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The evaluations performed in this thesis were intended to provide a partial basis for the selection of species and varieties for reseeding Central Tunisian rangelands.

The first evaluation determined the effects of four moisture regimes and two growth mediums on seedling emergence and early root and shoot development of eight plant species under greenhouse conditions. Seeds of Medicago laciniata (MELA), Hedysarum carnosum (HECA), H. spinosissimum (HESP), Argyrolobium uniflorum (ARUN), Oryzopsis miliacea (ORMI), and Dactylis glomerata [DAGL(TN)] were collected from indigenous sources in Central Tunisia. Seeds of Dactylis glomerata (Palestine) [DAGL(PN)] and Atriplex canescens (ATCA) were obtained from the United States. Days to 50% emergence and final emergence rates of all species were not affected by growth mediums and moisture regimes during the 15-day period.

Days to 50% emergence ranged from 1 day for MELA to 9 days for ORMI. Roots of HESP penetrated deeper than the others in clay under all moisture regimes. Roots of DAGL(PN) and DAGL(TN) penetrated deeper when pots were allowed to dry 3 weeks before being watered than 1, 2 or 4 weeks. Root to shoot weight ratios for all species were higher in sand than in clay. Root depth and root to shoot weight ratio of ATCA increased as soil moisture decreased in both growth mediums. Root to shoot weight ratio of ARUN increased as water deficits increased in sand. Limited potential to develop root and shoot growth as water deficits increased was shown for HECA and ORMI.

MELA, DAGL(PN and TN), and ARUN were suggested to revegetate sites with dry sand soils whereas HESP was recommended for revegetation sites with dry clay soils. In addition, DAGL(PN), DAGL(TN) and ATCA may also hold promise for reseeding clay soils.

The second evaluation determined the adaptability of 142 selected grass and forb species and varieties to Central Tunisia (BRIKATE, SAYADA NORD and SBIBA). Mean densities of species and varieties were recorded at the end of each growing season. Several species and varieties failed to emerge in each site while others emerged but failed to survive through the second growing season. Few species and varieties survived through the second growing season in each site. Based on the mean densities recorded at the end of the second growing season for species and varieties which survived, species recommended for each area included:

BRIKATE SITE
Scorpius myroculis
Plantago albicaulis
Medicago ciliaris
Hedysarum coronarium
Hedysarum carnosum

SAYADA NORD SITE
Agropyron sibiricum
Agropyron desertorum "Nordan"
Agropyron dasystachyum "Critana"
Plantago albicaulis
Hedysarum coronarium
Medicago truncatula

SBIBA SITE
Agropyron elongatum "Largo", "Gose"
Agropyron intermedium "Oahe", "Tegmar", "Trigo"
Agropyron trachycaulum "Revenue"
Agropyron sibiricum
Plantago albicaulis
Hedysarum coronarium
Trifolium vesiculosum
Hedysarum carnosum

EVALUATION OF NATIVE AND INTRODUCED PLANT SPECIES FOR REVEGETATING CENTRAL TUNISIAN RANGELANDS

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INTRODUCTION

Many factors influence the potential success of seedling establishment in semi-arid and arid regions. In Central Tunisia, where a prolonged hot and dry season causes high evapotranspiration rates, water shortage is the most important cause of the failure of seed germination and plant growth. In addition, removal of the upper soil horizons by overgrazing, trampling and erosion adds to the hostile environment for seedling establishement. Consequently, plants selected for revegetating Central Tunisia rangelands must be adapted to these conditons.

The natural vegetation of Central Tunisia, highly dominated by *Artemisia herba alba* (Asso.) and *Zygophyllum* spp., is usually sparse with few perennial plants surviving. Annuals although present in larger quantity during the rainy season (i.e. spring) are often restricted by soil conditions. An estimated average yearly production of all natural vegetation on the area is on the order of 80.0 forage units (UF) per hectare (700 kg/ha). However, actual production may vary considerably from this 80.0 U.F., depending on the yearly rainfall received.

Although ample forage is generally present during spring, there exists a need for more forage in Central Tunisia especially during late spring and summer seasons when annuals have completed their life cycle. Improvement of rangelands with varieties of well adapted native and introduced forage species can increase livestock carrying capacity of the area. This would benefit farmer's income beyond that of native rangelands, and improve the balance between forage production and forage needs during the critical seasons of the year (spring and summer). Also, plant cover improves water retention and limits erosion.

Selection of varieties and species of plants should be based on their adaptation to climate and soils of the area, their ability to establish easily and their capacity to maintain a sustained yield of forage. However, very little research has examined the ability of native or introduced range plants to survive under the environment of Central Tunisia.

It was felt that evaluation of early seedling growth and development under a range of environmental conditions may be useful for screening species used for range revegetation in Central Tunisia. The primary objective of this study was to compare emergence and establishment characteristics of both native and improved species in greenhouse and field environments, and select those species which appear useful for revegetating Central Tunisia rangelands. The following evaluations were performed:

1. Assessment of four moisture regimes and two soil types on the emergence, shoot and root development of *Medicago laciniata* (L.), *Hedysarum carnosum* Desf., *Hedysarum spinosissimum* (L.), *Argyrolobium uniflorum* (Dec), *Oryzopsis miliacea* (L.) Asch. et schw., *Dactylis glomerata* (Roth) (Tunisian cultivar), *Dactylis glomerata* var. Palestine and *Atriplex canescens* (Pursh) Nutt. grown under greenhouse conditions. Because of the scarcity and high unpredictability of the precipitation in Central Tunisia, the soil surface is wetted only infrequently and the emerging seedlings must compete for the rapidly diminishing moisture of the seedbed. Plant which exhibit the ability to develop an extended root system and adequate shoot development may hold potential for revegetating Central Tunisia rangelands.

2. Establishment and growth of native and improved grass and forb species grown on three range sites in Central Tunisia for two years. Because of longterm overuse and bad management of vegetative cover, desirable forages have all but disappeared from most of the area. Reestablishment of desirable plants to Central Tunisia rangelands is of prime need. A perennial grass must be

able to persist if it is to have any agricultural importance. Under environmental conditions of Central Tunisia, plants that have survived after experiencing two growing seasons may hold promise for revegetating the area.

EDAPHIC AND CLIMATIC CHARACTERISTICS OF CENTRAL TUNISIA

Tunisia is located at the Northeastern edge of Africa, bordered by Algeria, Lybia and the Mediterranean Sea. It has a Mediterranean climate with high summer temperatures and irregular precipitation. The most effective precipitation occurs in autumn, winter, and spring. The Atlas Mountains, which extend through North Africa divide Tunisia into two different climatic zones. In the north, the precipitation varies from 1500 mm to 380 mm annually. In the central and southern regions which occupy 80 percent of Tunisia's 15.5 million hectares, precipitation varies from 350 mm to less than 100 mm. (Novikoff and Skouri, 1981). Central Tunisia is geographically delineated by the Atlas Mountains in the North and a series of chott in the South (Fig. 1).

CLIMATE

Central Tunisia can be divided into 5 different native regions with some homogeneity in the climate, vegetation, and land use (Le Houerou, 1969). These are:

1. <u>The High Plains</u> (Tala area): This region has an altitude higher than 800 m. Precipitation is more than 350 mm/year with cold winters. The vegetation of this

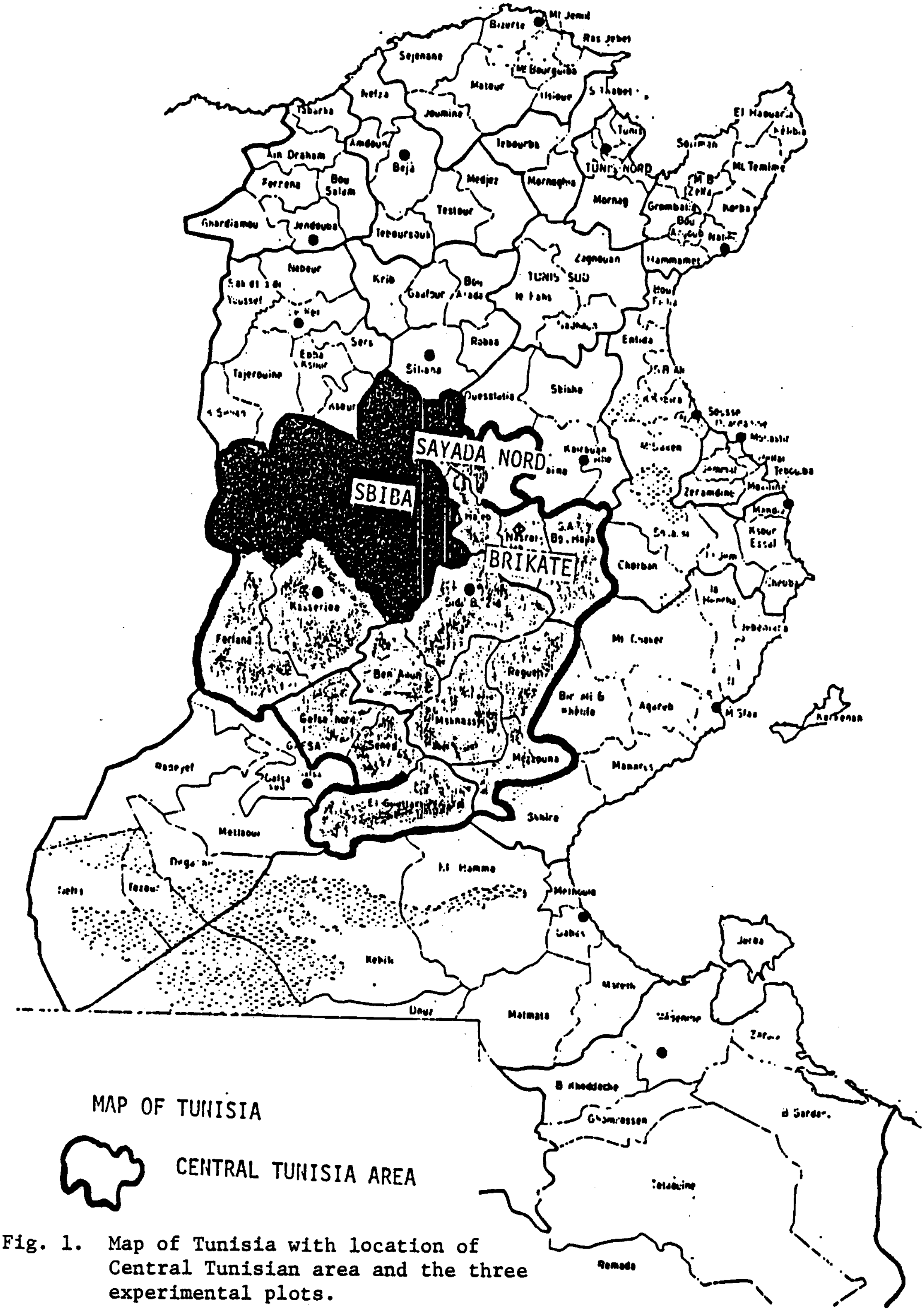


Fig. 1. Map of Tunisia with location of Central Tunisian area and the three experimental plots.

area is historically dominated by Pinus halepensis which occupies the higher elevations. Cereal crops and fruit trees are restricted to the plains.

2. The High Septentional Steppes (Sbiba area): The altitude of this region is between 400 and 800m. The annual average precipitation ranges from 325 to 250 mm with mild winters. This area was once occupied by Pinus halepensis which has completely disappeared and been replaced by Stipa tenacissima (L.). However, Artemisia compestris (L.) and Artemisia herba-alba grown at the lower elevations.

3. The High Meridional Steppes (Feriana): This region has a similar climatic regime as the high septentional steppes with annual average precipitation ranging from 780 mm to 250 mm. The vegetation is dominated by Stipa tenacissima and small shrubs such as Artemisia herba-alba and Artemisia compestris.

4. The Low Septentional Steppes (Haffouz-Nasrallah): The altitude ranges from 200 m to 400 m. The yearly average precipitation is between 250 and 350 mm. The vegetation is dominated by Stipa tenecissama, Genevriers de Phenicie and Artemisia herba-alba.

5. The Low Meridional Steppes (Maknassi-Mezzouna): It has a similar climatic criteria as the low septentional steppes but the average precipitation ranges from 150 to

200 mm. The vegetation is dominated by the *Artemisia herba-alba*, *Artemisia compestris* or *Ranterium suaveolens*. (Le Houerou 1969)

SOILS

Very heterogenous soil types characterize Central Tunisia. Six major soil types have been defined:

1. Spueleter soils exhibiting high percentage of rock content with very little soil formation. These soils are quite shallow and frequently overlay fractured bed rock or collivion deposits of stone and rock, highly occurring in Brikate site.

2. Regosols: these are soils developed from sea deposits exhibiting only marginal edaphic evolution, frequently gypsic in nature, and generally characteristic of the "bad land" terrain of Central Tunisia, around Shiba area.

3. Alluvial soils: these soils occur at bottom slope positions, valley bottoms, and along drainage sites. These soils, formed from water transported materials, originally highly fertile, deep, and loamy to clay loam in texture. This type of soil mainly occurs at Sayada Nord sites.

4. Collivial soils: these soils are formed from rock materials deposited by gravity movement from higher sites

to those at lower elevations. Edaphic characteristics of these soils are highly variable; however, they are originally less well-developed than alluvial soils and exhibit a higher rock content and a coarser texture.

5. Aeolian soils: these are wind deposited soils often characterized by moving sand dunes. Such soils can be frequently found in Central Tunisia because of their instability. They are generally classified as immature soils.

6. The other major category of soils include calcarous soils formed from lime stone and other calcium rich plant materials. In addition highly saline soils are common on topographically low site where high mountains of soil deposits and high salt content plant materials combine to form what is generally called saline or alkaline soil. Generally, these soils exhibit a heavy texture, resulting in very low infiltration rate and subsequent accumulation of salts.

LITERATURE REVIEW

PREVIOUS VARIETAL TRIALS CONDUCTED IN CENTRAL TUNISIA

Relatively little research has been conducted on establishment of forage species in Central Tunisia. Previous research on revegetating forage species has been conducted under the direction of FAO (Food and Agriculture Organization) and USSA (United States Secretary of Agriculture) (1961). Reseeding tests were carried out on existing pastures at Ouled M'Hamed (Sidi Bouzid) and Ousslatia (Kairouan) experimental stations. Three modes of reseeding were used:

1- Seeding in soils prepared by heavy cultivator.
2- Seeding in scarification lines (furrows).
3- Broadcasting of seed in basins after prior loosening of the bottom of the trough.

Summarization of results obtained from this study were as follows:

1. On soils prepared by heavy cultivator, reseeding of all species failed. However, indiginous vegetation, especially annual legumes and particularly *Cynodon dactylon* (Bermuda grass), benefited from the loosening of the soil.

2. Encouraging results were obtained when *Oryzopsis miliacea* and *Cenchrus ciliaris* were seeded into scarification lines.

3. Local ecotypes of Oryzopsis miliacea and Cenchrus ciliaris did well when seeds were broadcasted into basins.

Conclusions reached from this study were: perennial grass species such as Cenchrus ciliaris and Oryzopsis miliacea (local types) were best for reseeding Central Tunisian rangelands. However, Ehrharta calycina was the only introduced species to survive local conditions and establish good stands. Agropyron spp. and several other improved forb and grass species failed to establish in both sites. Detailed results of the test are given in Appendix 1 and 2.

ECOLOGICAL PATTERN OF PLANT SPECIES USED IN GREENHOUSE CONDITION:

Medicago laciniata (L.) Mill., is an omni-mediterranean annual leguminous plant. The natural habitat of this species is in dry, light soils of steppes and hemadas (Jordan 1980) and in sands or heavy clay on rocky hillsides, underbrush, or along roadsides (Lesins and Lesins 1979). It is represented by two varieties; M. laciniata var. laciniata boiss. and M. laciniata var. brachycantha boiss. (Friedman et al. 1976). The first variety (var. laciniata) has larger pods with markedly larger spines and occurs in relatively mesic habitats (Heyn 1963). It is commonly found on Northern slopes and wadibeds dominated by Artemisia herba alba and Zygophyllum dumosi. Both varieties are found native in arid and semi-arid regions of south and Central Tunisia where mean precipitation ranges from 150 to 550 mm. Seeds are mainly dispersed by rodents and ruminants in the area through the spiny pods tailed in their fur or in their feces. Seed longevity is considerable. Germination of 20 year-old seeds was found to be 85% after 48 h (Friedman and Orshan 1974).

Hedysarum carnosum Desf., is a biennial legume which is native to arid zones of North Africa. H. carnosum is found on medium to fine textured saline and alkaline soils and occurs on calcareous clay and gypsiferous soils (Le Houerou 1979 and Kernick, 1978). Germination under field conditions is poor and irregular, although laboratory experiments show that after hulling and scarifying, the germination approaches 90% (Hadar 1965). Salt tolerance is high (20 mm) as well as its palatability for all kinds of livestock (Le Houerou 1969).

Hedysarum spinossissimum (L.) is an annual legume, drought resistant and well adapted to steppe and desert areas with 100-400 mm annual rainfall, it is adapted to calcareous clay and sandy soils, and also to alluvial river soils (Kernick, 1978). It is a prostrate herbaceous species with numerous stems lying on the soil surface, in contrast to the erect stems characterizing H. carnosum (personal observation).

Argyrolobium uniflorum (Dec. Jaub and spech) is an undershrub perennial legume, occurring in all sandy steppes of the Saharan southern steppe of Tunisia, where average yearly precipitation is as low as 80 mm. It grows in areas dominated by the association of Ranterium suavelens and Retama retam. It is highly palatable and extremely drought resistant (Le Houerou 1979).

Oryzopsis miliacea (L.) Asch. et Schw. is a long lived perennial bunchgrass, growing in turft close to the surface (Kernick, 1978). The natural habitat of O. miliacea is found in various types of soils from clay to sand and from deep to shallow (Le Houerou 1979) and even skeletal soils free of weed competition. In Tunisia, the species is found under various climatic and soil conditions. Common habitats include degraded forests, under eucalyptus plantations and along wadis and roadsides where soils are often shallows and highly calcareous. Germination is irregular and varies with the season, requiring a high minimum temperature (15 C). However, its germination is not fully developed until six months after harvest and last two to three years (Le Houerou 1979). Once established, the plant lasts 10 to 15 years, owing to self reseeding, and does not show a summer dormancy as long as water is available. Meanwhile, winter growth is strongly reduced when daily minimum temperature reaches 3-5 C or less (Le Houerou 1979). *O. milicea* is extremely drought resistant and can survive several years under low precipitation amounts. When used at the proper time, good forage quality, with high protein content (12-15%) and digestive utilization rate of 65% characterize the plant (Le Houerou 1979).

Dactylis glomerata L. (Roth. Koch.), is a perennial cross-pollinated grass with natural distribution that includes parts of Europe, North Africa, and Asia (Knight 1973). It occurs in many places of the arid zones under average rainfalls as low as 150 mm. It is divided into two types; a winter-growing, summer-dormant type and a winter-dominant, summer-growing type. The winter-dormant ecotypes are indigenous to regions with cold winters, mainly at high latitudes, while the summer-dormant ecotypes are indigenous to Mediterranean-type climates with hot, dry summers (Knight 1973). *D. glomeratea* subsp. hispanica is more common in the semi-arid areas (Kernick, 1978).

Atriplex canescens ((Pursh) Nutt.) is a North American native chenopodiaceae. It occurs in saline and alkaline soils in the arid and semi-arid zones, where the rainfall ranges from 150 to 500 mm. It is an extremely drought-resistant species, withstanding rainless periods of one year or more (Le Houerou 1979). It is a much-branched, erect shrub 40 to 200 cm high, with branches and numerous evergreen leaves (McMinn 1951). Optimum germination of seeds is obtained at temperatures ranging from 13 to 24 c, when planting depth does not exceed one centimeter (Springfield 1969). It is the most widely distributed species of the Atriplex genus in North America. It is common on dry slopes, flats, and washes below 2100 m at in Alkali sink, Creosote bush scrub, and Pinyon juniper woodland (Kay et al. 1977).

GREENHOUSE EVALUATION TO SCREEN SPECIES

A. Emergence

1. Emergence response to soil moisture:

Emergence of seedlings in arid land environments is greatly influenced by availability of soil moisture. To ensure optimum germination and seedling establishment most range grass, legume and shrub seeds are planted at shallow depths (Valentine, 1980). This may result in rapid fluctuations of soil moisture around the seed, especially during warmer months. To germinate, a seed must obtain moisture from surrounding zones. It must overcome forces imposed by soil properties such as osmotic potentials and matric potentials (Ayres 1952). In addition, for a seedling to emerge it must not only germinate but also penetrates through surface crusts (Hanks and Thorp 1956).

Working on the emergence and survival response of grasses grown under six wet-dry sequences, Frasier, Cox and Woolhiser (1980) found that seedling emergence depended upon the wet period prior to seeding. Their studies showed that 'A-68' Lehman lovegrass (Eragrostis Lehmanniana Nees) and 'A-84' Boer lovegrass (E. curvula var. conferta (shred) Nees) have slow seedling emergence characteristics, requiring at least 3 wet days. They concluded that the slow seedling emergence may cause problems achieving successful field planting, unless it is a wet year with frequent precipitation events. Fulbright, Wilson and Redente (1984) reported that increasing severity of dehydration (-1.0 Mpa to -3.7 Mpa) of germinating Green Needlegrass (Stipa viridula Trim) seeds reduced seedling emergence. No seedlings emerged following a -3.7 Mpa dehydration treatment. Frelich et al. (1973) reported that decreasing osmotic potentials delayed the emergence of tall fescue (Festuca arundinacea Schreb) seedlings. On the other hand, Hanks and Thorp (1956) concluded that low seedling emergence is not entirely due to moisture content but also to the hardness of soil crust.

Ayres (1952) showed that when moisture in fine sandy loam was decreased from 12.4 to 7.2 percent, emergence time for onion seed was increased more than 48 hours and total emergence was decreased approximately 40 percent. Moreover, when percentage of moisture decreased to 6.1 percent, time of emergence decreased approximately 80 percent compared to seed germinated in soil containing 12.4 percent moisture. Emergence of vegetable seeds varied from 5 to 14.5 days under moisture conditions controlled from 8 to 18 percent in Yolo fine sandy loam (Doneen and MacGillivray 1943). In 2 to 42 days of dry soils, emergence of *Dactylis glomerata* seedlings decreased with increasing length of time after sowing (Kading and Kreil 1982).

2. *Emergence Response to Soil Types*:

Very little quantitative work has been done to determine the relationship between seedling emergence and soil physical and chemical conditions. Hanks and Thorp (1956) found that seedling emergence was nearly the same in three different soil types (silty clay loam, silt loam and fine sandy loam) when soil moisture content was maintained between field capacity and the wilting percentage. It appeared that seedling emergence was not entirely due to moisture content or crust strength but other factors such as oxygen diffusion rate, soil pH and soil temperature. Frelich, Jansen and Gifford (1973) studied the effect of crust rigidity (phenomena highly occurring in clay soils) and osmotic potential on emergence of grass species and found that increasing crust hardness delayed and reduced average seedling emergence over osmotic potentials ranging from 0 to -8.4 bars. Seedling emergence decreased as bulk density of the soil increased. Seedling emergence of wheat plants was limited when both silt clay loam and fine sandy loam soils reached 1.2 and 1.3 and 1.5 and 1.6 bulk density, respectively (Hanks and Thorp 1956).

As soil moisture content decreases, bulk density and crust strength increases leading to a decrease in seedling emergence percentage. Richards (1954) found that an increase of the soil crust on one soil from 108 to 273 millibars, was sufficient to decrease the emergence of bean seedlings from 100 to 0%. In addition at 1/2 available moisture in the soil (1/2 of the field capacity percentage maintained in the soil) and equal bulk density, seedling emergence percentages were 86% and 26% in silty clay loam and silt loam respectively.

B. Root Characteristics:

Range plants universally compete with each other for the limited resources of their ecosystem (Harris 1977). To endure periodic and probably prolonged soil drought and continue to survive, plants need adaptive physiological and morphological characteristics which enable them to maintain themselves within the plant community. One important character which enable a plant to be competitive is development and structure of below ground organs i.e., roots. Root studies are of special importance in arid environments as in Central Tunisia where the successful establishment of grasses, legumes and shrubs depends largely upon seedlings developing adequate below ground structures.

Plummer (1943), Tadmor and Cohen (1968) reported that in arid environments, rapid drying of seedbed layers makes fast elongation of the seedling root a prerequisite to successful establishment. Seedlings must produce a long root system if they are to effectively utilize soil moisture (Harris and Gobel 1976). In addition, rooting vigour is of primary importance when evaluating the ability of native species to establish in harsh environments (Eddleman 1980; Johnson 1982).

Root development and growth of a particular species depends upon soil and moisture conditions. Soil type, structure, availability of moisture and nutrients are largely the guiding factors of rooting patterns in the soil. Weaver and Kramer (1949) stated, "Although the root habits are governed, first of all, by the hereditary growth characteristics of the species, they are often quite as much a product of environment"

1. Root Growth Response to Soil Moisture:

The faster the root initiation, the better is the chance for the plant to establish. Rooting patterns differ from one plant to another as well as among species. As soil moisture depletion occurs, plants show physiological adaptation in their root response (Kummerow 1980). Such modifications are, root shedding, development of profuse system of small roots and shifts in root activity.

One of the important changes in rooting activity under conditions of moisture stress is alteration in rooting depth. Molyneux and Davies (1983) reported that soil drying had marked effects on the rooting depth of plants. They found that Timothy (*Phleum pratense* L. S48) seedlings which in wet soil were deep rooted decreased their depth of rooting in water-stressed condition. This was in contrast to roots of water stressed Dactylis glomerata L. S37 seedlings which grew deeper into the profile than did roots of well-watered plants. This also agreed with other findings that rather than reducing the growth of roots,a plant species adapted to arid environments may actually increase root growth under water stress conditions (Shantz 1927, Sharma and Ghildyal 1977, Osonubi and Davies 1978, 1981, Turner and Begg 1978, and Chae and Lee 1979). Other rooting characteristics which may influence establishment of species under dry conditions include root number, seasonal changes of the fine roots, vertical and horizontal extension of roots and root to shoot biomass ratio (Kummerow 1980).

As a rule, the seminal roots of perennial monocotyledones live only a short time. Thus, plant establishment requires the development of adventitious roots (Esau 1960). However, Taylor and McCell (1936); Boatwright and Ferguson (1967) stressed that it is not surprising that adventitious roots fail to grow in dry soil.

The development of secondary roots during early seedling growth is apparently an adaptation that provides an alternate source of water and nutrients if the seminal root is killed (Fulbright et al. 1984). In their studies of the effect of temporary dehydration on growth of green needlegrass (Stipa viridula) seedlings, they found that when dehydration injured the seminal primary root, the seedlings produced up to 3 seminal lateral roots as compared to the non injured seminal primary root. They also found that the length of the largest adventitious root per seedling was not affected by dehydration treatment. Dry conditions at the crown of the plant, which is likely to happen in seedbeds under low rainfall conditions, may prevent or delay the development of secondary root systems (Cornish 1982). These secondary roots are able to support seedlings in the absence of seminal roots which are likely to perish when soil surface layers dry around the crown area. However, such delay in their development may reduce tillering and leaf area of the plants (Cornish et al. 1984).

2. Root growth response to soil types:

Harris (1977) noted that rapid elongation of the primary root is critical for the establishment of annuals during the fall, when water potentials fluctuate widely at the soil surface. Flocker and Timm (1969) found in coarse sand, 100% of the roots growing in the upper 20 cm, while in fine sand, roots penetrated to a depth >30 cm. This resulted from soil moisture availability being greater in the fine sand than in the course sand at greater soil depths.

Soils with a high bulk density, large proportion of clay particles, and a hard pan may impede root penetration (Zimmerman 1961; Weaver and Crist 1922). Cracks produced as the upper soil layer dries may also cause roots to break and restrict plant survival. Schuurman (1961) studying the influence of soil density on root development found that root growth was more restricted in dense soil then in low density soils.

C. Shoot Characteristics:

In general, any root growth reduction results in a reduction of shoot growth. As soil moisture content declines, above ground parts are indirectly affected. Fulbright et al. (1984) showed that shoot length per seedling of Stipa viridula decreased with each increase in severity of dehydration (10.3, 7.0 and 6.4 mm corresponding to the dehydration levels of 0, -4 and -10 MPa respectively). Percent of leaf as compared to percent of stem was greater for water-stressed Cynodon dactylon (L.) Pers. and Panicum coloratum (L.) plants than for the well-watered plants, but the leaf area per plants was less due to reduction of growth and delayed maturation (Bade et al. 1985). However, they also found that dry matter yield of water-stressed plants increased more than corresponding well-watered plants as a result of increased rate of stem elongation and leaf development. In comparing native legumes and grasses as to seedling growth and resistance to soil drought, Potter (1953) found that after a favorable growth period of 30 days with adequate soil moisture no plants produced higher forage yields (dry matter) than Medicago sativa. But, by the time of permanent wilting, some plants produced equal dry shoot weights to *M. sativa*.

FIELD STUDY TO SCREEN SPECIES

A. Emergence:

Under field conditions seedling emergence is highly affected by infrequent wetting and drying regimes under field conditions. Adequate moisture, temperature and light for seed germination and emergence may occur at only a short time interval. Such situations are likely to be followed by a more or less prolonged dry period which reduce survival of the emerged seedling.

Roundy (1985) while working on emergence and establishment of *Elymus cinerus* and *Agropyron elongatum* in relation to moisture and salinity found that, in the absence of winter precipitation, seedlings of *E. cinerus* did not emerge until after irrigation. Maximum seedling emergence occurred when seedlings received winter precipitation. He concluded highest seedling emergence was produced by frequent spring precipitation when temperatures were warm enough for germination.

As to seedling emergence, planting depth is of prime importance. In arid zones species seeded at shallow depths may not germinate and emerge due to rapid drying of upper soil surface. In contrast deeply sown seeds, may not emerge due to the high energy required for the radicle to penetrate through the soil (Valentine 1980).

Murphy and Arny (1939) found that as the surface of a silty clay loam soil dried, emergence from surface plantings in the field was low compared to the emergence under greenhouse conditions. In the greenhouse, emergence from deeper depths was much higher than in the field. They also found that, in both field and greenhouse, legume seedlings emerged much more rapidly than grass seedlings. In addition, total emergence of the legumes was attained over a shorter period of time than the grasses. This ability to emerge more rapidly puts legumes in the advantage to compete earlier than the grasses when grown in mixture, but it also represents a high risk of disappearance if unfavorable growth condtions occur shortly after emergence.

B. Root Characteristics:

An extensive, vigorous root system is a prerequisite for plant establishment in arid and desert areas. Deep rooting system ensures optimum water absorption from deeper soil layers to overcome the water deficit which is likely to occur in the surface soil. But, root system extending over several meters requires high investment of carbon and nutrients produced by the shoot system. Under adequate growth condition, i.e. ample moisture, warm temperature, Plummer (1943) found wide differences in the rate of elongation of roots between several rangeland species. *Agropyron smithii*, *Festuca ovina* and *Stipa arida* showed slower root development, while *A. spicatum*, *Bromus inermis* and *B. carinatus* developed at a much more rapid rate. He concluded that a close relationship existed between rate of development of roots and subsequent establishment. Species with low initial rates of root growth i.e. *A. smithii*, *F. ovina* and *S. arida* were very difficult to establish. Others which showed a rapid rate of producing roots were more likely to establish successful stands.

Evenden (1983) studied the effect of different soil moisture regimes on the early seedling development of *Agropyron spicatum* and found that periods of surface and subsurface moisture above field capacity needed to be present when seedlings were in the three-leaf stage to assure development of adventitious roots. Fernandez et al. (1975) found elongation of Atriplex roots was still detectable even at water potentials of -70 Atm at 40 cm depth. In addition, as soil dries, a flush of root growth activity was observed characterized by a large profusion of laterals exploring large soil volumes.

C. Root/Shoot Characteristics:

Few studies have been conducted which correlate growth characteristics of shoot to root or root to shoot. Wiese (1968) found little correlation between rate of root elongation and plant height, top weight, or root weight. However, he found a positive correlation between root weight and shoot height or weight as well as between top weight and height.

Plants that are able to produce high root/shoot ratios indicate more roots are produced to support the increasing needs of a developing shoot. Roots have to penetrate deeper to absorb enough moisture to ensure the maintenance and continuity of the photosynthetic mechanism of the plant.

Troughton (1960) reported that the growth of root system was related to that of the shoot system, and both were effected by the environment. Loomis (1953) postulated that the correlation in the growth of roots and shoots were primarily competitive; root growth is limited by supplies of carbohydrates and other material, while shoot growth is limited by supplies of water and minerals obtained by the root.

Root/shoot biomass ratio is a conventional way to describe the varying degrees of carbon allocation to the above and below ground parts (Kummerow 1980). In both greenhouse and field conditions, roots and shoots show considerable seasonal fluctuation in their biomass.

Kummerow (1980) concluded that R:S ratios do not necessarily indicate an adaptational response of species to moisture stress, since ratios of arid sspecies have been shown to be below unity for certain species and well above 1 for others. Thus, he felt that the ratio of the absorbing root surface to the photosynthetically active leaf area of the plant would be a more useful measure of rooting importance. However, Rodin et al. (1972) reported that high root/shoot biomass ratios are particularly apparent for species adapted to region, where most of the precipitation occurs in the winter months. In Mediterranean climate, such as Central Tunisia, species with a high root/shoot weight ratios may be better suited for revegetation purposes.

SECTION I

EVALUATION OF PLANT SPECIES FOR REVEGETATING CENTRAL TUNISIAN RANGELANDS: GREENHOUSE ASSESSMENT

EVALUATION OF PLANT SPECIES FOR REVEGETATING CENTRAL TUNISIA RANGELANDS - GREENHOUSE ASSESSMENT

ABSTRACT

A greenhouse study was conducted to determine seedling emergence and early root and shoot development of eight range plants in two grwoth medium and four moisture regimes. The growth mediums consisted of a sand and clay and seedlings were watered at 1, 2, 3, and 4 week intervals. Species tested were: Medicago laciniata L. (MELA), Hedysarum carnosum Desf. (HECA), H. spinosissimum L. (HESP), Argyrolobium uniflorum Dec. (ARUM), Oryzopsis miliacea L. (ORMI), Dactylis glomerata (DAGL), and Atriplex canescens Pursh. (ATCA). For D. glomerata, both a Tunisian ecotype (DAGL(TN)) and an improved cultivar (DAGL var. Palestine (PN)) were used for comparisons.

Days to 50% emergence and final emergence rates of all species were not affected by growth medium and moisture regimes during the 15-day period. Days to 50% emergence ranged from 1 day for MELA to 9 days for ORMI.

Root to shoot weight ratios for all species were higher in sand than in clay soils. Roots of HESP penetrated deeper than the others in clay under all moisture regimes. Root depth and shoot weight ratio of ATCA were found to increase as moisture decreased in both

growth mediums. Greatest root penetration for DAGL(PN) and DAGL(TN) occurred when pots were allowed to dry 3 weeks before being watered. Root to shoot weight ratio of ARUN increased as water deficits increased in sand. HECA and ORMI exhibited a limited potential to develop root and shoot growth as water deficits increased.

On the basis of these results, MELA, DAGL(PN and TN), and ARUN were recommended for reseedings on dry sandy sites, whereas HESP was recommended for reseeding on dry clay sites. DAGL(PN), DAGL(TN) and ATCA may also hold promise for revegetating clay soils.

INTRODUCTION

Revegetation of rangelands in central Tunisia is a difficult task. The area is characterized by a Mediterranean climate with low rainfall amounts (250 -350 mm) and hot dry summer temperatures (30 - 45 C). The soil surface is wetted infrequently and emerging seedlings must compete for the rapidly diminishing moisture of the seedbed.

Establishment of seedlings in arid environment depends upon a number of factors. Harper (1977) stressed that under conditions of competition species which have rapid emergence rates, exhibit greater chances for establishment than species with slow emergence rates. Rate of root elongation and amounts of root biomass have also been shown to be important factors enabling certain species to adapt to xeric conditions (Moore 1943, and Whalley et al. 1966). As survace layers of the soil dry ability of roots to maintain contact with deeper soil layers becomes essential for survival of the plants. Research has indicated that species adapted to arid conditions exhibit greater root penetration under water stress conditions that when well watered (Doneen and MacGillivray 1943; Ayers 1952; Bade et al. 1985; Ng et al. 1975; Wilson et al. 1976; and Doescher et al. 1985). Also maintenance of an active shoot system and a favorable root/shoot ratio may aid in the adaptation of seedlings to arid environments (Barbour 1973, and Wilson and Briske 1978). This research was designed to evaluate the emergence and early root and shoot development of species under greenhouse conditions for their potential in revegetating Central Tunisian rangelands. It was felt that species which exibit extensive root growth, good shoot development and high root shoot ratio would be more likely to successfully establish in Central Tunisia than those with weak root and shoot development.

MATERIALS AND METHODS

Two sources of plant material were used in this study; native collections from the semi-arid and arid rangelands of Central Tunisia and improved cultivars from the United States. The following species were collected from indegineous sources in Central Tunisia: Medicago laciniata L. (MELA), Hedysarum carnosum Desf. (HECA), Argyrolobium uniflorum Dec. (ARUN), Oryzopsis miliacea Asch. et schw. (ORMI) and Dactylis glomerata, Tunisian Cultivar (DAGL(TN)). Improved cultivars of Dactylis glomerata var. Palestine (DAGL(PN) and Atriplex canescens (pursh) Nutt. (ATCA) were provided by Soil Conservation Service, Plant Material Center at Monteca, CA and Idaho, respectively.

Plants were grown in pots for 8 weeks under greenhouse conditions, in two growth mediums and under four different moisture regimes. Growth mediums used in this experiment consisted of a clay and sand. The clay soil was classified as the Carney series, typically dark brown dark clay (USDA, SCS 1981) collected from an area near Medford, OR. The surface 3-20 cm layer of the soil was transported back to Corvallis for use in this experiment. Characteristics of the two growth mediums were as follows:

Soil Properties	Clay	Sand
Ph	7.0	7.4
P (ppm)	10	7
<u>Extractable</u> <u>bases</u>		
K (ppm)	308	70
Can meg/100g	41	4.9
Mg meg/100g	14	1.4
Na meg/100g		
B (ppm)	.36	.10
CEC meg/100g	47.5	4.9
OM %	1.6	.10
TN %	.05	.01

Plants were grown in plastic "deepot inserts" filled with 650 grams and 700 grams of clay and sandy soil respectively. Clay soil was broken to fine texture prior to filling pots. Cotton balls were put at the bottom of each pot to prevent leakage of soil. Seeding rate for each species was based on the results of a preliminary test to ensure the emergence of at least four seedlings per pot. The number of seeds placed in each pot were 15, 25, 20, 30, 10, 10 and 45 for MEIA, HECA, HESP, ARUN, ORMI, DAGL(TN), DAGL(PN), and ATCA, respectively. Prior to sowing, MELA seeds were inoculated with appropriate Rhyzobium strains. Due to the non availability of inoculum, seeds of HECA, HESP and ARUN were sown non inoculated.

Four watering treatments were imposed on each of the eight species. These water treatments were designed to cover a wide range of conditions, from a relatively high level of soil moisture (watered every week) to very dry conditions (plants grown dry up to 30 days). Table I.1 summarizes the four moisture regimes used in the experiment. To determine the amount of water to bring each pot to field capacity at each specific watering date, extra tubes were set under the same conditions of the experiment. All pots were seeded with MELA and at the day of each specific watering. Soil and clay samples were

Table I.1: Watering scheme for four moisture regime treatments in the greenhouse study. X indicates when soil moisture of pots was increased to field capacity.

MOISTURE REGIMES	DAYS AFTER PLANTING 5	12	19	26	33	40	47	54
MR1	X	X	X	X	X	X	X	X
MR2	X		X		X		X	
MR3	X			X			X	
MR4	X				X			

taken from two pots each. Soil moisture was determined gravimetrically using soil samples of 10 g dried for 15 mn in a microwave. The amount of water to bring the soil to field capacity was then determined according to the soil moisture content of each soil (Table I.2).

Two days prior to the start of the experiment, all pots were watered to field capacity. Plants were randomly assigned to pots with seeds of each species, placed on the soil surface and covered with 1 cm of dried soil. The top soil surface was then wetted and all pots were covered with a plastic film to avoid the upper soil layer from drying, and, particularly, the formation of a surface crust on the clay soil. Plastic wrap was removed after four days. In addition to normal sunlight, VHO Flourescent lights with wide spectrum lamps were supplied to all plants for 16 hours. Lamp height was adjusted during the experiment with the initial height at 38 cm above the pots and then 18 days later the lamps were set at 47 cm above the pots.

On April 17, 1985 (Day 1) seeds were sown and the experiment continued until Day 56. During that period the mean daily temperature in the greenhouse varied from 15.5 to 21.1^{o}C.

Table I-2 Soil moisture content (%) of the soils used in the greenhouse study.

	Soil Water Content(%)				
Bars	0.1	.03	.08	2.0	15
<u>Soils</u>					
Clay	56.5	47.5	43.4	37.2	29.5
Sand	8.3	7.5	5.4	3.2	2.8

Beginning the second day after planting, counts of emerged seedlings were taken daily for the first week and continued every other day during the second week. Seedlings were thinned to two healthy plants per pot. Any subsequent seedlings which emerged were pulled out after counting.

Plant height and leaf number were measured at 1 week intervals starting 15 days after planting. Root and shoot biomass, as well as rooting depth measurements were taken at the end of the experiment. Root/shoot weight ratio was also calculated. Plants grown in clay soil were soaked in water for three days, after which soil and roots were pulled out of the pot. Roots were separated from the soil by washing with a hose on a screen having 75 mm mesh. Roots from sandy pots were immediately separated from the soil by washing with a fine mist. Roots and shoots were separated and oven dried for 2 days at 50^{o}C and weighed.

The factorial experiment was conducted using a 2 (soil type) x 4 (moisture regimes (MR)) x 8 (species) split-split plot design with four blocks and five replications of each combination of soil - moisture regime - species (Steel and Torrie 1980). Moisture regimes served as main plots while soil type was the subplot in the analysis. Parameters used for analysis were: days to 50% of emergence, defined as the day on which 50% of final (15-day) emergence was reached; final percentage of emergence (15th day after planting); root biomass, shoot biomass, root/shoot weight ratio, root depth, height and leaf number at the final day of the experiment. Differences (= .05) between, soil types, moisture regimes and species were assessed using Bonferroni test for multiple comparison of means (Neter and Wasserman 1974).

RESULTS

Days to 50% emergence

No significant interactions between moisture regimes, soil types and species or between soil type x moisture regimes were noted for days to 50% emergence. A significant interaction, however, was detected between soil type and species (Appendix I-1). Days to 50% emergence ranged from 1 day for MELA to 9 days for ORMI (Table I-3).

Table I-3: Number of days to 50% emergence of eight species grown in two soil types under four moisture regimes in greenhouse conditons.

Species	Mean days to 50% emergence
MELA	1a*
HECA	2.5ab
HESP	4bc
ARUN	2ac
ORMI	9d
DAGL(TN)	5b
DAGL(PN)	3.5ab
ATCA	4bc

* Similar letters denote non-significant differences between species (= .05).

B for 8 means = 2.862

Final Emergence:

No significant interactions were found for analysis of final emergence. Main effect means for soil and moisture regimes were also not significant, however, main effect means of species was significant (Appendix I-2). The relative order of response in final emergence was as follows: DAGL(PN), 85% > HESP, 77% > DAGL(TN) 65% = MELA 63% > HECA 38% > ARUN 31% > ATCA 18% > ORMI 9% (Fig. I-A).

Root Biomass:

A significant soil x moisture regime x species interaction was shown for analysis of variance of root biomass (Appendix I-3).

Figure I.B gives the mean dry weight of roots per pot of the eight species. The average dry weight of roots for MELA, HECA, ARUN, DAGL(PN), DAGL(TN) and ATCA were greater in clay than in sand soil over all moisture regimes. HESP exhibited greater root biomass in sand than in clay under moisture regime 1. The average dry weight of the roots per pot varied with the different species.

As a group legumes produced higher weights of roots than grasses in sand while the inverse occurred in clay soil (Fig. I-B). ATCA, on the other hand, produced greater weights of roots in clay than in sand, but far less than legumes and grasses. However, its weight of

Fig. I.A: Final percent of emergence of eight plant species grown in two soil types under four moisture regimes in greenhouse conditions

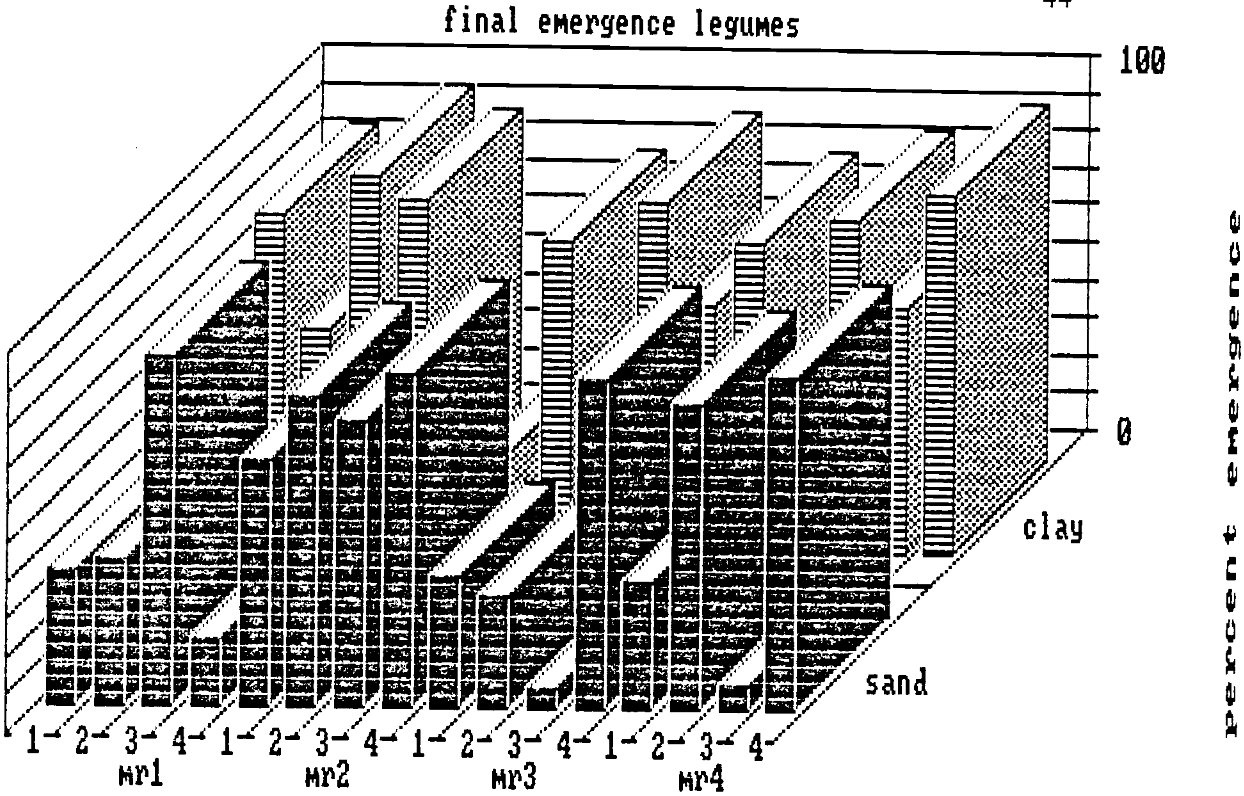
Legend:

a = Final percent of emergence of legumes:
- 1 - MELA
- 2 - HECA
- 3 - HESP
- 4 - ARUN

b = Final percent of emergence of grasses:
- 5 - ORMI
- 6 - DAGL(TN)
- 7 - DAGL(PN)

c = Final percent of emergence of shrubs:
- 8 - ATCA

a


final emergence legumes
100
0
clay
sand
percent emergence
1- 2- 3- 4- 1- 2- 3- 4- 1- 2- 3- 4- 1- 2- 3- 4-
mr1
mr2
mr3
mr4

b

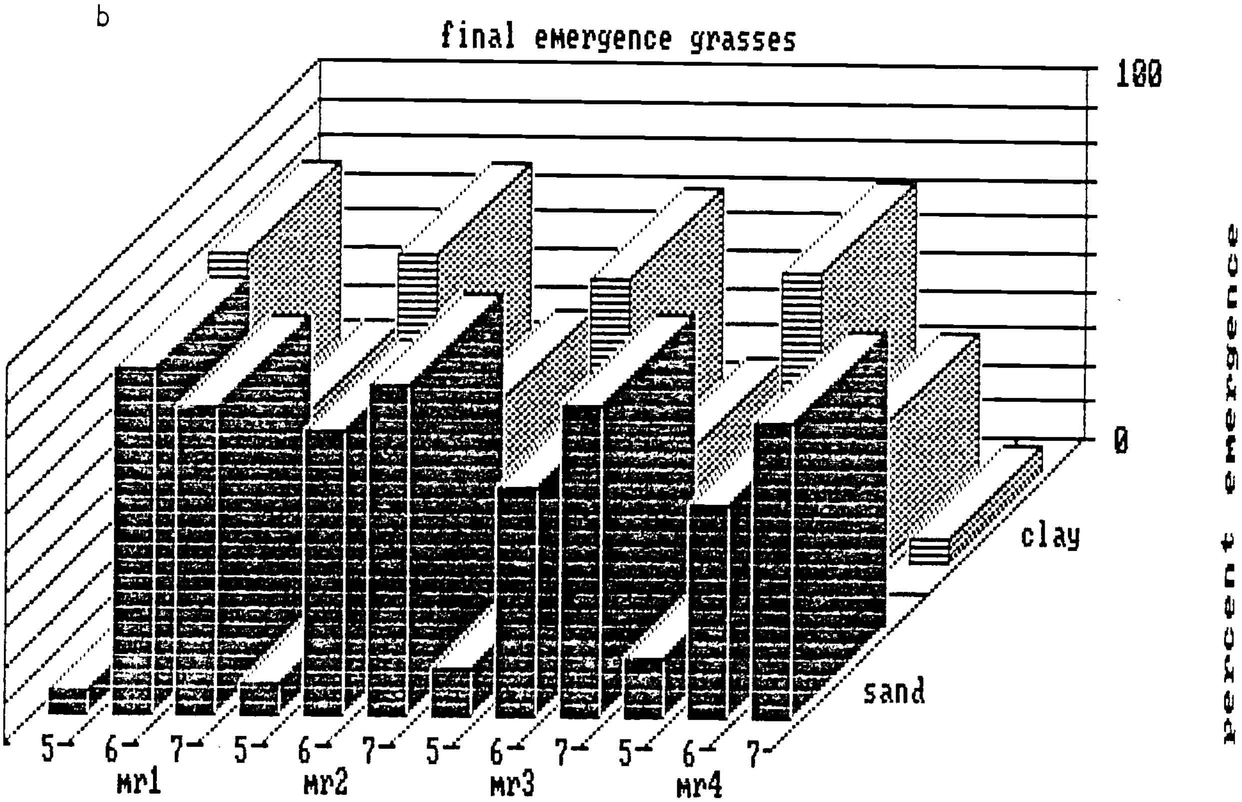

final emergence grasses
100
0
clay
sand
percent emergence
5- 6- 7- 5- 6- 7- 5- 6- 7- 5- 6- 7-
mr1
mr2
mr3
mr4

Fig.I.A

c

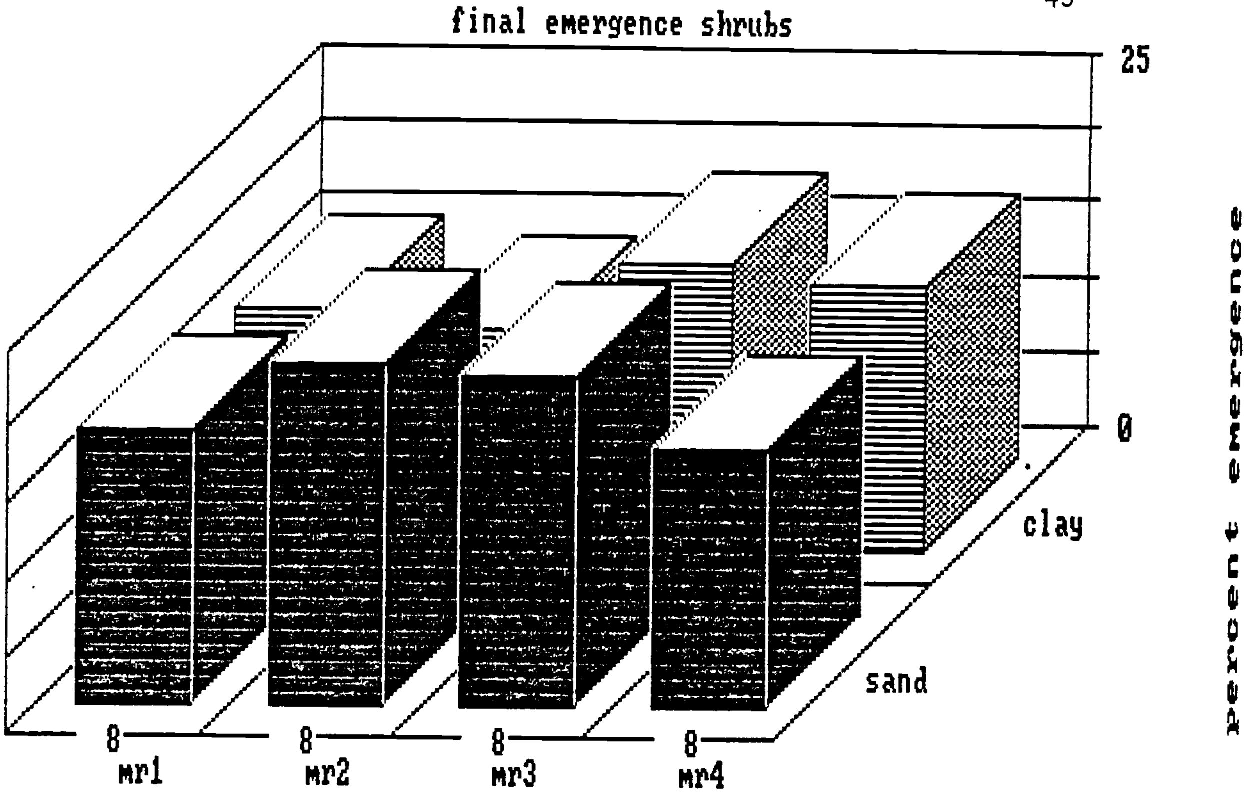

final emergence shrubs
25
0
percent emergence
clay
sand
8
mr1
8
mr2
8
mr3
8
mr4

Fig.I.A Cont.

Fig. I.B: Mean root biomass (mg) of eight species grown on two soil types under four moisture regimes in greenhouse conditions.

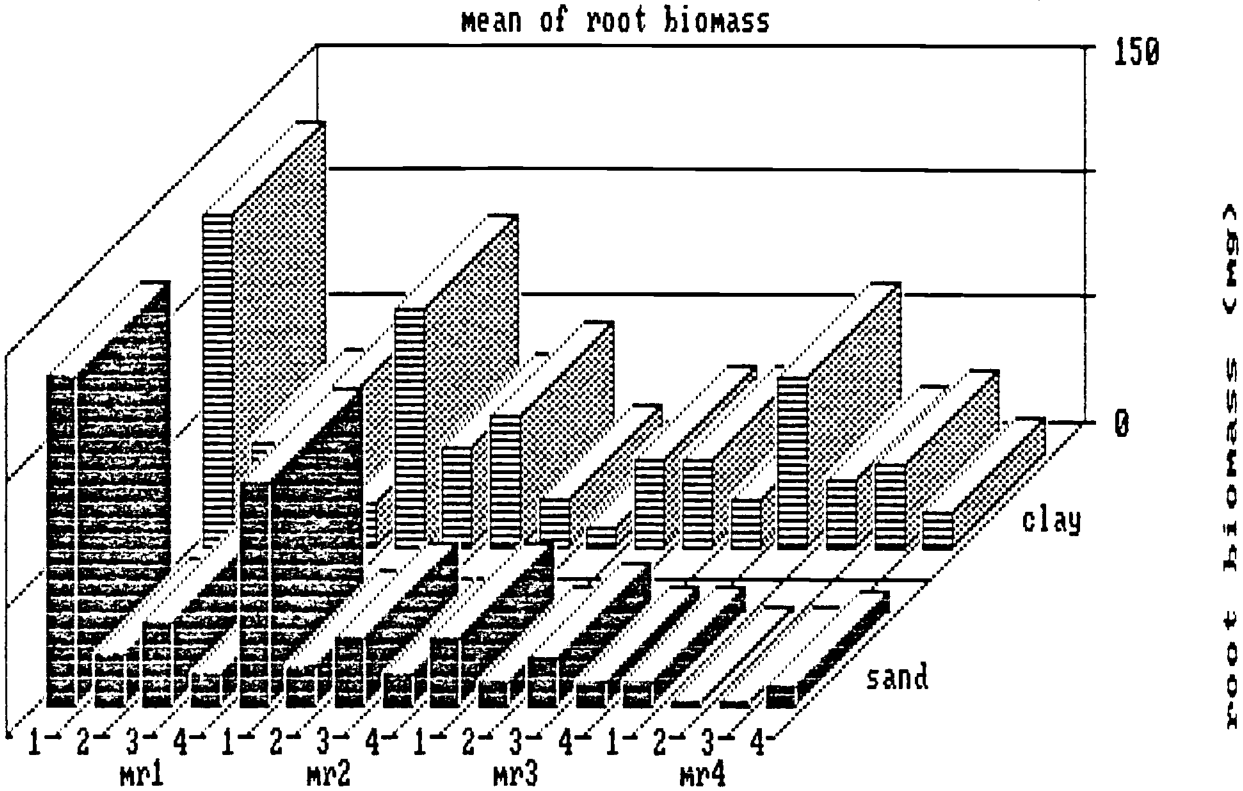
Legend:

a: Mean root biomass (mg) of legumes:
1 - MELA
2 - HECA
3 - HESP
4 - ARUN

b: Mean root biomass (mg) of grasses:
5 - ORMI
6 - DAGL(TN)
7 - DAGL(PN)

c: Mean root biomass (mg) of shrubs:
8 - ATCA

a


mean of root biomass
150
0
root biomass (mg)
clay
sand
1 2 3 4 1 2 3 4 1 2 3 4 1 2 3 4
mr1
mr2
mr3
mr4

b

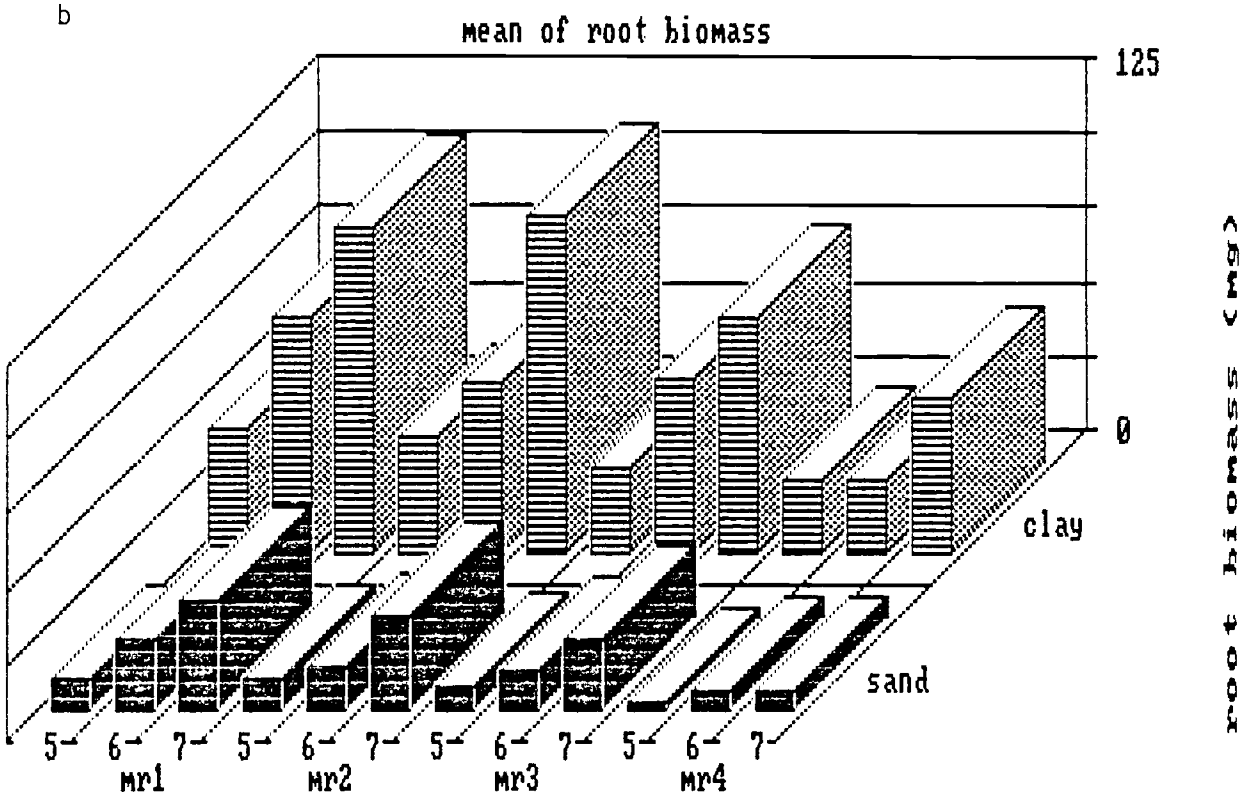

mean of root biomass
125
0
root biomass (mg)
clay
sand
5 6 7 5 6 7 5 6 7 5 6 7
mr1
mr2
mr3
mr4

Fig.I.B.

c

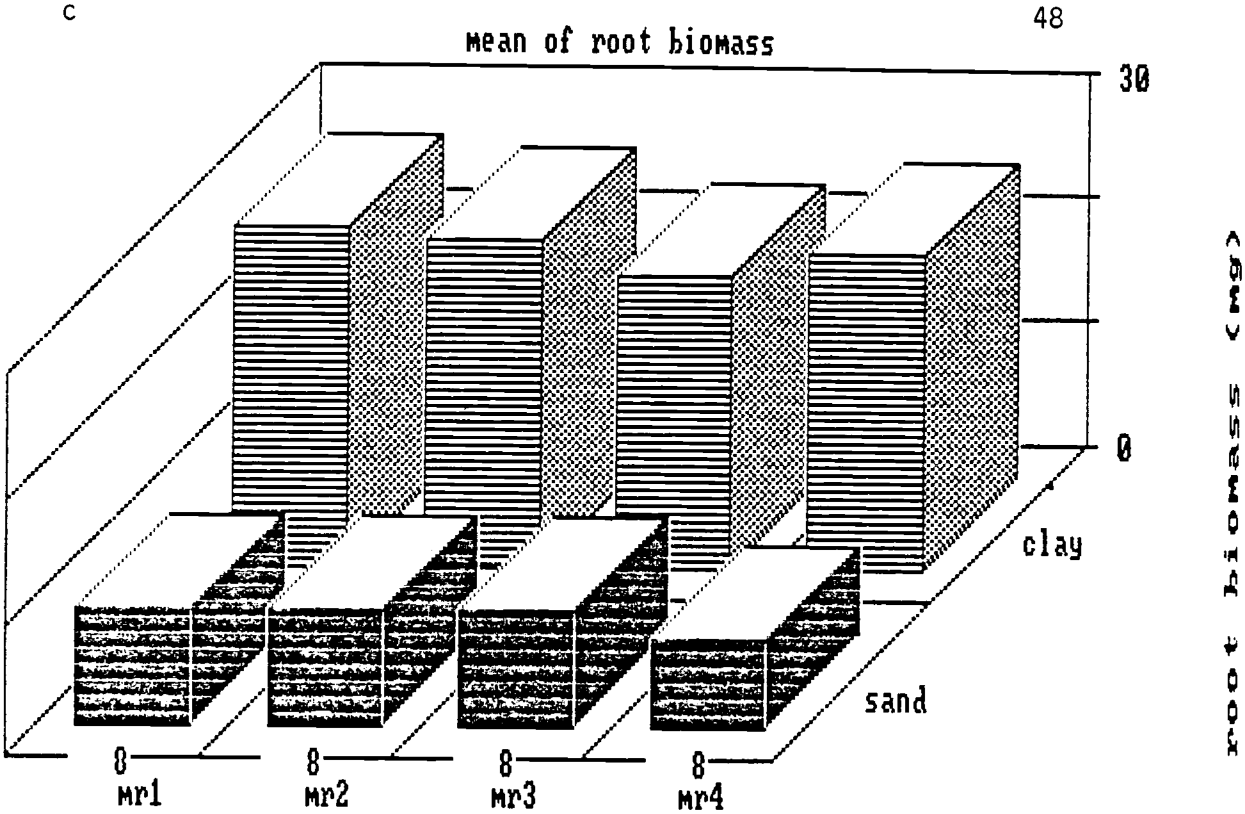

mean of root biomass
30
0
root biomass (mg)
clay
sand
8
mr1
8
mr2
8
mr3
8
mr4

Fig.I.B Cont.

roots was not significantly affected by moisture regimes in both growth mediums.

In both soils, MELA, HECA, HESP, ORMI, and DAGL (TN and PN) exhibited decline in root biomass with increasing soil moisture stress. For both ARUN and ATCA root biomass was not different over all moisture regimes. In sand the following order of species response to moisture regime was found.

Moisture regime 1:
MELA > HESP > DAGL(PN) > DAGL(TN) = HECA > ARUN = ORMI = ATCA

Moisture regime 2:
MELA > DAGL(PN) = HESP > HECA = DAGL(TN) = ARUN = ORMI = ATCA

Moisture regime 3:
MELA = DAGL(PN) > HESP > DAGL(TN) = HECA = ARUN = ORMI = ATCA

Moisture regime 4:
MELA = ARUN = DAGL(PN) = ATCA = DAGL(TN) > ORMI = HECA = HESP

In clay the species' rank was:

Moisture regime 1:
MELA > DAGL(PN) > DAGL(TN) > HESP > ORMI > HECA > ATCA > ARUN

Moisture regime 2:
MELA > DAGL(PN) > DAGL(TN) > HESP = ORMI > HECA > ATCA > ARUN

Moisture regime 3:
MELA > DAGL(PN) > DAGL(TN) > HESP = HECA > ORMI > ATCA > ARUN

Moisture regime 4:
MELA > DAGL(PN) > HESP > HFCA = ATCA = ORMI = DAGL(TN) > ARUN

Rooting Depth:

Soil types x moisture regimes x species interaction was significant (Appendix I-4). Grass roots penetrated deeper in both soils than legume roots. Significantly higher rooting depth occurred in clay for all species over all moisture regimes, except ARUN which penetrated deeper in sand than in clay under moisture regime 1 and DAGL(PN) under moisture regime 1 and 2 (Fig. I-C).

Decreased root depths as a function of declining soil moisture was shown for MELA, HECA, HESP in both growth medium and DAGL(PN) in sand and ORMI in clay. DAGL(PN) exhibited highest rooting depth in MR3 for clay, followed by MR1 and the similar MR2 and MR4 moisture regimes. Rooting depth of ORMI was greatest in sand for MR1 followed by MR3, MR2 and MR4.

For ARUN, rooting depth in clay was greatest in MR2, followed by MR3, MR4 and MR1. In sand, MR1 had greatest root depth followed by MR3, MR2 and MR4.

Greatest rooting depth in sand for DAGL(TN) was shown in MR3 followed by MR1, MR2, MR4. In clay, the greatest rooting depth was in MR1 followed by MR3, MR2 and MR4.

In sand ATCA exhibited similar rooting depth under MR1 and MR2, but had greatest rooting depth in MR3.

Fig. I.C: Mean rooting depth (mm) of eight species grown on two soil types under four moisture regimes in greenhouse conditions.

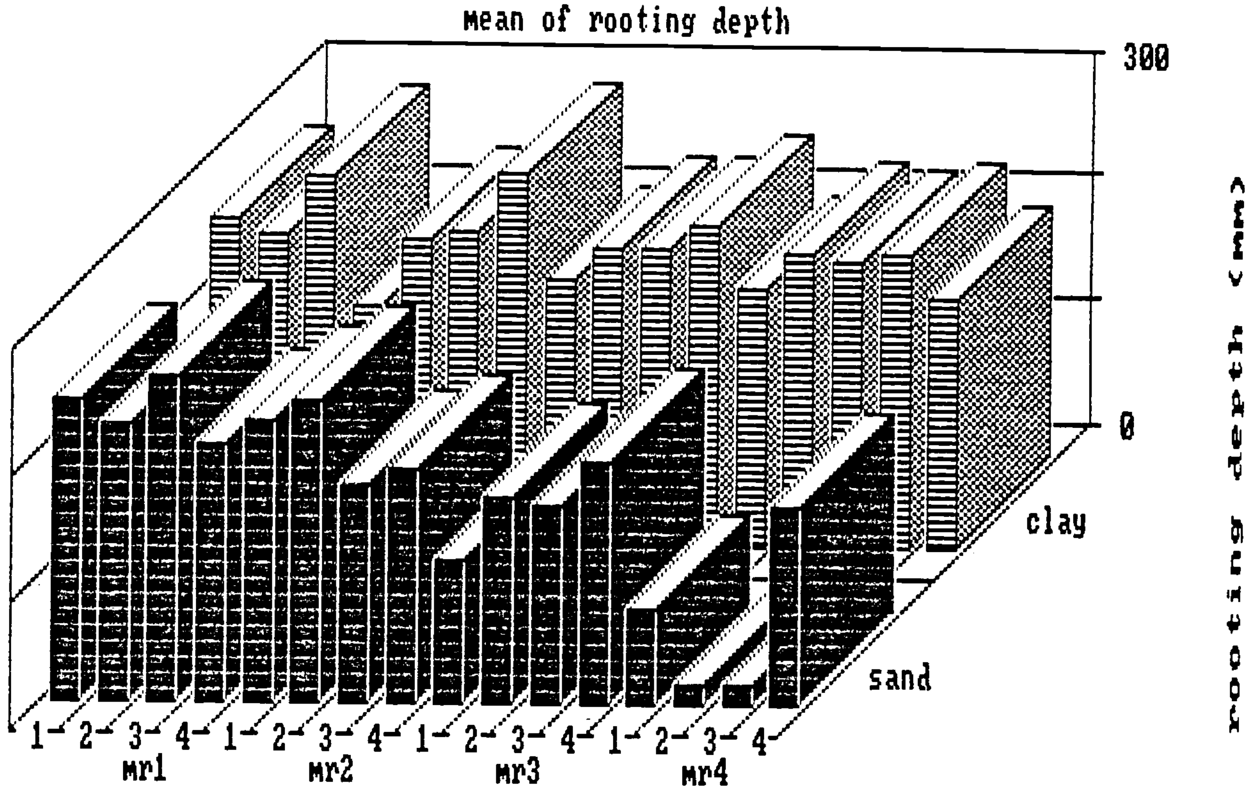
Legend:

a: Mean rooting depth (mm) of legumes
1 - MELA
2 - HECA
3 - HESP
4 - ARUN

b: Mean rooting depth (mm) of grasses:
5 - ORMI
6 - DAGL(TN)
7 - DAGL(PN)

c: Mean rooting depth (mm) of shrubs:
8 - ATCA

a


Mean of rooting depth
300
0
rooting depth (mm)
clay
sand
1- 2- 3- 4- 1- 2- 3- 4- 1- 2- 3- 4- 1- 2- 3- 4
mr1
mr2
mr3
mr4

b

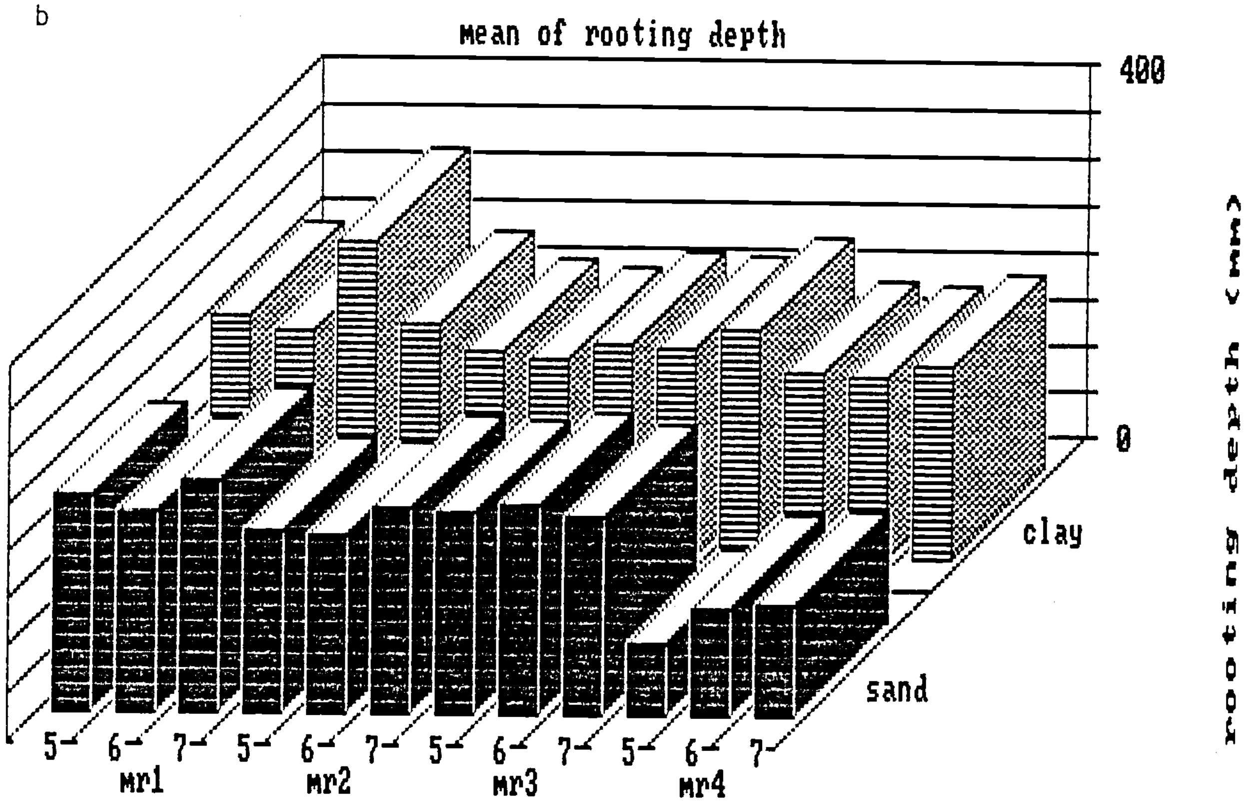

Mean of rooting depth
400
0
rooting depth (mm)
clay
sand
5- 6- 7- 5- 6- 7- 5- 6- 7- 5- 6- 7-
mr1
mr2
mr3
mr4

Fig.I.C

c

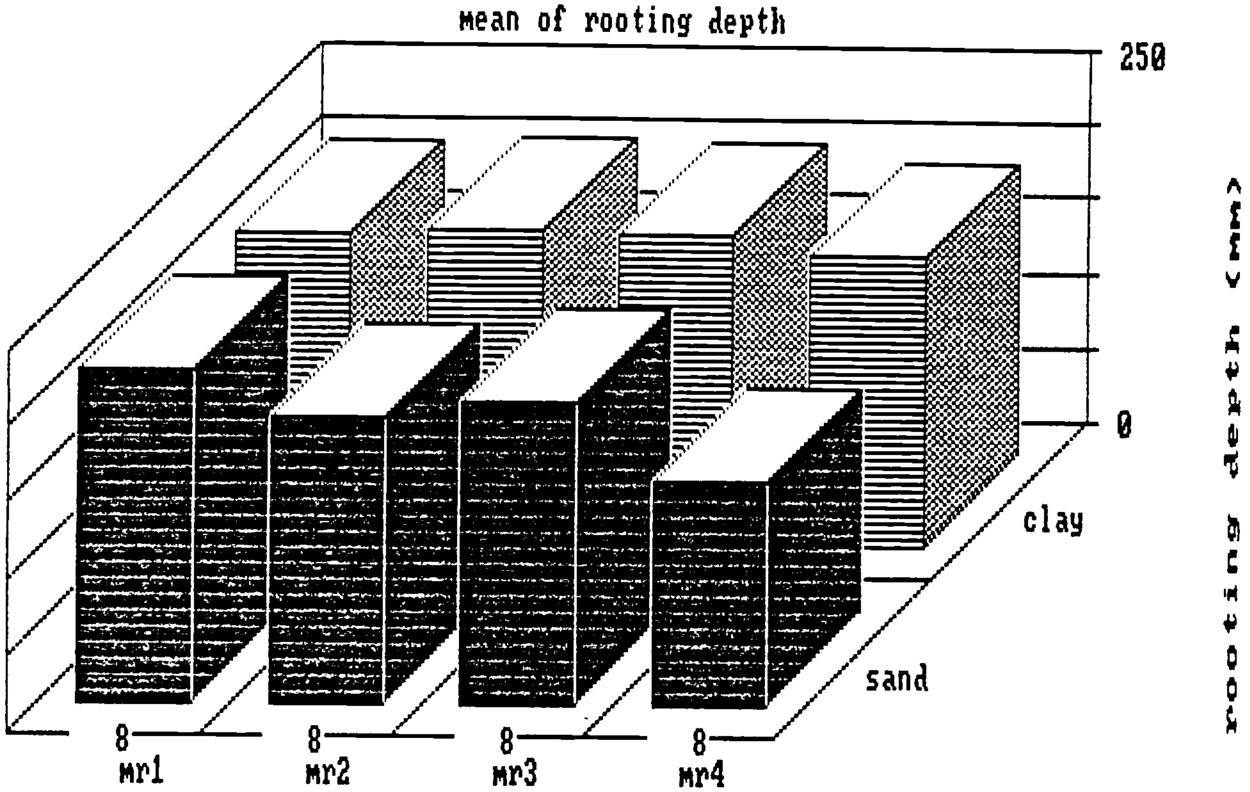

mean of rooting depth
250
0
rooting depth (mm)
clay
sand
8
mr1
8
mr2
8
mr3
8
mr4

Fig.I.C Cont.

In clay soil, rooting depth was not different between MR1 and MR2, while MR1 and MR3 did not differ from one another but MR3 differed from MR2.

In sand the following species response was shown:

Moisture regime 1:
HESP > DAGL(PN) > MELA > ORMI > HECA > DAGL(TN) > ARUN > ATCA

Moisture regime 2:
MELA > DAGL(PN) > ORMI > DAGL(TN) = ATCA = ARUN > HECA = HESP

Moisture regime 3:
DAGL(TN) > ORMI > DAGL(PN) > ATCA > ARUN > HECA > HESP > MELA

Moisture regime 4:
ARUN > ATCA > DAGL(PN) = DAGL(TN) > MELA > ORMI > HECA = HESP

In clay soil the species rank was:

Moisture regime 1:
HESP > ORMI > MELA > HECA > DAGL(TN) = DAGL(PN) > ATCA > ARUN

Moisture regime 2:
HESP > ORMI = HECA > MELA > DAGL(TN) > DAGL(PN) = ARUN = ATCA

Moisture regime 3:
HESP > DAGL(PN) > MELA = HECA > ORMI = DAGL(TN) > ATCA = ARUN

Moisture regime 4:
HESP = MELA > HECA > DAGL(PN) > ORMI > ARUN = DAGL(TN) ≥ ATCA

Shoot Biomass:

Analysis of variance showed significant soil x moisture regime x species interaction (Appendix I-5). Dry weights of shoots were significantly higher in favor of clay over all moisture regimes (Fig. I-D). The greatest shoot yield response to moisture regimes occurred with plants under the wettest moisture regime MR1. In both growth mediums, MELA produced the highest yield over all moisture regimes.

Legumes as a group produced greater shoot biomasses than grasses over all moisture regimes in both soils. In moisture regime 1 and 2 legumes produced as much as three times the production of the same plants in moisture regimes 3 and 4.

Shoot biomass declined in both soils from MR1 to MR4 for MELA, HECA, HESP, ORMI, and DAGL(TN and PPN). This trend was also evident in clay for ATCA and sand for ARUN. Moisture deficits did not reduce shoot biomass in sand for ATCA. For ARUN, similar shoot bionass was detected between MR1, MR2 and MR3.

The relative order of shoot biomass for all species in sand was:

Moisture regime 1:
MELA > HESP > HECA > DAGL(PN) = ARUN = ATCA > DAGL(TN) = ORMI

Moisture regime 2:
MELA > HESP > HECA = ATCA = DAGL(PN) = ARUN $\geq$ DAGL(TN) = ORMI

Moisture regime 3:
MELA > HESP > HECA = ATCA = DAGL(PN) > ARUN = ORMI = DAGL(TN)

Fig. I.D: Mean shoot biomass (mg) of eight species grown on two soil types under four moisture regimes in greenhouse conditions.

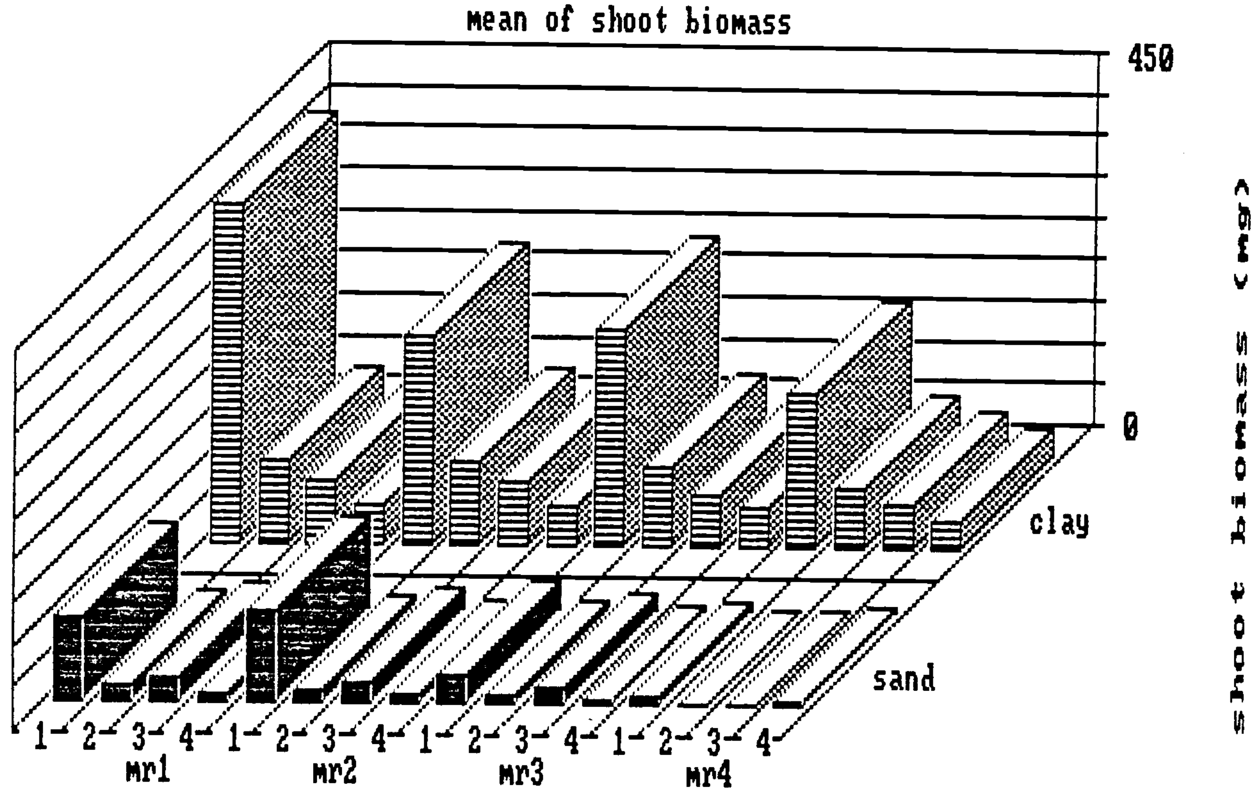
Legend:

a: Mean shoot biomass (mg) of legumes
   1 - MELA
   2 - HECA
   3 - HESP
   4 - ARUN

b: Mean shoot biomass (mg) of grasses:
   5 - ORMI
   6 - DAGL(TN)
   7 - DAGL(PN)

c: Mean shoot biomass (mg) of shrubs:
   8 - ATCA

a


mean of shoot biomass
450
0
shoot biomass (mg)
clay
sand
1- 2- 3- 4- 1- 2- 3- 4- 1- 2- 3- 4- 1- 2- 3- 4-
mr1
mr2
mr3
mr4

b

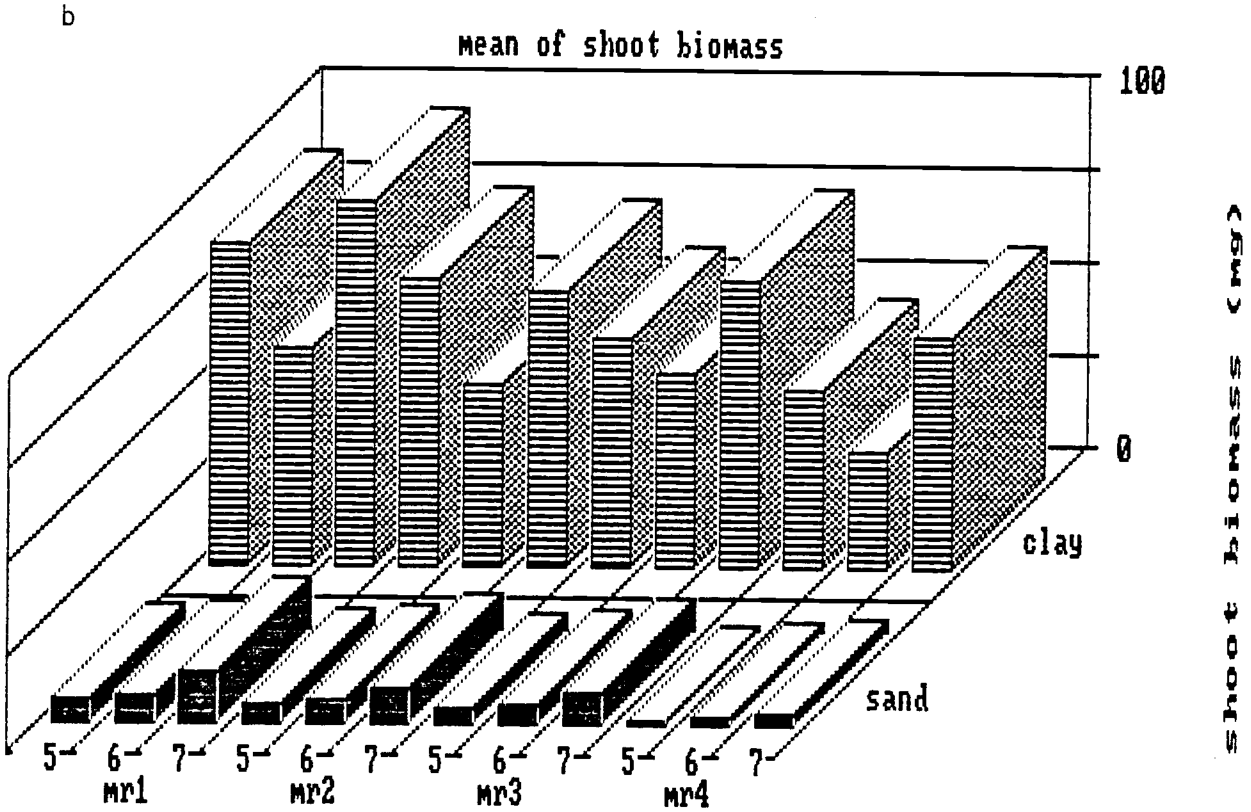

mean of shoot biomass
100
0
shoot biomass (mg)
clay
sand
5- 6- 7- 5- 6- 7- 5- 6- 7- 5- 6- 7-
mr1
mr2
mr3
mr4

Fig.I.D

c

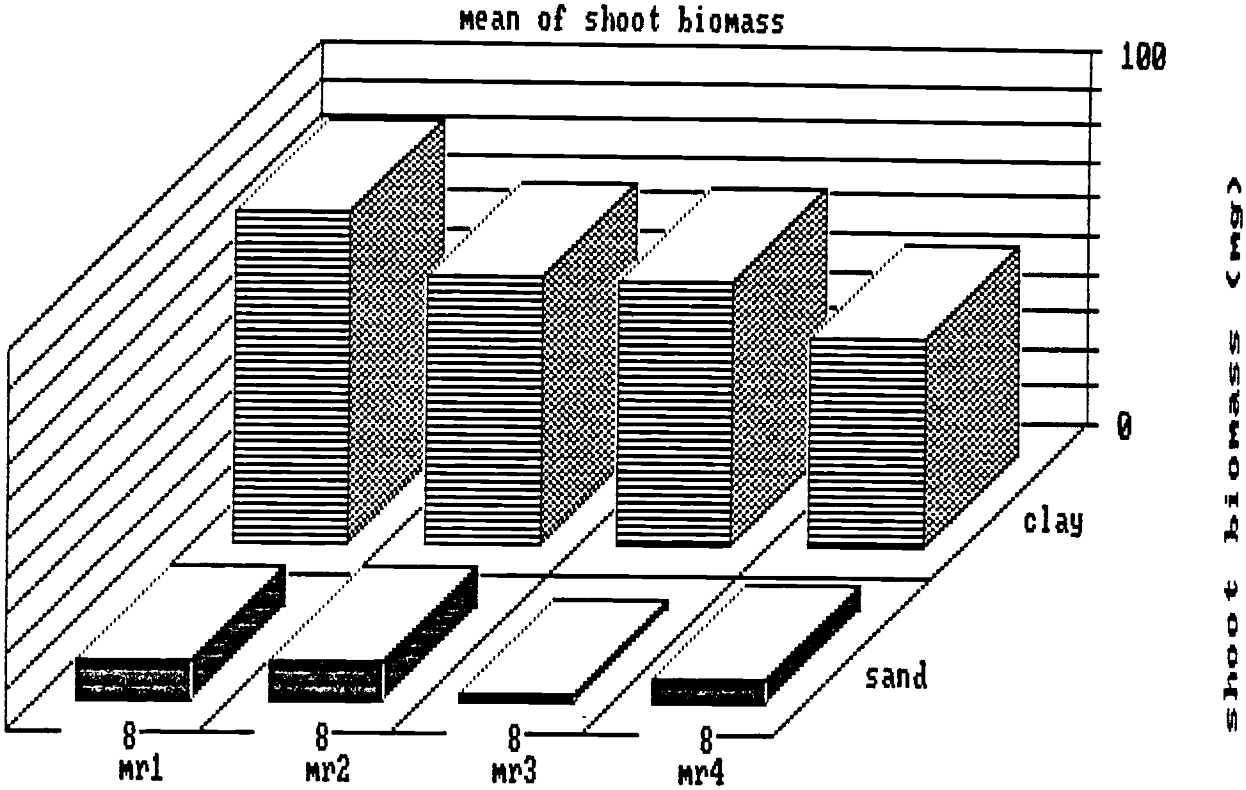

mean of shoot biomass
100
0
clay
sand
8
mr1
8
mr2
8
mr3
8
mr4
shoot biomass <mg>

Fig.I.D Cont.

Moisture regime 4:
MELA = ATCA $\geq$ ARUN > DAGL(PN) = HESP = DAGL(TN) = ORMI = HECA

In clay the species rank was:

Moisture regime 1:
MELA > DAGL(PN) = HECA > ATCA = ORMI > HESP > DAGL(TN) > ARUN

Moisture regime 2:
MELA > HECA > HESP = ORMI = DAGL(PN) $\geq$ ATCA > DAGL(TN) = ARUN

Moisture regime 3:
MELA > HECA > DAGL(PN) > ATCA > ORMI = HESP > DAGL(TN) > ARUN

Moisture regime 4:
MELA > HECA > DAGL(PN) > ATCA = HESP > ORMI > DAGL(TN) = ARUN

<u>Root/Shoot</u> <u>Ratio</u>:

A significant soil x moisture regime x species interaction occurred for root/shoot weight ratio (Appendix I-6).

Root to shoot weight ratios ranged from 3.74 for DAGL(PN) in MR1 to .07 for HESP in MR4. All species produced higher root to shoot weight ratios in sandy soil than in clay soil over all moisture regimes except ORMI and ATCA where root to shoot weight ratios were not different under moisture regime 3. Under the four week drying regime (MR4), legumes showed a significant decrease of root/shoot weight ratio in sand and an increase in clay soil. In contrast grasses showed an increase of root/shoot weight ratios in sand and a decrease in clay. In sand as soil moisture availability decreased (from MR1 to MR2) root shoot weight ratio of ORMI, DAGL(PN and TN) and ATCA increased (Fig. I-E). ATCA was the only species where root to shoot weight ratio increased as water deficits increased from moisture regimee 1 to moisture regime 4 in both soils, except for the decrease marked in clay soil in moisture regime 3. In clay root to shoot weight ratios for 1) HECA, HESP, ARUN and DAGL(TN), 2) ORMI, DAGL(PN) and ATCA, and 3) MELA were not different between moisture regime 2 and 3, moisture regime 1 and 2, and moisture regime 1, 2, and 3 respectively. However, root to shoot weight ratios for ORMI were similar over all moisture regimes in clay. The following species rank in sand was obtained:

Moisture regime 1:
DAGL(TN) = DAGL(PN) > ORMI > HESP > ARUN > HECA > MELA = ATCA

Moisture regime 2:
DAGL(PN) = DAGL(TN) > ORMI > ARUN > HESP > MELA = HECA > ATCA

Moisture regime 3:
ARUN > DAGL(PN) = DAGL(TN) > HECA = HESP = ORMI = MELA > ATCA

Moisture regime 4:
DAGL(PN) = DAGL(TN) > ARUN > ATCA > ORMI > MELA > HECA > HESP

Fig. I.E: Mean root/shoot weight ratio of eight species grown on two soil types under four moisture regimes in greenhouse conditons.

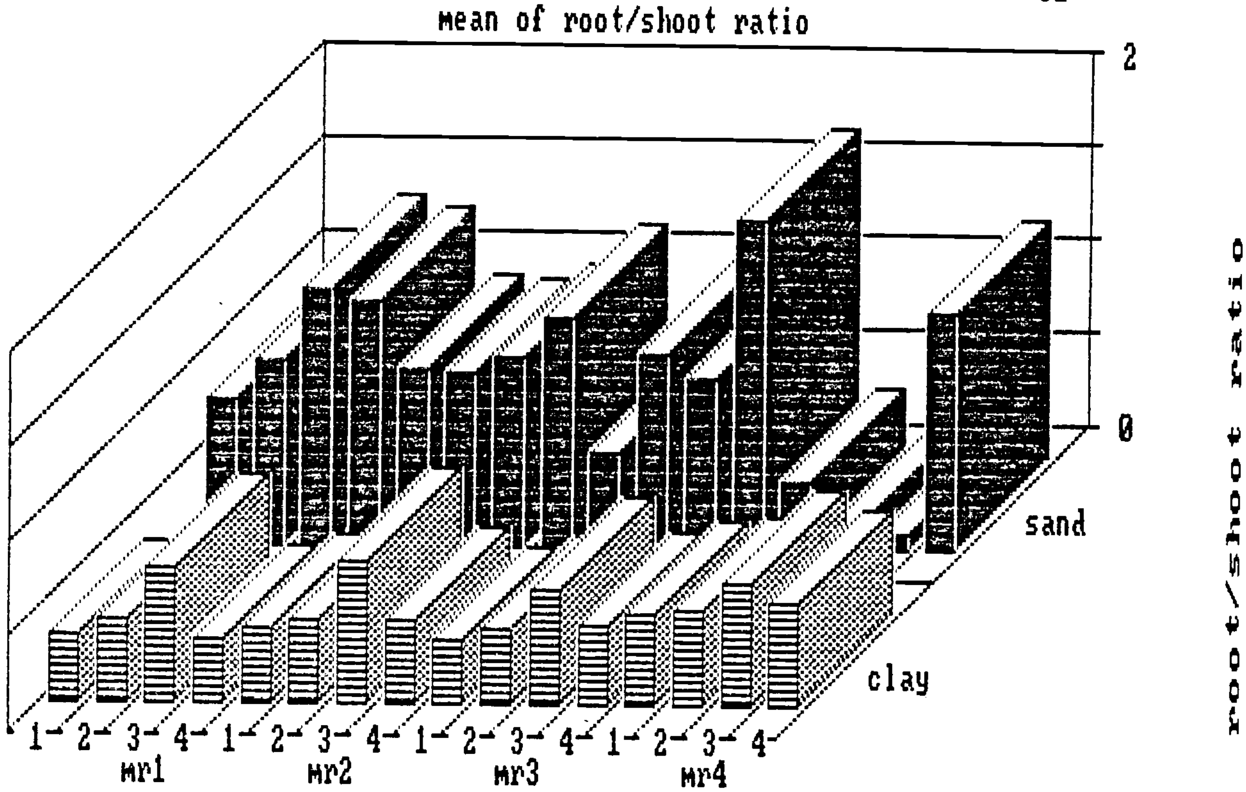
Legend:

a: Mean root/shoot weight ratio of legumes
1 - MELA
2 - HECA
3 - HESP
4 - ARUN

b: Mean root/shoot weight ratio of grasses:
5 - ORMI
6 - DAGL(TN)
7 - DAGL(PN)

c: Mean root/shoot weight ratio of shrubs:
8 - ATCA

a


mean of root/shoot ratio
2
0
sand
clay
1- 2- 3- 4- 1- 2- 3- 4- 1- 2- 3- 4- 1- 2- 3- 4-
mr1
mr2
mr3
mr4
root/shoot ratio

b

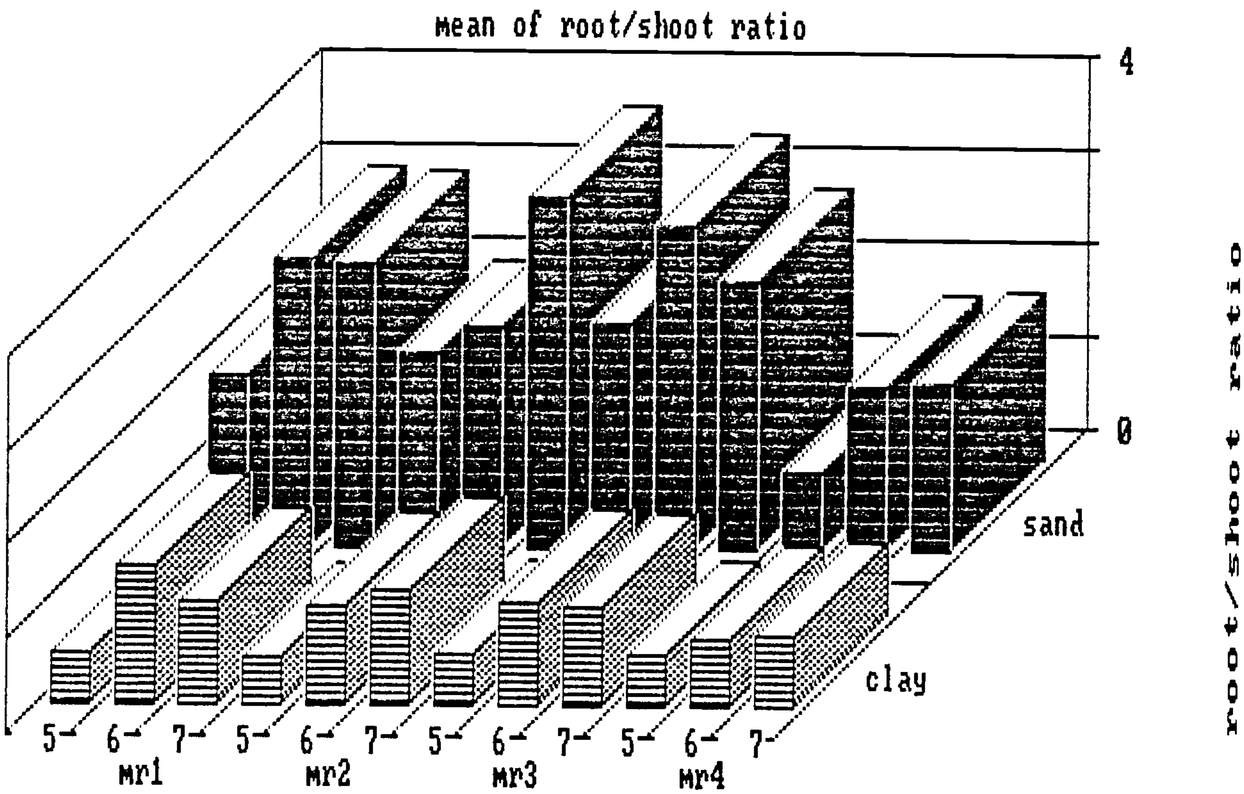

mean of root/shoot ratio
4
0
sand
clay
5- 6- 7- 5- 6- 7- 5- 6- 7- 5- 6- 7-
mr1
mr2
mr3
mr4
root/shoot ratio

Fig.I.E

c

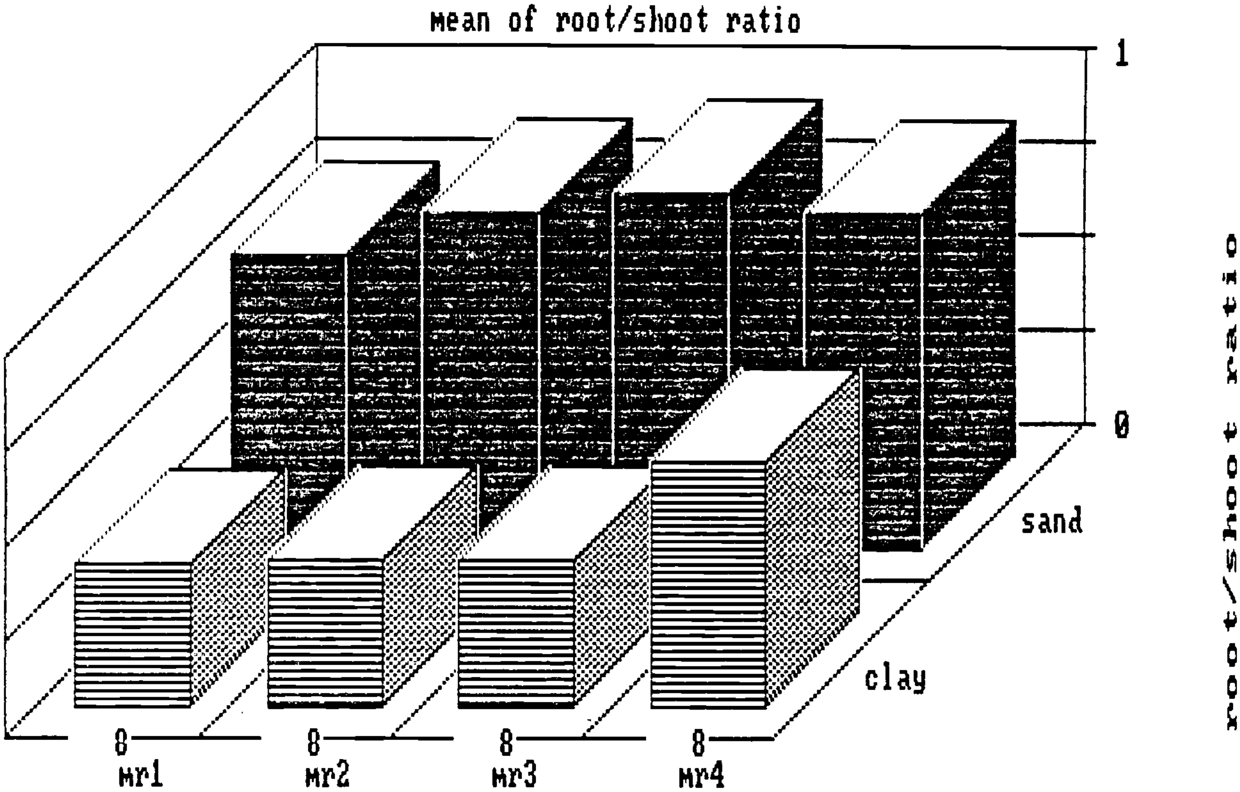

Mean of root/shoot ratio
1
0
sand
clay
root/shoot ratio
8
mr1
8
mr2
8
mr3
8
mr4

Fig.I.E Cont.

In clay the species rank was:

Moisture regime 1:
DAGL(TN) > DAGL(PN) > HESP > ORMI > HECA > ARUN = MELA = ATCA

Moisture regime 2:
DAGL(TN) > DAGL(PN) > HESP > ORMI > ARUN = HECA > ATCA = MELA

Moisture regime 3:
DAGL(TN) = DAGL(PN) > HESP > ORMI > ARUN = HECA = ATCA = MELA

Moisture regime 4:
DAGL(PN) > DAGL(TN) > ATCA = HESP > ARUN = ORMI > MECA = MELA

Shoot Height:

Soil x moisture regime x species interaction was significant for shoot height at the end of the experiment (Appendix I-7). Table I-4, summarizes the analysis of variance for shoot height.

Greatest heights were recorded in favor of the clay over all moisture regimes. A significant reduction in shoot heights was seen from moisture regime 1 to moisture regime 4 in both growth mediums for HECA, HESP, and ORMI (Table I.4). A similar response was shown for MELA, ARUN, DAGL(TN) and DAGL(PN) in sand and ATCA in clay. For MELA in clay, highest shoot height was shown in WR1 followed by WR4, WR2 and WR3. Shoot height for ARUN grown in clay were similar between MR1, MR2 and MR3, but declined in MR4. A similar shoot height was found for DAGL(PN and TN) between MR2 and MR4 but these were less

Table I.4: Three way interaction means for the Height of 56-day old seedlings of eight species grown on two soil types under four moisture regimes in greenhouse conditions. Error Mean Square value from analysis of variance was 707.9

than MR1. When ATCA was grown on sandy soils it exhibited greatest shoot height under MR2 in comparison to the similar shoot heights under MR1 and MR3.

In sand the ranking of species was:

Moisture regime 1:
MELA > DAGL(PN) > DAGL(TN) > ORMI > HESP > ATCA > HECA > ARUN

Moisture regime 2:
MELA > DAGL(PN) > DAGL(TN) = ORMI ≥ ATCA > HESP > HECA = ARUN

Moisture regime 3:
DAGL(PN) > DAGL(TN) = ORMI = ATCA > HESP = MELA > HECA = ARUN

Moisture regime 4:
DAGL(PN) > DAGL(TN) = ATCA = ORMI > MELA > ARUN > HESP = HECA

In clay the species rank was:

Moisture regime 1:
MELA > ORMI > DAGL(PN) > DAGL(TN) > ATCA > HESP > ARUN = HECA

Moisture regime 2:
MELA > ORMI > DAGL(PN) > DAGL(TN) > ATCA > HESP > ARUN = HECA

Moisture regime 3:
MELA > ORMI > DAGL(PN) > DAGL(TN) > ATCA > HESP = ARUN > HECA

Moisture regime 4:
MELA > ORMI > DAGL(PN) > DAGL(TN) > ATCA > HESP > ARUN > HECA

Leaf Number:

The analysis of variance of leaves showed the significance of all the main effects as well as the second order interactions of soil x species and moisture regime x species. In both growth mediums and over all moisture regime levels the number of leaves of MELA was significantly different from the other seven species. Moreover, this species showed the highest number of leaves in both growth mediums and under all moisture regime levels followed by ORMI (Table I-5). Greater number of leaves was in favor of clay for all the species studied.

Table I.5: Two interaction means for total leaf number of eight species grown on two soil types. Errormean square value from analysis of variance was 0.72

SPECIES	SAND(S1)	CLAY(S2)
MELA	7.388a *	28.700a
HECA	.900b	3.363b
HESP	1.675b	4.138bc
ARUN	1.113b	3.588b
ORMI	2.750b	6.913c
DAGL(TN)	2.475b	5.038bc
DAGL(PN)	2.700b	6.425bc
ATCA	2.625b	6.038bc

* Similar letters denote non significant differences between species at a particular Soil type /Moisture Regime level (α =.05).

B for 8 means = 2.862

DISCUSSION

Results revealed significant differences in the rate of emergence as well as final percent of emergence for all species studied. Both growth mediums and moisture regime did not affect the emergence of any species. Apparently, this observation resulted from adequate soil moisture levels being present for germination during the 15 day period. It may also be due to the fact that all pots were covered with a plastic film for 4 days after sowing, which helped reduce soil surface drying.

As a group, legumes emerged faster than grass in both growth mediums while the grasses reached higher percentages of emergence earlier in the 15 day period. This agrees with the findings of McWilliams et al. (1965) where legumes (*M. sativa* L., *Trifolium repens* L. and *T. subterraneum* L.) exhibited significantly higher rates of germination and emergence. They found that legumes imbibed water more rapidly than grasses, and reached higher rates of initial moisture content before germination.

The slow emergence encountered with ORMI, ARUN, ATCA and HECA may be due to physiological factors associated with seed dormancy. Such factors may include innate dormancy, inhibitor substances morphological barriers or polymorphic characteristics of seeds. For example, emergence of ORMI seeds may be retarded depending upon the season of harvest and the maturity of the embryo at harvest. It may take up to 6 months for seeds of this species to be fully developed (Le Houerou 1979).

Harper (1977) stressed the importance of the speed of germination in the establishment of seedlings when he stated "the faster a seed germinates, the greater is its potential for establishing under condition of competition." This response may or may not be an advantage for a species under the environment of Central Tunisia. If moisture is adequate for long periods of time, then fast germinating seeds may be an advantage when establishing under condition of competition. This scenario maybe more appropriate for fall seeding in Central Tunisia where a better chance exists for occurrence of long moist periods. If precipitation occurs at infrequent intervals and soils have a potential to dry out rapidly, then a rapidly germinating seed may be at a disadvantage since it faces immediate moisture shortage before developing enough roots. However, emergence is only one part of successful establishment ability. Ability to elongate roots to keep up with soil moisture is another important component of this process.

Given the uncertain duration of rainy periods, seedling establishment depends on early root growth being rapid enough to establish the plant in deeper soil before the surface layer dries (Barbour 1973). All species examined maintained relatively deep roots in clay soils across all moisture regimes. In sandy soils, both HECA and HESP exhibited marked decline in their rooting depth under MR4. This result may have occurred by the ability of clay to retain more moisture than sand. Lack of innoculum for HECA and HESP may have contributed to this result in comparison to the innoculated MELA. However, non-inoculated plants of ARUN were found to maintain good root growth in both soils which may indicate that this species does not depend upon innoculation during early developmental stages. In addition, the higher nutrient levels shown for the clay versus sand may have resulted in the increase of root reponse for the clay. One of the important findings of this research was the obeservation that certain species grew deeper roots under the relatively dry regime (MR3, MR4) than MR1. Roots of DAGL (TN), and ATCA penetrated deeper into sandy soils in the relatively dry moisture regime (MR3) than in the relatively wet regime (MR1). For clay soil, DAGL(PN) penetrated deeper under MR3 than MR1, and ARUN grew deeper roots in moisture regimes 3 and 4 than MR1. This is a significant result because it indicates that these plants are adapted to conditions of moisture stress by developing extended roots to ensure water pumping from still moist deep layers. These findings agree with the research of Molyneux and Davies (1983), who found roots of water stressed DAGL seedlings growing deeper into the profile than roots of well watered plants. They considered this to be an important adaptation for a species to cope with arid enviornments since deeper roots are promoted by water deficit conditions.

HESP, also, exhibited an interesting pattern of root elongation. It maintained the deepest roots of any species across all moisture regime in clay soils. However, deeper roots in sandy soils were restricted to moisture regime 1. The root performance of this species indicates that the plant relies for water almost entirely on the surface layer in sand soil and appears well adapted to clay soil regardless of water deficits.

Plants that maintain high root/shoot weight ratios may also be able to survive in dry soils better than plants with low root/shoot ratios. High root/shoot ratio indicates more roots are developed maintain the balance between water absorbed and transpired. In addition this behavior may indicate that under water stress conditions, the plant has a tendency to allocate carbohydrates toward more root growth than shoot growth to keep up with the high need of transpiration exhibited by the above ground parts. This phenomena may have occurred in this study for DAGL(PN), DAGL(TN), ARUN, ORMI and ATCA. These species exhibited significant increases in their root/shoot ratio as water deficits developed in sand or clay. These findings contrasted to those of Barbour (1973) who concluded that "Desert perennial plants do not possess a fast growing root system, and do not produce a high root/shoot ratio." He added that the highest root/shoot ratios appear in meadow communities. Yet, in this study, species originating from the driest areas (DAGL(PN), DAGL(TN) and ARUN) tended to have higher root/shoot weight ratio across all moisture, than those originated in mesic areas (MELA, HESP and ORMI).

CONCLUSION

Results obtained provided an initial basis for the screening of species suitable for revegetating Central Tunisia rangelands. It was felt that species which exhibited fast emergence rate, high total emergence, rapid root development, maintenance of a favorable root/shoot weight ratio and high shoot biomass under conditions of moisture stress may have a greater chance to successffully establish under arid land of Central Tunisia. Although, one species rarely exhibits all of these characteristics, a combination of traits conceivably enhances the probability of long term establishment.

Revegetation is most difficult on dry sites. On the basis of this research, the following recommendations can be made concerning the selection of plants on xeric rangelands of Central Tunisia:

1. Dry sandy sites:

Perennials such as DAGL(TN), DAGL(PN), ARUN and the annual MELA with good emergence characteristics, deep rooting systems, great root biomass and high root to shoot weight ratios may hold promise for revegetating these sites.

2. Dry clay sites:

HESP, which exhibited good root and shoot growth regardless to the depletion of soil moisture appears suitable for revegetating dry clay sites in Central

Tunisia. In addition, but to a lesser extent, DAGL(PN) and DAGL(TN) and ATCA may also have a good chance to successfully establish in the dry clay sites.

In addition to the above species, HECA and ORMI, which showed limited potential of root and shoot growth, may be restricted for revegetation of relatively mesic areas where adequate soil moisture is available later in the growing season.

Both seedling establishment and drought resistance at maturity are important factors in determining the adaptability of species for revegetating dry sites. It is necessary to conduct further investigations of the recommended species under field conditions to assess their potential for long term survival and persistence under climatic hazards of Central Tunisia. In addition, evaluations of the forage value to livestock need to be made to ensure that species will supply sufficient quantities of forage and nutrients during critical season of the year.

SECTION II

EVALUATION OF PLANT SPECIES FOR REVEGETATING CENTRAL TUNISIAN RANGELANDS: FIELD ASSESSMENT

EVALUATION OF PLANT SPECIES FOR REVEGETATING CENTRAL TUNISIAN RANGELANDS: FIELD ASSESSMENT

ABSTRACT

Testing of 142 grass and forb species and varieties for their adaptability to environmental conditions of Central Tunisia has been conducted on three range sites in Central Tunisia, BRIKATE, SAYADA NORD, SBIBA. Mean densities at the end of the second growing season were recorded for the species and varieties which survived at each site. Several species and varieties failed to emerge and several others emerged but failed to survive through the second growing season. Several factors such as inadequate conditons for germination and survival (inadequate rain and high temperature), seed predation by rodents and non-adaptability of the species to the site may account for mortality. Differences between mean densities at the end of the second growing season were not significant for cool season species "other" (other than Agropyron types) on the three sites, for warm season species on both BRIKATE and SBIBA sites and for cool season species "Agropyron" in SBIBA site. Significant differences were detected for forb species on the three sites, and for cool season species "Agropyron" on both SAYADA NORD and SBIBA sites. *Sporobolis myroculis*,

<u>Plantago albicualis</u> and <u>Medicago ciliaris</u> exhibited high mean densities on BRIKATE site. At SBIBA site <u>Agropyron elongatum</u> ("Largo" and "Gose"), <u>A. intermedium</u> ("Oahe", "Tegmar" and "Trigo"), <u>A. trachycanlum</u> ("Revenue"), <u>A. sibiricum</u>, <u>Plantago albicaiulis</u>, <u>Hedysarum coronarium</u>, <u>Trifolium vesiculosum</u> and <u>Hedysarum carnosum</u> were the most promising species based on their high mean densities at the end of the second growing season. <u>Agropyron sibiricum</u>, <u>A. desertorum</u> ("Nordan") and <u>A. dasystachyum</u> ("Critana") <u>Plantago albicaulis</u>, <u>Medicago spp</u>. and <u>Hedysarum caronarium</u> from the forb category appeared the most suitable for revegetating SAYADA NORD site.

INTRODUCTION

During the past twenty years livestock numbers have dramatically increased in Central Tunisia. In particular, sheep populations has increased from 750,000 in 1965 to a total of over 2,000,000 in 1982. This increase is a result of changes in the living patterns by the people of the area. Large nomadic movements of the past have been replaced by villages. Consequently, smaller herds of livestock are confined to specific areas which cause a higher grazing pressure on the vegetation of the area by continuous heavy use and poor management. As a general rule, livestock consume all of the available forage resources. This results in an imbalance between forage production and feed requirements of the livestock, and an overall degradation of plant communities.

One of the primary problems facing agriculture agencies of the Tunisian Government is the establishment of productive forage species for livestock production. This is a difficult process, for the area is characterized by a Mediteranean climate with low rainfall (250 to 450 mm annually) and very hot summer temperatures (30 to 45^{o}C). In addition, the sites in need of revegetation are characterized by harsh environments for seedling establishment and plant adaptation. The upper soil layer has been stripped of a large proportion of the vegetative cover as a result of overgrazing.

The selection of varieties and species of plants that have the capacity to establish and survive in Central Tunisia is of prime importance. Species must also be palatable to livestock and provide good cover to prevent soil degradation. To date, very little research has screened different species for their adaptability to these conditions. The purpose of this study was to test under field conditions native and introduced grass and forb species for the purpose of selecting those which appear promising for revegetating Central Tunisia rangelands.

DESCRIPTION OF THE STUDY AREA

Central Tunisia comprises approximately 2,186,790 ha of land, most of which is dominated by *Artemisia herba-alba* (Asso.) *Arthrophytum scoparium* and *Stipa tenassissima* (L.). Evaluation of the early establishment of planted species was performed in three range sites in Central Tunisia.

Brikate site: The elevation of the Brikate site is approximately 200 m and is dominated by the half shrubs *Artemisia herba-alba* and *Artrophytum schmittianism* (Pomel) Mand W. In the understory, few perennial plants survive in a stunted state, while annuals are present during a short period and are often restricted by soil conditions. Native plants in this area may include such desirable species as *Stipa retorta* (Desf.), *Cenchrus ciliaris* Linn. *Artemisia herba-alba*, as well as other forbs and browse species.

Average annual precipitation is 301 mm (average of 39 years) at the station of Sidi Saad, 207 mm was the average annual precipitation recorded during the time of the experiment at the station of Nasrallah (Table II.1). Most of the precipitation falls in the fall and spring months. During the last 3 years, fall and spring precipitation was 91%, 22% and 64% respectively of the yearly total of

207.4 mm. Brikate is also a part of the Higher Arid Mediterranean bioclimatic zone. Hence, summers are extremely hot and winters range from cold to temperate (Le Houerou 1969). Average yearly temperature is 18.7^{o}C, with the highest levels occurring in the June through October period (25.5^{o}C), and lowest between November and April (12^{o}C).

Soils at the Brikate site are shallow, rocky, loamy plains, with moderate permeabilty. A soil pit has shown that good and arable soil layers go to a depth of 8 cm, below which big rocks appear on the bare rock at a depth of 30 cm.

The area surrounding the Brikate experimental plot is used primarily for continuous grazing of sheep. Farming in this area is limited to deeper soils along basins where water accumulates during the rainy season.

<u>Sayada Nord site</u>: The Sayada Nord experimental site is an upland area surrounded by foothills and low mountains at an elevation of 500 m. The annual precipitation in this area is sparce and erratic, and ranges from 300 mm to 450 mm. Most of the annual precipitation falls during the fall and winter months. Spring rainfall pattern is generally irregular, while summer's rainfall is absent. During the last three years (1982-1984), precipitation during the fall and winter was

77%, 58% and 19% respectively of the average yearly total of 322 mm (Table II-2).

The soil is deep and loamy with a high salt content and a moderate to low permeability. Workable soil extends to 60 cm depth after which a hard pan appears.

Most of the arable area surrounding the experimental plot is used for dryland wheat and barley, with forage crops used during wetter years. Areas where the topography is too rough for farming are grazed by sheep and goats all year long.

Sbiba site: The Sbiba site is located 60 km southeast of Kasserine and 12 km south of Sbiba county. The elevation of Sbiba site is approximately 640 m and is typical of the *Stipa tenassissima* and *Artemisia herba-alba* vegetation type. The native vegetation is dominated by *Stipa tenassissima*, in association with *Lotus* spp., *Medicago* spp., *Plantago albicans*, and several annual forbs.

Average annual precipitation is 293 mm (average of 49 years), recorded at Sbeitla weather station (Table II-3). Records at Sbiba weather station showed yearly average of 281.0 mm from 1982 to 1984 (Table II-3). Precipitation in this site was seasonally distributed (46% fall, 17% winter, 25 spring, and 12% summer). Summer precipitation occurs as summer storms.

Table II.1: Average monthly precipitation from 1982 to 1984 and long time average for BRIKATE site.

Periods	S	O	N	D	J	F	M	A	M	J	J	A	Year (mm)
1923-62	28.5	35.4	33.3	22.2	22.0	28.1	43.5	32.3	28.6	12.3	5.4	9.7	301.7
1982	16.8	67.0	15.0	42.0	-	10.0	35.3	16.5	-	-	-	-	202.6
1983	4.00	103.5	9.0	33.0	27.0	-	6.0	-	23.8	10.0	-	-	216.3
1984	16.8	67.0	15.0	42.0	-	10.0	35.9	16.5	-	-	-	-	203.2
												X̄	207.4

Table II.2: Average monthly precipitation from 1982 to 1984 for SAYADA NORD site.

Periods	S	O	N	D	J	F	M	A	M	J	J	A	Year (mm)
1982	41.3	46.6	99.4	39.6	47.9	23.7	6.8	75.1	19.7	-	-	1	401.1
1983	27.0	76.5	6.0	10	40.3	-	7	-	34.5	43	-	9	210.3
1984	45	191.1	23.1	15.5	-	9	39	19.1	19	-	-	14	355.8
												X̄ =	322.4

Table II.3: Average monthly precipiation from 1982 to 1984 and long time average for SBIBA site.

Periods	S	O	N	D	J	F	M	A	M	J	J	A	Year
1909-62	31.2	41.2	26.5	13.8	21.2	20.6	35.9	29	27.9	19.1	8.3	18.3	293
1982	46.8	58.7	89.3	17.8	31.4	24.6	9.1	63.1	25.4	6	-	15.9	388.1
1983	.6	68.3	7.7	11.5	2.3	3.3	21.5	-	44.2	52.8	-	5.2	217.4
1984	52.3	30.9	34.6	33.6	9.1	11.3	26.7	12.4	9.7	.2	-	16.8	237.6
												X̄ =	281.0

Average yearly minimum temperature is 9.9°C, with the lowest levels occurring November through February (3.9°C January), and the highest from April to September (34.6°C).

The gypsic soils of the Sbiba experimental site are immature, characterized by shallow rocky and gypsic layers of 30 cm depth. The area is limited to yearlong sheep grazing, with industrial use of the *Stipa tenassisima* for paper.

METHODS AND PROCEDURES

One hundred and forty-two (123 introduced and 19 native) forage species and varieties were planted in three range sites in Central Tunisia. Each experimental plot was chosen to represent the edaphic and climatic characteristics of the region. Seeds of introduced plants were furnished by various plant materials centers in U.S.A. and by other organizations. Native varieties were obtained from the Institut National De Recherche Agronomique Tunis (INRAT), Institut National d'Agriculture Tunis (INAT), Office d"Elevage et des Paturages (OEP).

Seedings at each site were established according to physiognomic category. Grass species were seeded according to warm and cool season categories. All Agropyron species were grouped separately from other cool season grasses. This categorization of plant materials by life form and physiological characteristics was done so as to permit comparative evaluation between major plant material groupings. Appendix II-1 lists the species categories, and the seeding rate. Three range test plots of 1/2 ha at Brikate and Sbiba and 1 ha at Sayada Nord, representing the edaphic and climatic characteristics of the area were established in the Fall of 1982 to test plots on the three range sites to observe establishment and survival of promising species and varieties. All experimental plots were hand seeded at different seeding rates at 1 to 2 cm depth. Prior to seeding, existing vegetation was removed by a shallow scarification to loosen the soil surface at the Brikate site, while soils were two-way disked at Sayada and Sbiba sites. For each category a small 1 by 2 m plot was used for each species or variety. Each plot included five rows of plants spaced .25 m apart, with three replications of each variety seeded. The three internal rows of plants served for the density and survival measurements, while the two external rows were used for biomass harvest.

Seeding rates of the different species and varieties were felt to be very high. This was because of the absence of the pure live seed of species and varieties, and the need of increasing the chance to get enough emerged plants. For comparison purposes a randomized block design was used in the experiment for each category of plants. All plants were randomly assigned to the units within each block. Density counts were begun immediately and continued at monthly intervals until April of each growing season (2 years). Four random density observations were recorded each month from each plot using a 20 by 50 cm quadrat divided into four small section of 0.025 m^2 surface area. Plants which survived were then, recorded at the end of each growing season, i.e. April.

Analysis of covariance with first years survival serving as covariate was used to test the plant survival at the end of the second growing season. Those plants not surviving the second year were not included in the analysis. When "F" values were significant ($P < .05$) Tukey's test was used to separate means (Steel and Torrie 1980).

RESULTS AND DISCUSSION

In this study, three patterns of species response to conditions of each site were observed. First, a group of species failed to emerge during the two year trial. Possible reasons include:

1. Inappropriate seedbed preparation
2. Non-viable seeds
3. Environmental conditions such as inappropriate soil moisture and temperature for germination.

Second, another group of species emerged but failed to survive through the second growing season. Possible reasons for this occurrence were:

1. Species were not adapted to the site
2. Intraspecific competition between individuals as a result of high seeding rates.
3. Rodent activity which caused loss of individuals.

Third, another group of species or varieties survived through the second growing season. This indicates these species may be adapted to the conditions of the site. Mean densities of the species and varieties which survived the second growing season were extremly variable within each plant category. This variability may have been caused by the sampling method used in the study. Random samplings were used in each subplot which may over or underestimate the density of the plant species when samples were recorded on full or patchy stands, respectively. In addition, several people have recorded the data which may have increased the variability. However, this variability may have masked some other species that may hold promist to establish in such conditions.

BRIKATE SITE

Several varieties and species failed to emerge within each physiognomic group of plants (Table II.4). Species that emerged but failed to survive are summarized in Table II.5.

Table II.6 lists species and varieties that survived and their corresponding mean densities during the end of each growing season. The analysis of covariance revealed no significant differences between the mean densities of the plant species at the end of the second growing season (April 1984) for the following plant categories: cool season "Agropyron," cool season "other" and warm season species (Table II.6).

It should be noted that warm season species had zero emergence the first year (except *Eragrostis curvula*) but high emergence rates the second year. Climatic conditions may account for this occurence. Summer precipitation the second growing season was very high, and coupled with high temperatures probably initiated seed germination.

Highest mean densities among the forb plant category were recorded for Scorpius myroculis (111 p/m^2), Hedysarum caronarium (84 p/m^2), Plantago elbiculis (94 p.m^2), Hedysarum carnosum (52 p.m^2), Viscia sativa (34 p/m^2) and Medicago polymorpha (32 p.m^2).

Table II.4: Species and varieties which failed to emerge at BRIKATE site.

PLANT CATEGORY	SPECIES	"Vty"
COOL SEASON SP. "OTHER"	Dactylis glomerata	
	Stipa viridula	"GREEN STIPA GRASS"
	Stipa viridula	
	Psathyrostachys juncea	"VINALL"
COOL SEASON SP. "AGROPYRON"	Agropyron desertorum	
	Agropyron desertorum	
	Agropyron intermedium	"TOPAR"
	Agropyron intermedium	"GREENAR"
	Agropyron intermedium	"LUNA"
	Agropyron sibiricum	"P-27"
	Agropyron spicatum	
WARM SEASON SP.	Cenchrus ciliaris	"HIGGINS"
	Eragrostis curvula	"BOER"
	Eragrostis lehmanniana	"COCHISE"
	Eragrostis lehmanniana	"A-68"
	Eragrostis trichoides	"MASON"
	Eragrostis trichoides	"BEND"
	Panicum miliaceum	
	Sporobolis airoides	
	Sporobolis airoides	"SALTTALK"
	Sporobolis cryptandrus	"SAND DROP SEED"
	Sporobolis giganteus	"ISLETA"
	Psathyrostachys juncea	"VINALL"
FORBS	Coronilla varia	"ELMARD"

Table II.5: List of species and varieties that emerged but failed to survive the second grow at BRIKATE site.

PLANT CATEGORY	SPECIES	"Vty"
COOL SEASON SP. "OTHER":	Bromus inermis	
	Bromus inermis	
	Bromus uniloides	
	Bromus uniloides	
	Bromus uniloides	
	Dactylis glomerata	"POMAR"
	Dactylis glomerata	"HALLMARK"
	Dactylis glomerata	
	Dactylis glomerata	"PALESTINE"
	Dactylis glomerata	"BERBER"
	Elymus gigantus	
	Festuca arundinacea	
	Festuca arundinacea	
	Festuca arundinacea	
	Festuca arundinacea	
	Festuca longifolia	"DURAR"
	Festuca ovina	"COVAR"
	Lolium perenne	"NORLEA"
	Lolium perenne	"LINN PER. REYGRASS"
	Lolium perenne	"MANHATTAN"
	Oryzopsis holciformis	
	Oryzopsis hymanoides	
	Oryzopsis hymenoides	"NEZPAR"
	Oryzopsis hymenoides	"PALOMA"
	Oryzopsis hymenoides	
	Phalaris aquatica	"PERLA"
	Poa ampla	"SHERMAN"
	Poa canbyi	"CANBAR"
	Stipa comata	
	Stipa viridula	"GREEN STIPA GRASS"
	Vulpia myuros	"ZORRO"
	Vulpia myuros	"ZORRO"
COOL SEASON SP. "AGROPYRON"	Agropyron desertorum	
	Agropyron desertorum	
	Agropyron dasystachyum	"CRITANA"
	Agropyron dasystachyum	
	Agropyron elongatum	
	Agropyron elongatum	"JOSE"
	Agropyron intermedium	"TEGMAR"
	Agropyron intermedium	"LINN"
	Agropyron intermedium	

Table II.5 Cont.

	Agropyron intermedium	
	Agropyron intermedium	
	Agropyron intermedium	"OAHE
	Agropyron intermedium	"AMUR"
	Agropyron riparium	"SODAR"
	Agropyron smithii	"ROSANA"
	Agropyron smithii	"BARTON"
	Agropyron smithii	"ARRIBA"
	Agropyron spicatum	"SECAR"
	Agropyron trachyycaulum	"REVENUE SLENDER"
WARM SEASON SP.	*Eragrostis trichodes*	
	Ehrharta calycina	"MISSION VELD GRASS"
	Panicum miliaceum	
	Panicum miliaceum	
	Panicum miliaceum	
	Panicum miliaceum	
	Panicum miliaceum	
	Panicum miliaceum	
	Panicum miliaceum	
	Panicum miliaceum	
	Panicum miliaceum	
	Panicum miliaceum	"DOVE PROSO"
	Sporobolus airoides	"NM-184"
FORBS	*Coronilla varia*	
	Coronilla varia	
	Medicago lupiluna	
	Medicago polymorpha	
	Medicago polymorpha	
	Medicago polymorpha	
	Medicago sativa	
	Medicago sativa	
	Medicago truncatula	
	Onobrychis vicifolia	
	Trifolium alexandrium	
	Trifolium fragiferum	"O'CONNER"
	Trifolium alexandrium	
	Trifolium hirtum	
	Trifolium hirtum	
	Trifolium subterraneum	
	Trifolium vesiculosum	"AMCLO"
	Medicago polymorpha	
	Vicia sativa	"COMMON VETCH"
	Vicia villosa	"LANA"

Table II.6: Density at the end of 1983 and 1984 for species seeded at BRIKATE site.Species are grouped according to physiognomic categories and statistical analyses were performed within each category. First year density was used as a covariate in an analysis of covariance of second year density (α =.05).

PLANT CATEGORY	SPECIES	"Vty"	MEAN DENSITY 1st.Year (p/m2)	MEAN DENSITY 2nd.Year (p/m2)
COOL SEASON SP. "OTHER"	Avena sativa		90	10a
	Bromus carinatus	"CUCAMONGO"	140	54a
	Bromus mollis	"BLONDO"	513	115a
	Bromus mollis	"BLONDO"	180	119a
	Dactylis glomerata	"VA 70"	340	13a
	Lolium rigidum	"WIMMERA"	289	233a
	Oryzopsis miliacea		105	37a
	Stipa tenassissima		66	50a
COOL SEASON SP. "AGROPYRON"	Agropyron desertorum		261	21a
	Agropyron elongatum	"ALKAR"	62	13a
	Agropyron elongatum	"LARGO"	124	32a
	Agropyron intermedium	"TRIGO"	100	13a
	Agropyron riparium	"SODAR"	210	22a
	Agropyron sibiricum		261	13a
WARM SEASON SP.	Cenchrus ciliaris		0	190a
	Cenchrus ciliaris	"NUECES"	0	230a
	Cenchrus ciliaris		0	30a
	Eragrostis curvula		290	5a
	Eragrostis curvula	"CATALINA"	0	120a
	Ergrostis lehmaniana		0	114a
	Ergrostis lehmaniana	"A-68"	0	20a
	Eragrostis superba	"PALAR"	0	70a
FORBS	Hedysarum carnosum		33	52ab
	Hedysarum coronarium		134	27a
	Hedysarum coronarium		83	84ab
	Medicago ciliaris		45	19a
	Medicago polymorpha		66	32ab
	Scorpius myroculis		11	111b
	Plantago albicaulis		89	97ab
	Trifolium subterraneum		171	21a
	Viscia sativa		57	34ab
	Trifolium vesiculosum		60	20a

* Similar letters denote non significant differences between species at level (α = .05).

SAYADA NORD SITE

Table II.7, lists the species and varieties which failed to emerge within each plant category. Species which emerged but failed to survive are summarized in Table II.8. Differences between mean densities at the end of the second growing season were not significant for cool season "other" category while significant differences were revealed between mean densities for the species and varieties of cool season "Agropyron" and forb categories (Table II.9). Mean densities at the end of second growing periond in the cools season "Agropyron" plant category were highest for: *Agropyron sibiricum* (140 p/m^2), *A. desertorum* "Nordan" (104p/m^2), *A. desertorum* (100 p/m^2) and *A dasystachyum* "Critana" (70 p/m^2). For the forb plant category highest mean densities at the end of the growing season were recorded for *Hedysarum coronarium* (133 p/m^2), *Medicago truncatula* (265 p/m^2) *Plantago albicaulis* (277 p/m^2, and *Medicago polymorpha* (90 p/m^2), Table II.9.

Table II.7: Species and varieties which failed to emerge at SAYADA NORD site.

PLANT CATEGORY	SPECIES	"Vty"
COOL SEASON SP. "OTHER"	Dactylis glomerata	
	Festuca arundinacea	
	Stipa comata	"GREEN STIPA GRASS"
	Stipa viridula	
	Stipa viridula	
	Psathyrostachys juncea	"VINALL"
COOL SEASON SP. "AGROPYRON"	Agropyron desertorum	
	Agropyron dasystachyum	"CRITANA"
	Agropyron intermedium	"TOPAR"
	Agropyron spicatum	
	Agropyron spicatum	
WARM SEASON SP.	Cenchrus ciliaris	
	Cenchrus ciliaris	"HIGGINS"
	Cenchrus ciliaris	"NUECES"
	Cenchrus ciliaris	
	Eragrostis curvula	
	Eragrostis curvula	"BOER"
	Eragrostis curvula	"CATALINA"
	Eragrostis lehmanniana	
	Eragrostis lehmanniana	"COCHISE"
	Eragrostis lehmanniana	"A-68"
	Eragrostis superba	"POLAR-WILMANS"
	Eragrostis trichoides	"MASON"
	Eragrostis trichoides	
	Eragrostis trichoides	"BEND"
	Panicum miliaceum	
	Panicum miliaceum	
	Panicum miliaceum	
	Panicum miliaceum	
	Panicum miliaceum	
	Panicum miliaceum	
	Panicum miliaceum	
	Panicum miliaceum	
	Panicum miliaceum	
	Panicum miliaceum	
	Panicum miliaceum	"DOVE PROSO"
	Spropbolis airoides	"NM-184"
	Sporobolis airoides	
	Sporobolis airoides	"SALTTALK"
	Sporobolis cryptandrus	"SAND DROP SEED"
	Sporobolis giganteus	"ISLETA"
	Psathyrostachys juncea	"VINALL"
FORBS	None	

Table II.8: List of species and varieties that emerged but failed to survive the second growing season at SAYADA NORD site.

PLANT CATEGORY	SPECIES	VARIETY
COOL SEASON SP. "OTHER"	*Bromus carinatus*	"CUCAMONGA"
	Bromus inermis	
	Bromus inermis	
	Bromus uniloides	
	Bromus uniloides	
	Bromus uniloides	
	Dactylis glomerata	"POMAR"
	Dactylis glomerata	"VA-70"
	Dactylis glomerata	"HALLMARK"
	Elymus gigantus	
	Festuca arundinacea	
	Festuca arundinacea	
	Festuca arundinacea	
	Festuca arundinacea	
	Festuca longifolia	"DURAR"
	Lolium perenne	"NORLEA"
	Lolium perenne	"LINN PERENNIAL RYEGRASS
	Lolium perenne	"MANHATTAN"
	Oryzopsis hymenoides	
	Oryzopsis hymenoides	"NEZPAR"
	Oryzopsis hymenoides	"PALOMA"
	Oryzopsis hymenoides	
	Oryzopsis miliacea	
	Poa ampla	"SHERMAN"
	Poa canbyi	"CANBAR"
	Stipa comata	
	Stipa tenacissima	
	Stipa viridula	"GREEN STIPA GRASS"
	Stipa viridula	"LODERM"
	Stipa viridula	
	Vulpia myuros	"ZORRO"
	Vulpia myuros	"ZORRO"
	Psathyrostachys juncea	"VINNAL"
COOL SEASON SP. "AGROPYRON"	*Agropyron desortorum*	
	Agropyron elongatum	
	Agropyron elongatum	"JOSE"
	Agropyron elongatum	
	Agropyron intermedium	
	Agropyron intermedium	"LINN"
	Agropyron intermedium	
	Agropyron intermedium	

	Agropyron intermedium	
	Agropyron intermedium	
	Agropyron riparium	"SODAR"
	Agropyron riparium	
	Agropyron sibiricum	
	Agropyron smithii	"BARTON"
	Agropyron spicatum	
WARM SEASON SP.	*Ehrharta calycina*	"MISSION VELD GRASS"
FORBS	*Coronilla varia*	
	Coronilla varia	
	Coronilla varia	
	Medicago lupiluna	
	Medicago polymorpha	
	Medicago polymorpha	
	Medicago sativa	
	Medicago sativa	
	Scorpius muricatus	
	Onobrychis vicifolia	
	Trifolium alexandrium	
	Trifolium frgiferum	
	Trifolium alexandrium	
	Trifolium hirtum	
	Trifolium hirtum	
	Trifolium subterraneum	
	Trifolium subterraneum	
	Trifolium vesiculosum	
	Vicia sativa	

Table II.9: Density at the end of 1983 and 1984 for species seeded at SAYADA NORD site. Species are grouped according to physiognomic category and statistical analyses were performed within each category. First year density was used as a covariate in an analysis of covariance of second year density ($\alpha = .05$).

PLANT CATEGORY	SPECIES "Vty"	MEAN DENSITY 1st Year (p/m2)	MEAN DENSITY 2nd Year (p/m2)
COOL SEASON SP. "OTHER"	Avena sativa	85	50a
	Bromus mollis "BLONDO"	370	73a
	Bromus mollis "BLONDO"	210	105a
	Dactylis glomerataps "PALESTINE"	380	10a
	Dactylis glomerata "BERBER"	210	30a
	Festuca ovina "COVAR"	249	60a
	Lolium rigidum "WIMMERA"	340	480a
	Oryxopsis holciformis	170	60a
	Phalaris aquatica "PERLA"	290	40a
	Phalaris truncatula	247	215a
COOL SEASON SP. "AGROPYRON"	Agropyron desertorum "NORDAN"	60	104ab
	Agropyron desertorum	280	100ab
	Agropyron dsaystachyum "CRITANA"	240	70ab
	Agropyron elongatum "LARGO"	150	30a
	Agropyron intermedium "TEGMAR"	166	27a
	Agropyron intermedium "TRIGO"	203	30a
	Agropyron intermedium "OAHE"	70	50a
	Agropyron intermedium "AMUR"	250	46a
	Agropyron sibiricum	60	140b
	Agropyron smithii "ROSANA"	210	40a
	Agropyron smithii "ARRIBA"	6	16a
	Agropyron spicatum "SECAR"	136	27a
WARM SEASON SP.	None	--	--
FORBS	Hedysarum carnosum	5	27a
	Hedysarum coronarium	200	5a
	Hedysarum coronarium	174	133ab
	Medicago ciliaris	124	135ab
	Medicago polymorpha	110	55ab
	Medicago polymorpha	117	90ab
	Medicago truncatula	200	265b
	Plantago albicaulis	20	277b
	Medicago hispida	87	90ab
	Vicia sativa	210	73ab
	Vicia villosa	120	67ab

* Similar letters denote non significant differences between species at level ($\alpha = .05$).

SBIBA SITE

Table II.10 and II.11 list the species and varities which failed to emerge, and the species that emerged but failed to survive the second growing season, respectively. Table II.12, lists the species and varieties which survived and their corresponding mean densities at the end of each growing season (April 1983, 1984). No significant differences were detected between the mean densities for species and varieties of cool season "other" and warm season species plat categories. However, differences were significant for the species and varieties of cool season "Agropyron" and forb plant categories. The highest mean densities in cool season "Agropyron" category were recorded for Agropyron elongatum "Largo" (280 p.m^2), A. trachycaulum "Revenue" (210 p/m^2), A. intermedium "Oahe" (175 p/m^2), A. elongatum "Jose" (160 p/m^2), A. intermedium "Trigo" (140 p/m^2). In forb plant category, Plantago albicaulis (195 p/m^2), and Hedysarum caronarium (230 p/m^2) exhibited highest mean densities in comparison to the other species in this group (Table II.12). These were followed by Trifolium vesiculosum (102 p/m^2) and Hedysarum carnosum (96 p/m^2).

Table II.10: Species and varieties which failed to emerge at SBIBA site.

PLANT CATEGORY	SPECIES	"Vty"
COOL SEASON SP. "OTHER"	NONE	
COOL SEASON SP. "AGROPYRON"	*Agropyron desertorum*	
	Agropyron intermedium	"TOPAR"
	Agropyron intermedium	"GREENAR"
	Agropyron sibiricum	"P-27"
WARM SEASON SP.	*Cenchrus ciliaris*	"HIGGINS"
	Eragrostis curvula	"BOER"
	Eragrostis superba	"POLAR-WILMANS"
	Eragrostis trichoides	"MASON"
	Ehrharta calycina	"MISSION VELD GRASS"
	Panicum miliaceum	
	Panicum miliaceum	
	Panicum miliaceum	
	Panicum miliaceum	
	Panicum miliaceum	
	Panicum miliaceum	
	Panicum miliaceum	
	Panicum miliaceum	
	Panicum miliaceum	
	Panicum miliaceum	"DOVE PROSO"
	Sporobolis cryptandrus	"SAND DROP SEED"
	Sporobolis giganteus	"ISLETA"
	Psathyrostachys juncea	"VINALL"
FORBS	NONE	

Table II.11: List of species and varieties that emerged but failed to survive the second growing season at SBIBA site.

PLANT CATEGORY	SPECIES	VARIETY
COOL SEASON SP. "OTHER"	Bromus inermis	
	Bromus uniloides	
	Bromus uniloides	
	Bromus uniloides	
	Dactylis glomerata	"POMAR"
	Dactylis glomerata	
	Dactylis glomerata	
	Elymus gigantus	
	Festuca arundinacea	
	Festuca arundinacea	
	Festuca ovina	"COVAR"
	Lolium perenne	"NORLEA"
	Lolium perenne	"LINN PER.RYEGRASS"
	Lolium perenne	"MANHATTAN"
	Oryzopsis hymenoides	
	Oryzopsis hymenoides	
	Oryzopsis hymenoides	"NEZPAR"
	Oryzopsis hymenoides	"PALOMA"
	Oryzopsis hymenoides	
	Poa ampla	"SHERMAN"
	Poa canbyi	"CANBAR"
	Stipa comata	
	Stipa tenasissima	
	Stipa viridula	"GREEN ST PA GRASS"
	Stipa viridula	"LODERN"
	Stipa viridula	
	Psathyrostachys juncea	"VINNAL"
COOL SEASON SP. "AGROPYRON"	Agropyron desertorum	
	Agropyron dasystachyum	
	Agropyron intermedium	
	Agropyron riparium	
	Agropyron spicatum	
WARM SEASON SP.	Cenchrus ciliaris	
	Cenchrus ciliaris	"NUECES"
	Cenchrus ciliaris	
	Eragrostis lehmanniana	
	Eragrostis trichodes	
	Panicum miliaceum	
	Panicum miliaceum	
	Sporobolus airoides	"NM-184"
	Sporobolus airoides	"SALTTALK"
FORBS	Coronilla varia	
	Coronilla varia	
	Coronilla varia	

Medicago ciliaris	
Medicago lupiluna	
Medicago sativa	
Medicago sativa	
Trifolium alexandrium	
Trifolium frgiferum	"O'CONNER"
Trifolium alexandrium	
Trifolium hirtum	
Trifolium hirtum	
Trifolium subterraneum	
Trifolium subterraneum	
Trifolium vesiculosum	"AMCLO"
Vicia sativa	"COMMON VECH"
Vicia sativa	
Vicia sativa	
Vicia villosa	"LANA"

Table II.12: Density at the end of 1983 and 1984 for species seeded at SBIBA site. Species are grouped according to physigonomic categories and statistical analyses were performed within each category. First year density was used as a covariate in an analysis of covariance of second year density (α = .05).

PLANT CATEGORY	SPECIES "Vty"	MEAN DENSITY 1st Year (p/m2)	MEAN DENSITY 2nd Year (p/m2)
COOL SEASON SP. "OTHER"	*Avena sativa*	90	30a*
	Bromus carinatus "CUCAMONGO"	30	60a
	Bromus inermis "ELSBERRY"	167	80a
	Bromus mollis "BLONDO"	200	120a
	Bromus mollis "BLONDO"	96	216a
	Dactylis glomerata "VA 70"	140	90a
	Dactylis glomerata "HALLMARK"	207	60a
	Dactylis glomerata "PALESTINE"	310	64a
	Dactylis glomerata "BERBER"	134	107a
	Festuca arundinacea	120	56a
	Festuca arundinacea	150	140a
	Festuca longifolia	60	40a
	Lolium rigidum "WIMMERA"	130	115a
	Oryzopsis holciformis	130	60a
	Oryzopsis miliacea	75	120a
	Phalaris aquatica "PERLA"	120	130a
	Phalaris truncatula	96	140a
	Vulpia myurosa "ZORRO"	180	190a
	Vulpia myurosa "ZORRO"	170	230a
COOL SEASON SP. "AGROPYRON"	*Agropyron desertorum*	44	57ac
	agropyron desertorum "NORDAN"	226	113acd
	Agropyron desertorum	166	275b
	Agropyron dasystachyum "CRITANA"	76	80ac
	Agropyron elongatum	20	44ac
	Agropyron elongatum "JOSE"	160	155abc
	Agropyron elongatum "ALKAR"	50	60ac
	Agropyron elongatum "LARGO"	145	280b
	Agropyron intermedium "TEGMAR"	186	160ab
	Agropyron intermedium "LINN"	266	40ac
	Agropyron intermedium	115	125acb
	Agropyron intermedium	16	23c
	Agropyron intermedium	100	80ac
	Agropyron intermedium "TRIGO"	80	140abc
	Agropyron intermedium "OAHE"	226	175ab
	Agropyron intermedium "AMUR"	70	105ac

	Agropyron riparium "SODAR"	217	104ac
	Agropyron sibiricum	220	167ab
	Agropyron smithii "ROSANA"	10	25ac
	Agropyron smithii "BARTON"	37	70ac
	Agropyron smithii "ARRIBA"	44	97ac
	Agropyron spicatum "SECAR"	120	70ac
	Agropyron trachycaulum "REVENUE"	297	210b
WARM SEASON SP.	Eragrostis curvula	26	40a
	Eragrostis curvula "CATALINA"	0	86a
	Eragrostis lehmanniana "COCHIS"	0	73a
	Eragrostis lehmanniana "A-68"	0	105a
	Eragrostis trichoides "BEND"	50	20a
	Ehrharta calycina "MISSION"	130	115a
FORBS	Hedysarum carnosum	70	96ac
	Hedysarum coronarium	240	46a
	Hedysarum coronarium	164	230b
	Medicago polymorpha	40	59a
	Medicago polymorpha	20	20a
	Medicago polymorpha	140	15a
	Medicago polymorpha	70	61a
	Scorpius muricatus	40	50a
	Medicago truncatula	194	38a
	Onobrychis vicifolia	46	47a
	Plantago albicaulis	76	195bc
	Medicago polymorpha	67	13a
	Trifolium vesiculosum	105	103ac
	Trifolium hirtum	40	26a

* Similar letters denote non significant differences between species at level (α = .05).

SUMMARY AND CONCLUSION

From 1982 to 1984, studies were conducted at three sties in Central Tunisia to determine the adaptability of several important grass and forb species and varieties to conditions found in these areas. The mean density of plant species was determined at the end of each growing season (April 1983 and April 1984) for selected species and varieties. Although, meaningful conclusions concerning these trials must await several more years of various data accumulation, preliminary recommendations can be made on the basis of the failure to emerge and survival of species and varieties tested. On the basis of plant survival at the end of the second growing season, the following species may be suitable for revegetating the three range sites of Central Tunisia:

BRIAKTE SITE:

Scorpius myroculis
Plantago albicaulis
Medicago ciliaris

SAYADA NORD SITE:

Agropyron sibiricum
Agropyron desertorum "Nordan"
Agropyron dasystachyum "Critana"
Plantago albicaulis
Hedysarum coronarium

SBIBA SITE:

Agropyron elongatum "Largo", "Jose"
Agropyron intermedium "Oahe," "Tegmar,." "Trigo"
Agropyron trachycaulum "Revenue"
Agropyron sibiricum
Plantago albicaulis
Hedysarum coronarium
Trifolium vesiculosum
Hedysarum carnosum
Medicago truncatula

Other species which survived the second growing season may also hold promise for revegetation purposes. Further, research is needed to fully assess these species.

GENERAL RESULTS AND CONCLUSION

Central Tunisian sites in need of revegetation usually host harsh edaphic and climatic conditions for seedling establishment. The species and varieties used in reseedings need to be able to germinate and establish on the sites of limited moisture. The evaluations performed in this thesis were intended to provide an initial basis for the selection of the best species and varieties for reseeding Central Tunisian rangelands. On the basis of good emergence characteristics, deep rooting systems, great root biomass and high root to shoot weight ratios evaluated in the greenhouse study, Dactylis glomerata (Tunisian cultivar), D. glomerata (Palestine), Argyrolobium uniflorum and Medicago laciniata were suggested for revegetating on the most dry sandy sites, while Hedysarum spinosissimum and to a lesser extent DAGL(TN), DAGL(PN) and ATCA were suggested for revegetatin the most dry clay sites. Hedysarum carnosum and Oryzopsis miliacea, however, were suggested for revegetating the relatively mesic sites.

Results obtained from the field investigation were based on the survival of species and varities at the end of the second growing season. Results revealed the failure of emergence as well as the failure to survive two growing seasons of several species and varieties tested. Nevertheless, this study revealed the survival of certain species and varieties on the different sites. Plantago albicaulis produced high survival of individuals in all sites, while Agropyron cultivars were restricted to exhibit high densities in both SAYADA NORD and SBIBA sites. In addition, forb plants which exhibited high densities at the end of the second growing season were: Hedysarum carnosum, H. coronarium and Trifolium vesiculosum at SBIBA site and Medicago truncatula and Hedysarum carnosum at SAYADA NORD site.

It is apparent that the capacity of any species to grow in exceptionally dry habitats, or even through a wide range of habitats, and the production of quantities of highly viable seed that will germinate under a variety of soil moisture should not be considered as a complete indication of its value for use in artificial reseeding under Central Tunisia range conditions. To make artificial reseeding feasible, it is necessary to have species available that will establish themselves in at least average years and continue to grow and propogate through the climatic hazards to which the site is subjected. The selected species must also meet the nutrient requirements of the livestock to be grazed on it. The season of grazing, plant stage of growth, and the physiological state of the animals must also be considered. Grass and legume mixtures as well as shrub plantings as reserved forage should also be anticipated to maintain the forage balance between seasons. It is intended that future research will address these issues.

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APPENDICES

Appendix A: List of species used in previous trials in Central Tunisia.

1: PREVIOUS VARIETY TRIAL (Seeding done in Autumn 1961)

SPECIES	Origine	Germ.	Devlpt.
Oryzopsis holciformis	France	Good	Perished in summer
Oryzopsis miliacea	Tunisia	Poor	Good
Agropyron desertorum	U.S.A.	Mediocre	Perished in summer
Agropyron spicatum	U.S.A.	Poor	Perished in summer
Agropyron elongatum	U.S.A.	Nil	___
Cenchrus ciliaris	Australia	Poor	Not self seeding
Cenchrus setigerus	Australia	Good	Not self seeding
Ehrharta calycina	Australia	Poor	Mediocre
Festuca arundinacea	Tunisia	Mediocre	Poor
Phalaris truncata	Tunisia	Mediocre	Not self seeding

2: PREVIOUS VARIETY TRIAL (Other introduced species tested at OULED M'HAMED station).

SPECIES	Origine	Germ.	Devlpt.
Agropyron intermedium	U.S.A.	Mediocre	Perished
Agropyron elongatum	U.S.A.	Poor	Perished
Agropyron pubescens	U.S.A.	Mediocre	Perished
Agropyron smithii	U.S.A.	Poor	Perished
Agropyron elongatum	Australia	Mediocre	Perished
Agropyron intermedium	Australia	Poor	Perished
Agropyron obtussiusculum	Australia	Mediocre	Perished
Agropyron desertorum	Australia	Poor	Perished
Agropyron sibiricum	U.S.A.	Mediocre	Poor
Cenchrus setigerus	Australia	Poor	Perished
Cenchrus ciliaris	Australia	Poor	Perished
Cenchrus ciliaris Q412	Australia	Poor	Poor
Oryzopsis miliacea	Tunisia	Poor	Poor
Ehrharta calycina	Australia	Poor	Poor
Pennisetum villosum	Middl.East	Nil	Nil
Festuca arundinacea	Australia	Poor	Perished
Festuca arundinacea	Tunisia	Poor	Perished
Festuca arundinacea	U.S.A.	Mediocre	Perished
Bromus catharticus	U.S.A.	Poor	Perished
Phalaris tuberosa	U.S.A.	Poor	Perished
Eragrostis curvula	Morocco	Nil	
Eragrostis lucioides	U.S.A.	Nil	
Cymbopogon laniger	Iran	Nil	
Aeluropus repens	Iran	Nil	
Atriplex semibaccata	Australia	Poor	Poor
Argyrolobium argentum	Tunisia	Mediocre	Mediocre

Apptendix B: Analysis of variance for days to 50% emergence, final percent emergence, root biomass, root depth, shoot biomass, root/shoot weight ratio, and height of eight species grown in two growth mediums under four moisture regimes in greenhouse conditions.

I.1: Analysis of variance for final emergence of eight species grown in to soil types under four moisture regimes in greenhouse conditions.

SOURCES	OR	MEAN SQ.
BLOCK	3	533
MOIST. REG.	3	17.4
BLOCK X MOIST. REG.	9	302.4
SOIL	1	1.4
SOIL X MOIST. REG.	3	88.7
SOIL X BLOCK	3	52.8
BLOCK X SOIL X MOIST. REG.	9	51.4
SPECIES	7	25304*
SPECIES X MOIST REG.	21	68
SPECIES X SOIL	7	68
SPECIES X SOIL X MOIST. REG.	21	69
SPECIES X BLOCK	21	238
SPECIES X BLOCK X MOIST. REG.	63	364
SPECIES X SOIL X BLOCK	21	82
BLOCK X SOIL X MOIST. REG. X SPE.	63	78

* Significant at the 0.05 level.

I.2: Analysis of variance for final emergence of eight species grown in two soil types under four moisture regimes in greenhouse conditions.

SOURCES	DF	MEAN SQUARE
BLOCK	3	533
MOIST. REG.	3	17.4
BLOCK X MOIST.REG.	9	302.4
SOIL	1	1.4
SOIL X MOIST.REG.	3	88.7
SOIL X BLOCK	3	52.8
BLOCK X SOIL X MOIST.REG.	9	51.4
SPECIES	7	25304*
SPCIES X MOIST.REG.	21	68
SPECIES X SOIL	7	68
SPECIES X SOIL MOIST.REG.	21	69
SPECIES X BLOCK	21	238
SPECIES X BLOCK X MOIST.REG.	63	364
SPECIES X SOIL X BLOCK	21	82
BLOCK X SOIL X MOIST.REG. X SPE.	63	78

* Significant at the 0.05 level.

I.3: Analysis of variance for Root Biomass of eight species grown in two soil types under four moisture regimes in greenhouse conditions.

SOURCES	DF	MEAN SQUARE
BLOCK	3	.002
MOIST. REG.	3	.050 *
BLOCK X MOIST.REG.	9	.001
SOIL	1	.24 *
SOIL X MOIST.REG.	3	.0002
SOIL X BLOCK	3	.0008
BLOCK X SOIL X MOIST.REG.	9	.0006
SPECIES	7	.07
SPECIES X MOIST.REG.	21	.007 *
SPECIES X SOIL	7	.009 *
SPECIES X SOIL X MOIST.REG.	21	.002
SPECIES X BLOCK	21	.0002
SPECIES X SOIL X BLOCK	21	.0004
SPECIES X BLOCK X MOIST.REG.	63	.0006
BLOCK X SOIL X MOIST.REG. X SPE.	63	.0005

* Significant at the 0.05 level.

I.4: Analysis of variance for Root depth of eight species grown in two soil type under four moisture regimes in greenhouse conditions

SOURCES	DF	MEAN SQUARE
BLOCK	3	79534
MOIST. REG.	3	398932 *
BLOCK X MOIST.REG.	9	9328
SOIL	1	107950 *
SOIL X MOIST.REG.	3	157028
SOIL X BLOCK	3	32934
BLOCK X SOIL X MOIST.REG.	9	7739
SPECIES	7	11071
SPECIES X MOIST.REG.	21	17384
SPECIES X SOIL	7	51064 *
SPECIES X SOIL X MOIST.REG.	21	10233
SPECIES X BLOCK	21	6894
SPECIES X SOIL X BLOCK	21	4458
SPECIES X BLOCK X MOIST.REG.	63	4850
BLOCK X SOIL X MOIST.REG. X SPE.	63	3784

* Significant at the 0.05 level.

I.5: Analysis of variance for Shoot biomass of eight species grown in two soil types under four moisture regimes in greenhouse conditions.

SOURCES	DF	MEAN SQUARE
BLOCK	3	.007
MOIST. REG.	3	.09 *
BLOCK X MOIST.REG.	9	.003
SOIL	1	1.75 *
SOIL X MOIST.REG.	3	.008
SOIL X BLOCK	3	.005
BLOCK X SOIL X MOIST.REG.	9	.003
SPECIES	7	.40 *
SPECIES X MOIST.REG.	21	.03 *
SPECIES X SOIL	7	.10 *
SPECIES X SOIL X MOIST.REG.	21	.003
SPECIES X BLOCK	21	.0012
SPECIES X SOIL X BLOCK	21	.0014
SPECIES X BLOCK X MOIST.REG.	63	.0017
BLOCK X SOIL X MOIST.REG. X SPE.	63	.0018

* Significant at the 0.05 level.

I.6: Analysis of variance for Root/Shoot weight ratio of eight species grown in two soil types under four moisture regimes in greenhouse conditions.

SOURCES	DF	MEAN SQUARE
BLOCK	3	11
MOIST. REG.	3	23 *
BLOCK X MOIST.REG.	9	2.3
SOIL	1	225 *
SOIL X MOIST.REG.	3	11
SOIL X BLOCK	3	8
BLOCK X SOIL X MOIST.REG.	9	.4
SPECIES	7	52 *
SPECIES X MOIST.REG.	21	2.53
SPECIES X SOIL	7	18 *
SPECIES X SOIL X MOIST.REG.	21	.98
SPECIES X BLOCK	21	2.25
SPECIES X SOIL X BLOCK	21	1.22
SPECIES X BLOCK X MOIST.REG.	63	.71
BLOCK X SOIL X MOIST.REG. X SPE.	63	.48

* Significant at the 0.05 level.

I.7: Analysis of variance for the Height of eight species grown in two soil types under four moisture regimes in greenhouse conditions.

SOURCES	DF	ME.SQ. DAY 15	ME.SQ. DAY 22	ME.SQ. DAY 29	ME.SQ. DAY 36	ME.SQ. DAY 43	ME.SQ. DAY 50
BLOCK	3	720	432	933	1404	4470	5487
MOIST. REG.	3	4	590 *	6970 *	17040 *	24784 *	39451 *
BLOCK X MOIST.REG.	9	41	106	165	154	1050	1909
SOIL	1	7125 *	14593 *	64113 *	192007 *	645527 *	1319310 *
SOIL X MOIST.REG.	3	19	57	976 *	959	1431	1871
SOIL X BLOCK	3	69	96	72	248	966	1894
BLOCK X SOIL X MOIST.REG.	9	22	72	149	187	602	1054
SPECIES	7	16532 *	26613 *	32624 *	50072 *	116690 *	205290 *
SPECIES X MOIST.REG.	21	64	142	542	1181	1732	4988 *
SPECIES X SOIL	7	1429 *	734	2413 *	13270 *	48422 *	84210 *
SPECIES X SOIL X MOIST.REG.	21	36	60	651	1099	1884	2966
SPECIES X BLOCK	21	182	210	153	312	732	1237
SPECIES X BLOCK X MOIST.REG.	63	51	96	160	257	434	539
SPECIES X SOIL X BLOCK	21	49	65	131	193	455	806
BLOCK X SOIL X MOIST.REG. X SPE.	63	67	54	114	146	299	490

* Significant at the 0.05 level.

Appendix II.1: Species list for adaptation trials conducted in three range sites in Central Tunisia.

COOL SEASON SPECIES "OTHER"

SPECIES	SEEDING RATE (Kg/ha)
Avena sativa	45
Bromus carinatus "CUCAMONGO"	35
Bromus inermis	35
Bromus inermis	35
Bromus mollis	35
Bromus mollis "BLONDO"	35
Bromus mollis "BLONDO"	35
Bromus uniloides	30
Bromus uniloides	30
Bromus uniloides	30
Dactylis glomerata	30
Dactylis glomerata VA 70"	30
Dactylis glomerata "BERBER"NE"	30
Dactylis glomerata "HALLMARK"	30
Dactylis glomerata	30
Dactylis glomerata	30
Lolium rigidum "WIMMERA"	35
Oryzopsis miliacea	45
Phalaris truncatula	35
Stipa tenassissima	30
Phalaris aquatica "PERLA	35
Stipa comata	45
Poa ampla	25
Poa canbyi	35
Orizopsis holciformis	45
Oryzopsis hymenoides	35
Oryzopsis hymenoides	35
Oryzopsis hymenoides	35
Oryzopsis hymenoides	35
Oryzopsis hymenoides	35
Stipa viridula	25
Stipa viridula	25
Stipa viridula	25
Psathyrostachys juncea	25
Lolium perenne	30
Lolium perenne	35
Lolium perenne	35
Festuca arundinacea	30
Festuca longifolia	30
Festuca ovina "COVAR"	30
Festuca arundinacea	25
Festuca arundinacea	25
Festuca arundinacea	35
Vulpia myurosa "ZORRO"	35
Vulpia myurosa "ZORRO"	35

COOL SEASON "AGROPYRON" TRIAL

SPECIES	SEEDING RATE (Kg/ha)
Agropyron desertorum	35
Agropyron desertorum	35
Agropyron desertorum	35
Agropyron desertorum "NORDAN"	35
Agropyron cristatum	35
Agropyron dasystachyum "CRITANA"	35
Agropyron dasystachyum "CRITANA"	35
Agropyron elongatum	20
Agropyron elongatum "JOSE"	35
Agropyron elongatum "ALKAR"	35
Agropyron elongatum "LARGO"	35
Agropyron intermedium "TEGMAR"	35
Agropyron intermedium	35
Agropyron intermedium	35
Agropyron intermedium "LINN"	30
Agropyron intermedium	20
Agropyron intermedium	30
Agropyron intermedium	30
Agropyron intermedium	35
Agropyron intermedium "TRIGO"	30
Agropyron intermedium "OAHE"	35
Agropyron intermedium "AMUR"	35
Agropyron riparium "SODAR"	35
Agropyron riparium "SODAR"	35
Agropyron sibiricum	35
Agropyron sibiricum	35
Agropyron smithii "ROSANA"	30
Agropyron smithii "BARTON"	30
Agropyron smithii "ARRIBA"	30
Agropyron spicatum "SECAR"	20
Agropyron spicatum "SECAR"	20
Agropyron trachycaulum "REVENUE"	30

WARM SEASON SPECIES TRIAL

SPECIES	SEEDING RATE (Kg/ha)
Cenchrus ciliaris	25
Cenchrus ciliaris	25
Cenchrus ciliaris	33
Cenchrus ciliaris	33
Eragrostis cuvula	35
Eragrostis cuvula	35
Eragrostis cuvula	35
Eragrostis lehmanniana	35
Eragrostis lehmanniana	35
Eragrostis lehmanniana	35
Eragrostis trichoides	35
Eragrostis trichoides	35
Eragrostis trichoides	35
Ehrharta calycina	35
Panicum miliaceum	35
Panicum miliaceum	35
Panicum miliaceum	35
Panicum miliaceum	35
Panicum miliaceum	35
Panicum miliaceum	35
Panicum miliaceum	35
Panicum miliaceum	35
Panicum miliaceum	35
Panicum miliaceum	35
Panicum miliaceum	35
Sporobolis airoides	33
Sporobolis airoides	35
Sporobolis airoides	35
Sporobolis cryptandrus	35
Sporobolis gigantus	35

FORB SPECIES TRIAL

SPECIES	SEEDING RATE (Kg/ha)
Coronilla varia	25
Coronilla varia	25
Coronilla varia	25
Hedysarum carnosum	30
Hedysarum coronarium	30
Hedysarum coronarium	30
Medicago ciliaris	30
Medicago lupiluna	18
Medicago polymorpha	25
Medicago polymorpha	28
Medicago polymorpha	28
Medicago polymorpha	28
Medicago sativa	30
Medicago sativa	30
Scorpius myroculis	30
Medicago truncatula	30
Onobichis viscifolia	30
Plantago albicaulis	30
Plantago albicaulis	30
Trifolium fragiferum	30
PLantago albicaulis	30
Trifolium hirtum	25
Trifolium hirtum	33
Trifolium subterraneum	35
Trifolium subterraneum	35
Trifolium vesiculosum	35
Medicago polymorpha	28
Vicia sativa	35
Vicia sativa	40
Trifolium vesiculosum	35
Trifolium hirtum	33