PN ABN-142 C7-199
FINAL

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THE INSTITUTES FOR APPLIED RESEARCH

BEN-GURION UNIVERSITY
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THE INSTITUTES FOR APPLIED RESEARCH
BEN-GURION UNIVERSITY OF THE NEGEV

BGUN-ARI-51-92

FODDER PRODUCTION WITH SALINE WATER

Final Report
January 1989-December 1991

D. Pasternak[1], A. Nerd[1], Y. DeMalach[2]
and J. Nascimento[3]

[1]Institutes for Applied Research,
Ben-Gurion University of the Negev, Israel
[2]Ramat Negev Experimental Station, Israel
[3]Faculty of Pharmacy, University of Lisbon, Portugal

Submitted to the Office of the Science Advisor
U.S. Agency for International Development
Project Number: C7-199
Grant Number: DTE-5544-C-SS-08033-00
(File No.: 86454201)

Beer-Sheva, Israel

October 1992

SUMMARY

This report describes the results of a three-year cooperation project between Israel and Portugal on fodder production with saline water.

The objective of the program was to study the response of six forage species to a range of salinity levels with the idea of selecting salt-tolerant fodder for production with saline water irrigation.

The work in Israel started in the spring of 1989. Six forage crops — Rhodes grass (*Chloris gayana* Kunth) cv. common, Bermuda grass (*Cynodon dactylon* L. Pers.) cv. Suwannee, Kallar grass (*Leptochloa fusca* L. Kunth), salt (spike) grass (*Distichlis spicata* L.), seashore paspalum (*Paspalum vaginatum* Swartz), and alfalfa (*Medicago sativa* L.) — were sprinkler irrigated with water of electrical conductivity ranging from 1.2-10 dS/m.

In the first season, dry matter yields of th[illegible] rasses (Bermuda grass, salt grass and seashore paspalum) were unaffected by so[illegible] EC_e up to a value of 14 dS/m. In the second season only the yields of salt grass were unaffected by this high EC_e value. Maximum seasonal dry matter yields were 5.3 kg/m^2 for Rhodes grass, 3.8 kg/m^2 for seashore paspalum, 3.1 kg/m^2 for Bermuda grass and salt grass, and 2.2 kg/m^2 for alfalfa and Kallar grass. Due to its high yield potential, Rhodes grass outyielded the three tolerant grasses up to a soil EC_e of ~ 8 dS/m. There was no consistency in the effect of salinity on the crude protein, fiber and ash contents for the six forage species. Ash content varied in the second season from about 8% for Bermuda grass to about 15.5% for seashore paspalum. Crude protein content varied from ~ 11.5% for Rhodes grass to ~ 16% for Bermuda grass and ~ 22% for alfalfa. Both Bermuda grass and salt grass had a relatively high fiber content (40-42%). When water supply was limited, the yields of salt grass (~ 2 kg/m^2) were twice as high as in the yields ofother species, indicating an advantage for this species under non-irrigated rangeland conditions.

It was concluded that Bermuda grass is the most promising fodder crop for water and soils of high salinity, and that work must be continued to select cultivars with lower fiber contents. Furthermore, in view of the demonstrated high salt tolerance of salt grass, there is a need for further work with this nondomesticated species for the purpose of selecting and breeding genotypes with better nutritional value.

In Portugal, rye grass (*Lolium multiflorum*) was planted in the fall of 1990 on a slightly saline soil ($EC_e \sim 5.0$ dS/m). The crop was not irrigated. Dry matter yield was about 2.43 kg/m^2, a relatively high yield for dryland conditions. Rhodes grass, Bermuda grass, seashore paspalum, and salt grass were planted in the summer of 1991. Unfortunately, the trials planned for these grasses could not be carried out due to failure of the saline water well to supply adequate quantities of water to the field.

Key words: *Chloris gayana, Cynodon dactylon, Paspalum vaginatum, Leptochloa fusca, Medicago sativa, Lollium multiflorum,* salinity, water use efficiency.

INTRODUCTION

Salinity is a major problem in irrigated lands of the arid and semiarid regions. Over 50% of all irrigated lands are affected by salt-related problems, and the total area of salinized soils (man made and natural) is estimated to be 325 million ha (El Swaify, 1983). This is about 10% of the land surface of the globe (Buringh, 1982). At the same time, with the increasing scarcity of good quality water for irrigation, the utilization of saline water–whether drainage water or as ground water–is increasing in importance. The cultivation of salt-tolerant crops offers a solution to the problem of salt-affected soils, as well as to the problem of how to make use of saline water for irrigation. Certain forage crops, and particularly certain members of the Poaceae family (grasses), display a very high degree of salt tolerance (Maas, 1990).

Information on the response of salt-tolerant grasses to salinity is incomplete. Although there are many reports confirming the observed field or greenhouse tolerance of these crops, relatively few attempts have been made to compare a range of these species under field conditions under controlled and monitored levels of soil salinity.

Five reportedly salt-tolerant forage grasses were evaluated for salt tolerance. The list of grasses and respective sources confirming their salt tolerance is as follows: Rhodes grass cv. common (Guggenheim, 1977; Malkin and Weisel, 1986); Bermuda grass cv. Suwannee (Langdale and Thomas, 1971; Ackerson and Youngner, 1975; Francois 1988); Kallar grass (Sandhu et al., 1980; Malik et al. 1986); salt (spike) grass, a selected line from the University of Delaware (Hansen et al., 1976; Parrondo et al., 1978; Kemp and Cunningham, 1981; and Gallagher, 1985); and seashore paspalum, a broad leaf type obtained from the University of Arizona (Dudeck and Peacock, 1985; Peacock and Dudeck, 1985; and Marcum and Murdoch, 1990).

The performance of the five grasses was compared with that of alfalfa (cv. Gilboa), a high-quality perennial forage extensively grown in irrigated arid lands and regarded as moderately salt tolerant (Forsberg, 1953; Chang, 1961; Bernstein and Francois, 1973; and Moham et al., 1989.

MATERIALS AND METHODS

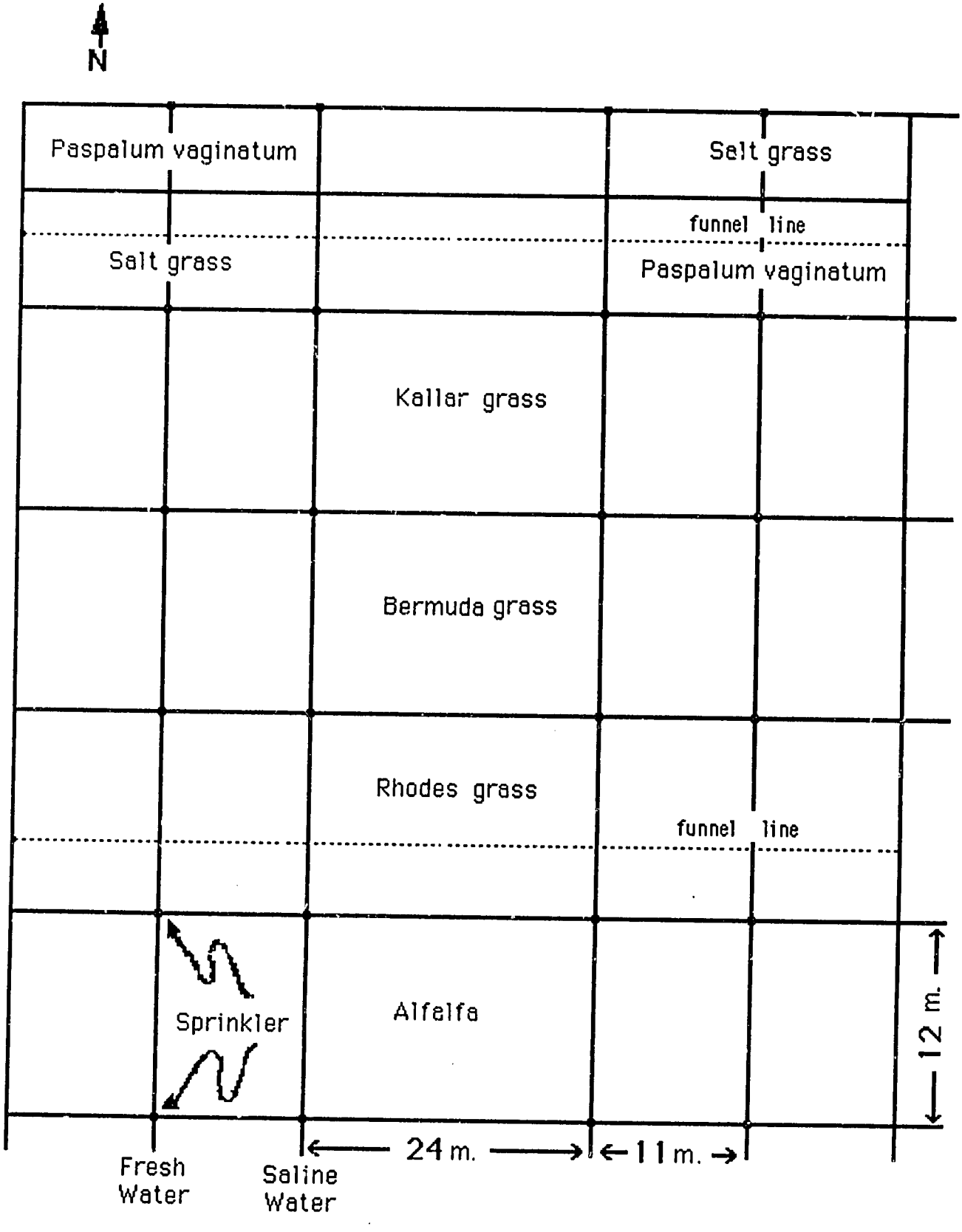
The experiment was conducted at the Negev Experimental Station for Desert Agriculture over a three year period starting in 1989. The soil was of a loess type containing 64% and 25% silt and 11% clay. The experimental set-up was a modification of the line source sprinkler system (Hanks et al., 1976) called the double line source (Magnusson et al., 1989). This system comprises two sprinkler lines placed so as to obtain full overlap of the sprinkled water. One of the lines delivers fresh water and the other saline water. In the present trials the electrical conductivity (EC_i) of the fresh water was 1.2 dS/m and that of the saline water 10 dS/m. In any sprinkler system the amount of discharged water reaching the soil diminishes with distance from the source. When a double line source system is used (one line delivering fresh and the other saline water), a progression of concentrations of salt ranging from the salt concentration of the saline to that of the fresh water line is obtained between the two lines.

This system is very useful for the determination of salt response curves at a given rate of water application for a range of crops or cultivars. The system also allows determination of water response curves under irrigation with the water delivered by the fresh and the saline water lines, respectively. This is done by correlating the amount of water reaching the ground at set distances away from the lines, i.e., between the lines and the perimeter of the field, with the yield at each of the points where water quantity and quality were measured.

A 0.4-ha field was planted in the spring of 1989 with the six forage species, as indicated in Fig. 1. There were two pairs of sprinkler lines to give two replications. The distance between lines in each pair was 11 m and between the two pairs 24 m. The interval between sprinklers in the line was 12 m. Na'an (model 323/92) sprinklers were used. Each sprinkler was equipped with two nozzles 3.5 and 2.8 mm in diameter. This arrangement gives a calculated rain intensity of 3.5 mm/hr at 4 atm.

Water was sampled using funnels 0.15 m in diameter attached through plastic tubes to 1-liter sampling bottles. The funnels were laid down in two lines perpendicular to the sprinkler lines at intervals of 2 m (Fig. 1) and at a height of 0.6 m above the ground. The samples were taken after each irrigation. The amount of water was determined together with water electrical conductivity and nitrogen and phosphorus contents. The field was watered every three days. In 1990 the amount of water applied was

Fig. 1. Schematic layout of the experimental field.



calculated as 0.9 E (E = evaporation) from a USWB Class A evaporation pan. In 1991 this factor was increased to 1.1 E. Potassium was added to the soil at the beginning of each season as KCl at the rate of 500 kg/ha. Liquid nitrogen (as ammonium nitrate) and phosphorus (as phosphoric acid) were injected with each irrigation into the water lines to give concentrations of 100 and 50 ppm N and P, respectively, in the irrigation water. Electrical conductivity of 10 dS/m in the saline water line was achieved by injecting a brine of $NaCl\text{-}CaCi_2 \cdot 2H_2O$ (3:1 w/w ratio) into the irrigation line using a system described by Pasternak et al. (1986).

The field was irrigated at about midnight to prevent leaf burn by salt (particularly for alfalfa) and minimize wind drift effects, since in Ramat Negev wind speed is lowest at night.

The field was planted in the spring of 1989 and established during the summer with fresh water irrigation. Irrigation with the two water types was begun in February 1990. First harvest was carried out in May 1990.

The field was clipped seven times during the spring, summer and autumn of 1990 and of 1991. Every year alfalfa (the only species which grew during the winter) was clipped an additional time. In 1990 the yield of the first two clippings was discarded because at that time soil salinity had not reached a steady state situation at the various yield sampling points.

Forage was collected from two 1-m^2 plots for each species at every clipping date, at five points between the two sprinkler lines in each pair of lines and at three points away from each of the sprinkler lines. Yield samples taken between the two lines in the pair were used to determine the effect of a range of salinity levels on yield and on forage quality at a constant level of water supply; the samples taken away from each line were used to determine the effect of irrigation water quantity on yield for water of 1.2 or 10.0 dS/m.

Forage fresh weight for each of the 1-m^2 plots was determined in the field. Weighed samples were taken to the laboratory and oven dried at 70°C to determine their dry weights. In each of the two years the dry matter of the mid-season sampling was ground and used to determine total nitrogen content by the Kjeldahl method, acid detergent fiber using a method described by Van Soest (1982), and ash content by

burning in a furnace at 500°C. Soil EC_e to a depth of 90 cm was determined in each plot three times during the season and averaged over depth and time.

RESULTS AND DISCUSSION

The pattern of distribution of irrigation water between and away from the sprinkler lines was similar in the two growing seasons; data for the 1990 season are presented in Fig. 2. Maximum variability for sampling points placed between the two sprinkler lines was only 7%. In 1991 mean water EC values were somewhat lower than in 1990 (Fig. 3). There were differences in soil EC_e between the 1990 and the 1991 season (Fig. 4): soil EC_e values at three sampling points between the pair of lines were lower in the 1991 season. There were two reasons for these differences. First, irrigation water EC was somewhat lower in 1991 (Fig. 3). Second, in 1991 irrigation water quantity were calculated as 1.1 E as against 0.9 E in 1990 to provide more effective salt leaching. Fig. 5 gives the mean minimum and mean maximum temperatures in the 1990 (A) and the 1991 (B) seasons together with evaporation from a USWB class A evaporation pan. While in both years mean maximum temperatures did not vary much from the beginning to the end of the growing season, there was a sharp drop in E from August onward reflecting the shorter days and the lower vapor pressure deficits prevailing in the autumn months at Ramat Negev.

The winter of 1990/1991 had a few frost events which burned much of the Kallar grass stand. Therefore, yield data for Kallar grass are presented for the 1990 season only.

The effect of soil salinity on the dry matter yields of the forage species under investigation is presented in Fig. 5. Overall yields for 1990 were smaller than for 1991. This is because in 1990 results were calculated for five out of seven clippings. Furthermore the summer of 1990 was drier and warmer than the summer of 1991 (Fig. 6) and probably exerted a stress influence on the plants.

Maas and Hoffman (1977) described the salt response of crops using the formula $y = 1 - b\,(EC_e - a)$, where the slope b represents the unit reduction in relative yield (y) with each increment in soil EC_e and a is the threshold EC_e for which relative yield starts to deviate from 1.0. Depending on on the magnitude of the b and a, Maas and Hoffman classified crops into four categories: salt-sensitive, moderate-sensitive, moderate-tolerant and tolerant. Using the yield-salinity relationship for the 1991

Fig. 2. Distribution of irrigation water between the two lines in the pair and away from the lines.

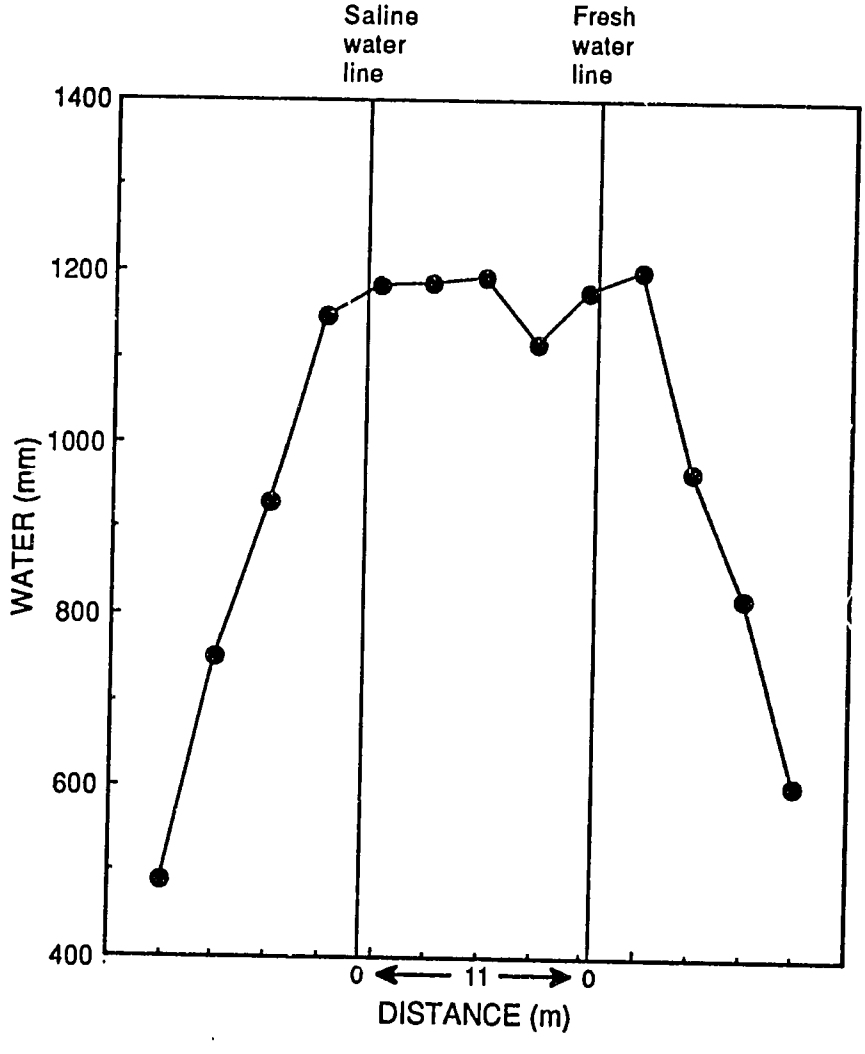


Fig. 3. Variation in irrigation water electrical conductivity (EC_i) between the two lines in the pair and away from the lines.

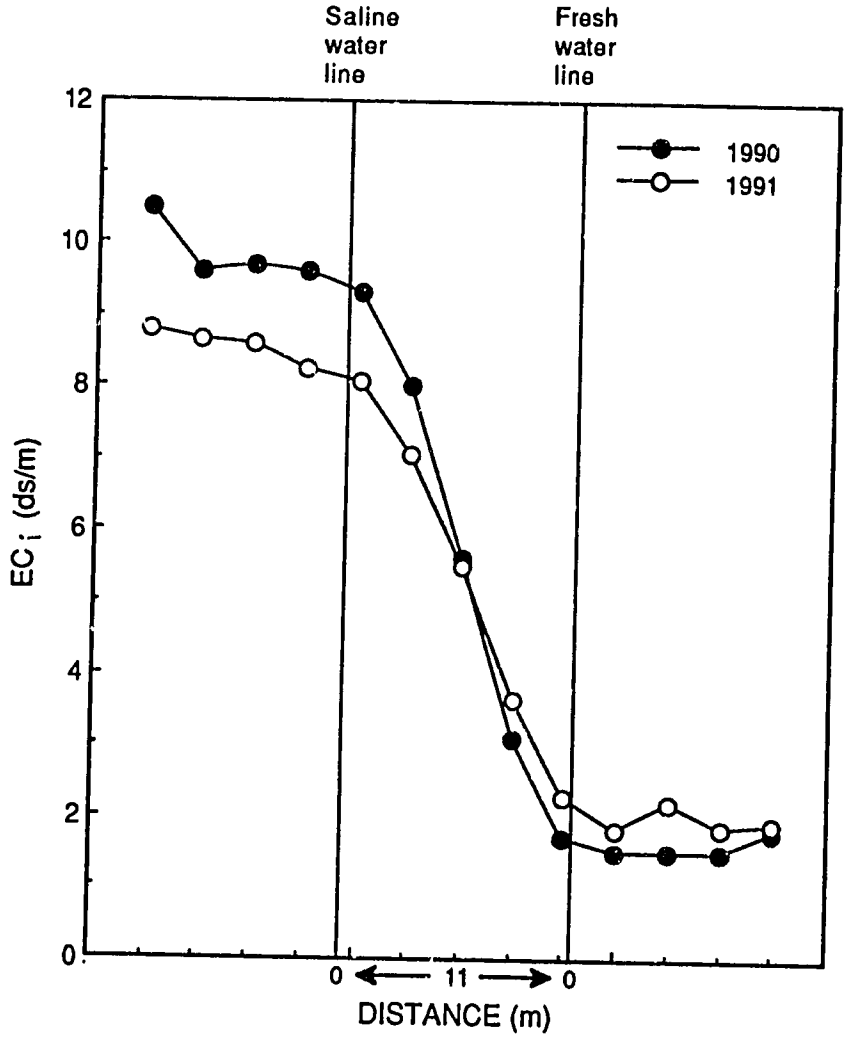


Fig. 4. Variation in soil solution electrical conductivity betwe . the two lines in the pair and away from the lines.

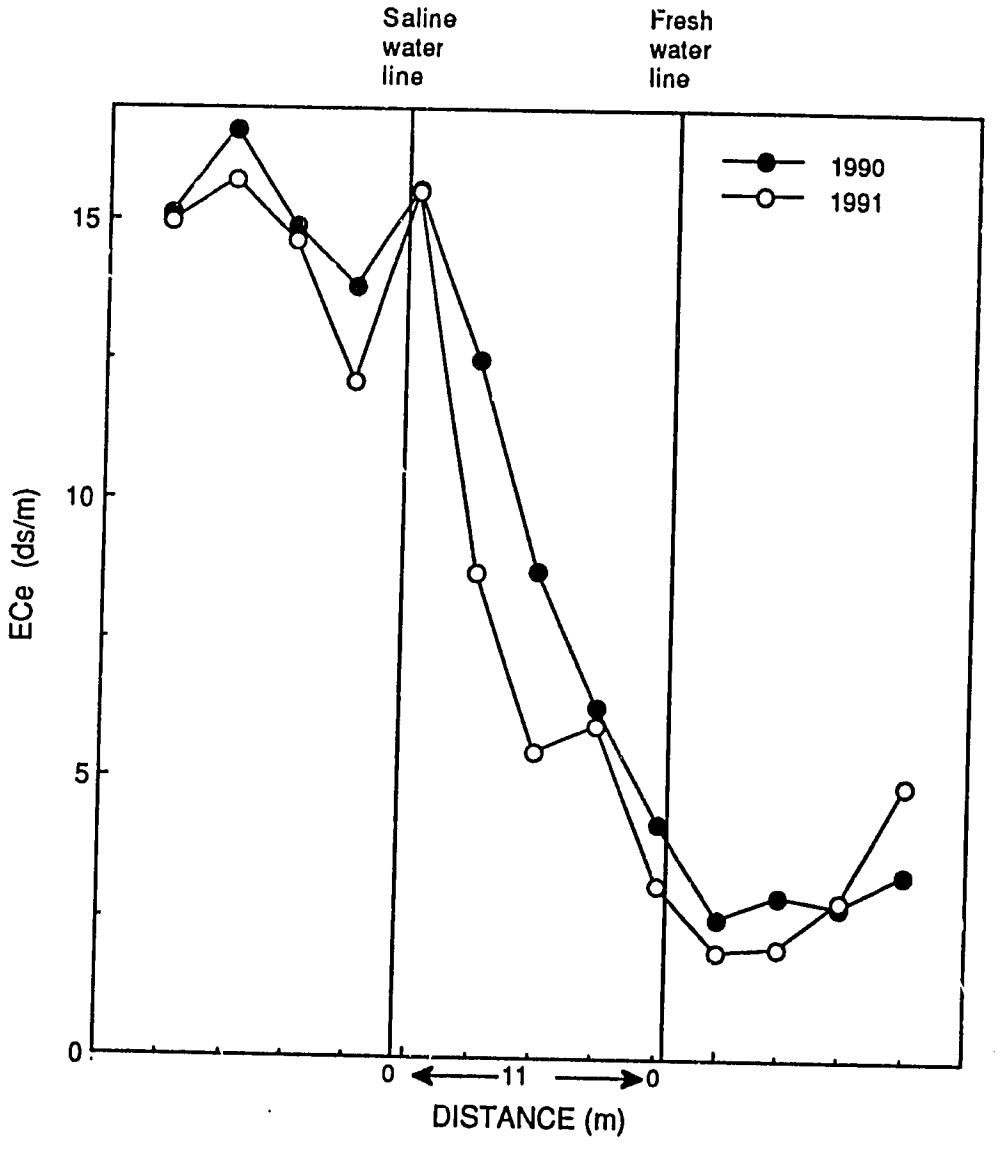
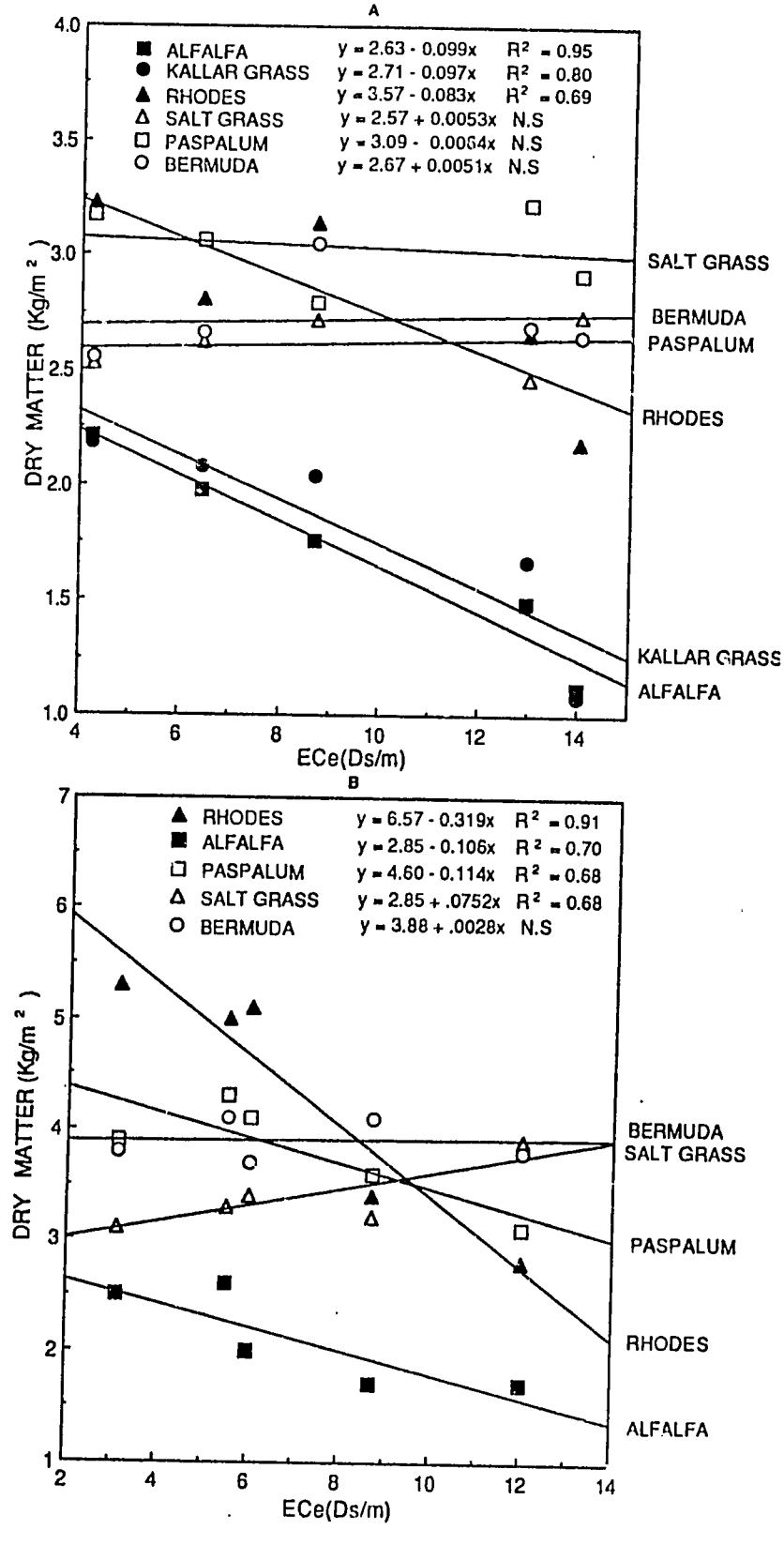
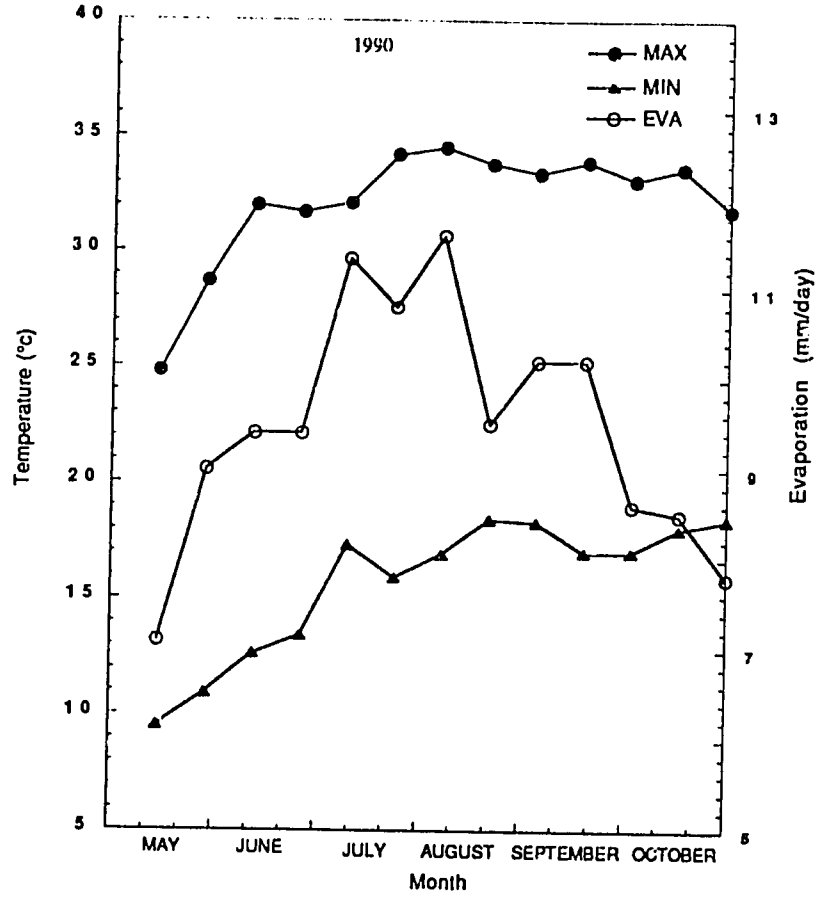


Fig. 5. Effect of soil salinity on dry matter production (kg/m^2) of six forage species in 1990 (A) and of five forage species in 1991 (B).





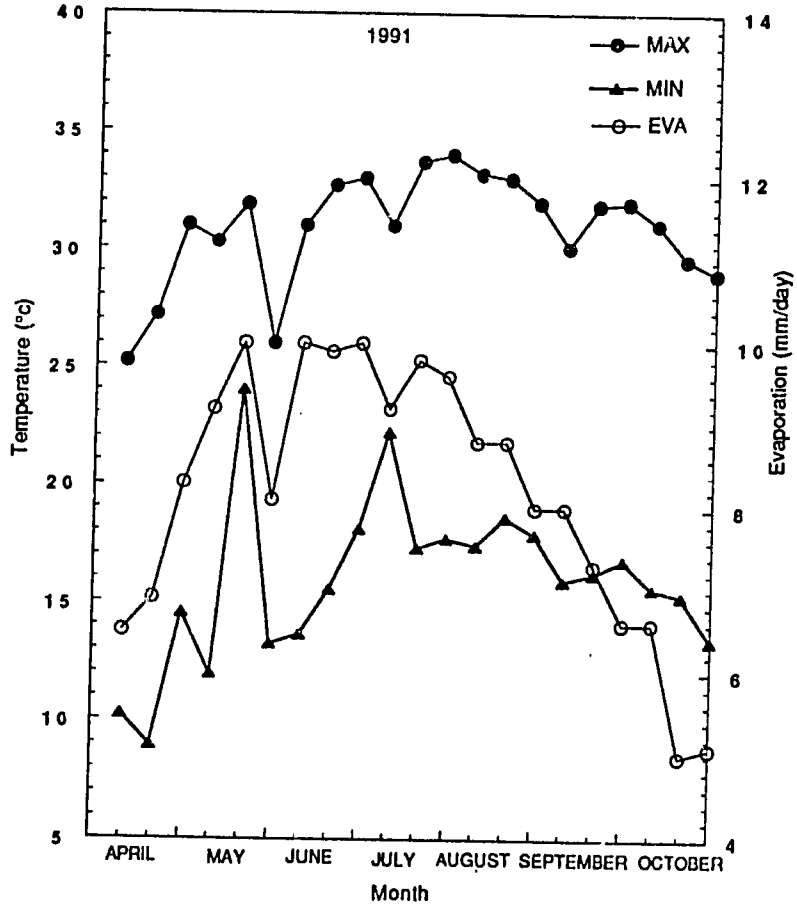


Fig. 6. Mean maximum and mean minimum temperatures and evaporation from a USWB Class A evaporation pan during the 1990 and the 1991 growing season.

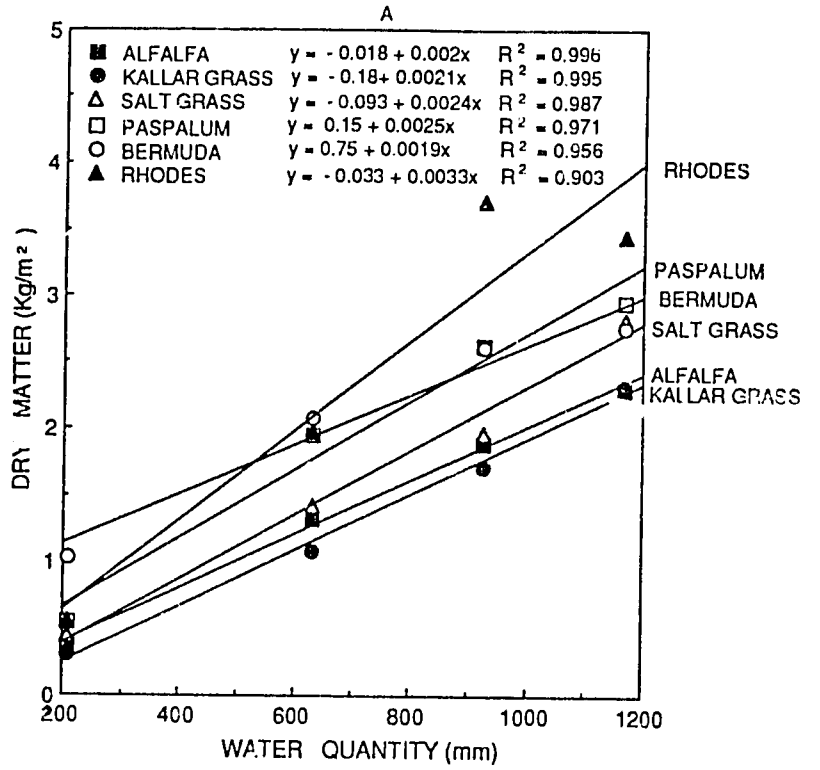
season, the Maas-Hoffman formulas for alfalfa, Rhodes grass, paspalum and Bermuda grass are respectively: $y = 1 - 0.06 (EC_e - 4)$; $y = 1 - 0.03 (EC_e - 8)$; and $y = 1 - 0.02 (EC_e - 14.0)$.

These results place alfalfa and Kallar grass, which in 1990 showed an almost identical yield-salinity behavior (Fig. 5), in the category of moderate-sensitive, and salt grass, Bermuda grass and paspalum in the class of tolerant crops. Although Rhodes grass was more sensitive than the three tolerant grasses, it had in 1991 a much higher initial absolute yield (Fig. 5). For this reason, up to a soil EC_e of about 8 dS/m this species maintained a higher yield than the other more salt-tolerant grasses. Alfalfa and Kallar grass did not have this advantage since initial dry matter yield was relatively small. The yield-salinity relationship for salt grass could not be described by the Maas and Hoffman formula since in that trial relative yield actually increased with salinity up to a soil EC_e of 14 dS/m. Salt grass was by far the most salt tolerant species tested in this trial.

The relationship between dry matter yield and irrigation water quantity for the 1990 and 1991 seasons is given in Figs. 7 and 8. The main cultural difference between the two seasons is that in 1991 more water was applied (irrigation rate of 1.1 E vs a rate of 0.9 E in 1990). In 1990 the relationship between dry matter production and the amount of fresh water was linear for most crops (except Bermuda grass), whereas in 1991 it was curvilinear; this pattern indicates that, under fresh water irrigation at Ramat Negev, optimal water use efficiency results when the application factor is about 0.9 E. A different picture emerges for saline water (10 dS/m) irrigation. With the exception of salt grass (which was the most salt tolerant of the species), high rates (1.1 E) of saline water irrigation produced linear relationships between yield and water quantity for all species, probably because the larger volume of water leached excess salts away.

The slope of the yield-water curves is a measure of the water use efficiency (WUE) of the crops. In both years Rhodes grass had the highest WUE under fresh water irrigation. However, under saline water salt grass, paspalum and Bermuda grass had higher WUE values than Rhodes grass. The point of intercept of the yield-water relationship with the y axis is an expression of the "drought tolerance" of the crop inasmuch as it is an indicator of the capacity of the crop to produce under a limited water supply. In 1991 salinity reduced the intercept for all crops except salt grass. In other words, salt grass appears to be the most drought-tolerant crop under saline

Fig. 7. Dry matter production (kg/m²) of six forage species in 1990 as a function of irrigation water quantity. A - fresh water (EC_i = 1.2 dS/m); B - saline water (EC_i = 10 dS/m).



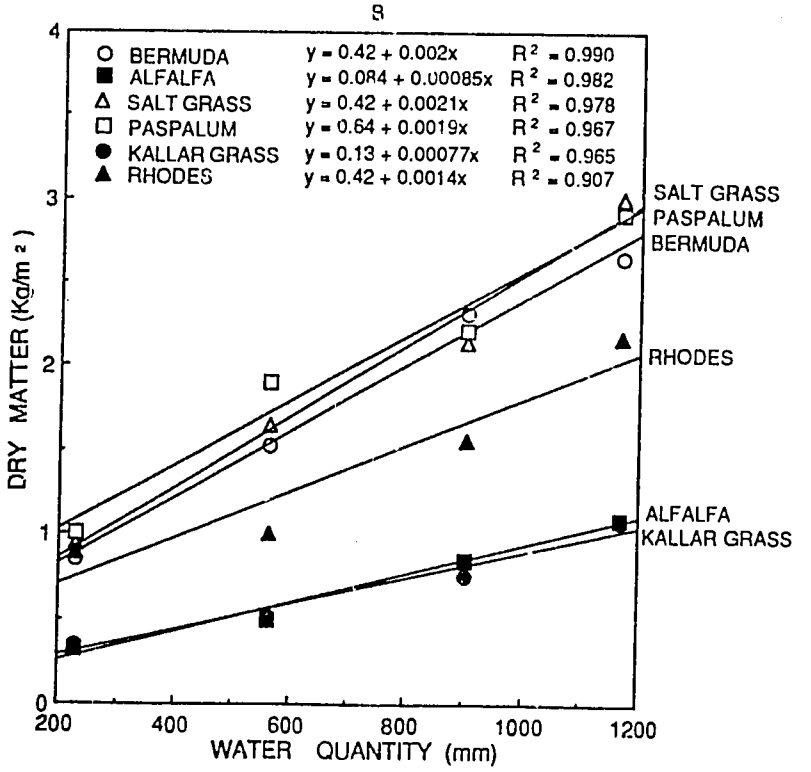
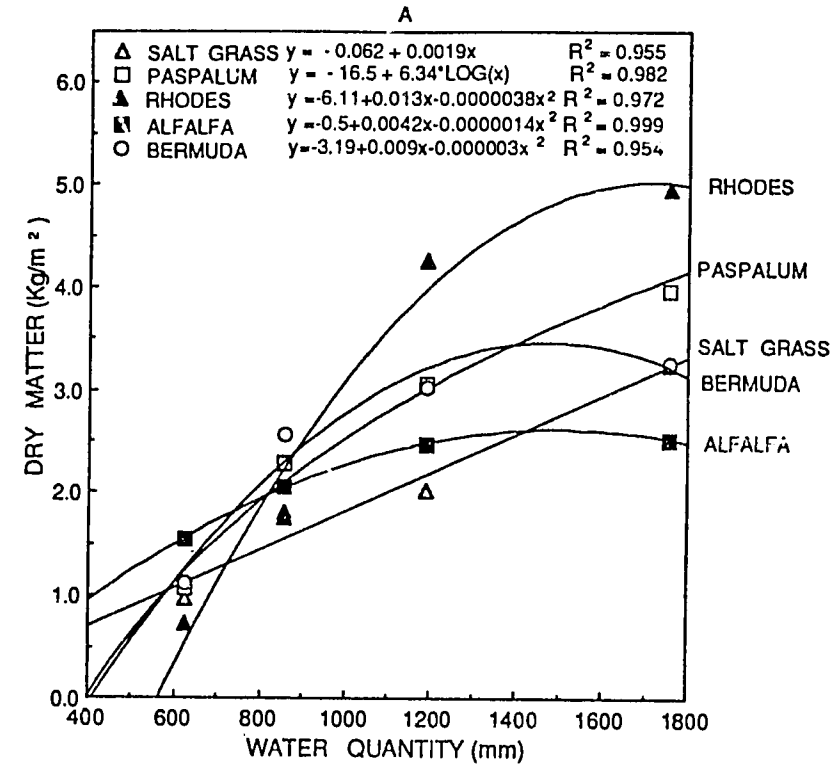
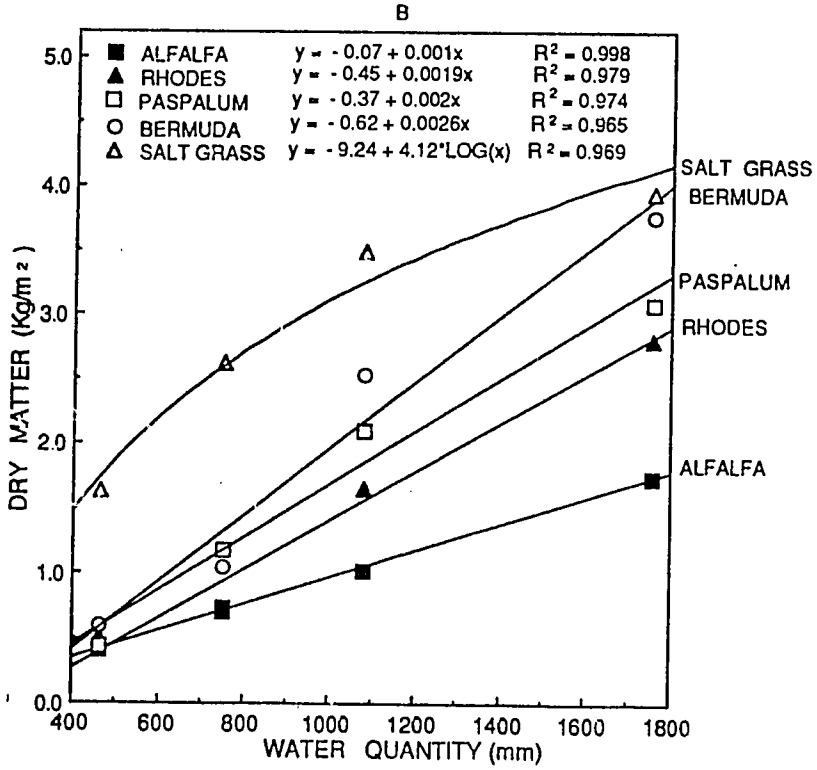


Fig. 8. Dry matter production (kg/m²) of five forage species in 1991 as a function of irrigation water quantity. A - fresh water (EC_i = 1.2 dS/m); B - saline water (EC_i = 8 dS/m).





conditions. From this point of view this species would seem to be the most appropriate candidate for planting in non-irrigated saline rangelands where water availability is often limited.

The effect of a range of soil salinities on the quality parameters of the forage species is shown in Figs. 9 and 10. There were large differences between species in all quality parameters measured. The outstanding features were as follows: Under non saline conditions paspalum had a much higher water content than the other species; however, increasing salinity drastically reduced its moisture content, lowering it to the levels of the other grasses. In most cases increasing salinity did not increase ash content. Bermuda grass had the lowest ash content, as noted by other workers (Francois 1988). Surprisingly, salt grass, which possesses active salt glands, had an ash content similar to that of Rhodes grass. The species with the highest ash content was paspalum (15-16%). There were also large variations in fiber content between species. Salt grass had a very high fiber content (~ 42%). It was followed by Bermuda grass, paspalum, Rhodes grass, Kallar grass and alfalfa. The crude protein (%N x 6.25) content of all forage species was higher in 1991 than in 1990. This could perhaps be attributed to the shorter clipping intervals in 1991 which resulted in harvesting of younger tissue higher in protein. Alfalfa had the highest crude protein content.

The present work shows that there is a considerable potential for production of high forage yields using 10 dS/m water. The potential yield of two grasses, salt grass and Bermuda grass, was affected only slightly or not at all by a soil EC_e of 14.0 dS/m. Work on these species should continue in order to identify the upper limits of their salt tolerance. Salt grass is basically a non domesticated species. Perhaps there is room for concentrated breeding and selection work with this exceptionally salt-tolerant species in order to increase its yields and reduce its fiber content. The Bermuda grass cultivar Suwannee used in this trial is an old cultivar with high fiber content. It has recently been replaced by other cultivars with much lower fiber content and higher digestibility (W. Hannah, private communication). Of the six tested species Bermuda grass is presently the most promising for production under saline conditions. Our results indicate that an evaluation of Bermuda grass cultivars for quality and yield under a range of saline conditions would be well worthwhile.

Fig. 9. Effect of irrigation water salinity on four forage quality parameters-1990 season.

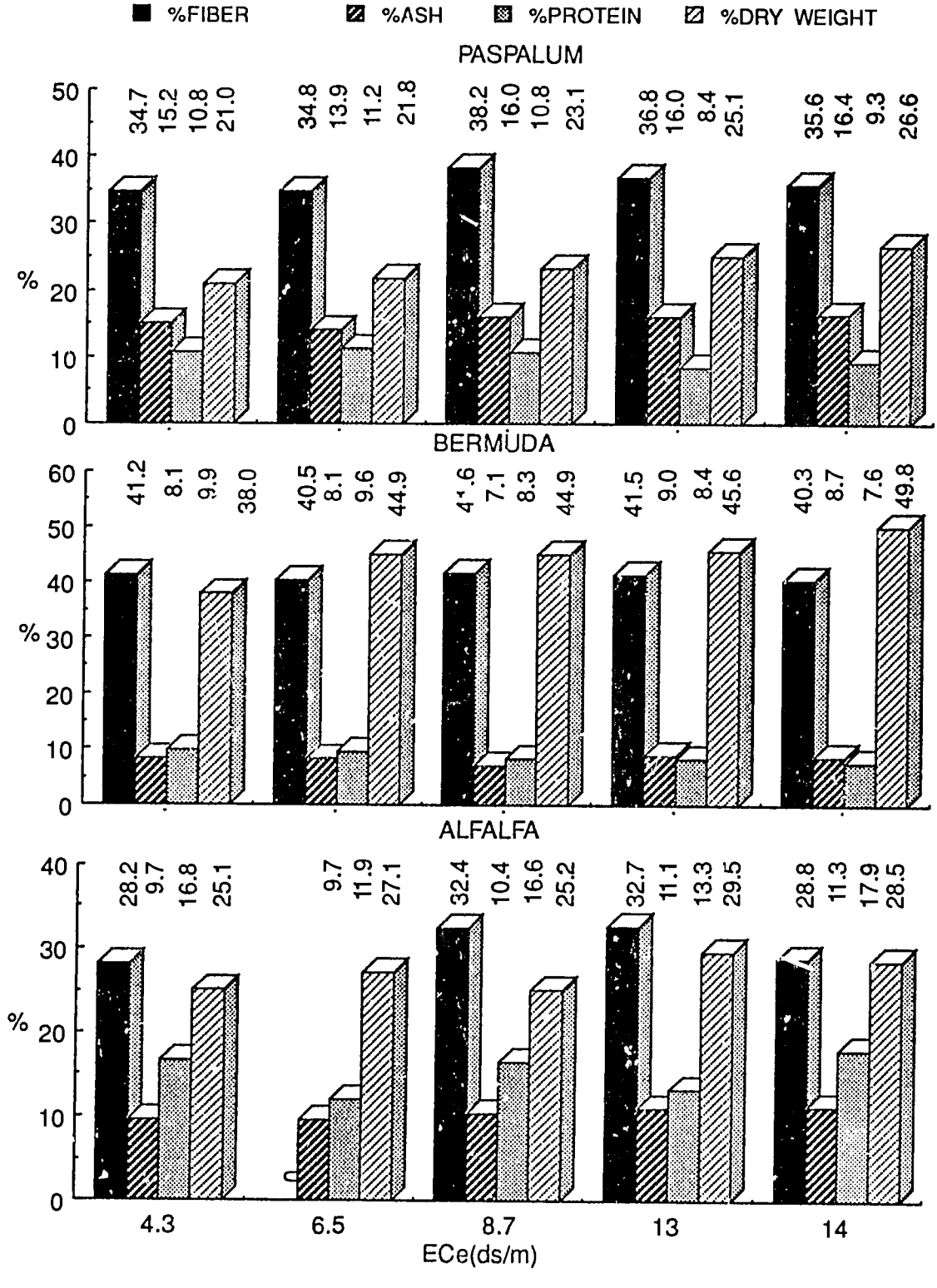


Fig. 9. Effect of irrigation water salinity on four forage quality parameters-1990 season, cont.

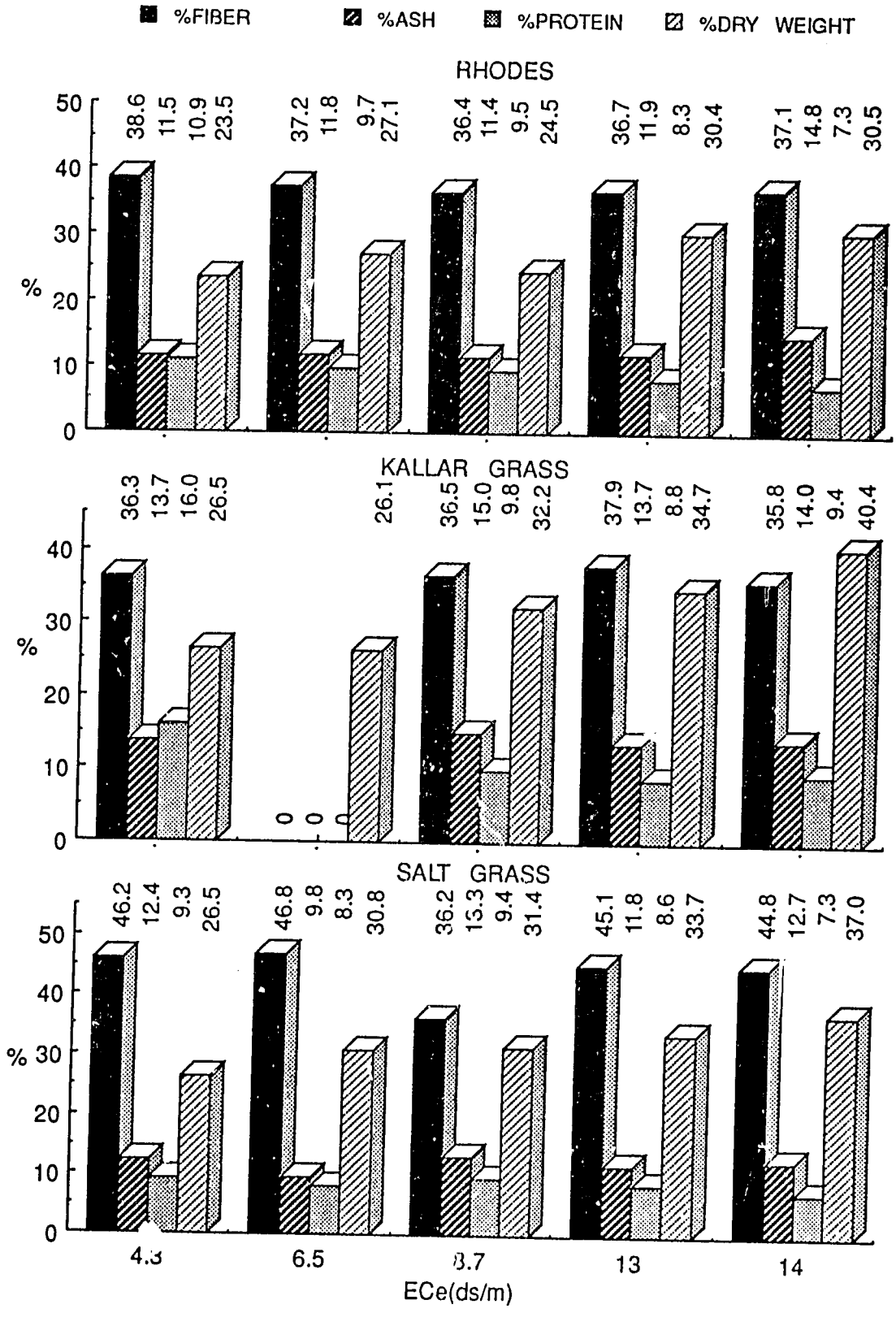


Fig. 10. Effect of irrigation water salinity on four forage quality parameters-1991 season.

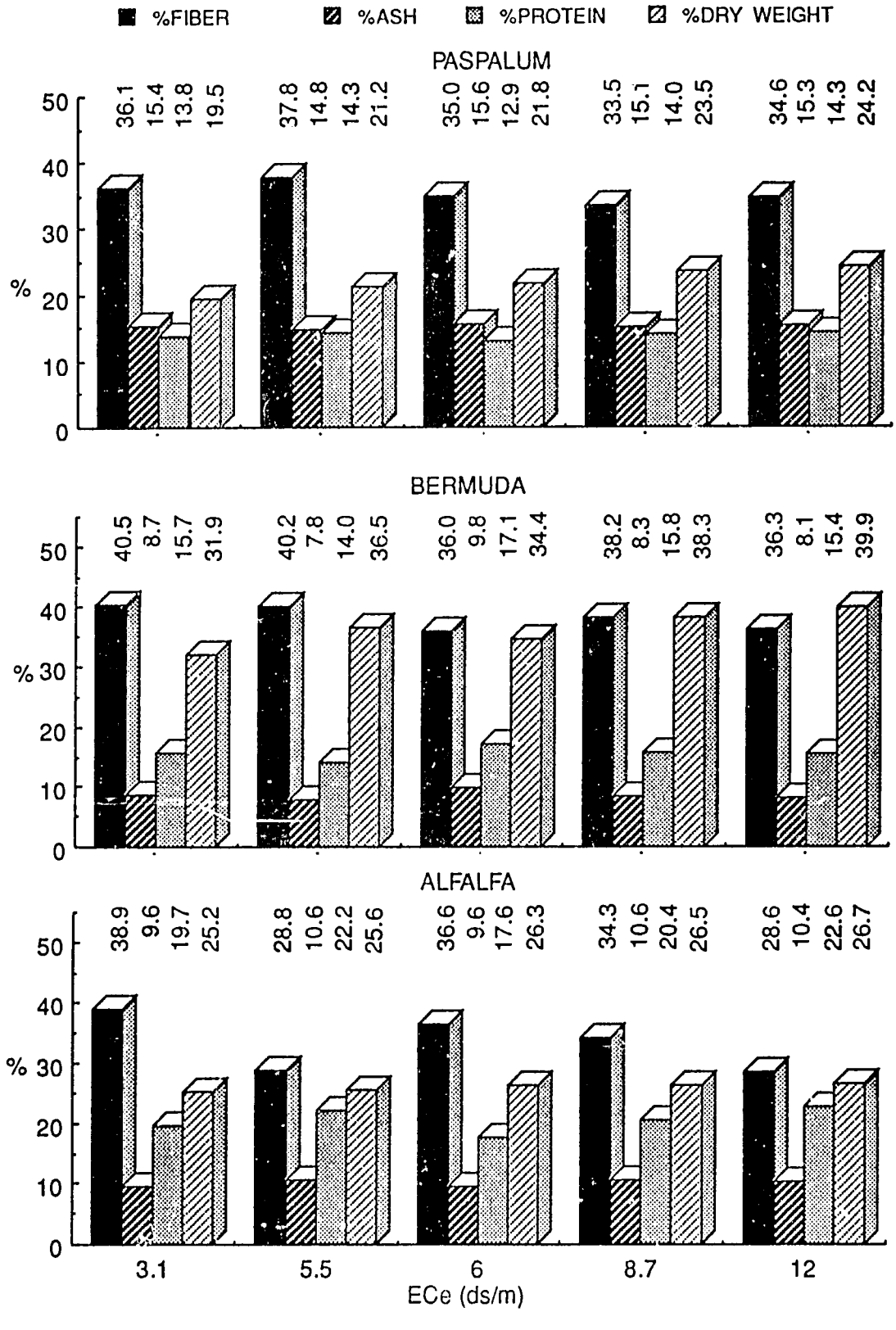
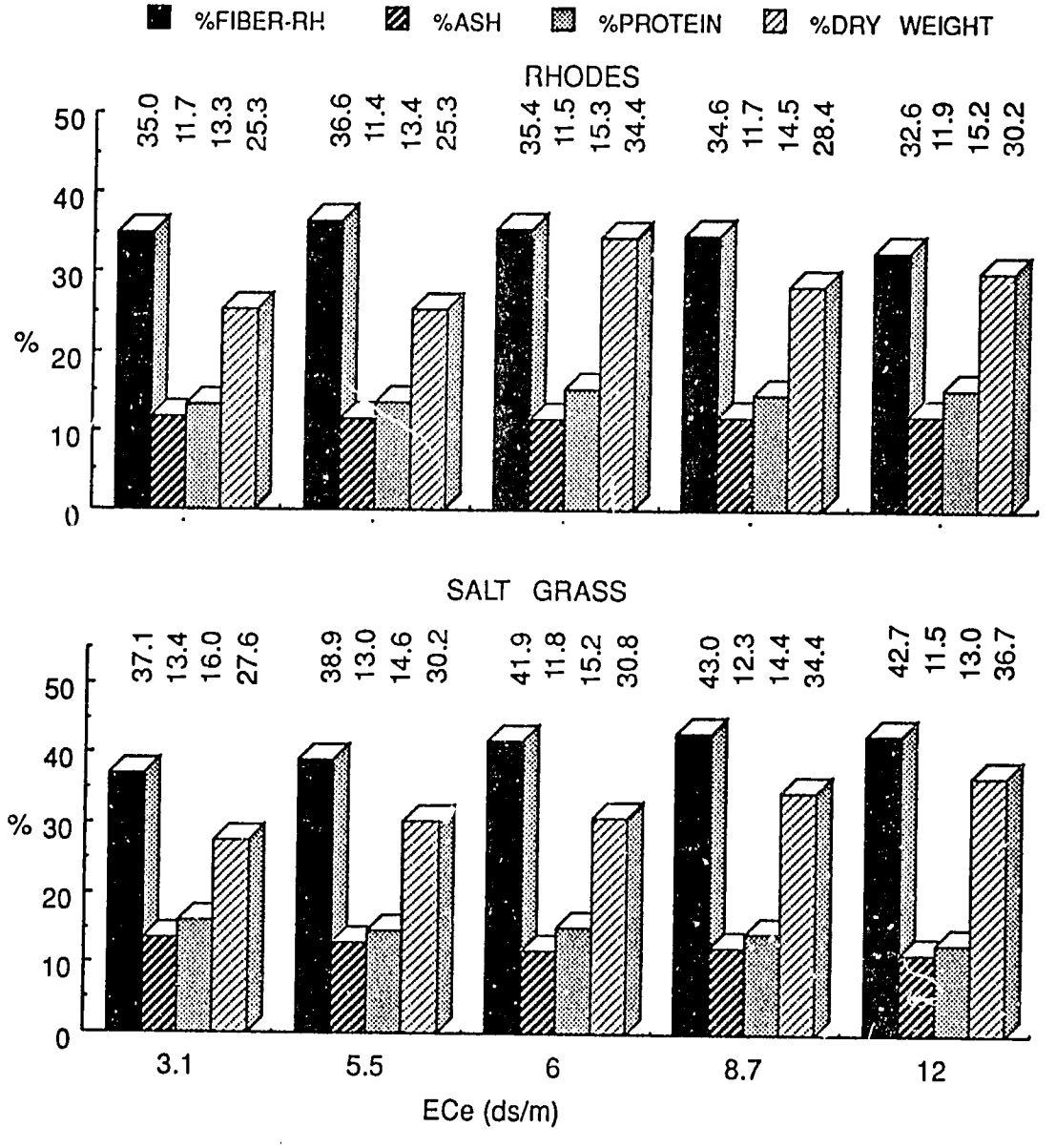


Fig. 10. Effect of irrigation water salinity on four forage quality parameters-1991 season, cont.



PORTUGAL

UNIVERSIDADE DE LISBOA
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PORTUGAL

The work in Portugal was carried out in two phases:

a) Training of a Portuguese engineer at the Institutes for Applied Research in Beer-Sheva
b) Implementation

TRAINING

A. Portuguese University graduate Mr. Carlo Graça spent seven months in 1989 at the Institutes for Applied Research in Beer-Sheva. Mr. Graça helped establish the experimental field at Ramat Negev. He was trained in all aspects of fodder production with saline water: plant propagation, field preparation, principles of saline water irrigation, harvesting and sampling, determination of soil and water salinity, laboratory analysis of soil and water, laboratory analysis of plant tissue ionic content, determination of total nitrogen, fiber and ash contents in animal feed, the use of computers for data processing and statistical analysis of experimental results.

IMPLEMENTATION

The experimental work was begun in Portugal in 1990.

1. The majority of the activities carried out during 1990 were linked with basic infrastructure preparation and installation, as follows:

- Basic preparation of the site: general cleaning. Clearing of stones and trees, first plowing, second cleaning, land levelling
- Preparation of drainage channels and adequate access road
- Installation of irrigation system tubes and sprinklers for all the site, inclusive of pumping station and water supply from the main channel
- Fence construction all around the site
- Setting up of a temporary nursery for perennial crops. Fig. 11 gives the layout of the experimental field at Castro Marim

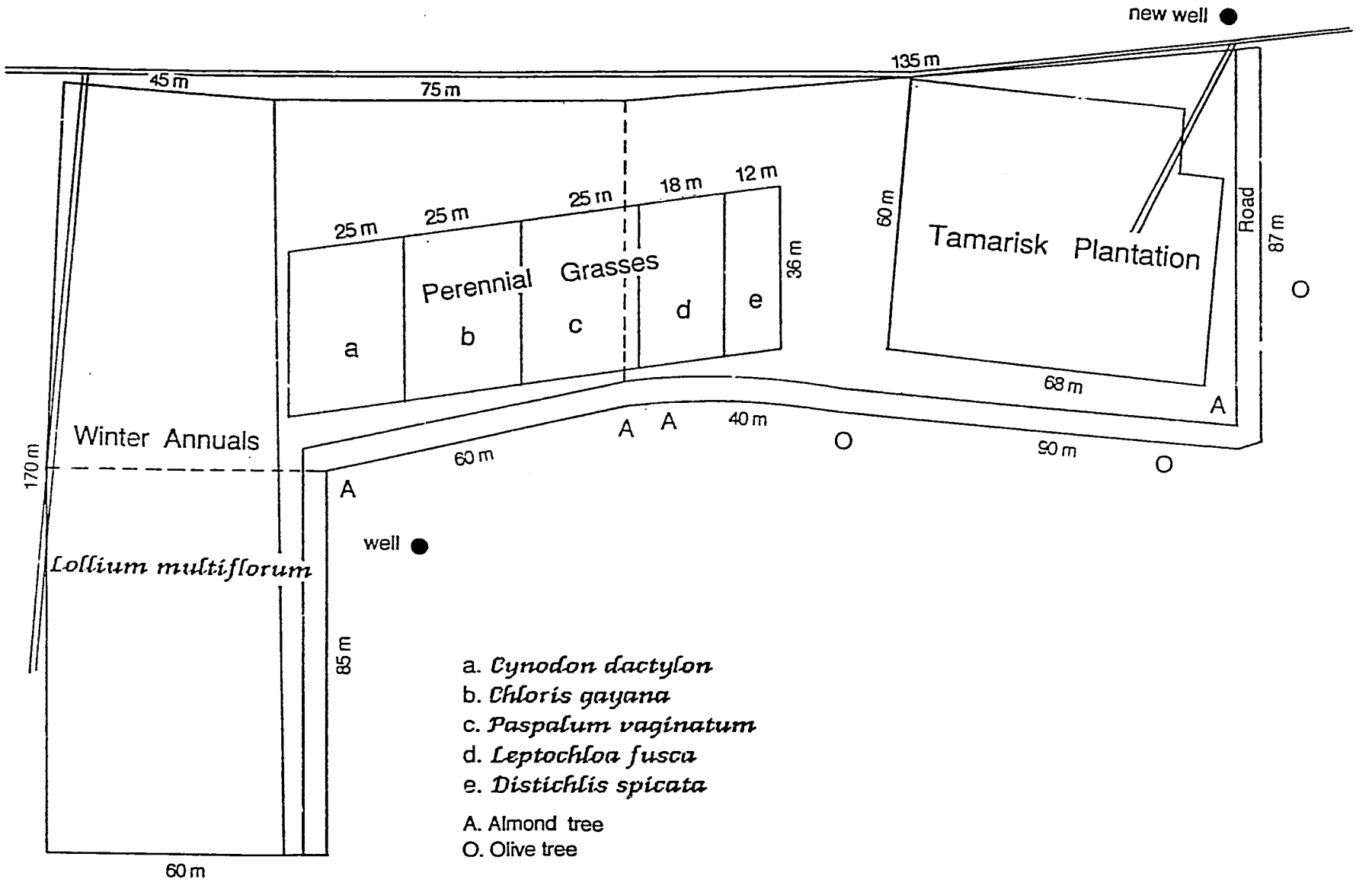

Fig. 11. The experimental layout at Castro Marim, Algarve, Portugal.

2. In the spring of 1990, before planting the perennial crops, we realized that the information supplied by the landowner regarding water supply in summer was not accurate: there was no water for irrigation. Perhaps this resulted from the lack of rain that year, mainly in late spring. In any event we were forced to take alternate measures:

- to replant the plants in the nursery to enable their maintenance for an additional year
- to study the possibility of drilling a well close to the site. The results of the study were positive. However, applying for permission to drill and later on to pump water took time

  The new pumping station was in place by April 1991.

3. The perennial crops were:

Rhodes grass, *Chloris gayana* cv. Katanbura; Bermuda grass, *Cynodon dactylon* cv. Suwannee; Kallar grass, *Leptochloa fusca*; *Medicago sativa* cv. Gilboa; as well as small quantities of *Medicago arborea*; salt grass, *Distichlis spicata*; *Paspalum vaginatum*; and *Atriplex barclayana*.

Throughout the year the site was kept cultivated and prepared for planting and sowing when necessary.

4. At the end of November 1990 we sowed some small demonstration areas with seeds of Australian origin:

Pitman-serradella, *Ornithopus compressus*	70 m^2
Puccinellia ciliata	80 m^2
Kangaroo valley rye grass	150 m^2
Cocksfoot currie	120 m^2
Trifolium subterraneum cv. nungarin	80 m^2
Festuca arundinacea	14 m^2
Dactylis glomerata	14 m^2

5. Winter annual crops.

At the beginning of November 1990 after the first rainfall we sowed 5000 m^2 of rye grass–*Lollium multiflorum* cv. vestervoldicum.

The field germinated and grew well.

Rye grass

The rye grass was not irrigated because the well was not ready during the winter of 1990/91. Electrical conductivity of the saturated soil solution to a depth of 60 cm was determined in the winter of 1992 at six places in the field. Mean EC_e for the soil was 5.2 dS/m.

Yield was harvested only once, on April 12, 1991. The dry matter yield was determined from six 1-m^2 plots in the field. Mean dry matter yield was 2.43 kg/m^2, which is a good yield for rye grass grown without irrigation in a semiarid environment. It appears therefore that rye grass can be a good winter forage for soils with a mean EC_e of 5 dS/m in the southern Algarve region.

Perennial grasses

Unfortunately there were problems with the new well. Although we reached an aquifer at a depth of 30 m, the water was not sufficient. The well was therefore deepened to a depth of 60 m. A new saline (EC ~ 4.5 dS/m) water layer was discovered, whereupon the pump and the whole irrigation set-up was installed. The perennial grasses were planted in July 1991. However, they could not be irrigated properly because the discharge was low and the quantity of water was not sufficient for irrigation.

The trial with the perennial grasses should be repeated after a better and more reliable source of saline water is established.

Acknowledgements

The authors are indebted to Ms. H. Klotz and Ms. E. Katz for technical help both in the field and in the laboratory in Israe, as well as and to Carlos Graça for carrying out the technical work in Portugal. This report was styled by Ms. A. Sen and typed by S. Shemesh.

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