679	45.713*	0.05
	TU	4	32095	12.259*	0.05
	Err.B	12	2618		

Table 12 (cont.)

$F_{0.05; 2,4} = 6.94$
$F_{0.10; 2,4} = 4.32$
$F_{0.05; 2,12} = 3.88$
$F_{0.10; 2,12} = 2.81$
$F_{0.05; 4,12} = 3.26$
$F_{0.10; 4,12} = 2.61$

Table 13: Analyses of variance of mean dry forage weights for grasses and forbs and the level of significance of the different experiments in 1984 and 1985.

Experiment	S.V.	d.f.	M.S.	F Value	Significance level of α
F-A, 84	R	2	17.53		
	U	2	36.73	6.25*	0.10
	RU	4	5.87		
	T	1	312.22	274.14*	0.05
	TU	2	61.00	53.56*	0.05
	Err.B	6	1.14		
F-A, 85	R	2	20.11		
	U	2	27.37	2.81	
	RU	4	9.75		
	T	1	60.99	5.45*	0.10
	TU	2	15.66	1.40	
	Err.B	6	11.18		
F-B, 84	R	2	9.91		
	U	2	13.82	0.69	
	RU	4	20.06		
	T	1	129.08	50.50*	0.05
	TU	2	37.67	14.74*	0.05
	Err.B	6	2.56		
F-B, 85	R	2	44.43		
	U	2	79.49	2.73	
	RU	4	29.07		
	T	1	28.85	7.60*	0.05
	TU	2	17.03	4.49*	0.10
	Err.B	6	3.80		
Spring, 85	R	2	41.66		
	U	2	830.22	3.09	
	RU	4	268.75		
	T	1	839.70	54.15*	0.05
	TU	2	132.80	8.56*	0.05
	Err.B	6	15.51		
Spring, 86	R	2	0.32		
	U	2	6.90	20.97*	0.05
	RU	4	0.33		
	T	1	3.46	17.00*	0.05
	TU	2	0.86	4.24*	0.10
	Err.B	6	0.20		

Table 13 (cont.)

$F_{0.05; 2,4} = 6.94$
$F_{0.10; 2,4} = 4.32$
$F_{0.05; 1,6} = 5.99$
$F_{0.10; 1,6} = 3.78$
$F_{0.05; 2,6} = 5.14$
$F_{0.10; 2,6} = 3.46$

Table 14: Mean soil moisture contents and C-I at $\alpha = 0.05$ of the treatments at different times and depths of the experiments in 1984 and 1985.

Experiment	Treat- ment	T_1	T_3	D_1	D_2
Fall-A, 84	U_1	8.34±0.41	8.22±0.41	7.61±0.54	8.95±0.54
	U_2	8.10±0.41	8.28±0.41	6.96±0.54	9.42±0.54
	U_3	8.32±0.41	8.22±0.41	7.50±0.54	9.04±0.54
	D_1	7.56±0.34	7.15±0.34		
	D_2	8.95±0.34	9.32±0.34		
Fall-A, 85	U_1	7.83±0.49	9.88±0.49	7.74±0.26	9.97±0.26
	U_2	7.83±0.49	9.70±0.49	7.59±0.26	9.94±0.26
	U_3	7.54±0.49	9.03±0.49	7.38±0.26	9.18A0.26
	D_1	6.55±0.40	8.59±0.40		
	D_2	8.92±0.40	10.48±0.40		
Fall-B, 84	U_1	8.67±0.39	8.56±0.39	7.20±0.94	10.03±0.94
	U_2	8.16±0.39	8.30±0.39	6.76±0.94	9.70±0.94
	U_3	8.68±0.39	8.74±0.39	7.70±0.94	9.72±0.94
	D_1	7.36±0.32	7.08±0.32		
	D_2	9.65±0.32	9.98±0.32		
Fall-B, 85	U_1	8.20±0.59	9.81±0.59	7.96±1.13	10.06±1.13
	U_2	8.59±0.59	9.36±0.59	7.67±1.13	10.28±1.13
	U_3	8.38±0.59	9.54±0.59	7.67±1.13	10.25±1.13
	D_1	7.10±0.48	8.43±0.48		
	D_2	9.68±0.48	10.71±0.48		
Spring, 85	U_1	13.55±1.01	7.83±1.01	9.05±0.89	12.34±0.89
	U_2	12.80±1.01	8.17±1.01	9.12±0.89	11.85±0.89
	U_3	13.55±1.01	8.65±1.01	9.18±0.89	13.03±0.89
	D_1	11.11±0.82	7.12±0.82		
	D_2	15.49±0.82	9.32±0.82		
Spring, 86	U_1	10.98±0.57	9.10±0.57	9.62±0.85	10.46±0.85
	U_2	10.20±0.57	8.89±0.57	8.70±0.85	10.39±0.85
	U_3	11.08±0.57	8.94±0.57	9.47±0.85	10.54±0.85
	D_1	10.78±0.46	7.75±0.46		
	D_2	10.72±0.46	10.20±0.46		

Table 15: Analyses of variance of mean soil moisture contents and level of significance in the treatments of the different experiments in 1984 and 1985.

Experiment	S.V.	d.f.	M.S.	F value	Significance level of α
Fall-A, 84	R	2	3.28		
	U	2	0.03	0.04	
	RU	4	0.77		
	D	1	28.52	98.19*	0.05
	DU	2	1.08	3.71	
	Err. B	6	0.29		
	T	1	0.002	0.01	
	TU	2	0.08	0.39	
	TD	1	1.36	6.34*	0.05
	TUD	2	0.01	0.03	
	Err. C	12	0.21		
Fall-A, 85	R	2	1.91		
	U	2	2.27	1.04	
	RU	4	2.18		
	D	1	81.41	619.55*	0.05
	DU	2	0.50	3.79*	0.10
	Err. B	6	0.13		
	T	1	58.50	98.12*	0.05
	TU	2	0.49	0.81	
	TD	1	1.01	1.70	
	TUD	2	0.26	0.43	
	Err. C	12	0.60		
Fall-B, 84	R	2	2.52		
	U	2	0.79	0.45	
	RU	4	1.74		
	D	1	60.61	68.37*	0.05
	DU	2	0.75	0.84	
	Err. B	6	0.89		
	T	1	0.01	0.05	
	TU	2	0.05	0.24	
	TD	1	0.84	4.28*	0.10
	TUD	2	0.10	0.49	
	Err. C	12	0.20		

Table 15 (cont.)

Experiment	S.V.	d.f.	M.S.	F value	Significance level of α
Fall-B, 85	R	2	0.19		
	U	2	0.01	0.02	
	RU	4	0.39		
	D	1	53.12	41.89*	0.05
	DU	2	0.24	0.19	
	Err. B	6	1.27		
	T	1	12.54	28.85*	0.05
	TU	2	0.52	1.20	
	TD	1	0.21	0.49	
	TUD	2	0.75	1.73	
	Err. C	12	0.43		
Spring, 85	R	2	3.27		
	U	2	1.19	0.15	
	RU	4	8.06		
	D	1	97.32	123.67*	0.05
	DU	2	0.94	1.19	
	Err. B	6	0.79		
	T	1	232.61	181.24*	0.05
	TU	2	0.96	0.75	
	TD	1	10.68	8.32*	0.05
	TUD	2	0.29	0.22	
	Err. C	12	1.28		
Spring, 86	R	2	3.31		
	U	2	1.84	1.43	
	RU	4	1.28		
	D	1	25.74	17.74*	0.05
	DU	2	1.18	0.82	
	Err. B	6	1.45		
	T	1	56.87	71.53*	0.05
	TU	2	1.07	1.35	
	TD	1	28.06	35.29*	0.05
	TUD	2	0.69	0.87	
	Err. C	12	0.80		

$F_{0.05}$; 2,4 = 6.94
$F_{0.10}$; 2,4 = 4.32
$F_{0.05}$; 1,6 = 5.99
$F_{0.10}$; 1,6 = 3.78
$F_{0.05}$; 2,6 = 5.14
$F_{0.10}$; 2,6 = 3.46
$F_{0.05}$; 1,12 = 4.75
$F_{0.10}$; 1,12 = 3.18
$F_{0.05}$; 2,12 = 3.88
$F_{0.10}$; 2,12 = 2.81

Table 16: Mean dry forage weights and C.I. at $\alpha = 0.05$ of ATNU (g/shrub), grasses and forbs (g/0.1m^2 quadrat) in the treatments at different times of the Fall-B experiment.

Experiment		Treat- ment	First Year T_1	First Year T_2	First Year T_3	Second Year T_1	Second Year T_2	Second Year T_3
ATNU	(heavy)	U_1	245±40	57±40	311±40	360±29	76±29	273±29
	(moderate)	U_2	177±41	94±41	272±41	322±30	159±30	274±30
	(control)	U_3	263±43	254±43	421±43	479±32	434±32	385±32

Experiment	Treatment		First year T_1	First year T^2	Second year T_1	Second year T_2
Grasses	(heavy)	U_1	1.95±0.55	0.00	1.16±0.97	0.00
and	(moderate)	U_2	2.05±0.55	0.00	1.93±0.97	0.00
forbs	(control)	U_3	1.70±0.55	1.80±0.55	2.77±0.97	3.18±0.97

Table 17: Analyses of variance of mean sheep live weights and level of significance in the Fall-A and B experiments in 1984 and 1985.

Experiment	S.V.	d.f.	M.S.	F value	Significance level of α
Fall-A, 84	R	2	10.94		
	U	1	14.85	1.27	
	RU	2	11.70		
	T	1	17.50	10.84*	0.05
	TU	1	3.60	2.23	
	Err. B	4	1.62		
Fall-B, 84	R	2	18.35		
	U	1	69.23	12.32*	0.10
	RU	2	5.62		
	T	1	21.13	32.74*	0.05
	TU	1	6.60	10.23*	0.05
	Err. B	4	0.65		
Fall-A, 85	R	2	6.00		
	U	1	118.84	1.81	
	RU	2	65.71		
	T	1	87.78	21.89*	0.05
	TU	1	3.78	0.94	
	Err. B	4	4.01		
Fall-B, 85	R	2	28.28		
	U	1	319.20	3.58	
	RU	2	89.18		
	T	1	1.56	1.27	
	TU	1	24.97	20.24*	0.05
	Err. B	4	1.23		

$F_{0.05;\,1,2} = 18.51$
$F_{0.10;\,1,2} = 8.53$
$F_{0.05;\,1,4} = 7.71$
$F_{0.10;\,1,4} = 4.54$

Table 18: Analysis of variance of mean water intake per sheep per day for Fall-A and B experiments in 1984 and 1985.

Experiment	S.V.	d.f.	M.S.	F value	Significance level of α
Fall-A&B, 84 and 85	R	2	0.16		
	U	1	0.63	28.63*	0.05
	RU	2	0.02		
	T	1	2.01	35.27*	0.05
	TU	1	0.00	0.00	
	E	4	0.06		

$F_{0.05; 1,2} = 18.51$
$F_{0.05; 1,4} = 7.71$

Table 19: Analyses of variance of chemically analyzed ATNU forage samples for saponins, soluble oxalates, total oxalates, chlorides, sodium, and total electrolyte cations concentration percentages.

Type	S.V.	d.f.	M.S.	F value	Significance level of α
crude saponins	G(grazing)	1	0.71	5.07*	0.09
	S(sex)	1	0.85	6.07*	0.07
	GS	1	1.09	7.79*	0.05
	Error	4	0.14		
soluble oxalates	G	1	0.20	1.43	0.30
	S	1	0.00	0.00	0.97
	GS	1	0.03	0.21	0.66
	Error	4	0.14		
total oxalates	G	1	0.20	1.82	0.24
	S	1	1.17	10.64*	0.03
	GS	1	0.16	1.45	0.29
	Error	4	0.11		
chloride	G	1	0.15	0.14	0.73
	S	1	1.36	1.27	0.32
	GS	1	0.66	0.62	0.48
	Error	4	1.07		
sodium	G	1	0.01	0.01	0.91
	S	1	0.18	0.43	0.55
	GS	1	0.85	2.06	0.22
	Error	4	0.41		
total caton electrolytes	G	1	0.15	0.22	0.66
	S	1	0.00	0.00	0.98
	GS	1	0.99	1.41	0.30
	Error	4	0.70		

$F_{0.05; 1,4} = 7.71$
$F_{0.10; 1,4} = 4.54$

VITA

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