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SUMMARY

Two flocks of sheep grazed during the winter in two shrub fields at the Migda Experimental Farm within two sheep production systems, one intensive and the other extensive. In the intensive system, the sheep grazed at a pressure of 71.7 sheep per hectare; in the extensive system, the sheep grazed initially at 13.8 and then at 32.7 sheep per hectare. In both systems the sheep were fed a supplement of up to 1.5 kg of concentrates per sheep per day. The weight changes of the two flocks were compared to those of two control flocks fed 0.8 kg of wheat straw per sheep per day supplemented with the same concentrate ration as the shrub grazing flocks. Grazing ewes in the intensive system consumed 0.69 kg of shrub dry matter (DM) per day, but lost 5 kg live weight during the 34-day grazing period compared with 3.6 kg lost by the control ewes. In the extensive system, ewes consumed only 0.23 kg of shrub DM per day, but lost only 0.6 kg live weight compared with 3.3 kg for the control ewes. Shrubs in the intensive system were almost completely defoliated and lost 14 to 37% of their branch biomass. In the extensive system shrubs were only partially grazed in the case of the least palatable species, *Atriplex nummularia* (60% of the shrub plantation), but the more palatable species were heavily grazed and lost up to 53% of their branch biomass.

During summer fodder shrub fields at the Migda Farm which included two sheep grazing systems - one extensive and one intensive - were grazed from May 1986 for a maximum of 102 days. In the extensive system 4.8 hectares of shrubs were grazed at a rate of 1.96 sheep/0.1 hectare. In the intensive system the rate was 3.2 sheep/0.1 hectares for a shrub field of 2.4 hectares. At the same time two control flocks grazed in aftermath fields not having a fodder shrub component. Estimated mean intakes for sheep grazing in the fodder shrub fields were 1.19 and 1.10 kg DM per sheep per day. Of these intakes, 18 and 35% were from the shrubs in the extensive and intensive systems, respectively, the remainder coming from dry annuals. In both systems all the shrubs, with the exception of *Acacia victoriae*, were completely defoliated and lost over 50% of their standing biomass. In the extensive system this was the second year of grazing. After complete defoliation in the first year, the regrowth of the shrubs from October 1985 to the beginning of grazing in May 1986 was sufficiently

vigorous to surpass the original total standing biomass measured in 1985 before grazing. However, the standing leaf biomass after regrowth was lower than that before grazing in 1985, i.e., the shrubs had a smaller portion of leaves in their biomass. Sheep in both treatment and control flocks failed to maintain their live weight and after 60 days of grazing were given supplements. Sheep conception rates in the treatment and control flocks were not significantly different in the two systems.

A flock of 77 weaned ewe lambs with a mean age of 196 days and a mean live weight of 40.8 kg grazed from July to November 1986 in a 9.6-hectare plantation of fodder shrubs at the Migda Farm together with breeding rams. Their live weight changes during the grazing period and their lambing performance the following spring were compared with those of a similar flock of 83 ewe lambs that had grazed a 9.6-hectare field of wheat aftermath and dry natural pasture. Similar live weight losses of up to 4.4 kg occurred in both flocks during the first 55 days of grazing. To prevent further weight losses, both flocks were supplemented with concentrates (12% crude protein) at the rate of 0.5 kg per day per ewe. At the end of the grazing period, the mean ewe live weight in both flocks was about 41.3 kg. The percent of ewes lambing and the number of lambs born to each lambing ewe were 49.4 and 1.553, respectively, for the flock grazing shrubs and 36.1 and 1.267, respectively, for the flock grazing wheat aftermath and natural pasture, 63% more lambs being born to the shrub grazing flock.

Atriplex nummularia, A. canescens and *Cassia sturtii* were planted in November 1984 at densities of 625, 1110, 2500, 4440, or 10,000 plants per hectare in six replicates. In December 1985, three of the replicates were fertilized with NPK. In June 1986, the shrubs were measured for height and diameter and eye-graded estimates were made of their biomass and of the densities of total biomass, leaf biomass and fruit biomass. With these data, a multiple regression analysis was performed on the cut biomass of 20 selected shrubs of each species. Resulting regression equations were used to estimate for each species the leaf, stem and total standing biomass per shrub in each planting density. In addition, the accumulated leaf fall per shrub in all treatments was measured. The standing biomass of annual herbaceous species growing between shrubs was also estimated by a double-sampling technique similar to that used for estimating the standing biomass

of the shrubs. Soil samples were taken in all treatments to estimate the soil moisture and the soil nitrogen and phosphorus status. No significant differences due to the fertilizer treatment were found. With increasing planting density the standing biomass per shrub decreased significantly in all density treatments but increased per unit area. The total biomass per shrub decreased from 4451 to 1474, from 1623 to 588 and from 1451 to 318 g of DM for *A. nummularia*, *A. canescens* and *Cassia sturtii*, respectively, while the total shrub biomass per hectare increased from 2880 to 14740, from 1020 to 5880 and from 910 to 3180 kg DM, respectively. The standing biomass of annual herbaceous species also decreased significantly with increasing shrub planting density - from approximately 2400 to 530 kg DM per hectare in the area of all shrub species. There were no significant differences in soil moisture or soil nutrient status between treatments.

During the winter of 1986-87 about 20 hectares of fodder shrubs were planted in microcatchments on the hill slopes of the Bedouin Demonstration Farm northeast of Beer-Sheva. Three species, *Atriplex nummularia* (50%) *A. canescens* (25%) and *A. halimus* (25%) are being used in this study. To compare the effects of a number of factors (type of seedlings, planting season, extent of control on competition by native vegetation) on the establishment and growth of shrubs, plantlets grown in bags and speedling trays were planted early (December 1986) or late (February 1987) in the winter in soil cleared either completely or only partially of the native perennials.

Azospirillum brasilense Cd in cell concentrations of 10^5-10^7 colony-forming units (CFU)/ml applied 24 h before *Rhizobium* (10^6 CFU/ml) inoculation increased nodule formation in the non-root-hair zone more than twofold in pouch-grown *Medicago polymorpha* and *Macroptilium atropurpureum* seedlings compared with inoculation with *Rhizobium* alone. There was a 20% increase in nodule formation in pouch-grown *Trifolium alexandrinum*, following pre-inoculation with *Azospirillum*. The percentage of nodulated seedlings rose from 0 to 25% when *Medicago polymorpha* was pre-inoculated with *Azospirillum*, followed by application of 10 CFU/ml *Rhizobium meliloti*, a concentration which on its own was not sufficient to initiate nodule formation. Acetylene reduction activity in *Medicago polymorpha* and *Macroptilium atropurpureum* seedlings after inoculation with

Azospirillum-Rhizobium was markedly increased. A possible reason for the increased susceptibility to *Rhizobium* infection may be that *Azospirillum* stimulates the formation of a larger number of epidermal cells that differentiate into infectable root hairs.

Azospirillum inoculum with a concentration higher than 10^7 CFU/ml applied to pouch-grown seedlings of *Medicago polymorpha* caused a significant decrease in root length, but significantly increased the number of lateral roots both in the absence and in the presence of *Rhizobium*. The diameter of rootlets and the length and number of root hairs were significantly increased when *Azospirillum* was applied to germinating seeds at a concentration greater than 10^6 CFU/ml.

Key words: Fodder shrubs, *Atriplex* spp., *Cassia sturtii*, *Acacia victoriae*, biomass, defoliation, regrowth, animal production system, grazing, natural pasture, aftermaths, protein, live weight, conception, lambing, planting density, legumes, nitrogen fixation, nodulation, *Azospirillum brasilense*, *Rhizobium meliloti*.

SUBPROJECT 1. EVALUATION OF THE USE OF INTRODUCED SHRUBS IN AGROPASTORAL SYSTEMS

WINTER GRAZING OF A FODDER SHRUB COMPONENT WITHIN SHEEP PRODUCTION SYSTEMS

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ABSTRACT

Two flocks of sheep grazed during the winter in two shrub fields within two sheep production systems, one intensive and the other extensive. In the intensive system, the sheep grazed at a pressure of 71.7 sheep per hectare; in the extensive system, the sheep grazed initially at 13.8 and then at 32.7 sheep per hectare. In both systems the sheep were fed a supplement of up to 1.5 kg of concentrates per sheep per day. The weight changes of the two flocks were compared to those of two control flocks fed 0.8 kg of wheat straw per sheep per day supplemented with the same concentrate ration as the grazing flocks. Grazing ewes in the intensive system consumed 0.69 kg of shrub dry matter (DM) per day, but lost 5 kg live weight during the 34-day grazing period compared with 3.6 kg lost by the control ewes. Grazing lambs gained 7 kg compared with 6 kg for the control lambs. In the extensive system, ewes consumed only 0.23 kg of shrub DM per day, but lost only 0.6 kg live weight compared with 3.3 kg for the control ewes. Grazing lambs gained 7 kg compared to 6 kg for the control lambs. Shrubs in the intensive system were almost completely defoliated and lost 14 to 37% of their branch biomass. In the extensive system shrubs were only partially grazed in the case of the least palatable species, *Atriplex nummularia* (60% of the shrub plantation), but the more palatable species were heavily grazed and lost up to 53% of their branch biomass.

INTRODUCTION

In the semiarid regions of Israel with annual rainfalls of up to 250 mm, sheep graze at stocking rates of up to 7.5 sheep per hectare. Under the prevailing conditions it is not possible to provide pasture from the beginning of the rainfall season in November up to mid-February, the actual length of the period depending on the amount and distribution of the rainfall. Since fodder shrubs are perennials, they can provide fodder in winter when pasture is not available and sheep would otherwise be fed in feedlots. However, fodder shrubs can be only planted in a portion of the total grazing area, the remaining land being reserved for the herbaceous species and sown crops, which normally provide fodder during other periods of the year. In the summer, however, herbaceous species and crop aftermaths have a low crude protein content and sheep need to be given supplementary nourishment. Because of their relatively high crude protein content, fodder shrubs may be able to help meet the summer nutritional requirements.

At the Midga Experimental Farm shrubs are planted in 22 and 33% of the total area of the intensive and extensive sheep production systems, respectively. The shrub area is divided into two equal subfields for winter or summer grazing. Since the stocking rates per hectare of system are 7.96 and 4.46, for the intensive and extensive systems, respectively, during the winter the grazing pressure on the shrub fields is very high, namely, 71.6 and 26.7 ewes per hectare, for the intensive and extensive systems, respectively. Under such conditions, shrubs are likely to be completely defoliated and lose at least 30% of their branch biomass, depending on the length of the grazing period. It is, however, essential that the sheep obtain at the very least, their protein requirements from the shrubs and that their lambs gain at least 200 g in live weight per day.

At Migda there are two major winter shrub subfields, one of 1.2 ha in the intensive system and the other of 4.8 hectares in the extensive system. Normally, sheep would be grazing in these fields from November until the biomass in the barley or wheat fields within the systems became high enough for grazing, but because of organizational and technical reasons grazing of the shrubs began only in January 1986.

This report describes the grazing of shrubs in the two subfields and the weight changes that occurred in ewes and lambs grazing shrubs vs. control animals fed straw and concentrates.

MATERIALS AND METHODS

Shrubs

The shrub subfields in the intensive and extensive systems were estimated for standing biomass before grazing on 12.11.85 (intensive system) and on 28.10.85 (extensive system). They were estimated again after grazing, on 12.2.86 and on 26.2.86, respectively. The methods used have been described in earlier reports (Seligman *et al.*, 1986). An unknown quantity of herbaceous biomass was available in the 4.8 hectare extensive subfield. In the 1.2 hectare intensive subfield the amount of herbaceous biomass was very small, since the area had been sprayed with herbicides the year before to prevent the development of weeds.

Sheep

In the intensive system 85 ewes and their lambs were weighed on 14.1.86 and allocated to the 1.2 hectare shrub subfield. By 6.2.86 they had completely defoliated all the shrubs and whatever herbaceous species had been present. It had been planned to allow the sheep to graze a barley field within the system area after grazing on the shrubs had stopped, but as the barley biomass was too low, this was not possible. The shrub grazing period being too short to detect significant differences in live weight, it was decided to transfer the sheep to the extensive system shrubfield, where shrub dry matter (DM) availability was still high.

In the extensive system 66 ewes and their lambs were weighed on 21.1.86 and allocated to the 4.8 hectare subfield. As mentioned, on 6.2.86, 85 ewes from the intensive system were also transferred to this field. Grazing continued up to 17.2.86, at which time ewes were reweighed and then allocated to the barley fields within their respective grazing systems.

Supplements

Sheep in both shrub subfields and in the control flocks in the two systems were fed supplementary doses of up to 1.5 kg of concentrates per day and

per head. In addition, sheep in the control flocks were given up to 0.8 kg of wheat straw (72% DM) per day.

Growth of shrubs during grazing

Shrub growth was tested in the intensive system by measuring shrub dimensions before and after the grazing period in an ungrazed control area.

RESULTS

The rainfall up to March 1986 is presented in Table 1. The first effective rain fell on 17.12.85, indicating that early grazing on pastures would be delayed until February. The total rainfall of 140 mm was 100 mm below the annual average of 250 mm (based on records over 20 years), so that DM production from pastures was expected to be low and wheat grain production negligible. It was also expected that the shrub growing period would be relatively short, as soil water penetration would be confined to the top 60 cm.

Measurements of shrub dimensions and estimates of biomass indices before and after grazing are given in Tables 2 and 3 for the intensive system and in Table 4 for the extensive system.

Estimates of standing biomass per shrub before and after grazing for the intensive and extensive system are given in Table 5 and 6, respectively.

Estimate of the total grazed biomass from the intensive and extensive systems are given in Table 7 and 8, respectively. The estimates are calculated from the leaf and branch biomass disappearance, which is assumed to be the shrub DM consumed by the sheep. The estimated mean biomass DM consumed per sheep per day is calculated by dividing the biomass disappearance by the total number of sheep grazing days in each shrub field.

Sheep weight changes are presented in Tables 9 and 10 for the intensive and extensive systems, respectively.

Table 1. 1985/86 winter rainfall up to March 1986

Date	Daily rainfall (mm)	Monthly rainfall (mm)	Accumulated rainfall (mm)
Oct. 1985	0	0	0
Nov. 1985	0	0	0
1.12.85	4.0		4.0
4.12.85	1.0		5.0
17.12.85	14.5		19.5
19.12.85	15.5		35.0
26.12.85	17.0		52.0
27.12.85	46.0	98.0	98.0
14.1.86	4.0		102.0
17.1.86	4.5		106.5
19.1.86	7.0	15.5	113.5
10.2.86	11.0		124.5
16.2.86	15.0	26.0	139.5

Table 2.
Intensive system. Dimensions of shrubs and estimates of biomass indices before (12.11.85) and after (12.2.86) winter grazing.
Total grazing: 85 ewes over 23 days (14.1.86 to 6.2.86)*

Species and date of sampling	Biomass index (1-7)	Height cm ± SE	Diameter cm ± SE	Vertical profile sq. cm ± SE	Biomass density index (1-7)
Atriplex nummularia (192)**					
12.11.85	4.13±-0.54	108.6±2.0	98.8±12.3	11342±1520	6.36±0.14
12.2.86	3.81± 0.11	94.0±1.9	91.6± 3.3	9132±439	1.80±0.04
Cassia sturtii (198)**					
12.11.85	4.27±0.11	68.9±1.6	84.7±2.5	6194±300	6.30±0.15
12.2.86	2.57±0.18	43.8±1.5	42.8±1.9	4336±362	1.86±0.04
Acacia victoriae (186)**					
12.11.85	3.58±0.19	57.8±3.1	78.0±4.4	5461±417	4.4±0.20
12.2.86	3.81±0.11	94.0±1.9	91.6±3.3	9128±440	1.8±0.04
Atriplex canescens (196)**					
12.11.85	3.82±0.16	68.1±1.7	89.8±3.8	6617±401	6.05±0.19
12.2.86	not measured				
Atriplex linearis (194)**					
12.11.85	3.73±0.18	71.8±2.7	79.0±4.2	6676±510	5.5±0.20
12.2.86	not measured				

*Measurements were made in Field 7 of the intensive system (1.2 ha)
**Numbers in parentheses indicate number of surviving shrubs/dunam (0.1 ha)

Table 3.
Intensive system. Measurements of ungrazed shrubs before (12.11.85) and after (19.2.86) grazing in a control area for estimation of possible growth

Species and date of sampling	Height cm ± SE	Diameter cm ± SE	Vertical profile sq. cm ± SE
Atriplex nummularia			
12.11.85	108.6 ± 2.0	98.8 ± 12.3	11342 ± 1520
19.2.86	110.6 ± 2.7	92.7 ± 3.6	10798 ± 596
Cassia sturtii			
12.11.85	68.9 ± 1.6	84.7 ± 2.5	6194 ± 300
19.2.86	70.0 ± 1.8	85.9 ± 2.5	6317 ± 353
Acacia victoriae			
12.11.85	57.8 ± 3.1	78.0 ± 4.4	5461 ± 417
19.2.86	58.2 ± 3.8	72.1 ± 4.7	5231 ± 648
Acacia canescens			
12.11.85	68.1. ± 1.7	89.8 ± 3.8	6617 ± 401
19.2.86	75.1 ± 10.9	78.3 ± 3.5	6767 ± 1356
Atriplex linearis			
12.11.85	71.8 ± 2.7	79.0 ± 4.2	6676 ± 510
19.2.86	70.8 ± 3.1	73.4 ± 3.7	5983 ± 476

Table 4.
Extensive System. Winter shrub subfield (4.8 ha). Mean measurements and estimates of biomass indices of shrubs before (21.1.86) and after (18.02.86) grazing
Total grazing: 66 sheep from 21.1.86 to 6.2.86 and 151 sheep from 6.2.86 to 17.2.86

Species and date of sampling	Biomass index (1-7)	Height cm ± SE	Diameter cm ± SE	Vertical profile sq. cm ± SE	Biomass density index (1-7)
Atriplex nummularia (200)*					
28.10.85	6.85	80.3 ± 5.8	69.8 ± 4.6	5604 ± 244	6.8 ± 0.4
26.2.86	2.69 ± 0.1	87.2 ± 1.8	62.9 ± 1.7	5725 ± 254	4.2 ± 0.22
Cassia sturtii (154)*					
28.10.85		60.8 ± 1.8	53.5 ± 1.8	3253 ± 189	
26.2.86		32.4 ± 1.7	23.4 ± 1.4	956± 92	
Acacia victoriae (182)*					
28.10.85		47.3 ± 4.5	38.3 ± 3.5	1811 ± 156	
26.2.86		35.3 ± 2.2	28.6 ± 1.8	1442 ± 145	

*Numbers in parentheses indicate number of surviving shrubs per dunam (0.1 ha)

Table 5.
Intensive system. Winter shrub subfield
Biomass before (12.11.85) and after (12.2.86) grazing*

Species and date of sampling	Total shrub biomass	Leaf biomass	Branch biomass
Atriplex nummularia			
12.11.85	1454±247	448±62	967±162
12.2.86	not estimated		687± 66
Cassia sturtii			
12.11.85	663±100	301±43	328±56
12.2.86	208± 37	0	208±37
Acacia victoriae			
12.11.85	435±129	114±25	315±107
12.2.86	294± 78	19± 6	275± 73
Atriplex canescens			
12.11.85	1014±170	428±64	579±110
12.2.86	not estimated		
Atriplex linearis			
12.11.85	1055±236	432±78	657±155
12.2.86	not estimated		

*Values in the Table are given in grams per shrub ± SE

Table 6. Extensive system. Winter shrub subfield.
Biomass before (28.10.85) and after (26.2.86) grazing

Species and date of sampling	Total shrub biomass	Leaf biomass	Branch biomass
Atriplex nummularia			
28.10.85	799±101	294±38	505±73
26.2.86	730± 42	231±18	500±44
Cassia sturtii			
28.10.85	172±14	11.3±1.0	161±14
26.2.86	86±14	0	75±13
Acacia victoriae			
28.10.85	136±35	19.5±5	118±31
26.2.86	73±30	4.2±2	69±20

*Values in the Table are given in grams per shrub ± SE

Table 7.
Intensive system. Winter shrub subfield (1.2 ha).
Biomass before (12.11.85) and after (12.2.86) grazing and estimated biomass disappearance*

Species and date of sampling	Leaf biomass	Branch biomass	Total disappearance of biomass
Atriplex nummularia			
12.11.85	619 ± 86	1337 ± 224	
12.2.86	0	950 ± 91	
Difference	619	387	1006
Cassia sturtii			
12.11.85	215 ± 31	234 ± 40	
12.2.86	0	148 ± 26	
Difference	215	86	301
Acacia victoriae			
12.11.85	25 ± 5	63 ± 21	
12.2.86	4 ± 1	54 ± 14	
Difference	19	9	28
Total disappearance			1355
No. of sheep grazing days (85 sheep x 23 days)			1955
Mean estimated intake per sheep per day			0.69 kg DM

*Values in the Table are given in kg DM per 1.2 ha field ± SE.

Table 8.
Extensive system. Winter shrub subfield (4.8 ha).
Biomass before (28.10.85) and after (26.2.86) grazing and estimated biomass disappearance*

Species and date of sampling	Leaf biomass	Branch biomass	Total disappearance of biomass
Atriplex nummularia			
28.10.85	1699±230	2909±432	
26.2.86	1330±103	2880±253	
Difference	369	29	398
Cassia sturtii			
28.10.85	25±3	360±29	
26.2.86	0	166±28	
Difference	25	184	184
Atriplex victoriae			
28.10.85	19±4	106±29	
26.2.86	4±2	60±17	
Difference	15	46	61
Total disappearance			643
No. of sheep grazing days (66 x 15) + (151 x 1):		2651	
Mean estimated intake per sheep per day:		0.24 kg DM	

* Values in the Table are given in kg/DM per 4.8 ha field ± SE

Table 9.
Weight changes of ewes and lambs grazing shrubs in the winter subfield of the intensive system (1.2 ha) at a grazing pressure of 72 ewes/ha from 14.1.86 to 6.2.86 and at a grazing pressure of 32 ewes/ha from 6.2.86 to 17.2.86

Sheep	Treatment	No. of sheep	Weights (kg) on: 14.1.86	18.2.86
Ewes	Shrubs	85	49.9	44.8
	Control*	85	51.8	48.2
Lambs	Shrubs	37	10.5	17.5
	Control*	64	8.6	14.7

*Control animals were fed concentrates and straw in feed lots.

Table 10.
Weight changes of ewes and lambs grazing shrubs in the winter subfield of the extensive system (4.8 ha) at a grazing pressure of 14 ewes/ha from 21.1.86 to 6.2.86 and at a grazing pressure of 31 ewes/ha from 6.2.86 to 17.2.86

Sheep	Treatment	No. of sheep	Weight (kg) on: 21.1.86	18.2.86
Ewes	Shrubs	66	45.1	44.5
	Control*	202	46.5	43.2
Lambs	Shrubs	42	12.1	19.0
	Control*	149	12.0	18.1

*Control animals were fed concentrates and straw in feed lots

DISCUSSION

Shrub biomass availability before grazing in the 1.2 hectare field can be assumed to be the total DM disappearance of 1355 kg, or 1129 kg per hectare. In the extensive system, which was only partially grazed, the shrub biomass availability before grazing can be assumed to be the total leaf biomass and 33% of the branch biomass or 595 kg DM/hectare.

In the intensive system the sheep appear to have consumed 0.69 kg of shrub DM/day, which is approximately equivalent to the straw consumption of the control flock. The shrub-grazing sheep lost 5 kg live weight during 34 days compared to 3 kg for the control sheep. However, grazing lambs gained 7 kg versus 6 kg for the controls.

In the extensive system, shrub-grazing sheep lost only 0.5 kg in 27 days compared to 3.3 kg for the controls, even though shrub DM consumption was only 0.24 kg per day. Grazing lambs gained 7 kg compared to 6 kg for the control animals. Because of the lower shrub consumption coupled with negligible weight loss of the grazing sheep, it is assumed that there was an appreciable intake of herbaceous species of up to 0.5 kg DM/day. In both systems weight gains were higher for shrub-grazing lambs, which may indicate a higher milk production by the grazing ewes.

The results cited in Table 3 show that during the winter months no significant growth takes place in any of the shrub species. It is thus reasonable to assume that, within the errors of standing biomass estimation, the biomass disappearance as calculated from the difference between the data before and after grazing provides a reasonable approximation of animal consumption.

At high grazing pressures shrub edible material was completely consumed by the sheep, and although there are definite palatability differences between species and within species, the end result was that all shrub were completely defoliated. At low grazing pressures shrubs were eaten in the order of relative palatability: first *Cassia sturtii*, then *Acacia victoriae* and last *Atriplex nummularia*. It appears from this experiment that the grazing of shrubs could replace wheat straw in sheep rations without any significant reduction in sheep performance. At the grazing pressures applied sheep

were able to consume about 0.7 kg of shrub DM per day, which was approximately the same as the intake of straw measured in the control flocks.

Even though the shrubs were completely defoliated, the high pressures used during winter grazing are justifiable if applied over a short period, since all the edible material was consumed when most needed. This allows the shrub a long period of recuperation in a season when optimum growth conditions, soil moisture and warmth are available.

It is reasonable to assume that the edible biomass available at the time of grazing (nearly two years after the planting date) will not increase significantly in subsequent years. Thus, the age at which shrubs should be first grazed may be of importance for future supply of edible biomass.

Up to 30% of the branch biomass was removed by the sheep. The impact of this fraction on the nutritive value of the diet is not clear, because as yet we do not know the chronological preference of sheep for the shrub components. Branches have a lower ash and crude protein content than leaves and are also less digestible. If eaten together with leaves they will lower the overall nutritive value of the material consumed in relation to leaves alone. However, it may well be that the sheep first eat the readily available leaves, consuming branches only when leaf availability becomes low. In this case the nutritive value of the shrub material will decrease with time. That this eating pattern may have taken place in our experiments is indicated by the sheep weight losses in the intensive system in comparison with the very low losses in the extensive system. In the former system shrubs were completely defoliated, whereas in the extensive system leaves were still available when sheep were removed from the shrub field.

CONCLUSIONS

Where the herbaceous component of the pasture is negligible, lactating sheep appeared to be able to consume about 0.7 kg of shrub DM per day when supplemented with 1.5 kg of concentrates. This amount was equivalent to 0.72 kg of straw DM intake by control sheep in this experiment.

- Under the conditions of the experiment weight losses during shrub grazing could not be prevented despite supplementation with 1.5 kg of concentrates. Only when herbaceous species could also be grazed were the weight losses negligible.

Higher weight gains for shrub-grazing lambs compared to feedlot lambs may indicate some advantage in shrub grazing of ewes over straw feeding in feedlots. However, the grazing period was too short to draw definite conclusions.

As in a previous grazing trial, sheep appear able to remove at least 30% of the standing biomass of branches from the shrubs. The effect of branch consumption is to lower apparent digestibility, crude protein content, and ash content.

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EFFECT OF ADDING A FODDER SHRUB COMPONENT TO SHEEP PRODUCTION SYSTEMS IN SUMMER GRAZING

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ABSTRACT

Fodder shrub fields which included two sheep grazing systems - one extensive and one intensive - were grazed from May 1986 for a maximum of 102 days. In the extensive system 4.8 hectares of shrubs were grazed at a rate of 1.96 sheep/0.1 hectare. In the intensive system the rate was 3.2 sheep/0.1 hectares for a shrub field of 2.4 hectares. At the same time two control flocks grazed in aftermath fields not having a fodder shrub component. Estimated mean intakes for sheep grazing in the fodder shrub fields were 1.19 and 1.10 kg dry matter (DM) per sheep per day. Of these intakes, 18 and 35% were from the shrubs in the extensive and intensive systems, respectively, the remainder coming from dry annuals. In both systems all the shrubs, with the exception of *Acacia victoriae*, were completely defoliated and lost over 50% of their standing biomass. In the extensive system this was the second year of grazing. After complete defoliation in the first year, the regrowth of the shrubs from October 1985 to the beginning of grazing in May 1986 was sufficiently vigorous to surpass the original total standing biomass measured in 1985 before grazing. However, the standing leaf biomass after regrowth was lower than that before grazing in 1985, i.e., the shrubs had a smaller portion of leaves in their biomass. Sheep in both treatment and control flocks failed to maintain their live weight and after 60 days of grazing were given supplements. Sheep conception rates in the treatment and control flocks were not significantly different in the two systems.

INTRODUCTION

In sheep production systems in the northern Negev sheep graze two components of equal area: a sown barley pasture and wheat fields harvested for grain. To study the effect of adding a fodder shrub component to this system, the pasture area in our trials was reduced by half and replaced with a field planted with fodder shrubs. This fodder-shrub field was divided into two equal subfields, one for winter and one for summer grazing. The performance of sheep in the system with a fodder shrub component was to be compared with that of sheep grazing at the same stocking rates without the fodder shrub component. The two systems were replicated twice: one for highly fertile sheep grazing at a high stocking rate and the other for less fertile sheep grazing at a lower stocking rate. A detailed description of the grazing systems may be found in our Fourth Annual Report (Dovrat, 1986).

In the winter fodder shrub fields grazing began in January 1986 and the results are reported separately in this annual report. Grazing in the summer shrub fields began in May 1986 and the results are reported herein.

MATERIALS

Pasture systems

Extensive system

In this system 94 crossbred ewes (1/4 Finn x 3/8 Awassi x 3/8 German Merino), with a potential fertility of 1.35 lambs per lambing, grazed on 4.8 hectares of summer shrubs (i.e., a grazing rate of 1.96 sheep/0.1 hectare). The control flock of 170 ewes of the same breed grazed on 20 hectares of wheat aftermath.

Intensive system

In this system 77 crossbred ewes (1/2 Finn x 1/4 German Merino x 1/4 Awassi) with a potential fertility of 1.65 lambs per lambing, grazed on 2.4 hectares of summer fodder shrubs (i.e., a grazing rate of 3.2 sheep/ 0.1 hectare). The control flock comprised 77 ewes of the same breed which grazed on 5.4 hectares of wheat aftermath.

Fodder shrub fields

Extensive system

The 4.8 hectares of shrubs in this system had been grazed by ewe hoggetts from July to the end of October 1985 and were completely defoliated (Dovrat, 1986). In summer of 1986, the fodder to be grazed from this field was the regrowth developed on the shrubs fom October 1985 to May 1986 and the ground cover produced by annuals growing from the winter rains of 1985/86.

Intensive system

The 2.4 hectares of fodder shrubs had not been previously grazed. The standing biomass consisted of the biomass accumulated on the shrubs since planting in November 1983 and of the ground cover produced by annuals. This field was initially only 1.2 hectares, but as a result of the poor rainfall of the last three years, 1.2 hectares were added to allow for a longer grazing period at the high grazing pressure imposed.

Aftermath fields

In years of adequate rainfall sheep graze first in the barley fields, and the wheat fields are grazed only after harvesting the grain. However, due to the poor rainfall of winter of 1985-86, all sheep in both systems had grazed during the late winter, spring, and early summer months in both the barley and the wheat areas allocated to them. Due to the low biomass production, the shrub flock of the extensive system had almost completely removed all the herbage by May 1986 and only the shrub field had significant biomass available for grazing. The same situation had occurred by June 1985 for the shrub flock in the intensive shrub system. In parallel, the control flocks grazed simultaneously the biomass remaining in both the barley and the wheat fields allocated to them, i.e., a total area of 39.2 hectares in the extensive system and of 10.8 hectares in the intensive system.

In both systems the areas allocated, both to the shrub treatment and to the control flocks were exhausted by 15 September 1986, and additional areas had to be given to the sheep. In the extensive system the shrub flock was allowed entry into a 9.6 hectare field of fodder shrubs (also grazed by 85 ewe hoggetts), and the control flock was allocated 28.8 hectares of aftermath previously grazed by other sheep. In the intensive system the shrub and

control flocks were allowed to graze together on 9.6 hectares of previously grazed wheat aftermath. In addition, from 29 September 1986 the sheep had to be supplemented with 0.5 kg of concentrates to prevent serious live weight losses.

The movements of the shrub and control flocks from November 1985 to November 1986 are summarized in Tables 1 and 2 for the extensive and intensive systems, respectively.

METHODS

Standing biomass of shrubs

The standing biomass of the shrubs of each species was estimated before and after grazing by a double sampling technique previously described in detail by Seligman *et al.* (1986). The heights and diameters of approximately 100 plants of each of the five fodder species were measured in the shrub fields of each system. In addition, standing biomass, density of total biomass, density of leaf biomass, and density of fruits were estimated by eye, and values were assigned on a relative scale. Twenty shrubs of each species were then harvested in each field and dried. The total dry biomass and the stem and leaf biomass were determined for each shrub by separation and weighing to the nearest gram. A multiple regression analysis was performed for the relationship between total, stem, and leaf biomass yield per shrub and the above-mentioned dimensions and estimates. The best fit equations ($r^2 > 0.9$) were used to estimate the mean biomass component for each species in each field.

Standing biomass of annuals

The standing biomass of the annuals comprising the herbaceous ground cover was also estimated by a double sampling technique. The biomass within a 25 x 25 cm quadrat was estimated by eye for dry matter yield. The estimate was repeated 100 times in each shrub field by covering the field in a grid fashion. Every fifth quadrat was harvested, and the harvest was dried and weighed. A regression analysis was performed between eye-estimated and actual biomass yield, and the resulting equations were used to calculate the mean dry matter yield in each field. The technique used has been described in full by Tadmor *et al.* (1975).

TABLE 1.
EXTENSIVE SYSTEM. SHEEP MOVEMENT AND SUPPLEMENTARY FEEDING FROM 4/11/85 TO 23/10/86

NO. OF SHEEP	FIELD	TYPE OF PASTURE	AREA HA	DATE OF ENTRY	DATE OF EXIT	CONCENTRATES KG/DAY	CONCENTRATES FROM:	COTTON WASTE QUANTITY	COTTON WASTE FROM:
SHRUB FLOCK									
94	HOLDING	NONE		4/11/85	21/1/86	1.00	4/11/86	AD LIB	4/11/85
	5 WINTER	SHRUB	4.8	21/1/86	18/2/86	1.00	14/1/86		
	6	BARLEY	9.6	18/2/86	1/5/86	0.00	18/2/86		
	4 *	WHEAT	9.6	27/3/86	1/5/86	0.00	18/2/86		
	5 SUMMER	SHRUB	4.8	1/5/86	10/8/86	0.50	29/7/86		
	4 *	AFTERMATH	9.6	11/8/86	14/9/86	0.50			
	9 *	SHRUB	9.6	15/9/86	23/10/86	1.00	1/11/86		
TOTAL AREA			*38.4*						
AREA/SHEEP			*0.41*						
CONTROL FLOCK									
170	HOLDING	NONE	0	4/11/85	15/1/86	1.00	4/11/86	AD LIB	
	19	BARLEY	19.20	16/1/86	10/4/86	0	15/1/86		4/11/85
	22	WHEAT	20.00	10/4/86	23/10/86	0.50	1/8/86		
	3 **	AFTERMATH	9.60	15/9/86	23/10/86				
	1+2 **	AFTERMATH	9.60	15/9/86	23/10/86	1.00	2/11/86		
	20 **	AFTERMATH	9.60	15/9/86	23/10/86				
TOTAL AREA			*68.00*						
AREA/SHEEP			*0.40*						

* Field 4 had been grazed from the winter up to 1/5/86.
Field 9 had been grazed by 84 weaned ewe lambs from 11/7/86. The same lambs also grazed there until 1/10/8
**Fields 3, 20 and 1+2 had been previously grazed by other sheep, and biomass availability was low.

TABLE 2.
INTENSIVE SYSTEM. SHEEP MOVEMENT AND SUPPLEMENTARY FEEDING FROM 4/11/85 TO 15/11/86

NO. OF SHEEP	FIELD	TYPE OF PASTURE	AREA HA	DATE OF ENTRY	DATE OF EXIT	CONCENTRATES KG/DAY	CONCENTRATES FROM:	COTTON WASTE QUANTITY	COTTON WASTE FROM:
SHRUB FLOCK									
87	HOLDING	NONE		4/11/85	13/1/86	1.00	4/11/86	AD LIB	4/11/85
86	7 WINTER	SHRUB	1.2	14/1/86	18/2/86	1.00	14/1/86		
86	16	BARLEY	4.2	18/2/86	2/6/86	0.00	18/2/86		
86	15	WHEAT	4.2	18/2/86	2/6/86	0.00	18/2/86		
77	7 SUMMER	SHRUB	2.4	2/6/86	2/9/86	0.50	29/7/86		
77	16	AFTERMATH	2.4	3/9/86	14/9/86	0.50			
77	15	AFTERMATH	2.4	3/9/86	14/9/86	0.50			
77	17*	AFTERMATH	4.8	15/9/86	15/11/86	1.00	2/11/86		
TOTAL AREA			*16.8*						
AREA/SHEEP			*0.20*						
CONTROL FLOCK									
86	HOLDING	NONE	0	4/11/85	16/2/86	1.00	4/11/86	AD LIB	4/11/85
80	15	WHEAT	5.40	17/2/86	28/9/86	0	17/2/86		
77	16	BARLEY	5.40	17/2/86	28/9/86	0.50	29/7/86		
77	18	BARLEY	1.20	17/2/86	28/9/86				
77	17*	AFTERMATH	4.80	29/9/86	15/11/86	1.00	2/11/86		
TOTAL AREA			*16.80*						
AREA/SHEEP			*0.20*						

* The control flock grazed in Field 17 together with the shrub flock from 29/9/86.
The estimated standing biomass was approximately 195 kg DM / 0.1 ha.

Sheep management

At least five mature crossbred rams (1/2 Awassi x 1/2 Finn) ran with each flock, in each shrub field from the beginning of grazing, and were removed at the end of October. The sheep were sprayed once a month for skin diseases and injected with a multispectrum vermicide to destroy and prevent stomach and lung worms. In addition, the sheep were vaccinated for foot and mouth disease and contageous abortion. Multimineral salt licks were made available in all grazing fields at all times.

Sheep live weight

All sheep were weighed after overnight fasting before entry to the shrub fields and at the end of grazing on shrubs. Intermediate weighings were carried out at intervals of up to 30 days.

Lambing performance

The most important parameter of sheep performance is lambing, which is a result of the grazing treatments imposed during the summer breeding months up to the end of October 1986. The results presented in this report cover the period until the end of February 1987. Data can be finalized only at the end of the lambing season (end of March 1987). Lambing performance also includes the death rate of born lambs which could, in part, be a function of the winter grazing treatments imposed from December and be related to grazing in shrub fields.

RESULTS

Rainfall

The rainfall distribution during the 1985/86 season is given elsewhere in this annual report. The total precipitation was 188 mm, about 70 mm below the long-term annual average of 250 mm. The first effective rain was late (17 December 1985). During December 96 mm fell, but in January, February and March there was only 15, 26 and 11 mm, respectively. The 37 mm of rain during April were too late to be effective for annual plant growth. Low and unfavorably distributed rainfall resulted in a drought year. The wheat crop was a failure, and its stand was too small to be harvested. In addition, there was no response to fertilizer application in any of the fields, a fact indicating that plant growth in this year was totally water limited. In normal years, the annual dry matter yields from fields fertilized

with nitrogen and phosphorus are at least twice as high as the approximately 2 tons per hectare obtained from nonfertilized areas in the region. This year the dry matter yields measured in various fields at the experimental site were rarely more than 2 tons per hectare.

Shrub dimensions and estimates of biomass before and after grazing

Data are presented in Tables 3 and 4 for the extensive and intensive system, respectively. The values for the extensive vs. intensive system were 102 vs. 93 grazing days for 97 vs. 77 sheep on 4.8 vs. 2.4 hectares, respectively. The grazing pressures for the extensive and intensive system were therefore 20.2 and 31.2 sheep per hectare, and the number of grazing days per hectare 2060 and 2902, respectively.

With the exception of *Acacia victoriae*, all shrub species in both systems were completely defoliated and lost at least 50% of their total biomass. *Cassia sturtii* was the most palatable and was eaten first, even before the herbaceous ground cover. Terminal stems were also eaten. In the extensive system 20, 30 and 45%, respectively, of the biomass removed from *Atriplex nummularia*, *Atriplex canescens* and *Cassia sturtii* was stem biomass. In the intensive system these values were 29, 0, and 54%, respectively.

Regrowth of shrubs in the extensive system

Table 5 presents the dimensions and biomass estimates of the shrub species before and after summer grazing in 1985 and 1986. All shrub species had a greater total biomass before grazing in 1986 than before grazing in 1985. However, the leaf biomass was lower and the stem biomass much higher.

Estimated biomass eaten from the shrub fields

The results presented in Tables 6 and 7 for the extensive and intensive systems, respectively, show the contribution of each shrub species to the eaten biomass. Though comprising only 20% of the fields, *Atriplex nummularia* contributed 33 and 43% of the shrub biomass removed in the extensive and intensive system, respectively. The higher percent contribution in the intensive system is due in part to the previous summer grazing in the extensive system, that resulted in a lower percentage of leaf in the total standing biomass and possibly also in a lower percentage of succulent terminal twigs. In both systems *Atriplex nummularia* and

TABLE 3.
EXTENSIVE SYSTEM. SUMMER GRAZING.
DIMENSIONS AND BIOMASS OF SHRUBS BEFORE AND AFTER GRAZING

SPECIES	DATE	HEIGHT CM	DIAMETER CM	LEAVES GRAMS DM	STEMS GRAMS DM	TOTAL GRAMS DM
ATRIPLEX NUMMULARIA						
BEFORE	1/5/86	89 ± 1.5	68 ± 1.6	281 ±13	665 ± 21	946 ±33
AFTER	10/8/86	79 ± 1.3	51 ± 1.4	0	594 ± 32	594 ± 32
DIFFERENCE	102 DAYS	10	17	281	71	352
ATRIPLEX CANESCENS						
BEFORE	1/5/86	70 ± 1.4	70 ± 2	168 ± 6	510 ± 28	678 ± 36
AFTER	10/8/86	61 ± 0.4	58 ± 2	0	369 ± 23	369 ± 23
DIFFERENCE	102 DAYS	9	12	168	141	309
CASSIA STURTII						
BEFORE	1/5/86	52 ± 2	39 ± 2	54 ± 4	165 ± 14	219 ± 19
AFTER	10/8/86	39 ± 2	36 ± 1	0	143 ±10	143 ±10
DIFFERENCE	102 DAYS	13	3	54	23	76
ATRIPLEX LINEARIS						
BEFORE	1/5/86	67 ± 2	59 ± 2	125 ± 18	352 ± 46	476 ± 64
AFTER	10/8/86	56 ± 2	48 ± 7	0	NOT MEASURED	NOT MEASURED
DIFFERENCE	102 DAYS	9	9	125	NOT MEASURED	NOT MEASURED
ACACIA VICTORIAE						
BEFORE	1/5/86	55 ± 3	49 ± 3	NOT MEASURED	NOT MEASURED	NOT MEASURED
AFTER	10/8/86	48 ± 2	47 ± 3	NOT MEASURED	NOT MEASURED	NOT MEASURED
DIFFERENCE	102 DAYS	7	2	NOT EATEN		

VALUES IN THE TABLE ARE MEANS ± SE.

TABLE 4.
INTENSIVE SYSTEM. SUMMER GRAZING.
DIMENSIONS AND BIOMASS OF SHRUBS BEFORE AND AFTER GRAZING

SPECIES	DATE	HEIGHT C M	DIAMETER C M	LEAVES GRAMS DM	STEMS GRAMS DM	TOTAL GRAMS DM
ATRIPLEX NUMMULARIA						
BEFORE	2/6/86	112 ± 2	96 ± 3	894 ±54	1275 ± 87	2169 ±127
AFTER	3/9/86	95 ± 2	77 ± 3	0	916 ±98	916 ±98
DIFFERENCE	93 DAYS	27	19	894	359	1253
ATRIPLEX CANESCENS						
BEFORE	2/6/86	80 ± 2	92 ± 4	460 ± 41	523 ± 39	983 ± 67
AFTER	3/9/86	69 ± 2	79 ±3	0	523 ± 63	523 ± 63
DIFFERENCE	93 DAYS	11	13	460	0	460
CASSIA STURTII						
BEFORE	2/6/86	73 ± 2	82 ± 3	265 ± 15	518 ± 38	783 ± 56
AFTER	3/9/86	68 ±3	61 ± 3	0	206 ±29	206 ±29
DIFFERENCE	93 DAYS	15	21	265	312	577
ATRIPLEX LINEARIS						
BEFORE	2/6/86	83 ±4	83 ±6	348 ± 49	850 ± 114	1198 ± 163
AFTER	3/9/86	78 ± 4	74 ± 6	0	NOT MEASURED	NOT MEASURED
DIFFERENCE	93 DAYS	5	9	348	NOT MEASURED	NOT MEASURED
ACACIA VICTORIAE						
BEFORE	2/6/86	67 ± 4	65 ± 4	38 ± 4	299 ± 49	337 ± 55
AFTER	3/9/86	66 ± 6	58 ± 5	NOT MEASURED	NOT MEASURED	NOT MEASURED
DIFFERENCE	93 DAYS	7	2	NOT EATEN		

VALUES IN THE TABLE ARE MEANS ± SE

TABLE 5.
EXTENSIVE SYSTEM. SUMMER GRAZING.
DIMENSIONS AND BIOMASS OF SHRUBS BEFORE AND AFTER GRAZING 1985 and 1986

SPECIES	DATE	HEIGHT CM	DIAMETER CM	LEAVES GRAMS DM	STEMS GRAMS DM	TOTAL GRAMS DM
ATRIPLEX NUMMULARIA						
BEFORE	21/5/85	82.8±1.8	65.6±1.7	398±50	330±45	728±92
AFTER	18/11/85	85.1±1.3	65.3±1.5	85±25	132±27	217±54
BEFORE	1/5/86	89±1.5	68±1.6	281±13	665±21	946±33
AFTER	10/8/86	79±1.3	51±1.4	0	594±32	594±32
ATRIPLEX CANESCENS						
BEFORE	21/5/85	70.3±1.1	79.1±2	309±40	291±37	596±76
AFTER	18/11/85	71.9±1.1	74.5±1.4	17±4	192±31	208±60
BEFORE	1/5/86	70±1.4	70±2	168±6	510±28	678±36
AFTER	10/8/86	61±0.4	58±2	0	369±23	369±23
CASSIA STURTII						
BEFORE	21/5/85	53.9±1.5	48.8±1.6	74±13	64±12	138±25
AFTER	18/11/85	44.5±1.4	30.0±1.1	0	52±12	52±12
BEFORE	1/5/86	52±2	39±2	54±4	165±14	219±19
AFTER	10/8/86	39±2	36±1	0	143±10	143±10
ATRIPLEX LINEARIS						
BEFORE	21/5/85	59.7±1.8	53.5±1.6	134±25	137±30	276±54
AFTER	18/11/85	71.6±1.8	60.6±1.9	96±26	347±72	443±96
BEFORE	1/5/86	67±2	59±2	125±18	352±46	476±64
AFTER	10/8/86	56±2	48±7	0	NOT MEASURED	NOT MEASURED
ACACIA VICTORIAE						
BEFORE	21/5/85	31.1±1.5	42.8±2.1	57±10	56±13	113±23
AFTER	18/11/85	44.9±1.7	37.4±1.6	16±4	45±11	61±13
BEFORE	1/5/86	55±3	49±3	NOT MEASURED	NOT MEASURED	NOT MEASURED
AFTER	10/8/86	48±2	47±3	NOT MEASURED	NOT MEASURED	NOT MEASURED

VALUES IN THE TABLE ARE MEANS ± SE

TABLE 6.
EXTENSIVE SYSTEM. SUMMER GRAZING
ESTIMATE BIOMASS EATEN IN 4.8 HECTARES OF SHRUBS

SPECIES	LEAVES G DM/SHRUB	LEAVES KG DM/0.1HA	LEAVES KG DM/FIELD	TOTAL SHRUB G DM/SHRUB	TOTAL SHRUB KG DM/0.1HA	TOTAL SHRUB KG DM/FIELD
BIOMASS BEFORE GRAZING 1/5/86						
ATRIPLEX NUMMULARIA	281	11	531	946	37	1789
ATRIPLEX CANESCENS	168	13	610	678	51	2460
ATRIPLEX LINEARIS	125	2	115	476	9	436
CASSIA STURTII	54	2	73	219	6	294
ACACIA VICTORIAE						
TOTAL		28	1329	2319	103	4979
BIOMASS AFTER GRAZING (10/8/86)						
ATRIPLEX NUMMULARIA	0	0	0	594	23	1123
ATRIPLEX CANESCENS	0	0	0	369	28	1339
ATRIPLEX LINEARIS	0	0	0	351	7	322
CASSIA STURTII	0	0	0	143	4	192
ACACIA VICTORIAE				NOT MEASURED		
TOTAL		0	0	1457	62	2976
BIOMASS EATEN						
ATRIPLEX NUMMULARIA	281	11	531	352	14	666
ATRIPLEX CANESCENS	168	13	610	309	23	1121
ATRIPLEX LINEARIS	125	2	115	125	2	114
CASSIA STURTII	54	2	73	76	2	102
ACACIA VICTORIAE	NOT EATEN					
TOTAL		28	1329	862	41	2003
ANNUALS					196	9408
TOTAL EATEN						11411

*Percentage of shrubs of each species planted in the field and no. of surviving shrubs per 0.1 ha:

A. nummularia:	20%; 197
A. canescens	40%; 189
A. linearis	10%; 191
C. sturtii:	20%; 140
Acacia victoriae:	10%; 150

TABLE 7.
INTENSIVE SYSTEM. SUMMER GRAZING
ESTIMATED BIOMASS EATEN IN 2.4 HECTARES OF SHRUBS

SHRUB SPECIES*	LEAVES KG DM/SHRUB	LEAVES KG DM/0.1HA	LEAVES KG DM/FIELD	TOTAL SHRUB KG DM/SHRUB	TOTAL SHRUB KG DM/0.1HA	TOTAL SHRUB KG DM/FIELD
BIOMASS BEFORE GRAZING (1/5/86)						
ATRIPLEX NUMMULARIA	894	35	840	2169	83	1999
ATRIPLEX CANESCENS	462	35	843	983	75	1793
ATRIPLEX LINEARIS	348	7	162	1197	23	557
CASSIA STURTII	265	10	252	785	31	746
ACACIA VICTORIAE	38	1	15	345	6	137
TOTAL		88	2112		218	5233
BIOMASS AFTER GRAZING (10.8.86)						
ATRIPLEX NUMMULARIA	0	0	0	916	35	844
ATRIPLEX CANESCENS	0	0	0	523	40	954
ATRIPLEX LINEARIS	0	0	0	849	16	395
CASSIA STURTII	0	0	0	206	8	196
ACACIA VICTORIAE		NOT MEASURED		345	6	137
TOTAL		0	0		105	2527
BIOMASS EATEN						
ATRIPLEX NUMMULARIA	894	35	840	1253	48	1155
ATRIPLEX CANESCENS	462	35	843	460	35	839
ATRIPLEX LINEARIS	348	7	162	348	7	162
CASSIA STURTII	265	10	252	579	23	550
ACACIA VICTORIAE	0	0	0	0	0	0
TOTAL		87	2097	2640	113	2706
ANNUALS					208	4992
TOTAL EATEN						7698

*Percentage of shrubs of each species planted in the field and no. of surviving shrubs per [illegible]:

A. nummularia:	20%;	192
A. canescens:	40%;	190
A. linearis:	10%;	194
C. sturtii:	20%;	198
Acacia victoriae:	10%;	166

Atriplex canescens were clearly the species that contributed most of the eaten biomass.

Sheep intake

The calculated intakes per sheep per day from shrubs and from annual vegetation in each system are shown in Tables 8 and 9. Probably because of the lower grazing pressure, sheep intake was slightly higher in the extensive system. However, the percentage of shrub material was only 18% of the intake in the extensive system vs. 35% in the intensive system. This was due to the greater standing biomass of shrubs in the intensive system. Because of the relatively low planting density of the shrubs, 2000 per hectare, and the resulting low shrub ground cover, most of the intake came from the annual herbaceous species.

Changes in sheep live weight

Results are presented in Tables 10 and 11 for the extensive and the intensive system, respectively. During July there was a loss of live weight in both the shrub and control flocks in both systems. This was considered a serious situation: during the mating season the body condition of the sheep should not deteriorate if high fertility is to be obtained in terms of the number of sheep conceiving and of the number of lambs to be born per lambing. For this reason, all the sheep, regardless of treatment, were supplemented in both systems with 0.5 kg of concentrates per day starting from 29 July 1986.

Only in the extensive system did sheep graze most of the summer (from May to the end of October 1986) in shrub fields. Although they received the same concentrate supplements as the other flocks, they were the only sheep that failed to increase their weight in the period from 21 April to 11 November 1986. In the other flocks weight increase was approximately 4 kg.

Lambing performance

The results up to the end of February are summarized in Table 12 for both the extensive and the intensive systems. They are not final, since the lambing season finishes at the end of March.

TABLE 8.
EXTENSIVE SYSTEM. CALCULATED DRY MATTER INTAKE FROM 4.8 HECTARE OF SHRUBS AND ANNUALS IN THE SUMMER OF 1986

INTAKE FROM:	NUMBER OF SHEEP	GRAZING DAYS	TOTAL EATEN KG DM	TOTAL EATEN PER SHEEP KG DM	TOTAL EATEN PER SHEEP/DAY KG DM	PERCENT OF TOTAL
SHRUBS	94	102	2003	21.30	0.21	18
ANNUALS	94	102	9408	100.09	0.98	82
TOTAL	94	102	11411	121.39	1.19	

TABLE 9.
INTENSIVE SYSTEM. CALCULATED DRY MATTER INTAKE FROM 2.4 HECTARE OF SHRUBS AND ANNUALS IN THE SUMMER OF 1986

INTAKE FROM:	NUMBER OF SHEEP	GRAZING DAYS	TOTAL EATEN KG DM	TOTAL EATEN PER SHEEP KG DM	TOTAL EATEN PER SHEEP/DAY KG DM	PERCENT OF TOTAL
SHRUBS	75	93	2706	36.08	0.39	35
ANNUALS	75	93	4992	66.56	0.72	65
TOTAL	75	93	7698	102.64	1.10	

TABLE 10.
EXTENSIVE SYSTEM. FASTED LIVE WEIGHT OF SHEEP (KG) DURING SUMMER GRAZING 1986.

	SHEEP	DEAD	21/4/86	3/6/86	1/7/86	28/7/86	2/9/86	29/9/86	11/11/86
SHRUB FLOCK									
NO. OF SHEEP	96	2	96	94	93	94	92	91	90
MEAN, KG			57.2	56.9	57.5	53.3	55.0	54.9	57.2
SD			9.2	9.2	9.2	8.0	8.2	8.0	8.4
SE			0.94	0.95	0.96	0.83	0.86	0.84	0.88
CONTROL FLOCK									
NO. OF SHEEP	170	1	167	165	168	169	166	162	162
MEAN, KG			54.4	55.2	54.7	53.8	50.8	57.3	58.2
SD			8.8	9.0	8.6	8.2	7.7	29.7	8.7
SE			0.68	0.70	0.66	0.63	0.59	2.33	0.68

TABLE 11.
INTENSIVE SYSTEM. FASTED LIVE WEIGHT OF SHEEP (KG) DURING SUMMER GRAZING 1986

PARAMETER	SHEEP	DEAD	27/4/86	2/6/86	8/7/86	28/7/86	3/9/86	30/9/86	19/11/86
SHRUB FLOCK									
NO. OF SHEEP	77	4	77	76	75	75	75	74	72
MEAN, KG			50.4	52.8	52.6	50.4	52.2	53.2	54.9
SD			8.6	10.5	8.0	7.0	7.3	6.9	6.8
SE			1.0	1.2	0.9	0.8	0.8	0.8	0.8
CONTROL FLOCK									
NO. OF SHEEP	80	2	79	80	78	77	78	79	77
MEAN, KG			52.3	54.8	54.7	53.3	54.8	55.4	57.8
SD			9.8	13.1	9.6	8.7	8.7	9.4	9.3
SE			1.11	1.46	1.09	0.99	0.99	1.05	1.06

TABLE 12.
LAMBING PERFORMANCE OF FLOCKS UNTIL 1/3/87

FLOCK	NO. OF EWES MATED	NO. OF EWES THAT LAMBED	PERCENT EWES THAT LAMBED	NO. OF LAMBS BORN	LAMBS/EWE LAMBING	NO. OF LAMBS DEAD	LIVE LAMBS/EWE LAMBING
EXTENSIVE SYSTEM							
SHRUB FLOCK	97	73	75.26	91	1.247	1	1.233
CONTROL FLOCK	170	126	74.12	146	1.159	6	1.111
INTENSIVE SYSTEM							
SHRUB FLOCK	77	51	66.23	69	1.353	1	1.333
CONTROL FLOCK	82	59	71.95	80	1.356	9	1.203

In the extensive system there was no substantial difference between treatments in the percentage of ewes lambing in the flock. The difference of 0.09 lambs born per lambing ewe is in favor of the shrub treatment. However, to date, only one lamb has died in the shrub flock compared with six in the control flock, thus the difference in number of live lambs per ewe was 0.12 or almost 10% more. In the intensive system 5% more sheep lambed in the shrub treatment, while there was no difference in the number of lambs born per ewe. However, again, only one lamb died in the shrub flock compared with nine in the control flock. Thus the shrub flock had 0.16 more live lambs per ewe or a difference of 12%.

DISCUSSION

Since 1985-86 was a poor rainfall year and biomass production was thus water limited, yields were no more than 2 tons of dry matter per hectare from herbaceous species ungrazed during the growing season. The stocking rates imposed in the production systems were too high to be sustained and the sheep had to be supplemented starting from 29 July 1987, with 0.5 kg of concentrates per day per head to prevent serious weight losses. Furthermore, starting from 2 September 1987, all flocks had to be given access to additional fields outside their production system (another form of

supplementation). In a drought year, such as this, it was difficult to find any advantage in grazing of sheep in the fodder shrub fields. The production of edible foliage from the shrubs was disappointing, especially in the extensive system, in which the standing biomass consisted of the shrub regrowth from October 1985 to May 1986. The most productive species, *Atriplex nummularia* and *Atriplex canescens*, yielded only the equivalent of 70 and 58 kg of edible DM per 0.1 hectare, respectively. The edible yield from the whole mixture of shrubs in the extensive system was only 42 kg DM. This value when added to the biomass of the herbaceous annuals (about 200 kg) is a substantial increase in biomass availability. Even so, no advantage could be shown in the performance of the sheep grazing in the shrub fields. They, like the control flocks, had to be supplemented with concentrates. Furthermore, the extensive system flock that grazed in shrub fields for six months, was the only flock not to increase in live weight during the summer, despite being supplemented with concentrates. The most promising advantage of grazing in shrub fields appears to have been the lower lamb death rates achieved this winter in comparison with control animals.

The edible yield from shrubs in the intensive system was 113 kg DM per 0.1 hectares, over twice that in the extensive system. However, the standing biomass from the shrubs in this system, was obtained from an additional year of growth before grazing. If the biomass grazed the previous year in the extensive system is taken into account, the difference between the edible biomass production of the two shrub fields was small. A one year delay in grazing has more significance than the difference in standing biomass available for grazing. It is important to remember that where land boundaries are finite, 1/4 of the land (that was planted with shrubs), is not available for grazing over the whole year and animals must be fed supplements to make up for the shortfall. Nevertheless, it is important to establish the optimum age or dimensions, at which initiation of shrub grazing should take place, since there are indications that the annual regrowth potential of the shrubs may be determined by their size when first grazed.

The fact that there was appreciable regrowth during a below-normal rainfall year and after complete defoliation in the previous summer, is encouraging for the future: this kind of grazing is to be expected in most semiarid

range-land systems both in the summer and in the winter, and shrubs must be able to survive such drastic treatment, if they are to be useful as a fodder source.

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PERFORMANCE OF REPLACEMENT EWE LAMBS GRAZING FODDER SHRUBS DURING THE SUMMER MONTHS OF 1986

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ABSTRACT

A flock of 77 weaned ewe lambs with a mean age of 196 days and a mean live weight of 40.8 kg grazed from July to November 1986 in a 9.6-hectare plantation of fodder shrubs together with breeding rams. Their live-weight changes during the grazing period and their lambing performance the following spring were compared with those of a similar flock of 83 ewe lambs that had grazed a 9.6-hectare field of wheat aftermath and dry natural pasture. Similar live-weight losses of up to 4.4 kg occurred in both flocks during the first 55 days of grazing. To prevent further weight losses, both flocks were supplemented with concentrates (12% crude protein) at the rate of 0.5 kg per day per ewe. At the end of the grazing period, the mean ewe live-weight in both flocks was about 41.3 kg. The percent of ewes lambing and the number of lambs born to each lambing ewe were 49.4 and 1.553, respectively, for the flock grazing shrubs and 36.1 and 1.267, respectively, for the flock grazing wheat aftermath and natural pasture, 63% more lambs being born to the shrub grazing flock.

INTRODUCTION

In the intensive lamb production systems practiced at the Migda Dryland Experimental Farm in the northern Negev, replacement ewe lambs are required to breed and conceive from six months of age during the summer months and to lamb in the following winter-spring. The ewe lamb used is bred from a Awassi-German Mutton Merino-Finnish Landrace (25%) ewe that is mated to a an Awassi-Finnish Landrace (50%) ram. The ewe lambs from this cross-breeding normally reach sexual maturity at 6-7 months of age and at a live-weight of approximately 40 kg.

In the normal management, ewe lambs are weaned in March-April at a mean live-weight of up to 30 kg and are then held in a fattening lot together with ram lambs. After a maximum of two months they are transferred, together with the rams, to graze in either a wheat aftermath or in a natural pasture field and are supplemented with a 12% crude protein concentrate at the rate of 0.5 kg per day per lamb. At the end of the summer, in December, replacement ewe lambs are selected by pregnancy testing and nonpregnant lambs are sold. In normal years up to 60% of the ewe lambs conceive.

Wheat aftermath and dry natural pasture fields are usually deficient in crude protein and have a low energy concentration so that ewe lambs must be supplemented, as mentioned, with up to 0.5 kg of concentrates per day in order to reach a live-weight of 40 kg or to maintain and increase that weight. It was hypothesized that *Atriplex* shrubs planted in natural pasture fields could possibly provide a better alternative to aftermath and /or natural pasture grazing because of their green leaves with a relatively high crude protein content of about 14%. To test this hypothesis a grazing trial was conducted during the summer months at the Migda Experimental Farm.

MATERIALS AND METHODS

Site

The Migda Dryland Experimental Farm is situated about 40 km northwest of Beer-Sheva. The mean long-term rainfall between October and April is 250 mm. The fields are flat with deep loess soils of a good water-holding capacity.

Fields

Atriplex nummularia (50%), *A. canescens*, and *A. linearis* (24%) and *Cassia sturtii* (26%) were planted in a 9.6 hectare field in November 1983. Due to below average rainfall in 1984 and 1985, the shrubs were irrigated by drip irrigation in the summer of 1985 to ensure that they would be ready for grazing in 1986.

The shrubs were planted in three equal blocks. In all blocks spacing within rows was 2.25 meters, but between rows spacing varied from block to block: in the first block 2.25 meters, in the second, 2.25 and 4.5 meters alternately, and in the third, 6.75 meters. This spacing design was originally planned to test the effect of shrub density on the performance of grazing sheep. Since it was not used for this purpose this year, it was utilized instead for the ewe lamb grazing experiment.

A field of 4.8 hectares sown with wheat in November 1985, but not harvested because of the drought conditions during the 1985/86 season (150 mm effective rainfall), was used together with an adjacent natural pasture field of 4.8 hectares, as the control grazing area.

Sheep

One hundred and sixty ewe lambs were selected from a flock of 180 heads born in winter 1985/86. They were weaned at 20-30 kg and had grazed since weaning in a wheat aftermath field while being supplemented with a 0.5 kg concentrate. They were matched for age and live weight and then allocated to one of two flocks, either the treatment flock for grazing in the shrub field or the control flock for grazing in the wheat aftermath and natural pasture fields. Four ram lambs aged 200 days and each weighing over 40 kg were added to each flock and were run with the ewe lambs at all times.

Sheep management

All lambs were dewormed and sprayed for skin diseases before entry to the grazing fields. Spraying was repeated approximately every 30 days during the experiment from 11/7/86 to 6/10/86. All purpose mineral licks were made available to both flocks in order to eliminate any possible mineral deficiency. Lambs were weighed at the beginning of the experiment after overnight

withdrawal from food and water, and then approximately every 30 days until the end of the experiment.

The object of the experiment was to at least maintain live weight. Since lambs had lost weight, they were supplemented in both flocks with 0.5 kg concentrate per day (12% crude protein) from 1/9/87. After the end of the grazing period on 6/10/86, the two flocks were transferred together to another wheat aftermath field and supplemented with 1.0 kg per day of concentrates. From 18/11/86 they were held in a holding paddock and were fed cotton-gin trash *ad libitum* together with 1 kg of concentrates per ewe per day. This ration was maintained until 8/1/87, when the sheep were again divided into two flocks, one (the treatment ewe lambs) grazed in a shrub field while being supplemented with 1 kg of concentrates, and the other (the control ewe lambs) continued to get gin trash and 1 kg of concentrates. On 26/1/87 each flock was transferred to a sown barley pasture, where they grazed, without supplements, until the end of the lambing season on 1/5/87.

By 15/9/86 most of the edible herbaceous annuals between the shrubs had been grazed, but most of the shrubs had not been evenly defoliated. For this reason, 94 mature ewes were introduced into the field and grazed together with the ewe lambs from 18/9/86 to 6/10/86. The ewe lambs were withdrawn at 6/10/86, while the mature ewes continued to graze until 23/10/86, when most of the shrubs had been defoliated.

Field Measurements

Before the beginning of grazing, the shrub fields were estimated for biomass availability. In each of the three spacing treatment blocks each species in a row of 100 shrubs per species was measured for height and diameter and estimated for total biomass by a relative grading index. In addition, the shrubs were graded for density of total biomass and for density of leaf and fruit biomass by the method described by Seligman *et al.* (1986). Multiple regression equations for relating total shrub, stem and leaf biomass to the measured parameters were used. The regression equations for each of the shrub species had been established in other shrub fields that had been measured and estimated in the same way a few days earlier in a concurrent experiment.

These measurements and estimates were repeated after the end of the grazing period on 20/11/86. The remaining standing biomass was calculated by using the set of regression equations established in the other shrub fields that had also been measured and estimated a few days earlier after termination of grazing.

The standing biomass of annual herbaceous species present between the shrubs before and after grazing was estimated in each planting density by a double sampling technique. Annuals were a mixture of grasses, forbs and thistles that had become very coarse and to a large extent inedible.

RESULTS AND DISCUSSION

Measurements and Estimates of Biomass

Mean measurements and estimates of leaf stem and total standing biomass for each shrub species in each spacing block together with the estimated amounts of biomass removed during grazing are presented in Table 1. The data before grazing represent the undisturbed growth during 31 months from planting in November 1983. The rainfall during 1984 and1985 was well below the annual mean of 250 mm. To ensure that the shrubs would be ready for grazing in 1986, they had to be drip irrigated to a depth of 1.8 meters during the summer of 1985. Therefore the standing biomass in July 1986 does not represent the production that would have been achieved under the rainfed conditions of the years 1983 to 1986.

A. nummularia was the highest producing shrub whether in terms of both leaf and total biomass. Its leaf biomass was two and nine times more than that of *A. linearis* and *C. sturtii*, respectively and about 54% of its total standing biomass compared with about 30% for the other two species. These results confirm the data from other shrub fields at Migda, that *A. nummularia* is by far the highest producing fodder shrub species for the soil and climatic conditions of the northern Negev.

All the shrubs were almost completely defoliated by the end of grazing and all lost approximately 50% of their standing biomass. In terms of palatability, *C. sturtii* was preferred over *A. nummularia* and *A. linearis*, in that order. *C. sturtii* was even preferred to the annual species and was

TABLE 1.
DIMENSIONS AND ESTIMATES OF BIOMASS BEFORE AND AFTER GRAZING BY HOGGETTS AND EWES IN FIELD 9
FROM 11/7/86 TO 20/11/86

SPECIES AND TREATMENT*	SAMPLING TIME**	HEIGHT CM	DIAMETER CM	DRY BIOMASS LEAVES GRAMS/SHRUB	STEMS GRAMS/SHRUB	SHRUB GRAMS/SHRUB	EATEN GRAMS/SHRUB
CASSIA STURTII							
3/3	BEFORE	70 ± 3	65 ± 4	185 ± 24	337 ± 35	545 ± 55	
	AFTER	54 ± 3	43 ± 3			265 ± 25	280
2/3	BEFORE	68 ± 4	64 ± 4	155 ± 19	299 ± 36	480 ± 52	
	AFTER		NOT MEASURED			233	247
1/3	BEFORE	78 ± 4	71 ± 4	191 ± 38	416 ± 76	633 ± 111	
	AFTER	66 ± 4	54 ± 4			331 ± 30	302
ATRIPLEX LINEARIS							
3/3	BEFORE	88 ± 3	92 ± 5	544 ± 58	1302 ± 131	1846 ± 189	
	AFTER	83 ± 3	73 ± 4			1143 ± 115	703
2/3	BEFORE	80 ± 3	71 ± 5	376 ± 52	869 ± 120	1246 ± 172	
	AFTER	69 ± 4	53 ± 4			664 ± 99	582
1/3	BEFORE	85 ± 4	85 ± 5	504 ± 60	1181 ± 138	1685 ± 198	
	AFTER	75 ± 3	60 ± 4			855 ± 90	830
ATRIPLEX NUMMULARIA							
3/3	BEFORE	102 ± 2	81 ± 3	1299 ± 101	1178 ± 87	2477 ± 182	
	AFTER	87 ± 2	60 ± 3			937 ± 65	1540
2/3	BEFORE	107 ± 2	87 ± 4	1397 ± 110	1162 ± 88	2559 ± 195	
	AFTER	93 ±2	70 ± 3			1236 ± 76	1323
1/3	BEFORE	109 ± 3	81 ± 3	1130 ± 96	875 ± 69	2005 ± 159	
	AFTER	90 ± 2	64 ± 3			1172 ± 72	833
ATRIPLEX CANESCENS							
3/3	BEFORE	76 ± 2	79 ± 4	361 ± 19	551 ± 45	9[illegible] ±62	
	AFTER	66 ± 2	58 ± 3			545 ± 54	383

*Spacing treatments: 3/3 = all rows spaced 2.25 m; 2/3 = rows spaced alternately 2.25 and 4.5 m; 1/3 = all rows spaced 6.75 m.
Shrub spacing within rows: 2.25 m in all treatments.
**Before = before grazing; After = after grazing.
Values in the Table are means ± SE.

defoliated by the end of the first 30 days of grazing. The estimate of total biomass removed and the reduction in the shrub dimensions show that about 12% of the stem biomass was also removed and assumed to have been eaten.

No estimates of the standing biomass were made in either the wheat aftermath field or the natural pasture field before or after grazing.

Biomass Eaten per Dunam (0.1 Hectare)

The calculation of biomass removed and assumed to have been eaten per dunam and from the whole field is shown in Tables 2 and 3, for shrubs and annuals, respectively. The number of surviving shrubs was highest for *A. nummularia*. It was also high for *A. linearis* (Table 2).

The estimated standing biomass of annuals was approximately 200 kg dry matter (DM) per dunam before and about 100 kg after grazing (Table 3). Differences between planting blocks were small and in favor of the block with the widest row spacing, but were not significant. This was to be expected, since the shrubs did not cover more than 10% of the field in the highest planting density. Most of the annual biomass, remaining at the end of grazing, was stem material from tall growing thistles that was too coarse for the sheep to eat.

Shrubs contributed 68, 53 and 30% of the total biomass eaten in the three blocks in order of decreasing planting density. The *Atriplex* species had a digestibility coefficient of about 60%, while that of the annuals was no more than 40%.

Mean Intake per Sheep

The calculated mean intake per sheep in the shrub field is summarized in Table 4. As no intermediate estimates of the standing biomass were made during the course of grazing, it was not possible to estimate the intake of the ewe lambs separately from that of the mature ewes. From subjective observations made on 15/9/86, when the mature ewes were introduced into the shrub field, most of the edible annual biomass had been removed, but the shrubs had only been partially defoliated, except for *C. sturtii*. The mean calculated intake of 1.91 kg DM per sheep per day appears to be too high. It

TABLE 2.
CALCULATED BIOMASS EATEN FROM 9.6 HECTARES OF SHRUBS AND ANNUALS
MIGDA - FIELD 9

TREATMENT*	SPECIES	NO. LIVE SHRUBS PER DUNAM	AREA PLANTED PER DUNAM %	BIOMASS EATEN PER SHRUB KG DM	BIOMASS EATEN PER DUNAM** KG DM	BIOMASS EATEN FROM FIELD KG DM	TOTALS KG DM
3/3	*A. NUMMULARIA*	198	50	1.54	152	4635	
	C. STURTII	113	24	0.28	8	231	
	A. LINEARIS	188	26	0.703	34	1045	
	ANNUALS				93	2827	
	TOTAL				287	8737	8737
2/3	*A. NUMMULARIA*	132	50	1.323	87	2654	
	C. STURTII	80	23	0.247	5	138	
	A. LINEARIS	125	27	0.582	20	597	
	ANNUALS				100	3040	
	TOTAL				212	6430	6430
1/3	*A. NUMMULARIA*	66	46	1.323	40	1221	
	C. STURTII	43	23	0.247	2	74	
	A. LINEARIS	63	31	0.582	11	346	
	ANNUALS				126	3830	
	TOTAL				180	5471	5471
ALL FIELD							20638

*See footnote to Table 1
** 1 dunam = 0.1 hectare

TABLE 3.
ESTIMATED BIOMASS OF GRAZED ANNUAL HERBACEOUS SPECIES

TREATMENT*	ESTIMATED BIOMASS BETWEEN SHRUBS KG DM /DUNAM**	GROUND COVER OF SHRUBS/ DUNAM**	ESTIMATED BIOMASS BEFORE GRAZING KG DM/ DUNAM**	ESTIMATED BIOMASS AFTER GRAZING KG DM/ DUNAM**	ESTIMATED BIOMASS GRAZED KG DM/ DUNAM**
3/3	216	0.107	193	100	93
2/3	215	0.071	200	100	100
1/3	235	0.037	226	100	126

TABLE 4.
CALCULATED MEAN INTAKE FROM GRAZING
MIGDA, FIELD 9, 11.7.86-23.10.86

SHEEP	NUMBER	GRAZING PERIOD	DAYS	GRAZING DAYS	TOTAL BIOMASS EATEN, KG DM/D*	BIOMASS EATEN/ SHEEP KG DM/ DAY
HOGGETTS	83	6/7-6/10/86	87	7221		
EWES	94	15/9-23/10/86	38	3572		
TOTAL				10793	20638	1.91

D = dunam = 0.1 hectare

was expected to be not higher than 1.5 kg considering that the sheep were also supplemented with 0.5 kg of concentrates from 1/9/86 and that a total intake of 2.4 kg of DM is at least 0.5 kg higher than the appetite of 40 kg ewe lambs fed such a ration.

The mean intake appears to be an overestimate, and, if so, this means that the standing biomass was overestimated by more than the 10% standard errors given in Table 1. This may be the result of the use of multiple regression equations established in other shrub fields. The eye estimates of biomass, shrub, leaf and fruit density are subjective and based on a grading index relative to shrubs present in the field under measurement. The estimator may have inadvertently, based his eye estimates on different types of reference shrub in each field so that in fact parameters in each shrub field were of a different index.

Weight Changes of the Ewe Lambs During Grazing

The live weights of the ewe lambs from the beginning to the end of grazing are given in Table 5. Lambs lost more weight in the shrub grazing flock than in the control flock up to 31/7/86, but weight losses were similar between 31/7/86 and 31/8/86. From 31/8/86, the lambs in both flocks were supplemented with 0.5 kg of concentrates and increased their weights. The higher weight increase in the shrub flock may have been due to rumen fill only. From 6/10/86 to 18/11/86, when the two flocks grazed together in

TABLE 5.
MEAN WEIGHT CHANGES DURING THE GRAZING PERIOD
MIGDA - FIELD 9, 6.7.86 - 18.11.86

DATE	SHRUB GRAZING FLOCK (n =77)	CONTROL FLOCK (n = 83)
6/7/86	40.9± 6.0	40.7± 6.0
31/7/86	38.6±6.0	39.6± 6.0
31/8/86	36.5± 6.0	37.3± 6.0
6/10/87	37.8± 6.0	37.6± 6.0
18/11/86	41.1± 6.0	41.4± 6.0

VALUES ARE KG LIVE WEIGHT ± S.D.

a previously grazed wheat aftermath field and were supplemented with 1 kg of concentrates/day, the lambs all had similar weight increases.

From the weight losses up to 31/8/86 it is evident that, despite the calculated mean intake of 1.91 kg of DM/day, the lambs in both flocks were unable to achieve an intake sufficient to meet their maintenance requirements. The addition of 0.5 kg/day of concentrates, as a supplement, was enough to enable the lambs to increase their live weight at a rate of up to 0.04 kg/day.

Lambing Performance of the Ewe Lambs

The percentage of lambing ewe lambs and the number of lambs born per lambing in each flock are presented in Table 6. The performance of the shrub grazing flock was about 18% better than that of the control flock for both parameters. The percent of ewe lambs that lambed was below that of 60% normally achieved in most years at Migda, but the number of lambs per lambing for the shrub grazing flock was higher (1.553). The differences between the two flocks appear to be significant and could only be due to the intake from shrubs, as all others factors were common. Since the

TABLE 6.
LAMBING PERFORMANCE OF EWE LAMBS PUT TO THE RAM DURING GRAZING FROM 11/7/86

PARAMETER	SHRUB GRAZING FLOCK	CONTROL FLOCK
EWE NO.	77	83
MEAN AGE (DAYS) ON 11/7/86 ±SD	196±25	196±25
LAMBED (EWE NO.)	37	30
% LAMBING	49.4	36.1
LAMBS/ LAMBING	1.553	1.267
LAMBS/EWE IN FLOCK	0.746	0.457
DAYS TO CONCEPTION AFTER ENTRY TO FIELD ± SD	94±24	94±25

shrub-grazing flock lost more weight initially and later had similar weight increases, it would appear that the shrub intake contributed qualitatively rather than quantitatively to the nutrition of lambs during mating and conception. This could have been a result of the green feed in the intake from the shrubs, which would have supplied more vitamins and protein than those in the intake of the control flock.

The analysis of the lambing performance, according to the weights of the ewe lambs at the beginning of the experiment, is given in Table 7. While the performance of the lambs up to 35 kg was similar in the two flocks, lambs over 35 kg had a better lambing performance in the shrub-grazing flock. This would indicate that in both flocks, the nutrition of the lambs below 35 kg, was not sufficient to increase their live weight and at the same time to meet mating and conception requirements, but, for lambs weighing over 40 kg, it was more suitable in the shrub grazing system.

TABLE 7.
LAMBING PERFORMANCE OF EWE LAMBS ACCORDING TO THEIR WEIGHT ON 11/7/86

WEIGHT RANGE KG	SHRUB GRAZING FLOCK		CONTROL FLOCK	
	NO. LAMBS	% LAMBING	NO. LAMBS	% LAMBING
25-30	7	0.0	7	0.0
30-35	5	40.0	7	42.8
35-40	27	40.7	31	29.0
40-45	20	55.0	21	52.0
>45	18	77.8	17	47.1

CONCLUSIONS

1. *A. nummularia* is the fodder shrub species with the highest yield of both total and edible leaf biomass, being able to produce at least 200 kg of edible dry matter after 31 months of undisturbed growth after planting.
2. Ewe lambs grazing shrub fields with poor natural pastures have no advantage in maintaining live weight over ewe lambs grazing wheat aftermath and/or natural pastures. Both types of grazing result in weight losses.
3. When supplemented with 0.5 kg of concentrates (12% crude protein content) ewe lambs can increase their live weight by up to about 50 grams/day when grazing either fodder shrub or wheat aftermath fields.
4. The experiment indicates that summer grazing of fodder shrub fields can improve, by up to 60%, the lambing performance of ewe lambs compared to the grazing of wheat aftermath and/or natural pastures.
5. The improvement of the lambing performance by up to 60% has important consequences for the overall production from sheep grazing systems in semiarid regions. It has been calculated that a 5% improvement in the flock lambing performance can justify the planting of fodder shrubs as a feed component in such systems. It is therefore essential that this experiment be repeated to ensure that the results were not obtained by chance.

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STANDING BIOMASS OF THREE SPECIES OF FODDER SHRUBS PLANTED AT FIVE DIFFERENT DENSITIES 18 MONTHS AFTER PLANTING

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ABSTRACT

Atriplex nummularia, A. canescens and *Cassia sturtii* were planted in November 1984 at the densities of 625, 1110, 2500, 4440, and 10,000 plants per hectare in six replicates. In December 1985, three of the replicates were fertilized with NPK. In June 1986, the shrubs were measured for height and diameter and eye-graded estimates were made of their biomass and of the densities of total biomass, leaf biomass and fruit biomass. With these data, a multiple regression analysis was performed on the cut biomass of 20 selected shrubs of each species. Resulting regression equations were used to estimate for each species the leaf, stem and total standing biomass per shrub in each planting density. In addition, the accumulated leaf fall per shrub in all treatments was measured. The standing biomass of annual herbaceous species growing between shrubs was also estimated by a double-sampling technique similar to that used for estimating the standing biomass of the shrubs. Soil samples were taken in all treatments to estimate the soil moisture and the soil nitrogen and phosphorus status. No significant differences due to the fertilizer treatment were found. With increasing planting density the standing biomass per shrub decreased significantly in all density treatments but increased per unit area. The total biomass per shrub decreased from 4451 to 1474, from 1623 to 588 and from 1451 to 318 g of dry matter (DM) for *A. nummularia, A. canescens* and *Cassia sturtii*, respectively, while the total shrub biomass per hectare increased from 2880 to 14740, from 1020 to 5880 and from 910 to 3180 kg DM, respectively. The standing biomass of annual herbaceous species also decreased significantly with increasing shrub planting density - from approximately 2400 to 530 kg DM per hectare in the area of all shrub species. There were no significant differences in soil moisture or soil nutrient status between treatments.

INTRODUCTION

The effect of shrub planting density on biomass production per unit area is not fully understood. In general terms, without quantification, increasing planting density will decrease the individual shrub biomass production, but the actual shrub production per unit area is not known. In addition, in order to improve the total biomass production in both quantity and quality by introducing shrubs into a particular area, the biomass production of annual herbaceous species native to an area must be taken into consideration: increasing the density of shrubs will decrease the biomass production of annuals, and this situation may not be always desirable.

In semiarid Mediterranean regions the plant-animal annual cycle may be divided into three main seasons: the spring green plant growing season from January to May, when in good rainfall years the supply of nutritious herbage for the grazing animal is plentiful; the summer period from June to October, when dry herbage of low quality is available; and a transitional period from November to January, when herbage availability is very low. Perennial shrubs can provide feed both in the transitional period when fodder availability from other sources is scarce and in the dry summer, when the quality of fodder from herbaceous species is low, but rarely are they needed during the growing season. Thus, other factors being equal, it would be desirable to have areas of high low and intermediate shrub productivity for the transitional, green growing and summer seasons, respectively. In drought years, however, this generalization would not apply, and high shrub productivity would probably be desirable all the year round.

In Israel, with a small land area, stocking rates are relatively high - as high as 7.5 sheep per hectare at the Migda Experimental Farm in the semiarid northern Negev. Sheep production at this site is integrated with winter small grain production, half the area being sown with grain, the other half being used for pasture. Since only the pasture area can be considered for the introduction of shrubs as a grazing component, this will be at the expense of the annual pasture production from herbaceous species.

Thus, a prerequisite for planning the grazing area of a farm to meet its animal feed requirement, is the understanding of the relationship between the shrub planting density and the annual edible forage production from all

sources, in particular, the interaction effect of shrub density on the biomass production of the annual species.

This report describes an experiment conducted to study the effect of shrub planting density on biomass production per unit area from all sources, and the interaction between shrub and annual herbaceous production with and without the application of fertilizer.

MATERIALS

In November 1984 a field of 4.8 hectares was planted with the species *Atriplex nummularia, A. canescens* and *Cassia sturtii* at densities of 625, 1110, 2500, 4440, and 10000 shrubs/hectare. Six replicates were used for each density. In December 1985, three of the replicates were fertilized with NPK at the rate of 60 kg/hectare of nitrogen and 40 kg/hectare of phosphate applied as potassium nitrate and superphosphate, respectively. Details of the experimental design and layout have been described in previous reports (Progress Reports Feb.-July,1984, p. 4; Aug.-Oct. 1984, p. 6; May-July 1985 p. 2; Fourth Annual Report 1985, p. 83).

METHODS

In June 1986, in all six replicates of the five density treatments, the nine central shrubs of each species were measured for height and diameter, and relative grading estimates were made by eye of biomass, density of total biomass, density of leaf biomas, and density of fruit biomass. With these parameters a multiple regression analysis was performed on the cut biomass of 20 selected shrubs of each species. Resulting regression equations were used to estimate for each species the leaf, fruit, stem, and total standing biomass per shrub in each density. Details of the methodology used have been described by Seligman *et al.* (1985).

The accumulated leaf fall per plant was estimated by gathering the fall from all 9 central shrubs in all treatments within a special quadrat constructed to the dimensions of one quarter of the basal area of the largest plant.

The accumulated standing biomass of the annual species growing between shrubs was calculated by estimating the biomass within a 25 x 25 cm quadrat. Twelve estimates were made for each treatment and species in all six

replicates, giving a total of 1080 estimates. Estimates were then calibrated by cutting every fifth quadrat and carrying out regression analysis on the data for the harvested material. The resulting regression equation was used to correct the eye estimates and to calculate the standing biomass per hectare. The accumulated standing biomass of annual species growing in the absence of shrubs was calculated by making 100 eye estimates and harvesting 20 samples within six blocks of about 0.1 hectare each.

Soil water, and mineral nitrogen and phosphorus status were estimated in each treatment by boring, close to one of the central shrubs, a hole down to 120 cm and taking samples every 30 cm. Sampling with a soil drill of one inch diameter was repeated in each replicate.

RESULTS AND DISCUSSION

Rainfall (Table 1)

The rainfall in each of the years 1983/84, 1984/85 and 1985/86 was below the 250 mm mean of 20 years. In terms of the wheat grain yields harvested (about 300 kg/hectare/year), these must be considered drought years.

Standing biomass yields per shrub and per 0.1 hectare (Tables 2, 3, and 4)

No significant differences could be shown between the yields of fertilized and nonfertilized shrubs or their annual biomass per dunam (0.1 ha) or between fertilized and nonfertilized biomass yields of annual herbaceous species, probably because the monthly rainfall distribution and total rainfall in 1985/86 were bad. For this reason, the standing biomass results presented are means from all six shrub replicates. Data are shown for *A. nummularia*, *A. canescens* and *Cassia sturtii* in Tables 2, 3 and 4, respectively. The biomass yields for the different shrub components are shown together with the total biomass production. Total biomass less stem biomass production was considered to be the edible biomass production, even though it is known that sheep are able to eat some of the stem biomass. *A. nummularia* was the highest yielding fodder shrub in all treatments followed by *A. canescens*.

In the *A. nummularia* areas the accumulated biomass from all biomass components per hectare after 18 months of growth (5 months for the

annuals) was higher than or equal to that from the annuals alone (about 500 kg dry matter per 0.1 hectare for two years) in all except the lowest density treatment. The edible biomass from *A. nummularia* was higher than that from two years of annuals alone in the two highest density treatments. None of the *C. sturtii* treatments out-yielded production from annuals alone in either total edible biomass or total biomass. Only the highest *A. canescens* density treatment out-yielded annuals for total, but not for edible biomass production.

Relationship between density of planting, standing biomass per shrub, and biomass components per shrub (Figures 1, 2 and 3)

The relationships are shown in Figures 1, 2 and 3, respectively, for *A. nummularia, A. canescens* and *C. sturtii.* The relationships are curvilinear, and the best fit equations are logarithmic. The contribution of each plant component to the total shrub biomass production is also presented and was approximately 54, 40 and 6% for leaves, stems and leaf fall, respectively, in all treatments for *A. nummularia.* For *A. canescens* these values were about 34, 50 and 16%, and for *C. sturtii* 33, 55 and 12%, respectively.

Relationship between shrub planting density, edible standing biomass per shrub and edible biomass components per shrub (Figures 4, 5 and 6)

The relationships for *A. nummularia, A. canescens* and *C. sturtii,* are shown in Figures 4, 5 and 6, respectively. These relationships are also curvilinear, and the best fit equations are logarithmic.

The contribution of leaves accounted for approximately 90% of the total edible biomass for *A. nummularia* and was constant for all treatments. For *A. canescens and C.sturtii,* leaf biomass tended to increase with increasing shrub density from 62 to 73% and from 62% to 78%, respectively. Leaf fall was much smaller in *A. nummularia* than in the other two species and this species appears to retain leaves much better.

Relationship between shrub planting density, total standing biomass from shrubs and annuals per 0.1 hectare, and biomass components per 0.1 hectare (Figures 7, 8 and 9).

The relationship was linear for *A. nummularia* and *C. sturtii,* but logarithmic

for *A. canescens*. Thus, after 18 months of growth there did not appear to be any effect of planting density on total biomass production for *A. nummularia* and *C. sturtii* under the conditions prevailing at Migda. For *A. canescens*, competition for soil nutrients and light appears to have effected biomass production at a density greater than 2500 shrubs per hectare. The percent contribution of the biomass components to total biomass changed considerably with increasing shrub planting density. The contribution of annuals decreased from 45 to 6%, from 70 to 8%, and from 62% to 7-19% for *A. nummularia*, *A. canescens* and *C. sturtii*, respectively. The lower production of annuals in the *A. nummularia* area is probably a result of the greater basal area (diameter) of the shrubs.

The contribution of stems to the total standing biomass per 0.1 hectare increased with increasing planting density for all species from approximately 15-20 to 40-50%. The contribution of leaves also increased from approximately 30 to 50% in *A. nummularia*, 9 to 39% in *A. canescens* and 11 to 30% in *C. sturtii*.

Relationship between shrub planting density, edible standing biomass from shrubs and annuals per 0.1 hectare, and edible biomass components per 0.1 hectare (Figures 10, 11 and 12)

The relationship was linear for *A. nummularia*, while good relationships were not found for *A. canescens* and *C sturtii*. The contribution of annuals generally decreased with increasing shrub density for all species: from 58 to 9%, from 83 to 14% and from 77 to 30-15% for *A. nummularia*, *A. canescens* and *C. sturtii*, respectively. Leaf biomass increased with increasing shrub density for all species: from 38 to 82%, from 10 to 63% and from 14 to 52% for *A. nummularia*, *A. canescens* and *C. sturtii*, respectively. Leaf fall contribution also increased with increasing shrub density for all species: from 4 to 9%, 7 to 23% and 9 to 15-20% for *A. nummularia*, *A. canescens* and *C sturtii*, respectively. *A. nummularia* appears to be able to retain leaves better than either *A. canescens* or *C sturtii*.

Shrub growth from August 1985 to June 1986 (Tables 5, 6 and 7)

Dimensions (height and diameter), biomass estimates for leaf, stem and total standing biomass per shrub, as well as the total biomass per 0.1 hectare are summarized for three estimation dates (16.8.85, 30.12.85 and 8.7.86)

in Tables 5, 6, and 7 for *A. nummularia*, *A. canescens*, and *C. sturtii*, respectively. Between August 1985 and July 1986, the diameter of *A. nummularia* in all treatments increased up to 53%, while height increased only from 4 to 27%. Both tended to increase with decreasing planting density. Total biomass per plant, however, increased by up to 330%. For *A. canescens* the height increased up to 36% and the diameter up to 77%, with a tendency to increase with decreasing planting density. Total biomass did, however, increase by 446% in the highest density. For *C sturtii* the height increased by up to 48% and the diameter by up to 46%, with a tendency to increase with decreasing planting density. Again, total biomass increased by 243% in the highest density. The higher relative standing biomass increases appear to have been due mainly to an increase of biomass density within the dimensions of the shrubs. Unfortunately, this hypothesis cannot be verified on the basis of the data collected, because the values given at each estimation time are relative to that time only, as they relate to a specific shrub each time. Most of the biomass increase took place between December 1985 and July 1986 during and after the seasonal rains. In the dry period, from August to December 1985, soil moisture status would have been too low to support substantial growth. In this respect, one would expect the smaller shrub species, with a lower water requirement, to have grown more than the larger species at the lower planting densities. However, this is not fully apparent from the data. The smallest shrub species (*C. sturtii*) grew less during the entire August 1985 to July 1986 period, but more than the others in the lower densities between August and December 1985.

Growth of shrubs cut down in August 1985 and measured in July 1986 (Table 8)

In August 1985 shrubs of the three species were sampled for calibration purposes by cutting down to 10 cm from soil level. Their mean height and diameter, and the estimated leaf, stem and total standing biomass are shown in Table 8. Greatest growth was exhibited by *A. nummularia*. Biomass was estimated by using the regression equations calculated in July 1986 for uncut shrubs. Since the sampled plants have a different conformation and density of biomass, the estimates may be inaccurate. The cut shrubs were periphery shrubs, distributed evenly among all the density treatments, and it is difficult to compare their growth with that of the uncut shrubs which have characteristics specific to each treatment. Recovery was very good, and

since no shrub deaths occurred, these results may have important relevance to cut-and-carry situations.

Soil moisture and nutrient status (Table 9)

Since no differences in biomass production between fertilized and nonfertilized treatments were found, it was thought that nonutilized nitrogen would be found in the soil profile. This was not verified by the soil tests, no significant differences being found in nitrogen content between fertilizer treatments or shrub density treatments. Values found are not presented since the samples are being reanalyzed.

Soil water differences between treatments were also not significant. Depth of water penetration during the rainfall season of 1985/86 was never below 60 cm. Most of the water at this depth was either transpired or lost by evaporation. In both 1983/84 and 1984/85, rainfall was also low and unfavorably distributed. Since water penetration was again not lower than 60 cm, the soil water present down to 210 cm in 1983/84 was depleted.

CONCLUSIONS

1. Shrub biomass production per unit area increased with increasing planting density within the range of 625 to 10000 plants per hectare.
2. During the 18 months of shrub growth, only the joint biomass production of *A. nummularia* and annuals was able to give higher edible yields than that from annual species alone.
3. Neither *A. canescens* or *C. sturtii* appear to be able to improve on biomass production from annual herbaceous species. They appear to be desirable only in drought years, when little or no production from annuals is expected. However, even then, it is not clear whether in Israel their yields are economically more valid than the alternative of buying cheap available feeds such as cotton waste or poultry litter.
4. Growth of shrubs, like that from annual herbaceous species, is dependent on soil moisture availability. If this is depleted during the growing season by the end of May, very little growth occurs during the summer.
5. Cutting shrubs of all species does not appear to have had any deleterious effects and opens the possibility of cut-and-carry methods of utilization.

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TABLE 1.
RAINFALL (MM) PER MONTH AT MIGDA: 1983/84, 1984/85, AND 1985/86

MONTH	1983/84	1984/85	1985/86
OCTOBER		17	
NOVEMBER	2	21	
DECEMBER	13.5	27	98
JANUARY	123	5	15.5
FEBRUARY	1	68.5	26
MARCH	37	20	11
APRIL		22	37
TOTAL	176.5	180.5	187.5

TABLE 2.
ATRIPLEX NUMMULARIA BIOMASS PRODUCTION 18 MONTHS AFTER PLANTING. JUNE 1986

SHRUBS/ 0.1HA	SPACING M X M	PRODUCTION, GRAMS DM /SHRUB ±SE					
		LEAVES	STEMS	LEAF FALL	ANNUALS	TOTAL	TOTAL EDIBLE
BIOMASS PRODUCTION PER SHRUB							
1000	1 X 1	765±148	619±102	90±8	NA	1474±258	855±156
444.4	1.5 X 1.5	999±81	775±77	119±11	NA	1893±169	1118±92
250	2 X 2	1508±106	1085±90	198±21	NA	2791±217	1706±127
111	3 X 3	1903±147	1436±109	221±24	NA	3560±280	2124±171
62.5	4 X 4	2402±159	1798±132	251±27	NA	4451±318	2653±186
BIOMASS PRODUCTION PER 0.1 HECTARE							
1000	1 X 1	765±148	619±102	90±8	82±15	1556±375	937±273
444.4	1.5 X 1.5	444±31	344±34	53±5	40±11	881±81	537±47
250	2 X 2	377±26	271±23	43±5	35±8	726±62	455±39
111	3 X 3	211±16	159±12	25±3	148±21	543±52	384±40
62.5	4 X 4	150±10	122±8	16±2	228±23	516±43	394±35

NA = not applicable

TABLE 3.
ATRIPLEX CANESCENS BIOMASS PRODUCTION 18 MONTHS AFTER PLANTING. JUNE 1986

SHRUBS/ 0.1HA	SPACING M X M	PRODUCTION, GRAMS DM /SHRUB ± SE					
		LEAVES	STEMS	LEAF FALL	ANNUALS	TOTAL	TOTAL EDIBLE
BIOMASS PRODUCTION PER SHRUB							
1000	1 X 1	250±13	247±29	91±11	NA	588±53	341±24
444.4	1.5 X 1.5	361±25	496±52	143±16	NA	1000±93	504±41
250	2 X 2	453±35	712±73	172±20	NA	1337±128	625±55
111	3 X 3	453±27	719±60	208±18	NA	1380±105	661±45
62.5	4 X 4	488±26	836±58	299±30	NA	1623±114	787±56
BIOMASS PRODUCTION PER 0.1 HECTARE							
1000	1 X 1	250±13	247±29	91±11	53±7	641±60	394±31
444.4	1.5 X 1.5	160±11	220±23	64±7	93±11	537±52	317±29
250	2 X 2	113±9	178±18	43±5	99±14	433±46	255±28
111	3 X 3	50±3	80±7	23±2	218±24	371±36	291±29
62.5	4 X 4	31±2	52±4	19±2	240±28	342±36	290±32

NA = not applicable

TABLE 4.
CASSIA STURTII BIOMASS PRODUCTION 18 MONTHS AFTER PLANTING. JUNE 1986

SHRUBS/ 0.1HA	SPACING M X M	PRODUCTION, GRAMS DM /SHRUB ± SE					
		LEAVES	STEMS	LEAF FALL	ANNUALS	TOTAL	TOTAL EDIBLE
BIOMASS PRODUCTION PER SHRUB							
1000	1 X 1	119±9	165±14	34.1±4.9	NA	318±26	153±12
444.4	1.5 X 1.5	248±19	399±33	78.6±4.9	NA	726±50	327±21
250	2 X 2	247±14	411±26	66.3±4.9	NA	724±40	313±16
111	3 X 3	407±23	673±39	153.1±4.9	NA	1233±60	560±24
62.5	4 X 4	435±30	753±54	262.8±4.9	NA	1451±81	698±31
BIOMASS PRODUCTION PER 0.1 HECTARE							
1000	1 X 1	119±9	165±14	34±5	75±12	393±36	228±20
444.4	1.5 X 1.5	110±8	177±15	35±3	26±6	348±26	171±11
250	2 X 2	62±4	103±7	17±2	58±7	240±14	137±7
111	3 X 3	45±3	75±4	17±2	105±17	242±21	167±14
62.5	4 X 4	27±2	47±3	17±2	148±24	239±16	192±13

NA = not applicable

TABLE 5.
ATRIPLEX NUMMULARIA: MEAN DIMENSIONS AND ESTIMATES OF STANDING BIOMASS ON 16.8.85, 30.12.85, AND 8.7.86

SHRUBS/ 0.1HA	SPACING M X M	DATE	DIMENSIONS (CM) HEIGHT	DIAMETER	BIOMASS GRAMS DM/SHRUB LEAF	STEM	TOTAL	TOTAL KG DM/ 0.1 HA
1000	1 X 1	16.8.85	83.6	44.1	161	188	349	349
		30.12.85	105.4	48.1	189	222	411	411
		8.7.86	87.9	67.5	765	619	1384	1384
444.4	1.5 X 1.5	16.8.85	86.1	57.7	227	264	491	218
		30.12.85	92.4	64.1	256	293	549	244
		8.7.86	95.9	74.7	999	775	1774	788
250	2 X 2	16.8.85	89.4	69.5	326	380	706	177
		30.12.85	98.5	82.2	394	466	860	215
		8.7.86	102.0	93.0	1508	1085	2593	648
111	3 X 3	16.8.85	90.4	70.7	354	413	767	85
		30.12.85	101.7	90.0	460	546	1006	112
		8.7.86	107.0	103.0	1903	1436	3339	371
62.5	4 X 4	16.8.85	85.8	80.4	451	526	977	61
		30.12.85	99.5	106.8	605	711	1316	82
		8.7.86	109.0	119.0	2402	1798	4200	263

TABLE 6.
ATRIPLEX CANESCENS: MEAN DIMENSIONS AND ESTIMATES OF STANDING BIOMASS ON 16.8.85, 30.12.85 AND 8.7.86

SHRUBS/ 0.1HA	SPACING M X M	DATE	DIMENSIONS (CM) HEIGHT	DIMENSIONS (CM) DIAMETER	BIOMASS GRAMS DM/SHRUB LEAF	BIOMASS GRAMS DM/SHRUB STEM	BIOMASS GRAMS DM/SHRUB TOTAL	BIOMASS TOTAL KG DM PER 0.1 HA
1000	1 X 1	16.8.85	54.4	40.7	52	39	91	91
		30.12.85	54.8	45.5	80	61	141	141
		8.7.86	66.1	57.1	250	247	497	497
444.4	1.5 X 1.5	16.8.85	60.0	59.9	140	105	245	109
		30.12.85	53.1	60.0	123	92	215	96
		8.7.86	73.4	78.2	361	496	857	381
250	2 X 2	16.8.85	57.5	66.4	168	127	295	74
		30.12.85	60.2	66.5	181	136	317	79
		8.7.86	76.3	95.8	453	712	1165	291
111	3 X 3	16.8.85	53.7	66.3	150	114	264	29
		30.12.85	53.8	60.0	177	133	310	34
		8.7.86	73.3	97.0	453	719	1172	130
62.5	4 X 4	16.8.85	60.3	70.4	198	150	348	22
		30.12.85	62.6	78.1	249	188	437	27
		8.7.86	80.9	124.9	488	836	1324	83

TABLE 7.
CASSIA STURTII: MEAN DIMENSIONS AND ESTIMATES OF STANDING BIOMASS ON 16.8.85, 30.12.85 AND 8.7.36

SHRUBS/ 0.1HA	SPACING M X M	DATE	DIMENSIONS (CM)		BIOMASS			
			HEIGHT	DIAMETER	GRAMS DM/SHRUB			TOTAL KG DM/ 0.1 HA
					LEAF	STEM	TOTAL	
1000	1 X 1	16.8.85	37.0	39.0	55	40	95	95
		30.12.85	37.0	39.0	54	40	94	94
		8.7.86	50.7	49.7	119	165	284	284
444.4	1.5 X 1.5	16.8.85	51.0	64.0	152	110	262	116
		30.12.85	51.0	63.0	163	120	283	126
		8.7.86	64.4	74.9	248	399	647	288
250	2 X 2	16.8.85	53.0	68.0	170	123	293	73
		30.12.85	57.0	69.0	201	156	357	89
		8.7.86	68.3	76.9	247	411	658	165
111	3 X 3	16.8.85	56.0	72.0	203	147	350	39
		30.12.85	68.0	90.0	306	233	539	60
		8.7.86	78.8	98.7	407	673	1080	120
62.5	4 X 4	16.8.85	54.0	68.0	201	145	346	22
		30.12.85	70.0	98.0	343	257	600	38
		8.7.86	80.0	97.0	435	753	1188	74

TABLE 8.
REGROWTH OF SHRUB SPECIES FROM AUGUST 1985 TO JUNE 1986*

SPECIES	NO. OF SHRUBS	DIMENSIONS, CM ± SE		BIOMASS, G DM ± SE			% LEAF
		HEIGHT	DIAMETER	LEAF	STEM	TOTAL	
ATRIPLEX NUMMULARIA	44	70.5±2.8	60.6±4.1	534±110	830±147	1364±257	39
ATRIPLEX CANESCENS	44	58.9±2.0	60.0±2.9	240±13	244±31	484±40	50
CASSIA STURTII	36	41.4±1.8	36.9±2.5	91±11	95±5	186±24	49

* SHRUBS WERE CUT TO 10 CM FROM GROUND LEVEL IN AUGUST 1985.

TABLE 9.
SOIL MOISTURE IN PLOTS OF DIFFERENT DENSITIES IN AUGUST 1986*

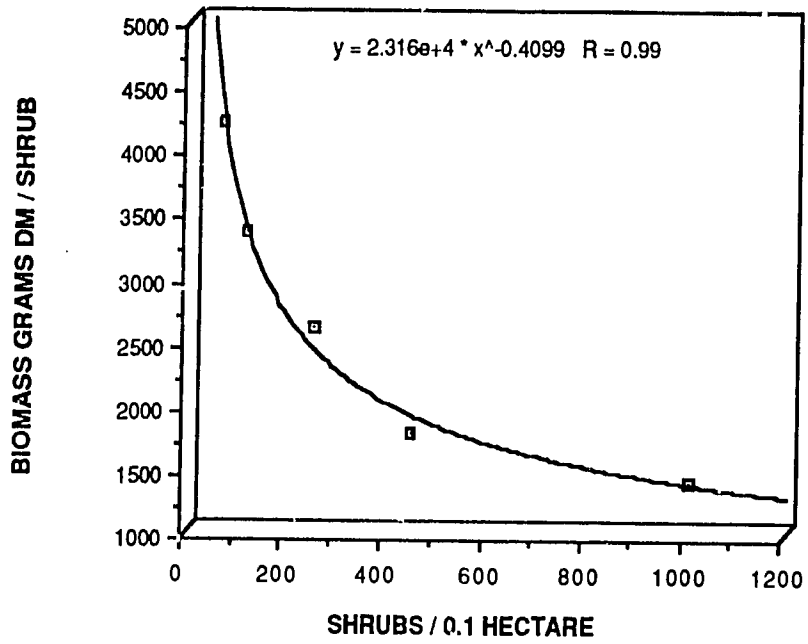
DEPTH	*C. sturtii*	*A. nummularia*	*A. canescens*	*C. sturtii*	*A. nummularia*	*A. canescens*	*C. sturtii*	*A. nummularia*	*A. canescens*
	1 m x 1 m			1.5 m x 1.5 m			2 m x2 m		
0-30	2.9 ± 0.1	3.5 ± 0.2	2.9 ± 0.1	3.0 ± 0.2	3.2 ± 0.2	3.0 ± 0.1	3.0 ± 0.1	3.2 ± 0.1	3.1 ± 0.1
30-60	4.3 ± 0.1	5.0 ± 0.2	4.8 ± 0.3	5.0 ± 0.1	5.1 ± 0.4	5.0 ± 0.1	4.7 ± 0.4	4.8 ± 0.5	4.4 ± 0.1
60-90	6.1 ± 0.2	6.1 ±0.3	6.2 ± 0.3	6.5 ± 0.2	5.9 ± 0.3	6.5 ± 0.2	6.4 ± 0.2	6.4 ± 0.4	6.1 ± 0.2
90-120	6.4 ± 0.1	5.8 ± 0.4	6.5 ± 0.2	6.0 ± 0.2	6.5 ± 0.4	6.2 ± 0.2	6.7 ± 0.2	6.3 ± 0.2	6.3 ± 0.2

	3 m x 3 m			4 m x 4 m			CONTROLS (NATURAL PASTURE WITHOUT SHRUBS) N=6	
							FERTILIZED	NONFERTILIZED
0-30	3.2 ± 0.1	3.0 ± 0.2	2.6 ± 0.1	3.3 ± 0.1	3.0 ± 0.1	3.0 ± 0.1	3.1 ± 0.1	2.8 ± 0.1
30-60	5.1 ± 0.2	4.8 ± 0.2	4.8 ± 0.3	5.3 ± 0.2	4.2 ± 0.3	5.1 ± 0.2	5.3 ± 0.4	4.8 ± 0.3
60-90	6.6 ± 0.2	6.4 ± 0.2	6.8 ± 0.2	6.3 ± 0.4	5.4 ± 0.2	6.5 ± 0.1	7.0 ± 0.2	6.5 ± 0.2
90-120	6.6 ± 0.2	6.8 ± 0.2	7.1 ± 0.1	7.2 ± 0.4	5.8 ± 0.2	6.8 ± 0.1	6.8 ± 0.4	7.0 ± 0.3

* VALUES IN THE TABLE ARE MEAN PERCENT MOISTURE BY WEIGHT ± SE

FIG. 1

ATRIPLEX NUMMULARIA: TOTAL BIOMASS PER SHRUB AT DIFFERENT PLANTING DENSITIES 18 MONTHS AFTER PLANTING. JUNE 1986



ATRIPLEX NUMMULARIA: COMPOSITION (%) OF BIOMASS PER SHRUB AT DIFFERENT PLANTING DENSITIES 18 MONTHS AFTER PLANTING. JUNE 1986

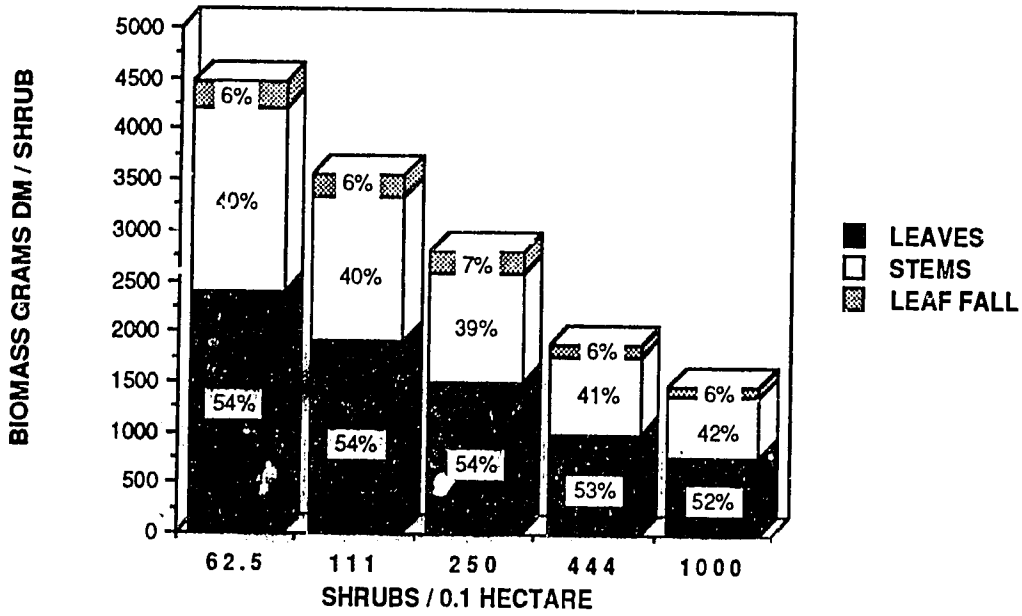
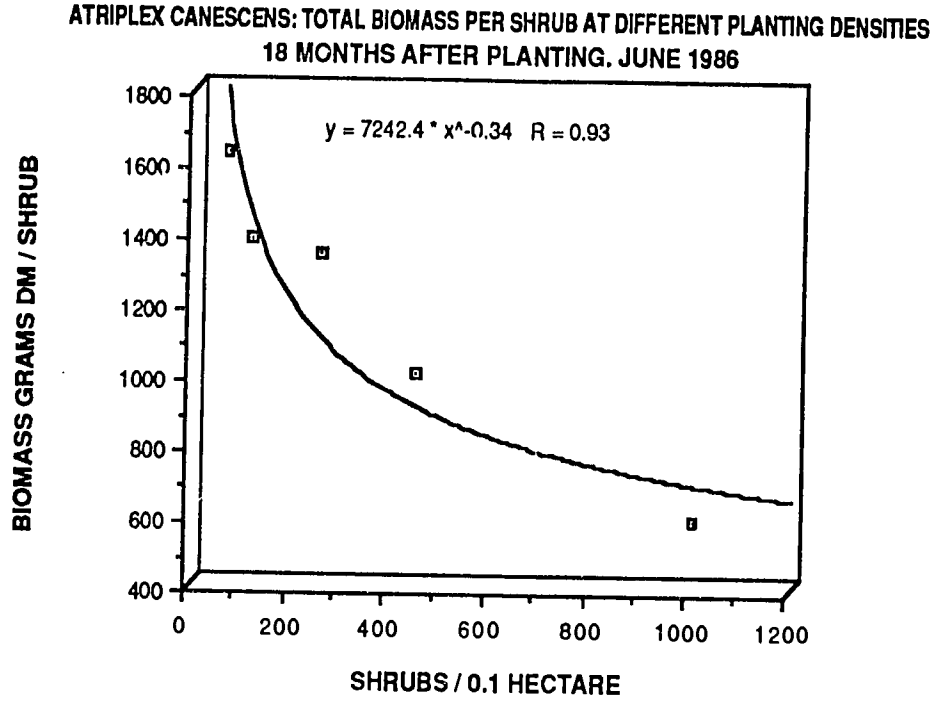


FIG. 2


ATRIPLEX CANESCENS: TOTAL BIOMASS PER SHRUB AT DIFFERENT PLANTING DENSITIES
18 MONTHS AFTER PLANTING. JUNE 1986
y = 7242.4 * x^-0.34 R = 0.93
BIOMASS GRAMS DM / SHRUB
1800
1600
1400
1200
1000
800
600
400
0
200
400
600
800
1000
1200
SHRUBS / 0.1 HECTARE

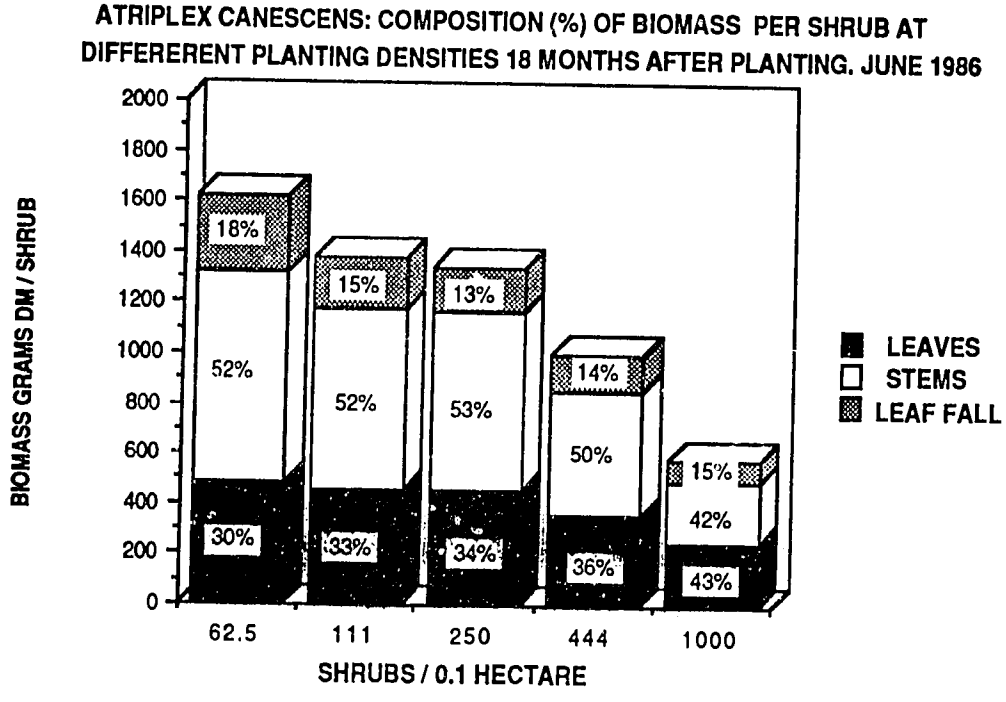
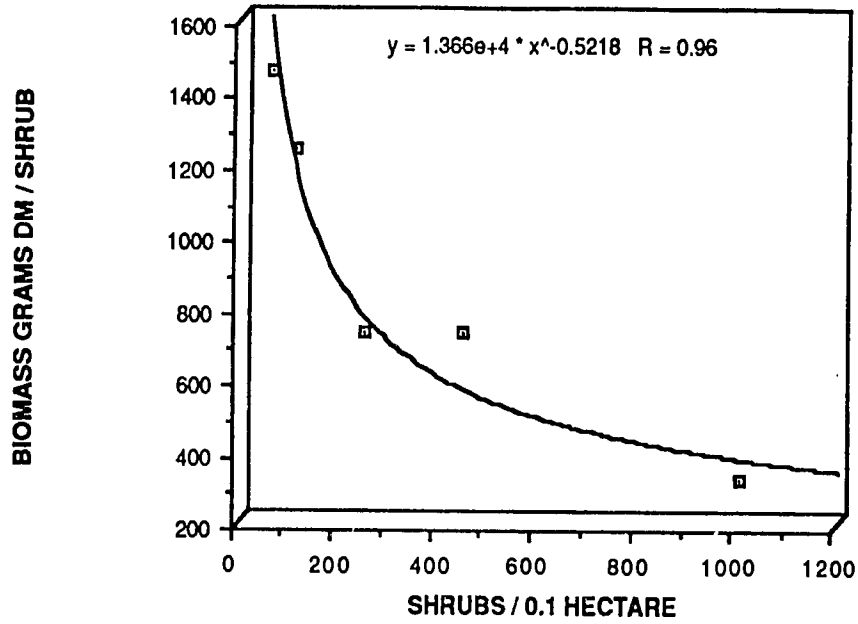

ATRIPLEX CANESCENS: COMPOSITION (%) OF BIOMASS PER SHRUB AT
DIFFERERENT PLANTING DENSITIES 18 MONTHS AFTER PLANTING. JUNE 1986
BIOMASS GRAMS DM / SHRUB
2000
1800
1600
1400
1200
1000
800
600
400
200
0
18%
52%
30%
15%
52%
33%
13%
53%
34%
14%
50%
36%
15%
42%
43%
62.5
111
250
444
1000
SHRUBS / 0.1 HECTARE
LEAVES
STEMS
LEAF FALL

FIG. 3
CASSIA STURTII: TOTAL BIOMASS PER SHRUB AT DIFFERENT PLANTING DENSITIES
18 MONTHS AFTER PLANTING. JUNE 1986



CASSIA STURTII: COMPOSITION (%) OF BIOMASS PER SHRUB AT
DIFFERENT PLANTING DENSITIES 18 MONTHS AFTER PLANTING . JUNE 1986

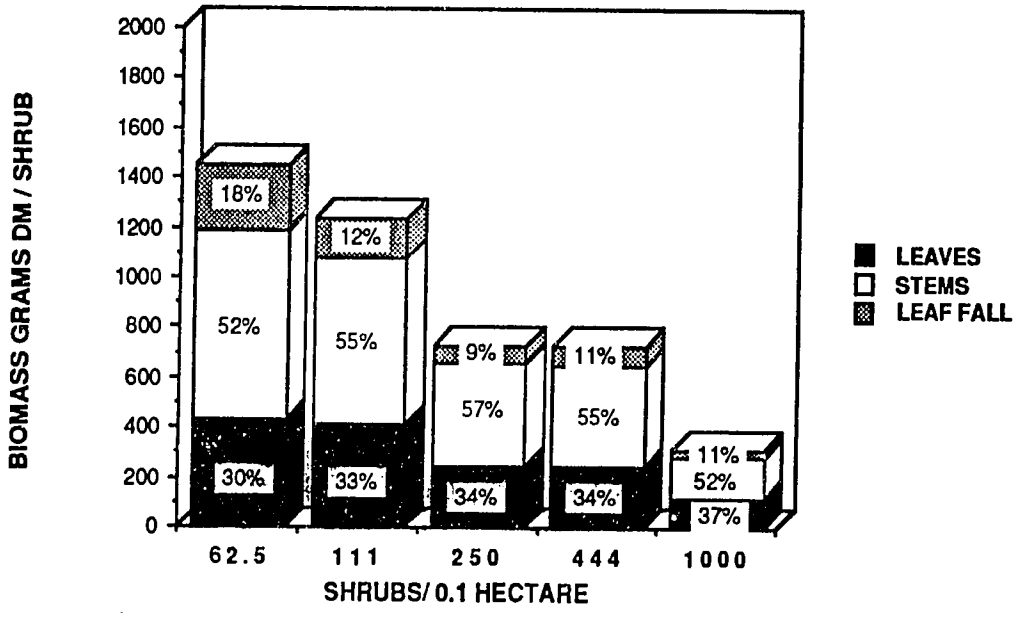
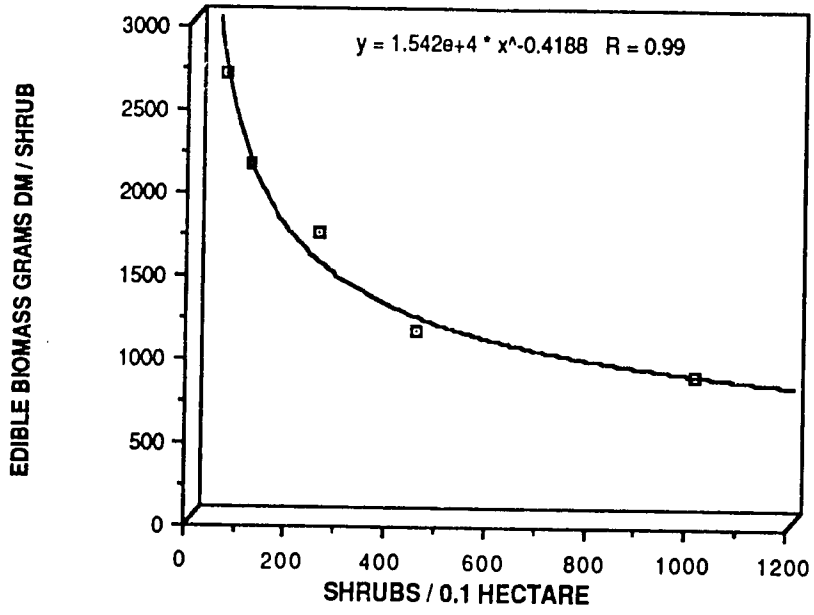


FIG. 4

ATRIPLEX NUMMULARIA: EDIBLE BIOMASS PER SHRUB AT DIFFERENT PLANTING DENSITIES 18 MONTHS AFTER PLANTING. JUNE 1986



ATRIPLEX NUMMULARIA: COMPOSITION (%) OF EDIBLE BIOMASS PER SHRUB AT DIFFERENT PLANTING DENSITIES 18 MONTHS AFTER PLANTING. JUNE 1986

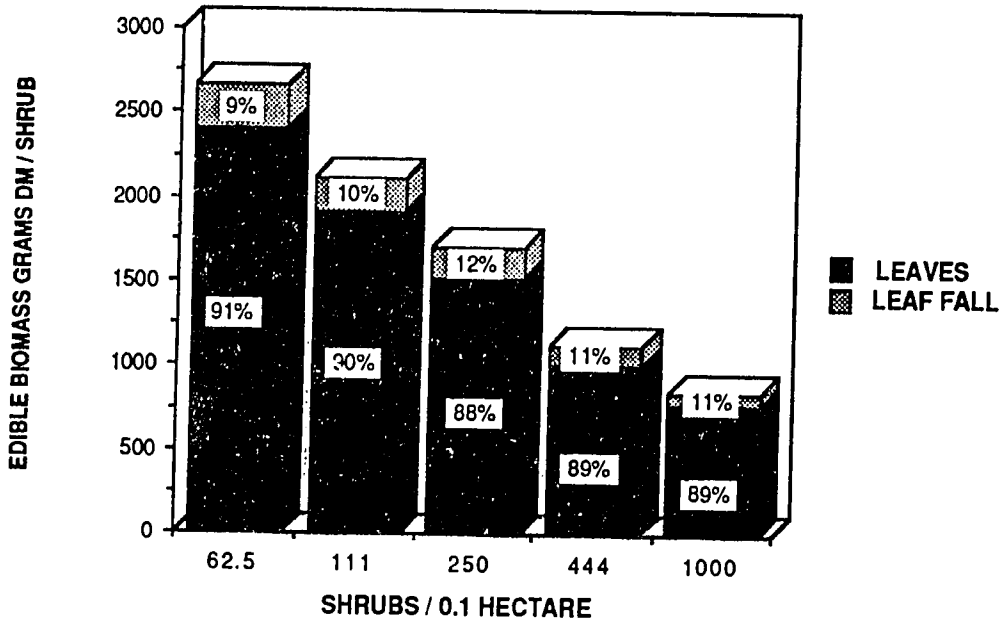
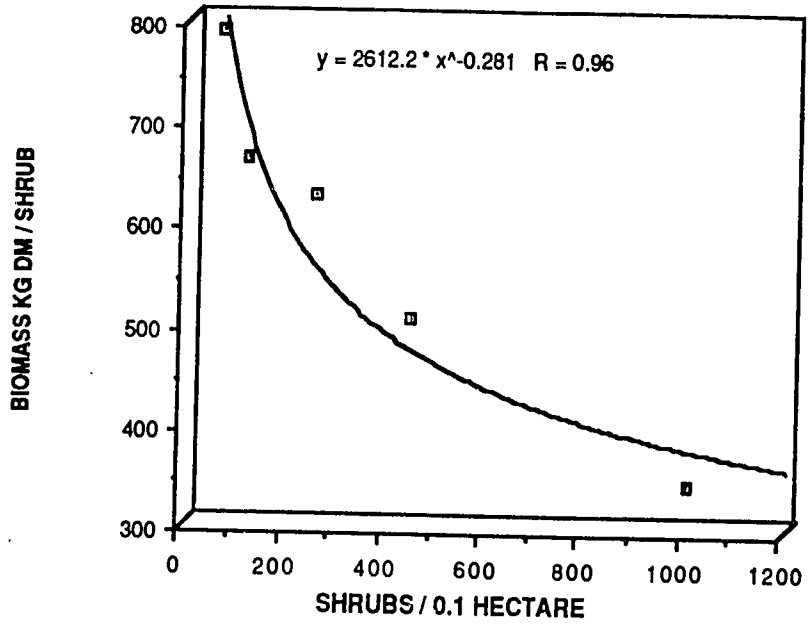


FIG. 5

ATRIPLEX CANESCENS: EDIBLE BIOMASS PER SHRUB AT DIFFERENT PLANTING DENSITIES 18 MONTHS AFTER PLANTING. JUNE 1986



ATRIPLEX CANESCENS: COMPOSITION (%) OF EDIBLE BIOMASS PER SHRUB AT DIFFERENT PLANTING DENSITIES 18 MONTHS AFTER PLANTING. JUNE 1986

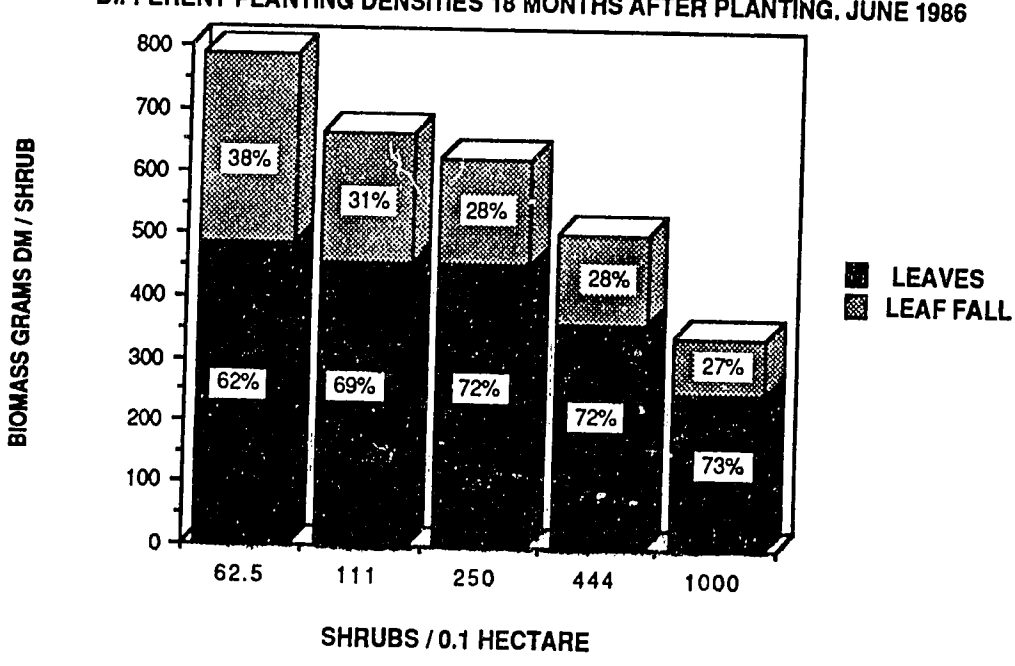
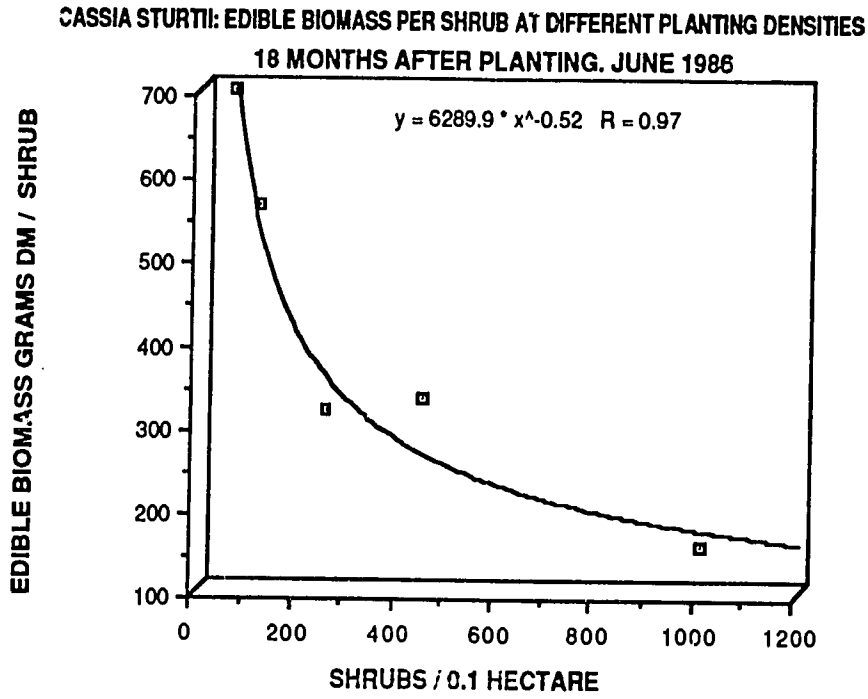


FIG. 6


CASSIA STURTII: EDIBLE BIOMASS PER SHRUB AT DIFFERENT PLANTING DENSITIES
18 MONTHS AFTER PLANTING. JUNE 1986
y = 6289.9 * x^-0.52 R = 0.97
EDIBLE BIOMASS GRAMS DM / SHRUB
700
600
500
400
300
200
100
0
200
400
600
800
1000
1200
SHRUBS / 0.1 HECTARE

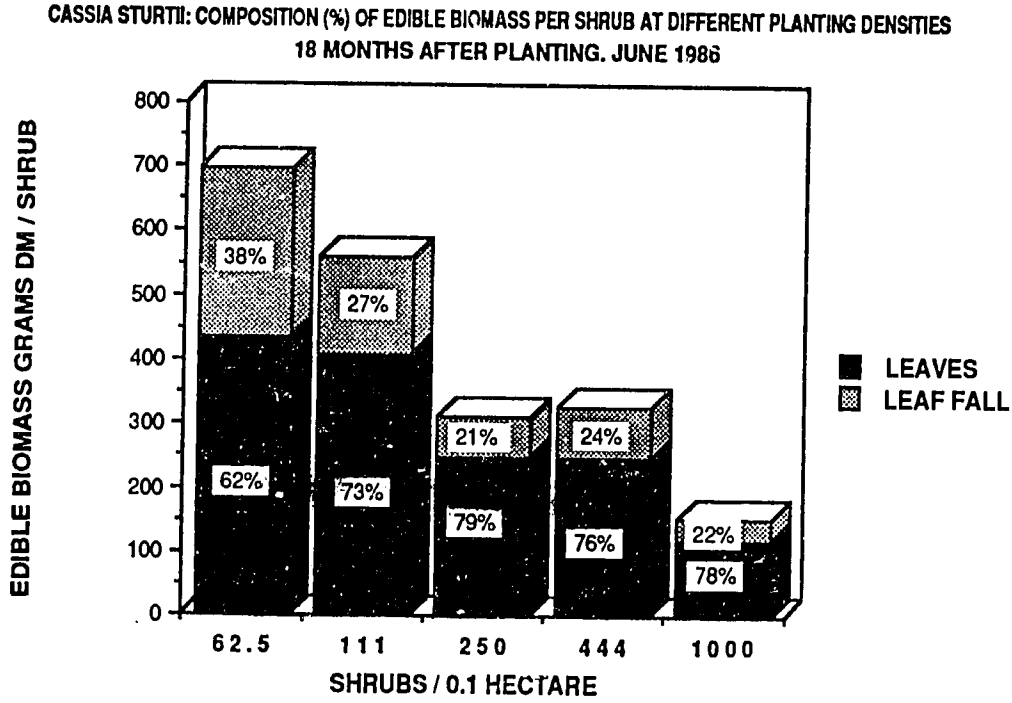
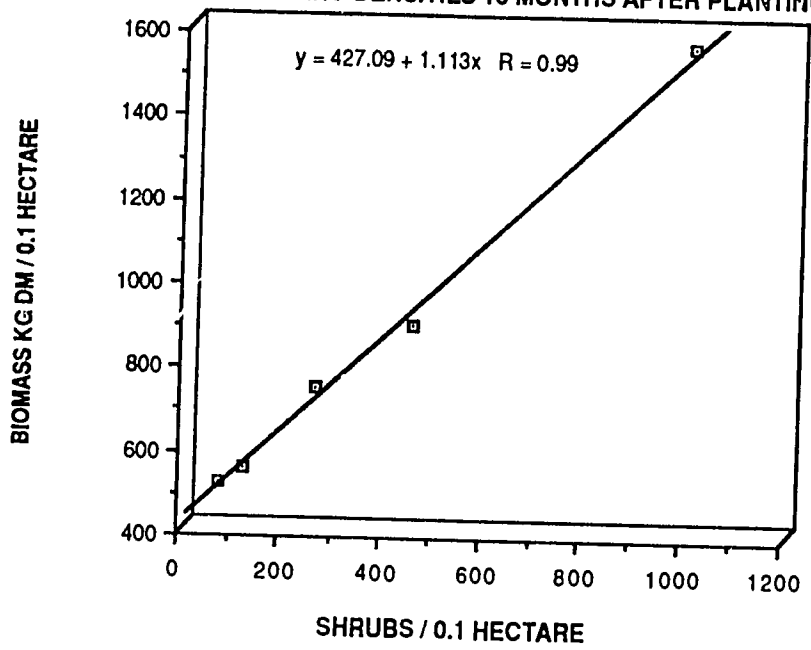

CASSIA STURTII: COMPOSITION (%) OF EDIBLE BIOMASS PER SHRUB AT DIFFERENT PLANTING DENSITIES
18 MONTHS AFTER PLANTING. JUNE 1986
EDIBLE BIOMASS GRAMS DM / SHRUB
800
700
600
500
400
300
200
100
0
38%
62%
27%
73%
21%
79%
24%
76%
22%
78%
LEAVES
LEAF FALL
62.5
111
250
444
1000
SHRUBS / 0.1 HECTARE

FIG. 7

ATRIPLEX NUMMULARIA AREA: TOTAL BIOMASS FROM SHRUBS AND ANNUALS AT DIFFERENT PLANTING DENSITIES 18 MONTHS AFTER PLANTING. JUNE 1986



ATRIPLEX NUMMULARIA AREA: COMPOSITION (%) OF BIOMASS FROM SHRUBS AND ANNUALS AT DIFFERENT PLANTING DENSITIES 18 MONTHS AFTER PLANTING. JUNE 1986

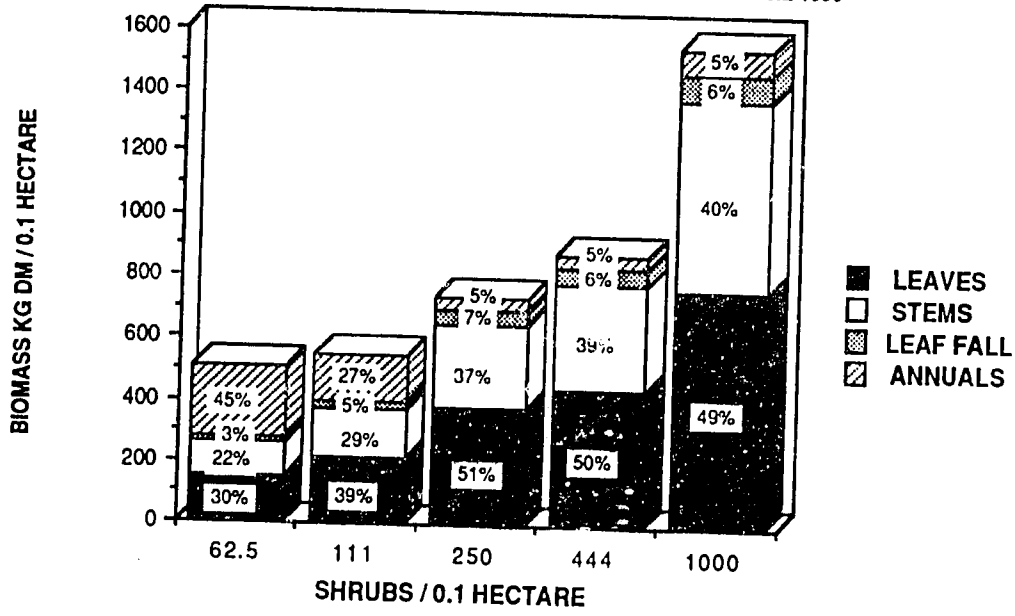
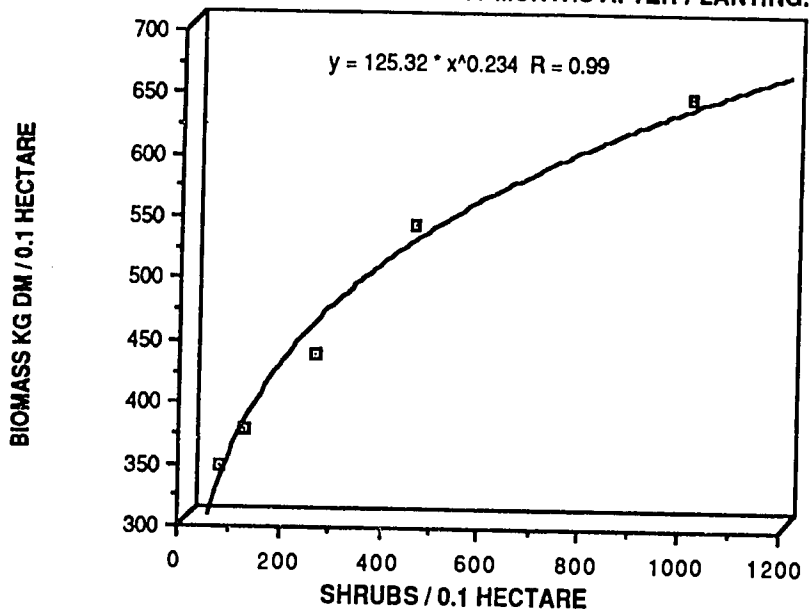


FIG. 8

ATRIPLEX CANESCENS AREA: TOTAL BIOMASS FROM SHRUBS AND ANNUALS AT DIFFERENT PLANTING DENSITIES 18 MONTHS AFTER PLANTING. JUNE 1986



ATRIPLEX CANESCENS AREA: BIOMASS FROM SHRUB COMPONENTS AND ANNUALS AT DIFFERENT PLANTING DENSITIES 18 MONTHS AFTER PLANTING. JUNE 1986

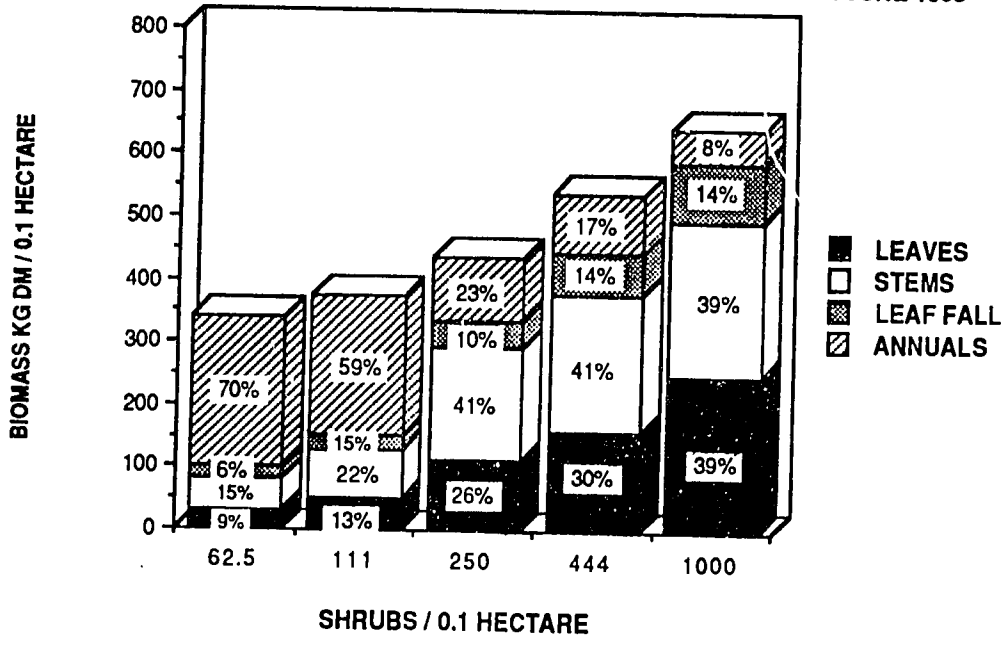
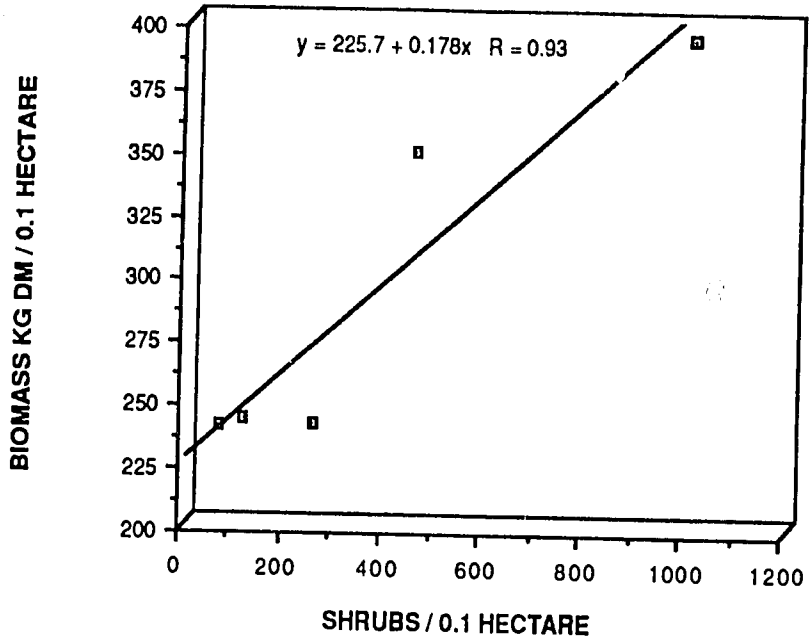


FIG. 9

CASSIA STURTII AREA : TOTAL BIOMASS FROM SHRUBS AND ANNUALS AT DIFFERENT PLANTING DENSITIES 18 MONTHS AFTER PLANTING. JUNE 1986



CASSIA STURTII AREA: BIOMASS FROM SHRUB COMPONENTS AND ANNUALS AT DIFFERENT PLANTING DENSITIES 18 MONTHS AFTER PLANTING. JUNE 1986

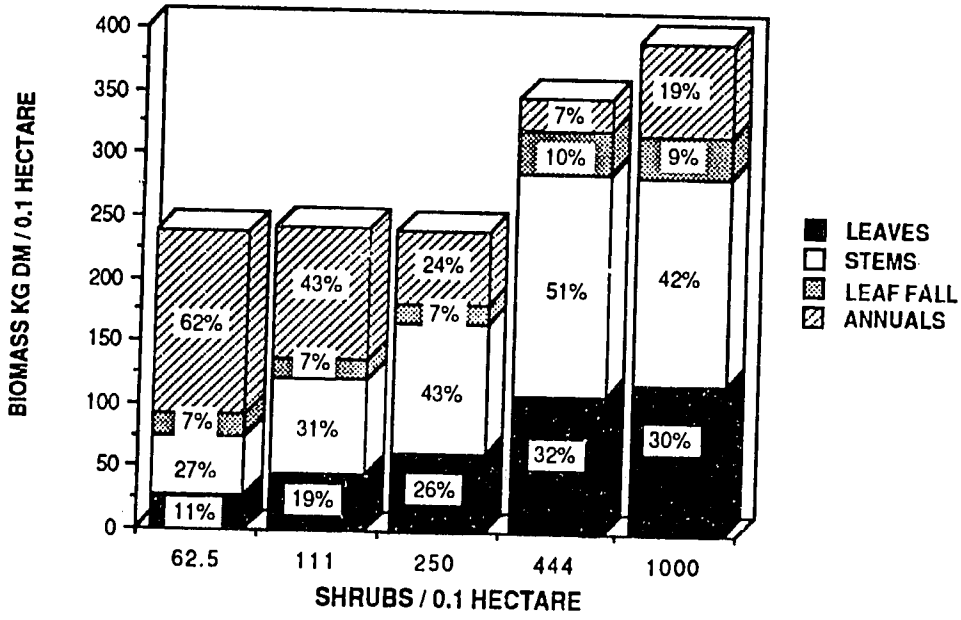
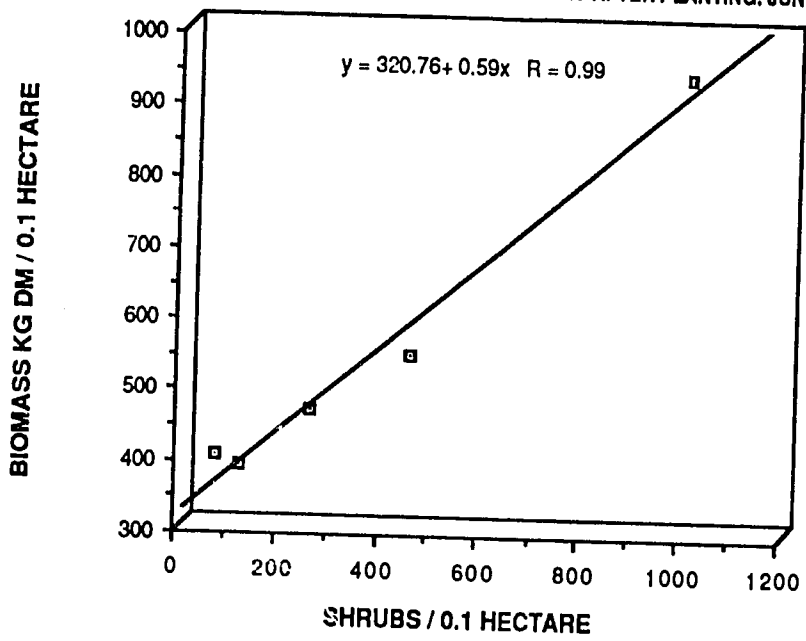


FIG. 10

ATRIPLEX NUMMULARIA AREA: EDIBLE BIOMASS PER 0.1 HECTARE FROM SHRUBS AND ANNUALS AT DIFFERENT PLANTING DENSITIES 18 MONTHS AFTER PLANTING. JUNE 1986



ATRIPLEX NUMMULARIA AREA: EDIBLE BIOMASS PER 0.1 HECTARE FROM SHRUB COMPONENTS AND ANNUALS AT DIFFERENT PLANTING DENSITIES 18 MONTHS AFTER PLANTING. JUNE 1986

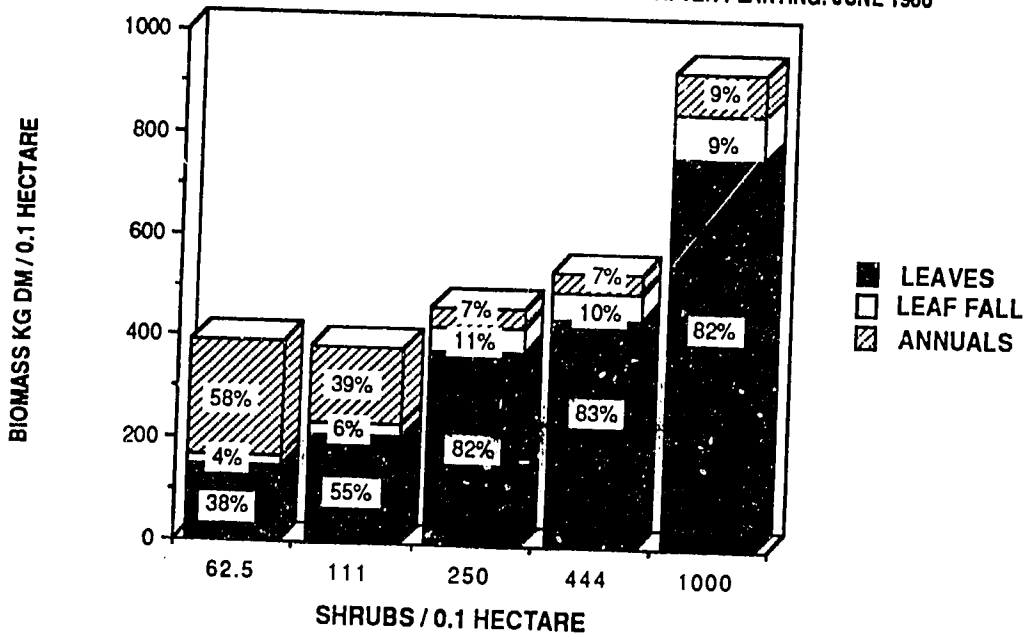
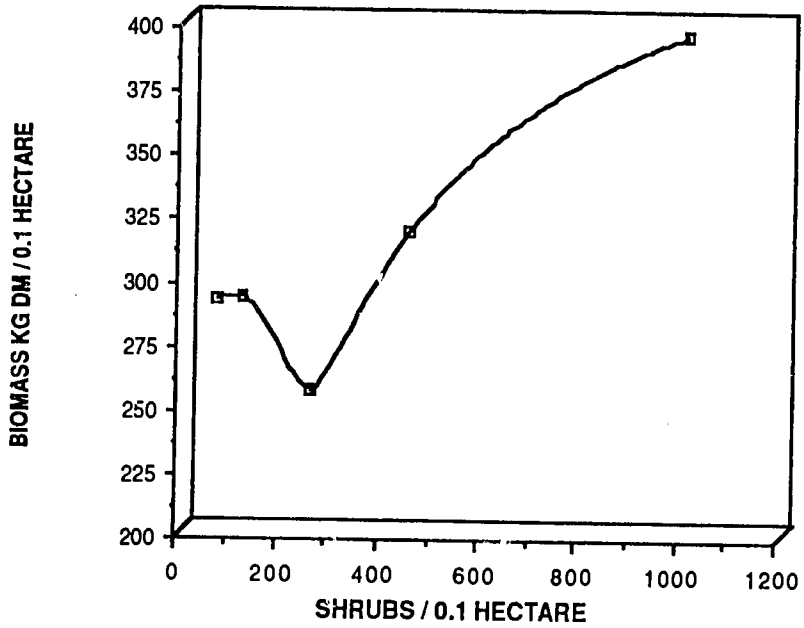


FIG. 11

ATRIPLEX CANESCENS AREA: EDIBLE BIOMASS PER 0.1 HECTARE FROM SHRUBS AND ANNUALS AT DIFFERENT PLANTING DENSITIES 18 MONTHS AFTER PLANTING . JUNE 1986



ATRIPLEX CANESCENS AREA: EDIBLE BIOMASS PER 0.1 HECTARE FROM SHRUB COMPONENTS AND ANNUALS AT DIFFERENT PLANTING DENSITIES 18 MONTHS AFTER PLANTING. JUNE 1986

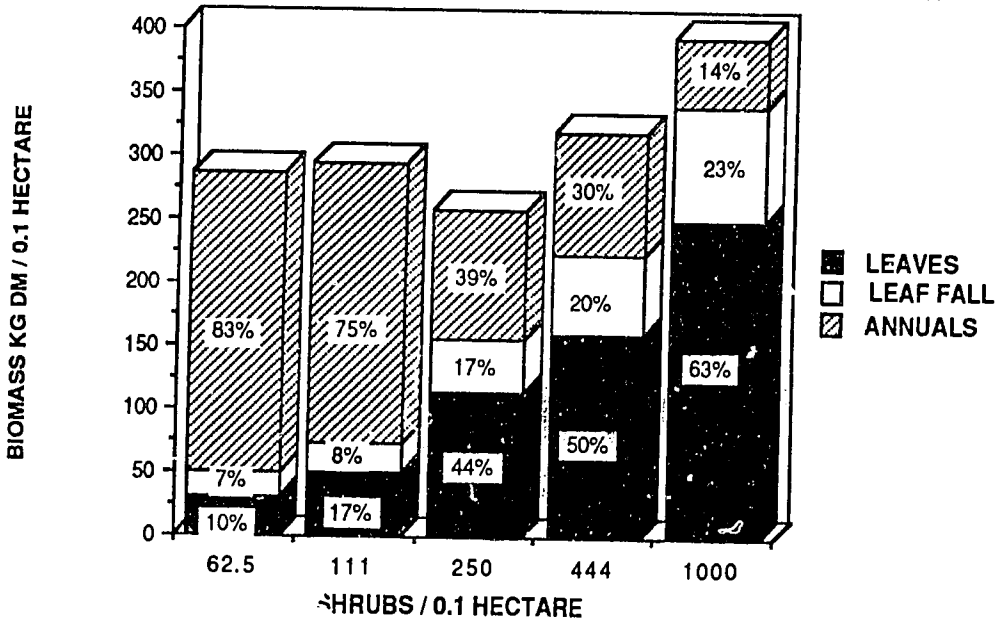
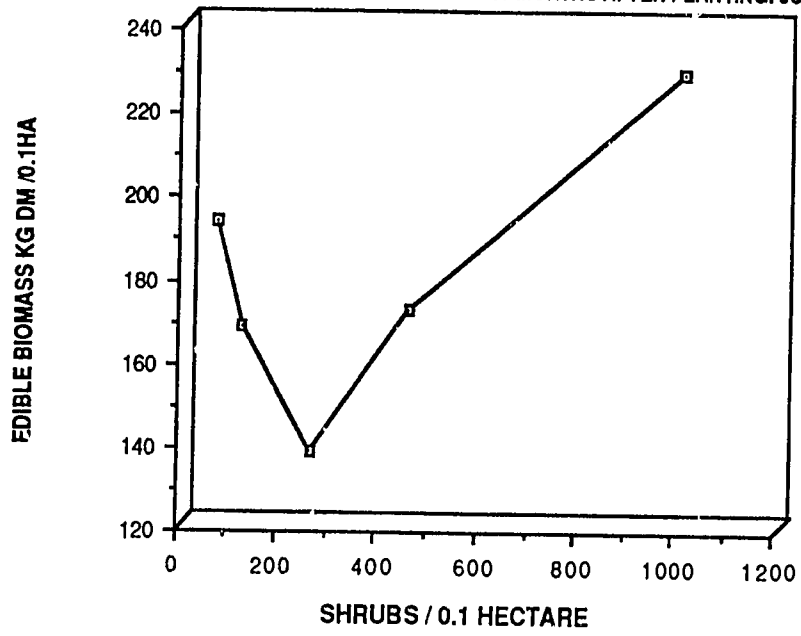


FIG. 12

CASSIA STURTII AREA: EDIBLE BIOMASS PER 0.1 HECTARE FROM SHRUBS AND ANNUALS AT DIFFERENT PLANTING DENSITIES 18 MONTHS AFTER PLANTING. JUNE 1986



CASSIA STURTII AREA: EDIBLE BIOMASS PER 0.1 HECTARE FROM SHRUB COMPONENTS AND ANNUALS AT DIFFERENT PLANTING DENSITIES 18 MONTHS AFTER PLANTING . JUNE 1986

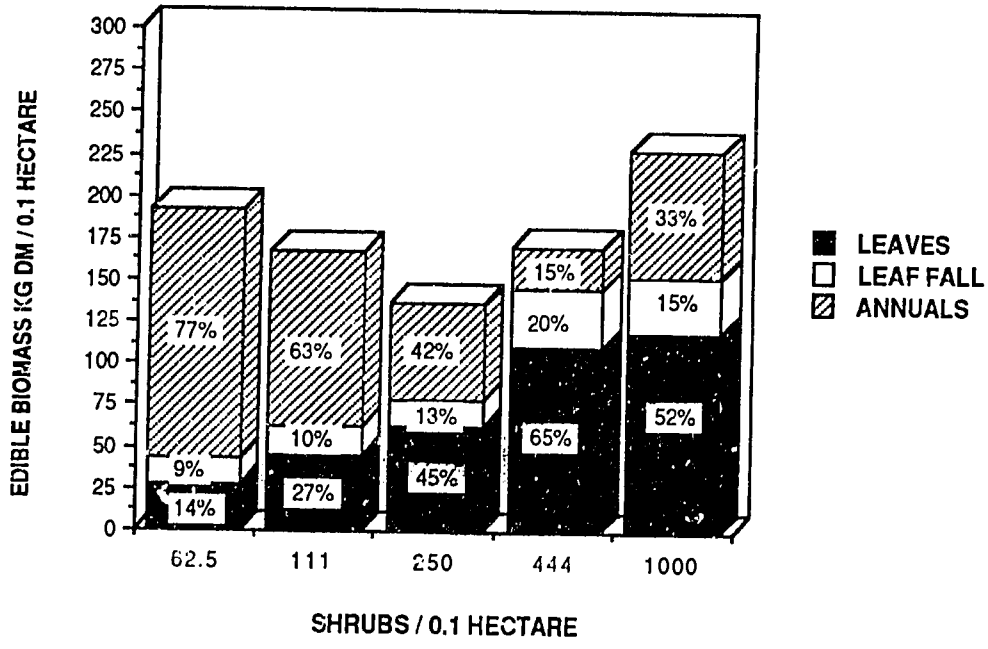
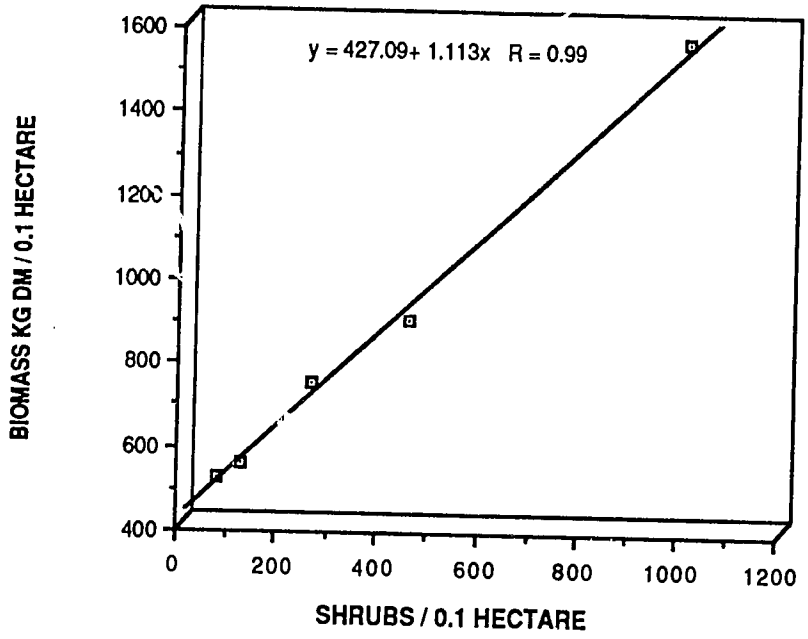
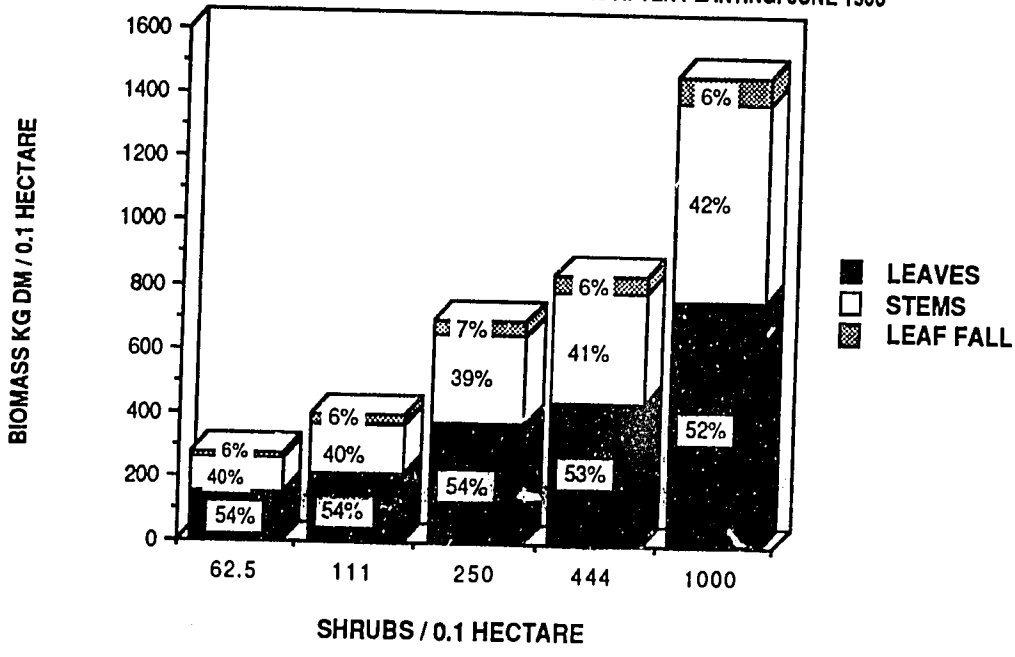


FIG. 13

ATRIPLEX NUMMULARIA AREA: SHRUB BIOMASS PER 0.1 HECTARE AT DIFFERENT PLANTING DENSITIES 18 MONTHS AFTER PLANTING. JUNE 1986



ATRIPLEX NUMMULARIA AREA: BIOMASS COMPOSITION (%) OF SHRUBS PER 0.1 HECTARE AT DIFFERENT PLANTING DENSITIES 18 MONTHS AFTER PLANTING. JUNE 1986



PLANTING FODDER SHRUBS IN THE BEDOUIN DEMONSTRATION FARM

M. Forti and Y. Lavie
The Institutes for Applied Research, Ben-Gurion University of the Negev
and
R.W. Benjamin
Agricultural Research Organization, Israel

ABSTRACT

During the winter of 1986-87 about 20 hectares of fodder shrubs were planted in microcatchments on the hill slopes of the Bedouin Demonstration Farm northeast of Beer-Sheva. Three species, *Atriplex nummularia* (50%) *A. canescens* (25%) and *A. halimus* (25%) are being used in this study. To compare the effects of a number of factors (type of seedlings, planting season, extent of control on competition by native vegetation) on the establishment and growth of shrubs, plantlets grown in bags and speedling trays were planted early (December 1986) or late (February 1987) in the winter in soil cleared either completely or only partially of the native perennials.

INTRODUCTION

The hilly areas in the vicinity of the Beer-Sheva plain are traditionally used as grazing land by the Bedouins. In that area a demonstration project has been conducted for several years by the Ministry of Agriculture and the Jewish National Fund with the purpose of demonstrating: 1) correct management of limited pasture resources by integrating into the system the utilization of agricultural by-products and the cultivation of barley and wheat; 2) increment of animal production by introduction of improved sheep breeding and husbandry practices; and 3) improvement of pastoral resources by application of advanced technologies.

The integration of perennial fodder shrubs in pasture management could be one of the means of improving range and contributing to the stabilization and expansion of animal production. Such shrubs would provide green feed, which is relatively rich in protein and vitamins, during critical periods of the pastoral cycle, when pasture is scarce and/or of low nutritive value, in particular at the end of summer and in winter before green fodder becomes available after rain has fallen.

In the estimation of the economic viability of a fodder shrub project, the costs of seedlings, land preparation, and planting are of utmost significance. Seedlings grown in bags have an inbuilt additional cost component consisting of the price of nonrecyclable containers and extra materials and manpower. Compared with seedlings grown in speedling trays, those grown in bags require larger nursery areas, longer growing periods in the nursery, higher transport expenses, and more work in moving the plantlets to the final location in the field and in planting them, particularly in harsh terrain such as steep hill slopes. It appears that the advantages of using speedlings, including the possibility of propagation at times other than the normal sowing seasons, could compensate for the cost of the facilities required for this type of plantlet. However, once planted in the field, the small volume of soil mixture available to the speedlings and its physical characteristics could be an obstacle to survival and rapid growth, when irrigation is not possible. In addition competition from the native vegetation can hinder successful establishment. It has been observed that, because of this competition, rainy years may be less favorable to shrubs than

less rainy winters. This phenomenon could be even more marked with small seedlings like speedlings.

Weather conditions, weed competition, and establishment and growth of shrubs under dryland conditions are interrelated and must therefore influence any planting program. Towards the end of the rainy season, the amount of rain water stored in the soil is known (and may facilitate a decision whether to transplant or delay planting); higher temperatures which enhance growth prevail; and no additional weed germination or, at least, no vigorous and prolonged competitive weed growth is still to be expected, provided that the field has been kept clean. In the light of these considerations, planting late may be more advantageous than planting early in the season, when seedlings are exposed to cold for a prolonged period, to the incertitudes of the erratic rainfall and to competition from a native vegetation well adapted to the environment.

The planting of 20 hectares of fodder shrubs in the Bedouin Demonstration Farm and the methods adopted in order to try to test some of the hypotheses and alternatives mentioned above are described in this report.

PURPOSES

1. To study the possibility of applying the information and technology developed on the establishment, cultivation and use of fodder shrubs in an integrated animal production system aimed at stabilizing and improving the traditional grazing-land utilization practices of the Bedouin.

2. To compare, in the establishment phase, the effect of the following factors on survival and growth of shrubs:
Planting season - early (December) vs. late (February-March) winter
Competition from native vegetation - total vs. partial clearing
Seedling type - large seedlings grown in plastic bags vs. small, young seedlings grown in speedling trays

3. To study, after establishment and adequate growth, the contribution of a fodder shrub component to sheep grazing.

MATERIALS

The Bedouin Demonstration Farm is located 15 km northeast of Beer-Sheva on 875 hectares of hilly land, 10% of which consists of small cultivable valleys. The area is fenced in and subdivided into five subfields with a sheepshed, yards and other facilities. Five hundred Awassi ewes, owned and managed by a Bedouin, graze in the farm.

Rainfall, only in the cold season, averages 240 ± 80 mm per year with variable seasonal distribution. Soil along the slopes ranges from shallow and stony to denuded rock and supports an annual vegetation of low biomass, green in winter but rapidly drying out and losing its nutritional value once the warm season starts. The dominant perennial plants are most often either inedible, like *Thymelaea hirsuta*, or accepted by animals only in certain phenological stages, for instance *Poterium spinosum* for its fruits and *Asphodelus microcarpus* for its dry leaves after entering summer dormancy.

METHODS

Fodder shrub species. Three species were propagated and planted: *Atriplex nummularia*, which had so far proved to be the most productive shrub in the trials at the Migda Farm, *A. canescens*, and the native *A. halimus*, which had been tested in nearby areas.

Seedling type. All species were propagated both in plastic bags containing 1 kg of soil mixture and in speedling trays. Plantlets in bags were grown in the nursery of the Jewish National Fund in Gilat, northwest of Beer-Sheva and were at least one year old at planting time. Speedlings were propagated and grown under shelter in the nursery of The Institutes of Applied Research in Beer-Sheva. Speedling seeds were sown in July-August 1986 in a mixture containing approximately, by volume, 45% vermiculite, 35% peatmoss, 8% soil, 6% sand and 6% compost. Irrigation was provided by an automatic overhead mist system. At planting time (December or February) the speedlings were five to seven months old.

Planting area. An area of about 20 hectares in the Bedouin Demonstration Farm was used. It lies above the sheep shed on the steep slopes oriented to the North.

Soil preparation. Individual microcatchments approximately 0.80 x 0.25 cm in size and spaced approximately 2.5 x 2.5 m were hand prepared. The soil dug from each catchment was piled on its side, and seeedlings were planted in the deeper and looser soil of this mound. In this way water collecting capacity was also improved.

Elimination of native vegetation. During summer 1986, about 50% of the area was completely hand cleared of the native perennial vegetation. The remaining 50% was only partially cleared around the catchments. The entire area was air sprayed before the rains with Simazine (4 kg/hectare) to prevent the emergence of annuals.

Planting. Planting was carried out in two phases: early winter from 21 to 30 December 1986 and late winter from 23 February to 1 March 1987. Irrigation was not applied in either phase. In both phases approximately half of the seedlings were planted in the completely cleared area and half in the partially cleared area. In the two phases the planting percent of the three species was approximately as follows: *Atriplex nummularia* 50%, *A. canescens* 25%, *A. halimus* 25%. In the first phase most of the seedlings were grown in bags and only a small number of speedlings of *A. nummularia* and *A. halimus* were planted for comparison purposes. In the second phase only speedlings were used. Since seedlings in bags were very large, cutting back was recommended to facilitate establishment. In total, 31,100 seedlings were planted. Details are summarized in Table 1.

RESULTS

Planting was carried out close to the end of the period surveyed, and results on establishment and survival are therefore not yet available. The following remarks and observations can be made.

Rainfall. Winter 1986-87 was rainy and precipitations had a favorable distribution. Planting took place in moisted soil and considerable amounts of water appear to have run from the slope into the microcatchments and to have been stored there.

Table 1.
Bedouin Demonstration Farm. Planting of fodder shrubs in the winter of 1986-87. Distribution according to species, type of seedling, planting time, and method of clearing vegetation

Vegetation clearing	No. of seedlings						
	A. nummularia		*A. canescens*		*A. halimus*		Total
	Bags	Speedlings	Bags	Speedlings	Bags	Speedlings	
Planting Dec. 1986							
Complete	5000	800	2800	0	1500	200	10300
Partial	4300	700	1800	0	2500	500	9800
Total for Dec. 1986	9300	1500	4600	0	4000	700	20100
Planting Feb. 1987							
Complete	0	2650	0	1000	0	1100	4750
Partial	0	3450	0	1500	0	1300	6250
Total for Feb. 1987	0	6100	0	2500	0	2400	11000
Grand Total of Shrubs Planted	**9300**	**7600**	**4600**	**2500**	**4000**	**3100**	**31100**

Table 2. Bedouin Demonstration Farm.
Planting work performances*

Parameters	Early planting: Bags	Late planting: Speedlings
No. of seedlings planted	20,100	11,000
No. of hectares planted	13	7
No. of working days	262	80
No. of working days/hectare	20.1	11.4
No. of seedlings planted/working day	77	138

*Work included: cutting back of seedlings in bags, manual transfer of plantlets inside the field, repairing damaged catchments, breaking of soil crust, opening of the holes, and planting.

Vegetation control. The Simazine treatment was effective in controlling weed emergence. No damage to the shrub seedlings was observed. Hand clearing of perennial vegetation was also effective and prevented its re-growth, at least during the establishment phase.

Planting performances. Data covering all the phases and operations involved in propagation and planting of the shrubs have not yet been summarized. However, from the figures presented in Table 2, the advantage of using speedlings instead of seedlings grown in bags appear evident in terms of working days and work performances: almost twice as many speedlings were planted per working day.

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The invaluable contribution to this project of the Jewish National Fund, of its directors and personnel, by supplying seedlings and by carrying out soil preparation and planting is thankfully acknowledged. The assistance of Mr. I. Rosilio, Ministry of Agriculture, Beer-Sheva and of Mr. Mohammed El Sayad, the owner of the flock, is also warmly appreciated.

SUBPROJECT 2. ENHANCEMENT OF NITROGEN SUPPLY TO MEDITERRANEAN PASTURE SPECIES BY MEANS OF RHIZOSPHERE BACTERIA

EFFECT OF *AZOSPIRILLUM* ON SUSCEPTIBILITY TO *RHIZOBIUM* NODULATION AND ON NITROGEN FIXATION IN SEVERAL FORAGE LEGUMES

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ABSTRACT

Azospirillum brasilense Cd in cell concentrations of 10^5-10^7 colony-forming units (CFU)/ml applied 24 h before *Rhizobium* (10^6 CFU/ml) inoculation increased nodule formation in the non-root-hair zone more than twofold in pouch-grown *Medicago polymorpha* and *Macroptilium atropurpureum* seedlings compared with inoculation with *Rhizobium* alone. There was a 20% increase in nodule formation in pouch-grown *Trifolium alexandrinum*, following pre-inoculation with *Azospirillum*. The percentage of nodulated seedlings rose from 0 to 25% when *Medicago polymorpha* was pre-inoculated with *Azospirillum*, followed by application of 10 CFU/ml *Rhizobium meliloti*, a concentration which on its own was not sufficient to initiate nodule formation. Acetylene reduction activity in *Medicago polymorpha* and *Macroptilium atropurpureum* seedlings after inoculation with *Azospirillum-Rhizobium* was markedly increased. A possible reason for the increased susceptibility to *Rhizobium* infection may be that *Azospirillum* stimulates the formation of a larger number of epidermal cells that differentiate into infectable root hairs.

INTRODUCTION

The yield of various cereals and forage grasses is known to be enhanced following inoculation with a free-living nitrogen-fixing bacteria of the genus *Azospirillum* (Okon, 1984). This increase in yield has been attributed to the improvement of root development, to the increase in the rate of water and mineral uptake from the soil by the roots, and, to a lesser extent, to biological nitrogen fixation (Lin et al., 1983: Yahalom et al., 1984).

The shoot yield of soybean increased after inoculation with a mixed culture of *Rhizobium japonicum* and either *Azotobacter vinelandii* or *Azospirillum brasilense* compared with *Rhizobium* alone (Sing and Subba Rao, 1979; Burns et al, 1981; Iruthayathas et al., 1983). Similarly, an increase in grain yield, nodule dry weight, and acetylene reduction activity was obtained in chick pea inoculated with a mixture of *Azospirillum brasilense* and *Rhizobium* (Rai, 1983). Sarig et al. (1986) reported that, under field conditions in Israel, both nodulation and crop yield were increased in vetch, garden pea and chick pea following inoculation with *Azospirillum*. Recently, Plazinski and Rolfe (1985) reported the stimulation or inhibition of nodule formation in white clover, depending on the ratio of *Rhizobium*: *Azospirillum* in the inoculum in agar plate assays.

In this report we describe the effect of *Azospirillum* in increasing sensitivity of several legumes to infection by *Rhizobium*.

MATERIALS AND METHODS

Organisms and growth conditions

Rhizobium meliloti RT-1 was obtained from the South African Rhizobium Collection, Rietondale Research Farm, Pretoria. *Rhizobium* 280-A for inoculating *Macroptilium* and *Rhizobium trifolii* 3115 was obtained from the Department of Field Crops, Volcani Center, Bet Dagan. Cultures used for inoculation were grown for three days in yeast mannitol broth (Vincent, 1970) at 30°C in 250-mL Erlenmeyer flasks on a rotary shaker (110 strokes/m). The cells were harvested by centrifugation at 10,000 rpm and washed twice with sterile distilled water.

Azospirillum brasilense Cd (ATCC-29 729) was grown on malate liquid medium (Okon et al., 1977) supplemented with 0.25% NH_4Cl and

0.01% yeast extract for 20 h at 30°C. Cells were harvested at the late logarithmic growth phase by centrifugation (3000 rpm) and were washed twice in 30 mM potassium phosphate-buffered saline (pH 7). The bacterial suspensions that were used for inoculation were diluted to the appropriate number of cells per milliliter.

Growth of seedlings

Seeds of *Medicago polymorpha*, *Macroptilium atropurpureum* and *Trifolium alexandrinum* (cv. Tabor) were obtained from the Department of Field Crops, Volcani Center. Seeds of *Macroptilium* were disinfected by immersion in concentrated H_2SO_4 for 20 min. *Medicago* and *Trifolium* seeds were disinfected by immersion in 70% methanol for 5 min, followed by double washing with water, and immersion for 5 min in a solution of $HgCl_2$. Seeds of all species were washed eight times over period of 3 h at 27°C with sterile water and stored overnight at 4°C. Swollen seeds were germinated on yeast extract mannitol agar in petri dishes in an upside-down position. Seedlings free of microbial contamination (bacterial colonies) were transferred to paper-towel-lined plastic growth pouches, 16 x 17 cm (diSPo Seed-Pack, Scientific Products, Evanston, Il.) which had been previously moistened with 9 ml of sterilized half strength free Jensen's medium (Vincent, 1970). Tiny holes were made in the top of the paper towel prior to inserting the roots of the germinating seeds. Four seedlings were placed in each pouch. All of the above-described operations were carried out under aseptic conditions. The growth pouches containing the seedlings were placed in boxes in an upright position and covered with aluminium foil until inoculation to prevent drying and to maintain aseptic conditions. The boxes with seedlings were placed in a growth chamber under the following conditions: 50-70% relative humidity; 25°C light and 18°C dark; 13-h photoperiod; light intensity at bench level 150 $\mu E\ m^{-2}\ sec^{-1}$. The paper towels were kept moist with sterile water throughout the experiment.

MARKING AND INOCULATION

The seedlings were inoculated with *Rhizobium* two days after transfer to the pouches, when the roots were approximately 3 cm long. In most experiments *Azospirillum* was applied either 24 h before inoculation with *Rhizobium* or together with *Rhizobium*. A waterproof marking pen was used to indicate the position of the root tip (RT) and the position of the smallest emerging root hair (SERH) at the time of inoculation, as determined by

viewing through a stereomicroscope. The region between the RT mark and the SERH was denoted the no-root-hair (NRH) zone (Bhuvaneswari et al., 1980). Seedlings were inoculated by applying 0.5 ml of bacterial suspension of *Rhizobium* or *Azospirillum* to the roots of the seedlings in each pouch. The controls received an identical amount of culture medium but without the *Azospirillum* inoculum.

Scoring of nodulation

After inoculation, seedlings were kept in the growth chamber for six to eight days and scored when most of the mature nodules on the primary root were at least 0.75 mm in diameter. The position of the nodules on the primary root was determined within the nearest 0.5 mm with the aid of a stereomicroscope. The relative distance of each nodule from the RT mark was expressed as a percentage of the length of the NRH. Dead or injured seedlings were discarded.

Acetylene reduction activity

Pouches with seedlings were rolled into glass tubes (32 mm diameter) and sealed with rubber stoppers, and 10% of the air was replaced with acetylene gas. Tubes were then returned to the growth chamber for 20 min, and ethylene production in the tubes was assayed according to Burris (1974). After the assay, the pouches containing the seedlings were removed from the tubes, transferred back to the boxes, and allowed to continue growing until the next assay.

RESULTS

Cell concentration of *Azospirillum*

Increasing the cell concentration of *Azospirillum*, when applied as a pre-inoculant 24 h before the inoculation with *Rhizobium* onto *Medicago polymorpha*, had a more pronounced effect on the number of nodules formed above the RT mark than on the total number of nodules (Fig. 1). *Azospirillum* cell concentrations containing 10^5-10^7 CFU/ml increased nodulation above the RT more than twofold, whereas concentrations lower or higher than these doses caused a much smaller increase. Similarly, the total number of nodules increased but not more than approximately 40% when the cell concentration of *Azospirillum* in the inoculum contained 10^5-10^8 CFU/ml.

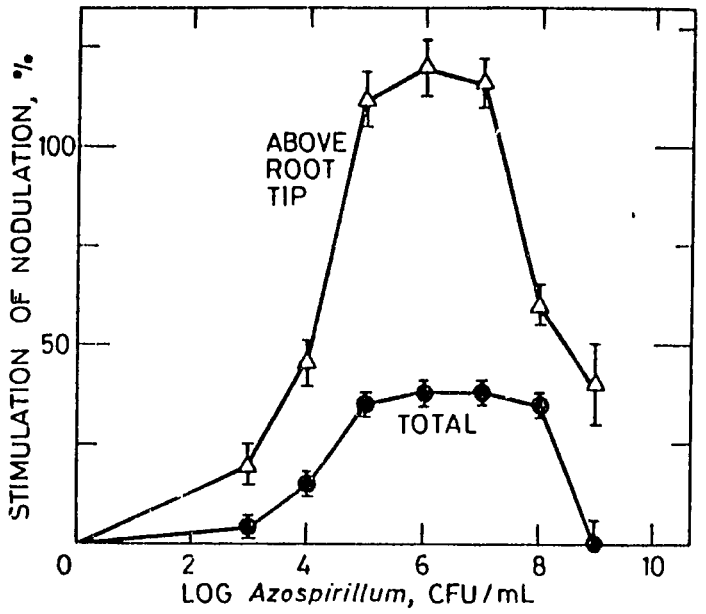

Fig. 1. Effect of the concentration of *Azospirillum brasilense* Cd inoculum, applied 24 h before inoculation of *Medicago polymorpha* with *Rhizobium meliloti* (10^6 CFU/ml), on the nodulation of pouch-grown seedlings. The *Medicago polymorpha* seedlings were scored 7 days after inoculation. Values are means of 40 seedlings per treatment.

Nodulation patterns

The pattern of nodule formation on the roots of the seedlings was expressed as the distance between the location of nodules relative to the position of the RT mark at the time of nodulation.

The frequency of nodules above the RT of *Medicago polymorpha* was approximately 30% higher following pre-inoculation with *Azospirillum* or inoculation of *Rhizobium* together with *Azospirillum* compared with *Rhizobium* alone. Furthermore, the combined *Azospirillum-Rhizobium* inoculation not only increased nodule formation above RT mark but it also increased significantly the total number of nodules formed on the root (Fig. 2A). The increased nodule formation was more marked when *Azospirillum* was pre-inoculated 24 h before the inoculation with *Rhizobium* than when inoculated together with *Rhizobium*.

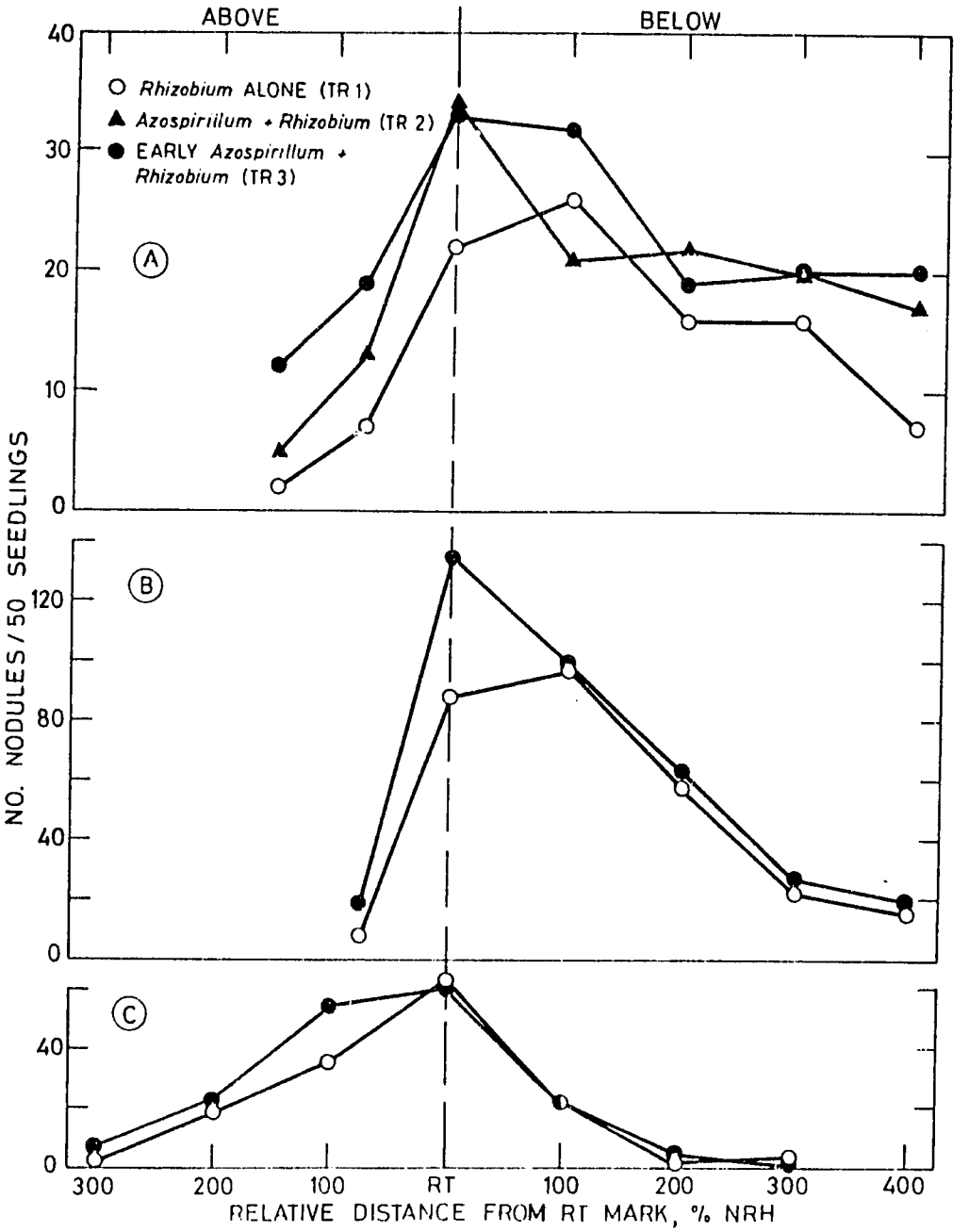

Fig. 2. Frequency of nodules formed above and below the root tip (RT) mark [expressed as % of non-root-hair zone distance (NHR)] after inoculation with *Azospirillum brasilense* (10^6 CFU/ml) and/or *Rhizobium* (10^6 CFU/ml) on the primary roots of pouch-grown seedlings of: (A) *Medicago polymorpha*, (B) *Macroptilium atropurpureum* and (C) *Trifolium alexandrinum*. Data are taken from 2 experiments, and the number of replicates was modified for 50 seedlings for each species. Means of number of nodules per seedling ± SE are given below.

		Rhizobium alone					*Azospirillum+Rhizobium*				
		N*	above RT		Total		N*	above RT		Total	
Medicago	(Tr1,3)	60	0.6±0.8	b**	2.6±0.2	b	70	1.2±0.1	a	3.8±0.2	a
Macroptilium	(Tr1,2)	42	1.0±0.2	b	5.3±0.7	a	45	1.9±0.2	a	7.2±0.7	a
Trifolium	(Tr1,3)	45	2.0±0.3	a	2.8±0.4	a	47	2.4±0.2	a	3.3±0.2	a

* N = number of seedlings per treatment

** Significant differences (P=0.05) according to the Kruskal-Wallis Test (Conover, 1980).

Similar phenomena were observed when *Macroptilium atropurpureum* seedlings were inoculated with a mixture of *Azospirillum-Rhizobium* inoculant compared with *Rhizobium* alone (Fig. 2B). With this plant the combined inoculation almost doubled nodule formation in the NRH zone and increased the total number of nodules formed by 25%, the increase not being significant. The effect of pre-inoculation with *Azospirillum* followed by *Rhizobium* also increased nodule formation at or above the RT mark in *Trifolium alexandrinum* by 20%, the increase not being significant (Fig. 2C).

The proportion of seedlings of *Medicago polymorpha* that developed nodules increased linearly with the logarithm of the *Rhizobium* inoculum dose (Fig. 3). When pre-inoculation was performed with *Azospirillum* followed by inoculation with *Rhizobium*, the proportion of plants that nodulated rose between 10 to 25 units percent over the entire range of *Rhizobium* doses tested. Of particular interest was the finding that at the lowest *Rhizobium* concentration of 10 CFU/ml, no nodules were formed, whereas after the pre-inoculation with *Azospirillum* and identical *Rhizobium* dose, the percentage of nodulated seedlings rose from 0 to 25%. Nodules were scored six to eight days after inoculation.

Nitrogen fixation

The effect of pre-inoculation of *Medicago polymorpha* with *Azospirillum* on acetylene reduction activity was measured daily beginning on the seventh day after the inoculation with *Rhizobium*. The average increase in acetylene reduction activity per pouch during this period was approximately 13-fold in the presence of *Azospirillum* compared with *Rhizobium* alone (Fig. 4A).

Similarly, acetylene reduction activity was measured in *Macroptilium atropurpureum* seedlings inoculated with a mixture of *Azospirillum* and *Rhizobium*. On day 13 from inoculation, acetylene reduction activity per pouch was increased by approximately 25% and at day 20 by approximately 80% in the presence of *Azospirillum* compared with *Rhizobium* alone (Fig. 4B).

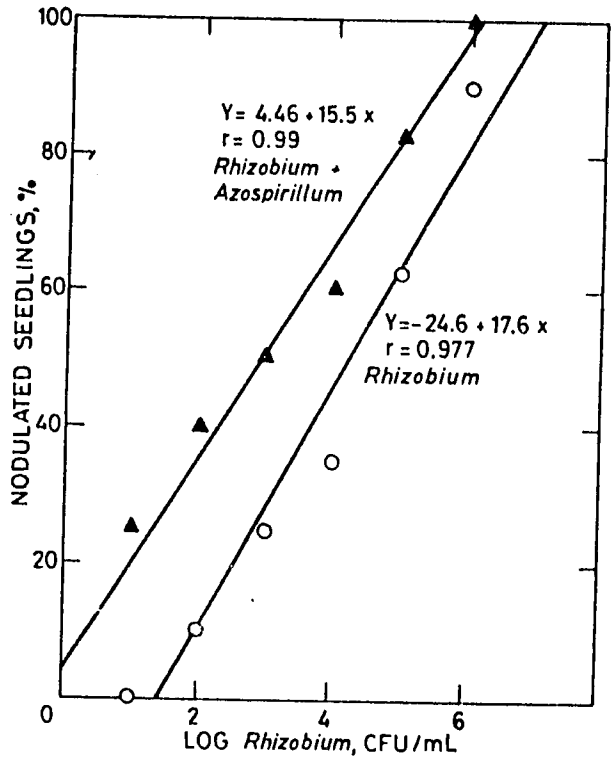

Fig. 3. Effect of the concentration of the *Rhizobium meliloti* inoculum, applied 24 h after inoculation with *Azospirillum brasilense* (10^6 CFU/ml), on nodulation of pouch-grown seedlings of *Medicago polymorpha* scored 7 days after inoculation. Values are means of 25 seedlings per treatment.

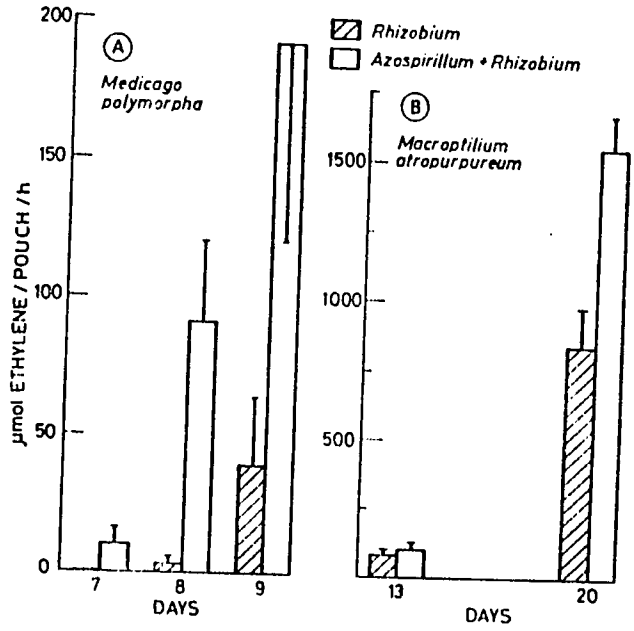

Fig. 4. Effect of pre-inoculation with *Azospirillum brasilense* (10^6 CFU/ml) and/or *Rhizobium* (10^6 CFU/ml) alone on the acetylene reduction activity in seedlings of pouch-grown : (A) *Medicago polymorpha* and (B) *Macroptilium atropurpureum*. Values are means of 24 seedlings.

DISCUSSION

The use of transparent growth pouches enabled the recording of root and nodule development relative to the position at the time of inoculation. This technique was successfully used by Bhuvaneswari et al. (1981) who found that the area on the roots sensitive to infection with *Rhizobium* moves with root elongation in the NRH zone in soybean, alfalfa and cowpea. In clover, the nodules are also formed in the region of developed root hairs (DRH) at the time of *Rhizobium* inoculation (Bhuvaneswari et al. 1980).

Recently, it was reported that mixed cultures of *Azospirillum* and *Rhizobium trifolii* caused either inhibition or stimulation of nodule formation, depending on their ratio and time of inoculation in *Trifolium repens* and in *T. subterraneum* (Plazinski and Rolfe, 1985a). *Azospirillum* could be isolated from within nodules and root segments (Plazinski and Rolfe, 1985b). It caused stimulation of plant growth without nodule formation at a ratio of *RhizobiumAzospirillum* of 1:200 to 1:2500 (Plazinski and Rolfe, 1985c) and caused root hair distortion at multiple sites probably due to the activity of hydrolytic (pectinolytic) enzymes. These distortions inhibited or aborted *Rhizobium* infections (Plazinski and Rolfe, 1985d). In earlier studies (Kapulnik et al., 1985; Okon, 1985) it was found that the absolute number of *Azospirillum* cells in the inoculum was decisive in causing either promoting or inhibiting effects on grass roots.

The experimental technique used by us differed from that of Plazinski and Rolfe in that they used an agar rapid plate screen method (Rolfe et al. 1980) in which the initial inoculum formed colonies in agar, the actual number colonizing the roots not being known and the roots being embedded in the bacterial colonies. However, with our pouch technique more accurate control of the inoculum level actually reaching the roots was achieved. With this technique nodulation was recorded six to eight days after inoculation, whereas Plazinski and Rolfe (1985a) recorded nodulation as long as four to eight weeks after inoculation.

The nodulation profile that was obtained in this study after inoculation of *Medicago polymorpha* with *Rhizobium* alone was similar to the profile of *Medicago sativa* obtained by Bhuvaneswari et al. (1981). Inoculation with

Rhizobium and the appropriate number of *Azospirillum* (10^6 CFU/ml) caused a significant shift of the average distance of the uppermost nodule.

Inoculation with *Azospirillum* 24 h before *Rhizobium* resulted in a fivefold increase in the number of nodules in the DRH zone and increased significantly the number of nodules above the RT mark as compared with the mixed *Rhizobium-Azospirillum* inoculation but did not affect the total number of nodules. The phenomenon of increased nodulation above the RT mark has been also obtained by pretreating roots of white clover with sterile *R. trifolii* exudate (Bhuvaneswari et al., 1981).

The nodulation profile for cowpea described by Bhuvaneswari et al. (1981) was similar to that obtained in this study with *Macroptilium*. A significant enhancement of nodulation above the RT mark was obtained when *Azospirillum* was applied together with *Rhizobium*, but no nodules were observed in the DRH zone of *Macroptilium* (Fig. 2B).

In *Medicago polymorpha* inoculated with *Rhizobium* at 10 CFU/ml no nodulation was observed. In seedlings treated with *Azospirillum* at 10^6 CFU/ml, 25% were nodulated. This observation could explain previous results where nodulation was enhanced by *Azospirillum* in plants naturally nodulated by indigenous *Rhizobium* in the field (Singh and Subba Rao, 1979; Sarig et al,. 1986).

A logarithmic increase of the *Rhizobium* inoculation level usually results in a linear increase in the percentage of nodulation above the RT mark in soybean (Bhuvaneswari et al., 1980). In our study, with the increase of the *Rhizobium* dose, the percentage of nodulation increased linearly (Fig. 3). It was estimated by extrapolation that the minimal number of 5-25 *Rhizobium* cells/plant might be required to initiate the infection process in both soybean (Bhuvaneswari et al., 1980) and clover (Purchase and Nutman, 1957). In *Medicago polymorpha* we estimated by extrapolation that 20-30 *Rhizobium meliloti* cells/pouch caused nodulation in 10% of the plants (Fig. 3). Pre-inoculation with *Azospirillum* enabled an apparent number of 1-5 cells of *Rhizobium* to form nodules on 10% of the plants (Fig. 3).

Azospirillum at optimal cell concentration promotes proliferation of root hairs in grasses (Kapulnik et al., 1985; Okon, 1985) and in *Medicago polymorpha* (unpublished results). The *Rhizobium* infection process starts at the site where a root hair is about to be formed (Bauer 1981). It is possible that at a low *Rhizobium* concentration, *Azospirillum* causes proliferation of the number of these sites, say, by stimulation of epidermal cells to differentiate into infectable root hair cells, and may thus increase the probability of colonization of the specific infection site by *Rhizobium*. On the other hand, higher (more than 10^9 CFU/ml) concentrations of *Azospirillum* - such as those that may be arranged in petri dishes, but are unlikely to occur in the soil in the field - may be deleterious to nodule formation (Plazinski and Rolfe, 1985ab). It is not known whether the changes in root hair differentiation are caused by plant growth-promoting substances (auxins, kinetins, gibberellins) produced by *Azospirillum*, as has been detected in pure culture. This remains to be investigated by developing methodology for detecting plant growth-promoting substances *in vivo* (Okon, 1985).

The early appearance of nodules could be proved indirectly by measuring acetylene reduction activity without disturbing plant development whilst in the growth pouch. Inoculation with *Rhizobium* and *Azospirilum* resulted in earlier and higher acetylene reduction activity. This, together with the improvement of root proliferation, mineral uptake and the water status of the plant due to the *Azospirillum* inoculation (Okon 1985), may have practical applications in terms of enhancement of nodulation, establishment of legumes, and increase in crop yield (Sarig et al., 1986). In preliminary experiments in pots, we have observed increased growth and nitrogen fixation in several legumes inoculated with both *Azospirillum* and *Rhizobium* in comparison with those inoculated with *Rhizobium* alone (unpublished data).

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EFFECT OF *AZOSPIRILLUM* AND *RHIZOBIUM* ON THE ROOT MORPHOLOGY OF *MEDICAGO POLYMORPHA* SEEDLINGS

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ABSTRACT

Azospirillum inoculum with a concentration higher than 10^7 colony-forming units (CFU)/ml applied to pouch-grown seedlings of *Medicago polymorpha* caused a significant decrease in root length, but significantly increased the number of lateral roots both in the absence and in the presence of *Rhizobium*. The diameter of rootlets and the length and number of root hairs were significantly increased when *Azospirillum* was applied to germinating seeds at a concentration greater than 10^6 CFU/ml.

ELONGATION OF MAIN ROOT AND DEVELOPMENT OF LATERAL ROOTS

Methods

Disinfected seeds of *Medicago polymorpha* were germinated on agar medium in petri dishes. As soon as 10 mm rootlets were visible, the seedlings were transferred to 16 x 17 cm plastic growth pouches and inoculated with 0.5 ml *Azospirillum* in concentrations ranging from 0 to 10 colony-forming units (CFU)/ml. For each concentration 8 replicate pouches, each with 4 seedlings per pouch, were used. *Rhizobium* inoculum at a concentration of 10^6 CFU/ml was applied to all treatments 24 h after the inocoulation with *Azospirillum*. Measurements were carried out once a day.

Results

The initial rate of elongation of the main root of seedlings inoculated with *Azospirillum* in concentrations up to 10^7 CFU/ml was not different from that in the controls (i.e., without *Azospirillum*), whereas concentrations higher than 10^7 CFU/ml significantly decreased the rate of root elongation, at least from the 3rd day after inoculation, both in the absence (Fig. 1A) and in the presence of *Rhizobium* (Fig. 1B).

Fourteen days after inoculation, the seedlings which had been inoculated with *Azospirillum* concentrations between 10^6-10^8 CFU/ml, had almost three times the number of lateral roots compared with non-inoculated seedlings. When *Rhizobium* was added to *Azospirillum*, the number of lateral roots per seedling was significantly increased, on an average by 50% at *Azospirillum* concentrations between 10^5-10^8 CFU/ml as compared with *Rhizobium* alone (Fig. 2).

LENGTH OF NON-ROOT-HAIR (NRH) ZONE

The length of the NRH zone was affected only when the concentration of *Azospirillum* was higher than 10^8 CFU/ml, both in the presence and in the absence of *Rhizobium*. The NRH zone was particularly shortened in the roots of seedlings which had been inoculated 70 h previously with *Azospirillum* at a concentration of 10^9 CFU/ml in the absence of *Rhizobium*. However, in the presence of *Rhizobium*, the shortening effect of the high concentration of *Azospirillum* on the length of the NRH zone was less pronounced (Fig. 3).

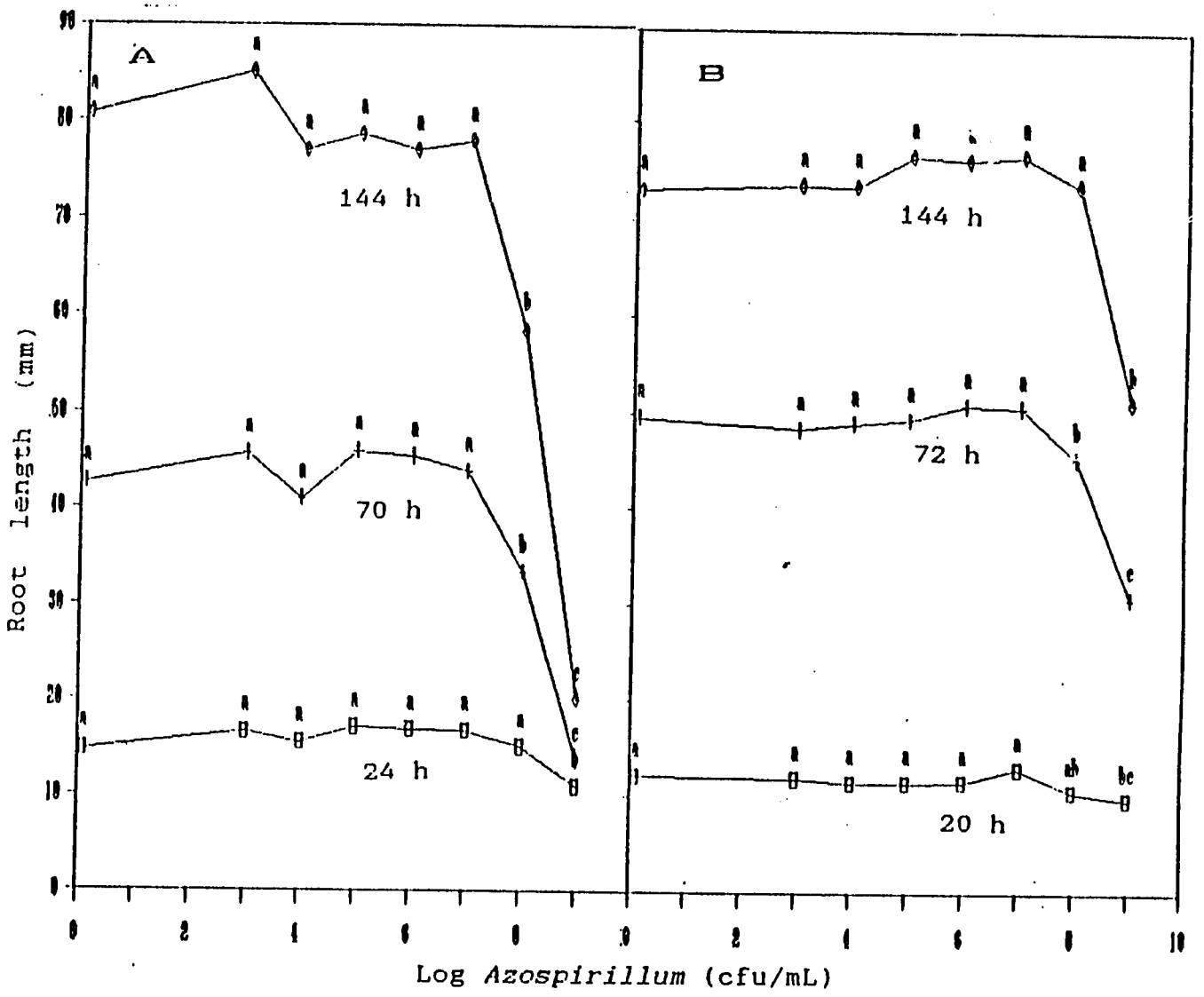


Fig. 1. Effect of *Azospirillum* concentration on the elongation of the main root of pouch-grown seedlings of *Medicago polymorpha* in the absence (A) and in the presence (B) of *Rhizobium* (10^6 CFU/ml) inoculum. Values in the Figure are means of 32 seedlings.

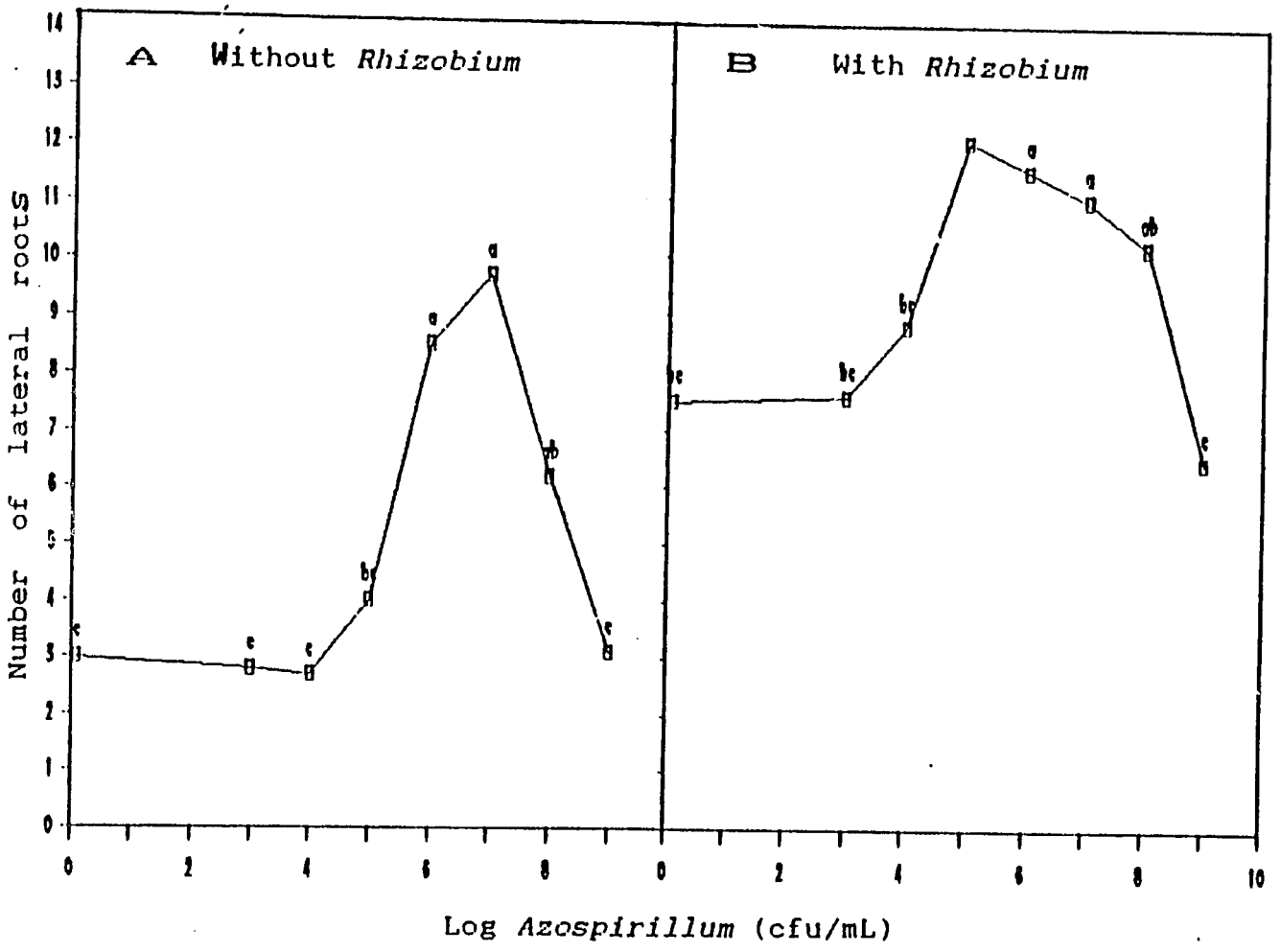


Fig. 2. Effect of *Azospirillum* concentration on the number of lateral roots of 14-day old pouch-grown seedlings of *Medicago polymorpha* in the presence or in the absence of *Rhizobium* inoculum (10^6 CFU/ml). Values in the figure are means of 25 seedlings.

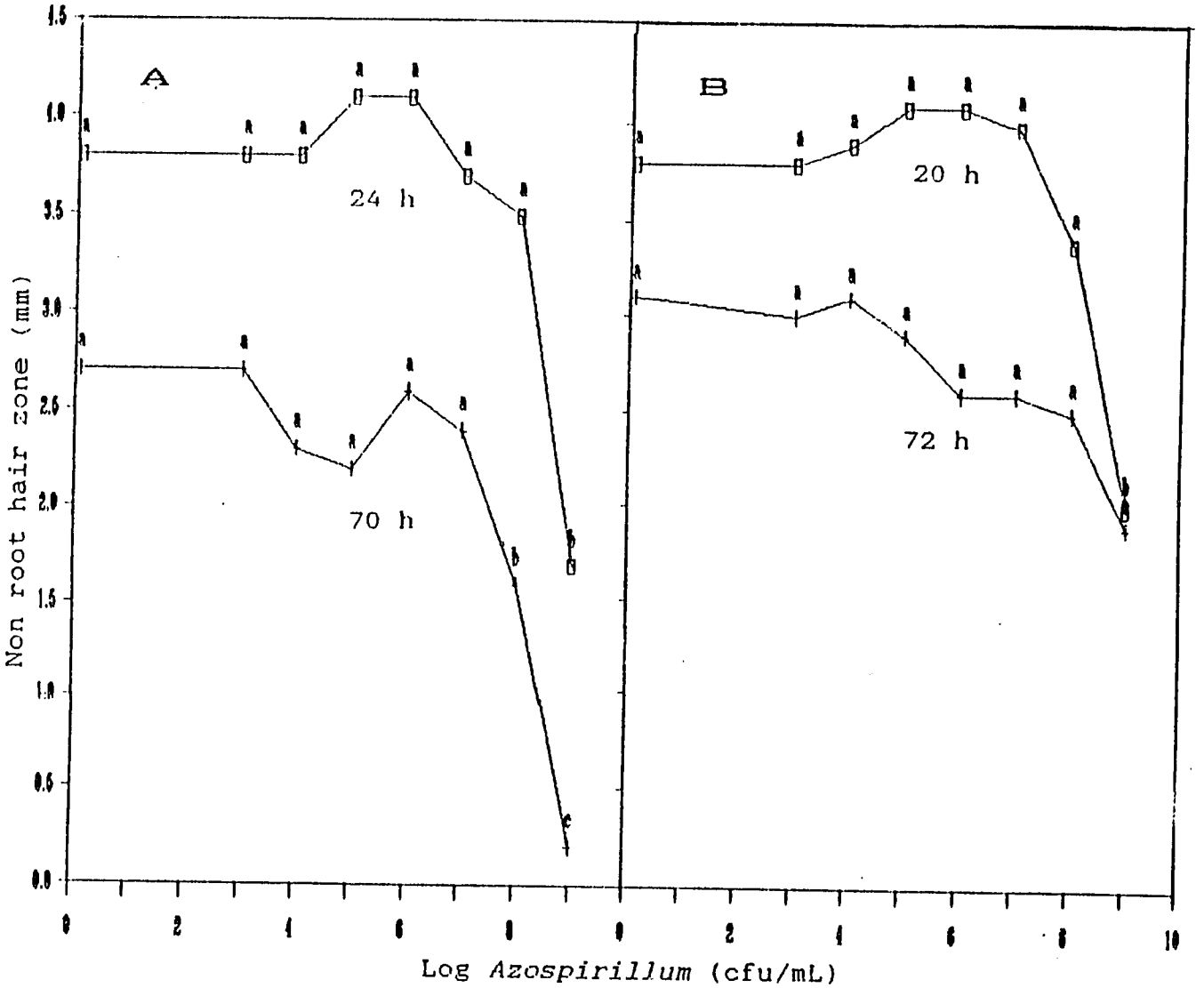


Fig. 3. Effect of *Azospirillum* concentration on the length of the non-root- hair zone of pouch-grown seedlings of *Medicago polymorpha* in the absence (A) and in the presence (B) of *Rhizobium* inoculum (10^6 CFU/ml). Values in the Figure are means of 32 seedlings.

ROOT HAIRS

Methods

Six germinated seeds of *Medicago polymorpha*, each having rootlets of approximately 8 mm long, were placed in a row on wet filter paper in petri dishes. The location of the root tip (RT) was marked on the filter paper after which the seedlings were inoculated with different concentrations of *Azospirillum*. Each treatment was replicated three times. Twenty four hours later, the part of the rootlet that had elongated below RT since the inoculation, was separated with a scalpel from each one of the seedlings and its length was determined. These root pieces then were immediately fixed with gluteraldehyde, dehydrated with acetone, dried in CO_2 (critical-point dryer), mounted on stubs, coated with gold, and viewed under a scanning electron microscope. Photographs were prepared from the area located 5 mm below RT at half root width from which the number of root hairs per 200 μm^2 surface was determined. The diameter of the rootlets and the length of the root hairs were also determined.

Results

The inoculation with *Azospirillum* at 10^6 CFU/ml resulted, 24 h after its application, in a significant increase in the diameter of the rootlets and in the length of the root hairs. However, it did not alter the number of root hairs per unit area of root surface. Thus, the apparent number and length of root hairs per rootlet of seedlings inoculated with *Azospirillum* were greater than those of the non-inoculated seedlings (Table 1).

The application of an *Azospirillum* concentration higher than 10^6 CFU/ml, i.e., 10^9 CFU/ml, caused a further significant thickening of the rootlet and an increase in the length of the root hairs but shortened the root length. However, the density of root hairs remained unchanged (Table 1 and Fig. 4).

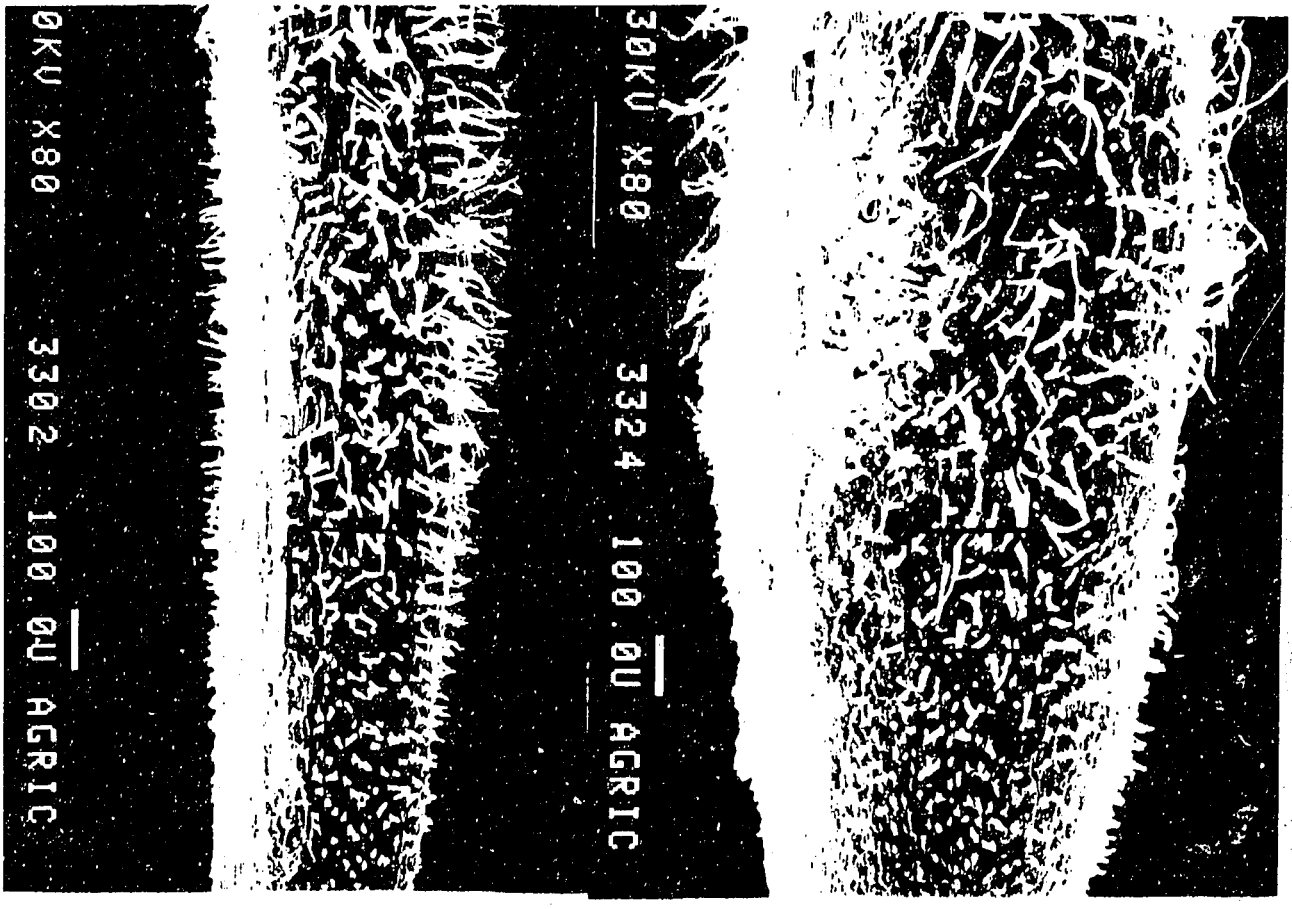
Table 1. Effect of *Azospirillum* concentration on the root diameter, root hair length and number of root hairs of germinated seeds of *Medicago polymorpha*, 24 h after application*

Parameter	Control	*Azospirillum*, CFU/ml	
		10^6	10^9
Root diameter, mm	0.39 c**	0.50 b	0.69 a
Root hair length, mm	0.05 c	0.08 b	0.12 a
No. root hairs ***	31 a	32 a	29 a
Root length, mm	16 a	17 a	10 b

*Initial length of rootlet was approximately 8 mm. Values in the table are the means of 6 replications.

** Values followed by the same letter do not differ significantly (P=0.05).

***Per 200 μm^2 root surface.



A B

Fig. 4. Electron micrograph of rootlets of germinating seeds of *Medicago polymorpha* 24 h after application of *Azospirillum* (10^9 CFU/ml): A, and control: B. Square shows area (200 μm^2) in which the number of root hairs was counted. x 80