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THE USE OF INDIGENOUS PLANTS IN LANDSCAPE OF SAUDI ARABIA

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ABSTRACT

Throughout the world increasing use is being made of native plants in urban landscapes, both to preserve regional visual character, conserve native biodiversity and to reduce energy inputs in the urban landscape. In Saudi Arabia most designed urban landscapes employ non indigenous plants. This use of exotic plants is problematic as these species require considerably more water and maintenance.

This study establishes a basic understanding of the use of twenty Saudi indigenous plants for semi-nature landscape. We have identified the suitable methods for breaking dormancy and the germinating of these species. We have also selected the most appropriate time for germination by defining the optimal germination temperature of each species. In general most of these species were found to have adaptation to cope with water stress and salinity. For most of these species the maximum germination percentage was at the temperatures between 20 °C and 30 °C.

Competition is one of the most important factors which controls the success of a sown community. Therefore we have investigated the establishment of species in mixture under simulated Saudi conditions using microcosm competition experiments within communities of native species. The results show that in the survival of sown species soil moisture stress was the major factor determining survival. Greater competition for moisture was demonstrated in the weedy treatment. It is clear that weeds would be a problem in practice in the field in dry climate. In terms of the growth of these species, at high water stress; weeds are less competitive than under low water stress. Therefore on very weedy sites irrigation would not be valuable in practice. Cutting may be helpful for the establishment of these species within a community in weedy sites.

Overall, the results of these studies demonstrate that these twenty Saudi indigenous species could be used in landscape within the target species method where plants are grown individually or in-groups of one or two species. Also they can be used within the target community method for creating communities in practice in semi-natural landscape projects in Saudi Arabia.

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1. INTRODUCTION

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1. INTRODUCTION

1.1 RATIONALE AND RESEARCH OBJECTIVES

The significance of landscape vegetation to the aesthetic, psychological and climatic design of our human environments is well understood. In arid regions like Saudi Arabia, trees, shrubs, climbers, groundcover, forbs and grasses, provide shade, reduce glare and heat, retain moisture in the soil and the air, ameliorate wind, dust, soil erosion, and other adverse environmental factors.

There is a wide range of various plant species which can be used in urban landscape design in these regions. All these species can be categorized according to their morphological properties. For example, shape, density of foliage, size, branching and flowering characteristics. Other factors which may govern their suitability or unsuitability for landscape design include the plants relative environmental tolerance to drought, wind and salinity.

Throughout the world increasing use is being made of native plants in urban landscapes, both to preserve regional visual character, conserve native biodiversity and to reduce energy inputs in the urban landscape. In Saudi Arabia most designed urban landscapes employ non-indigenous, i. e. alien, species of plants. This use of non-indigenous plants is sometimes problematic, as these species often require considerably more water and maintenance than indigenous plants. Moreover, such plants are often much less sustainable in the environment. Beyond a certain critical temperatures, for example (>49°C) many non-indigenous species will often die (Kelly, 1976).

The Saudi Arabian flora has evolved in a wide range of climatic regions, habitats and soil types. The resulting vegetation types are consequently diverse ranging from extreme arid to semi-arid lands. Within these different ecosystems, survival of each species may largely depend on inherent germination responses that maximize survival and establishment of seedling. The most crucial aspect of germination concerns its timing in relation to the onset of favorable conditions for seedling development. This timing of germination is controlled by an interplay between the physiological state of the seed and the seeds' response to environmental factors such as moisture, temperature, salinity and light. Relatively little is known of how Saudi indigenous species respond to these factors.

The seed of many agriculturally important crops possess little or no dormancy, and therefore few problems are encountered in germination. This is a direct result of the domestication of plants, where an important basis of selection over a long period has been the ease, uniformity and promptness of seed germination (i.e. minimum dormancy). For native wild plants where no such artificial selection has been imposed, seed dormancy remains a most important consideration.

One of the most important environmental factors influencing germination is soil moisture (Hegarty and Ross, 1981). All stages of the germination process are sensitive to water stress, but some plants are more tolerant of water stress during germination than other (Sharma, 1973). In general however there is little variation among plant species in terms of tolerance to low water potentials (Mott, 1972).

Temperature is the other key environmental factor influencing germination. Not only does temperature affect germination, but in many plants it also determines seed dormancy. The literature often does not clearly separate these two distinct processes (Bewley and Black, 1982). In non-dormant seeds there is an optimum temperature regime for germination and subsequent growth. Some plants especially annuals, which germinate in summer in temperate regions, may require high temperature for optimum germination (Mott, 1972).

In arid regions salinity is an important environmental factors influencing germination. In saline environments, plants must first overcome the moisture stress imposed by salinity at the germination stage, before they can colonize the habitat successfully. Dewey (1964, in Johnson, 1990) found that although salinity tolerance is an important property, tolerance at germination is often unrelated to tolerance at later developmental stages. Consequently selections at different growth stages are needed to improve total plant salinity tolerance.

Post germination in most plant ecosystems nutrient supply is one of the major factors affecting the species composition of the plant community (Kruijne et al., 1967; Vermeer and Berendse, 1983; Tilman, 1984, 1988). An issue that recently has evoked much debate is the question of what plant features contribute to a high competitive ability under nutrient-poor conditions and what features do so in relatively nutrient-rich environments (e.g., Newman, 1973; Grime, 1973; Thompson, 1987; Tilman 1987). There is still much debate over what determines which species will be successful in competition under different environmental conditions, and the relative importance of competition itself in determining of plant communities (Newman, 1973; Tilman, 1987;Thompson, 1987).

Knowledge of the dynamics of plant communities will improve our ability to chose and use species in the landscape. Investigations aimed at plant v plant interaction and the relationships which affect dominance, community dynamics and plant establishment are critical to the development of successful management systems.

To use Saudi native plants more effectively in urban landscapes more information on the ecology of these species is required. Most research to date (e.g. Migahid, (1974); Al-Zoghet, (1989); Heemstra, Al Hassan and Al Minwer, (1990); Al-Zoghet and Al-Alsheikh (1999), and Chaudhary and Al-Jowaid (1999)) on Saudi native species is concerned with the characteristics of individual species, to be used as substitutes for non-native species in traditional planting design. This study differs from this approach in that it is aimed at developing seed mixed of key herbaceous and woody species indigenous to Saudi Arabia. These indigenous plants communities will be established by seeding rather than by planting in conjunction with urban fringe and infrastructure landscape such as Al-thommamh national desert park, Al Damam motorway, Saad national park, Wadi hanifa area, Riyadh city ring road, Al-kharj motorway and mkkah motorway in Riyadh.

The rationale behind this work is to try to develop appreciation in Saudi Arabia of the role of non-irrigated sustainable vegetation. In time may lead to a shift in the landscape asthetic as described by Alturki, (2001) and allow Saudis to return to a more sustainable vegetation forms.

1.1.1 RESEARCH OBJECTIVE

The overall aim is to better understand the ecology behind the establishment of semi-natural vegetation in the Riyadh area of Saudi Arabia by direct sowing. By the end of the experiments we hope to able to identify suitable methods for breaking dormancy and the germinating of approximately twenty Saudi indigenous plants. We also hope to be able to select the most appropriate time for germination by defining the optimal germination temperature of each species. Moreover understanding the affect of moisture and salinity on the germination of these seeds also needs to be investigated. After establishing this basic knowledge of these species we will investigate the establishment of species in mixture under simulated Saudi conditions using microcosm competition experiments within communities of native species. The results of these experiments will form the basis on which future more applied research on creating communities in practice will be built, as semi-natural landscape projects in Saudi Arabia. The specific objectives of the study can be summarized as follows:

- To study the context for research (the Saudi Arabian landscape, the history of the Riyadh landscape and important factors in the Riyadh regional landscape).

- To investigate the native vegetation of the Riyadh area of Saudi Arabia, and environmental variables (e.g. climate) that affect the growth and distribution of the plant species in their habitat.

- To identity suitable species for landscape uses in urban fringe landscape and collect seed of these species for use in subsequent research.

- To study the effect of moisture stress, temperature and salinity on the germination of the collected species under laboratory conditions.

- Investigate establishment of species in mixture under simulated Saudi conditions. Inter and intra-specific competition within microcosm communities of native species will be investigated.

- To produce preliminary guidelines for landscape practice in Saudi Arabia on how to use native species in landscape projects.

THE RESEARCH PLAN

Phase 1: CONTEXT TO THE STUDY
- ➢ Riyadh area and its landscape
- ➢ Geology, Geomorphology, of Saudi Arabia
- ➢ Riyadh Flora and plants communities
- ➢ History of Riyadh landscape
- ➢ Important factors in Riyadh region landscape
- ➢ The use of indigenous plants in designed landscape

Phase 2: SPECIES SELECTION, SEED COLLECTION AND PREPRATION

Phase 3: LABORATORY WORK
- ➢ Seed germination and tetrazolium test
- ➢ Treatments for breakage of seed dormancy
- ➢ Effect of temperature on the germination
- ➢ Effect of moisture on the germination
- ➢ Effect of salinity on the germination

Phase 4: GLASSHOUSE WORK
- ➢ Effect of competition on a sown community of Saudi native species

Phase 5: DEVELOPING GUIDELINES FOR LANDSCAPE PRACTICE
- ➢ The process of using indigenous plants within semi-natural landscape projects in Riyadh

Table. 1.1 The plan of the research

1.2 THE LANDSCAPE OF SAUDI ARABIA

Saudi Arabia is one of the largest Arab nations of the middle east (Fig 1.1). It is 2,200km^2 from North to South and 1,000 km from East to West. Al-Jazirah which, is the ancient name of Saudi Arabia slopes gently from the Hijaz Hills on the West coast of the Red sea to the Gulf on the East. In Asir, the South West region, the hills reach up to 2000m in height, where the climate is cold-temperate. But towards the Central Region, the climate is extremely arid. Saudi Arabia consists of five regions; the Central, Eastern, Western, Northern, and the Southern or Empty Quarter (Fig 1.2). All regions maintain the same social and religious traditions. They vary, generally in ecological habitat from the subtropical to the arid. To investigate the factors influencing landscape design in arid regions, the Central (Riyadh) Region of S.A. has been chosen as the case study. Essentially a raised plateau, it is defined by the Twaiqi mountain range, the curved spine of the Arabian peninsula, extending from the Nafud desert in the north down to the Empty Quarter in the south. To the west, the mountains slope to a flat plateau with extensive isolated pinnacles, cliffs and narrow gorges on either side. To the east the Twaiqi slope down gradually with many finger-like shuaibs or gullies, eroded into the limestone plateau.

The Central Region generally has an extensive wadi system that is rich in flora and contains a diverse range of habitats. The most important and longest wadi in the Central Region is Wadi Hanifah which passes adjacent to Riyadh city. It rises to the east, high in the Tuwaiq range, about 100 km northwest of Riyadh. The wadi contains many farms, which cultivate fruit trees and herbs.

Fig. 1.1 The map of Arabian peninsula showing the location of Saudi Arabia and Riyadh

1.2.1 GEOLOGY AND GEOMORPHOLOGY

Saudi Arabia covers about four-fifth of the Arabian Peninsula. In Precambrian time the Peninsula was attached to Africa as a part of the African shield, before the formation of the Red Sea. In the late Precabrian, its surface was deeply eroded and peneplaned. In the Middle Tertiary, the Arabian plate split away from the African Shield along the Red Sea trough. It then began moving slowly northward, impinging on the edge of the great Asian plate. The Arabian Peninsula is a huge crustal plate composed of ancient sedimentary and volcanic rocks deformed and metamorphosed and injected by plutonic intrusions (Chapman, 1978).

Presently, Arabia can be divided geologically into two structural provinces, the Arabian Shield and Arabian Shelf. The Arabian Shield (The Western Province) is a part of the Precambrian crustal plate, generally exposed and locally covered by Tertiary volcanic rocks. The Arabian Shelf (The Eastern Province) consists of a thick sedimentary sequence covering the plate. geomorphologically Saudi Arabia consists of 7 regions (Fig.1.2); Arabian Gulf Coastal Region, Al Summan Plateau, Eolian Sand Areas, Cuesta Region, Central Plateau, Mountains of Western Arabia and Red Sea coastal Plain (Champman, 1978).

Mobile sand covers about one third of Saudi Arabia. In the northern part, the term "Nefud" is applied to areas of deep sand and wind built dunes. In the southern part there is another area of eolian sand, the Great Arabian Desert of Rub'Al Khali (the Empty Quarter) in which sand lies in huge basin with approximate length of 1,200 km. and maximum width of about 650 km.

The immense area of elevated terrain in west central Saudi Arabia is known as the central plateau region. It is a trapezoidal shape with a width of 500-600 km. This plateau can be divided into three physiographic units: 1. Al-Hijaz plateau in the west, from Al-Taif southward to Abha. It is about 180 km wide. 2. Hisma plateau in the NW. 3. Najd pediplain which is a vast area nearly 600 km. The mountains of western Saudi Arabia are often referred to as scarp mountains. They are covered in the steep western edge of the eastward tilted Arabian shield. The NW escarpment is the result of Tertiary faulting that lowered the Red Sea coastal plain some 3000 m below the shield (Al-Hijaz plateau). The mountain belt runs the full western length of Saudi Arabia from the Gulf of Aqaba on the north to Bab-Al-Mandab on the south, varies in width form 40-140 km. The highest elevation of this range is about 3,760 m. The eastern coastal plain of the Red Sea is known as Tuhama. It is bounded inland by the scarp mountains and seaward by the shelf area.

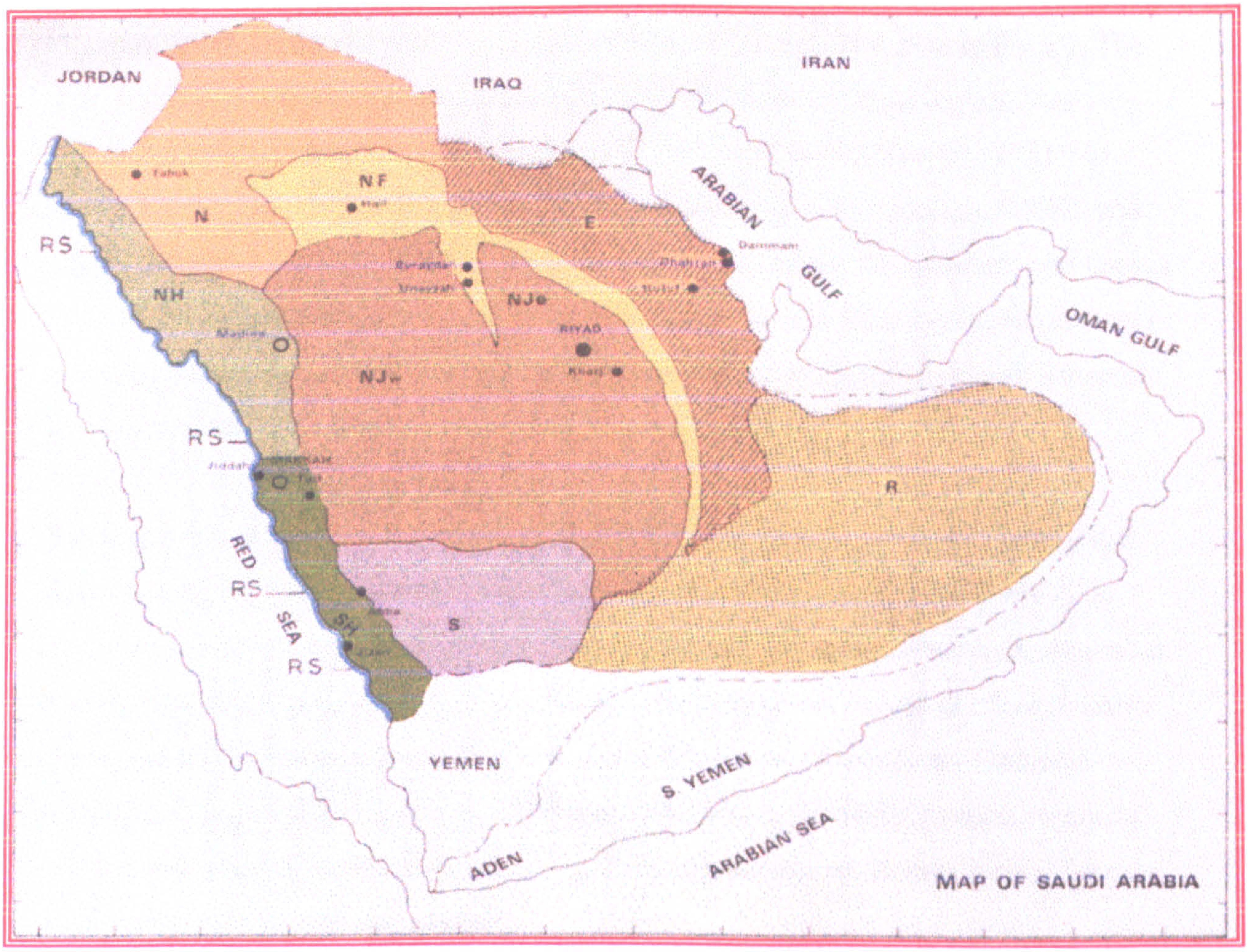

Fig. (1.2) Phytogeographical Regions of the Kingdom of Saudi Arabia; (Migahid 1974)
N. Northern r.egion, including Tabuk, Al-Jawfand Sakaka areas. **NF**. Nefud region, including the great northern Nefud area, Oahna' and Al-Qasim area. **NH**. North Hijaz, representing the western part of Saudi Arabia that extends alongside the Red Sea coast north of Jeddah. **SH**. South Hijaz, representing the southern part of the i western region extending south of Jeddah till :1 Yemen boundaries. **S**. Southern region, lying to the east of South Hijaz, to the south ofNajd and to the north of Yemen. It includes Abha, Bisha and Najran regions. **NJw**. WesternNajd. NJe. Eastern Najd. **E.** Eastern region, between Oahna' and the Arabian Gulf. **R.** Al-Rub' Al-Khali, representing most of the southern and south-eastern parts of Saudi Arabia . **RS**. Red Sea region, representing a narrow strip of Red Sea water alongside the Saudi coast.

1.2.2 THE VEGETATION

The principal recent sources of our knowledge on the flora of Saudi Arabia are : Zohary, (1957); Khattab and El-Hadidy, (1971); De Marco and Dinelli, (1974); Cope, (1985); Collenette, (1985); Choudhary and Akram, (1987); Chaudhary, (1989); Al-Zoghet, (1989); Migahid, (1988-1990); Mandaville, (1990); Heemstra, Al Hassan and Al Minwer, (1990); Al-Zoghet and Al-Alsheikh, (1999); and Chaudhary and Al-Jowaid, (1999).

Migahid, (1988-1990) classified Saudi Arabia into the 10 regions shown in Fig.1.2. The central area of Saudi Arabia that contains Riyadh constitutes the Najd region; Vesey-Fitzgerald, (1975); Migahid and El-Sheikh, (1977); Yossef and El-Sheikh, (1981); El-Sheikh and Yossef, (1981); El-Sheikh, (1985); Al-Zoghet and Al-Alsheikh, (1999); and Chaudhary and Al-Jowaid, (1999) have described its vegetation. The northern part known as the Great Nafud extends in a southeasterly direction into the Dahna crescent; the latter extends southwards through some eight degrees of latitude to form the western fringe of the Rub'al Khali sand desert.

The vegetation of the central Arabian sands has been observed in some detail at several places. Along the southern fringe of the Great Nafud in the vicinity of Ha'il which is characterized by wind-swept dunes of red sand and outcrops of sandstone rock, *Artemisia monosperma* and *Calligonum comosum* are abundant. *Monsonia nivea* and *Scrophularia deserti* are the commonest perennial forbs. The most frequent annuals are *Cutandia memphitica, Gypsophila capillaris, Heliotropium diaynum, Mathiola arabica, Neurada procumbens, Plantago ciliata, P. cylindrica, Polycarpaea repens, Rumex pictus, Senecio desfontainei and Stipagrostis plumosa.*

Between Ha'il and Linah, the southeastern part of the Great Nafud is prolonged as a series of sand ridges overlying a limestone plain. Wherever a great depth of sand is accumulated, as for instance in the Nafud at Shama, *Calligonum* and *Artemisia* are found. The annual vegetation here is prolific after good rains. *Plantago cylindrica* is the most abundant species, *Neurada procumbens* and *Rumex pictus* are also common.

Rhanterium epapposum is the characteristic and most abundant perennial over wide areas of north - central Arabia. Steppe vegetation dominated by this plant extends from about 30° N to about 25° N. Rhanterium steppe is encountered in north-central Arabia in the vicinity of Al Jawf on a plain of Cretaceous limestone which is heavily overblown with sand. At Sakakah the *Rhanterium* shrublets are spaced several metres apart and are not very robust, and *Artemisia* sp. is a frequent associate which becomes locally dominant. Annual herbs and grasses form a thin carpet between the shrubs, and a variety of species occur in the sandy areas, but *Stipa capensis* is the dominant grass on firmer ground. Within the sands of the Great Nafud to the south there occur extensive level belts of gravel which are largely bare of vegetation, due probably to lack of penetration of rainfall and excessive surface run-off. In some places the gravel is overlaid with ribs of wind-blown sand, where *Rhanterium* is again characteristic.

The Dahna sand belt comprises a series of sandy ridges alternating with strips of gravel, and culminating in high dunes along the western face. *Rhanterium* is abundant over areas of shallow, level or undulating sand overlying the gravel throughout the Dahna. The most abundant herbaceous species associated with it are *Neurada procumbens, Plantago albicans* and *Stripagrostis plumosa.* To the east of the Summan plateau, *Rhanterium* steppe is well developed around Qaryat and extends into the state of Kuwait. Along the western edge of the Dahna sands, from al Ajfar to the south of Ar Rumah, there is a sandy-silty plateau which supports *Rhanterium* steppe.
Stipa capensis is the characteristic and most abundant cool-season grass over wide areas of north-central Arabia. *Stipa* does not occur in sandy habitats. Throughout the area occupied by the *Rhanterium* steppe, *Stipa* is the characteristic annual on all the finer silty soils. In the vicinity of Unayzah there is a rough plain which drains into saline depressions along the contact with the sands. Brackish lakes are formed in these depressions during the rains. *Gymnocarpos decander* is frequent over the plain and is the characteristic dwarf-shrub of the area; *Diplotaxis acris, Fagonia myriacantha, Helianthemum kahiricum* and *H. lippii* occur, *Stipa capensis* grows there after favorable rains.

In the desert wadis near Riyadh the following species are abundant: *Aristida obtusa, Heliotropium luteum, Rhazya stricta, Blepharis persicae, Malva parviflora, Pergularia tomentosa, Polycarpaea repens and Zilla spinosa* (Abd El-Rahman 1986).

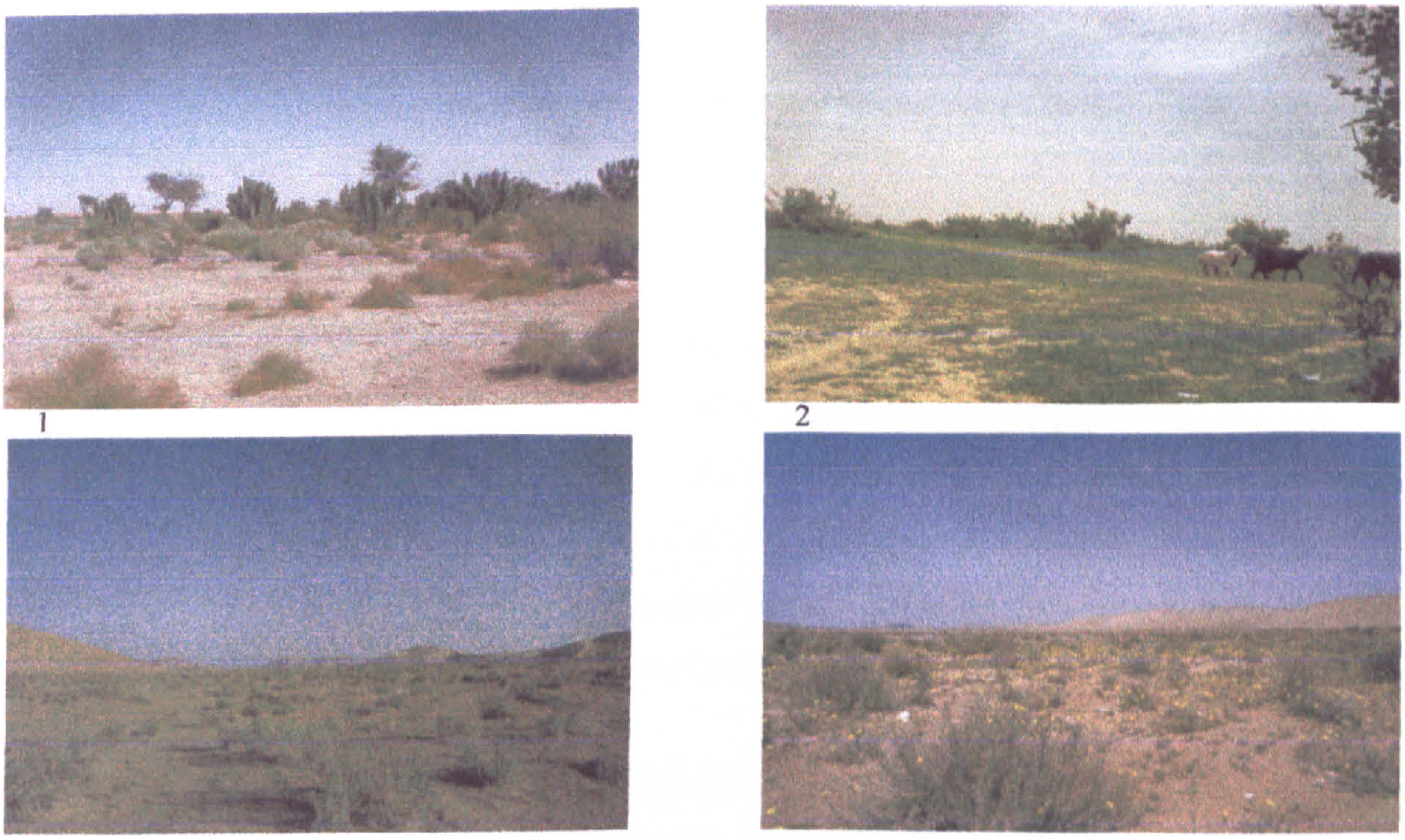

Fig. (1.3) . 1- Raudhat kharaim (Near Riyadh), some species grow in and along the water flow channels. 2- Raudhat kharaim with the winter – spring cover of annual and perennial herrbs. 3- The saline sabkhas covered with sand sheets of varying depth.(*Zygophyllum mandvillei* plant community) 4- *Traganum – Haloxylon salicornicum* community.

1.2.3 PLANT COMMUNITIES OF CENTRAL SAUDI ARABIA

In the global terms, areas with abundant rain support forests, as trees require more moisture. Decreasing availability of water results in woodland or scrub vegetation. Below a certain level or rainfall, normal soils support grassland vegetation in warmer parts of the world. With increasing aridity, and/or exceptionally demanding soil condition, only adapted kinds of plants and plant communities can survive. The latter is the case in most parts of Saudi Arabia, such as the Riyadh region.

The vegetation of central Saudi Arabia is mostly hyper aridity tolerant. The topography here, too, and the consequent "water-harvesting", water-shed-off and water conservation factors govern subtle to major changes in the plant communities. No trees are to be seen in the general landscape except in the wadis (valleys) or water-receiving areas or unnels. Therefore in the general landscape trees are occasional and not part of the major vegetation communities. The habitats here support shrubs like *Lycium* and other smaller shrubs specially adapted to the extremes of the climatic conditions in this region.

Of the specially adapted shrubs for the area without deep sands the more prominent species; *Gymnocarpos decandrium, Haloxylon salicornicum, Rhanterium epapposum* and *Artemisia sieberi* which from outstanding components of the plant communities. The community that at one time existed in the wadis (valleys) in this areas comprised a tree layer of *Prosopis koelziana.* How extensive this community was at that time can only be a matter of conjecture as this tree is now seen only as a relic here and there in different wadis (valleys) of the central region. This demonstrates however the major impact of people on shaping current day plant communities.

In general, the two major community complexes are the *Haloxylon salicornicum* and the *Rhanterium epapposum* community complexes. These complexes change in response to human/biotic interference. The single most important factor, is the deposition (or loss) of sand cover and its thickness (or absence) over the lower soil or rock layer. The well-drained gravel-covered areas with different depths of sand over limestone usually support the *Rhanterium epapposum* community complexes. Areas where water may stand for even short periods usually lack *Rhanterium epapposum. Haloxylon salicornicum* can tolerate higher salinity but luxuriates in non-halophytic conditions. It forms communities in a wide range of habitats from sand sheets to well-drained shallow soils to basin-like area to coastal plains. As a result, we have a mosaic of community complexes centered around these two shrubs. In general, the annual and perennial herb components of these two community complexes are similar. Their density and vigour vary with the timing and amount of rain received during a particular year/season (Caudhary and Al-Jowaid, 1999).

In the Riyadh region in general, the more significant plant communities/habitat are as below. This list was derived from studies of Migahid, (1974); Al-Zoghet and Al-Alsheikh, (1999); and Chaudhary and Al-Jowaid, (1999):

Table 1.2: ***Acacia gerrardii – Lycium* community** formed in wadi (valley) floors, wadi flood channels, larger runnels and erosional gullies

Tree Layer:	Tall shrub layer:	Low shrub layer:	Herbaceous layer:
Acacia ehrenbergiana	*Calotropis procera*	*Astragalus spinosus*	*Alhagi graecorum*
Acacia gerrardii,	*Lycium shawii*	*Atriplex leucoclada*	*Astragalus spp*
	Ochradenus baccatus	*Capparis cartilaginea*	*Centaurea bruguierana*
	Prosopis farcta	*Capparis spinosa*	*Citrullus colocynthis*
		Deverra triradiata	*Eremobium aegypticum*
		Ephedra foliata	*Erodium spp*
		Farsetia aegyptia	*Filago desertorum*
		Ochradenus baccatus	*Harwoodia dicksoniae*
		Ochradenus arabicus	*Ifloga spicata*
		Ochradenus bccatus	*Kickxia aegyptiaca*
		Rhanterium epapposum	*Launaea spp*
		Salsola imbricata	*Leysera leyseroides*
		Teucrium oliverianum	*Linaria haelava*
		Zilla spinosa	*Malva parviflora*
			Medicago spp
			Monsonia nivea
			Notoceros bicornis
			Paronychia aradica
			Picris cyanocarpa
			Plantago boissieri
			Plantago ciliata
			Sclerocephalus arabicus
			Stipagrostis spp
			Trigonella spp

Table 1.3: ***Lycium - Gymnocarpos – Tripogon* Community** formed in the plateau top

Tall shrub layer:	Low shrub and Herbaceous layer:	Grasses:
	Anisosciadium lanatum	Enneapogon desvauxii
Lycium shawii	*Anvillea garcinii*	*Stipagrostis raddiana*
Gymnocarpos decandrum	*Atractylis carduus*	*Tetrapogon villosus*
	Blepharis ciliaris	*Tripogon africanus*
	Diplotaxis harra	*Tripogon multiflorus*
	Fagonia bruguieri	
	Halothamunus bottae	
	Helianthemum lippii	
	Kohautia caespitosa	
	Pterogaillonia calycoptera	

Table 1.4: ***Acacia – Lycium - Gymnocarpos* Community** formed in the slopes. The areas with deposited soil in the cracks and between rocks support this mixed community.

Tree Layer:	Tall shrub layer:	Low shrub layer:	Herbaceous and Grasses layer:
Acacia ehrenbergiana	*Capparis cartilaginea*	*Capparis cartilaginea*	*Blepharis ciliaris*
Acacia tortilis	*Lycium shawii*	*Convolvulus oxyphyllus*	*Cenchrus ciliaris*
		Farsetia aegyptia	*Cymbopogon commutatus*
		Gymnocarpos decandrum	*Fagonia bruguieri*
		Helianthemum lippii	*Glossonema varians*
		Kohautia caespitosa	*Hyparrhenia hirta*
		Lycium shawii	*Morettia parviflora*
		Ochradenus arabicus	*Stipagrostis raddiana*
		Ochradenus baccatus	
		Pulicaria glutinosa	
		Teucrium polium	
		Trichodesma africanum	

Table 1.5: ***Acacia tortilis – Acacia raddiana* Community** formed in alluvial fans; this is the typical original vegetation in the central province

Tree Layer:	Tall shrub layer:	Low shrub layer:	Herbaceous layer:
Acacia ehrenbergiana	*Lycium shawii*	*Astragalus spinosus*	*Andrachne telephioides*
Acacia raddiana	*Ochradenus baccatus*	*Achillea fragrantissima*	*Anvillea garcinii*
Acacia tortilis	*Pulicaria glutinosa*	*Deverra triradiata*	*Astragalus sieberi*
		Farsetia aegyptia	*Convolvulus oxyphyllus*
		Gymnocarpos decandrum	*Khohautia caespitosa*
		Halothamunus bottae	*Morettia parviflora*
		Heliotropium crispum	*Pterogaillonia calycoptera*
Grass layer:		*Rhanterium epapposum*	*Rhynchosia sp.*
Chrysopogon plumulosus		*Salsola lachnantha*	*Teucrium polium*
Cymbopgon commutatus		*Salvia aejyptiaca*	
Lasiurus scindicus		*Scorzonera musilii*	
Panicum turgidum		*Teucrium oliverianum*	
Pennistum divisum		*Zilla spinosa*	

Table 1.6: ***Acacia - Maerua* Community** formed in bluffs receiving run-off from the plateau above.

Trees:
Acacia ehrenbergiana
Acacia raddiana
Acacia spp.
Acacia tortilis
Maerua crassifolia

Table 1.7: ***Ochradenus - Haloxylon salicornicum - Gymnocarpos* Community** formed in level top of plateau (without water run off). This enables some perennial vegetation to survive on the thin to deeper soil on the surface and in fissures

Shrub layer:	Herbaceous layer:
Gymnocarpos decandrum	*Anvillea garcinii*
Haloxylon salicornicum	*Blepharis ciliaris*
Ochradenus baccatus	*Convolvulus austro-aegytiacus*
Rhanterium epapposum	*Convolvulus oxyphyllus*
	Farsetia aegyptia
	Farsetia burtoniae
	Heliotropium crispum
	Lasiurus scindicus
	Scorzonera musilii

Table 1.8: ***Ficus* Community** formed in gullies receiving run-off

Trees:	Shrub layer
Ficus salicifolia	*Hibiscus microanthus*
	Ficus palmata

Tanle 1.9: ***Haloxylon salicornicum* Community** formed in gently undulating alluvial basins of bare gravelly areas.

Shrubland and perennial herbs:	
Anabasis setifera	*Stipagrostis plumosa*
Convolvulus oxyphyllus	*Blepharis ciliaris*
Halothamunus iraqensis	*Artemisia sieberi*
Haloxylon salicornicum	*Zilla spinosa*

Table 1.10: ***Haloxylon salicornicum -Astragalus - deverra* Subcommunity** formed in *wadi (valley)-like areas within the general Haloxylon salicornicum habitat.* The topography is hummocky because of flood erosion. The soil is alluvial sand over lower, finer-textured material.

1st layer:	2nd layer:	3rd layer:	
Acacia gerrardii	*Lycium shawii*	*Astragalus spinosus*	*Rhanterium epapposum*
		Convolvulus oxyphyllus	*Teucrium oliverianum*
		Deverra triradiata	*Zilla spinosa*
		Haloxylon salicornicum	

Table 1.11 ***Aeluropus* Community** formed in a heavy clay, highly saline area

Aeluropus lagopoides

Table 1.12: ***Haloxylon salicornicum -Artemisia sieberi* Subcommunity** formed in gently sloping areas in the general *Haloxylon salicornicum* region. Soil sandy over a loamy-sand

1st layer:	2nd layer:
Haloxylon salicornicum	*Astragalus spp*
Artemisia sieberi	*Calendula arvensis*
	Erodium spp
	Filago desertorum

Fig. 1.4 Remnants of *Haloxylon salicornicum -Artemisia sieberi* Subcommunity

Fig. 1.5 Calligonum – *Artemisia onosperma* community

Table 1.13 ***Rhanterium* Community** formed in shallow to moderately deep gravelly-sandy soil over limestone areas

Species	
Rhanterium epapposum	*Lycium shawii*
Haloxylon salicornicum	(Rhanterium steppe)

Table 1.14 ***Lycium - Rhanterium - Deverra* Community** formed in shallow runnel areas and gently sloping or level areas between raised gravel-covered bare areas

1st layer:	2nd layer:	3rd layer:	
Lycium shawii	*Astragalus spinosus*	*Astragalus spp*	*Linaria haelava*
	Anvillea garcinii	*Arnebia decumbens*	*Notoceros bicornis*
	Convolvulus oxyphyllus	*Calendula arvensis*	*Paronychia aradica*
	Deverra triradiata	*Eremobium aegypticum*	*Picris cyanocarpa*
	Ephedra foliata	*Filago desertorum*	*Plantago ciliata*
	Farsetia aegyptia	*Heliotropium crispum*	*Polycarpaea repens*
	Hyparrhenia hirta	*Horwoodia dicksoniae*	*Polycarpaea robbairea*
	Rhanterium epapposum	*Ifloga spicata*	*Stipagrostis plumosa*
	Teucrium oliverianum	*Kickxia aegyptiaca*	
	Zilla spinosa	*Leysera leyseroides*	

Fig. 1.6: A view of Raudhat Sebalah after rains in the area

Fig. 1.7: The extensive *Rhanterium* community

Table 1.15 ***Haloxylon salicornicum - Rhanterium* Community** formed in large bare gravelly areas and sandy vegetated area. The soil under the community is sandy to sandy-loam, shallow to moderately deep.

1st layer:	2nd layer:
Haloxylon salicornicum	*Astragalus hamosus*
Rhanterium epapposum	*Astragalus achimperi*
	Calendula arvensis
	Erodium spp
	Medicago spp
	Notoceros bicornis
	Plantago spp

Table 1.16 ***Ziziphus nummularia - Lycium* Community** formed in Raudha-like clayey areas receiving flood water

1st layer:	2nd layer:	3rd layer:
Ziziphus nummularia	*Lycium shawii*	*Zilla spinosa*
	Prosopis farcta	*Caylusea hexagyna*
		Ochthochloa compressa
		Stipagrostis plumosa
		Erodium spp
		Lepidium aucheri
		Convolvulus oxyphyllus
		Convolvulus pilosellifolius
		Cynodon dactylon

Fig. 1.8 The annual and perennial herbs in the *Haloxylon salicornicum* community

Fig. 1.9 *Ziziphus nummularia* and *Capparis decidua* can withstand flooding

Fig. 1.10: Dense stands of *Pulicaria crispa* and *Rhazya sp.*

Fig. 1.11: Part of Raudat Kharaim receives and retains most of the water before the water seeps down under the sand mass beyond this area, *Ziziphus nummularia* and *Capparis decidua*

1.3 THE HISTORY OF THE RIYADH CULTURAL LANDSCAPE

1.3.1 TRADITIONAL CITY FORM

The landscape pattern in the ancient towns of the Riyadh Region is characterized by many features such as compact urban fabric creating a close-grained open space pattern. The pattern reflects the traditions and religious way of life i.e. no segregation between community levels; the poor live in harmony with the rich, large houses intermingle with small reflecting the cohesion of the community structure.

Historically the wealth of a family was counted by the number of palm trees they owned, which encouraged people to cultivate more palm trees (Albrahime, 1988). Again there was no segregation between rich and poor farmers, no right of way or water control i.e. each farmer shared water in case of drought, in a way typical of Islamic society.

Moreover, in ancient cities the mud wall of the houses defined the roads. The widths of the roads, which were principally for pedestrians, vary from 2-6 m (secondary) or 6-12 m (primary). The height of the buildings were usually approximately 8m. Also the form of native species such as *Phoenix dactvlifera* were permited the use of this species in small spaces. The distribution of native settlements were linked with both the availability of water and certain native species such as *Ziziphus spina-christi* and *Phoenix dactvlifera.* Native species are usually found in the courtyards, which dominate the urban patterns. (Salama, 1990)

The courtyard is an important landscape element in the traditional Saudi urban landscape; it acts as an active element in the house. There are certain species used in planting the courtyards. Traditionally the palm tree was favoured for its useful dates and long life. Under the palm tree vines and citrus trees or sometimes *Ficus pseudosycamorus* were grown. Although subtropical species were found to thrive under such conditions, they were rarely used.

Tamarix aphylla was used as the main source of building wood. People planted these as wind protection, and wood for general use. *Capparis spinosa,* associated with dry mud walls, proved a successful species for these compact urban landscapes.

The landscape pattern in traditional settlements is characterized by features such as; canal and basin irrigation, the geometrical distribution of plants such as palm canopies. The form of the landscape is also heavily influenced by the presence of water wells. To provide maximum shade to create cooler microclimatic conditions for cultivating other important crops and also to provide desirable places for recreation.

1.3.2 HISTORICAL USE OF INDIGENOUS PLANT

1.3.2.1 PALM AND CROP GROVES

The native plant communities were dominated by *Phoenix dactlyfera* planted in groves, which varied in size and direction according to the wealth of the owners, ground water availability, soil conditions and wind direction. These palm groves were planted by both manual seeding methods and natural succession. They were planted in a hierarchy of densities from urban centres out to the urban fringe.

The middle intensively planted zone was mainly for cropping dates and using the modified microclimate under the palm canopy to cultivate different crops and for recreational use such as camping, walking, hunting and sometimes horse riding out into the desert. The maximum camping period was usually one week.

In the urban fringe the palms were planted extensively at low densities to act as a transition belt to define the urban growth, satisfy recreational needs and filter the sand storms common in the Najd. The external ring of landscape, which was exposed to the desert, modified the harsh macroclimate and acted as a transition zone to the desert communities. Over time these transition zones gradually integrate and overlapped with the desert communities starting with stand of *Acacia arabica, Ziziphus numelaria* shrub land, to open and sparse grass land (Salama, 1990).

1.3.2.2 RECREATIONAL USE OF INDIGENOUS PLANT COMMUNITIES

The desert communities were used by the native people during the winter as short camping and recreational facilities, while in the summer the recreation activities could be classified into two parts. Firstly during the morning, when hot conditions prevailed, residents tended to utilise the naturally developed microclimatic conditions beneath the palms canopy. Secondly at night, when they migrated to the open stands of acacia trees in the desert especially during moon lit nights, which persist for a period of 14 days every Arabic month. The existing traditional and recreational activities usually covered camping, horse riding, and other sports facilities.

1.3.2.3 MEDICINAL USE OF INDIGENOUS PLANT COMMUNITIES

The inhabitants of the Najdi manipulated indigenous vegetation through a variety of methods; particularly as a useful source for medical remedies. Historical records show ancient Arab physicians to have been medical pioneers as recorded by "Ibn-Sainaa" on his tomb (Khalifah, 1980).

1.3.2.4 AGRICULTURAL USE OF INDIGENOUS PLANT COMMUNITIES

The stands of indigenous vegetation provided grazing for domesticated animals. As a result people developed an understanding of their environment tending to classify the habitats according to value for animal foraging. Ancient management methods were common in manipulating the desert resources. Grazing zones were regularly and closely monitored to achieve sustainable plant communities.

1.3.3 THE WESTERN TRANSFORMATION

In Saudi Arabian cities the growth of urbanization in the kingdom was rapid and intensive, as a result of oil wealth. From 1970 the government gave full support for unlimited urban growth, by guaranteeing and providing infrastructure, utilities, housing and other important services. This intensive urbanization will continue, especially in Riyadh. Urban expansion during the last 20 years was so fast that the master plan of the Riyadh capital Saudi Arabia has undergone four or even five distinct revisions.

The old town which represents and respects Saudi Arabian culture, traditions, heritage and lifestyle was distorted without a transitional zone between the compact and rich old pattern and the low density new pattern. The centre was planned and built without keeping in mind the Saudi Arabian heritage, lifestyle, culture and even environment. This also applies to open spaces and plant use. Exotic subtropical plants imported from Egypt, South Asia, Australia and the U.S.A replaced native trees. Even the palm trees were replaced by another species, *Washingtonia filifera* which was used as a specimen in the streets and squares.

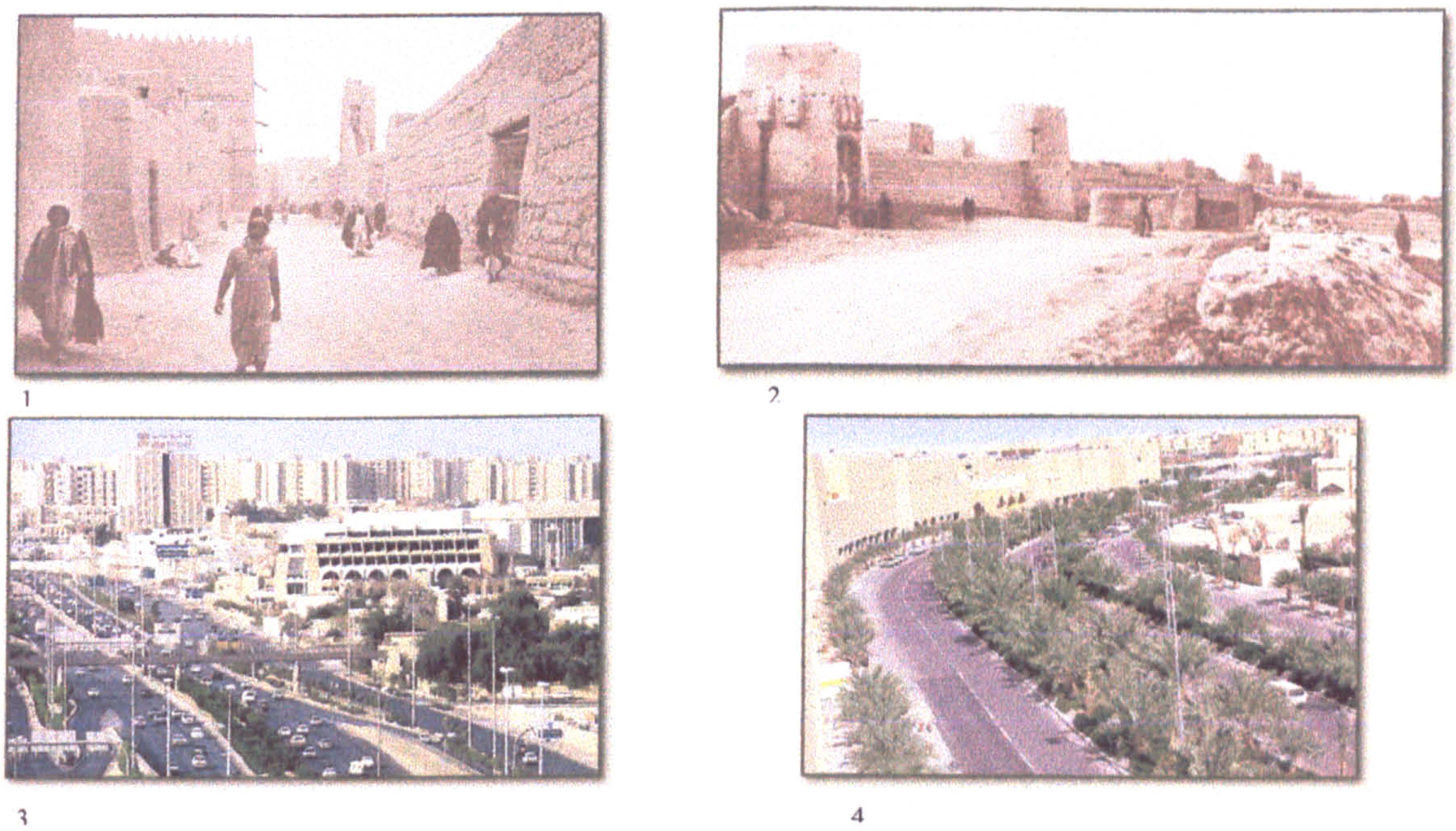

Fig. (1.12) Street landscape in Riyadh approximately sixty years ago (1,2) and now (3,4).

1.3.4 LANDSCAPE AND PUBLIC POLICY

The Riyadh administrative Region covers approximately 20% of the total area of the Kingdom with a population of approximately 4,500,000. The region is considered by the government to be an area in which priority should be given to development as it contains the capital, the centre of commerce, industry and the government.

During the last fifteen years the Saudi Arabian government provided this programme with full support. The first landscape department in the municipality of Riyadh was opened in 1978. It was treated generously by the council of ministers who approved a large budget; from 1979 until now a large number of parks have been completed. Table 1.16 shows the landscape work proposed and completed since 1971 by the municipality of Riyadh; this excludes street planting, which has not yet been measured. Riyadh Development Authority (A.D.A..) is the second landscape authority in the Riyadh, the main agent commissioning important planning and construction projects (Table 1.17).

The landscape works proposed and completed since 1970 by the municipality of Riyadh	
Regional parks under tendering	1,000,000m^2
District parks constructed	243,397m^2
Children's play areas	312,840m^2
Proposed Regional and Nature parks	
Riyadh wadi park	40 km^2.
nature park	20 km^2. (approx)
District park (Riyadh and Central Region towns)	6,000,000 - 8,000,000m^2

Table (1.16): Public landscape spaces in Riyadh which indigenous species could be used in. (Municipality of Riyadh and A.D.A 1990)

Landscape works constructed by A.D.A.	
Intensive landscape	536,644m^2
Extensive landscape	336,616m^2
Public parks	144,000m^2

Table (1.17): Public landscape spaces in Riyadh, in which indigenous species could be used (*Riyadh Development Authority (A.D.A)*)

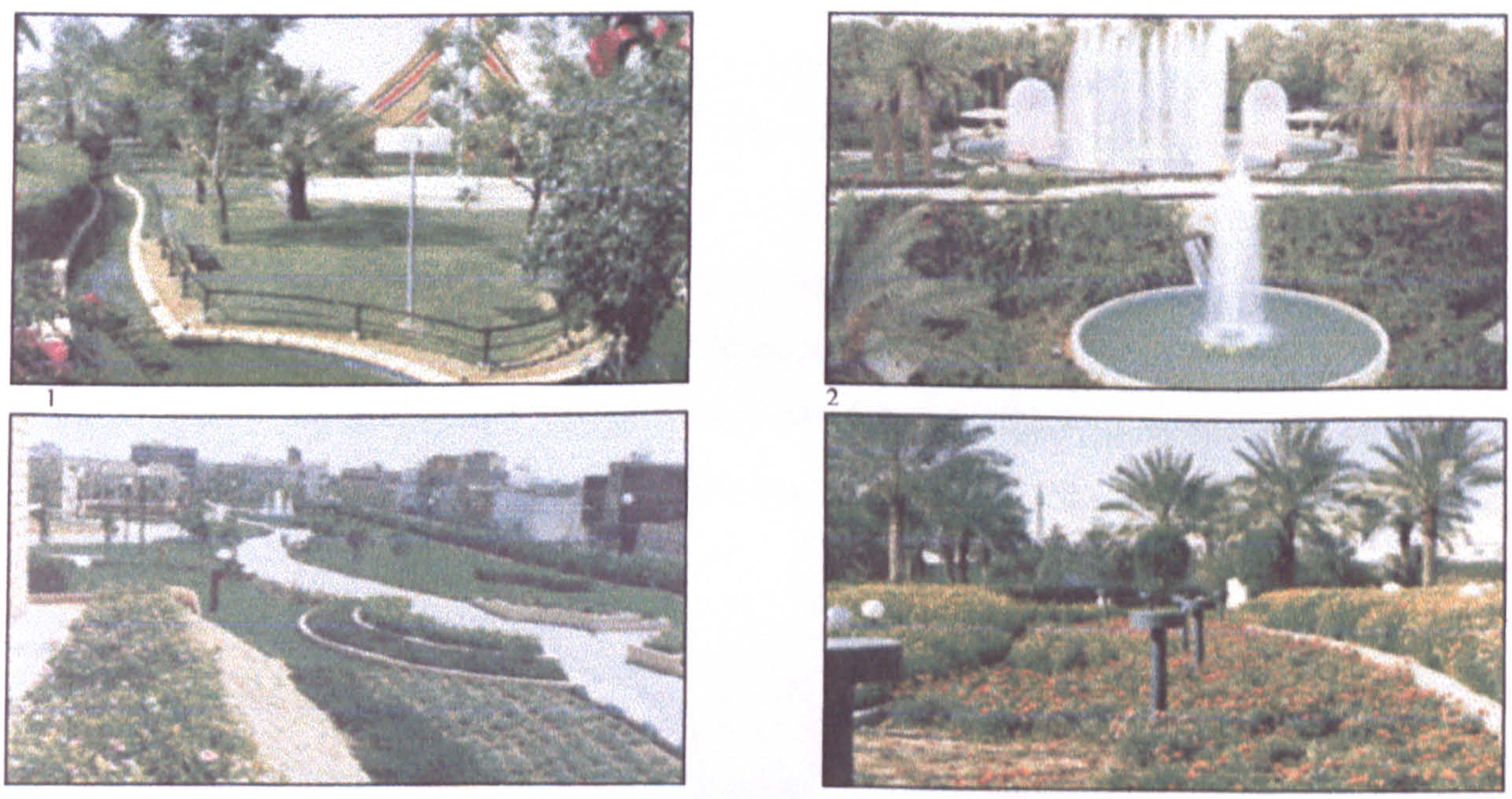

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Fig.(1.13) A view of some Riyadh parks, showing the use of non-indigenous plants.

1.4 IMPORTANT FACTORS IN THE SAUDI LANDSCAPE

1.4.1 INTRODUCTION

Arid land dominates the Middle East and this must be clearly understood before any new man made, activity is undertaken. Fifty years ago climatic and physical factors were the strongest influences on settlement design and the surrounding landscaping. Arid lands are complex and sensitive ecosystems. One must observe the dynamic behaviour and the interaction of the components. The primary limiting resource is moisture, this determines the pattern of the ecosystem. This shortfall of moisture has driven natural selection to produce a diverse ecosystem of plants and animals.

It is obvious to most people that to establish planting in the mainly arid or semi-arid conditions the Middle Eastern countries demands a very different approach from temperate European practice. In addition to climate factors, the people and their cultural, social and traditions, also need to be considered.

By studying such environmental factors, it becomes clear that native plant material, which has successfully adapted to the aridity of Riyadh region, is generally likely to be most suitable for landscaping projects in Riyadh, and especially those where resources for management are limited. Imported species are generally less suitable, although still valuable for some roles. Riyadh City is taken as representing the general meteorological conditions in Riyadh region. It is situated at 24° 39'N, 46° 22'S, at an elevation of 590 metres above sea level. It is located approximately in the middle of the Riyadh administrative region.

1.4.2 PHYSICAL FACTORS

1.4.2.1 THE CLIMATE OF SAUDI ARABIA

Mean annual cloud cover is generally less than 10% in the Arabian Peninsula. During the summer, global solar radiation can exceed 700-cal $cm^{-2} day^{-1}$, dust and moisture in the atmosphere reduce this by as much as 25%. In Saudi Arabia extreme temperatures usually occur during summer (the temperature in shade > 48°C over much of the central part of the country). In winter the temperature often drops below freezing in the central and most northern of the country but snow and ice are uncommon except in the mountains. Zahran, (1983) provides data on the mean monthly temperature (Table 1.18), rainfall (Table 1.19) and relative humidity (Table 1.20).

Mean monthly temperature	Inland regions	Red Sea coast	Arabian Gulf coast
Winter	5 - 20°C	19 - 27°C	11 - 21°C
Spring	15 - 30°C	22 - 37°C	18 - 31°C
Summer	28 - 37°C	28 - 34°C	35 - 37°C
Autumn	13 - 37°C	24 - 31°C	22 - 32°C

Table 1.18: The mean monthly temperature of different regions of Saudi Arabia.

Annual rainfall	Southwestern region	Western region	Northern region	Central region	Eastern region	Empty Quarter
	156 - 355	150 - 277	56 - 127	104 - 125	7 - 102	0 -92

Table 1.19: Annual rainfall in different regions of Saudi Arabia

Relative humidity	Inland regions	Southern part of the Red Sea coast	Northern part of the Red Sea coast	Arabian Gulf coast
Winter	35 – 75%	57% - 74%	53 – 57%	45 – 77%
Summer	13 – 47%	57% - 74%	73 –75%	15 – 54%

Table 1.20: Relative humidity in different regions of Saudi Arabia

Saudi Arabia is characterized by high solar radiation. Sunshine days are >300 in most regions. According to the isolene map of Kettani and Lam, as quoted by Zahran, (1983), the average daily solar radiation received on the ground during the 1970 varied from 409 to 663-cal $cm^{-2} day^{-1}$. The lowest value recorded in the northwest part of the country and the highest in the Empty Quarter.

1.4.2.2 MACROCLIMATIC OF RIYADH CITY

i. Temperature

The maximum temperatures recorded in Riyadh occur in July (49 °C) and the minimum in January (-7.2 °C), giving a range of 56.2 °C. Mean monthly temperatures are 14.4 °C in January and 33.60 in July. The spring and autumn means are both approximately 26 °C. The difference between summer and winter is wide enough to cause damage to imported plants (Fig,1.14).

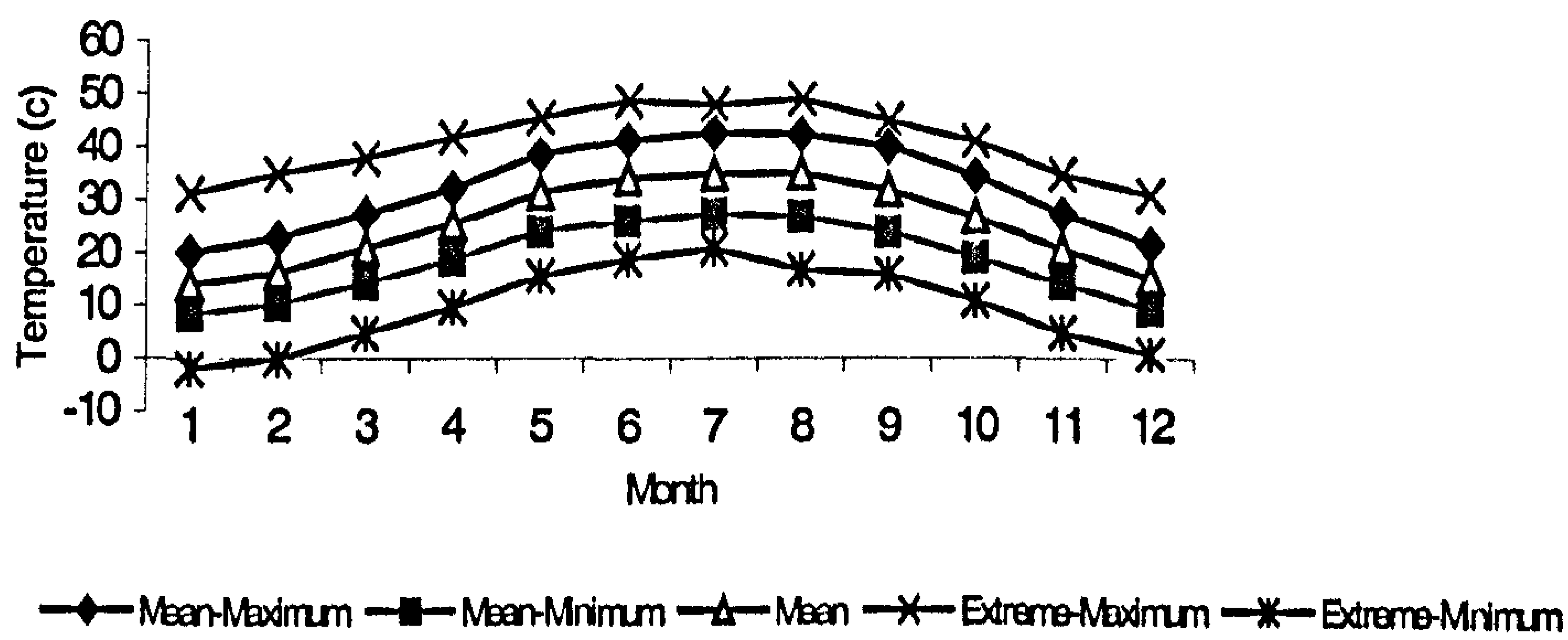

Fig. 1.14: Monthly averages of temperature – Riyadh city

ii. Relative humidity

The relative humidity in Riyadh differs from those of Hail and Jeddah as these latter settlements are located near the coast. In Jeddah, the values are relatively constant at 60%, with Riyadh being considerably lower during the summer period. Riyadh's mean relative humidity is 43% due to relatively high values during the winter months. This factor of higher and constant relative humidity in Jeddah and Hail is reflected in the greater success of imported flora in those regions.

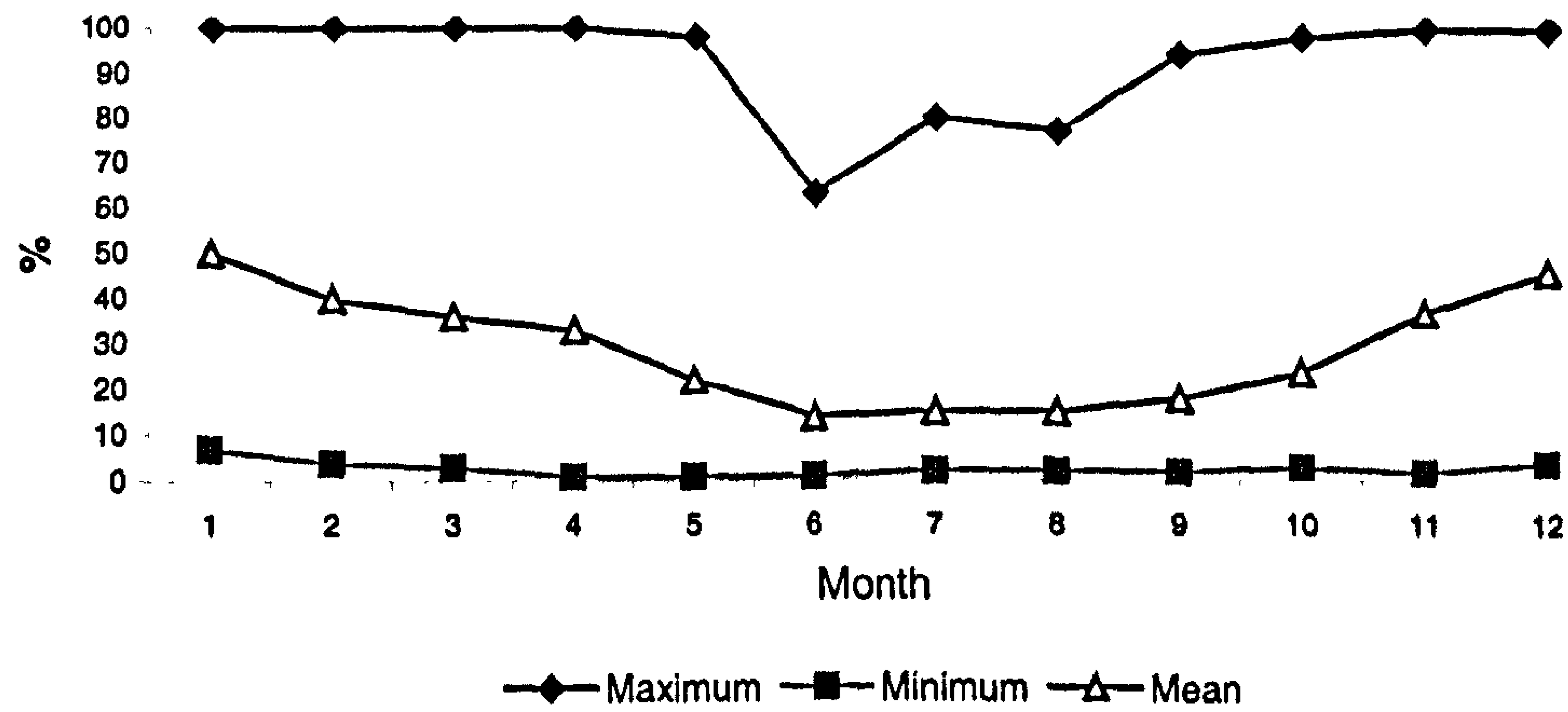

Fig. 1.15: Monthly averages of Relative Humidity -Riyadh city

iii. Rainfall

Unlike other regions of Saudi Arabia, the Central Region is excessively dry, with Riyadh receiving significantly less precipitation than cities closer to the Red Sea and the Gulf. Such rainfall as occurs in Riyadh, tends to fall in February, March and April, with a tendency for severe storms, which often cause floods in the lower lying land.

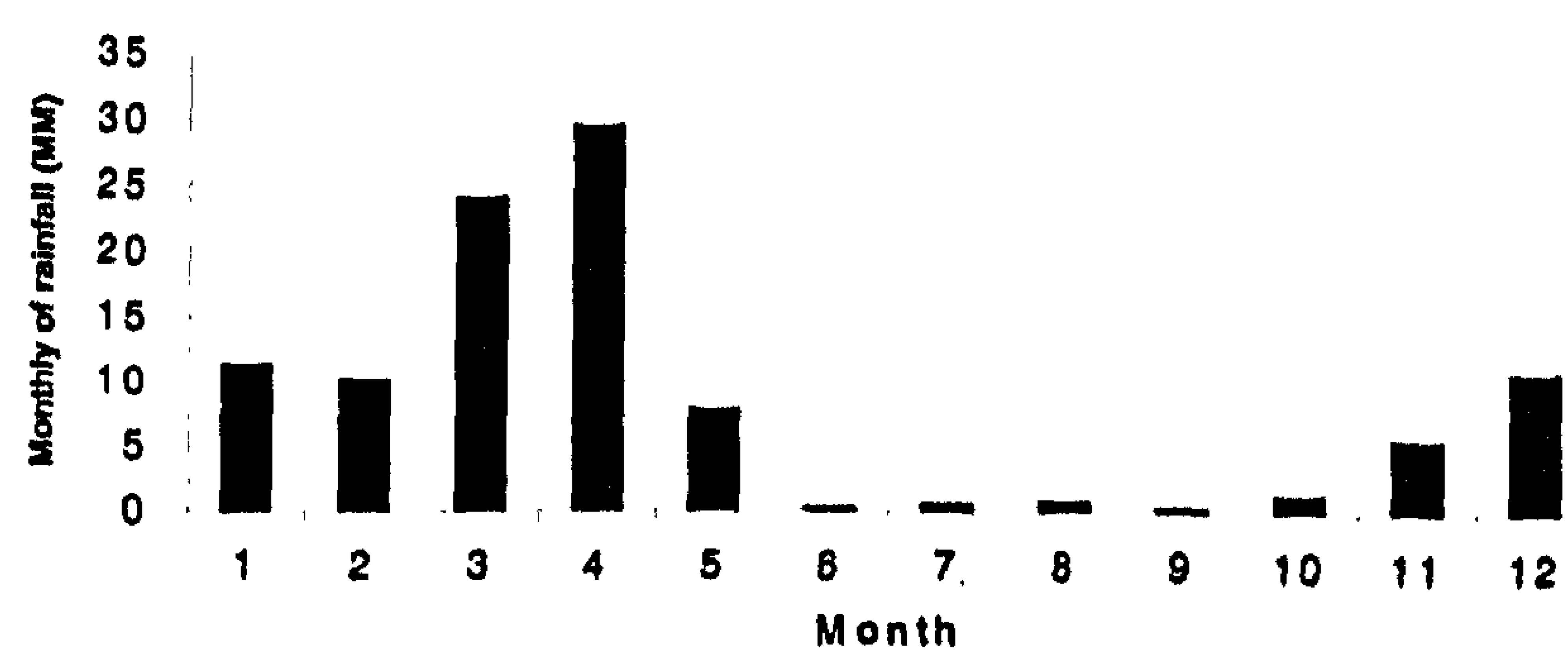

Fig. 1.16: Mean Monthly rainfall – Riyadh city

iv. Wind

Riyadh is influenced by two different global air movement systems. In winter the effect of a cold air current from the eastern Mediterranean areas sometimes penetrates down the Arabian peninsula in the form of relatively moist northwesterly winds.
Wind directions are very variable, and maximum velocities tend to occur during spring and early summer; speeds of over 40 knots have been registered in Riyadh. In Najd sand and dust storms are typical of this type of climate and terrain. They usually occur from March to May when hot and cold air masses converge in this zone, creating particularly unstable atmospheric conditions.

v. Evapotranspiration

The mean annual potential evapotranspiration is 1367 mm, although this accommodates significant seasonal variation, being high in the summer and low in the winter. These values are greatly affected by the influence of wind, vegetation and other factors which are not readily quantifiable, the figure of 1367 mm per annum is often exceeded . Such levels of evaporation will increase the water consumption by non adapted flora, which tend to transpire water to cool their leaves effects adding to the problem of salinity and underground water quality.

1.4.2.3 SOIL

The identification of soil and surface geology for a particular site will inform the appropriate selection of a plant or plant community. The classification of the Riyadh region's soil is an important factor in the design assessment of the landscape and relates to the availability of natural materials.

The Riyadh Region contains the following phyto-ecogeomorphological systems: cliffs, steep ridges and rocky outcrops, gravelly plains, gravelly hills, sandy formations, wadis, shuaibs. These features are now described as an introduction to Riyadh Region geomorphology (Salama, 1990).

Soils in the region (Fig.1.17) are very much of desert type resetting from aridity and other harsh climatic factors (Zoghet and Al-Alshikh, 1999). Most of the higher quality soils are found in the wadis and shuaibs known as alluvial fans: all the soil used in the current landscape projects come from those shuaibs and wadi beds. In Riyadh those wadis and shuaibs contain a valuable habitat, now being destroyed by this soil removal, largely to supply the requirements of imported species.

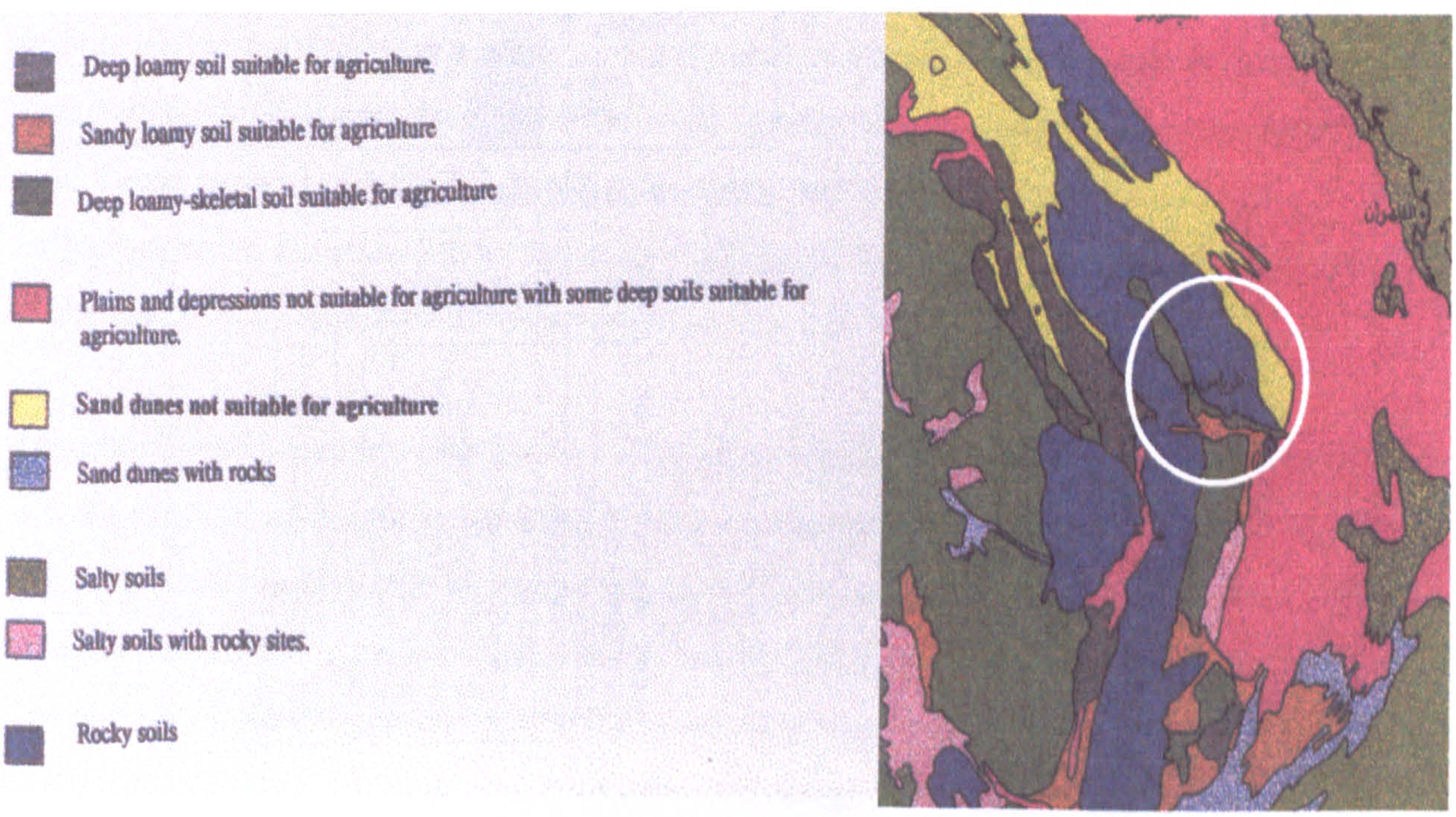

Fig. (1.17): General Riyadh soil map (Zoghet and Al-Alshikh, 1999). The approximate boundary of the city is shown as circle.

1.4.2.4 WATER

i. LANDSCAPE IRRIGATION

Water is the missing element in the establishment of arid zone landscape, it gains its highest importance where the amount of rainfall is generally low and spasmodically distributed, in infrequently and unpredictable discrete pulses. Ecologists observe that water availability structures and controls desert communities. The introduction of water triggers biological activities and rapid increases in biomass and carrying capacity that can crash shortly after. In general, deserts receive less water than any other habitat, and consequently deserts are often considered to be the least productive habitats on earth (Louw and Seely, 1982).

Throughout the drier parts of the arid zones irrigation for amenity planting is a necessity during the plant establishment period. The traditional irrigation method employed in the middle east is flood irrigation using a mud channel or a hose whereby water is flooded into flat "basins" or parcels or ground at periodic intervals and then left to soak into the soil. These methods are extremely wasteful, and leads to a high salt build up. Drip irrigation, either above or below the surface and sprinklers are now the favorite method of the majority of designed landscape projects in Saudi Arabia.

The fundamental questions the landscape architect needs to answer are: how much water is to be applied, when and at what rate?. What method of irrigation is preferable? What quality of water is desirable for the particular soil type and nature of plant material? What are the alternative sources of water and the quality and quantity likely to be available? The answer of these questions need to be resolved at least in principle in the early stages of a project for they will have major influence on design (Clouston, 1978).

Water management requires a far more essential approach to the use of this finite resource, involving changes in plant selection and the very form of urban landscape. Irrigation is only one of the strategies involved in this process.

The aim of water management of urban vegetation should be to achieve an appropriate level of performance both in aesthetic and functional terms for the least amount of water (Hitchmough, 1994).

ii. LANDSCAPE WATER BUDGETS IN THE RIYADH REGION

An estimated water budget for irrigating imported plant material used in landscaping in Riyadh region is now being undertaken by the Ministry of Agriculture and Water. The estimated daily amount of water used is 3,200,000,000 litres of water in the summer decreasing by winter by 65%. Water is scarce in the Kingdom. Using native species could largely save this quantity of water, which is currently consumed by imported flora. This reduction in water could reach 75% in the summer and 95% in winter.

The only natural source of water in the Central region comes from the rain which is discharged to the underground impermeable layer. The rest is imported from a desalination plant on the gulf coast at Dammam. But as mentioned previously, there is little rain in the Central region and the distribution is also uneven and much of it is evaporated. There are no perennial streams in the area, and the rare heavy showers are usually accompanied by considerable run-off especially on the impermeable slopes of The Tuwayq mountains. Records indicate that the rainfall decreases from north to south and from west to east as follows: 160 to 80 mm/annum from west to east in the northern part of the area; with average of 100 mm annually in the west of the region 80-40mm annum in the south, while the annually average is 110 to 85 mm over the whole area (Salamah, 1990). This data supports the argument that water is scarce and too valuable to waste on imported flora while the country is rich in native species, which require less irrigation water.

1.4.3 CULTURAL FACTORS

1.4.3.1 THE USERS OF OPEN SPACES

Users needs should always be considered in landscape design and this is also true in Central Saudi Arabia. The Islamic way of life greatly affects the use of open spaces. In Riyadh separation between male and female is essential in any public area. However, in recently developed public open spaces this requirement has not been met. Most of the parks in Riyadh have been designed and constructed to suit a Western lifestyle. This is displayed clearly in their design concept, and planting composition. Also the choice both of imported plant species and building materials are often inappropriate in terms of character, for example they lie outside the traditional vernacular palette. These Westernized parks, therefore, are used solely by foreign workers and their families, leaving the native people house bound.

Redesign and reconstruction of these parks is the logical approach. The prime requirements for native users are: firstly complete visual and physical separation between families and bachelors. Secondly, Saudi Arabian people have inherited a respect for nature from their recent past as farmers and bedouin (Philby, 1955). For these reasons the use of open space should be oriented to their traditional way of life. In addition to traditional civic spaces this might also involve creating areas, which are, more like natural camping sites, buffered from each other by native plants, rocks and sand formation as described by Salama, (1987).

" *The existing mean of traditional parks in Saudi Arabian life is found in two ways. The first potential open space for Riyadh residents is simply the desert, where some depression in the desert is colonized by some desert species. where the depression modifies the macro-climate to be suitable for outdoor activity. The asr (after noon) period* 3:00 - 7 :00 *P.M. is the time for active use of those depressions (sports, etc.) and then all the night is for other passive activities. The main users for these places are families (mainly big groups of relatives) who use their cars to form a lee area where they start a fire and barbecue. Playing cards, walking, hunting and talking are the main activities at night when the temperature decreases to the minimum. In order to maintain the privacy for each family, a radius of 50m area should be for one, family. Some families use tents especially for the weekend. The second potential traditional and recreational open space for Riyadh residents is the surrounding farm land which is mainly palm* *groves creating under their canopy a modified desired micro-climate. The record of the difference between the macro-climate and the micro-climate under the canopy could reach up to 7°c. The typical farm is used primarily for growing dates and the rest of the year for grasses and minor crops"* (Salama, 1987)

This suggests that urban planting might involve native landscape elements that are visually attractive to Riyadh region natives, it is also important to provide public spaces that provide privacy for family groups, as opposed to essentially open park design. (Al-Hammadi, 1991).

1.4.3.2 AVAILABILITY OF SPECIES

The availability of plant material is one of the factors any landscape architect working in the Riyadh Region must consider. A study was carried out in the summer of 1987 by Salama, (1990) in order to obtain a record of the plant material available in the market and their country of origin. The main emphasis was to record newly introduced species and their source, how they were specified and by whom and also to find out if any native species were in general landscape use.

Most of the species found in nurseries are still imported from tropical and subtropical countries such as North Africa and south Asia, also from USA, Australia and European countries as a result of continuous demand for such species from foreign consultants. Many of these species are poorly fitted to severely arid condition, they are typically species that naturally grow in monsoonal summer rainfall dimates. Commercial nurseries supplying plant material in the Riyadh are located along Wadi Hanifah under the long established canopy of the palm groves. The original rich soil is removed for potting soil. Stripping wadi soil is a destructive practice while the use of this soil for growing imported plant species is extremely costly.

Trees	Shrubs	Ground covers	Summer annuals
Acacia arabica	Agave spp	Acalypha wilkesiana	Amaranthus tricolor
Acacia farnesiana	Atriplex spp.	Aloe vera	Celosia cristata
Acacia salicina	Caesalpinia spp	Alternathera spp.	Cosmos bipinnatus
Albizia lebbek	Cestrum spp.	Althaea rosea	Gomphrena globosa
Azdarachta indica	Dodonea viscosa	Asparagus sprengeri	Helianthus annus
Bauhinia spp	Duranta repens	Canna spp.	Kochia tricophylla
Bombax malabaicum	Euphorbia schimperii	Carpobrotus spp	Portulaca grandiflora
Brachychiton spp.	Hibiscus rosa sinensis	Carrissa grandiflora	Tagetes erecta
Callistemon spp.	Jasminum sambac	Chatharanthus roseus	Zinnia elegans
Cassia fistula	Lantana camara	Cynodon dactylon	
Casuarina spp.	Lawsonia spp.	Dianthus caryophlus	
Cordia myxa	Malvaviscus arboreus	Gazania spp.	**Winter annuals**
Dalbergia sisso	Myrtus communis	Helianthus annuus	Allyssum maritimum
Delonix regia	Opuntia spp.	Loliom perenne	Antirrhinum majus
Enteroloium saman	Plumbago capensis	Petunia spp.	Calendula officinalis
Eucalyptus spp.	Plumeria spp.	Plumbago auriculata	Callistephus chinensis
Euphorbia tirucali	Punica granatum	Rosmarinus officinalis	Chrysanthemum carenatum
Ficus altissima	Rosa spp.	Ruellia patula	Cinenaria cruenta
Ficus carica	Tecoma spp.	Tifgreen spp.	Clarkia elegans
Ficus nitida	Tecomaria capensis	Wedelia trilobata	Delphinium spp.
Ficus religiosa	Thevetia spp.	Paspalum spp.	Dianthas barbatus
Jacaranda mimosifolia	Vites agnus - custus	Santolina chamaecyparissus	Dimorphoteca aurantiaca
Leucaena glauca	Yucca spp.		Gaillardia pulchella
Melia azadarach			Gypsophailla elegans
morus spp.		**Flowering bulbs**	Lathytus odoratus
Olea spp.	**Creepers and climbers**	Anemone coronaria	Lobelia erinus
Parkinsonia aculeata	Antigonon leptopus	Canna indica	Mathiola iancana
Pithecellobium dulce	Bougainvillea spp.	Crocus spp.	Petunia hybrida
Prosopis spp.	Clerodendron inerme	Dahlia spp.	Phlox drummondii
Schinus molle	Clerodendron splendens	Freezia refracta	Salvia spp.
Schinus terebinthifolius	Ipomea pes-capre	Gladiolus spp.	Tropaeolum majus
Tamarix spp.	Jasminum spp.	Hippaestrum spp.	Verbena spp.
Terminalia catappa	Quisqualis indica	Iris spp.	Viola tricoler
Thespesia spp.	Vitis vinifera	Lilium spp.	
Zizyphus spina christi		Narcissus spp.	
		Oxalis cernua	
		Ranunculus asiaticus	
Ornamental Palms		strelitzia spp.	
Oredoxa regia		Tulipa spp.	
Phoenix canariensis		Zantedeschia spp.	
Phoenix dactylifera			
Washingtonia spp.			
Cycas revoluta			

Table 1.21: Some ornamental imported plants that are widely available in Riyadh gardens and nurseries (Abudjain 1994).

1.4.4 ECOLOGICAL / HORTICULTURE FACTORS THAT AFFECT PLANT USE

Plants that are native to arid zones are adapted to water and heat stress, salinity, lack of nutrients and indigenous insects, pests or diseases. It is not simply a question of a landscape architect using such species in landscape projects, since many indigenous plants available in local nurseries are propagated from only a single genotype under ideal conditions, such as modified micro-climate, rich soil and irrigation. This means that other wild occurring varieties with their unique adaptation to particular environments are essentially lost and with them considerable landscape opportunities that might have employed their special adaptive characteristics (Kelly, 1976).

- **Microclimate**

Species of imported plant material require the creation of a suitable microclimate before their successful introduction, i.e., irrigation, suitable soil, fertilizers, implementation of humidifiers and intensive sheltering. Apart from this being expensive, the addition of chemicals and fertilizers to the soil in order to achieve suitable growing conditions for imported species, is a considerable cost factor. As the existing native species are adapted to poor soil conditions, drought and a certain level of salinity, these problems are largely avoided.

- **Pests and diseases**

Native plant materials may not be immune to local pests and diseases, however many are able to persist albeit with some damage. Some imported species may be immune to local pests and diseases however in some case they have proved to be very susceptible.

- **Water consumption and irrigation**

In Riyadh, meteorological conditions tend to encourage excessive use of water. This applies mostly to imported plant material, since most native plant materials are adapted to these conditions. These adaptations may involve fleshy leaves covered by thick waxy cuticles in which water is stored, sunken stomata to minimise water loss, control of stomatal opening, and hairy leaves that slow down movement of air. They may also develop an extensive system of roots to acquire water and may roll their leaves to prevent water loss from a large surface area. Native species will survive with only 100 mm of annual rain fall, but irrigating native species regularly will result in changes in their habit, leading to reduced resistance to heat, wind and other environmental factors.

Native plant material, which require minimal irrigation and are adapted to Riyadh environmental factors, can optimise the efficient use of plant material and irrigation water. Assessing water requirements, water application and the design and operating of an irrigation network is a complex and expensive process and only necessary when using imported plant material.

Irrigation systems disrupt natural growth patterns. The fast growth, and dramatic decrease in root : shoot ratio as a result of irrigation plants poorly fitted to the environment. The application of such irrigation systems in the municipality of Riyadh has result in the loss by wind blow of approximately 3000 trees of *Prosopois iuliflora* (Municipality of Riyadh, 1988). Continual irrigation changed the root structure from extensive and deep to small and shallow.

- **Soil**

Sandy soil cover large areas in the Riyadh region, and has very low water-holding capacity. The efficiency of water use is exceedingly low under the current irrigation methods. It is also very costly to improve existing soil to suit some imported flora (Clouston, 1978).

- **Salinity**

The saline ground water table in some areas adversely affects imported plant material. An imported soil is essential for such plant material to raise the root ball level above the saline water. The use of this plant material requires a capillary break between the saline ground water and the non-saline irrigation water in low-lying areas. However, close to ground water, salt tolerant plants are particularly appropriate and most native species can fulfil that role

The climate is hot and arid with rainfall not exceeding 101.3 mm year and usually torrential in nature. Irrigation under such arid conditions generally leads to increased soil salinity and over consumption of the already small amount of ground water. This results in decreasing the quantity of the water resources and increasing salinity levels. Such irrigation problems could be greatly reduced by using indigenous species when we know how to use them.

CHAPTER 2

2. THE USE OF INDIGENOUS PLANTS IN THE DESIGNED LANDSCAPE

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3. THE USE OF INDIGENOUS PLANTS IN THE DESIGNED LANDSCAPE

3.1 INTRODUCTION

Using plants successfully can help us make the best use of our environment. Good planting design is an essential element in creation and management of a landscape. It can also help to restore the balance between people and nature by recognising and maintaining valuable natural plant communities, and by helping to create new vegetation associations. Landscape design and, in particular, planting design offer us the opportunity to improve both of the quality of human life and our relationship with the rest of living world (Robinson, 1992).

The modern name of Riyadh, the capital of Saudi Arabia was first applied to the sections of the town where the gardens and fruit orchards predominated. Gradually the name was used to describe the entire settlement. The city now has over 900 kms of planted streets and 25,000 ha of parks and gardens. There are more than 300 large public garden varying between 50 ha. and 2400 ha. in size, as well as 150 playgrounds and 250 landscaped public squares (Riyadh Municipality, 1996). Extensive landscaping works have been carried out across the city also through a large number of individual public and private building projects. Further, many large private farms around the city contribute to the total green area.

The wild plants of the Riyadh region, which grow without human agency, also tell a story of natural adaptation and developing ecology over the ages. They have evolved in response to a harsh climate, drifting sands, high salinity and long periods of hyperaridity. They constitute part of the renewable natural resources of the environment in which we all live. The beauty and values of wild plants are only now being fully appreciated, but

Saudi people have had a close relationship with wild plants and natural landscape from early times. When they lived in the desert with these plants. It is the intent of this study to contribute to updating that understanding.

2.2 NATURALISTIC LANDSCAPES

2.2.1 PREFACE

Interest in using nature vegetation in cultural landscapes is not a recent development. Landscape architects have been advocating naturalistic landscapes since the 18th century, while ecologists and naturalists have always favored the most natural and diverse of habitats with their studies. But the essentially horticultural idea of reconstructing complete biological habitats or communities, warts and all, is very much a contemporary phenomenon.

There are many reasons underpinning the development of nature-like landscape plantings. The aim has generally been to establish semi-natural plant communities, which in someway resemble the semi-natural original, although not necessarily re-creating the full diversity. Nature conservationists, planners, landscape architects, landscape managers and educationalists all have widely differing views on how far this process should be taken. Such objectives generally include:

- Creating visually attractive semi-natural landscape
- Providing educational and possibly scientific interest
- Safeguarding rare species or scarce ecological communities,
- Constructing low maintenance landscapes.

Habitat reconstruction is however a relatively new scientific discipline which often relies more on practical demonstration than hard science (Buckley, 1989)

2.2.2 PHILOSOPHIES UNDERPINNING MAKING NEW LANDSCAPE HABITAT

Philosophies vary on the extent to which landscape habitat reconstruction should anticipate, copy or influence nature. As Hitchmough, (1994) point out there are different approaches to the make or the care of landscape habitat. The following are derived form cultural landscape conservation but are also relevant to plant communities. **Conservation** is defined as, "All the processes of looking after a place so as to retain its cultural significance. It includes maintenance and may according to circumstance include preservation, restoration, reconstruction and adaptation and will be commonly a combination of more than one of these". **Maintenance** is defined as; "The continuous protective care of the fabric, contents and setting of place, and is to be distinguished from repair. Repair involves restoration or reconstruction and it should be treated accordingly". **Preservation** is defined as; "Maintaining the fabric of a place in its existing state and retarding deterioration". **Restoration** is defined as: "Returning the existing fabric of a place to a known earlier state by removing accretion or by re-assembling existing component without the introduction of new material". **Reconstruction** is defined as; "Returning a place as nearly as possible to a Known earlier state and is distinguished by the introduction of materials (new or old) into the fabric". **Creation** is defined by Gilbert and Anderson, (1998) as: "Regarded in certain areas as a universal remedy for mitigating adverse human impacts on the environment", but specifically refers to making new plant communities.

Creating colorful, interesting and attractive landscapes and plant communities for people in the places where they live is a goal of Landscape architects, while nature conservationists are committed to protecting good quality semi-natural habitats from excessive human influence. But as Baines, (1989) points out, there is a place for both these positions and even for some reconciliation and compromise. In the urban environment, the cultivation of colourful meadows, informal woodland and ponds in place of traditional parkland has a distinctly educational ever propaganda role. In these surroundings the horticultural ethic prevails: there is no pressing need to attempt the construction of a habitat facsimile as long as the result is attractive and stage-managed for effect. Moreover such habitats undeniably reinforce public appreciation and awareness of real semi-natural countryside.

In other hand, the conservation ethic aims to maintain and defend the small areas of high quality habitat scattered amongst our predominantly cultivated and urbanized landscapes. Genetic contamination of these areas is seen as unacceptable, although conservationists have occasionally promoted or re-introduced rare species. The most that can be allowed is to encourage the land adjacent to these high quality habitats to diversify through natural colonisation and appropriate management. This is the habitat 'duplication' solution offered by Newbold, (1983). He suggests a compromise for habitats that are heavily degraded and well beyond the pale, such as intensively farmed or urban areas remote from semi-natural areas. Wells et al., (1981) define several criteria for the inclusion of species in seed mixtures for species-rich grassland. These include the avoidance of rare species in favour of those, which are uninvasive and widely distributed, so as to prevent possible contamination of genetic resources elsewhere. This is somewhat at odds with the landscape view -for example Baines's advocation of mixing exotics with native species in the town 'for rapid, recognizable beauty' and with the policies of some amenity seed suppliers (Buckley, 1989).

2.3 THE PHILOSPHY OF USING NATIVE PLANTS IN DESIGNED LANDSCAPE

2.3.1 WHAT IS A NATIVE PLANT?

Native plants (also called indigenous plants) are plants that have evolved over thousands of years in a particular region. They have adapted to the geography, hydrology, and climate of that region. Native plants occur in communities, that is, they have evolved together with other plants. As a result, a community of native plants provides habitat for a variety of native wildlife species. Kendle and Rose, (2000) have reported that:
"Webb (1985) defined native plant in the UK as: "a native plant is one that has arrived before Neolithic times, or has arrived since without human agency" This definition embodies many (sometimes implicit rather then explicit) elements that can be examined through three perspectives -boundaries, timescales and the role of human agency".

In Al-Zoghet, (1999) definition, native desert species are very much characterized or associated with drought and aridity. They have arrived in the Arabic peninsula a long time ago without human assistance and grow under the influences of the harsh desert environmental condition, such as high summer temperature, winds, sand storms, low rainfall and high evaporation.

In contrast, non-native plants (also called non-indigenous plants, exotic species, or weeds) are plants that have been introduced into an environment in which they did not originally evolve. Introduction of non-native plants into Saudi landscape has been both accidental and deliberate. Purple loosestrife, for example, was introduced from other countries in ship ballast and as a medicinal herb and ornamental plant. It quickly spread and now may be found in wet land in the whole of Saudi Arabia.

2.3.2 HISTORY OF NATURAL LANDSCAPE AND USING NATIVE PLANTS

Hitchmough, (1994) has said the following about using native species in designed landscapes

"Using native plants in designed landscapes as reconstruction of indigenous communities is often viewed as a relatively recent phenomenon. It could be argued, however that the impetus behind this movement can be traced bark to the eighteenth century English landscape school, and the ideas of Pope, Kent and Brown. The concept was further developed and applied to the design of urban public open space, in the United States, by Olmsted in the latter part of the nineteenth century. In Europe, the twentieth century saw the utilization of the nature-like landscape in urban Holland, for example in Heem Parks (park for native plants) by Thijsse and Sipkes in 1925 in Haarlem. The nature-like landscape has been a recurrent theme in the urban landscape of the Netherlands ever since, and has encouraged similar developments in other countries".

Kendle and Forbes, (1997) and Hitchmough, (1994) have chronicled natural landscaping and its development in many countries as following;

- **Germany**

This country has had one of the strongest traditions of naturalistic landscaping in Europe. This styles have become the most important topic in most coexisting landscapes. The idea of this style is to encourage local wildlife and consider the place for people. Gamboeck, (1887) in his book *(The Interpretation of Nature in the Garden in Theory and Practice)* is one of the earliest authors in such a style. In 1906, Willy Lange designed his own garden under the influence of new scientific achievements in the world of phytosociology and botanical geography, using these as inspiration to design vegetation pictures and associations. Today landscape-planning policy throughout Germany is very supportive of semi-nature landscape styles. Munich can be seen as a good example of naturalistic landscape, there are lists of native plants which must be followed by designers (Kendle and Forbes, 1997).

- **In Holland**

In the early days of the twentieth century, some landscape designers in Holland began to focus on native species. Jaques P. Thijsse started with the idea of an instructive landscape garden, he believed that existing parks failed to demonstrate the significance of natural beauty. In 1925 the first garden Thijsse Hof, opened and a 400 ha native woodland designed and created specifically for the urban public was created in 1933 in Amsterdam. A number of the ecological landscapes in Holland had the primary objective of introducing Nature into the urban environment, and while creating the best of all possible recreational and aesthetic values. There was a high priority on encouraging the participation of people (Kendle and Forbes, 1997).

- **United States of America**

In the USA the influence of some late twentieth century European ecological landscapes affected the work of blossoming designers, but the gardens remained heavily structured and costly to maintain. As the landscape architecture profession emerged between 1850 and 1900 so too did a new naturalistic or landscape style of design. And many parks with this style have been designed in a number of American cities. Casual, sweeping informality in many respects echoed the freedom and openness of the American landscape; the style was visually modeled on natural landscapes, but there was no attempt to look for native integrity in the species used (Cramer, 1993). Between 1930 and 1970 modernism and the functional, easy-to-maintain style took over. The richness of the natural flora in the USA influences the potential social acceptance of natural landscaping enormously (Kendle and Forbes, 1997).

- **Australia**

In Australia until recently, the perception of the urban populace has been that indigenous vegetation was boundless and relatively close to urban centres. This increasingly misinformed view has suppressed interest in the nature-like landscape in urban public open space until last twenty years. Mackenzie, (1979) is one of the first papers to appear on the use of simple, nature-like landscapes in urban open space (Hitchmough,1994).

2.3.3 USE OF NON-NATIVE PLANT MATERIAL

Habitat restoration is most successful in areas where the environment is still rich in wildlife. This is because the surrounding habitats provide a steady influx of colonizing species. However, in areas that have been intensively farmed over a long period there is no longer a reservoir of species to invade in this way; they need to be introduced. (Gilbert and Anderson, 1998).

A naturalistic style that is currently gaining strongly in interest in the UK is a continental European mixed plant communities that are composed of compatible species that may have arisen from many different countries around the world. Hansen and stahl, (1993) describe such an approach. Because of the need to work outside of the ideological constraints of nativism the main proponents of such styles are usually from landscape design or horticultural rather than strictly ecological backgrounds. Rather than follow existing habitat paradigms, the aim is to maximize flower colour and create an intimately mixed Persian carpet of bloom (Hitchmough, 1994)."*The style shares many themes related to the need to understand the ecological functioning of plant communities rather than the behavior of individual species under horticultural cultivation*" (Kendle and Forbes, 1997).

2.4 SEMI-NATURAL LANDSCAPE CREATION

The establishment of new semi-natural landscape habitat can be done in different ways, at different scales, and to satisfy different objectives and functions, including non-ecological ones. Gilbert and Anderson, (1998) have reported that:

> *"The Peterborough Natural Environment Audit Consultation Document (Peterborough Environment City Trust 1995) provides a good example of a multiple, integrated approach, which sets its plans for habitat creation in a framework of land uses. First, there are the non-recreatable sites considered essential for the maintenance of biodiversity in the area; these are akin to nature reserves and designated the 'critical natural capital'. Buffer areas adjacent to the above, which are needed to sustain them, are known as 'supportive capital'. Next in significance are 'constant natural assets', which are important for maintaining the ecological framework of the district; these formerly widespread communities provide much of the local character and will be recreated on a large scale".*

The following methods can be use to create new semi-natural landscape (Gilbert and Anderson, 1998):

i. **Natural colonization:**

Allowing natural processes to determine the habitats developing on an unmodified site.

ii. **Framework habitats.**

Engineering restoration is undertaken on the topography, soils, drainage, etc., with or without some planting to provide key desired features and to provide a framework within which natural colonization can take place. If a particular habitat or mosaic of habitats is required this method is usually the best option.

iii. **Designer habitats:**

This method involves complete landscaping to a predetermined design; trees are planted, scrub established, and grassland sown to a precise scheme, and managed to ensure conformity with the original plan, These are also known as facsimile habitats.

iv. Political habitats:

These are colorful, interesting and attractive habitats created for people in urban areas. They have an educational and propaganda role and do not attempt to reproduce any particular target habitat (Baines, 1989).

It should be remembered that habitat creation is only one of a palate of techniques that can be uses to increase the nature conservation interest of an area. Habitat creation needs to be distinguished from habitat restoration, which attempts to restore existing degraded semi-natural vegetation

2.5 XERISCAPE DESIGN

Xeriscaping is the practice of landscaping with slow-growing, drought-tolerant plants to conserve water and reduce garden green waste and is strongly associated with native species in dry environments. It may reduces the amount of water used to maintain the landscape by approximately 20 to 50 percent, thereby conserving a valuable resource and providing immediate cost savings. Additionally, since the irrigation system is used less frequently, it requires less maintenance, which will provide even more savings. Xeriscapes generally require less fertilizer and less pest control measures than traditional landscapes. Because these materials can inadvertently harm beneficial organisms, as well as impact on air and water quality, reducing their use is beneficial to the environment. Less fertilizer and pesticides also saves money. Xeriscape was coined in United States of America from the Greek 'xeris' meaning 'dry' and "scape," meaning a view or scene. Xeriscape is an attractive, sustainable landscape philosophy that conserves water and is based on sound horticultural practices (Green, 1999).

Lucas, (1993) identified xeriscape as a type of landscape design about which very little is known in Britain at present. It developed out of the need to save water and makes use of items of hard landscape such as rock, cobbles, gravel, slate and wood to form an almost maintenance-free design. In United States it is unusual to find manufactured materials, such as brick, in the design as the aim is to make the landscape appear as natural as possible. Only drought-resistant plants are incorporated and are used sparingly as points of focus.

Xeriscape has not historically been restricted to native plants only. The California Integrated Waste Management Board, (1996) reported the following;

> *"While indigenous plants are naturally accustomed to local climates and are good choices for landscapes, xeriscaping doesn't mean planting native plants only. One can draw from many colorful drought-tolerant plants native to similar climates such as southern Europe, North Africa, western Asia, South Africa, some parts of United States and Australia.*
>
> *Xeriscape landscapes need not be cactus and rock gardens. They can be green, cool landscapes full of beautiful plants maintained with water-efficient practices. Xeriscape landscaping, quality landscaping that conserves water and protects the environment, is the most exciting concept to hit the landscape industry in decades. Whether called Xeriscape, water-wise or water-smart landscaping, landscape and water industry professionals throughout the nation of many countries have embraced landscape water conservation through education such as in United States and Australia."*

Whilst this type of design may be considered less interesting when compared with some traditional forms of planting it does have its benefits and can be attractive if well designed. For instance, the design may be such as to give an impression of movement. Thus small rocks or cobbles may be placed so as to represent a flowing river or lake out of which larger rocks may protrude. Slates placed on edge may represent water falling over a rock and gravel may be integrated with stone to provide interesting variation in texture (Lucas, 1993).

2.6 NATURAL LANDSCAPE IN SAUDI ARABIA

Presently there is encouragement from the Saudi Arabian government to rehabilitate the spirit of traditional architecture and landscaping, as a result of their increased awareness of the value of national heritage, and the danger of losing this architectural and landscape identity. This adds to the pressure on foreign consultants to start the process of understanding and of considering indigenous Saudi Arabian design factors. Many early landscape projects were not successful due to the lack of a comprehensive understanding of the indigenous flora. There is no literature or research on using this flora in landscape design, in urban and extensive. The first attempt to use native Riyadh flora in the public domain was carried out by the A.D.A in the Diplomatic Quarter (Salama, 1990)

2.6.1 STUDIES ABOUT USING NATIVE PLANTS IN SAUDI DESIGNED LANDSCAPE

A concentrated search failed to locate any studies about using natural vegetation of Saudi landscape as communities in design or semi-natural landscape. However there some studies about specific characteristics of some Saudi native species:
Migahid, (1974), in his book " *Flora of Saudi Arabia*" (Three volume) described many wild species and their families of Saudi Arabia. Kelly and Schnadelbach, (1976) presented the scientific and common names and the botanical uses of over 100 plants listed as recommended ornamental plants for Riyadh region of Saudi Arabia. Most of them were however imported species. Glasspoole, (1978) mentioned the scientific and common names of 30 botanical families. Lee, (1978) described the botanical features and the ornamental uses of 115 plant species grown in the Western region of Saudi Arabia. Batanony, (1981), in his book on the Ecology and Flora of Qatar described many species occurring in the Eastern Province of Saudi Arabia. This book can be used as a guide to identification and description.

Sturdy, (1982), studied some wild plants in Western region of Saudi Arabia in order to provide information on native and adopted plant species suitable for amenity planting in the western region of Saudi Arabia. He also suggested some species for further study e.g.

Asphodelus spp., Barleria sp., *Citrullus colecynthis,Llycium shari, Opuntia spp., Urtica forskali* and other species. Sturdy put all studied species into their families and described them with some information about their distribution, propagation, conditions and design use.

Al-Zoghet, (1989) in his book " *Wild plants of Jubail and Ynbu*" studied and reported that plant formations in these regions are of desert type. He recorded about 85 different species belonging to 37 families, mostly dicotyledons . Each family was often represented with one species except in some families such as Leguminosae, Chenopodiaceae, and Asteraceae which have more than 5 species. Also, Al-Zoghet described all the species and gave some information about growth, propagation, ecology, soil, species uses and maintenance.

Mandaville, (1990), in his book "*Ecology and Flora of eastern of Saudi Arabia*" described 565 species in 322 genera occurring in the 605,000 square-kilometer area. Overall, 73 families are represented. Chaudhary and Al-Jowaid, (1999) in " *Vegetation of the Kingdom of Saudi Arabia*" introduced more important and or interesting plant communities, plant families and individual plant species through photographs in addition to, usually, easy to understand description.

Heemstra, Al Hassan and Al Minwer, (1990) in their illustrated guide " Plants of Northern Saudi Arabia" studied and reported 44 different plant families with 171 species, most of them annual and perennial herbs and shrubs.

Al-Zoghet and Al-Alsheikh (1999) in their book "*Wild plants in the region of Riyadh*" recorded 125 different species belonging about 41 families.

2.6.2 SOME OF SAUDI INDIGENOUS PLANTS SUITAPLE TO USE IN LANDSCAPE DESIGN

Tables 2.1, 2.2, 2.3 and 3.4, present a list of Saudi indigenous plant s that are valuable for use in landscape design. The list is arranged according to broad categories of plant types; herbaceous, small shrubs, large shrubs and grasses. Individual plants are arranged alphabetically by their Latin names. This list was derived from studies of Migahid, (1974), Al-Zoghet, (1989); Heemstra, Al Hassan and Al Minwer, (1990); Al-Zoghet and Al-Alsheikh, (1999); and Chaudhary and Al-Jowaid, (1999).

2.6.2.1 FORBS:-

No.	Plants name	Character	Size cm	Growth	Plant use	Habitat
1	*Aerva javanica*	Perennial, Erect	50	Very fast	White flowers, can be used as a ground cover.	Can be found around urban areas in sandy and rocky soils.
2	*Alhagi maurorum*	Perennial, Bushy Spiny	30	Fast	Red flowers, can be used as a ground cover	
3	*Aloe vera*	Succulent	50	Med.	Red and yellow flowers, can be used as a ground cover and bedding plant	
4	*Anthemis deserti*	Small , erect, Annual	20	Very fast	White and yellow center flowers, can be used as a ground cover and bedding plant	In wadis with sandy loam soil
5	*Blepharis ciliaris*	Thorny, Perennial	30	Fast	Thorny, silver-green, in geometric pattern, with blue flowers, can be used as ground cover and in rock gardens	-
6	*Citrullus colocynthis*	Annual, Procumbent	300	Very fast	Spread to 3m, narrow triangular leaves with deep lobes.	-
7	*Cleome spp.(africana)*	Annual	35	Fast	Green branchy, alternate leaves, small yellow terminal flowers, can be used as ground cover	-
8	*Convolvulus cephalopodus*	Perennial, Dense	40	Very fast	Leafy spreading, flower; pink-white trumpet-shaped, can be used as ground cover.	-
9	*Cyperus congomeratus*	Perennial	30	Fast	Long stiff terete leaves, coarse, hairy flowers. Can be used as ground cover.	-
10	*Datura innoxia*	Erect, Annual	70	Very fast	Erect forb, white big flowers. Can be used as ground cover and bedding plant.	Disused fields in sandy, silty and rocky soil.
11	*Diplotaxis harra*	Erect perennial	50	Very fast	Yellow flowers with sweet scent. Can be used as ground cover and border plant.	-

12	*Dipterygium glaucum*	Annual, Bushy	50	Fast	Small leaves and small yellow flowers, Can be used as ground cover.	-
13	*Euphorbia retusa*	leafy perennial	35	Fast	Blue-green cordate leaves, crimson with bracts flowers. Can be used as ground cover.	-
14	*Farsetia burtonae*	Leafy annual	20	Very fast	Grey hairy linear leaves, rosy lilac flowers, Can be used as ground cover.	-
15	*Flaveria trinervia*	Leafy	35	Fast	Branchy plant, dentate leaves, yellow clusters at bases of branches. Can be used as ground cover and bedding plant.	-
16	*Gypsophila antari*	Perennial	50	Fast	Densely spreading herb, small and few leaves, numerous white and small flowers. Can be used as ground cover and bedding plant.	-
17	*Haplophyllum tuberculatum*	Perennial, Erect	40	Med.	Branchy with tubercles and strong scent herb, yellow flowers , Can be used as ground cover.	-
18	*Heliotropium arbainense*	Perennial, Bushy	30	Fast	Oblong-ovate leaves, white turning to yellow with age. Can be used as ground cover and bedding plant.	-
19	*Heliotropium crispum*	Perennial, Bushy	50	Medium	Sessile dark green leaves, white flowers, Can be used as ground cover.	In various habitats ranging from sand covered slopes to sandstone hills to loamy wadi-beds.
20	*Launaea nudicaulis*	Branchy, perennial	50	Very fast	Rosette base white edges leaves, yellow flowers, Can be used as ground cover and bedding plant.	-
21	*Moricandia sinaica*	Perennial	65	Fast	Erect with tough green branches herb, large thik leaves, pinkish-blue flowers. Can be	-

					used as ground cover.	
22	*Peganum harmala*	Perennial	60	Med.	Erect herb, white-yellow flowers. Can be used as ground cover and bedding plant.	It is found growing wild in waste places, orchards etc. in sandy desert soil.
23	*Plantago albicans*	Perennial, Short leafy	35	Fast	Rosette linear leaves, creamy in heads flowers, Can be used as ground cover.	In sand in depressions between hummocks and in sandy drainage channels on limestone gravel plain. Often in Haloxylon salicornicum - Rhanterium Community
24	*Rumex villosa*	Annual	50	Very fast	Erect branchy herb, light red winged; in full sun. dark red flowers. Can be used as ground cover and bedding plant.	Between limestone boulders in small, sandy drainage channels and on rocky limestone slopes
25	*Salsola imbricata*	Succulent	50	Med.	Succulent leaves, Can be use as ground cover.	-
26	*Solanum villosum*	Perennial, Leafy	30	Fast	Green branchy herb, ovate to oblong leaves, pale lilac flowers, red fruit, Can be used as ground cover.	-
27	*Suaeda hortensis*	Annual	100	Very fast	Dark green stem and foliage, densely branching. Can be used as ground cover on salty areas.	-
28	*Verbesina encelioides*	Annual	70	Very fast	Erect herb, yellow flowers. Can be used as ground cover and bedding plant.	It is found growing wild in waste places, orchards etc. in sandy desert soil. Also in wadi Haniffa

Table: 2.1 list of Saudi indigenous herbaceous can be used in landscape design

2.6.2.2 SMALL SHRUBS:-

No.	Plants name	Character	Size cm	Growth	Plant use	Habitat
1	*Achillea fragrantissima*	Fragrant	60	fast	Small erect shrub, yellow flowers. Can be used as ground cover	In loamy to clayey soils in depressions and wadis. Also in *Acacia tortilis – Acacia raddiana* Community which formed in alluvial fans
2	*Anvillea garcini*	Dwarf	40	Med.	Grey densely woolly shrub, yellow flowers. Can be used as ground cover	Can be found around urban areas and on plateau top in *Lycium - Gymnocarpos – Tripogon* Community
3	*Astragalus spinosus*	Woody	70	Very fast	Small erect spiny shrub, woody branching at base stem. Can be used as ground cover	Widespread in wadis with sandy to loamy soil, also in shallow sand covering limestone duricrust. Also in *Haloxylon salicornicum - Astragalus - deverra* community.
4	*Artemisia herba alba*	Dwarf	50	Med.	Aromatic grey-woolly shrub. Can be used as ground cover	Widespread especially in wadis with loamy soils, also in depressions on limestone plateau.
5	*Artemisia judaica*	Fragrant	70	fast	Aromatic grey-woolly shrub, yellow flowers. Can be used as ground cover.	Occasional in sandy depressions on the Buseita gravel plain and in clayey loam soil in a valley north of Riyadh
6	*Artemisia monosperma*	Erect bushy	75	Very fast	Linear leaves, green-yellow flowers. Can be used as ground cover, for sand dune stabilisation and hedges.	-
7	*Atriplex leucoclada*	Perennial	100	fast	Deltoid grayish leaves, bill-like on apical spikes flowers. Can be used as ground cover.	Can be found in wadi (valley) floors, wadi flood channels, larger runnels and erosional gullies in Acacia gerrardii – Lycium community
8	*Capparis spinosa*	Dense	50	Fast	Spread to 3 m, white flowers, can be used as ground cover.	Found along the edge of wadi Haniffa and around clay pans in Al-Draia and Riyadh

9	*Cassia italica*	Dense	50	Fast	Yellow flowers, dark green compound leaves, can be used as ground cover and bedding plant.	In disused fields in sandy, silty and rocky soil. Also found along the edge of wadi Haniffa.
10	*Cassia senna*	Shrub	70	Very fast	Yellow flowers, dark green compound leaves, can be used as ground cover and bedding plant.	In disused fields in sandy, silty and rocky soil. Also found along the edge of wadi Haniffa.
11	*Fagonia spp.*	Small spiny	50	Fast	Small spiny plant, flowers are solitary axillary, pink and purple.	-
12	*Farsetia aegyptia*	Grey bushy	30	Fast	Entire and linear leaves, red to purple flower.	Can be found in wadi (valley) floors, wadi flood channels, larger runnels and erosional gullies in Acacia gerrardii – Lycium community
13	*Forsskalea tenacissima*	Bushy	30	Very fast	Slender tomentose bush, small serrate and ovate leaves with tomentose on lower surface. Can be used as ground cover.	-
14	*Hamada elegans*	Without spines	75	Mediu m	Desert shrub with no spines opposite scale-like or absent leaves, small yellow flowers. Can be used as ground cover, for sand dune stabilisation.	-
15	*Pergularia tomentosa*	Twining shrub	100	Fast	Densely branching from base, Grey leaves, pale red flowers. Can be used as ground cover and hedges.	-
16	*Pulicaria crispa*	Bushy,Per ennial	40	Fast	Aromatic, yellow flowers, Can be used as ground cover.	Widespread in wadi beds with sandy to loamy soil. And around urban areas.
17	*Rhanterium epapposum*	Very bushy	40	Mediu m	Whitish branchy stem, yellow flowers, Can be used as ground cover.	Locally abundant; the dominant species in shallow sand around Nafud sand-desert.

18	*Rhazya stricta*	Evergreen	100	Fast	Branching at base with sessile leaves, white clusters flowers. Can be used as ground cover, for sand dune stabilization and hedges.	This species can be found in sandy soils especially in degraded areas, it increases in numbers and size with increased degradation of range-land.
19	*Salsola chaudharyi*	Dwarf	60	Medium	A semi-succulent dwarf shrub, flowers small. Can be used as ground cover.	-
20	*Teucrium polium*	Dwarf	45	Fast	White-woolly dwarfshrub, branched from the base, pale cream flowers, Can be used as ground cover.	-
21	*Withania somnifera*	Erect	100	Fast	Branching at base small shrub, green flowers, Can be used as ground cover and hedges.	Grow fast in disused fields in sandy, silty and rocky soil. Also can be found in wadi Haniffa around Riyadh
22	*Zilla spinosa*	bushy	60	Medium	Dense thorny bushy shrub, branching and nearly leafless stem. Can be used as ground cover and erosion control.	-
23	*Zygophyllum coccineum*	Desert bush	50	Medium	Small fleshy shrub, yellow flowers. Can be used as ground cover	-

Table: 2.2 list of Saudi indigenous small shrubs can be used in landscape design

2.6.2.3 MEDIUM SHRUBS:-

No.	Plants name	Character	Size cm	Growth	Plant use	Hbitat
1	Atriplex halimus	Evergreen	250	Very fast	Triangular woody stem, grayish alternate leaves. Can be used as hedges.	Locally common; in saline, loamy to clayey soil in parts of wadi Haniffa.
2	*Cassia occidentalis*	Evergreen	150	Very fast	Red-yellow flowers. Can be used as ground cover and hedges.	In disused fields in sandy, silty and rocky soil. Also found along the edge of wadi Haniffa.

3	Calligonum comosum	Evergreen	200	fast	Leafless shrub, dark green and profusely branching stem, yellowish white flowers. Can be used for sand dune stabilization, hedges, windbreaks and for afforestation.	Widespread on sand dunrs; dominant in part of the Nafud desert. Can be part of the *Calligonum- Artemisia monosperma* community.
4	Dodonea viseosa	Erect evergreen	180	Very fast	simple pale green leaves, green and purplish flowers, Can be used as hedges and along roads.	Widespread in Saudi planted as hedge or ornamental bush elsewhere.
5	Haloxylon ammodendron	Evergreen	200	Mediu m	Without spines large shrub, woody silver-gray stem with very slender erect branches, very small rudimentary leaves. Can be used for sand dune stabilization, hedges, windbreaks and for afforestation.	-
6	Lycium shawii	thorny	200	Fast	Thorny shrub, densely branching stem. Can be used as hedges, windbreaks and for afforestation.	Can be found in wadi (valley) floors, wadi flood channels, larger runnels and erosional gullies in Acacia gerrardii – Lycium community or in Lycium – Gymnocarpos – Tripogon Community formed in the plateau top
7	Ochradenus baccatus	Evergreen	200	Fast	Large shrub, dark green and branching stem, small linear leaves, yellow flowers. Can be used as hedges, windbreaks and for afforestation.	-
8	Ziziphus nummularia	Dense thorny	200	Mediu m	Large shrub, light brown branched stem, small oval leaves, yellow-green flowers. Can be used as hedges, windbreaks, erosion control and for afforestation.	-

Table: 2.3 list of Saudi indigenous large shrubs can be used in landscape design

2.6.2.4 GRASSES AND REEDS: -

No.	Plants name	Character	Size cm	Growth	Plant use	Hbitat
1	*Cenchrus ciliaris*	Perennial	100	Fast	Erect clumpy grass, long dark green linear leaves, pink spikes flowers. Can be used as ground cover, rock gardens and hedges.	Found in loam soil in valley near farms, also reported from other habitats such as *Acacia – Lycium - Gymnocarpos* Community
2	*Juncus rigidus*	Dense Perennial	100	fast	Tall grass, slender stem, rigid terete with terminal spike leaves. Can be used as ground cover for wet areas.	-
3	*Lasiurus scindicus*	Thick clumpy	50	Fast	Densely branching grass, white solitary spikes flowers. Can be used as ground cover and for sand dune stabilisation.	Widespread in sandy, silty and saline soil, can be found around Riyadh, and in *Ochradenus – Haloxylon salicornicum - Gymnocarpos* Community
4	*Phragmites australis*	Perennial	300	Very fast	Tall perennial reed, flat and firm with rough margin leaves, flowers large multi-branched spikes. Can be used in swampy areas as hedges, windbreaks and for fencing.	-
5	*Stipagrostis plumosa*	Annual	35	Fast	Short fine clumpy grass, silver fine leaves, silver in spikes flowers. Can be used as ground cover and for sand dune stabilisation.	-

Table: 2.4 list of Saudi indigenous grasses can be used in landscape design

2.6.3 SOME SEMI-NATURAL LANDSCAPE PROJECTS WHERE NATIVE SPECIES MIGHT BE USED IN RIYADH

2.6.3.1 AL-THUMAMA PARK

This park covers an area measuring 170 square kilometers. It is being developed to provide a recreational facility for rest and recreation and for conservation of the desert environment. The master plan for this park and related detailed designs have already been completed and the project is set to be implemented in various stages. Eight camps were established for experimental purposes. Evaluation will be made as to how suitable the construction materials of these camps fit in with the nature of the location and with the climatic and social conditions of the area. Al-Thumama desert park is located about 35 kilometers northeast of Riyadh. By establishing this Park, Riyadh development Authority aims at the following:

- Establish a recreational facility suitable for rest and recreation
- Preserve the environment and the natural properties of the desert
- Broaden the knowledge of citizens on the nature of the desert and the significance of preserving its natural beauty (Riyadh Development Authority, 2001)

2.6.3.2 WADI HANIFA

This valley is the most important natural landmark in Riyadh; covering an area of more than 120 square kilometers and penetrating into Riyadh itself. Slanting from the northwest towards the southeast, the valley constitutes a natural basin where more than forty seasonal streams flow.

The valley contains most of the remaining aspects of the traditional environment in the area, manifested in villages, groves and farms. It is rich with numerous agricultural, cultural and recreational components sufficient to turn it into a recreational, agricultural and cultural centre for the city residents.

Riyadh Development Authority designed a strategy for the development of Wadi Hanifa since 1996 in order to preserve the natural environment of the valley, and restrict human activity harmful to it; prepare it for it's role as a natural water course; and utilise it as a recreational, agricultural and cultural centre. The Authority has declared the valley an environmentally protected area.

Studies resulted in a comprehensive strategy for the development of the valley to stop its environmental deterioration, preserve and develop it's resources, organise the utilisation of it's land, establish recreational facilities and complete the infrastructure in it to attract developmental projects. Developmental projects included in the master plan for the development of Wadi Hanifa incorporate the following: implementation of the construction project of the valley's water channel, construction of fixed surveillance points, fencing of the public lands and areas of environmental protection, implementation of projects for purification of water through natural means, establishment of recreational areas, establishment of a number of sight-seeing points as well as walkways, coordination of locations in the valley, construction of a main road in the valley and asphalt roads for the sub-valleys in addition to roads linked to the recreational areas, and completion of landscaping, greenery and trees using native species (Riyadh Development Authority, 2001).

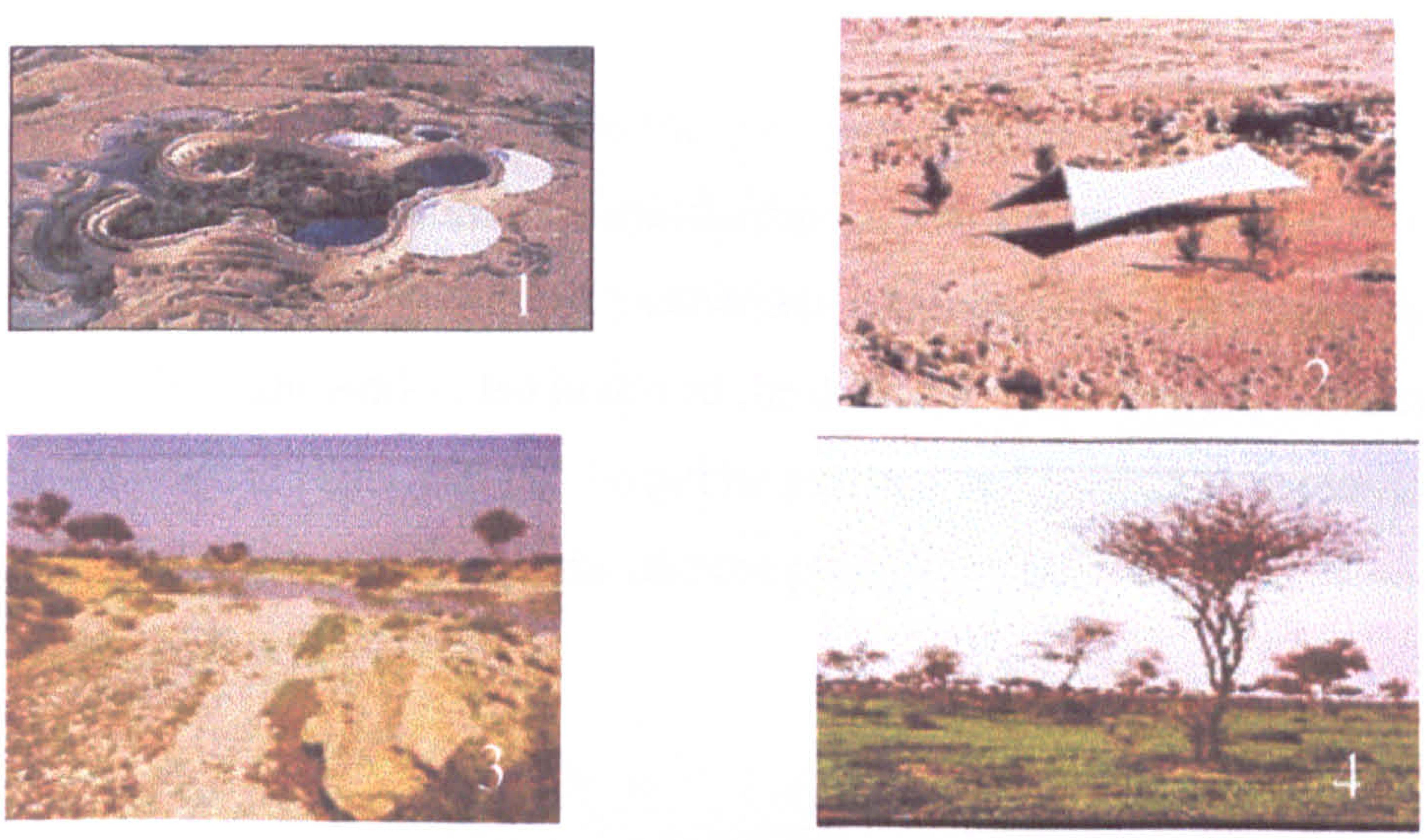

Fig. 2.1: 1) Twaik Palace in the diplomatic quarter (top left), 2) Al-Thumama desert park, 3) and 4) nature landscape around Riyadh (Spring season).

2.6.3.3 DIPLOMATIC QUARTER:

This is located Northwest of Riyadh on an area of approximately eight square kilometres. This area is adjoined from the west by Wadi Hanifa, and by Salbok and Al-Hijaz expressways from the east and south respectively. The quarter represents a ring in the chain of urban development around Riyadh. Upon the completion of the stages of it's development, it is expected to accommodate approximately 22,000 persons, and more than one hundred and twenty diplomatic corps; in addition to some regional organisations and bodies.

The architectural design of the Quarter was done in the local traditional style. Strips of Desert style landscape is used to of separate the residential areas from Wadi Hanifa. The designation of such open areas is meant to prevent construction on the edge of the valley in order to maintain the valley's spectacular natural views, in addition to securing recreational centres overlooking the valley. A dust barrier of trees and shrubs is also separates the residential areas from the expressways near the Quarter. This barrier was made to protect the residential areas from noise and other natural effects resulting from the traffic in these roads, and to serve as a beautifying element and an open recreational area.

Coordinated pedestrian walkways connect the residential areas with the central area together with some main public services facilities. The walkways were created in the first place to encourage the movement of pedestrians and reduce the use of vehicles inside the Quarter. Coordination works also involved the external areas of the Quarter adjacent to Wadi Hanifa and the expressways, the public gardens and parks, the network of pedestrians walkways, public squares and the planting of native species (Riyadh Development Authority, 2001).

CHAPTER 3

3. GERMINATION AND DORMANCY OF SOME SAUDI NATIVE SPECIES

CHAPTER 3

3. GERMINATION AND DORMANCY OF SOME SAUDI NATIVE SPECIES SEEDS

3.1 INTRODUCTION

3.1.1 SPECIES SELECTION

In Chapter 2 more than 70 species of small shrubs, forbs and grasses indigenous to the Kingdom of Saudi Arabia that could be use in designed landscape have been identified. For the second stage of this study approximately 40 species from that list have been selected (Table 3.1), and their seed collected in the wild for subsequent experiments. The criteria used to decide upon species selection were as follows:

- All of these species are common plants indigenous to the desert areas in Saudi Arabia including the Riyadh area.
- These species are small-medium shrubs, sub-shrubs, grasses and forbs, which range in height from 30cm to > 150cm.
- These species have attractive form, flowers or foliage.
- According to the literature these species seeds may be available and germinable in the field and the laboratory, and these species can be use in designed landscape.

Abutilon pannosum	*Cassia occidentalis*	*Ocimum sp.*
Achillea fragrantissima	*Cassia senna*	*Peganum harmala*
Aerva javanica	*Cenchrus ciliaris*	*Plantago albicans*
Aloe vera	*Datura innoxia*	*Pulicaria crispa*
Anthemis deserti	*Dipterygium glaucum*	*Retama reatam*
Anvillea garcini	*Dodonaea viscosa*	*Rhanterium epapposum*
Artemisia herba alba	*Ephedra foliata*	*Rhazya stricta*
Artemisia judaica	*Farsetia aegyptia*	*Ricinus communis*
Astragalus spinosus	*Heliotropium crispum*	*Rumex villosa*
Atriplex halimus	*Lasiurus scindicus*	*Scorzonera musilii*
Atriplex leucoclada	*Launaea mucronata*	*Scrophularia hypericifolia*
Calligonum comosum	*Lavandula pubescens*	*Verbesina encelioides*
Capparis spinosa	*Lycium shawii*	*Withania somnifera*
Cassia italica	*Malva parviflora*	

Table. (3.1) List of selected species for the first experiments.

3.1.2 SEEDS GERMINATION AND DORMANCY

Increased interest is now being given to the use of seed of Saudi Arabian native plants for landscape and horticultural purposes. Several investigators have studied seed germination of some indigenous plants of Saudi Arabia. However, most of the work has been concerned with the effect of temperature and salinity on the germination process. Overall however there is a shortage of data concerning the germination of Saudi indigenous species.

One of the most important stages in the plant life cycle is germination and seedling growth (Guttermann, 1993). Natural regeneration through seeds is generally considered to be occasional in arid and semi-arid areas, where establishment of seedling is often difficult in these inhospitable environments (Briede and McKell, 1992). Germination represents a critical event in the plant life cycle and its timing largely predetermines the chances of survival of a seedling to maturity. Amongst mechanisms responsible for coordinating germination with physical characteristics of the environment two of the most important are the response of imbibed seed to temperature and the proportion of seeds subject to dormancy (Mahmoud, 1983). Most Saudi indigenous species exhibit inherent seed dormancy, which although ecologically advantageous as a mechanism to escape unfavorable environments, complicates use in restoration ecology projects. Often release from dormancy does not depend on a single factor but on a combination of environmental cues which in nature may not be present at the same time; this limiting the success of broadcast sowing at a particular time.

Seed of many species may pass through a dormant state during ripening, and whilst in this state they are unable to germinate even when subjected to suitable conditions. Much of the seed used in agriculture or horticulture loses its dormancy either just before abscission from the parent plant or shortly afterwards, but with wild plants the situation is different. Long-term dormancy is widespread amongst seed of wild plants. It is generally believed that environmental factors such as temperature, osmotic conditions, and light quality and in particular darkness are important in inducing dormancy in seed (Roberts and Neilson, 1982; Baskin and Baskin, 1985; Hazebroek; and Metzger, 1990; and Bewley and Black, 1994).

Dormancy mechanisms are complex and varied, but primary dormancy can be either seed coat- or embryo-imposed (Adkins and Bellairs, 1997). According to Nikolaeva (1969, 1977) there are two general types of seed dormancy: endogenous and exogenous as shown in (Table 3.2). In nature the action of saprophytic fungi, animal ingestion and bushfire can make the coat permeable but for rapid germination of broadcast seed with an impermeable seed coat artificial scarification is often necessary (Richards and Beardsell, 1987). For artificial scarification treatment to be acceptable it should break dormancy in a high proportion of the seeds and must be inexpensive in term of labour and resources (Jhuree et al, 1998).
Embryo dormancy is the inability of a seed to germinate because the enbryo itself is unable to overcome the blocks in some or all of its axes that prevent germination even when isolated from the tissue surrounding it (Bewey and Black, 1994). For example, the embryo could be immature when dispersed from the mother plant, or the embryo may have some inhibitors such as abscisic acid (ABA) which can be leached out of cotyledons resting on a wet substratum (Bewey and Black, 1982).

Table. (3.2) Simplified version of Nikolaeva's (1977) Classification Scheme of Types of Seed Dormancy (Baskin and Baskin 2001).

Type	Cause	Broken by
ENDOGENOUS DORMANCY		
Physiological	Physiological inhibiting mechanism (PIM) of germination	Warm and/or cold stratification
Morphological	Underdeveloped embryo	Appropriate conditions for embryo growth/germination
Morphophysiological	PIM of germination and underdeveloped embryo	Warm and/or cold stratification
EXOGENOUS DORMANCY		
Physcal	Seed (fruit) coats impermeable to water	Opening of specialized structure
Chemical	Germination inhibitors	Leaching
Mechanical	Woody structures restrict growth	Warm and/or cold stratification

Seed dormancy is a wide spread phenomenon among woody plants causing long delays in seed germination. Hard coats that prevent water from penetrating the seed, is sometimes responsible for delayed germination (Goor, and Barney,1976). Buendia Lazaro (1966) reported low germination rates in some species within the Fabaceae, due to the high proportion of seeds with hard coats, and recommended scarification with hot water as the best treatment to break dormancy. The most common chemical scarification method for hard seeds of legume species is to soak the seeds in concentrated sulfuric acid for a prescribed period of time. The length of the soaking period in acid for optimum germination varies, depending on the species being treated. Nasroun and Al-Mana, (1992), found that seeds of five *Acacia* spp. responded significantly to mechanical scarification of the seed coat, soaking seeds in concentrated sulfuric acid and pouring boiling water on seeds. The germination percentages of hard seed treated with boiling water are typically not as high as with chemical scarification. In *Cassia senna,* sulphuric acid was more effective in breaking seed coat dormancy than boiling water, soaking in methanole or incision of the testa (Al-Helal, 1989).

In other species leaching of germination inhibition can break dormancy. In *Rhazya stricta* dormancy can be broken by seed leaching for 24 hours (Al-Seed, 1998). In *Atriplex,* dormancy can be broken by several treatments such as washing in water (Fernandez and Johnston, 1980), also as well as physical or chemical scarification (Fernandez, 1978).

Even after dormancy is broken seed emergence in the field depends on factors such as depth of burial, soil moisture and temperature. Mahmoud, (1983) studied germination of *Artemisia abyssinca* in a series of sowing depth experiments. Under favourable conditions of soil moisture and temperature, it was found that high percentage of seedling penetrated to the surface from seeds buried at 5 mm. The rate of emergence increased with decreasing depth of burial. (Mahmoud, 1983). Low emergence capacities were found to be a common feature of seed of some species of the *Capparidaceae* (Schopmeyer, 1974)

The purpose of this preliminary study was to evaluate the germination percentage of some Saudi indigenous species and investigate the influence of some pre-sowing treatment methods on the seed germination percentage to understand the best methods to break the dormancy of these seeds.

3.2 MATERIALS AND METHODS

3.2.1 SEED COLLECTION AND PREPARATION

3.2.1.1 SEED COLLECTION

Unfortunately there is no seed industry in Saudi Arabia where can provide the indigenous seeds needed in this research. For this reason we collected these species seeds by hand. The collection of the seeds was started in April 2000 and continued until June 2000 in the Riyadh area of Saudi Arabia. Assistance of specialists in this field was gained and advice provided on the best places and times to collect seeds from Department of Botany (Botanical Garden), College of Science, King Saud University, Department of Plant production, College of Agriculture, King Saud University. Range and Animal Development Research Center, Ministry of Agriculture, KSA. Maps of the distribution of these plants in their habitats were made to help complete collection of seeds.

Using a specific technique for the seed collection depends on the species. In some species such as *Cassia italica, Cassia occidentalis, Cassia senna, Retama reatam* and *Rhazya stricta* pods were collected by hand and left for few days to dry and opened to get seeds. In some species such as *Abutilon pannosum, Pulicaria crispa, Rhanterium epapposum* and *Verbesina encelioides* we collected whole mature inflorescences flowers, which were left for few days to dry then broken to release the seeds inside them. For seeds of *Capparis spinosa, Datura innoxia, Lycium shawii* and *Withania somnifera* we picked these species in fruit and left them for few days to dry before extracting the seeds inside them. Shaking the plant and collecting the seeds on a plastic groundcover was the method used for some species such as *Farsetia aegyptia, Heliotropium crispum* and *Plantago albicans.* Also for some species *Dodonaea viscosa* and *Rumex villosa* seeds were easily collected from the plants and after drying off the flower parts were removed.

3.2.1.2 SEED PREPARATION

Most of the seeds needed preparation before they were suitable to use in the experiments to remove foreign matter, and appendages. For example, with some

species seed needed to be separated from the pod such as *Cassia senna, Cassia italica, Rhazya stricta* and *Cassia occidentalis.* In other species seed needed to be separated from the fruit, such as *Capparis spinosa, Cenchrus ciliaris, Datura innoxia, Lasiurus scindicus, Lycium shawii, Ricinus communis* and *Withania somnifera.* With small seeds it was necessary to separate seed from the chaff by sieving or using a fan as an innovative method of winnowing seed. This method was used for many species such as *Achillea fragrantissima, Aerva javanica, Anthemis deserti, Anvillea garcini, Artemisia judaica, Plantago albicans* and *Verbesina encelioides.*
All seeds were dry stored at room temperature (approximately 20°C) until the various experiments were undertaken.

3.2.2 SEED STERILIZATION AND SOWING

Using a fresh solution of 10% bleach, autoclaved 90mm Whatman Number 1 filter papers circles, and sterile autoclaved petri dish, seed were treated sowed as per the following protocol:

- Beakers containing seed and 10% bleach solution were agitated for 15 minutes in a shaker, then the bleach decanted off.
- Seed were washed three times in deionised water, the seeds were then sown in petri dishes with Whatman Number 1 filter paper.
- 30 seeds were sown in every petri dish, with four replicates for each species.

The incubator temperature was maintained between 20 – 25°C, lit for a 14-hour day by fluorescent lamps. Germination counts were taken every day.

3.2.3 THE TETRAZOLIUM TEST

The Tetrazolium test (TZ) is one of the most widely recognized means of estimating seed viability (Copeland and McDonald, 1995). Professor Georg Lakon developed this method in Germany in early 1949 (Mackay, 1972; Copeland and McDonald, 1995). The TZ test is based on enzyme activity during respiration; enzymes responsible for the reduction processes in living tissue provides hydrogen for reduction of the TZ solution, which stains the living tissue red (Mackay, 1972).

The tetrazolium test has two advantages over the regular germination test: TZ is a quick method to complete, and is not influenced by dormancy. Furthermore, TZ is very good technique for determining the reason for poor germination due to seed dormancy. The ability of a seed to germinate in the field is correlated to the degree to which the growing area of the embryo is stained red in the laboratory test (Mackay, 1972). There are however some disadvantages associated with TZ testing: First, TZ test results are difficult to interpret especially with non-crop species. Secondly there is a lack of acceptance for the TZ test as an accurate method to estimate seed viability from many seed companies (Copeland and McDonald, 1995).

TZ test results are usually obtained within a 24 to 48 hour period. Fifty seeds were allowed to imbibe water between a moistened germination paper blotter overnight. They were then dissected either longitudinally or transversely using a scalpel so that the embryo was exposed and could be treated with tetrazolium chloride solution. One half of this seed (usually with most of the embryo) was used for the test while the other half (usually smaller and damaged) was discarded. Tetrazolium solution must come in contact with the embryo. In some species the seed coat were broken. However, in legumes little preparation is needed because tetrazolium solution passes readily through the seed coat. Other kinds of seed must have their thick, or tough seed coats removed or pierced before placing in tetrazolium solution.

A solution of 2,3,5 triphyenyl-tetrazolium chloride was added to water to form a colourless solution. The seeds are placed in a 1% solution. Care was taken to prevent breaking of radicles.

Upon penetration into living cells, the tetrazolium chloride is reduced by dehydrogenase enzymes present in living tissue to formazan which is a reddish, water-insoluble compound. The reaction occurs within or near living cells which are releasing hydrogen in respiration processes. The rate of hydrogen release in viable living tissues is slow in comparison to that in damaged tissues. Viable living tissues are stained red. During early stages of deterioration, damaged tissues become a darker red more rapidly than viable, healthy tissues. Dead tissues do not stain, remaining usually white because the lack of respiration prevents formazan production.

Depending on their size, seeds were examined under a stereo microscope at 10-30x power. Larger seeds were examined without a microscope. All tetrazolium chloride test results are recorded as percentages.

3.2.4 BREAKAGE OF SEED DORMANCY

The primary germination test showed that some seed did not germinate. However according to the tetrazolium results some of these species had high viability. These species and some species that showed very low germination percentage were subjected to the following dormancy breaking treatments:

i. **Acid treatment:** Seeds were placed in a beaker and covered by sulphuric acid (98%). After 15, 60 and 120 minutes, seeds were washed in a stream of water for 30 seconds, and then they were sowed as per the standard method.

ii. **Hot water treatment:** Seeds were immersed in hot deionised water (90 °C), then it was left to cool at room temperature for 24 hours. They were then sown as for the standard method.

iii. **Seed Scarification:** Seeds were mechanically scarified by abrasion with a fine-grained sandpaper, removing the outer layers of the testa, Scarification was done by placing the seeds between two layers of sand paper, and rubbed between them for forty seconds.

iv. **Seed Leaching:** Seeds were placed in a sealed muslin bag in a glass funnel. Water from a dripping tap was directed through the seeds for 48 hours. The temperature of water at the time of undertaking the experiment was approximately 10°C.

Allocation of species to treatments depended on seed type (Table3.2), and information found in the literature. Seeds of most of our species were thought likely to have exogenous dormancy (Mechanical) due to woody structures that restrict growth. In these species dormancy can be broken by warm and/or cold stratification (Baskin and Baskin 2001), consequently we used acid treatment, hot water treatment and seed scarification for the seeds of *Abutilon pannosum, Calligonum comosum, Capparis spinosa, Malva parviflora, Retama reatam, Ricinus communis.* Early experiment indicated that *Anthemis deserti, Ephedra foliata* and *Withania somnifera* seeds the long periods of acid treatment (60, 120 min.) destroyed their seeds, therefore we did not continue with these treatments, but use only 15 minutes in acid.

In seeds of *Cassia italica, Cassia occidentalis, Cassia senna* and *Dodonaea viscosa* as we used the short period of acid treatment (15 min.). As this provided almost 90% germination (incommon with the work of Al-Helal (1989), other treatments were not explored. *Atriplex halimus, Atriplex leucoclada*, and *Rhazya stricta* seed were likely have exogenous dormancy (chemical) in which germination inhibitors can be removed by leaching according to Al-seed (1998), and Fernandez and Johnston, (1980). Thus with these species we used only leaching treatment.

Species were subjected to dormancy breaking treatments as follows (Table 3.3):

Species	Treatment					
	Acid (15 minutes)	Acid (60 minutes)	Acid (120 minutes)	Hot water	Seed Scarification	Seed Leaching
Abutilon pannosum	x	x		x	x	
Anthemis deserti	x			x	x	
Atriplex halimus						x
Atriplex leucoclada						x
Calligonum comosum	x	x	x	x	x	x
Capparis spinosa	x	x	x	x	x	
Cassia italica	x			x		
Cassia occidentalis	x			x		
Cassia senna	x			x		
Dodonaea viscosa	x			x		
Ephedra foliata	x	x			x	
Malva parviflora	x	x	x	x	x	
Retama reatam	x	x	x	x	x	
Rhazya stricta						x
Ricinus communis	x	x	x	x	x	
Withania somnifera	x			x	x	x

Table. (3.3). Allocation of species to dormancy breaking treatments.

3.3RESULTS

3.3.1 SEED GERMINATION

These studies showed a high difference in the germination percentage of indigenous species of Saudi Arabia. It can be seen from the following charts (Fig.3.1, 3.2 and 3.3) that the greatest percentage of mean germination was in *Farsetia aegyptia* and *Lasiurus scindicus* (97.5%), and the smallest percentage of germination was in *Anthemis deserti* (1.66%). However there was no germination at all in *Retama reatam, Heliotropium crispum, Calligonum comosum* and *Dipterygium glaucum* (0%). The other species can be divided to three groups:-

First group: High germination percentage (more than 70%): -

Achillea fragrantissima, Aerva javanica, Aloe vera, Anvillea garcini, Artemisia herba alba, Datura innoxia, Ocimum spp., Peganum harmala and *Pulicaria crispa.*

Second group: Medium germination percentage (40% - 70 %): -

Artemisia judaica, Cenchrus ciliaris, Lavandula pubescens, Rumex villosa and *Verbesina encelioides.*

Third group: low germination percentage (less than 40%): -

Abutilon Pannosum, Anthemis deserti, Astragalus spinosus, Atriplex halimus, Atriplex leucoclada, Capparis spinosa, Cassia italica, Cassia occidentalis, Cassia senna, Dodonaea viscosa, Ephedra foliata, Launaea mucronata, Lycium shawii, Pantago albicans, Rhanterium epapposum, Rhazya stricta, Ricinus communis, Scorzonera musilii and *Scrophularia hypericifolia.*

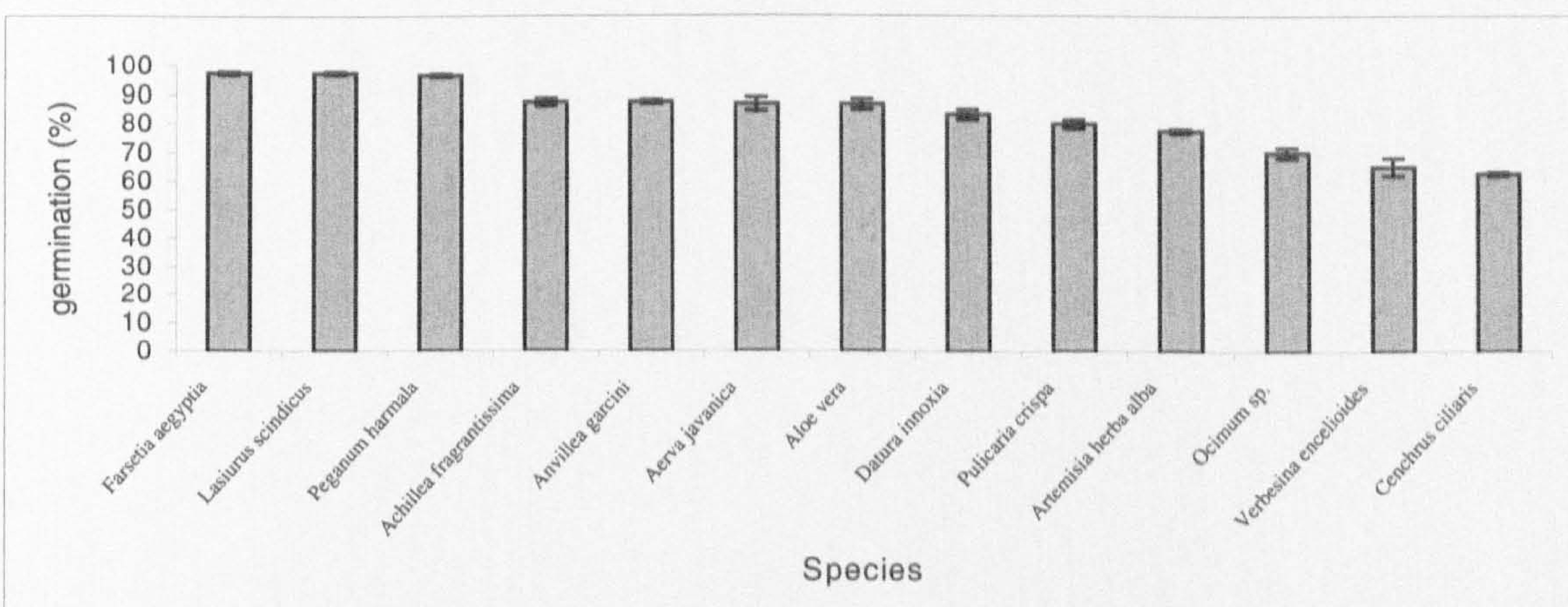

Fig. 3.1: Germination percentage of Saudi indigenous plants showing germination >60%. Error bars represent 1 SEM.

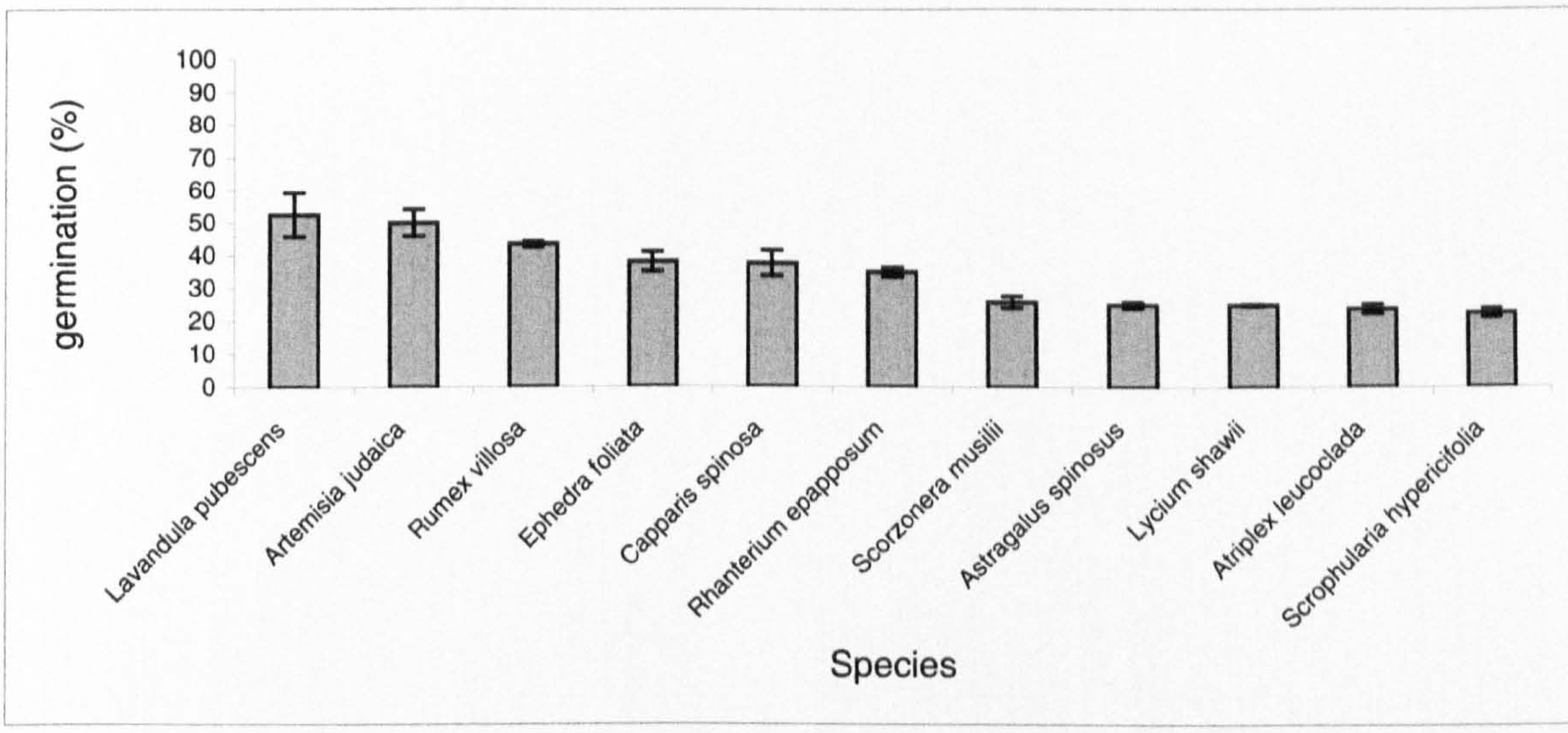

Fig. 3.2: Germination percentage of Saudi indigenous plants showing germination 20 - 60%. Error bars represent 1 SEM.

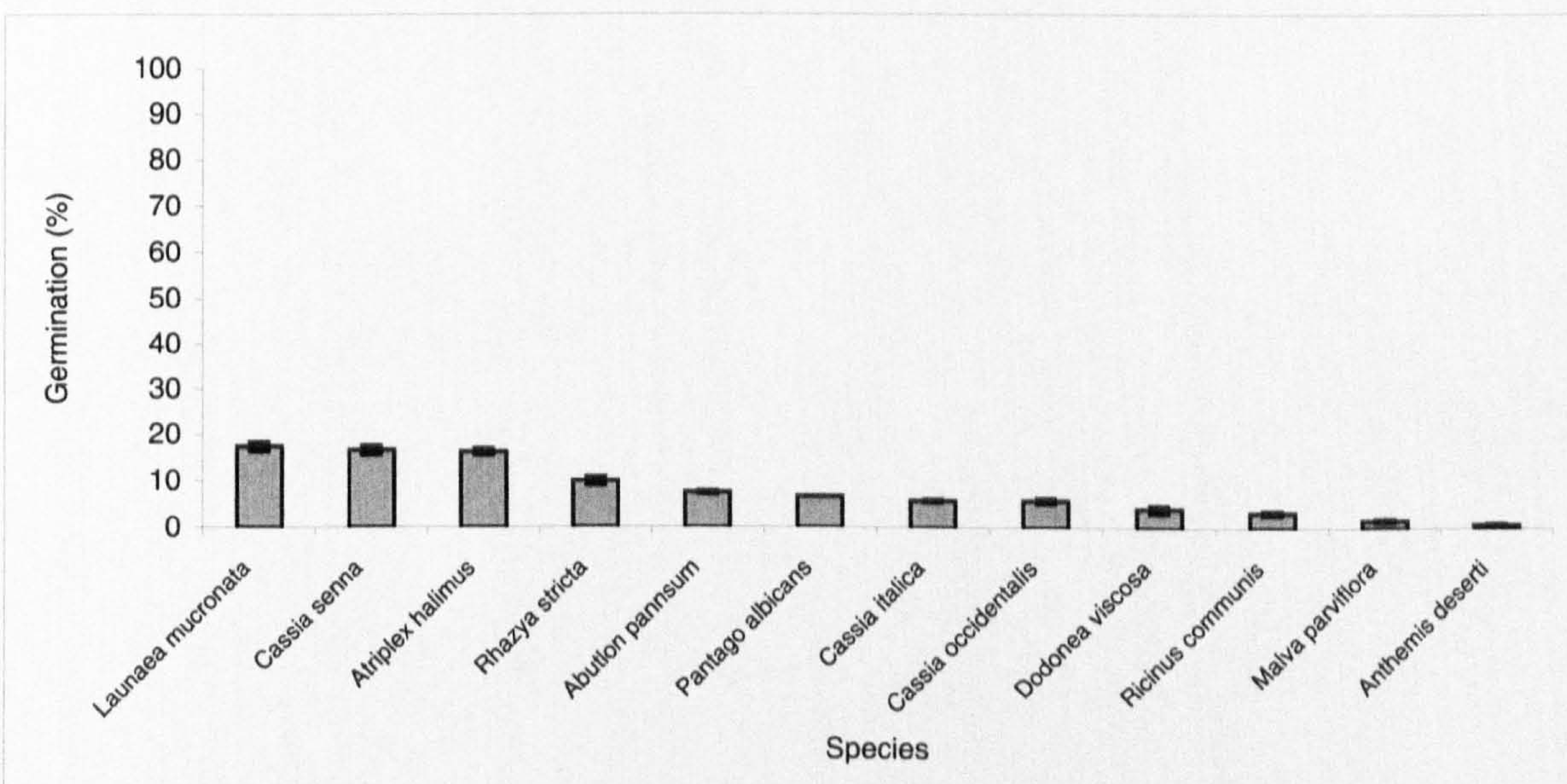

Fig. 3.3: Germination percentage of Saudi indigenous plants showing germination <20%. Error bars represent 1 SEM.

3.3.2 TETRAZOLIUM TEST

Result of tetrazolium chloride test can be seen from Table.3.4: -

	% Viable seed.		% Viable seed.
Aerva javanica	100	*Pantago albicans*	86
Aloe vera	100	*Pulicaria crispa*	86
Cassia occidentalis	100	*Lavandula pubescens*	84
Farsetia aegyptia	100	*Atriplex leucoclada*	80
Lasiurus scindicus	100	*Atriplex halimus*	76
Peganum harmala	100	*Heliotropium crispum*	74
Achillea fragrantissima	98	*Scorzonera musilii*	74
Datura innoxia	98	*Capparis spinosa*	66
Cassia senna	96	*Ricinus communis*	66
Ocimum sp.	96	*Lycium shawii*	66
Verbesina encelioides	94	*Artemisia judaica*	60
Dodonaea viscose	92	*Calligonum comosum*	60
Artemisia herba alba	92	*Abutilon Pannosum*	60
Rumex villosa	90	*Retama reatam*	50
Scrophularia hypericifolia	90	*Rhazya stricta*	50
Anvillea garcini	90	*Malva parviflora*	46
Cassia italica	88	*Launaea mucronata*	44
Ephedra foliata	88	*Rhanterium epapposum*	42
Cenchrus ciliaris	88	*Anthemis deserti*	40
Withania somnifera	88	*Astragalus spinosus*	36

Table. (3.4) Percentage of viable seed according to tetrazolium chloride test.

3.3.3 BREAKING SEED DORMANCY

From the germination experiment and tetrazolium test it was clear, there was a group of species with low germination percentage (less than 40%), but with mostly high viability. We tried to increase their germination percentage of the latter by applying dormancy breaking treatments. The result of each species as following:

3.3.3.1 *ABUTILON PANNOSUM*

It can be seen from Fig. 3.4 that the maximum germination (approximately 55%) of *Abutilon pannosum* was achieved with the sulphuric acid (60 minutes) treatment. This germination percentage was recorded by the sixth day. Approximately 30% germination was observed with sulphuric acid (15 minutes) and scarification (40-second) treatment. Hot water treatment was less successful with germination <15%. Without treatment the germination percentage was 6.3%. There was a significant difference in germination percentage between untreated seeds and the others treatments (P<0.05). However there were non-significant differences in germination percentage between untreated seeds and hot water treatment (P>0.05). Rate of germination was greatly increased with the sulphuric acid (60 minutes) treatment.

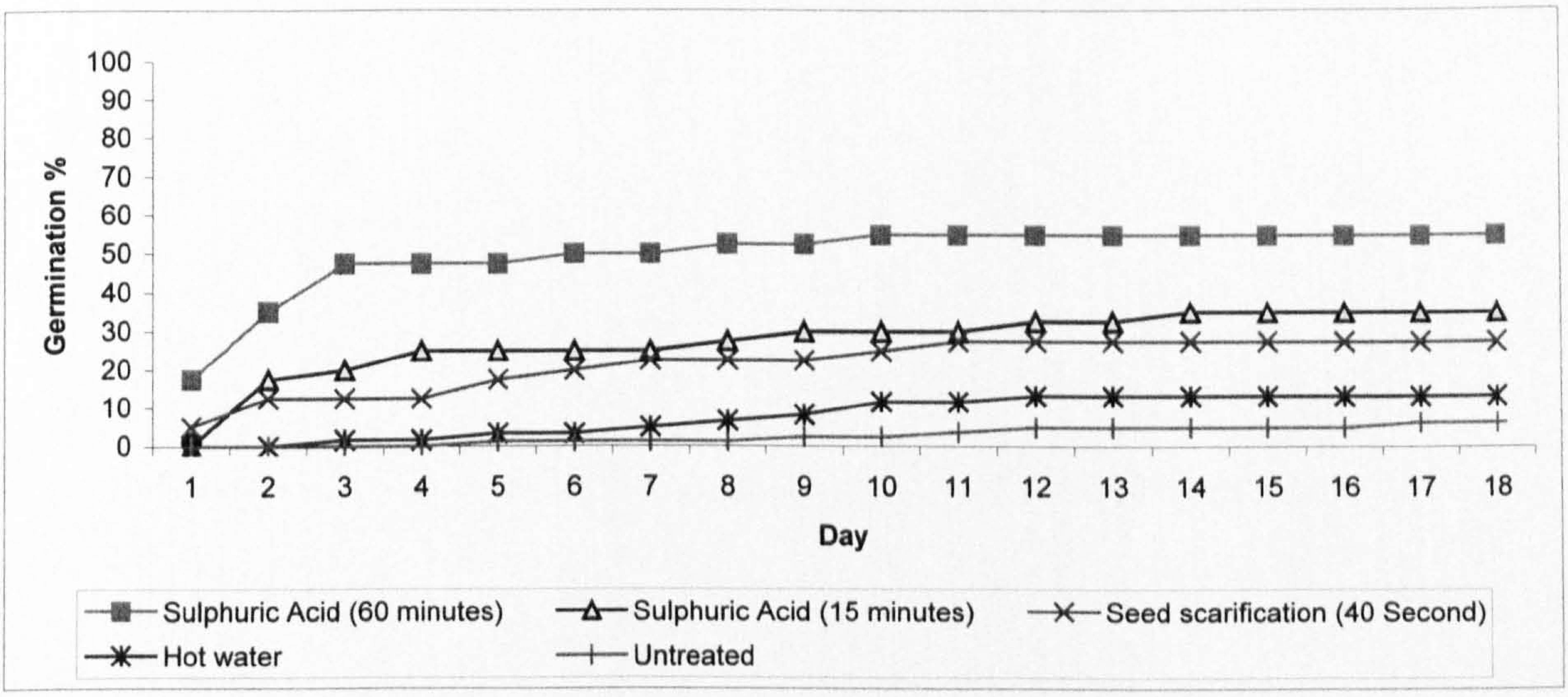

Fig. 3.4: Effect of dormancy breaking treatments on germination in *Abutilon pannosum.*

3.3.3.2 *ANTHEMIS DESERTI*

Maximum germination (approximately 40%) of *Anthemis deserti* was achieved with the seed scarification (40 Second) treatment. This was recorded by the fourteenth day. Twenty five % germination was observed with sulphuric acid (15 minutes). All other treatments failed to break dormancy. There was a significant difference between untreated seeds and seed scarification and sulphuric acid (15 minutes). Rate of germination was greatly increased with the sulphuric acid (15 minutes) treatment.

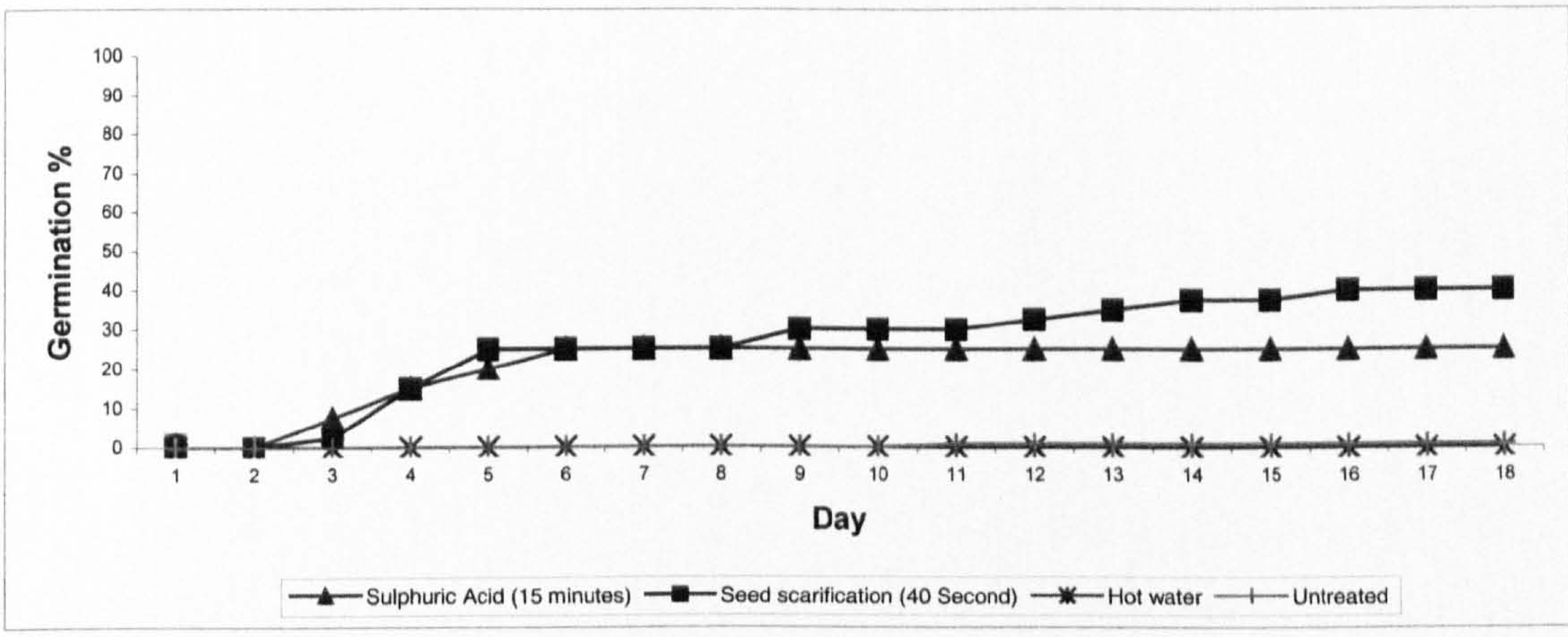

Fig. 3.5: Effect of dormancy breaking treatments on germination in *Anthemis deserti*.

3.3.3.3 *ATRIPLEX HALIMUS*

It can be seen from Fig. 3.6 that germination of untreated seeds of *Atriplex halimus* was 19 %. Leaching increased germination percentage to 23%, but this was not statistically significant. Rate of germination was not greatly increased with the leaching treatment.

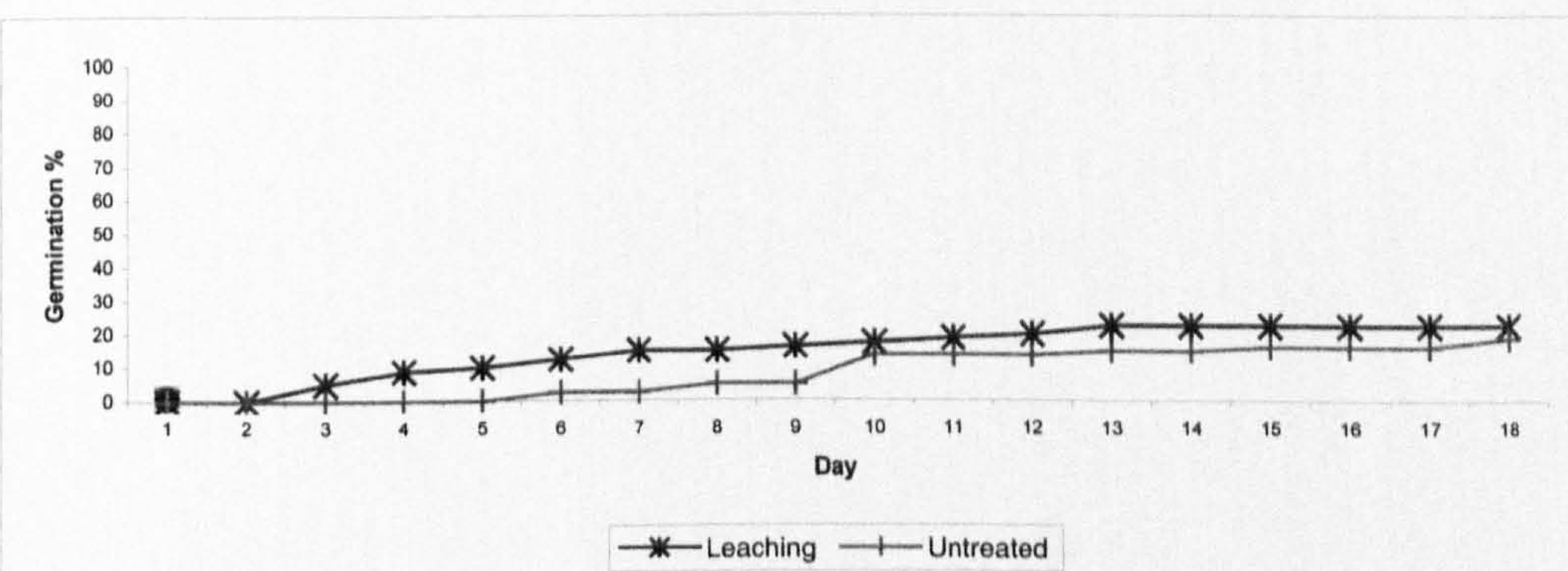

Fig. 3.6: Effect of dormancy breaking treatment on germination in *Atriplex halimus*.

3.3.3.4 *ATRIPLEX LEUCOCLADA*

It can be seen from Fig. 3.7 that germination of untreated seeds was 31 %. Leaching increasing this to 41%, but this was not statistically significant (P>0.05). Rate of germination was not greatly increased by leaching treatment.

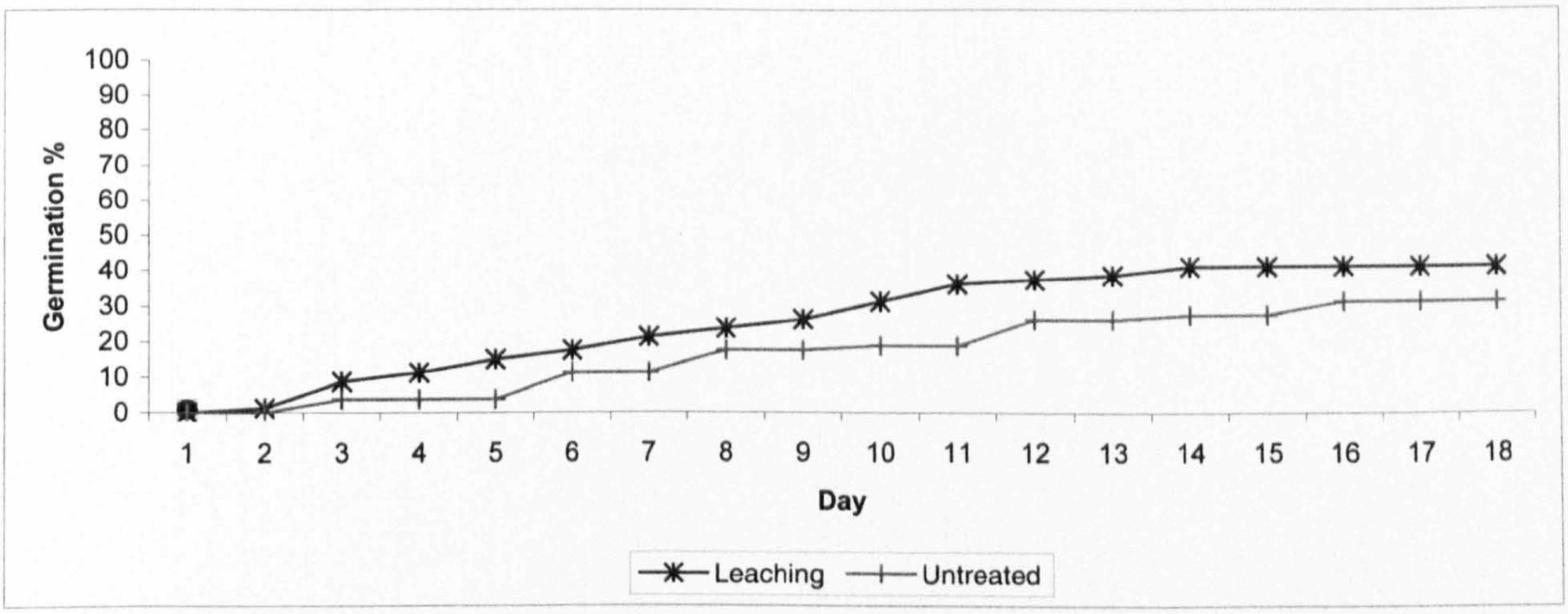

Fig. 3.7: Effect of dormancy breaking treatment on germination in *Atriplex leucoclada.*

3.3.3.5 *CALLIGONUM COMOSUM*

Maximum germination (33%) of *Calligonum comosum* was achieved with sulphuric acid (120 minutes) treatment. This germination percentage was recorded from the twelfth day. Approximately 25% germination was observed with leaching. However with seed scarification (40 second) treatment the germination percentage was only 7.5 %. Other treatments were unsuccessful. There was a significant difference in germination percentage between untreated seed and the sulphuric acid (120 minutes) treatment ($P<0.05$). Other differences were not significant . Rate of germination was greatly increased with the sulphuric acid (120 minutes) treatment.

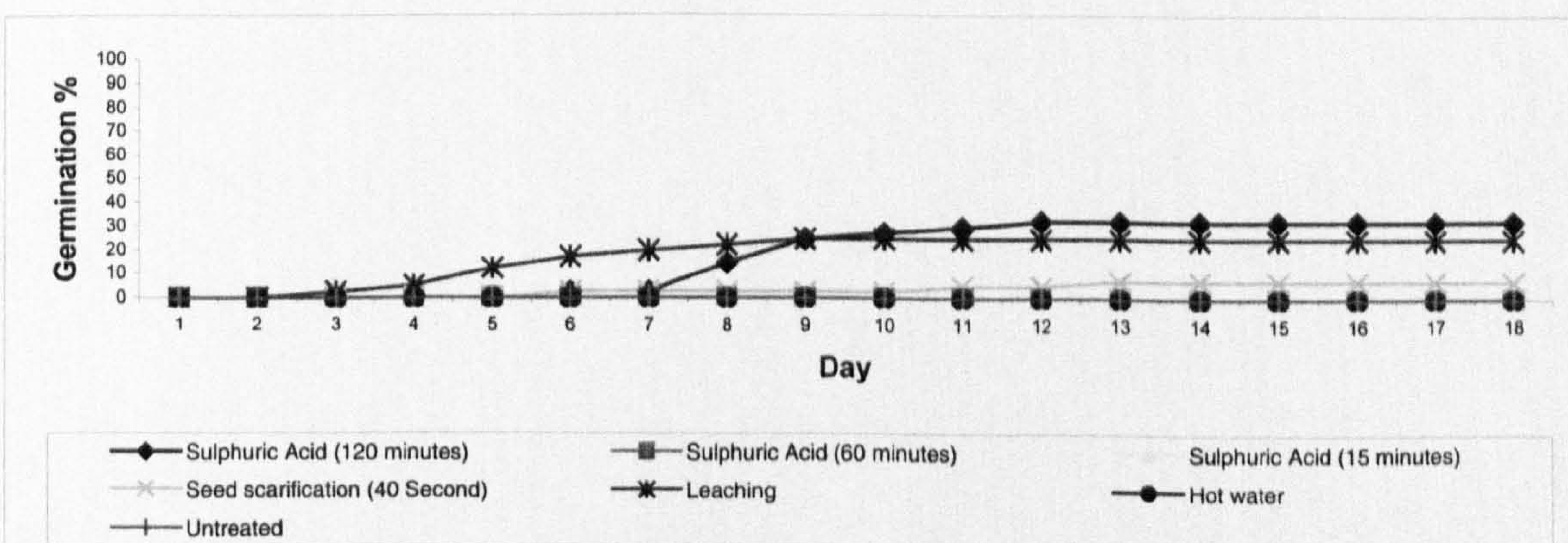

Fig. 3.8: Effect of dormancy breaking treatment on germination in *Calligonum comosum*

3.3.3.6 *CAPPARIS SPINOSA*

It can be seen from Fig. 3.9 that untreated seed showed germination of 38 %. Other treatments reduced germination and rate of germination.

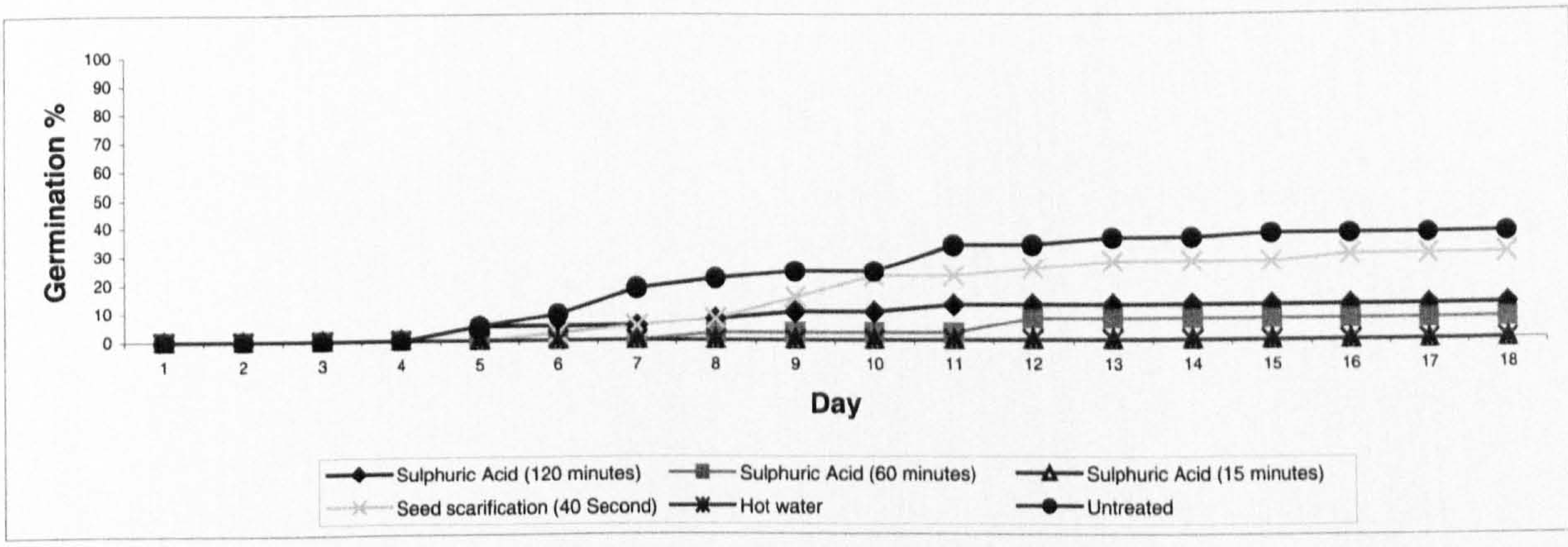

Fig. 3.9: Effect of dormancy breaking treatment on germination in *Capparis spinosa*.

3.3.3.7 *CASSIA ITALICA*

It can be seen from Fig. 3.10 that the maximum germination *Cassia italica* (≅ 43%) was with sulphuric acid (15 minutes) treatment. This germination percentage was recorded from the seventh day. There was a significant difference in germination percentage between untreated seed and the sulphuric acid (15 minutes) treatment. Germination percentage of untreated and hot water treatments was not significantly difference ($P>0.05$). Rate of germination was increased with sulphuric acid (15 minutes) treatment.

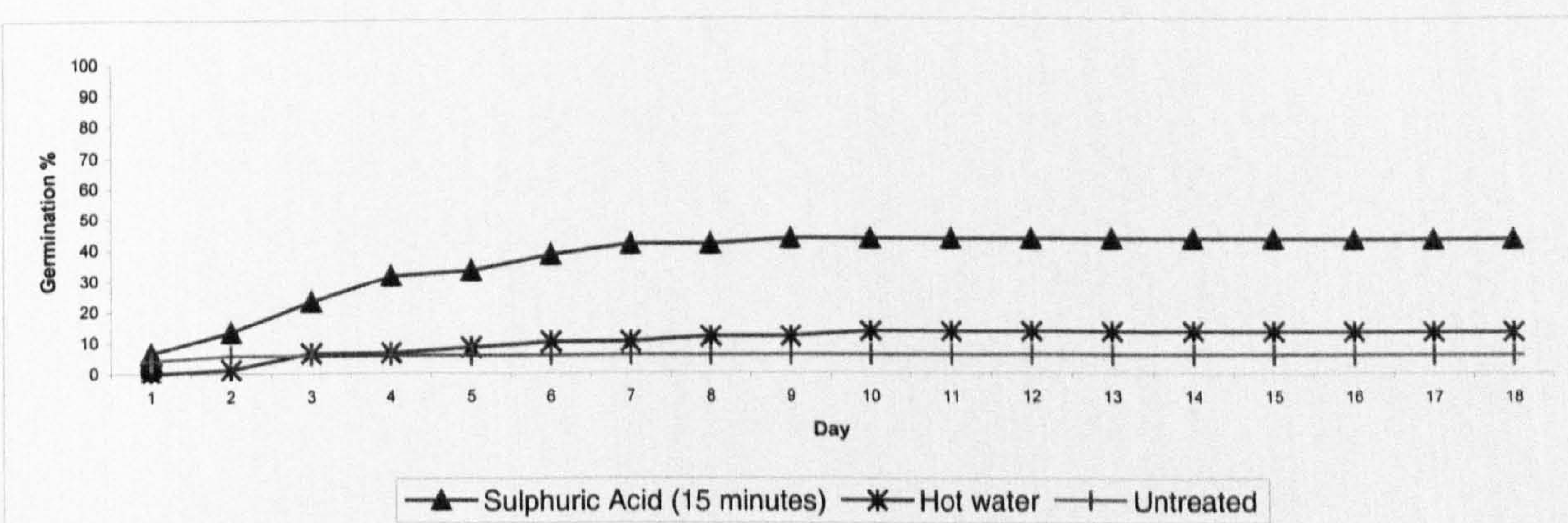

Fig. 3.10: Effect of dormancy breaking treatment on germination in *Cassia italica*

3.3.3.8 *CASSIA OCCIDENTALIS*

Maximum germination of *Cassia occidentalis* was with sulphuric acid (15 minutes) treatment, (≅95%). This was recorded from the seventh day. High germination (58%) was observed with hot water treatment. There was a significant difference in germination percentage between untreated seeds and sulphuric acid (15 minutes) and hot water treatments ($P<0.0001$). Rate of germination was greatly increased with aulphuric acid (15 minutes) and hot water treatments.

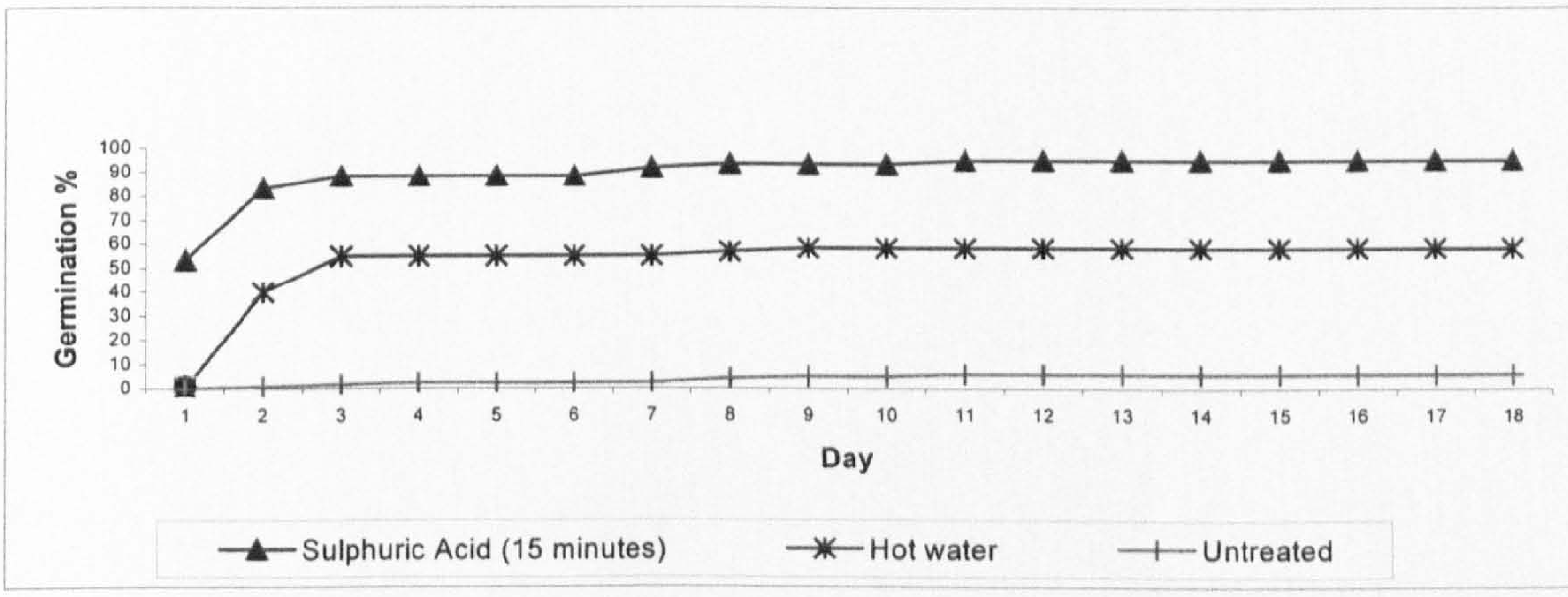

Fig. 3.11: Effect of dormancy breaking treatment on germination in *Cassia occidentalis*

3.3.3.9 *CASSIA SENNA*

It can be seen from Fig. 3.12 that the maximum germination of *Cassia senna* was approximately 77% with sulphuric acid (15 minutes) treatment. This was recorded from the seventh day. Hot water treatment was also successful (>65%). There was a significant difference in germination percentage between untreated and treated seed ($P<0.05$). Rate of germination was greatly increased with sulphuric acid (15 minutes) and hot water treatments.

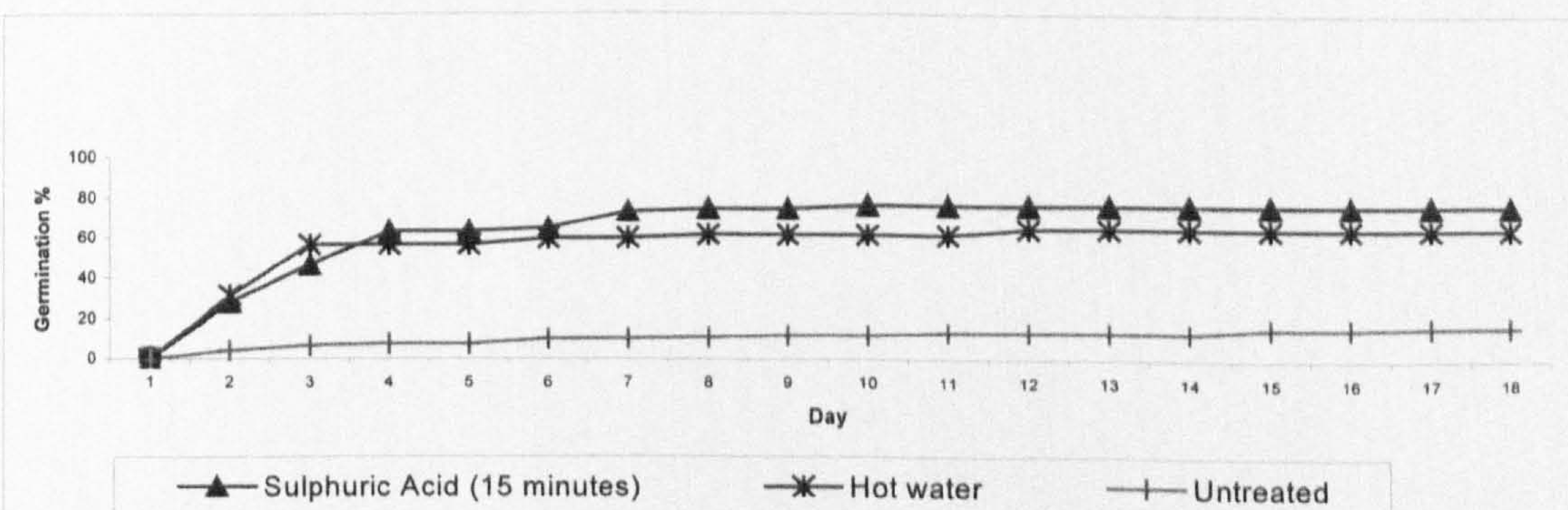

Fig. 3.12: Effect of dormancy breaking treatment on germination in *Cassia senna*

3.3.3.10 *DODONAEA VISCOSA*

Maximum germination (82%) of *Dodonaea viscosa* was achieved with sulphuric acid (15 minutes) treatment, this was recorded from the seventh day. Hot water treatment was also successful (77%). Germination of untreated seed was 0 %. There was a significant difference in germination between untreated and sulphuric acid (15 minutes) treatment (P<0.0001), and hot water treatments (P<0.0001). Rate of germination was greatly increased with sulphuric acid (15 minutes) and hot water treatments.

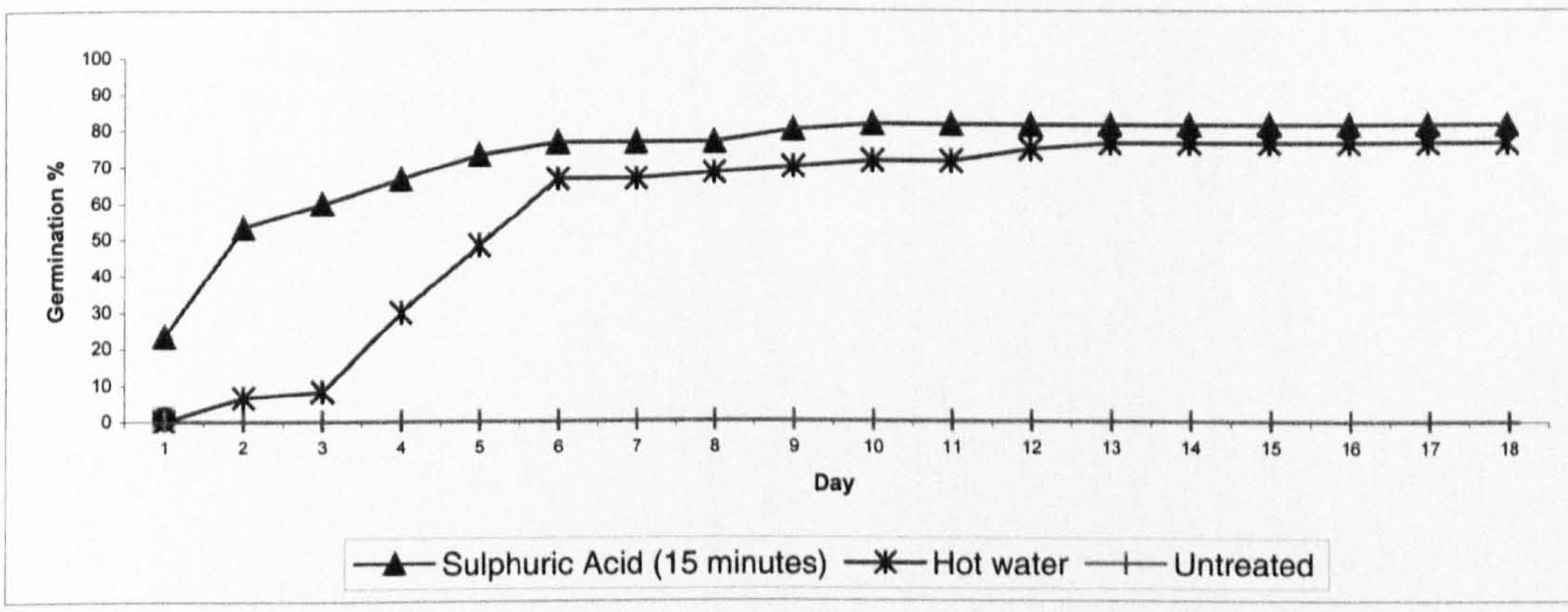

Fig. 3.13: Effect of dormancy breaking treatment on germination in *Dodonaea viscosa*

3.3.3.11 *EPHEDRA FOLIATA*

Maximum germination of *Ephedra foliata* (43%) was with sulphuric acid (15 minutes) treatment. This was recorded from the ninth day. Hot water treatment (23%) was less effective than no treatment (38%). Rate of germination was increased by the sulphuric acid (15 minutes) treatment.

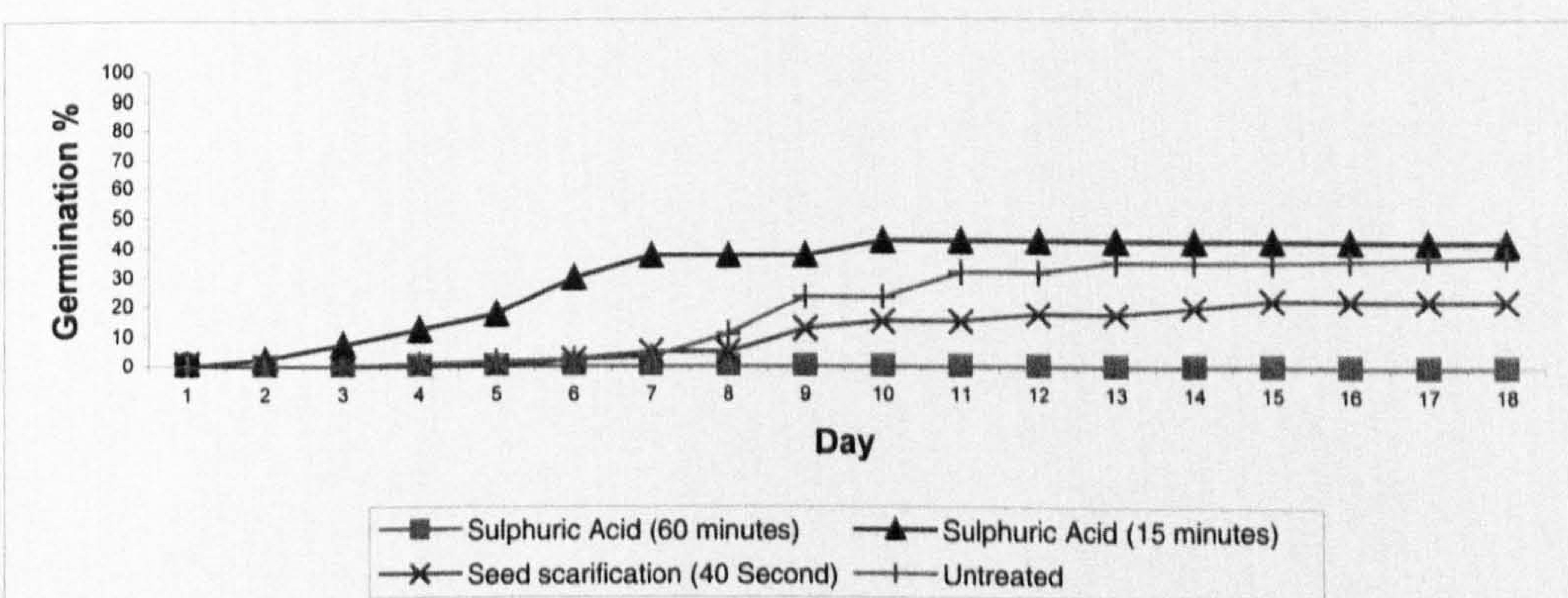

Fig. 3.14: Effect of dormancy breaking treatment on germination in *Ephedra foliata*

3.3.3.12 *MALVA PARVIFLORA*

Maximum germination of *Malva parviflora* was achieved with sulphuric acid (120 minutes) and (60 minutes) treatments. This germination percentage was recorded from the sixth day. Seed scarification (40 second) treatment was also successful (58%). There was a significant difference in germination percentage between untreated seeds and other treatments ($P<0.05$). Differences between hot water and untreated were not significant ($P>0.05$). Rate of germination was greatly increased with sulphuric acid (120 and 60 minutes) treatments.

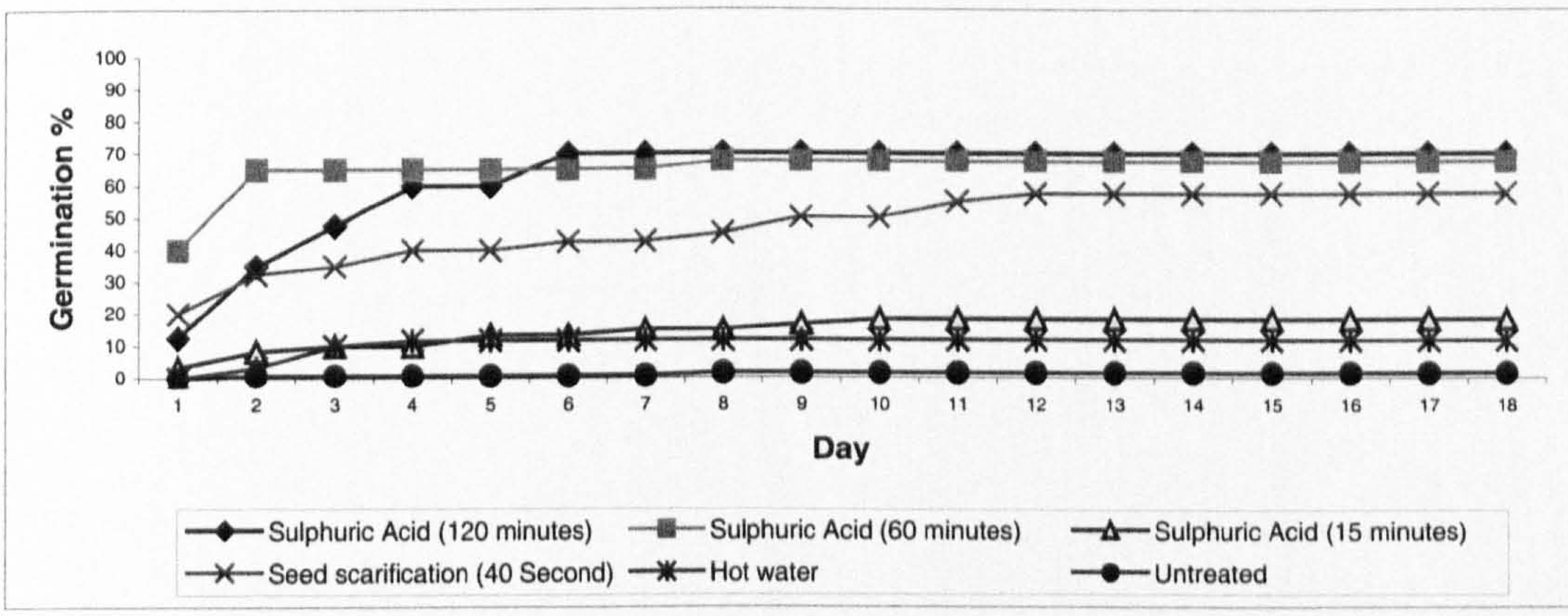

Fig. 3.15: Effect of dormancy breaking treatment on germination in *Malva parviflora*

3.3.3.13 *RETAMA REATAM*

None of the treatments used were very successful in breaking dormancy in this species. Differences in germination between treatments were non- significant. Rate of germination was slightly increased with the treatments.

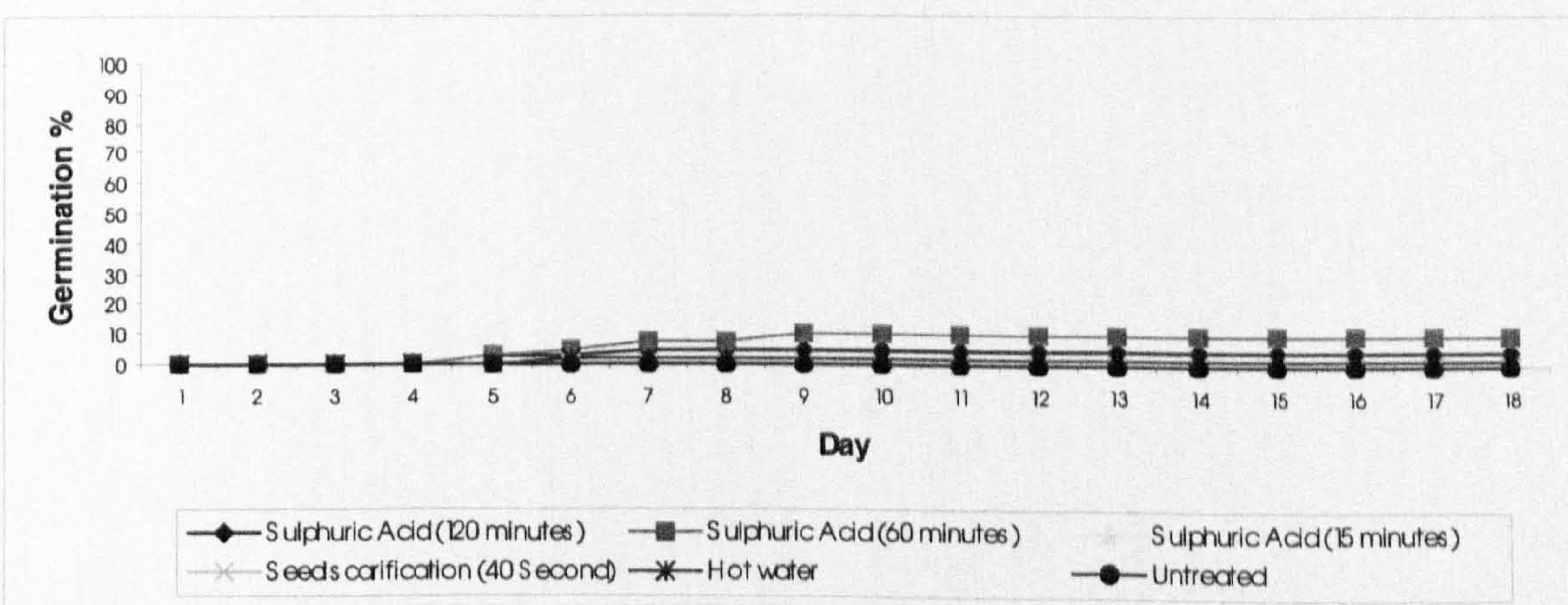

Fig. 3.16: Effect of dormancy breaking treatment on germination in *Retama reatam*

3.3.3.14 *RHAZYA STRICTA*

It can be seen from Fig. 3.17 that germination of untreated seed of *Rhazya stricta* was 10%. Leaching treatment increased this to 39%, a significant difference ($P<0.05$). Rate of germination increased with the leaching treatment.

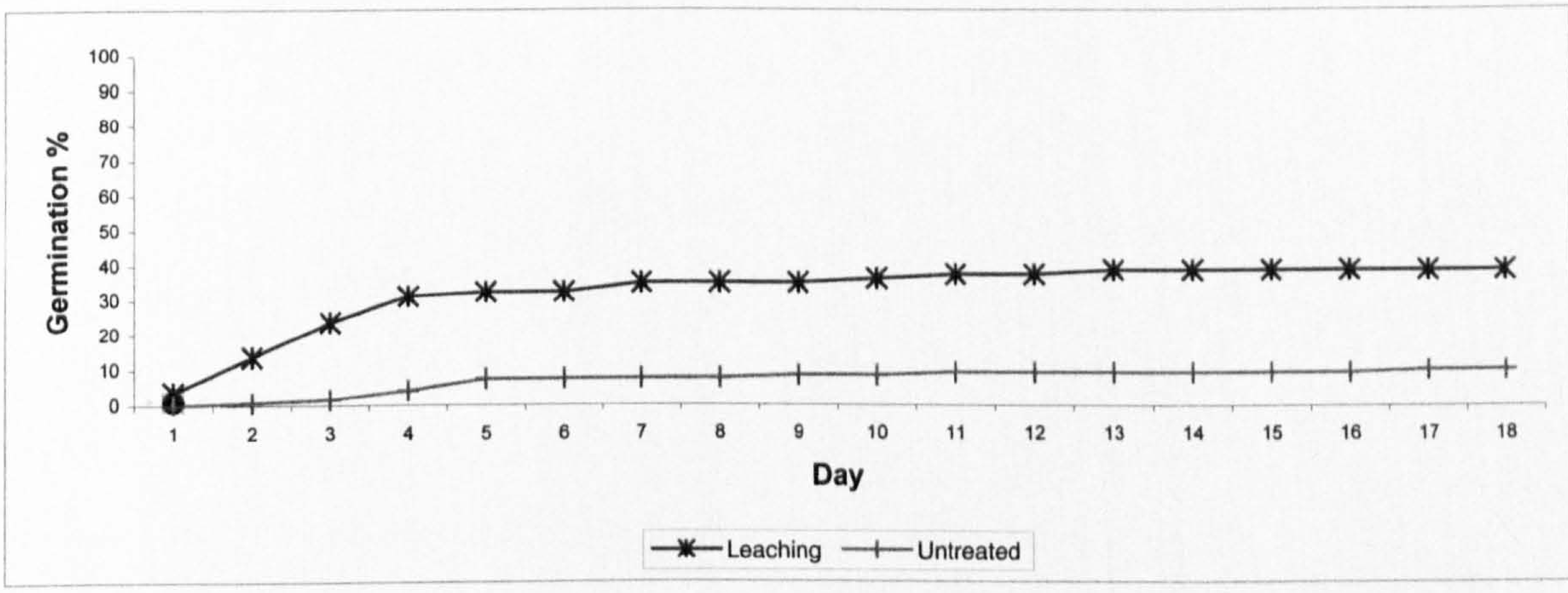

Fig. 3.17: Effect of dormancy breaking treatment on germination in *Rhazya stricta*

3.3.3.15 *RICINUS COMMUNIS*

Maximum germination (7%) of *Ricinus communis* was achieved with seed scarification (40 second) treatment. Other treatments were less effective. These differences in germination percentage were non-significant ($P>0.05$). Rate of germination was slightly increased with seed scarification (40 second) treatment.

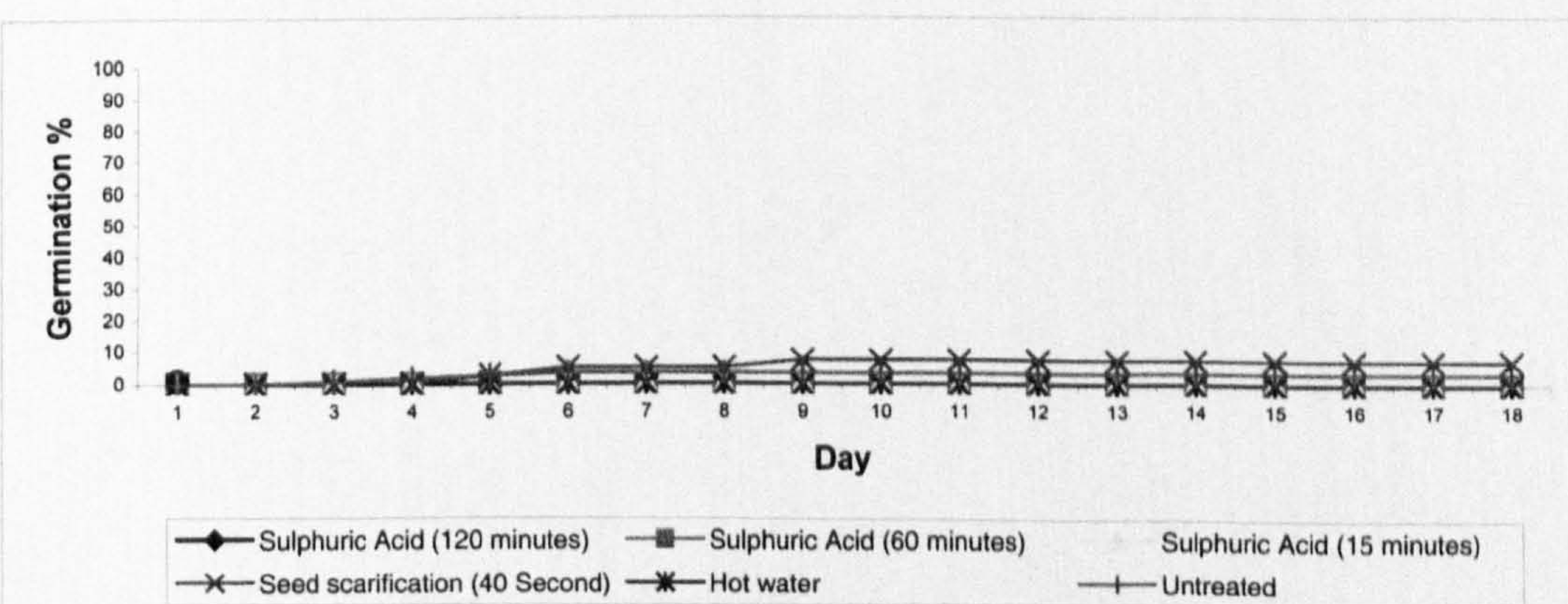

Fig. 3.18: Effect of dormancy breaking treatment on germination in *Ricinus communis*

3.3.3.16 *WITHANIA SOMNIFERA*

It can be seen from Fig. 3.19 that germination of *Withania somnifera* with sulphuric acid (15 minutes) treatment was 25% and with seed scarification (40 second) treatments it was 20 %. However with leaching and hot water it was less than 7 %. Germination of non-treated seeds was 0.8 %. There was non-significant difference in germination percentage between untreated seeds and all treatments ($P<0.05$). Rate of germination was slightly increased with sulphuric acid (15 minutes) and seed scarification (40 second) treatments.

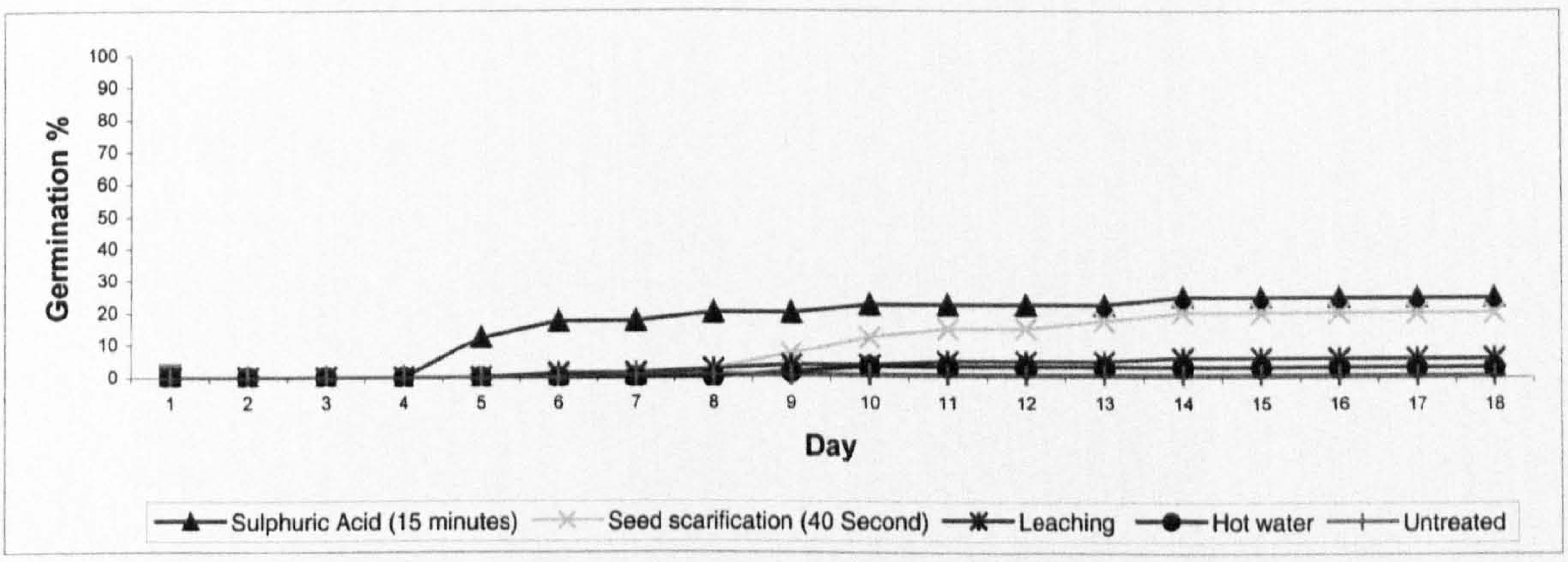

Fig. 3.19: Effect of dormancy breaking treatment on germination in *Withania somnifera*

3.4 DISCUSSION

3.4.1 GERMINATION OF UNTREATED SEED.

The results showed high differences in seed germination percentages between the species. It was more than (70%) for thirteen species; *Achillea fragrantissima, Aerva javanica, Aloe vera, Artemisia herba alba, Cenchrus ciliaris, Datura innoxia, Farsetia aegyptia, Lasiurus scindicus, Ocimum spp., Peganum harmala, Pulicaria crispa* and *Verbesina encelioides.* The germination percentage of these species showed that the species can be use in landscape without any dormancy breaking treatments, whilst considering these different percentage values when making up seeds mixes for sowing.

Germination percentage was (between 60 to 20%) for; *Artemisia judaica, Astragalus spinosus, Atriplex leucoclada, Capparis spinosa, Ephedra foliata, Lavandula pubescens, Lycium shawii, Rhanterium epapposum, Rumex villosa, Scorzonera musilii, , Scrophularia hypericifolia.* Some of these species are clearly subject to seed dormancy, for example *Atriplex leucoclada* need seed washing (Fernandes and Johnston 1980) to break dormancy.

However germination percentage was less than (20%) for twelve species seeds for instance; *Launaea mucronata, Cassia senna, Atriplex halimus, Rhazya stricta, Abutlon pannsum, Plantago albicans, Cassia italica, Cassia occidentalis, Dodonea viscosa, Ricinus communis, Malva parviflora* and *Anthemis deserti.* Four species seeds didn't germinate at all; *Calligonum comosum, Heliotropium crispum* and *Retama reatam.* All of these species seeds were dormant state, or their seeds were damaged or the viability of these seeds had expired. From previous studies it was clear that some species for example; *Cassia spp.* need dormancy breaking treatments such as sulphuric acid (Al-Helal, 1989). *Rhazya stricta* dormancy can be broken by leaching (Al-Seed, 1998).

3.4.2 TETRAZOLIUM TEST

From the germination test, there was a group of species with low germination percentage this is may be due to low seed viability. By using the tetrazolium test we were able to assess this. The results showed high differences in seed viability, and also showed many species and high viability regardless the low germination percentage in the germination test (Table 3.5)

Species	Germination percentage	Viability percentage
Abutlon pannsum	7.5	60
Anthemis deserti	0.8	40
Atriplex halimus	16.3	76
Atriplex leucoclada	23.8	80
Calligonum comosum	0	60
Capparis spinosa	37.5	66
Cassia italica	5.8	88
Cassia occidentalis	5.8	100
Cassia senna	16.7	96
Dodonea viscosa	4.2	92
Heliotropium crispum	0	74
Lycium shawii	25	66
Malva parviflora	1.7	46
Pantago albicans	6.7	86
Retama reatam	0	50
Rhazya stricta	10	50
Ricinus communis	3.3	66

Table 3.5: Comparison of germination and viability percentages in some Saudi indigenous species.

3.4.3 DORMANCY BREAKING

Some species are difficult to germinate, even though their viability is high. Seed of many species may pass through dormant state during ripening, and whilst in this state they are unable to germinate even when subjected to suitable conditions. For species that had low germination but higher viability we tried to increase germination by applying dormancy breaking treatments as summarised in Table 3.6.

Dormancy type:	Seed scarification (Mechanical, acid, hot water)	Seed leaching
Physical	*Abutilon pannosum* *Anthemis deserti* *Calligonum comosum* *Cassia italica* *Cassia occidentalis* *Cassia senna* *Dodonaea viscosa* *Ephedra foliata* *Retama reatam* *Ricinus communis* *Withania somnifera*	
Chemical		*Atriplex halimus* *Atriplex leucoclada* *Calligonum comosum* *Rhazya stricta* *Withania somnifera*
Mechanical	*Abutilon pannosum* *Anthemis deserti* *Calligonum comosum* *Ephedra foliata* *Retama reatam* *Ricinus communis* *Withania somnifera*	

Table 3.6:, Dormancy breaking treatments of some Saudi indigenous species

The results of the dormancy experiments have showed that the effect of breakage of dormancy treatments differed greatly from one species to another. Some of these species have given significant results in germination percentage (Fig 3.20). With sulphuric acid (15 minutes) treatment *Cassia italica, Cassia occidentalis, Cassia senna* and *Dodonaea viscosa* have given significant results in germination percentage. Furthermore with sulphuric acid (60 minutes) treatment *Abutilon pannosum* has given a significant result. Also germination percentage of *Calligonum comosum* and *Malva parviflora* increased significantly with sulphuric acid (120 minutes) treatment. Furthermore *Anthemis deserti* has given significant results with seed scarification (40 second) treatment. In addition *Rhazya stricta* germination percentage increased significantly with leaching treatment.

However some species didn't germinate well after breaking dormancy treatment even though these seeds viability was high, such as *Calligonum comosum, Capparis spinosa* and *Ricinus communis* (Table 3.7).

Species	Maximum germination percentage (After dormancy breaking treatments)	Viability percentage (Tetrazolium Test)
Calligonum comosum	25 (Leaching)	60
Capparis spinosa	30 (Scarification)	66
Retama reatam	10 (Sulphuric Acid (60 minutes))	50

Table 3.7: Maximum germination percentage after dormancy breaking treatments for some species with high viability percentage

From Table 3.5 some species show high viability with TZ test but show low germination percentage after dormancy breaking treatments, that may be by reason of difficulties in interpreting TZ test or those dormancy breaking treatments did not work with these species seeds. Alternatively it may because that 20-25°C was not appropriate temperature for these species seed germination.

Overall however the results correspond with some previous studies in that field; (Fernandez and Johnston, 1980; Al-Helal, 1989 and Al-Seed, 1998), and it will allow us to use most of chosen species in the next experiments and in Saudi designed landscape after later studies.

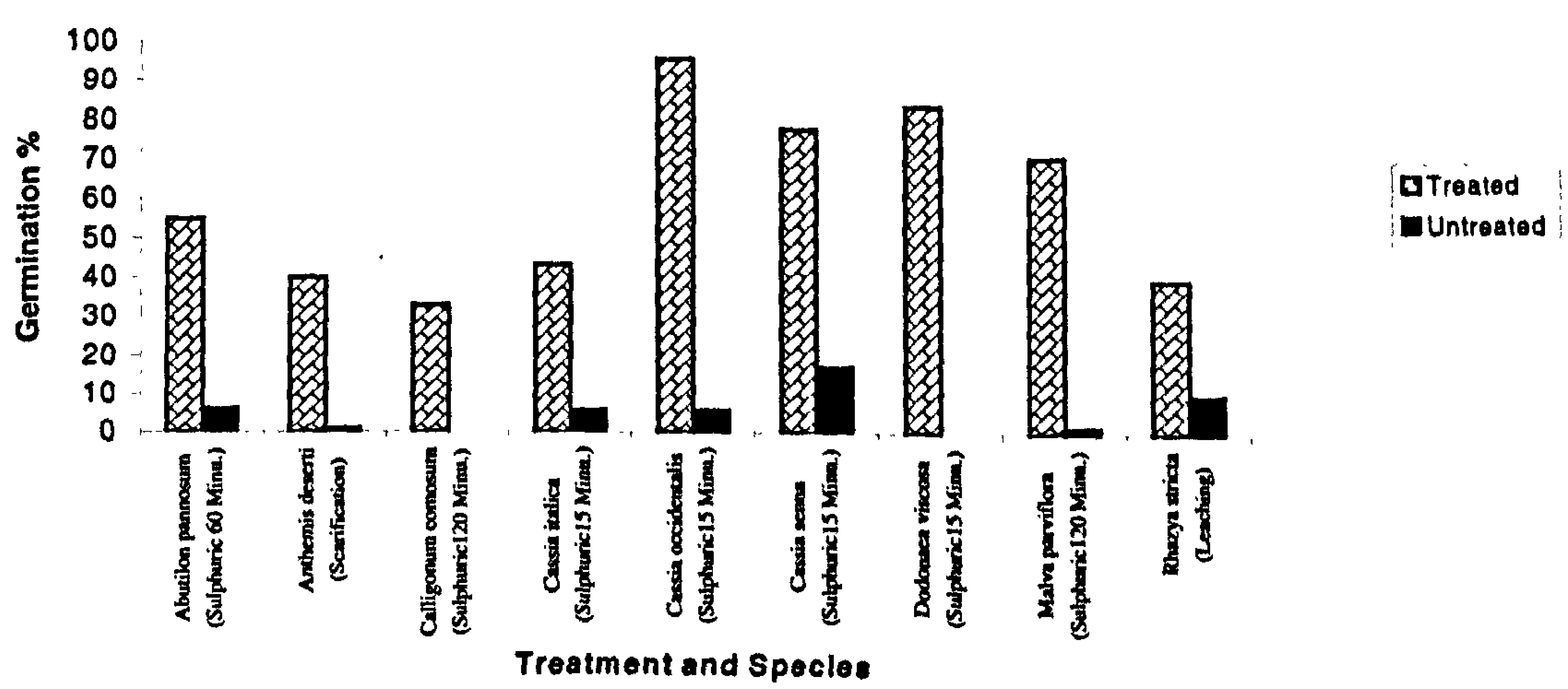

Fig. 3.20: Some Saudi indigenous species, which have given significant results in germination percentage with dormancy breaking treatments.

CHAPTER 4

4. EFFECT OF TEMPERATURE ON THE GERMINATION

CHAPTER 4

4. EFFECT OF TEMPERATURE ON THE GERMINATION

4.1-Introduction

The failure of many seeds to germinate may be independent of the need for pretreatment but be due merely to specific requirements not being satisfied. One of the most important of these requirements for germination is an appropriate temperature (Crocker and Barton, 1957). Temperature has long been recognized as the major environmental factor that determines the rate, and overall success of germination and development (Landsberg, 1975; Johnson and Thornley, 1985; Mckenzie and Hill, 1989).

Different seeds have different temperature ranges within which they germinate. At very low temperatures and very high temperature the germination of all seeds is prevented. The optimum temperature differs according to the species. The temperature range within which seed of a given species germinates is determined by the population from which the seed is drawn, seed storage conditions, and particular treatment prior to sowing, as well as by the age of seeds (Mayer and Mayber, 1989). While studies on the effect of temperature on germination commonly use incubators or controlled environment facilities, the capacity for an exhaustive investigation using these methods is limited by the number of germination environments available. The temperature-gradient bar is a device designed to overcome this limitation by simultaneously providing a gradient of temperature treatments, within a pre-determined range, with a single item of equipment.

Temperature plays a particularly important role in the climatic determination of geographical and ecological range of species. Treshow, (1970) states that " if the temperature in any given geographical area is unsuitable for even a single phase of plant development, the species may perish; or if it lives, it may not reproduce, or be able to compete successfully with better-adapted biota".

Seed germination is a complex process involving many individual reactions and phases, each of which is affected by temperature. Harper, (1965) has shown the importance of the season of germination on the prospects of establishment of a species in an alien environment "unless temperature responses (for germination) are closely linked to the ecological requirements of a particular species.

Successful temperature-gradient bars have been operated by several workers. Wagner, (1967) used a temperature- gradient bar to study germination patterns in successional herbs. Chatterton and Kadish, (1967) built a bar for use in germination studies. Larsen (1965) used a temperature-gradient bar to study germination of alfalfa seed and Kessler and Blank, (1971) used a temperature-gradient incubator to study the effect of temperature on fungal spore germination.

The duration of the germination process decreases as temperature rises to an optimum. The period over which germination takes place increases with further rises in temperature above this optimum (Squire, 1990). High temperatures during germination have been shown to damage metabolic pathways of many seed (Langridge, 1976). This induces disruption of membranes and the associated reactions resulting in restricted germination (Raison et al., 1980) The ability to germinate at high temperature is related to the sensitivity of the embryo and for most plants the upper limits range between 45 and 65 °C (Levitt, 1980).

The effect of temperature on germination can be expressed in terms of cardinal temperatures, that is base (minimum) (Tb), optimum (To) and maximum (Tm) temperatures at which germination can occur. The responses on either side of the optimum are not linear. However the rate of germination, which is simply the reciprocal of the duration, increases linearly with temperature up to To and then decreases rather sharply. The highest rate of germination occurs at the optimum temperature which can thus be estimated by the intersection of two regression lines describing the temperature below and above the optimum (Garcia-Huidobro, 1982). The two other cardinal temperature Tb and Tm can also be estimated on the basis of these relationships. At both these cardinal temperature, the rate of germination is considered to be zero. The value of

Tb and Tm are estimated from the rate and temperature relationships by the intercepts of the two regression lines with the temperature axis on either the below optimum range or above-optimum range (Squire, 1990).

The dependence of germination on temperature has been investigated for many plant species (Garcia-Huidobro et al., 1982; Covell et al., 1986; Mohammed el al., 1988 and Baskin & Baskin, 2000). The range of temperatures for germination of non- tropical species is typically 15-30°C with an optimum of around 22°C (Aisien and Ghosh, 1978). Most seeds of tropical species germinate between 15-40°C though few will do so below 10°C or above 50°C. Relatively little is known of the temperature requirement of Saudi native plants for germination. Seed of *Artemisia abyssinica* and *Cassia senna* from two contrasting habitats of Saudi Arabia were germinated by Basahy, (1996) at six alternating temperature regimes (18/8 °C, 20/10°C, 25/15°C, 30/20°C, 35,25°C and 40/30°C). At (18/8°C) there was no germination of either species. The germination percentage increased with rise of temperature attaining a maximum at 30/20°C. Germination decreased at 35/25°C and was even lower at 40/30°C. In general there is a shortage of data concerning the germination biology of Saudi indigenous species.

In this study seed germination of some indigenous species in Saudi Arabia was studied to understand how the temperature effects seed germination.

4.2-Materials and methods

The influence of temperature upon germination percentage was studied at seven constant temperatures over the range 5-35 °C (at 5 °C intervals), using temperature gradient bars. The experiment was conducted between October 2000 and July 2001. The thermal gradient bar was calibrated with the aim of establishing a linear temperature sequence from 5 °C to 35 °C with provision for adjustment to compensate for minor fluctuations in ambient temperature. Accordingly, liquid cooling and heating systems were adopted.

The thermal gradient bar consisted of an aluminum block, 33.5cm wide, 4.5cm deep and 50cm long. The bar surface is machined to provide eight germination channels 3.5cm wide, 1.5cm deep and 42cm long, with 0.5cm between each channal. The bar was heated at one end and cooled at the other, generating a range of temperatures along its length (Fig. 4.1).

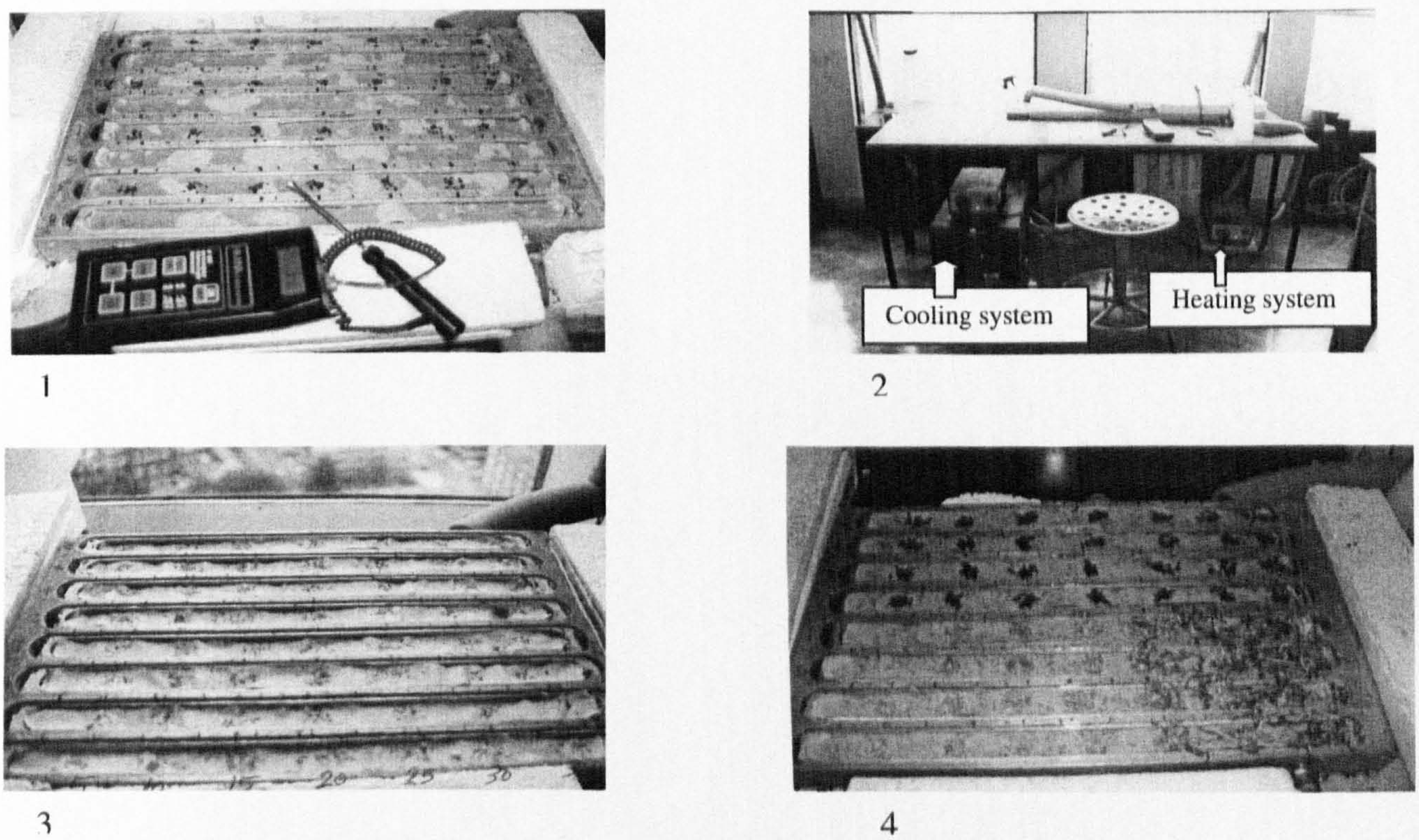

Fig 4.1: (1) The thermal gradient bar, (2) all of the system (Cooling system and Heating system), (3) - The bar after sowing the seeds, (4) The seeds of some indigenous species after their germination.

Filter paper (Whatman 3MM chromatography paper), moistened with distilled water, was laid on the surface of each line, and left to equilibrate at the set temperature for 24 hours before an experiment began.

Groups of 30 seeds were placed on the moist paper at seven positions (5, 10, 15, 20, 25, 30, 35 °C) between the cool and warm ends of the bar. Each position treatment was replicated four times across the bar, which allowed us to germinate seeds of two species at the same time. For some species seeds we applied dormancy breaking treatments as following:-

Species	Treatment	Species	Treatment
Anthemis deserti	scarification	*Cassia senna*	Sulphuric Acid 15 min.
Cassia italica	Sulphuric Acid 15 min.	*Dodonea viscosa*	Sulphuric Acid 15 min
Cassia occidentalis	Sulphuric Acid 15 min.	*Rhazya stricta*	Leaching

Table 4.1 Techniques for breaking of seed dormancy.

The germinated seeds were counted daily until no more germinated for sixteen days. A one way ANOVA was undertaken using *SPSS version 10* to determine whether significant differences occurred at $P=0.05$; in term of the number of seeds that had germinated by to day 16. Post hoc tests were used (LSD and Tukey test) were undertaken as appropriate.

4.3-Results

4.3.1. *ACHILLEA FRAGRANTISSIMA*

It can be seen from Fig. 4.2 that the maximum germination percentage of *Achillea fragrantissima* was at 30°C, with approximately 95% germination recorded from the third day. High percentage germination was also observed at 10, 15, 20, 25, 35°C. However at 5°C the germination percentage was lower than 50%. There was a significant difference in germination percentage between 5°C and the others temperatures ($P<0.0001$). however there were no significant differences in germination percentage at temperatures of 10, 15, 20, 25, 30 and 35°C ($P>0.05$). Rate of germination was greatly reduced at 5°C.

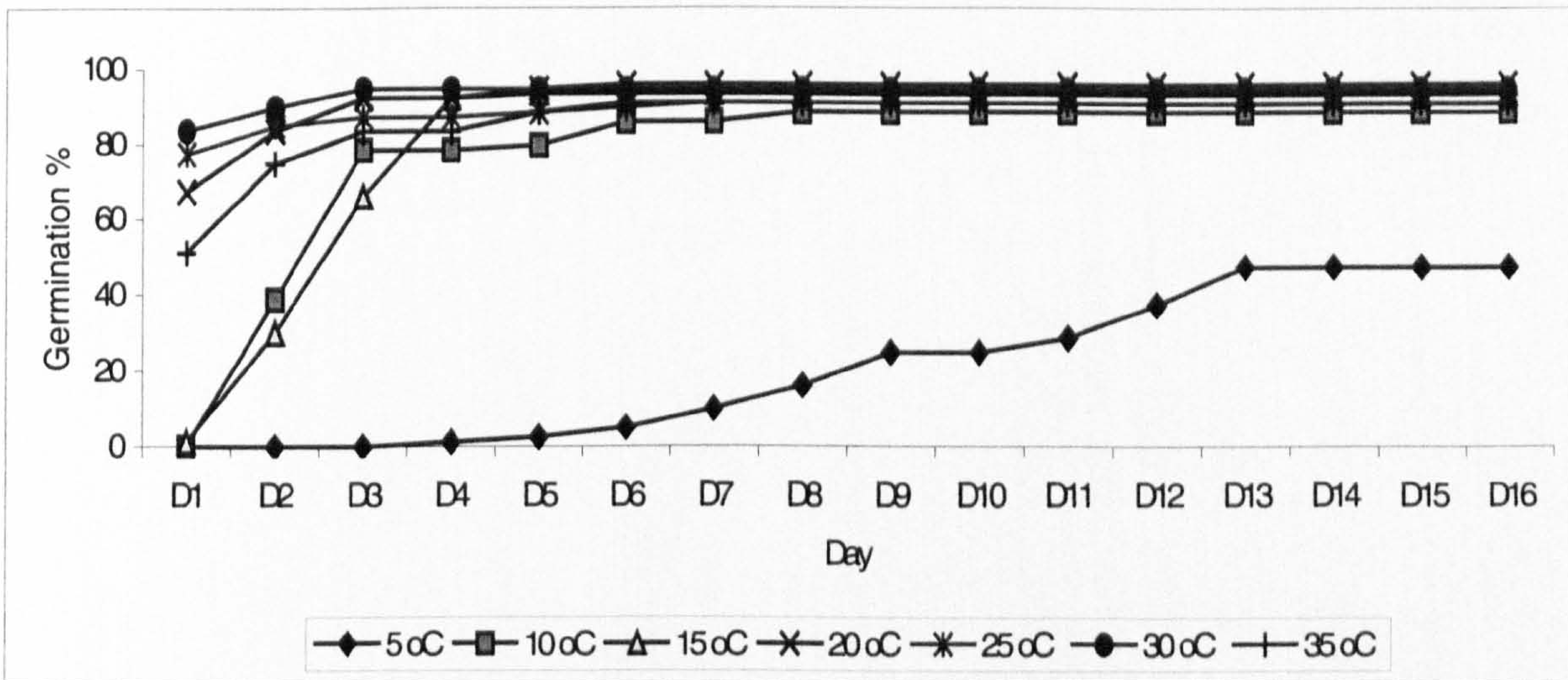

Fig. 4.2: Effect of temperature on germination of *Achillea fragrantissima*

4.3.2. *AERVA JEVANICA*

Maximum germination percentage of *Aerva jevanica* was at 25°C, approximately 40% germination was recorded at the end of the experiment (See fig. 4.3). At 20 °C and at 30 °C germination was 22.5% and 17.5% respectively. However at 5, 10, 15, 35 °C, the germination was less than 2.5%. There was a significant difference in germination percentage between 25°C and the others temperatures ($P<0.05$). However there were no significant differences in germination percentage between 20 °C and 30 °C ($P>0.05$). There was however a significant difference in germination percentage between 20 °C and 30 °C and the others temperatures($P<0.05$). Rate of germination was greatly reduced at 5°C, 10°C 15°C and 35°C.

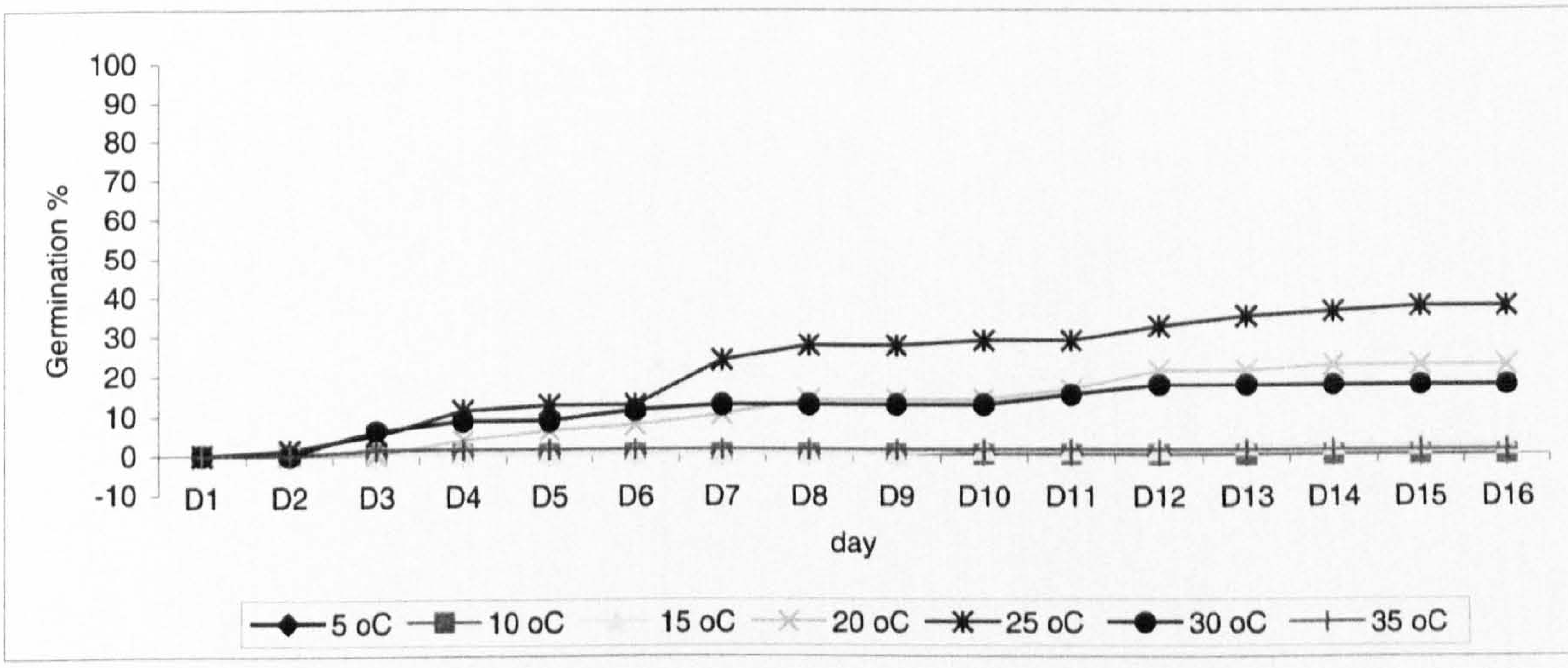

Fig. 4.3: Effect of temperature on germination of *Aerva jevanica*

4.3.3. *ALOE VERA*

It can be seen from Fig. 4.4 that the maximum germination percentage of *Aloe vera* was at 25°C, with 46.66 % germination recorded by the eighth day. Moreover at 20 and 30°C germination percentage was 44.2% and 42.4% respectively. However at 15°C the germination was less than 35 % and less than 21% at 35°C . However at 5, 10 °C, the germination percentage was lower than 3.5%. There was a significant difference in germination percentage between 25°C and 5, 10, 15 °C ($P<0.05$). however there were no significant differences in germination percentage at temperatures of 20, 25 and 30°C ($P>0.05$). Rate of germination was greatly reduced at 5°C and 10°C.

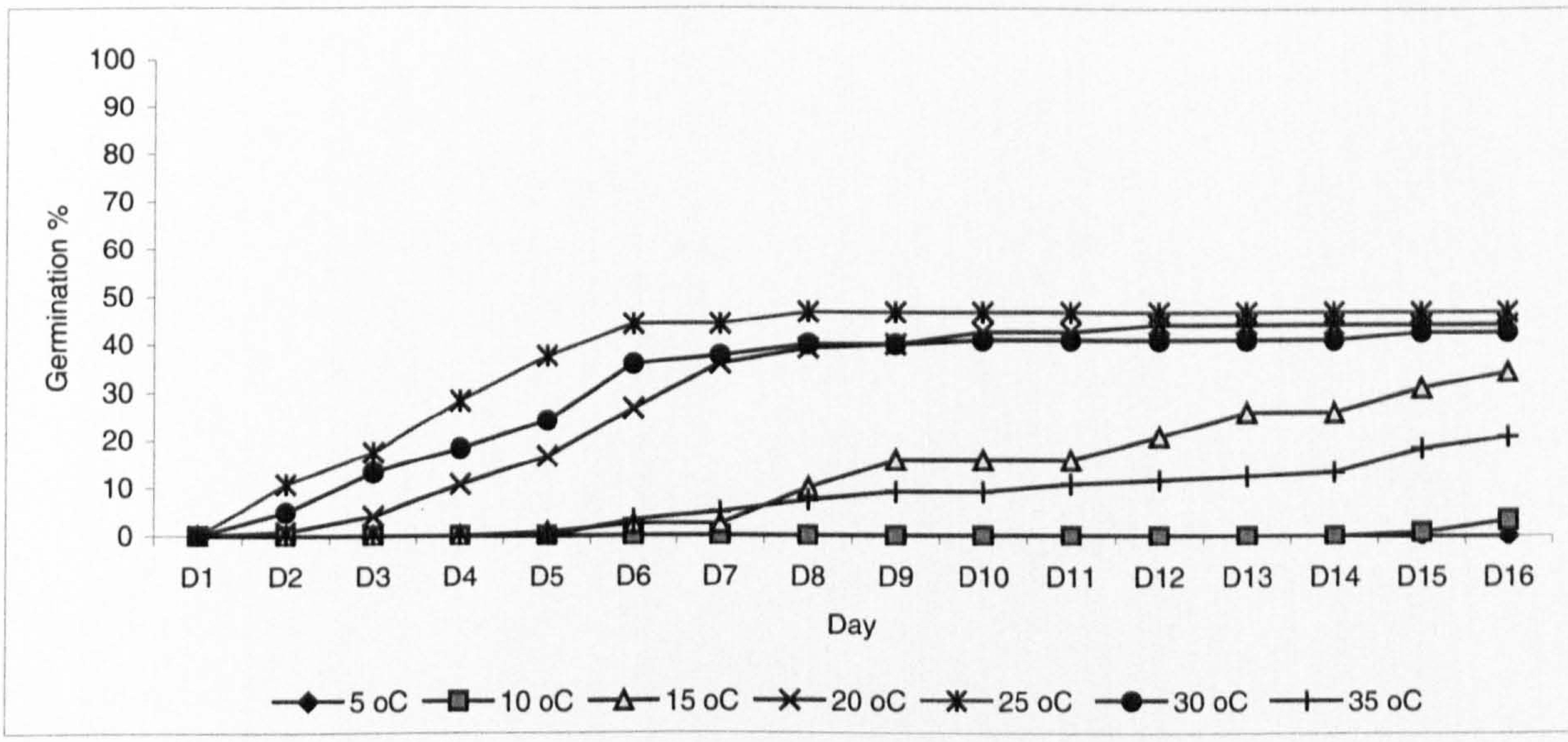

Fig. 4.4: Effect of temperature on germination of *Aloe vera*

4.3.4. *ANTHEMIS DESERTI*

As can be seen from Fig. 3.5 that the maximum germination percentage of *Anthemis deserti* was at 15 °C, with 21.67 % germination recorded from the eleventh day. Germination percentage was 20 % at 10 °C. At 35 °C the germination percentage was zero, and at 5, 20, 25 and 30 °C less than 10 %. There was a significant difference in germination percentage between 10 and 15°C and the others temperatures ($P<0.05$). However there were no significant differences in germination percentage at temperatures of 10 and 15°C ($P>0.05$). Rate of germination was greatly reduced at 5, 20, 25, 30 and 35°C.

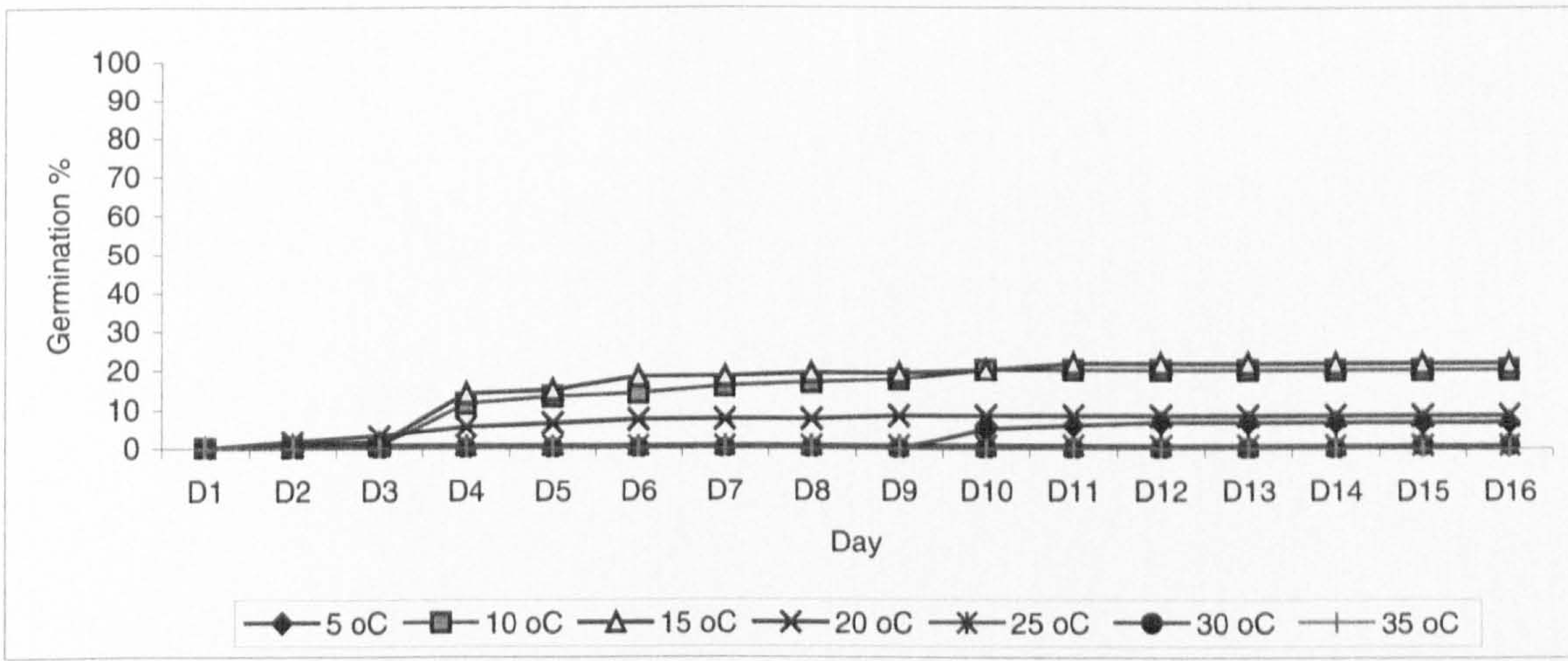

Fig. 4.5: Effect of temperature on germination of *Anthemis deserti*

4.3.5. *ANVILLEA GARCINI*

Maximum germination percentage of *Anvillea garcini* was recorded at 20 and 25°C, with 43.33 % germination was recorded from the thirteenth day (Fig. 4.6). Percentage germination at 15°C was 30% and 26% at 30. At 5 °C the germination percentage was zero, and at 10 and 35 °C less than 10 %. There was a significant difference in germination percentage between 20 and25°C and 5, 10, 15, 30 and 35 °C temperatures ($P<0.05$). There were no significant differences in germination percentage at temperatures of 20, and 25 °C ($P>0.05$).

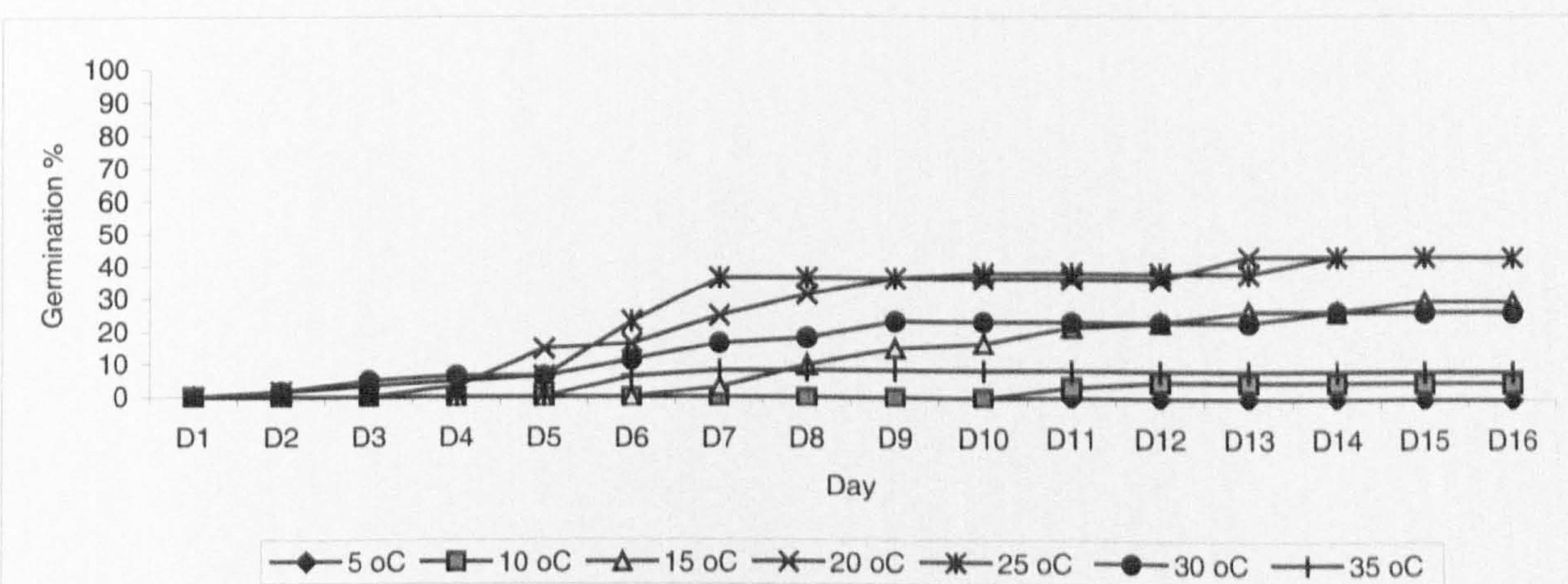

Fig. 4.6: Effect of temperature on germination of *Anvillea garcini*

4.3.6. *ARTEMISIA JUDAICA*

The maximum germination percentage of *Artemisia judaica* was at 25°C, with 78.33 % germination was recorded by the ninth day (see fig. 4.7). At 15, 20°C germination percentage was 68.33 and 71.67. At 30°C the germination percentage fell to below 52 % and to 41% at 10°C. However at 5 and 35 °C, the germination percentage was lower than 6.5%. There was a significant difference in germination percentage between 25°C and 5, 10, 35 °C temperatures ($P<0.05$). However there were no significant differences in germination percentage at 15, 20 and 25°C ($P>0.05$). Rate of germination was greatly reduced at 5°C and 35°C.

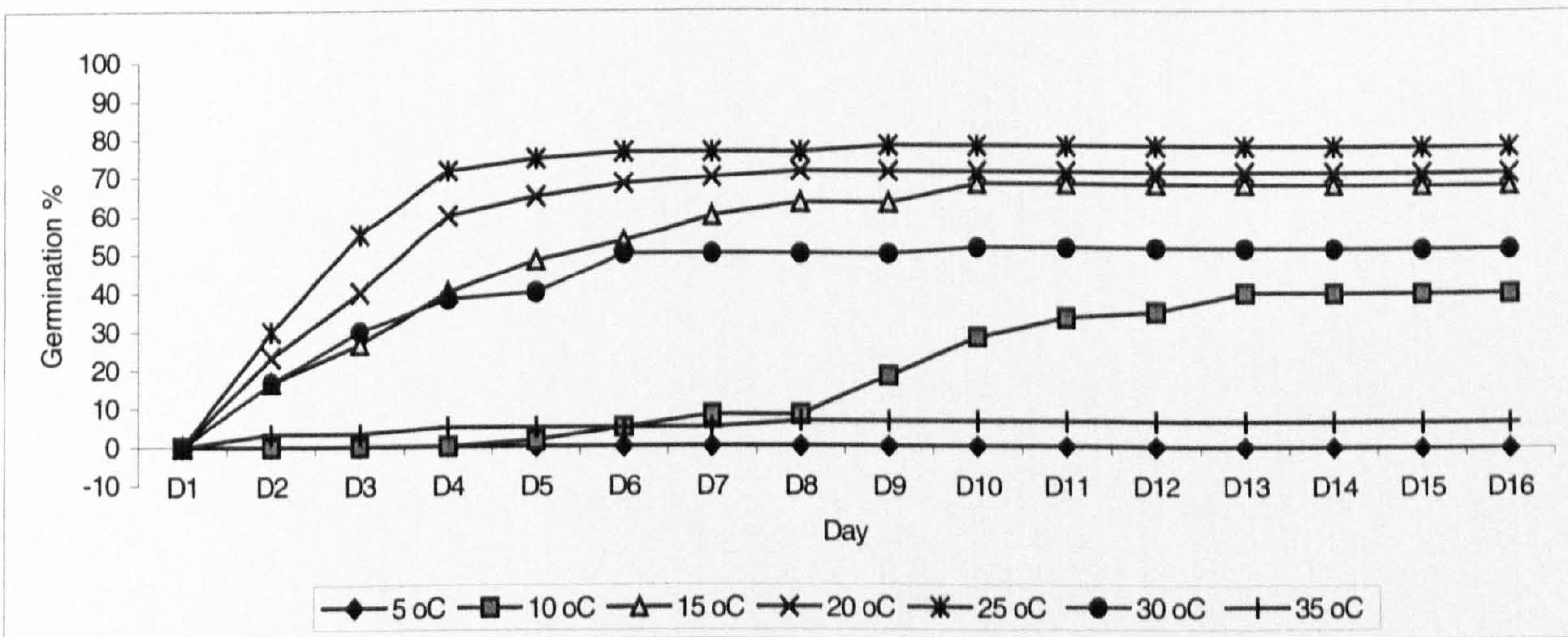

Fig. 4.7: Effect of temperature on germination of *Artemisia judaica*

4.3.7. *CASSIA ITALICA*

Maximum germination percentage of *Cassia italica* was at 30°C, with 67.5 % germination recorded from the ninth day (fig.4.8). High percentage germination was also recorded at 20, 25 and 35 °C. At 5,10 and 15°C the germination percentage was less than 13 %. There was a significant difference in germination percentage between 30°C and 5, 10, 15 °C ($P<0.05$). However there were no significant differences in germination percentage at temperatures of 20,25,30 and 35°C ($P>0.05$).

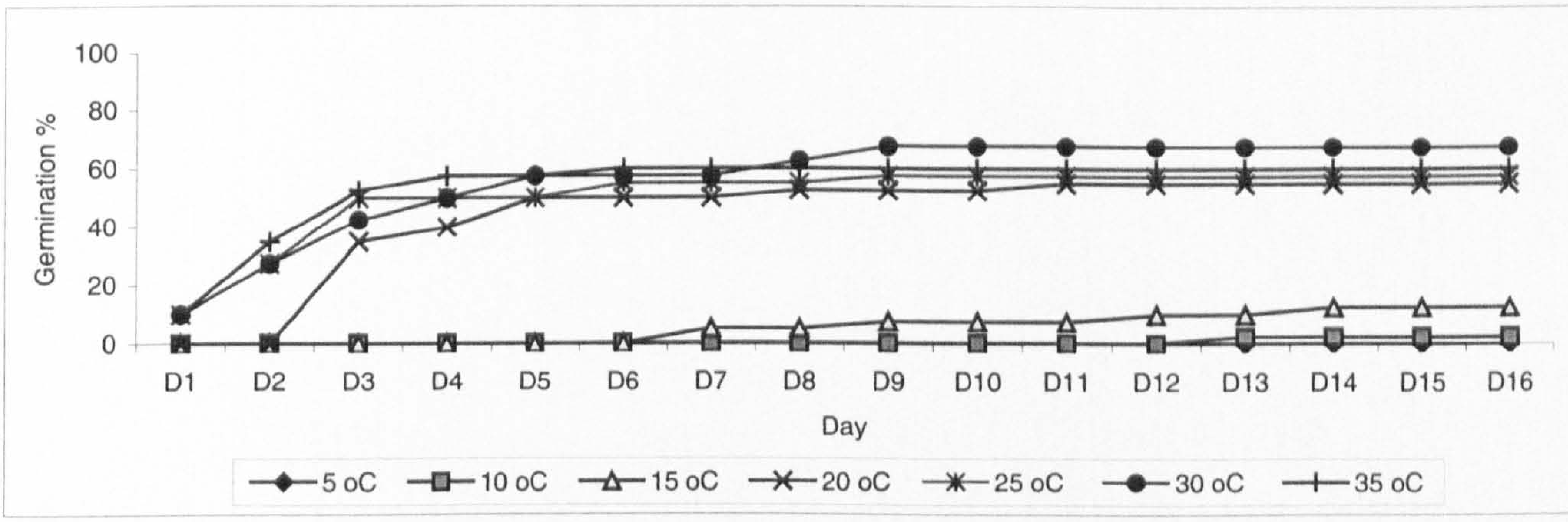

Fig. 4.8: Effect of temperature on germination of *Cassia italica*

3.3.8. *CASSIA OCCIDENTALIS*

As can be seen from Fig. 4.9 maximum germination percentage of *Cassia occidentalis* was at 25, 30 and 35°C, with 100 % germination recorded from the third day. High percentage germination was also observed at 20°C. At 5, 10 and 15°C the germination percentage was zero. There was a significant difference in germination percentage between 5, 10 and 15°C and the others temperatures ($P<0.0001$). however there were no significant differences in germination percentage at temperatures of 25, 30 and 35°C ($P>0.05$). Rate of germination was greatly reduced at 5, 10 and 15°C.

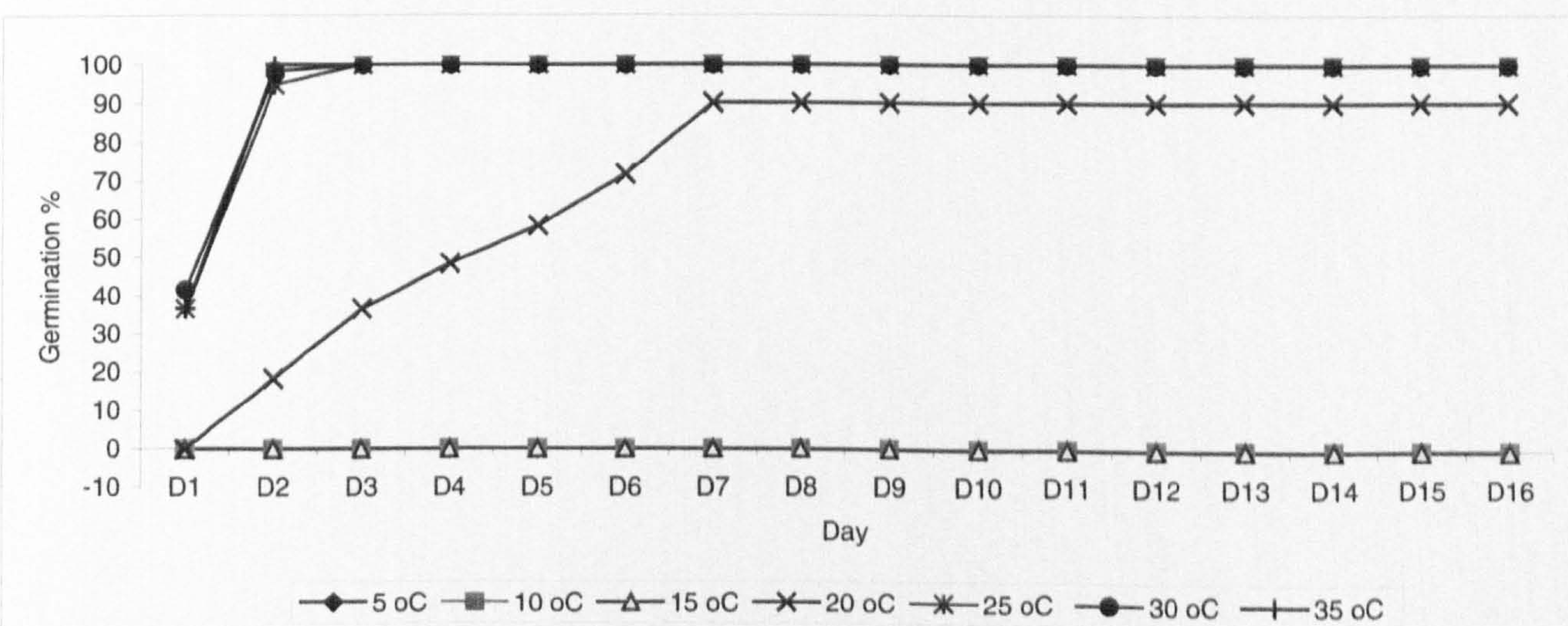

Fig. 4.9: Effect of temperature on germination of *Cassia occidentalis*

4.3.9. *CASSIA SENNA*

Maximum germination percentage of *Cassia senna* was at a temperature of 30°C, 85 % germination recorded from the sixth day (Fig. 4.10). High percentage germination was also recorded at 25 and 35°C. However at 20°C the germination percentage fell to less than 47 %, and at 5, 10 and 15°C was zero. There was a significant difference in germination percentage between 30°C and 5, 10, 15, 20 °C ($P<0.0001$). However there were no significant differences in germination percentage at temperatures of 30 and 25°C ($P>0.05$). Rate of germination was greatly reduced at 5, 10 and 15°C.

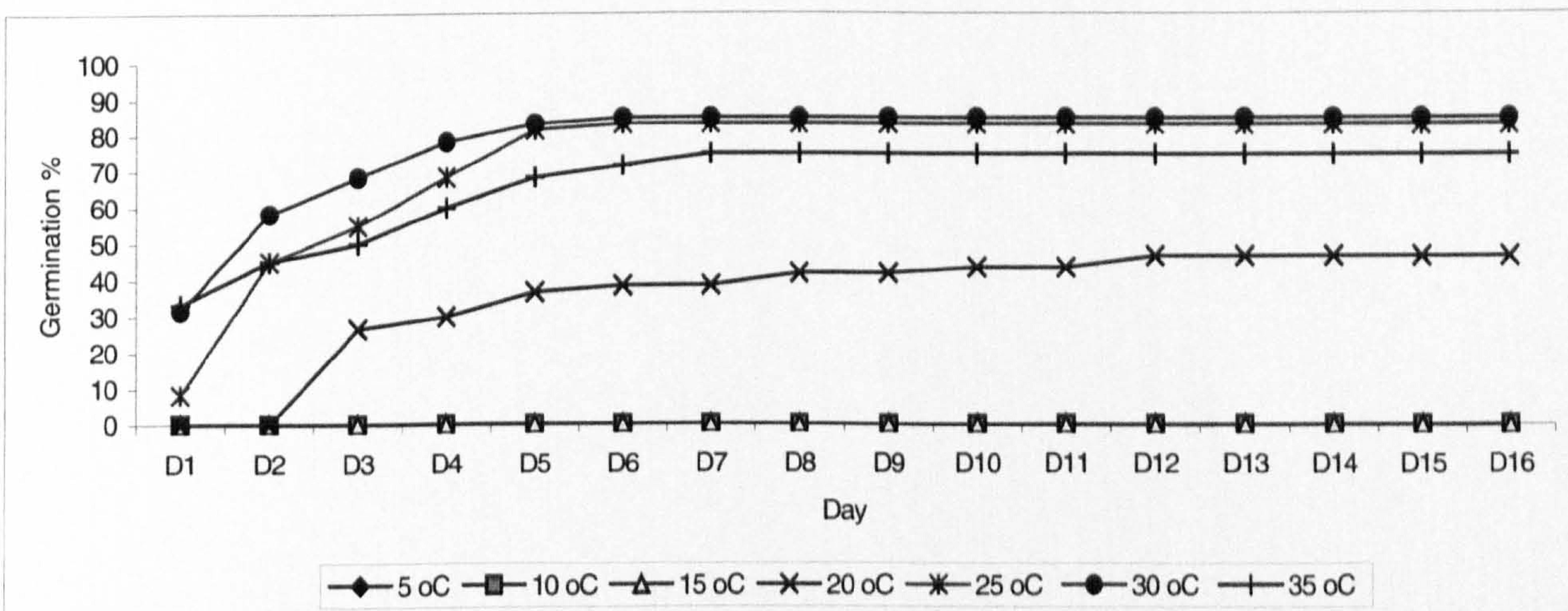

Fig. 4.10: Effect of temperature on germination of *Cassia senna*

4.3.10. *DATURA INNOXIA*

It can be seen from Fig. 4.11 the germination percentage was approximately zero at all temperatures up to the end of the experiment.

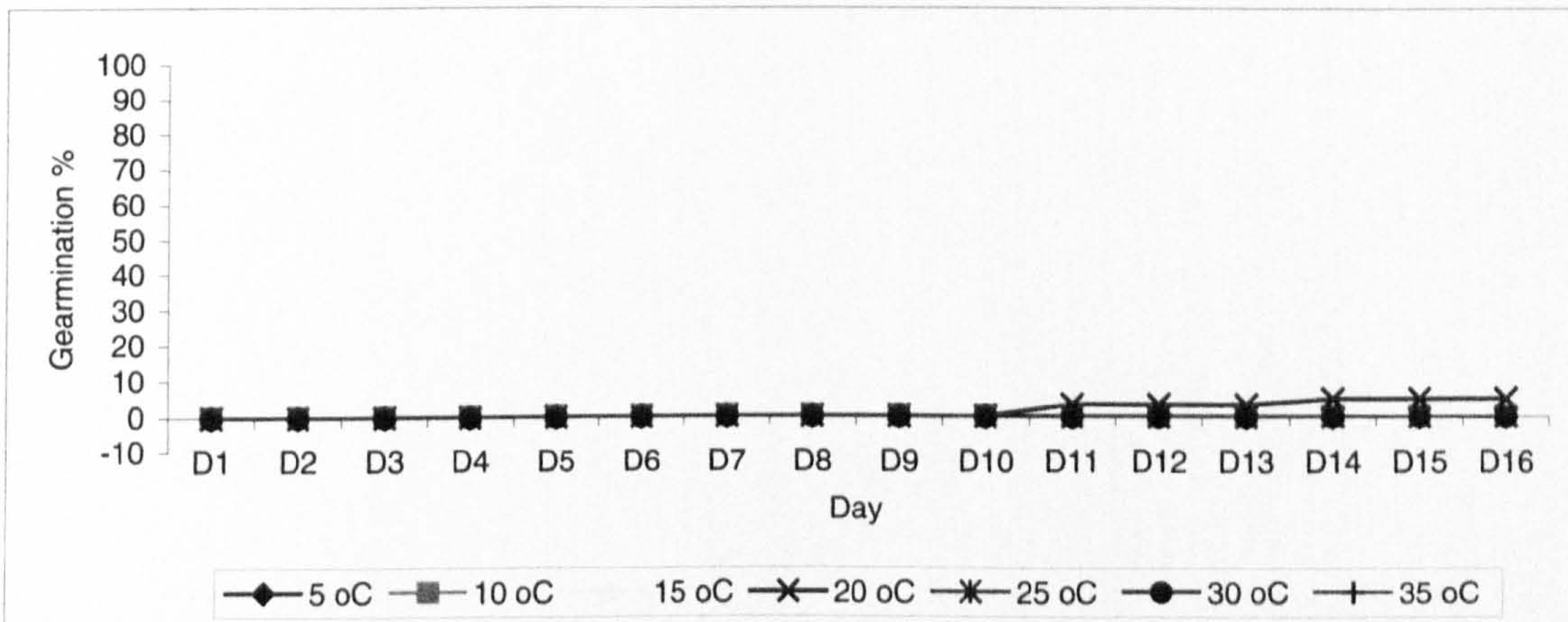

Fig. 4.11: Effect of temperature on germination of *Datura innoxia*

4.3.11. *DODONEA VISCOSA*

Maximum germination percentage of *Dodonea viscosa* was 25°C, with 97.5 % germination recorded from the seventh day. Very high percentage germination was also observed at (20, 30 °C). At 5 and 10°C germination percentage was zero, rising to approximately 50% at 15 and 35 °C. There was a significant difference in germination percentage between 25°C and 5, 10, 15, 35°C ($P<0.05$). However there were no significant differences in germination percentage at temperatures of 20,30 and 25°C ($P>0.05$). Rate of germination was greatly reduced at 5 and 10°C.

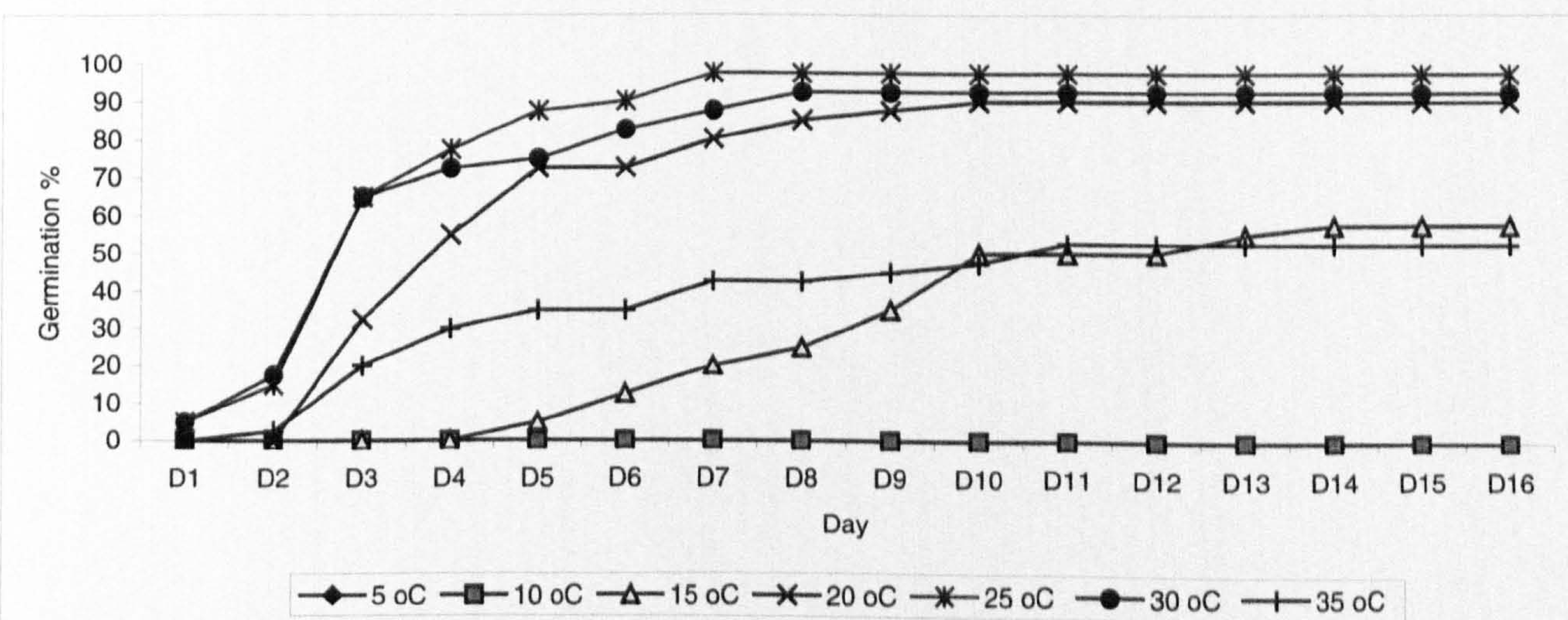

Fig. 4.12: Effect of temperature on germination of *Dodonea viscosa*

4.3.12. *FARSETIA AEGYPTIA*

Maximum germination percentage of *Farsetia aegyptia* was recorded at 25°C, with 93.7 % germination recorded from the fourth day (Fig. 4.13). Very high percentage germination was also observed at 20 and 30 °C. However at 5 °C the germination percentage was zero and less than 17 % at 10 °C, rising to approximately 55% at 15 and 35 °C. There was a significant difference in germination percentage between 25°C and 5, 10, 15, 35°C ($P<0.05$). However there were no significant differences in germination percentage at temperatures of 20,30 and 25°C ($P>0.05$). Rate of germination was greatly reduced at 5 and 10°C.

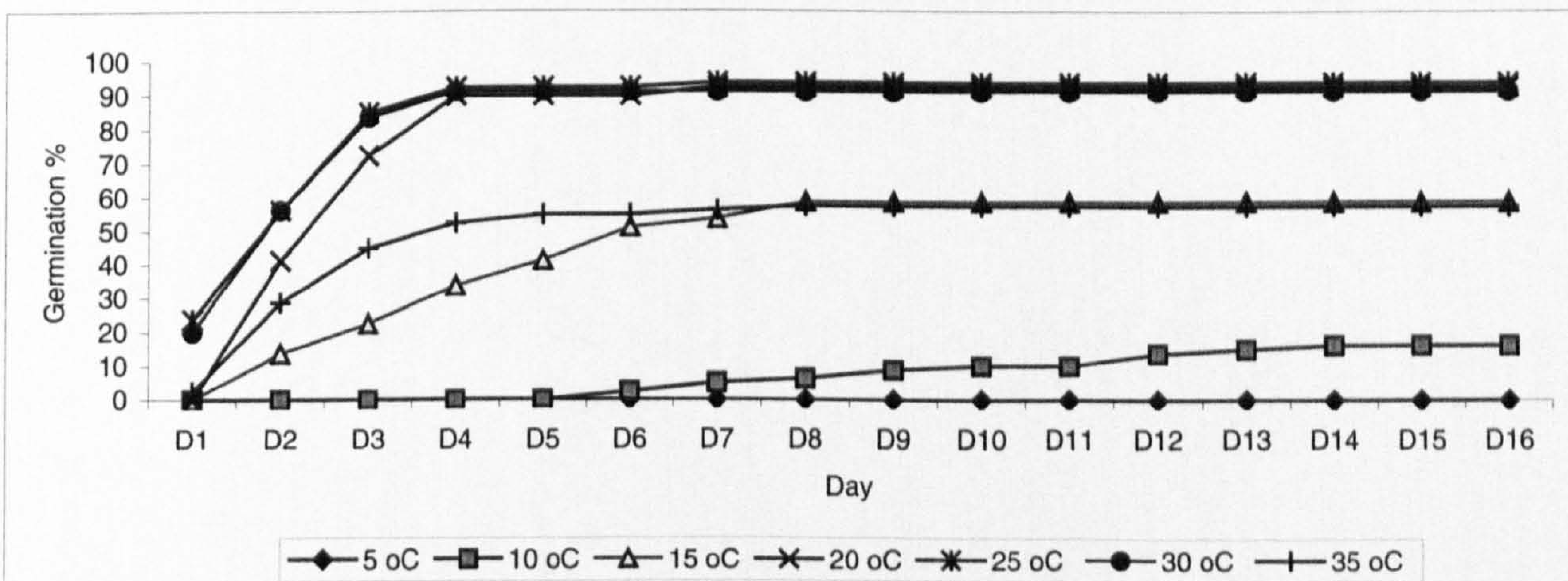

Fig. 4.13: Effect of temperature on germination of *Farsetia aegyptia*

4.3.13. *LUNNAEA MUCRONATA*

As can be seen from Fig. 4.14, maximum germination percentage of *Lunnaea mucronata* was at 25 and 30°C, with 44.66 % germination recorded from the fifteenth day. At 15 and 20 °C 23.3 % was recorded, felling to approximately 15% at 10 and 35 °C. At 5 °C the germination percentage was lower than 2 %. There was a significant difference in germination percentage between 25 and 30°C and 5, 10, 15 and 35°C ($P<0.05$). However there were no significant differences in germination percentage at temperatures of 20 and 15°C ($P>0.05$). Rate of germination was greatly reduced at 5 °C.

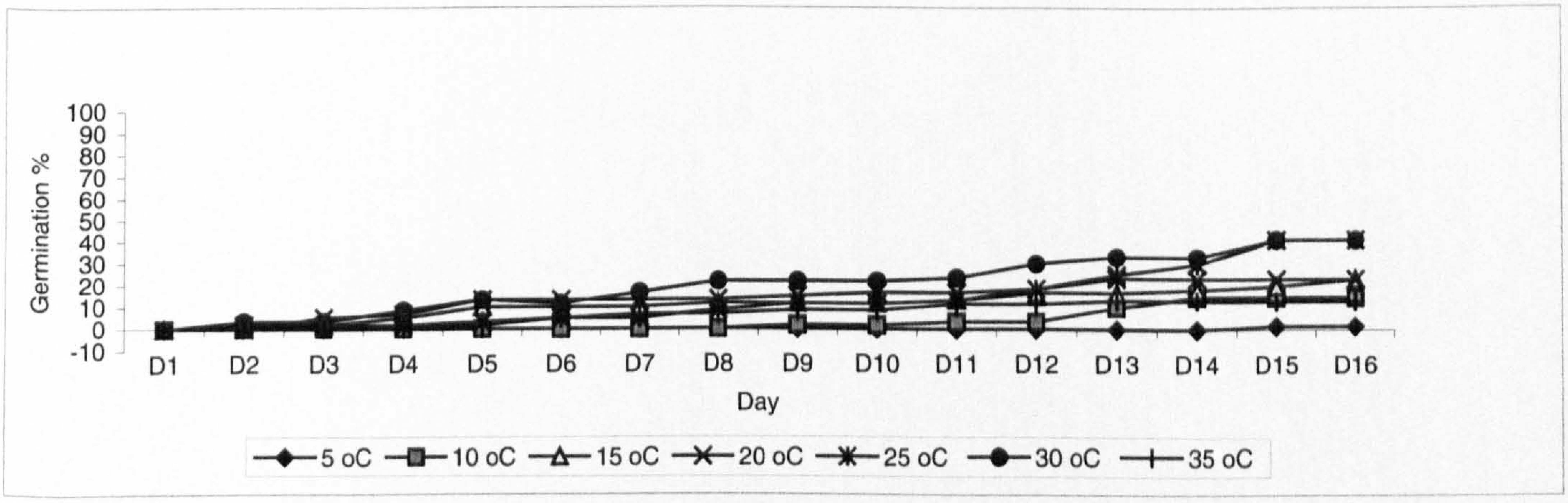

Fig. 4.14: Effect of temperature on germination of *Lunnaea mucronata*

4.3.14. *LYCIUM SHAWII*

Maximum germination percentage of *Lycium shawii* was at 20 and 25°C, with 60 % germination recorded from the thirteenth day. Percentage germination was 48% at 15 °C. At 5 °C the germination percentage was zero, and at 35 °C less than 4 %, rising to approximately 12 % at 10 °C, and 18.33 % at 30 °C. There was a significant difference in germination percentage between 20 and 25°C and the others temperatures ($P<0.05$). However there were no significant differences in germination percentage at temperatures of 20 and 25 °C ($P>0.05$). Rate of germination was greatly reduced at 5 and 35°C.

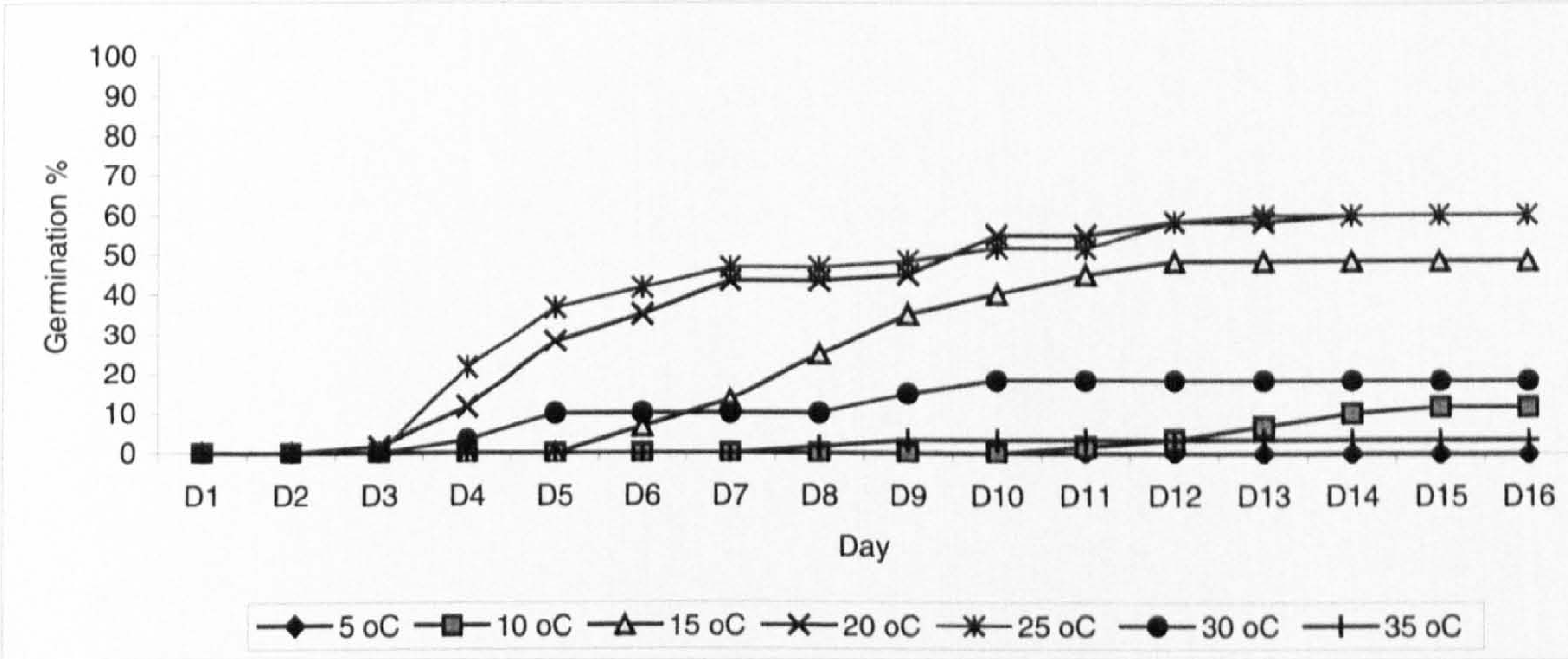

Fig. 4.15: Effect of temperature on germination of *Lycium shawii*

4.3.15. *MALVA PARVIFLORA*

Maximum germination percentage of *Malva parviflora* was at 15, 20, 25 and 30°C, approximately 46 % germination was recorded by the thirteenth day (Fig. 4.16). At 10 and 35°C the germination percentage was less than 11 %, and at 5 °C was zero. There was a significant difference in germination percentage between 15, 20, 25, 30°C and 5, 10, 35 °C ($P<0.05$). However there were no significant differences in germination percentage at temperatures of 15, 20, 25 and 30°C ($P>0.05$). Rate of germination was greatly reduced at 5, 10 and 35°C.

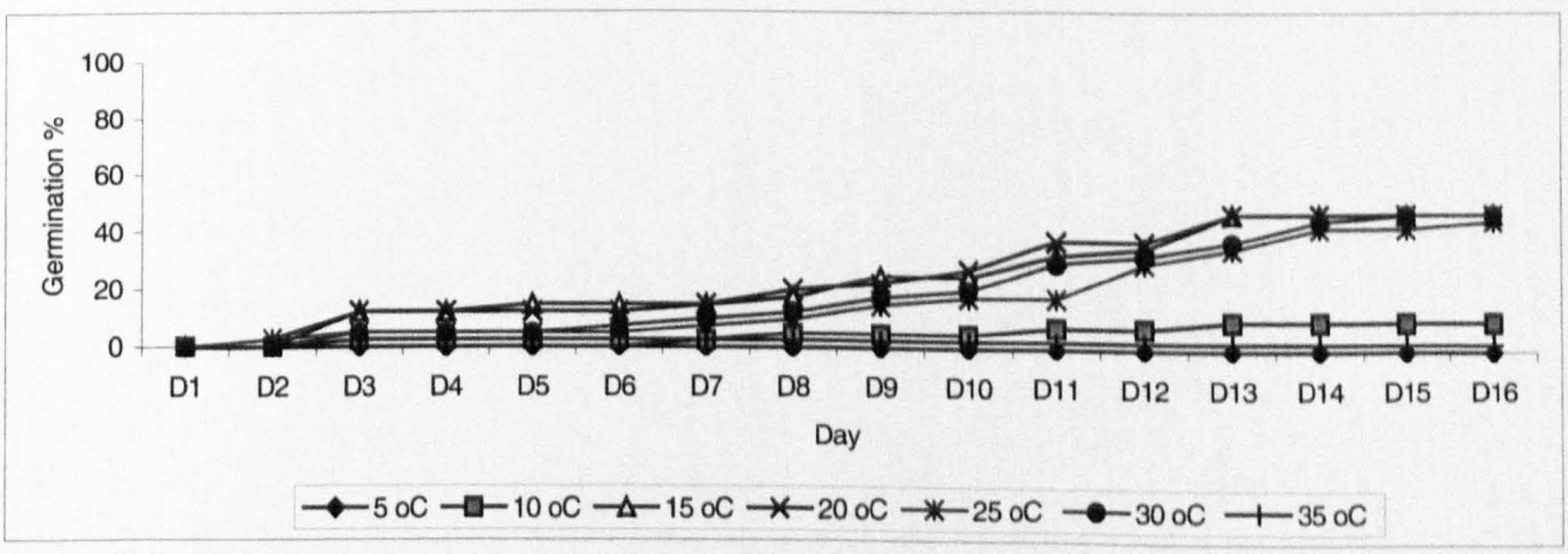

Fig. 4.16: Effect of temperature on germination of *Malva parviflora*

3.3.16. *PEGANUM HARMALA*

Maximum germination percentage of *Peganum harmala* occurred at 30°C, with 93.33 % germination recorded from the eighth day. High percentage germination was also observed at 25, 35 °C. At 5, 10 and 15°C germination percentage was zero, rising to approximately 8% at (20 °C). There was a significant difference in germination percentage between 30°C and 5, 10, 15, 20°C ($P<0.0001$). However there were no significant differences in germination percentage at temperatures of 30 and 35°C ($P>0.05$). Rate of germination was greatly reduced at 5, 10, 15 and 20°C.

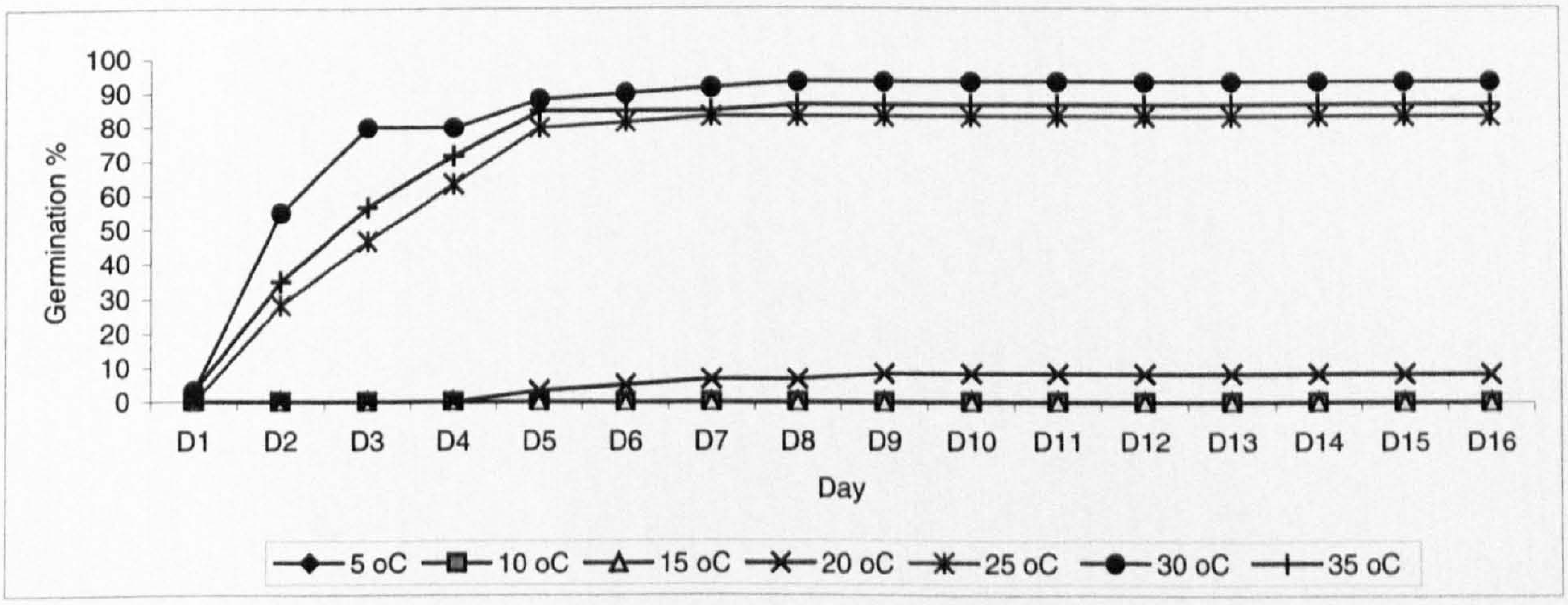

Fig. 4.17: Effect of temperature on germination of *Peganum harmala*

4.3.17. *PLANTAGO ALBICANS*

Maximum germination percentage of *Plantago albicans* occurred at the temperature 15 °C, with 51.67 % germination recorded from the tenth day (Fig. 4.18). At 10 °C and 20 °C 44.17 % and 50 % germination respectively was recorded. At 5, 25, 30 and 35 °C the germination percentage was less than 10 %. There was a significant difference in germination percentage between 15 and 10°C and 5, 20, 25, 30 and 35°C ($P<0.05$). There were no significant differences however in germination percentage at temperatures of 10 and 15°C ($P>0.05$). Rate of germination was greatly reduced at 5, 25, 30 and 35 °C.

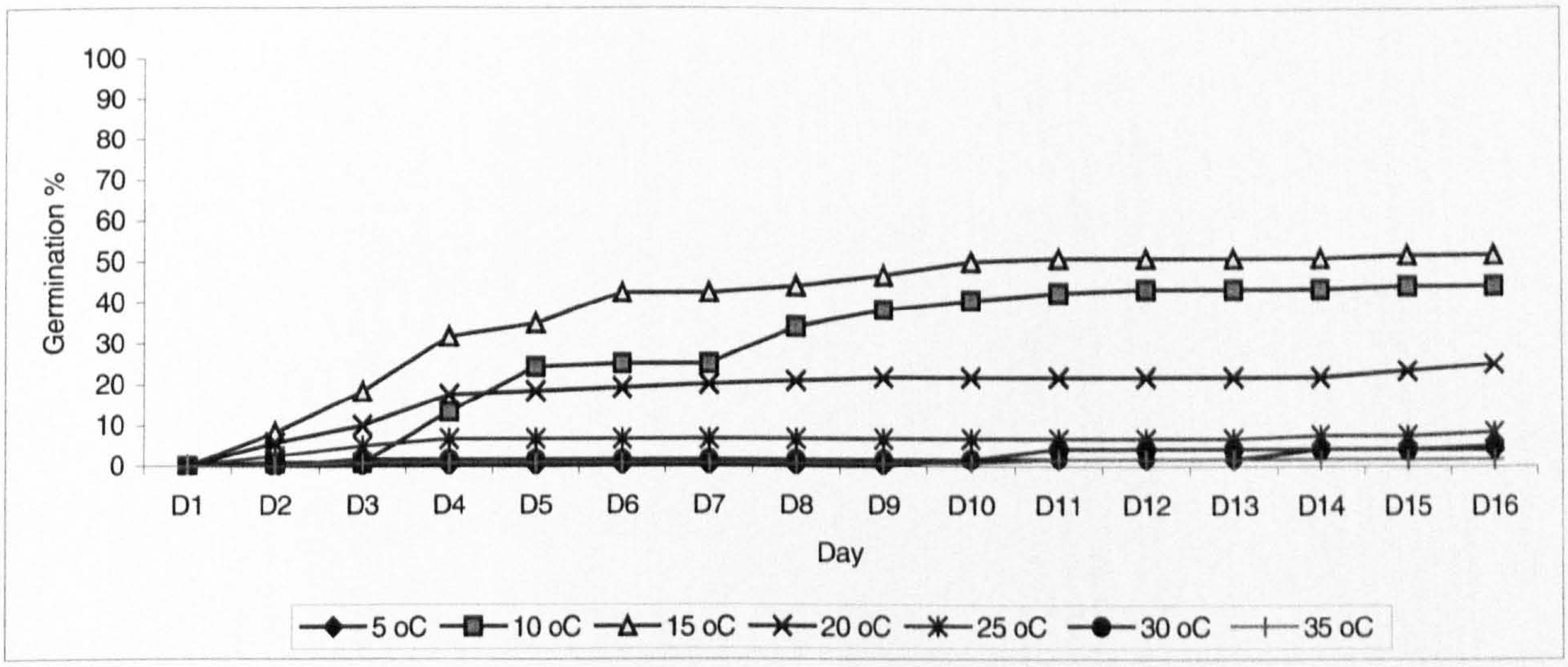

Fig. 4.18: Effect of temperature on germination of *Plantago albicans*

4.3.18. *PULICARIA CRISPA*

Maximum germination percentage of *Pulicaria crispa* occurred at 25°C, with 78.33 % germination recorded from the seventh day. High percentage germination was also observed at 20 °C. At 5 °C the germination percentage was zero, and at 35 °C less than 24 %, rising to approximately 42 % at 15 and 30 °C. There was a significant difference in germination percentage between 25°C and the other temperatures ($P<0.05$), and between 20°C and the other temperatures ($P<0.05$). However there were no significant differences in germination percentage at temperatures of 15 and 30 °C ($P>0.05$). Rate of germination was greatly reduced at 5 and 10°C.

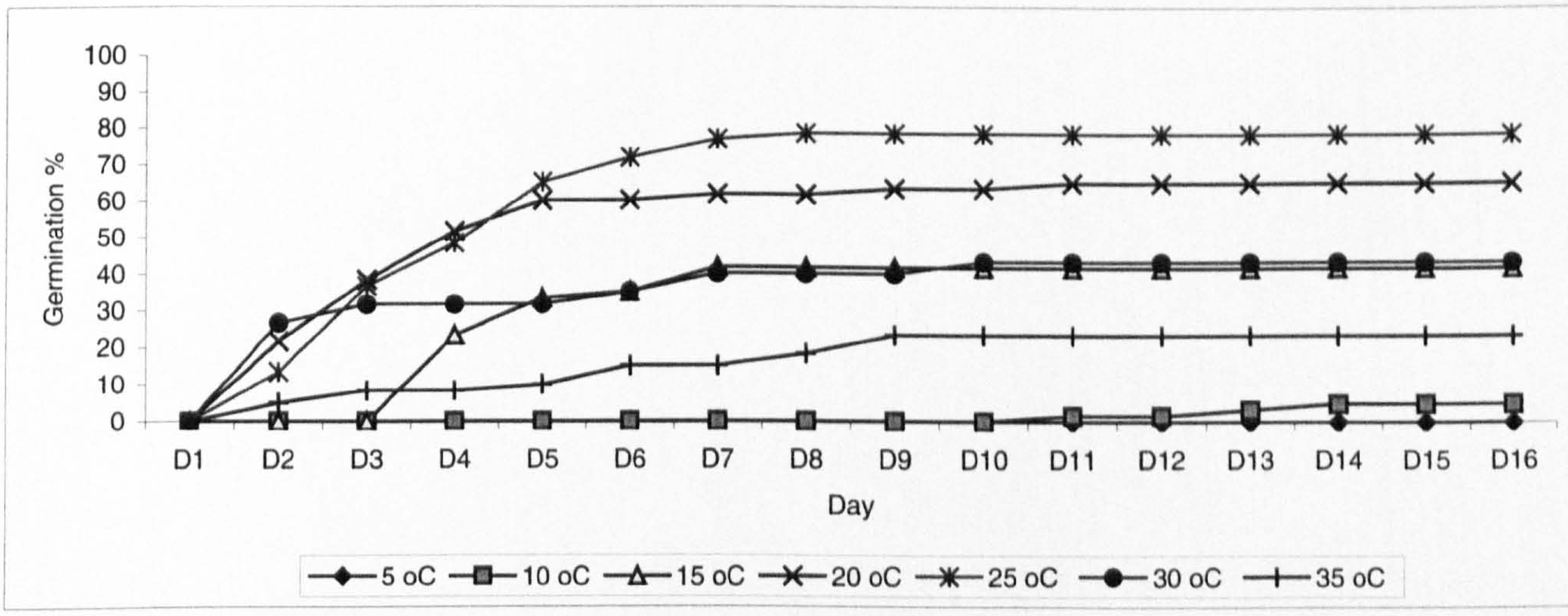

Fig. 4.19: Effect of temperature on germination of *Pulicaria crispa*

4.3.19. *RHAZYA STRICTA*

Maximum germination percentage of *Rhazya stricta* was at 30°C, with approximately 62 % germination recorded from the eighth day (Fig. 4.20). At 35 °C and 25 °C, 35% and 31.67 %germination respectively was recorded. At 5,10 and 15 °C the germination percentage was zero and at 20 °C less than 7 %. There was a significant difference in germination percentage between 30°C and the others temperatures ($P<0.05$). However there were no significant differences in germination percentage between 25 °C and 35 °C ($P>0.05$).

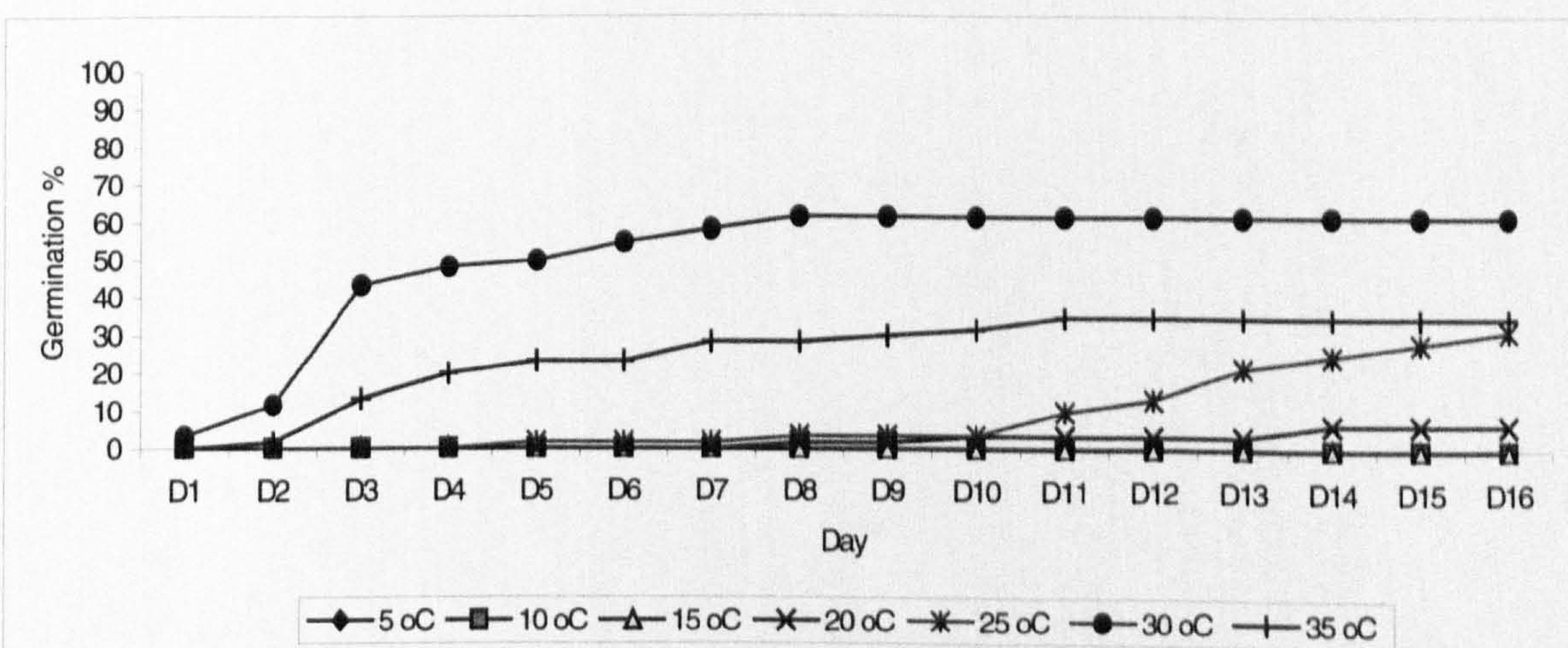

Fig. 4.20: Effect of temperature on germination of *Rhazya stricta*

4.3.20. *RUMEX VILLOSA*

As can be seen from Fig. 4.21, maximum germination percentage of *Rumex villosa* was recorded at 25 °C, with 47.5 % germination from the ninth day. Germination percentage was 43.3 % at 20 °C, and approximately 38 % at 10, 15 and 30 °C. At 35 °C the germination percentage was less than 5 %. There was a significant difference in germination percentage between 25 °C, 35°C and 5 °C (P<0.05). There were no significant differences in germination percentage at temperatures of 10, 15, 20, 25 and 30 °C (P>0.05). Rate of germination was greatly reduced at 35 °C.

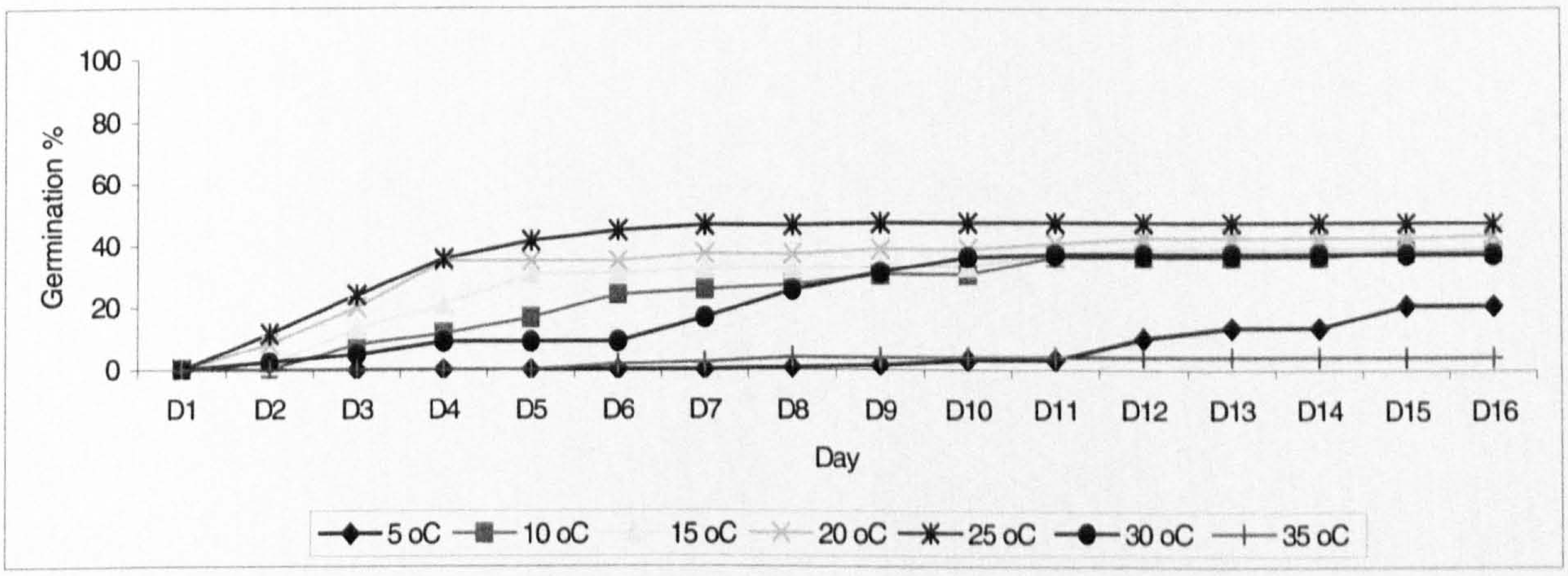

Fig. 4.21: Effect of temperature on germination of *Rumex villosa*

4.3.21. *VERBESINA ENCELIOIDES*

Maximum germination percentage of *Verbesina encelioides* occurred at 25 °C, with 57.5 % germination recorded from the thirteenth day. Germination percentage was 47.5 % at 20 °C, and 17 % at 15 °C. At 5,10 and 35 °C the germination was zero and at 30 °C less than 6 %. There was a significant difference in germination percentage between 20 and 25°C and the others temperatures (P<0.05). However there were no significant differences in germination percentage at temperatures of 20 and 25°C (P>0.05). Rate of germination was greatly reduced at 5, 10, 30 and 35 °C.

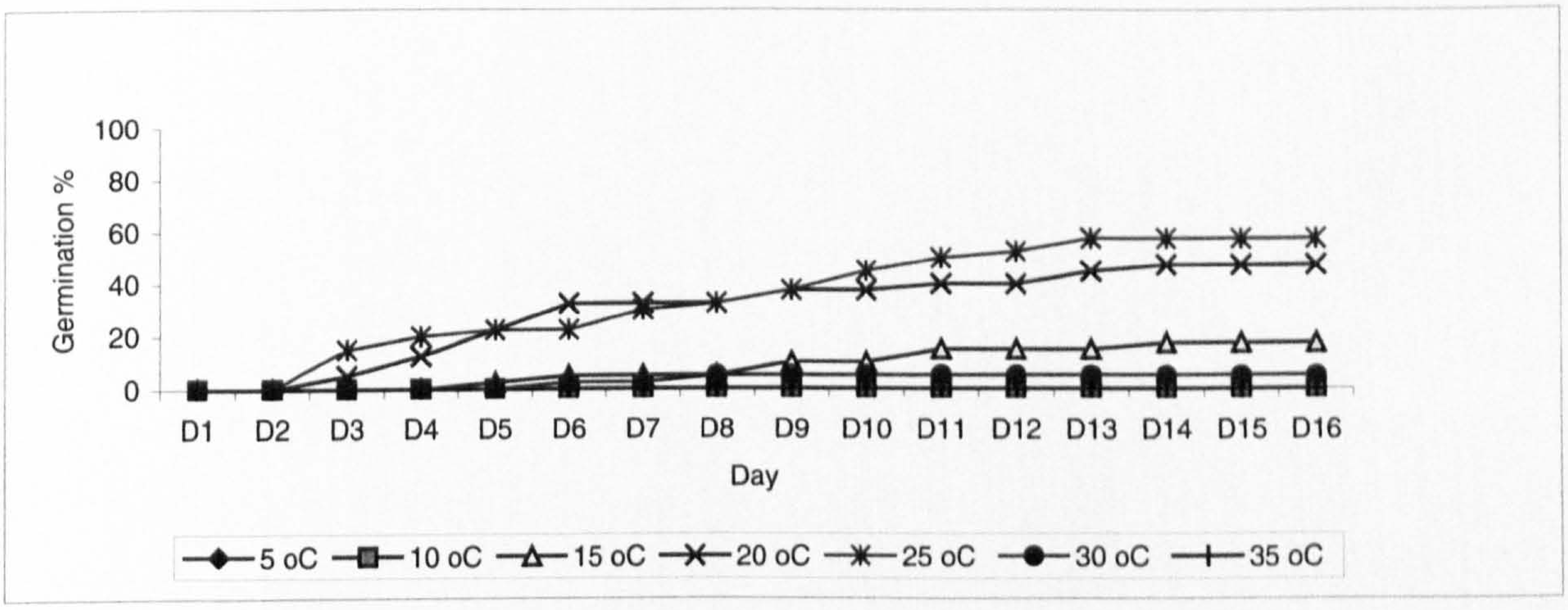

Fig. 4.22:Effect of temperature on germination of *Verbesina encelioides*

3.4 Discussion

Results obtained from these experiments show that in absence of other limiting factors (e.g. water stress) the germination of these Saudi native species is significantly controlled by temperature, also there were some differences between species in the optimum germination temperature (Fig. 3.23). For most of these species the maximum germination percentage was at the temperatures between 20 °C and 30 °C. This finding is in general agreement with many previous investigations such as those of Basahy (1996) who found the seed of *Artemisia abyssinica* and *Cassia senna* did not germinate at low temperature (18/8°C). Also he found the germination percentage increased with rise of temperature attaining their maximum at 30/20°C being lower at 35/25°C and even lower at 40/30°C. Aisien and Ghosh, (1978) mentioned that the range of temperatures for germination of non- tropical species is typically 15-30°C with an optimum of around 22°C.

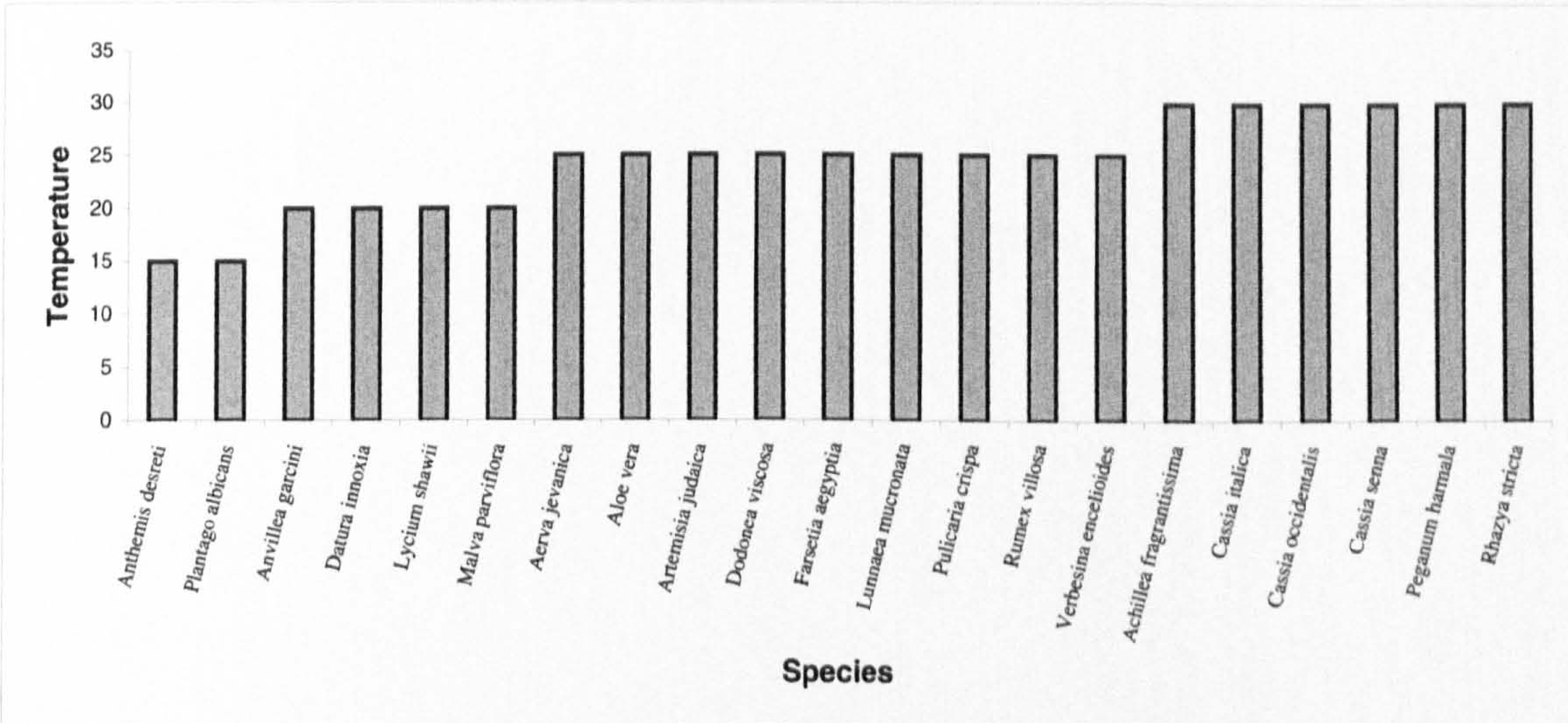

Fig. 3.23: The optimum germination temperatures of some Saudi indigenous species.

In deserts, where rainfall is unpredictable, it is important that seeds do not germinate unless the soil contains enough water to enable the resulting seedlings to establish successfully. It therefore is significant for germination to be controlled by a regulated response to the environment. One factor that contributes to synchronising germination and adequate soil moisture is temperature. In Riyadh the best months for establishing these species is the six months starting from November when Riyadh receives the highest amount of rainfall, and the mean temperature is between about 20 °C and 30 °C (Fig. 3.24).

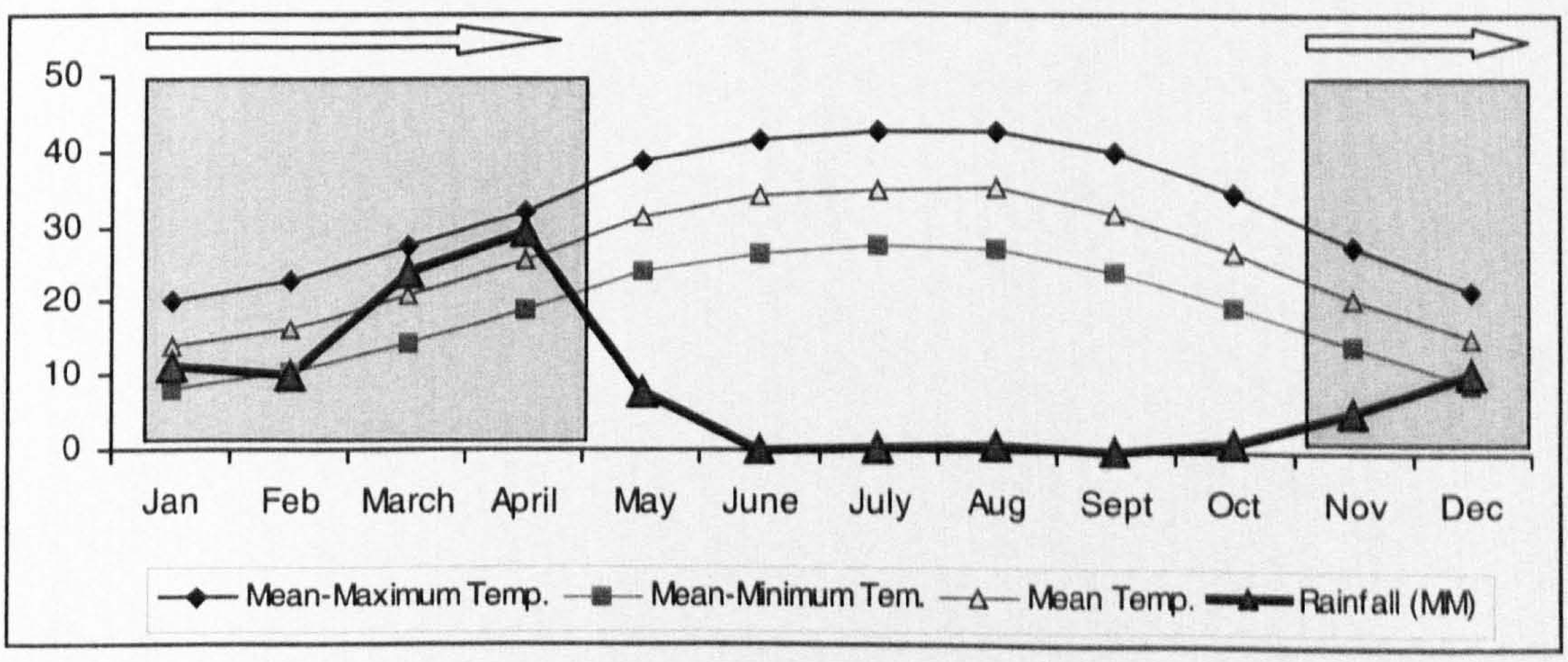

Fig. 3.23: Mean monthly rainfall and temperature of Riyadh. Likely germination in windows show in grey.

It appears from Fig. 3.21 and Fig. 3.23 that different species will naturally germinate at different times between November and April, i.e. *Anthemis deserti* and *Plantago albicans* will germinate early and *Achillea fragrantissima, Cassia italica,* Cassia occidentalis, *Cassia senna, Peganum harmala* and *Rhazya stricta* will germinate late.

It is essential to note that the data presented here are the result of an investigation into only one aspect of the effect of temperature on germination and will achieve a proper perspective when related to the results of other germination studies using the same seed collections. Factors other than temperature may clearly play a significant role in the germination ecology of many of these species.

CHAPTER 5

5. EFFECT OF SALINITY ON THE GERMINATION OF SAUDI NATIVE SPECIES

CHAPTER 5

5. EFFECT OF SALINITY ON THE GERMINATION OF SAUDI NATIVE SPECIES

5.1 -INTRODUCTION

In arid regions such as Saudi Arabia salinity is an important environmental factor influencing germination. In saline environments, plants must first overcome the salinity stress at the germination stage, before they can colonize the habitat successfully. Dewey (1964, in Johnson, 1990) found that although salinity tolerance is an important property, tolerance at germination is often unrelated to tolerance at later developmental stages. Consequently selections at different growth stages are needed to improve total plant salinity tolerance.

In the arid and semi arid regions of the word, the scarcity of precipitation and high evaporation frequently cause salinity problems that limit or prevent seeds germination. Saline soile cover a substantial proportion of the earth's surface with estimates varying from 400 to 950 million ha. One third of the world's irrigated agriculture is already affected to some degree by excess salinity, primarily caused by inadequate drainage (Bresler, McNeal and Carter, 1982). Salinity of soil water is caused by the presence of soluble salts originating from deteriorating and dissolving rock and concentrated by evaporation and plant transpiration (Shannon, 1984). Ions that contribute to this soil salinity include chloride, sulphate, bicarbonate, sodium, calcium, and magnesium (Bernstein, 1975).

Salt tolerance at germination and during early growth is critical for plant survival and growth in saline soils or when vegetation is sown and irrigated with saline irrigation water. In many plant species, sensitivity to NaCl is known to vary between growth stages (Maas and Hoffman, 1977) and sensitivity at germination or during early seedling growth does not necessarily indicate that the plant species will show similar sensitivity as a mature plant. Many plant species are substatially more salt-tolerant as mature plant than they are at germination or during early seedling growth (Ayers and Eberhard, 1966; Norlyn and Epstein,1984; Peason, Allen, Dobrenz and Bertels, 1986; Rogers and Noble, 1991).

For many plants, salt stress is more inhibitory during seed germination than at any other stage of growth (Bewley and Black, 1982; Mayer and Poljakoff-Mayber, 1982). Salinity may affect the germination of seed in two ways: (a) osmotically, by decreasing the ease with which seeds may take up water; and (b) ionically, by facilitating the uptake of ions in sufficient amounts to be toxic (Ayers, 1952). Germination can also be influnced by the type of salts involved (Ryan, Miyamoto and Stroehlein, 1975).

With NaCl a reduction in the percentage and rate of germination under saline conditions can be due to osmotic effects limiting seed hydration, or to toxic effects on the seed embryo or endosperrm cell membranes (Bliss, Platt-Alioia and Thomson, 1986) or to poor seedling vigour lowering the emergence percentage. Differences in salt tolerance between plant species are more likely to be caused by variations in sensitivity to toxic ion effects since the threshold water requirements for germination are similar between species (Bliss, et al. 1986). Several authors have found that the rate of germination is more sensitive to salinity than is overall germination percentage (West and Taylor, 1981; Dudeeck and Peacook, 1985; Marcar, 1987).

In this part of the research seed germination of some indigenous species in Saudi Arabia was studied to understand how salinity effects percentage seed germination.

5.2-MATERIAL AND METHODS

The experiments took place in a laboratory incubator at 12-h/day, at 22°C and 12-h, 13°C/night. Six salinity concentrations were employed using Na Cl at 0, 1000, 5000, 10000, 15000 and 20000 ppm. 30 seeds (except where shortage of seeds or large seeds necessitated fewer seeds per replicate) of the different species were sown on top of a sheet Whatman No.1 filter paper in 9 cm plastic petri dishes containing 7 ml of salt solution or deionised water for the control. The petri dishes were sealed until the end of the experiment with parafilm to prevent evaporation, which would otherwise lead to an increase in salt concentration as the experiment progressed. The salt solution was not refurbished during the course of the experiment. Four replicates of each species were tested at each salinity level. Daily observations were made and seeds with approximately a 2 mm or longer exposed radicle were recorded as germinated seed. Data for germination were recorded daily for sixteen days. For some species seeds we applied dormancy breaking treatments as following: -

Species	Treatment	Species	Treatment
Cassia italica	Sulphuric Acid 15 min.	*Dodonea viscosa*	Sulphuric Acid 15 min
Cassia occidentalis	Sulphuric Acid 15 min.	*Atriplex spp.*	Leaching
Cassia senna	Sulphuric Acid 15 min.	*Rhazya stricta*	Leaching

Table 5.1 Techniques for breaking of seed dormancy.

One way ANOVA was undertaken using *SPSS version 10* to determine whether significant differences occurred at P=0.05 in term of the number of seeds that had germinated by day 16 for each salinity level. To determine where significant differences occurred at P = 0.05 post hoc tests were used (LSD and Tukey test).

5.3-RESULTS

5.3.1 ABUTILON PANNOSUM

Germination of *Abutilon pannosum* with deionised water (0 ppm) was 12.5 %. Maximum germination (12.5 %) was recorded in the treatments at (1000 ppm). Low germination (7.5 %) was observed at 5000 ppm. At 10000 ppm germination was 5 %, falling to zero at 15000 and 20000 ppp (Fig. 5.1). Germination percentage between 1000, 5000 and 10000 ppm and deionised water (0 ppm) was not significantly different (P>0.05). However there was a significant difference in germination percentage between 15000 and 20000 ppm and the other concentrations ($P<0.05$).

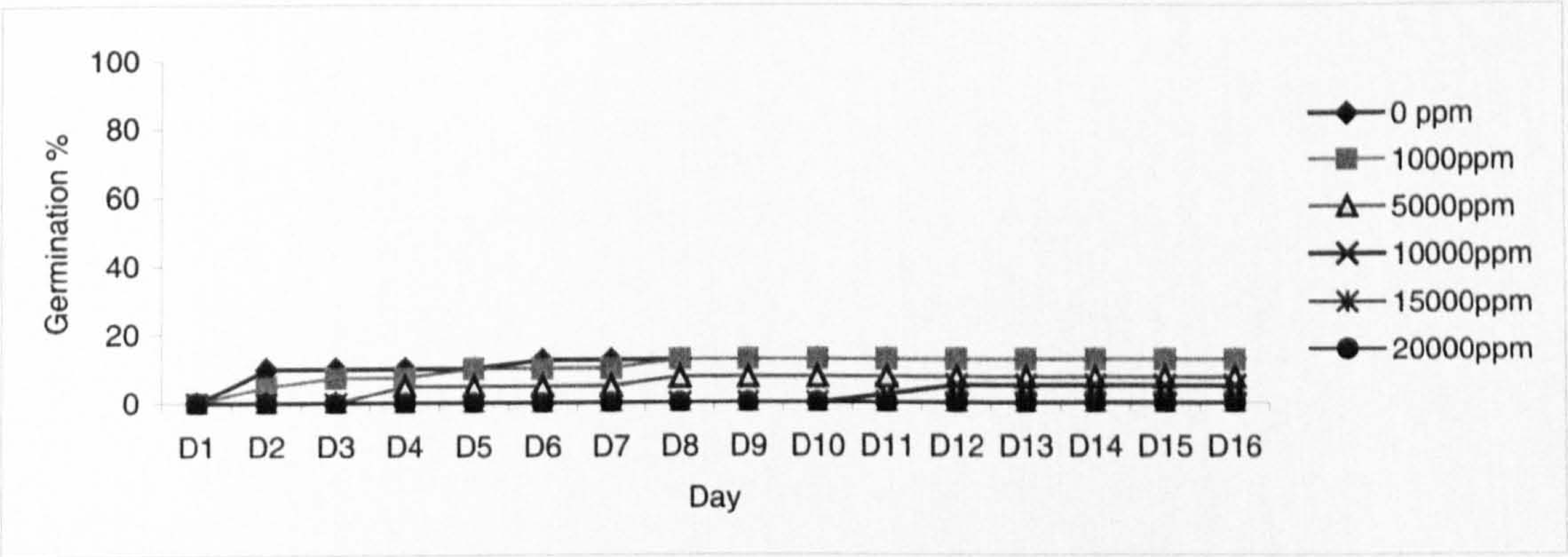

Fig. 5.1: Effect of salinity on germination percentage of *Abutilon pannosum*

5.3.2 *ACHILLEA FRAGRANTISSIMA*

Germination of *Achillea fragrantissima* with deionised water (0 ppm) was 100 %. Maximum germination (97%) was recorded at 1000 ppm. Very high percentage germination (90) was also observed at 5000 and 10000 ppm. At 15000 ppm germination percentage was 15 %, falling to zero at 20000 ppm (Fig. 5.2). Germination percentage between 1000, 5000 and 10000 ppm and 0 ppm was not significant ($P>0.05$). However there was a significant difference in germination percentage between 15000 and 20000 ppm and the others concentrations ($P<0.0001$). Rate of germination was greatly reduced at 15000 and 20000 ppm.

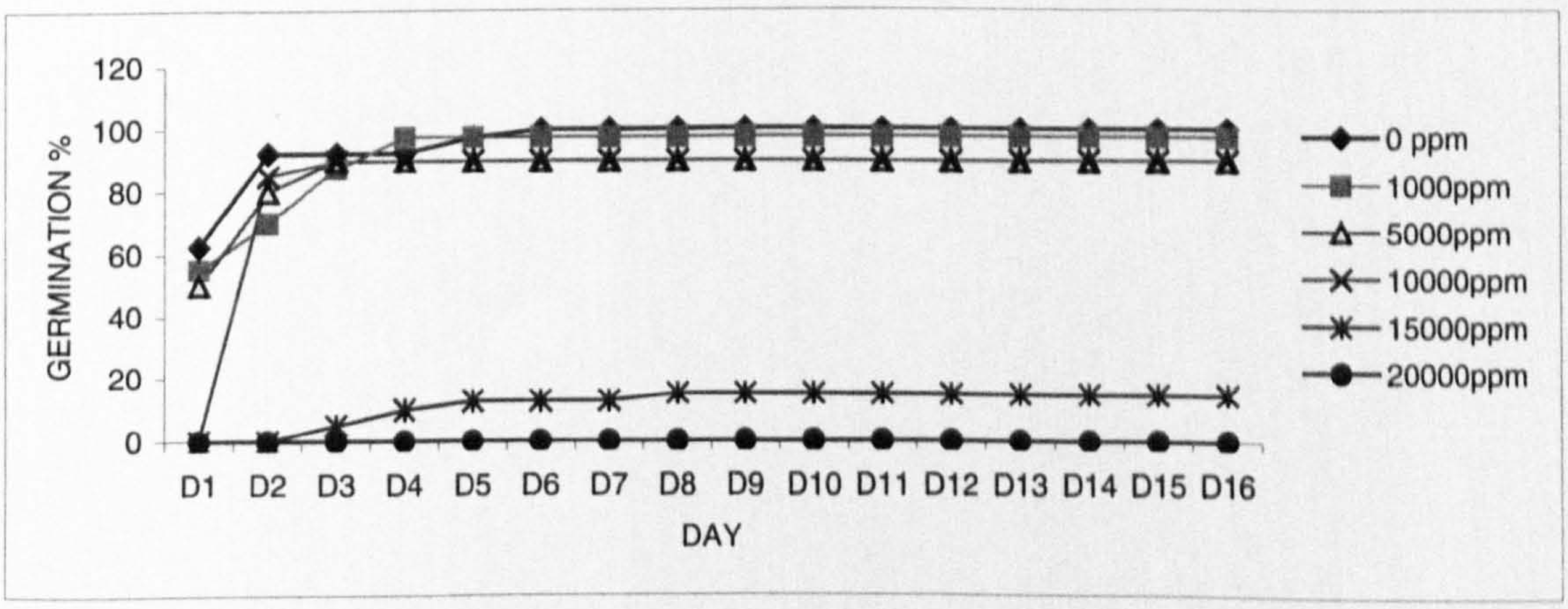

Fig. 5.2: Effect of salinity on germination percentage of *Achillea fragrantissima*

5.3.3 *AERVA JAVANICA*

It can be seen from Fig. 5.3 that the germination percentage of *Aerva javanica* in deionised water (0 ppm) was 70 %. Maximum germination (68%) was recorded at 1000 ppm. At 5000 ppm this fell to 13 %, and was zero at 10000, 15000 and 20000 ppm. Germination between 1000 ppm and 0 ppm was not significantly different (P>0.05). However there was a significant difference in germination percentage between (5000, 10000,15000 and 20000 ppm) and the others concentrations (P<0.0001). Rate of germination was greatly reduced at 5000, 10000, 15000, 20000 ppm.

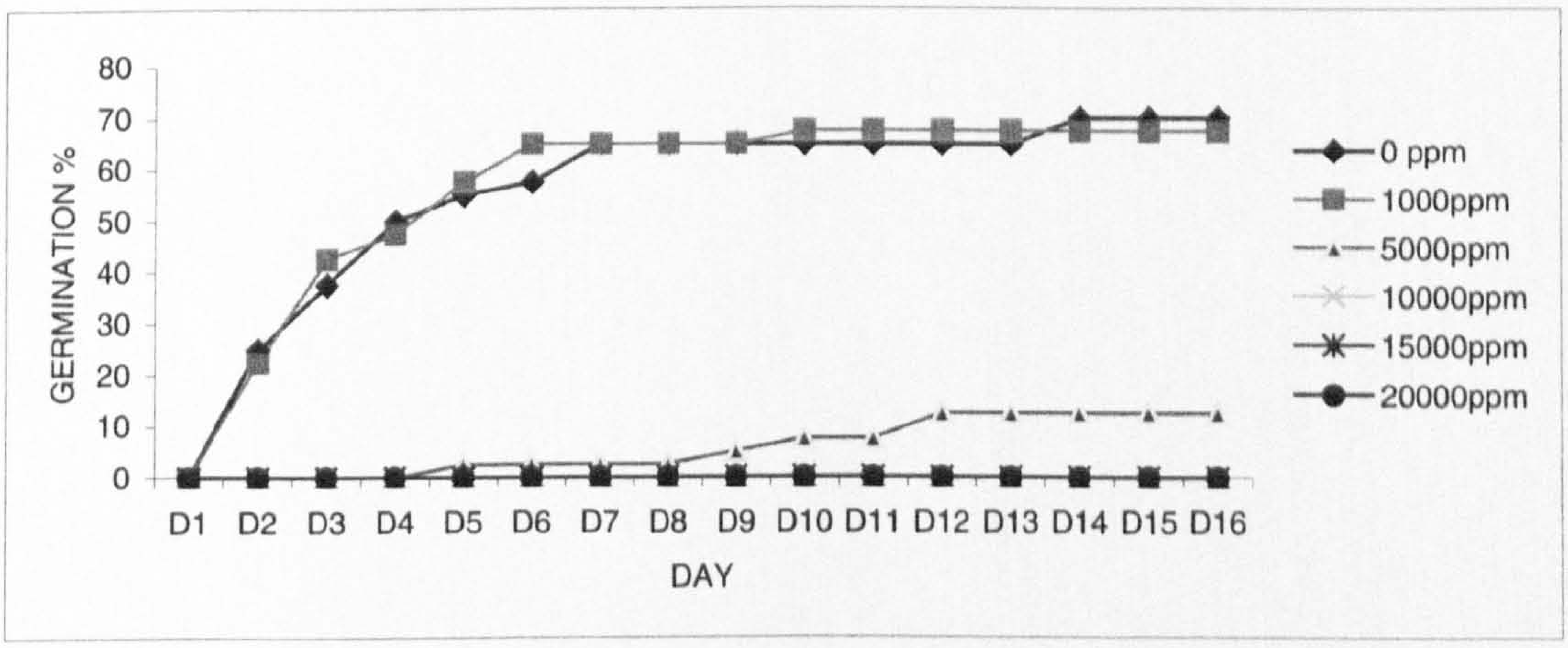

Fig. 5.3: Effect of salinity on germination percentage of *Aerva javanica*

5.3.4 *ALOE VERA*

Maximum germination of *Aloe vera* with deionised water (0 ppm) was 97%. Maximum germination (95%) was recorded in the treatment at 1000 ppm. High percentage germination (90 %) was also observed at 5000 ppm. However with salinity (10000 ppm) the germination percentage was 32 %. At 15000 and 20000 ppm it was zero (Fig. 5.4). Germination between 5000 and 1000 ppm and deionised water (0 ppm) was not significantly different (P>0.05). However there was a significant difference in germination percentage between 10000, 15000 and 20000 ppm and the deionised water (0 ppm) (P<0.0001). Rate of germination was greatly reduced at 15000 and 20000 ppm.

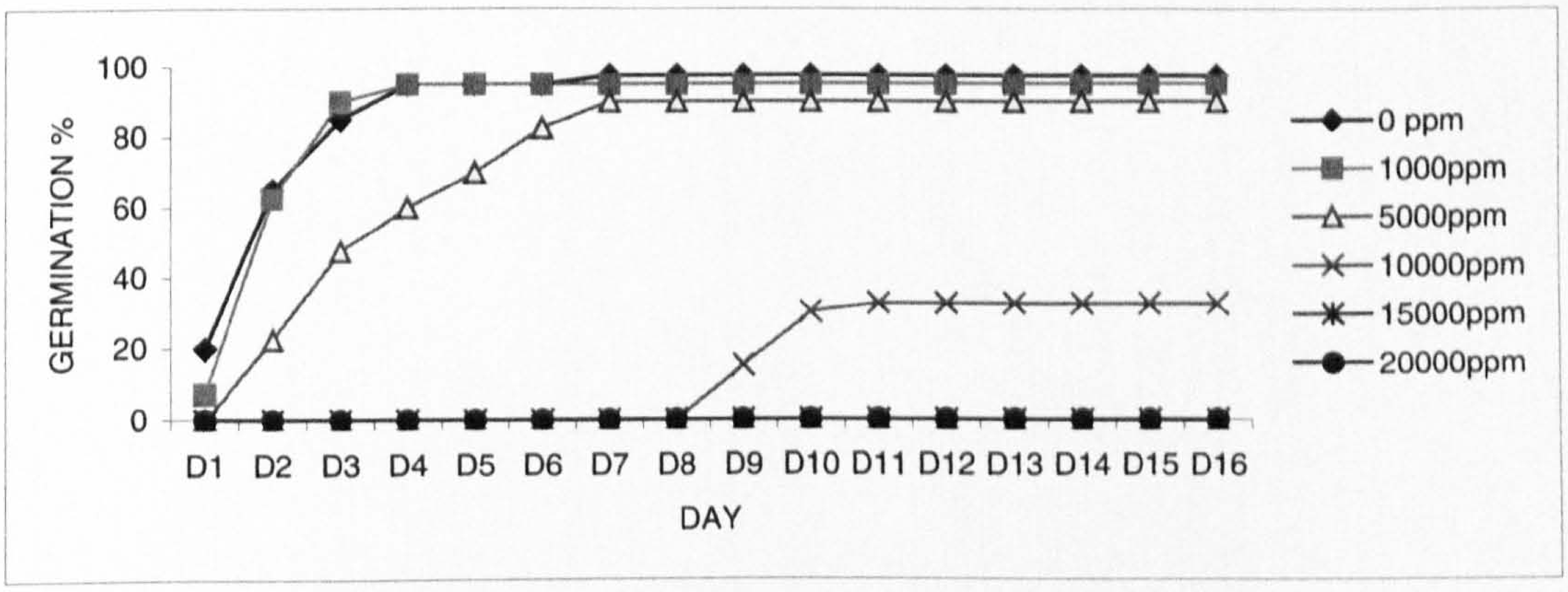

Fig. 5.4: Effect of salinity on germination percentage of *Aloe vera*

5.3.5 *ANVILLEA GARCINI*

Germination percentage of *Anvilla garcini* in deionised water (0 ppm) was 32.5 %. At salinity concentration of 1000 ppm was 32 %, and at 5000 ppm was 40 %. This fell to (5%) at 10000 ppm and to zero at 15000 and 20000 ppm (Fig. 5.5). Germination percentage between 1000, 5000 ppm and deionised water (0 ppm) was not significantly different ($P>0.05$). There was a significant difference in germination percentage between 10000, 15000 and 20000 ppm and the deionised water ($P<0.05$).

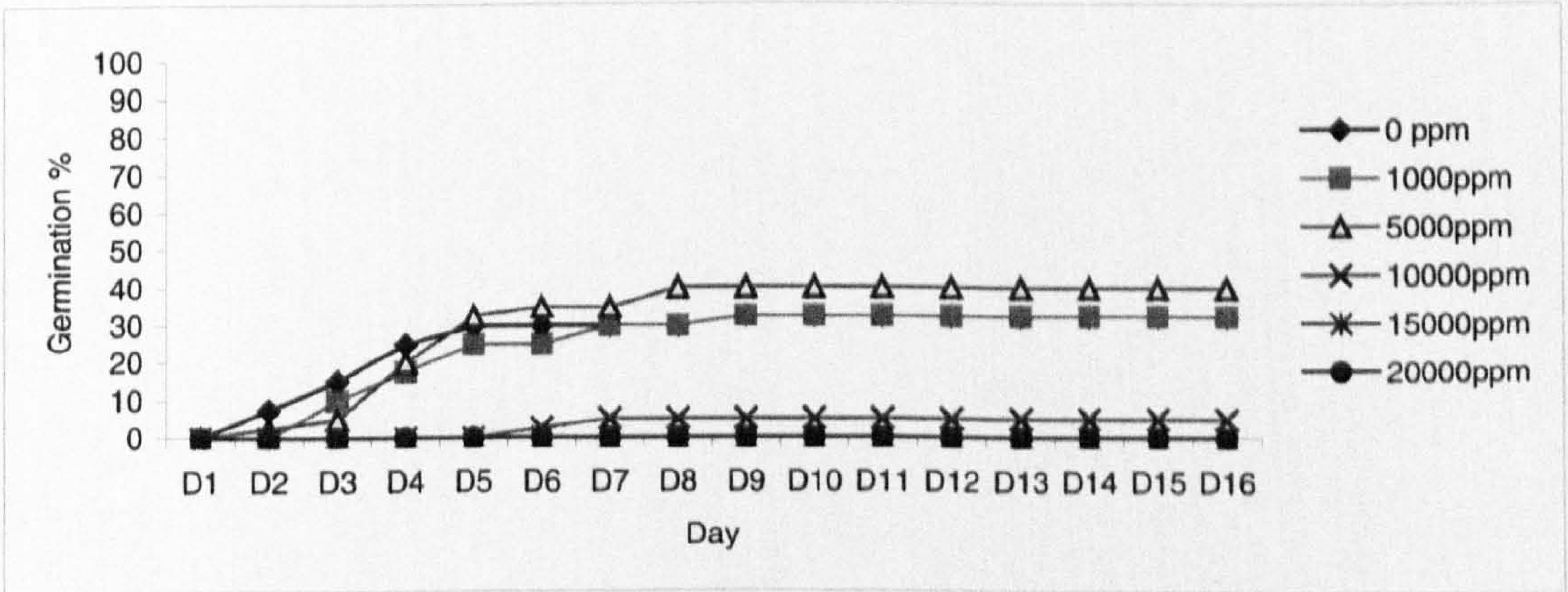

Fig. 5.5: Effect of salinity on germination percentage of *Anvillea garcini*

5.3.6 *ARTEMISIA HERBA-ALBA*

The maximum germination percentage of *Artemisia herba-alba* with deionised water (0 ppm) and at 1000 ppm was 72.5 %. High germination (52 %) was also observed at 5000 ppm. At 10000 ppm, 25 % germination was recorded, falling to zero At 15000 and 20000 ppm (Fig. 5.6). Germination percentage between 5000 and 1000 ppm and deionised water (0 ppm)was not significantly different (P>0.05). However there was a significant difference in germination percentage between 10000, 15000 and 20000 ppm and the other concentrations (P<0.0001). Rate of germination was greatly reduced at 10000, 15000 and 20000 ppm.

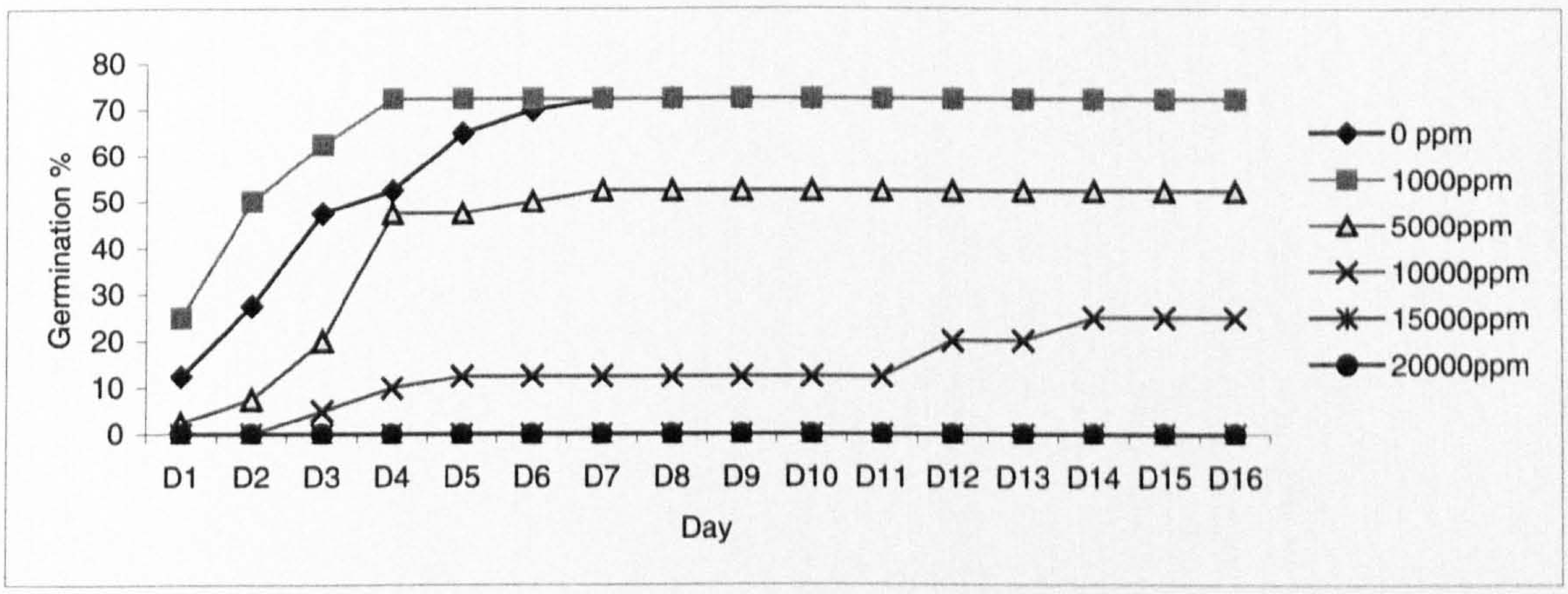

Fig. 5.6: Effect of salinity on germination percentage of *Artemisia herba-alba*

5.3.7 ARTEMISIA JUDAICA

It can be seen from Fig. 5.7 that the germination of *Artemisia judaica* in deionised water (0 ppm) was 80 %. Maximum germination (77%) in the treatments was recorded at 5000 ppm. High germination was also observed at 1000 ppm (approximately 72 %). At 10000 ppm germination was 12 %. This fell to zero at 15000 and 20000 ppm. Germination percentage between 5000 and 1000 ppm salinity and deionised water (0 ppm) was not significantly different (P>0.05). However there was a significant difference in germination percentage between 10000, 15000 and 20000 ppm and the deionised water (0 ppm) (P<0.0001). Rate of germination was greatly reduced at 10000, 15000 and 20000 ppm.

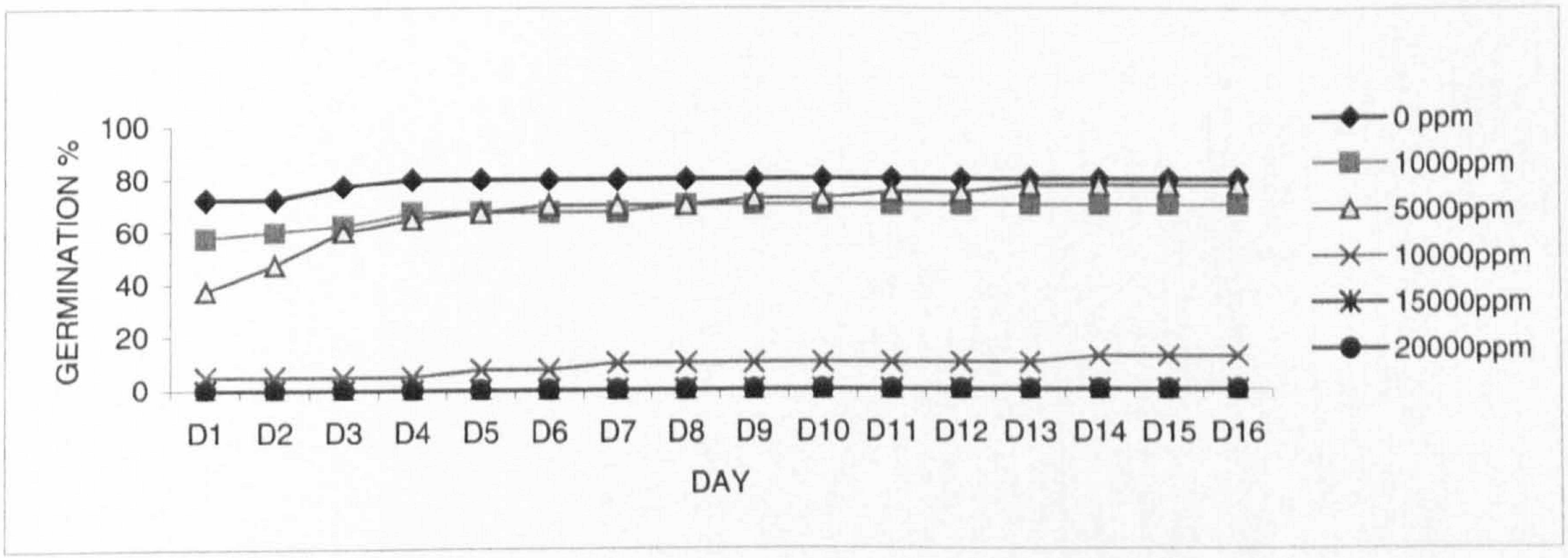

Fig. 5.7: Effect of salinity on germination percentage of *Artemisia judaica*

5.3.8 ATRIPLEX HALIMUS

Germination percentage of *Atriplex halimus* with deionised water (0 ppm) was 30 %. Maximum germination (35%) was recorded at 1000 ppm. At 5000 and 10000 ppm was approximately 27.5 %. Low germination was also observed at 15000 ppm, this fell to zero at 20000 ppm (Fig. 5.8). Germination percentage between 1000, 5000 and 10000 ppm and deionised water (0 ppm) was not significantly different (P>0.05). However there was a significant difference in germination percentage between 15000 and 20000 ppm and the other concentrations (P<0.05). Rate of germination was greatly reduced at 15000 and 20000 ppm.

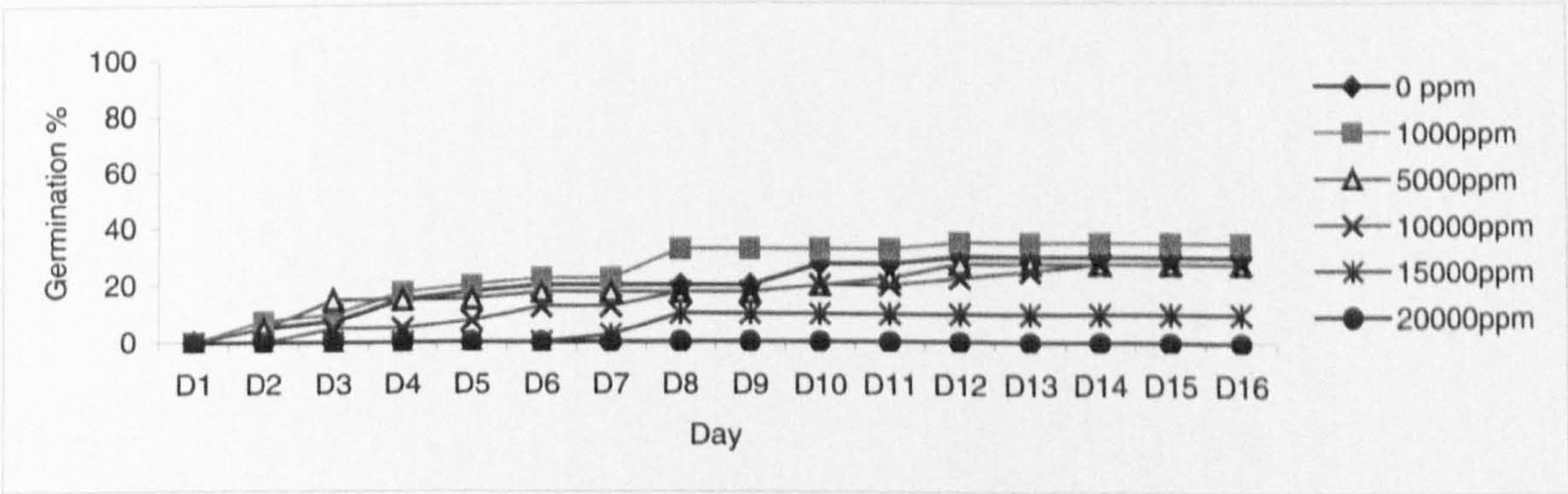

Fig. 5.8: Effect of salinity on germination percentage of *Atriplex halimus*

5.3.9 ATRIPLEX LEUCOCLADA

Germination percentage of *Atriplex leucoclada* in deionised water (0 ppm) was 42.5 %. Maximum germination (45%) was recorded at 1000 ppm. At 5000 ppm it was approximately 40 %. At 10000 ppm germination, it was 30 %, and this fell to less than 5% at 15000 and 20000 ppm (Fig. 5.9). Germination percentage between 1000, 5000 ppm salinity and deionised water (0 ppm) was not significantly different (P>0.05). However there was a significant difference in germination percentage between 10000, 15000 and 20000 ppm and the deionised water (P<0.05).

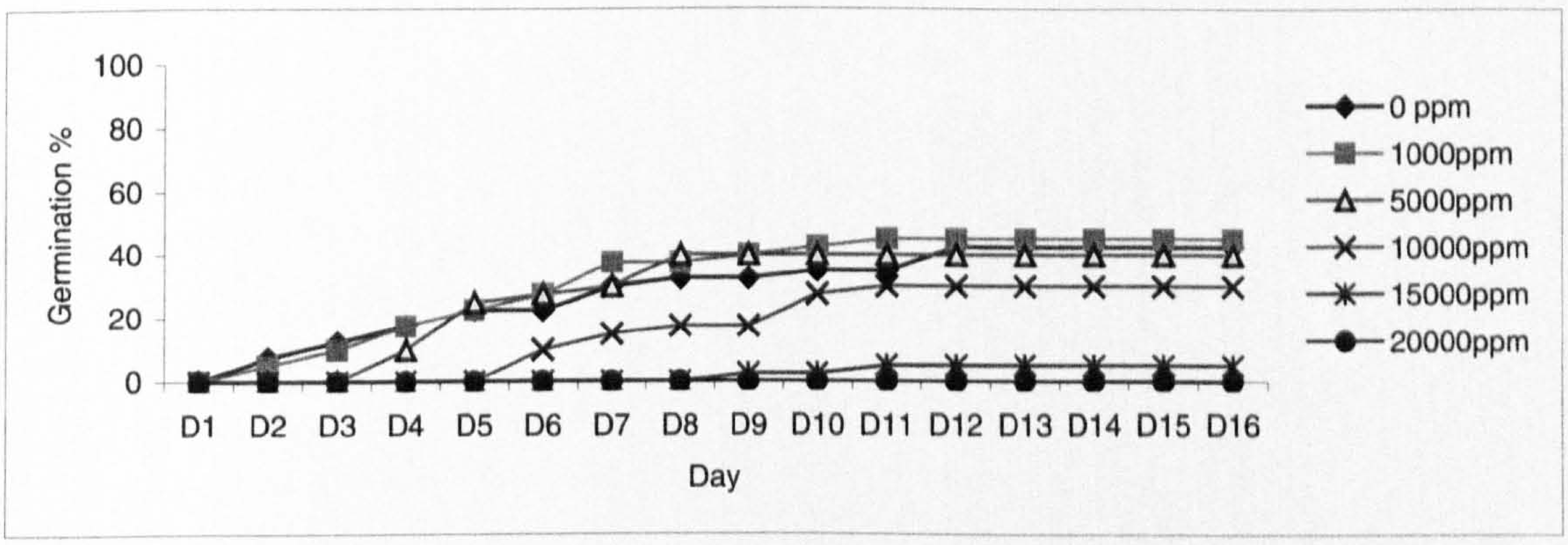

Fig. 5.9: Effect of salinity on germination percentage of Atriplex leucoclada

5.3.10 *CASSIA ITALICA*

Germination of *Cassia italica* in deionised water (0 ppm) was 55%. At salinity concentrations 10000 ppm approximately 62 % germination was recorded. Germination at 1000ppm was 45%, at 5000 ppm was 35% and at 15000 ppm was approximately 25 %. This fell to 5% at 20000 ppm (Fig. 5.10). Germination between 1000, 5000, 10000 and 15000 ppm and deionised water (0 ppm) (P>0.05). However there was a significant difference in germination percentage between 20000 ppm and deionised water (0 ppm) (P<0.0001). Rate of germination was greatly reduced at 20000 ppm.

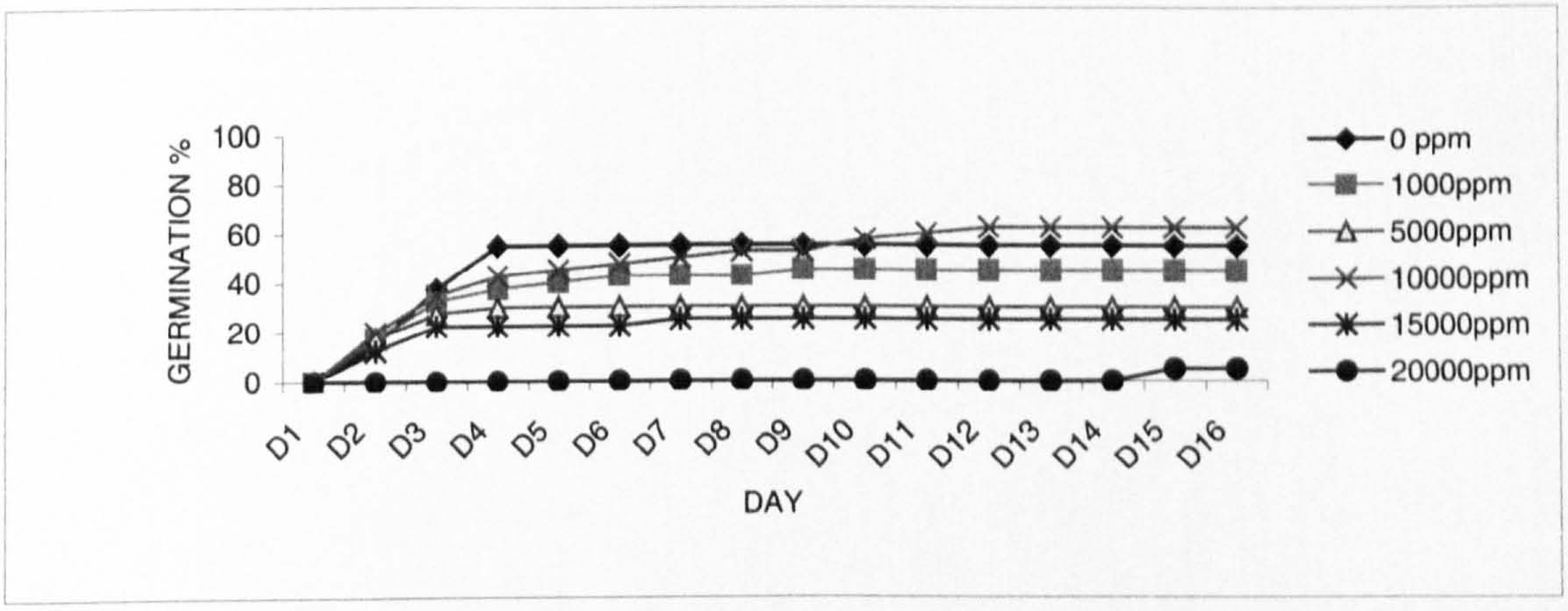

Fig. 5.10: Effect of salinity on germination percentage of *Cassia italica*

5.3.11 CASSIA OCCIDENTALIS

Germination percentage of *Cassia occidentalis* with deionised water (0 ppm), 1000ppm and 5000 ppm was 100%. High germination (approximately 90 %) was also observed at 10000 ppm. At salinity 15000 ppm germination was 32 %. This fell to zero at 20000 ppm (Fig. 5.11). Germination percentage between 1000, 5000 and 10000 ppm and deionised water (0 ppm) was not significantly different (P>0.05). There was a significant difference in germination percentage between 15000 and 20000 ppm and the others concentrations (P<0.0001). Rate of germination was greatly reduced at 15000 and 20000 ppm.

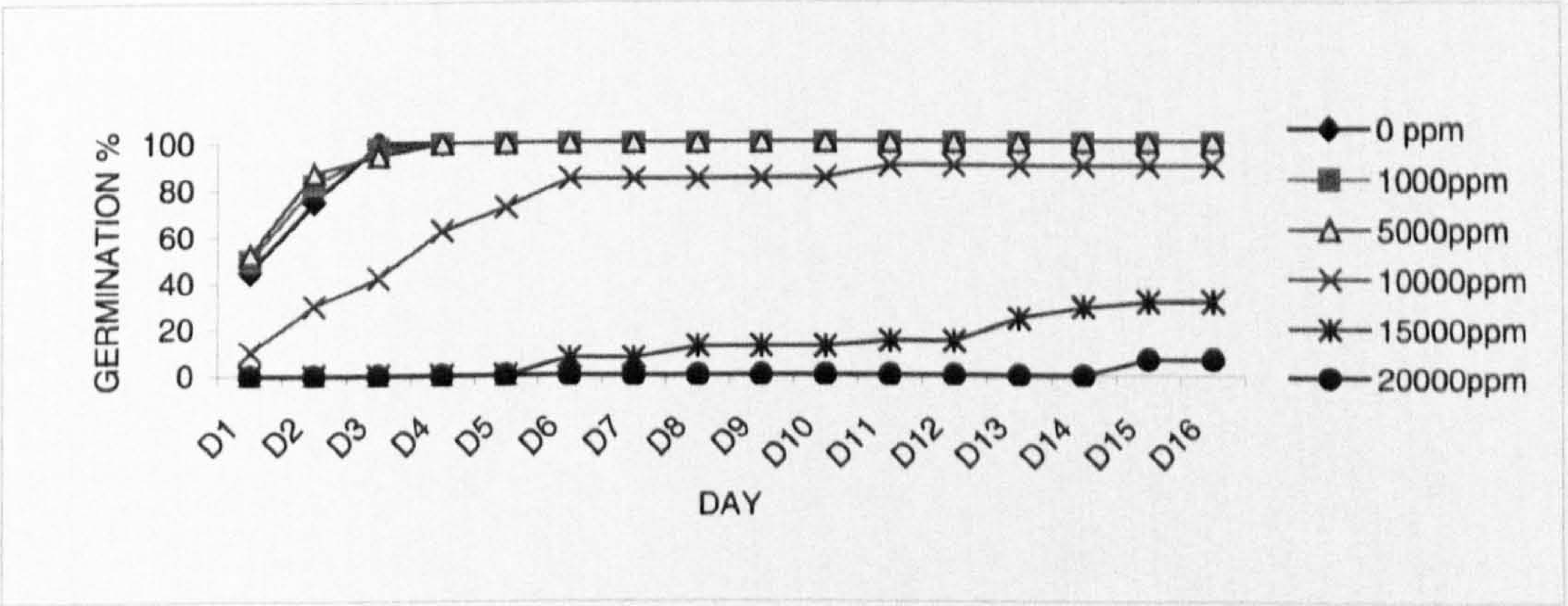

Fig. 5.11: Effect of salinity on germination percentage of *Cassia occidentalis*

5.3.12 *CASSIA SENNA*

Maximum germination percentage of *Cassia senna* with deionised water (0 ppm) was 80 %. Maximum germination (77%) in the treatments was recorded at 1000 ppm. Moreover high germination was also observed at 5000, 10000 and 15000 ppm (approximately 50 %). At salinity 20000 ppm the germination was zero (Fig. 5.12). Germination between 1000, 5000 and 10000 ppm salinity and 0 ppm was not significantly different (P>0.05). However there was a significant difference in germination between 20000 ppm and the others concentrations (P<0.0001). Rate of germination was greatly reduced at 20000 ppm.

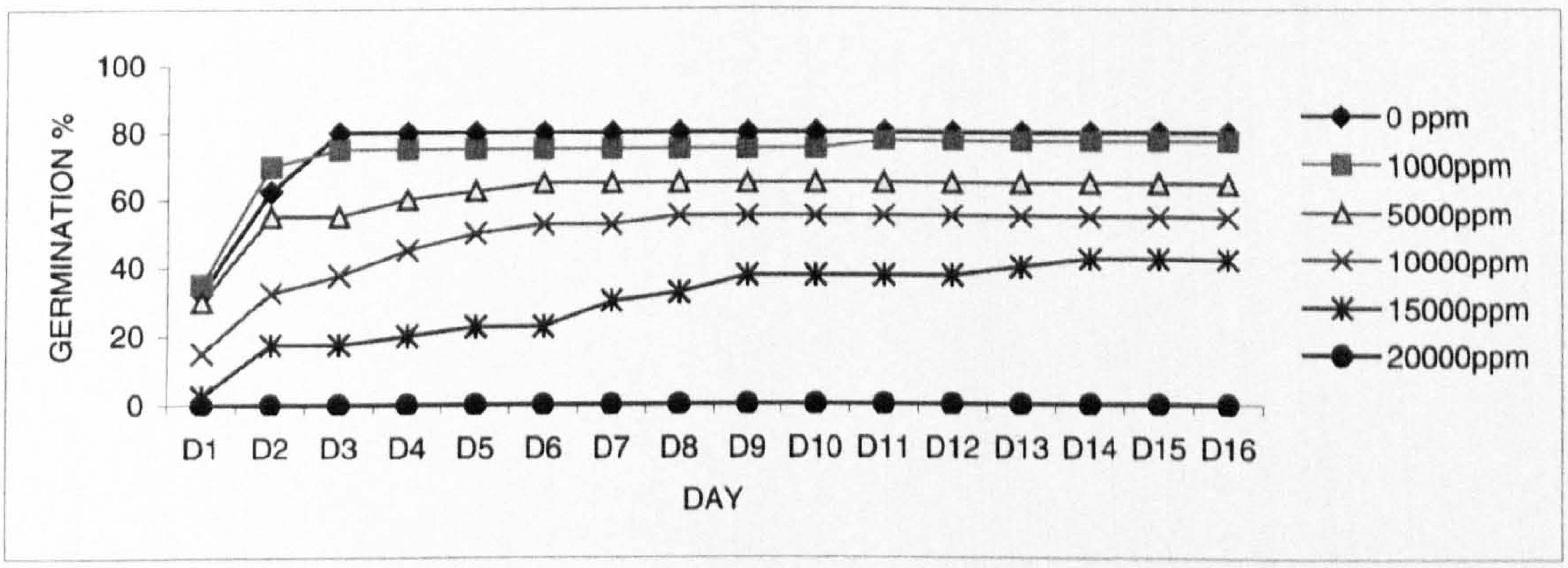

Fig. 5.12: Effect of salinity on germination percentage of *Cassia senna*

5.3.13 *DATURA INNOXIA*

The maximum germination percentage of *Datura innoxia* with deionised water (0 ppm) was 52%. At 1000ppm and 5000 ppm, approximately 44% germination was recorded. Germination was zero at 10000, 15000, 20000 ppm (Fig. 5.13). Germination percentage between 1000 and 5000 ppm and the normal germination (0 ppm) was not significant (P>0.05). There was a significant difference in germination percentage between 10000, 15000, 20000 ppm and the others concentrations (P<0.0001). Rate of germination was greatly reduced at 10000, 15000, 20000 ppm.

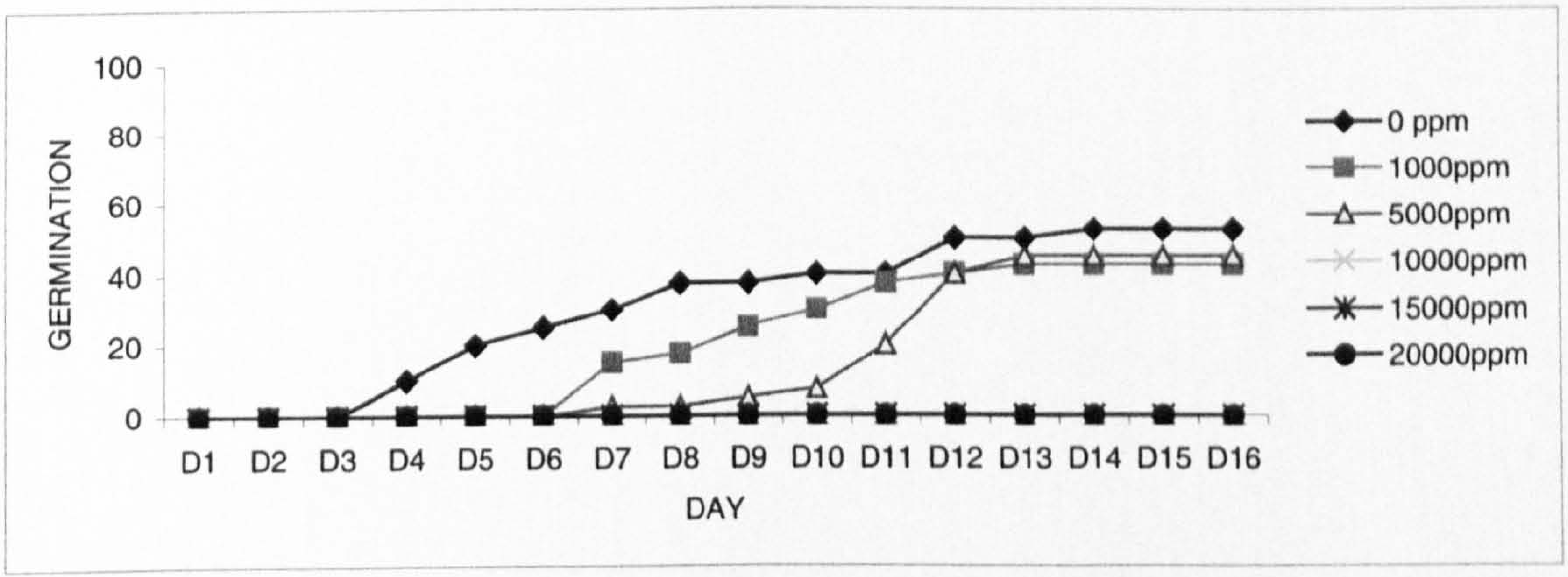

Fig. 5.13: Effect of salinity on germination percentage of *Datura innoxia*

5.3.14 *DODONEA VISCOSA*

Maximum germination of *Dodonea viscosa* in deionised water (0 ppm) was 80 %. At 1000 and 5000 ppm approximately 70 % germination was decorded. High germination (52%) was also observed at 10000 ppm. At 15000 and 20000 ppm germination was zero (Fig. 5.14). Germination between 1000 and 5000 ppm and 0 ppm was not significantly different ($P>0.05$). There was a significant difference in germination between 1000, 15000 and 20000 ppm and the others concentrations ($P<0.0001$). Rate of germination was greatly reduced at 15000, 20000 ppm.

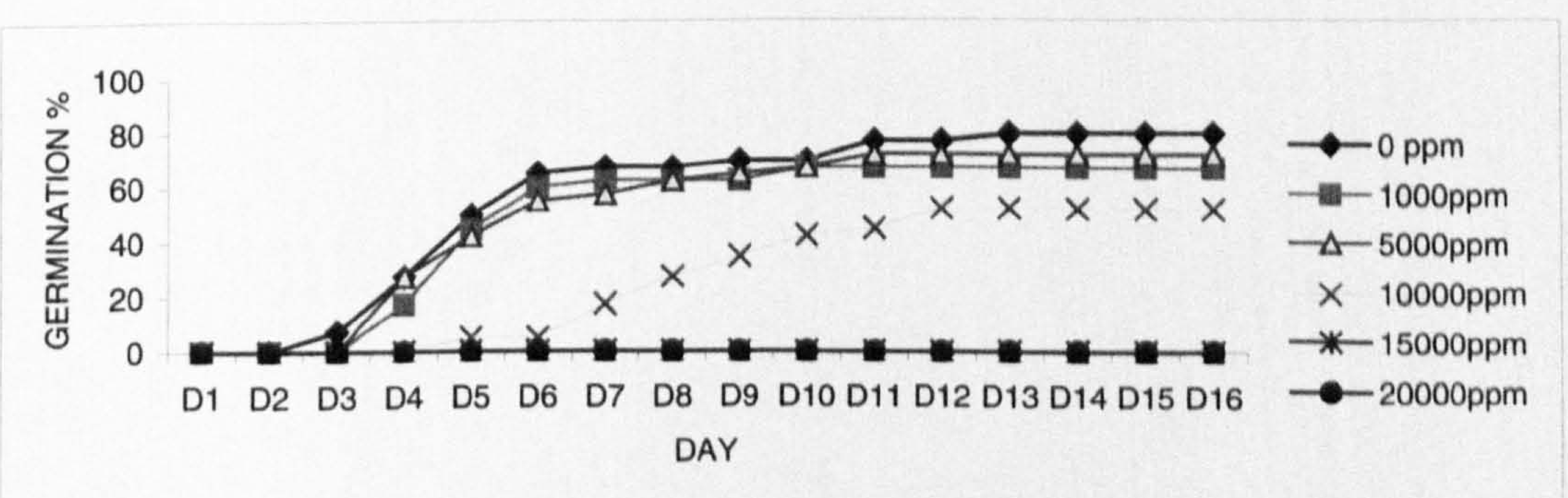

Fig. 5.14: Effect of salinity on germination percentage of *Dodonea viscosa*

5.3.15 *FARSETIA AEGYPTIA*

It can be seen from (Fig. 5.15) that the germination of *Farsetia aegyptia* in deionised water (0 ppm) was 95%. At salinity concentrations of1000 and 5000ppm approximately 90 % germination was recorded. High germination was also observed at 10000 ppm (72 %). This fell to zero at 15000 and 20000 ppm. Germination between 1000 and 5000 ppm salinity and 0 ppm was not significantly different (P>0.05). There was a significant difference in germination percentage between 10000,15000 and 20000 ppm and the others concentrations (P<0.0001). Rate of germination was greatly reduced at 15000 and 20000 ppm.

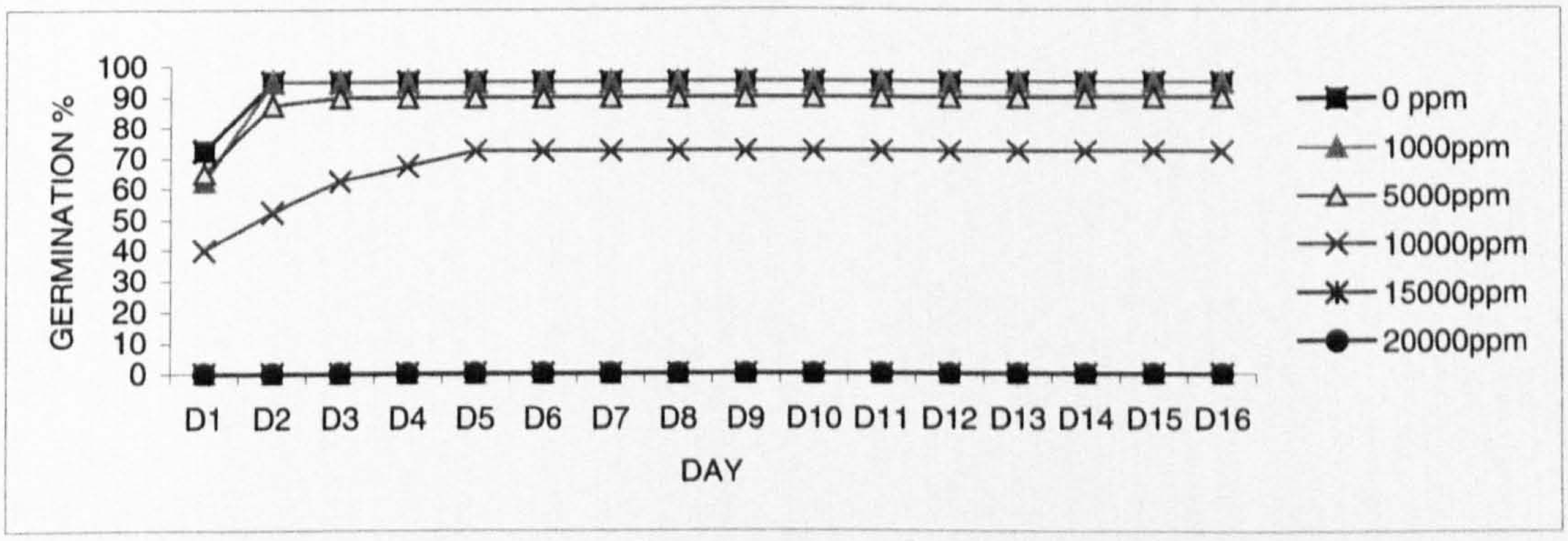

Fig. 5.15: Effect of salinity on germination percentage of *Farsetia aegyptia*

5.3.16 *LASIURUS SCINDICUS*

It can be seen from Fig. 5.16 that germination of *Lasiurus scindicus* in deionised water (0 ppm) was 83%. Maximum germination (80 %) was recorded in the treatments at 1000 ppm. At 5000 and 10000 ppm germination was less than 16 %. This fell to zero at 15000 and 20000 ppm. Germination percentage between 1000 ppm and deionised water (0 ppm) was not significantly different (P>0.05). There was a significant difference in germination percentage between 5000, 10000, 15000 and 20000 ppm and the deionised water (0 ppm) (P<0.0001). Rate of germination was greatly reduced at 5000, 10000, 15000 and 20000 ppm.

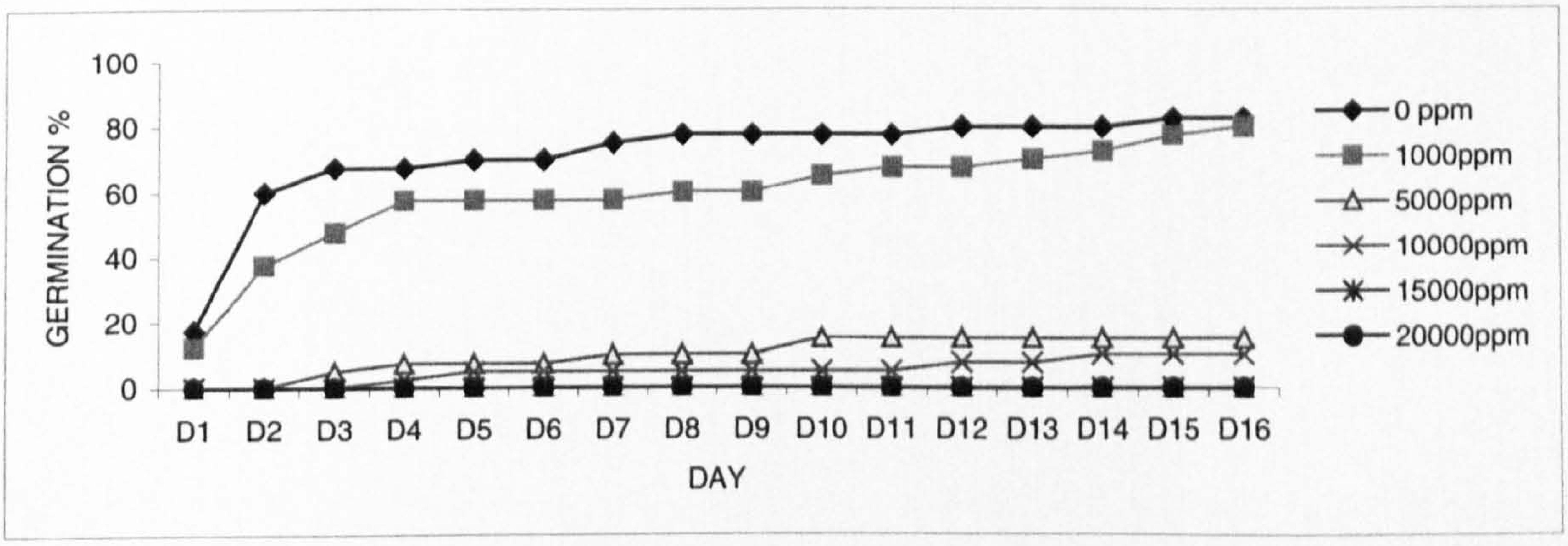

Fig. 5.16: Effect of salinity on germination percentage of *Lasiurus scindicus*

5.3.17 *LYCIUM SHAWII*

Germination percentage of *Lycium shawii* in deionised water (0 ppm) was 47.5 %. Maximum germination (27%) was recorded in the treatments at 1000 ppm. At 5000 ppm was approximately 25 % falling to zero at 10000 15000 and 20000 ppm (Fig. 5.17). Germination percentage between 1000 ppm and deionised water (0 ppm) was not significant (P>0.05). However there was a significant difference in germination percentage between 5000, 10000, 15000 and 20000 ppm and the deionised water (0 ppm) (P<0.0001). Rate of germination was greatly reduced at 10000, 15000 and 20000 ppm.

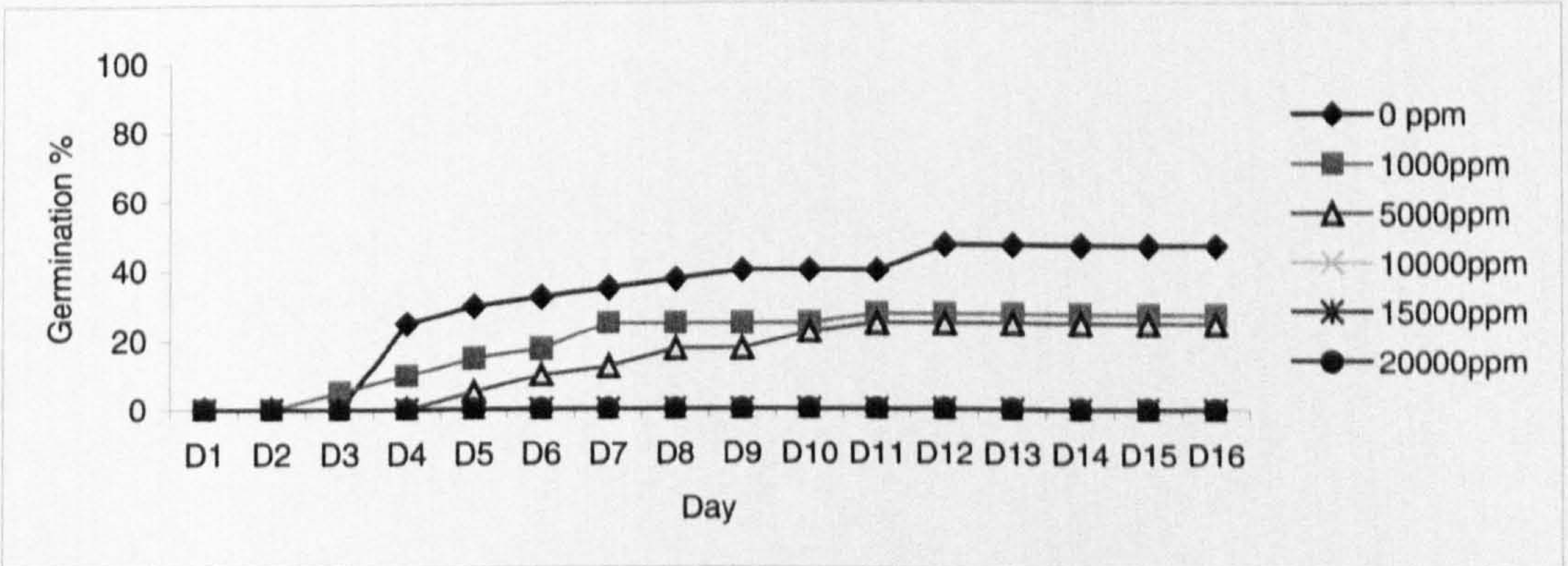

Fig. 5.17: Effect of salinity on germination percentage of *Lycium shawii*

5.3.18 *PEGANUM HARMALA*

Germination percentage of *Peganum harmala* in deionised water (0 ppm) and at 1000 ppm and 5000 ppm salinity was approximately 80%. This fell to 25% at 10000 ppm and to zero at 15000 and 20000 ppm (Fig. 5.18). Germination percentage between 5000 and 1000 ppm and deionised water (0 ppm) was not significant (P>0.05). There was a significant difference in germination percentage between 10000, 15000 and 20000 ppm and the deionised water (0 ppm) (P<0.0001). Rate of germination was greatly reduced at 10000, 15000 and 20000 ppm.

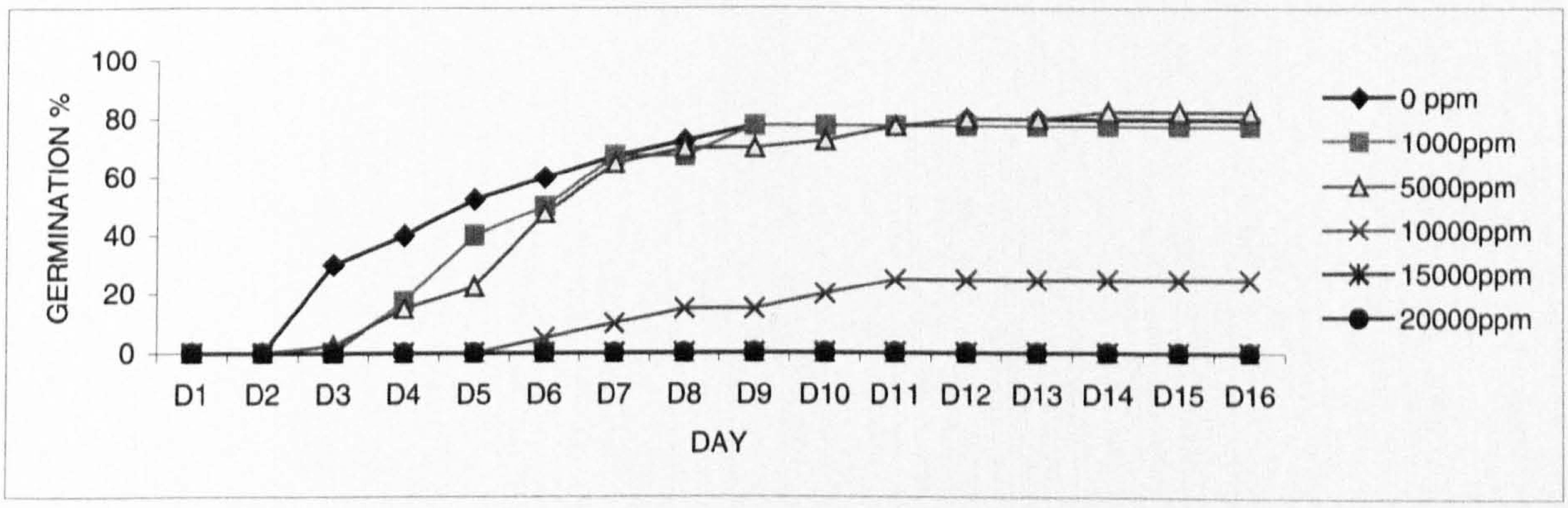

Fig. 5.18: Effect of salinity on germination percentage of *Peganum harmala*

5.3.19 PULICARIA CRISPA

It can be seen from Fig. 5.19 that germination of *Pulicaria crispa* in deionised water (0 ppm) was 95 %. Maximum germination (87 %) with salinity concentrations was recorded at 1000 ppm. High germination (72%) was also observed at (5000 ppm). At 10000 ppm the germination percentage was 7.5 %. This fell to zero at salinity 15000 and 20000 ppm. Germination between 1000 ppm and deionised water (0 ppm) was not significantly different (P>0.05). There was a significant difference in germination percentage between 5000, 10000, 15000 and 20000 ppm and the other concentrations (P<0.0001). Rate of germination was greatly reduced at 10000, 15000 and 20000 ppm.

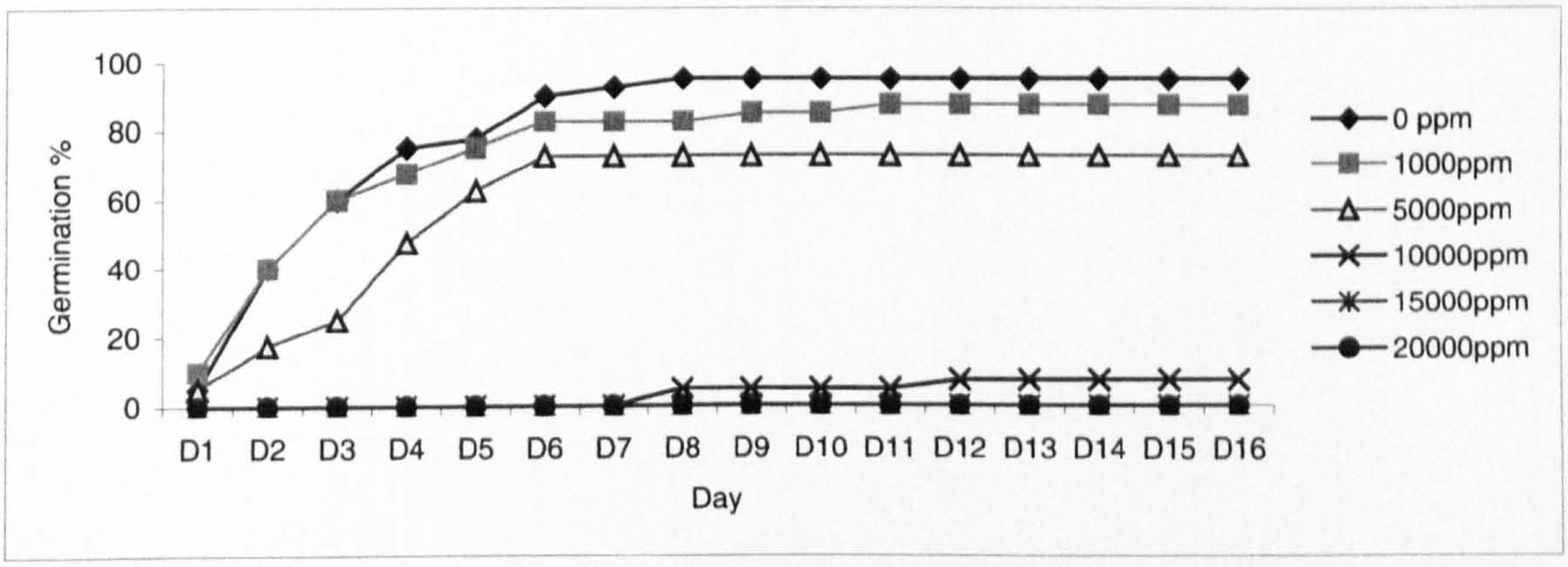

Fig. 5.19: Effect of salinity on germination percentage of *Pulicaria crispa*

5.3.20 RHAZYA STRICTA

It can be seen from Fig. 5.20 that germination percentage of *Rhazya stricta* in deionised water (0 ppm) was 22.5 %. Maximum germination (17.5 %) was recorded in the treatments at 1000 ppm. At 5000 ppm and 10000 ppm was approximately 6 %. Germination fell to zero at 15000 and 20000 ppm. Germination percentage between 1000, 10000 ppm and deionised water (0 ppm) was not significantly different (P>0.05). However there was a significant difference in germination percentage between 5000, 15000 and 20000 ppm and the deionised water (P<0.05).

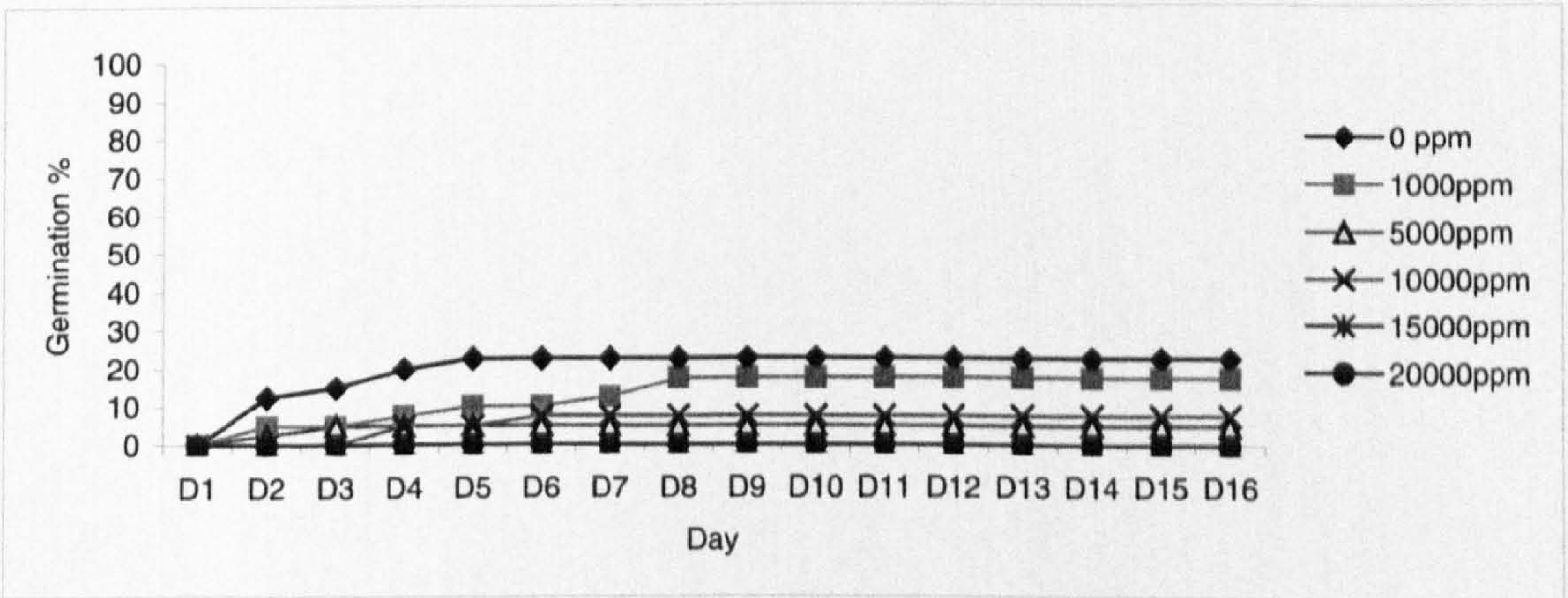

Fig. 5.20: Effect of salinity on germination percentage of *Rhazya stricta*

5.3.21 RUMEX VILLOSA

Germination of *Rumex villosa* in deionised water (0 ppm) was 82.5 %. Maximum germination (85%) was recorded in the treatments at 1000 and 5000 ppm 85 %. High germination (67.5 %) was also observed at (10000 ppm). At 15000 and 20000 ppm germination was zero (Fig. 5.21). Germination percentage between 1000, 5000 and 10000 ppm salinity and deionised water (0 ppm) was not significantly different (P>0.05). There was a significant difference in germination percentage between 15000 and 20000 ppm and the other concentrations (P<0.0001).

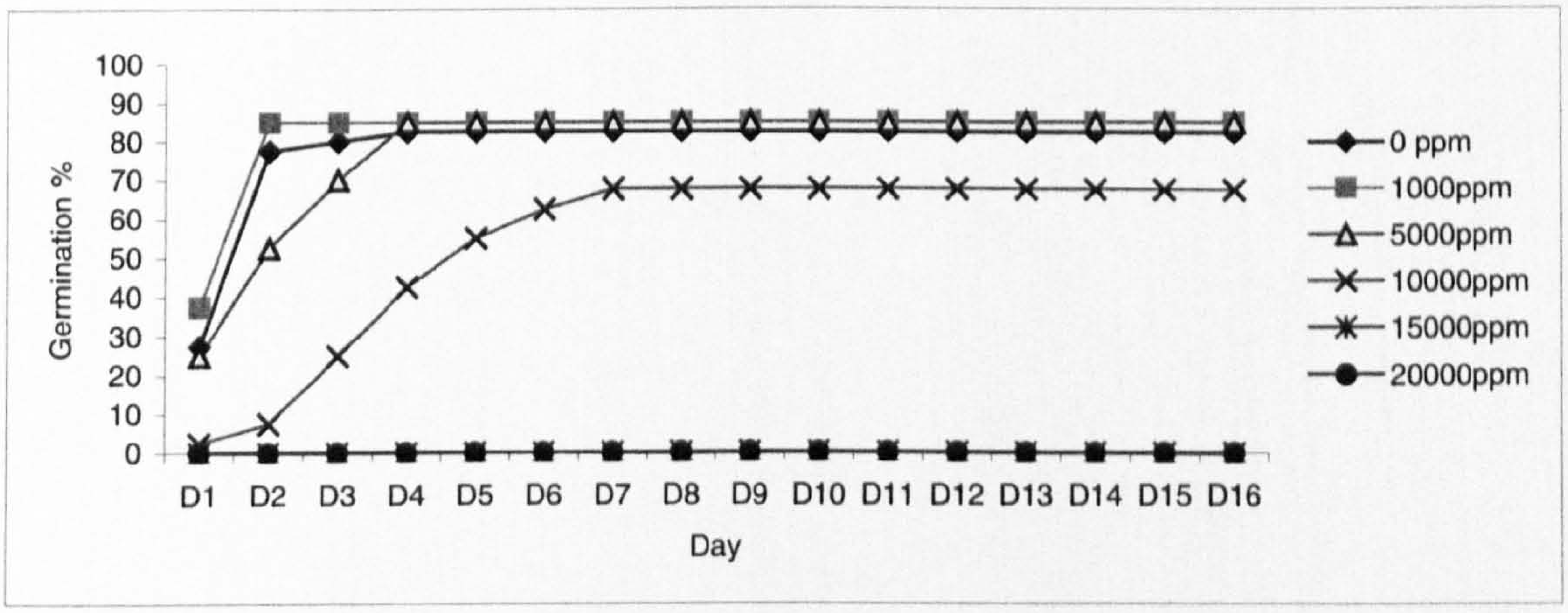

Fig. 5.21: Effect of salinity on germination percentage of *Rumex villosa*

5.3.22 *VERBESINA ENCELIOIDES*

It can be seen from Fig. 5.22 that germination of *Verbesina encelioides* in deionised water (0 ppm) and at 1000 and 5000 ppm salinity was approximately 90 %. High germination (72.5 %) was also observed at 10000 ppm. This fell to 10% at 15000 ppm and to zero at 20000 ppm. Germination between 1000, 5000 and 10000 pp) salinity and deionised water (0 ppm) was not significantly different (P>0.05). There was a significant difference in germination percentage between 15000 and 20000 ppm and the other concentrations (P<0.05). Rate of germination was greatly reduced at 15000 and 20000 ppm.

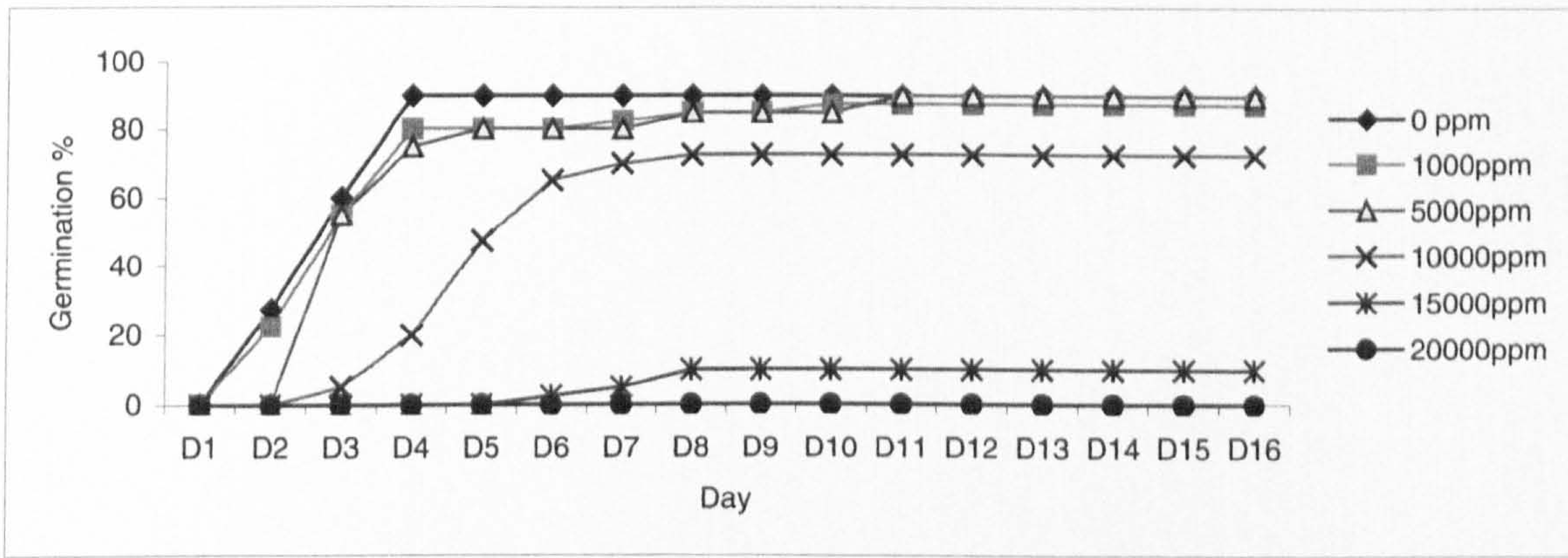

Fig. 5.22: Effect of salinity on germination percentage of *Verbesina encelioides*

5.4 DISCUSSION

In general an increase in salinity resulted in a significant decrease in germination percentage of all species (Table 5.1). Similar results have been obtained in many studies mentioned earlier. This decrease is probably the result of a physio-chemical effect, either osmotic or toxic (Bewley and Black, 1982).

		0 ppm	1000ppm	*P**	5000ppm	*P**	10000ppm	*P**	15000ppm	*P**	20000ppm	*P**
1	ABUTLON PANNSUM	**12.5**	12.5	*1.000*	7.5	*.570*	5	*.177*	0	*.007*	0	*.007*
2	ACHILLEA FRAGRANTISSIMA	**100**	97.5	*.996*	90	*.421*	90	*.421*	15	*.000*	0	*.000*
3	AERVA JAVANICA	**70**	67.5	*1.000*	12.5	*.000*	0	*.000*	0	*.000*	0	*.000*
4	ALOE VERA	**97.5**	95	*.995*	90	*.643*	32.5	*.000*	0	*.000*	0	*.000*
5	ANVILLEA GARCINI	**32.5**	32.5	*1.000*	40	*.914*	5	*.019*	0	*.005*	0	*.005*
6	ARTEMISIA HERBA ALBA	**72.5**	72.5	*1.000*	52.5	*.212*	25	*.000*	0	*.000*	0	*.000*
7	ARTEMISIA JUDAICA	**80**	70	*.654*	77.5	*.999*	12.5	*.000*	0	*.000*	0	*.000*
8	ATRIPLEX HALIMUS	**30**	35	*1.000*	27.5	*1.000*	27.5	*.727*	10	*.006*	0	*.002*
9	ATRIPLEX LEUCOCLADA	**42.5**	45	*1.000*	40	*.914*	30	*.019*	5	*.005*	0	*.005*
10	CASSIA ITALICA	**55**	45	*.915*	30	*.184*	62.5	*.974*	25	*.075*	5	*.001*
11	CASSIA OCCIDENTALIS	**100**	100	*1.000*	100	*1.000*	90	*.047*	32.5	*.000*	7.5	*.000*
12	CASSIA SENNA	**80**	77.5	*1.000*	65	*.574*	55	*.111*	42.5	*.007*	0	*.000*
13	DATURA INNOXIA	**52.5**	42.5	*.623*	45	*.840*	0	*.000*	0	*.000*	0	*.000*
14	DODONEA VISCOSA	**80**	67.5	*.62*	72.5	*.926*	52.5	*0.026*	0	*.000*	0	*.000*
15	FARSETIA AEGYPTIA	**95**	95	*1.000*	90	*.852*	72.5	*.001*	0	*.000*	0	*.000*
16	LASIURUS SCINDICUS	**82.5**	80	*1.000*	15	*.000*	10	*.000*	0	*.000*	0	*.000*
17	LYCIUM SHAWII	**47.5**	27.5	*.053*	25	*.024*	0	*.000*	0	*.000*	0	*.000*
18	PEGANUM HARMALA	**80**	77.5	*.999*	82.5	*.999*	25	*.000*	0	*.000*	0	*.000*
19	PULICARIA CRISPA	**95**	87.5	*.399*	72.5	*.000*	7.5	*.000*	0	*.000*	0	*.000*
20	RUMEX VILLOSA	**82.5**	85	*.998*	85	*.998*	67.5	*.191*	0	*.000*	0	*.000*
21	RHAZYA STRICTA	**22.5**	17.5	*.916*	5	*.029*	7.5	*.077*	0	*.004*	0	*.004*
22	VERBESINA ENCELIOIDES	**90**	87.5	*.999*	90	*1.000*	72.5	*.258*	10	*.000*	0	*.000*

* Compared with deionised water (0 ppm) treatment

(Table 5.2): Effect of salinity on germination percentage of some Saudi indigenous plants. P values for comparison with 0 ppm (control) are in italics

The results show that the effect of salinity on germination percentage of Saudi indigenous plants differed considerably from one species to another (Table 5.1).The species that appear to be least tolerant of salinity, having significantly greater germination below 1000 ppm include: *Artemisia judaica, Lasiurus scindicus, Lycium shawii, Pulicaria crispa, and Rhazya stricta.* A second group can be identified that demonstrate high germination at salinities as high as 5000 ppm, for example: *Aloe vera, Anvilla garcini, Artemisia herba-alba, Artemisia judaica, Atriplex leucoclada, Calligonum comosum, Datura innoxia, Dodonea viscosa, Farsetia aegyptia,* and *Peganum harmala.*
The most salinity tolerant species that showed high germination at salinities as high as 10000ppm include: *Abutilon pannosum, Achillea fragrantissima, Atriplex halimus, Cassia senna, Rumex vesicarius* and *Verbesina encelioides. Cassia italica* was the only species, that gave high germination at a salinity of 15000 ppm. No species gave significant results in germination at salinity of 20000 ppm.

These results correspond with many previous studies and will allow landscape architect to select species for Saudi (Riyadh) designed landscape after later studies. In a saline environment, germination and establishment will limit stages in the growth of some of these species in Riyadh. It may be necessary to reduce topsoil salinity before sowing especially if the soil water salinity more than 5000ppm, possibly by pre-irrigation to leach the soil surface.

CHAPTER 6

6. EFFECT OF MOISTURE STRESS ON THE GERMINATION OF SAUDI NATIVE SPECIES

6.1 -INTRODUCTION

6.2-MATERIAL AND METHODS

6.3-RESULTS

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6.3.2 *Achillea fragrantissima*
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5.4 DISCUSSION:

CHAPTER 6

6. EFFECT OF MOISTURE STRESS ON THE GERMINATION OF SAUDI NATIVE SPECIES

6.1 -INTRODUCTION

Soil moisture stress is particularly important ecological factor in hot semi-arid climates such as that of Saudi Arabia where the indigenous species grown in a hostile environment. In A desert environment rainfall is extremely variable in space and time; droughts are extended. These characteristics are likely to affect plant physiology and ecology (Westoby, 1980) Two critical steps in the life-cycle of most plant species are seed germination and seedling establishment (Gutterman, 1993, 1994). It has been suggested that in desert environments, soil water potential (SWP) and temperature are the key factors affecting seed germination (El-sharkawi and Farghali, 1988).

Germination is the physiological process through which growth is re-established in the embryo (Welbaum et al, 1998). It is believed that the seed critical is species specific (Hadas and Russo, 1974). Therefore, after a seed is embedded in soil, the rate of water intake directly affects germination. Seed water intake may be regulated by the water potential and the resistance of water movement at the seed soil interface (Evans and Etherington, 1990).

Moisture stress affects every aspect of plant growth and metabolism. The germination phase is of prime importance in the growth cycle of plants (Hadas, 1976). Water stress may result in delayed and reduced seed germination or may prevent germination completely (De and Kar, 1995). Poor soil water supply is an important environmental factor controlling germination and seedling establishment (Kramer and Kozlowsky, 1979; Come, 1982 and Alyemeny, 1989). Taylor (1982), Singh and Singh (1983), Bhatt and Rao, (1987) demonstrated that seed germination and emergence are reduced at a small negative osmotic potential although the exact potential inhibiting germination varied considerably between some species. Moreover, it has been found that initiation of cell elongation (germination) and cell elongation itself (radicle growth) during germination are differentially sensitive to water stress (McDonough, 1975; Hegarty and Ross, 1978). Severe soil moisture stress is a recurrent problem in establishing some exotic vegetation by sowing in Saudi Arabia.

Several investigators have studied the effect of water stress on the germination of Saudi indigenous plants. However, most of the work has been concerned with the effect of water stress associated with soil salinity on vegetation growth. Overall there is a shortage of data concerning the effect of water stress on the germination of Saudi indigenous species. It has been reported that seed of some plant species are adapted to germinate under high water stress conditions. In arid zones some species germinate at low water potential (Adams, 1999) thereby avoiding moisture stress.. This is not surprising since high SWP is rarely achieved in the soil surface of arid environments. In addition it has been reported that some plants species exhibit an inverse correlation between germination and substrate water potential until a lower threshold below which germination decreases (Potter et al., 1986).

Larcher (1995) reported that "*Drought resistance is the capacity of a plant to withstand periods of dryness and is a complex characteristic. A plant need not necessarily be drought resistant in order to live in dry regions. There are species which escape drought by timing their growth and reproduction to occur in the brief period when sufficient water is available*". Figure 6.1 summarises the possible ways for plants to survive in dry regions (xerophytes) according to Larcher (1995).

In the present study seed germination and seedling growth of some indigenous species in Saudi Arabia will be studied under water stress induced by *PEG-8000* (Polyethylene glycol) solutions to understand how water stress effect of seed germination.

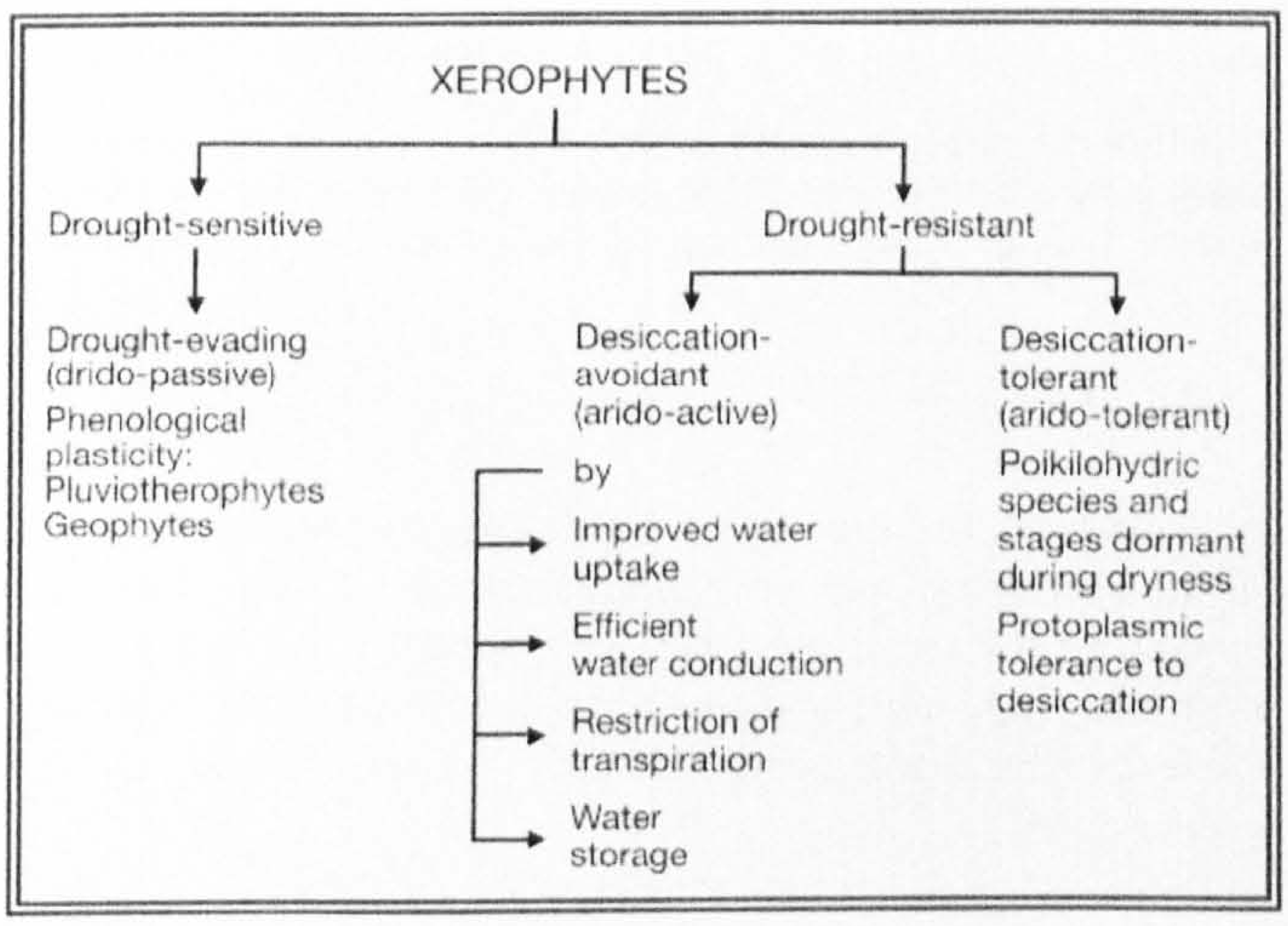

Fig. 6.1 Survival mechanisms of plants in dry regions Larcher (1995).

6.2-MATERIAL AND METHODS

The effect of water stress on germination was studied in twenty-two Saudi indigenous species using *Polyethylene glycol 8000* (PEG) solution. The water potential of the germination substrates 0, -2, -4, -6 and –8 bars were determined by means of aqueous solutions of PEG prepared using the temperature dependent regression formulas provided by Michel (1983) (Fig.6.2 and Table 6.1). PEG is a chemical commonly used to regulate water potential. The water potential of PEG solutions can be calculated, consequently the effect of water stress on germination can be calculated as well.

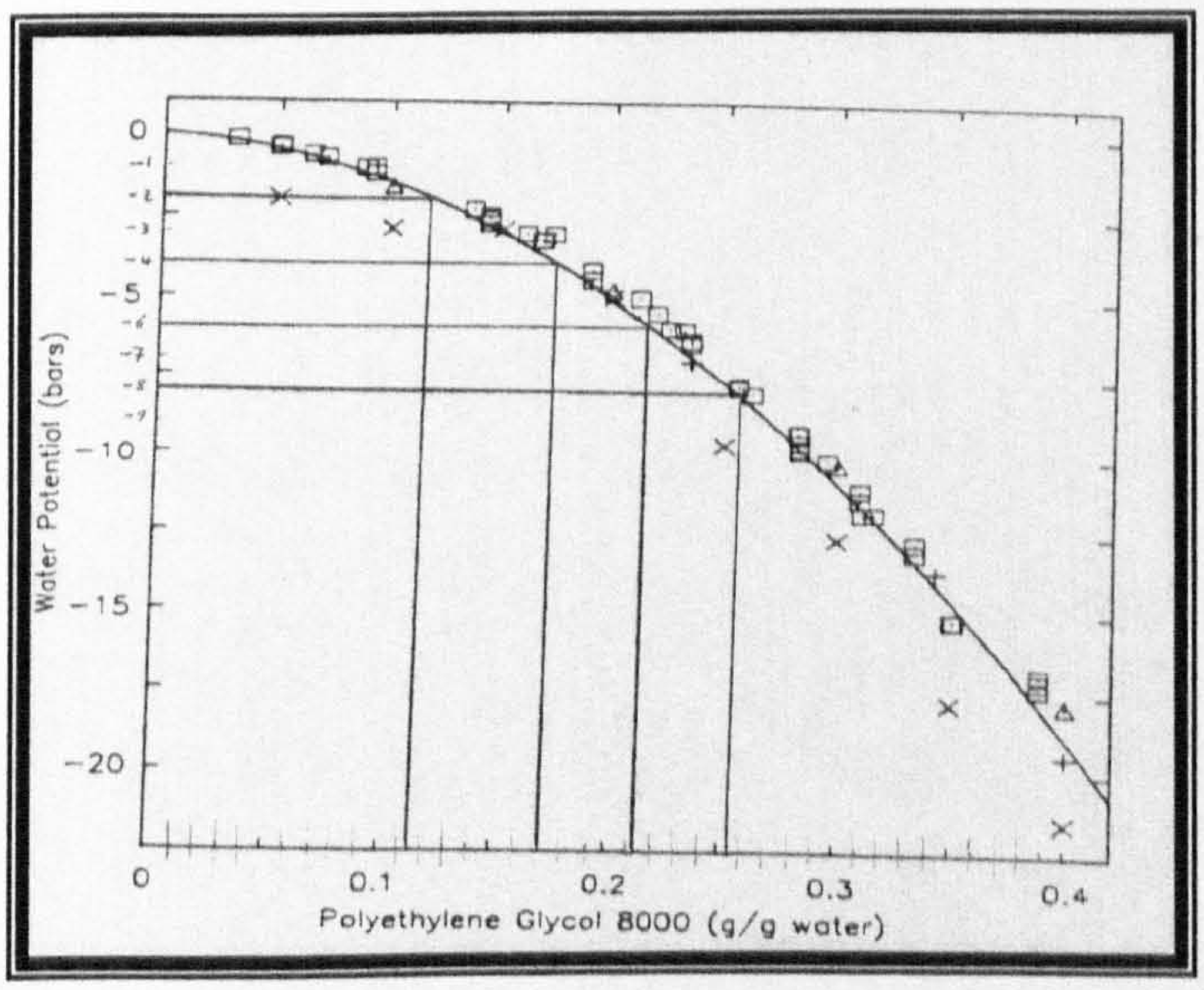

Fig. 6.2 Water potentials of *Polyethylene glycol 8000* (PEG) at 25°C (Michel 1983)

Target water potential	Polyethylene Glycol 8000
	g / 1000g water
0 bar	0
-2 bar	115
-4 bar	170
-6 bar	212
-8 bar	255

Table 6.1:The preparation of *Polyethylene Glycol 8000* solutions in 1000g water.

Thirty seed of some Saudi indigenous plants (Table 6.2) were placed on filter paper moistened with deionised water (control) and with different concentration of PEG-8000 in petri dishes. Each treatment was replicated four times for each species.
The experiments took place in a laboratory incubator at 12-h/day, at 25°C and 12-h, 25°C/night. Germination counts were recorded every day for 16 days.

Plants name	Life form	Plants name	Life form
Abutlion pannosum	Shrub	*Cassia senna*	Shrub
Achillea fragrantissima	Shrub	*Datura innoxia*	Forb (Annual)
Aerva javanica	Forb (Perennial)	*Dodonea viscosa*	Shrub
Aloe vera	Succulent	*Farsetia aegyptia*	S. Shrub
Anvillea garcini	Shrub	*Lasiurus scindicus*	Grass
Artemisia herba alba	Shrub	*Lycium shawii*	Shrub
Artemisia judaica	Shrub	*Peganum harmala*	Forb (Perennial)
Atriplex halimus	Shrub	*Pulicaria crispa*	Shrub
Atriplex leucoclada	Shrub	*Rhazya stricta*	Shrub
Cassia italica	Shrub	*Rumex villosa*	Forb (Annual)
Cassia occidentalis	Shrub	*Verbesina encelioides*	Forb (Annual)

Table 6.2: List of species tested in this experiment.

For some species we applied dormancy breaking treatments as follows; *Cassia italica, Cassia occidentalis, Cassia senna,* and *Dodonea viscosa* were treated by Sulphuric Acid (15 min). For *Atriplex halimus, Atriplex leucoclada* and *Rhazya stricta* the treatment was leaching

One way ANOVA was undertaken using *SPSS version 10* to determine whether significant differences occurred at P=0.05 in term of the number of seeds that had germinated by to day 16, for each salinity level. To determine where significant differences occurred at P = 0.05 post hoc tests were used (LSD and Tukey test).

6.3-RESULTS

Differences in germination percentages are only reported in the text, when they are significant (P < 0.05).

6.3.1 *ABUTILON PANNOSUM*

It can be seen from Fig 6.3 that germination of "control" seed of *Abutilon pannosum* was 22.5%. Rate of germination was slightly decreased in the treatments (-2, -4, -6 and -8 bar water potential). Differences in germination between treated and untreated seeds were however non-significant.

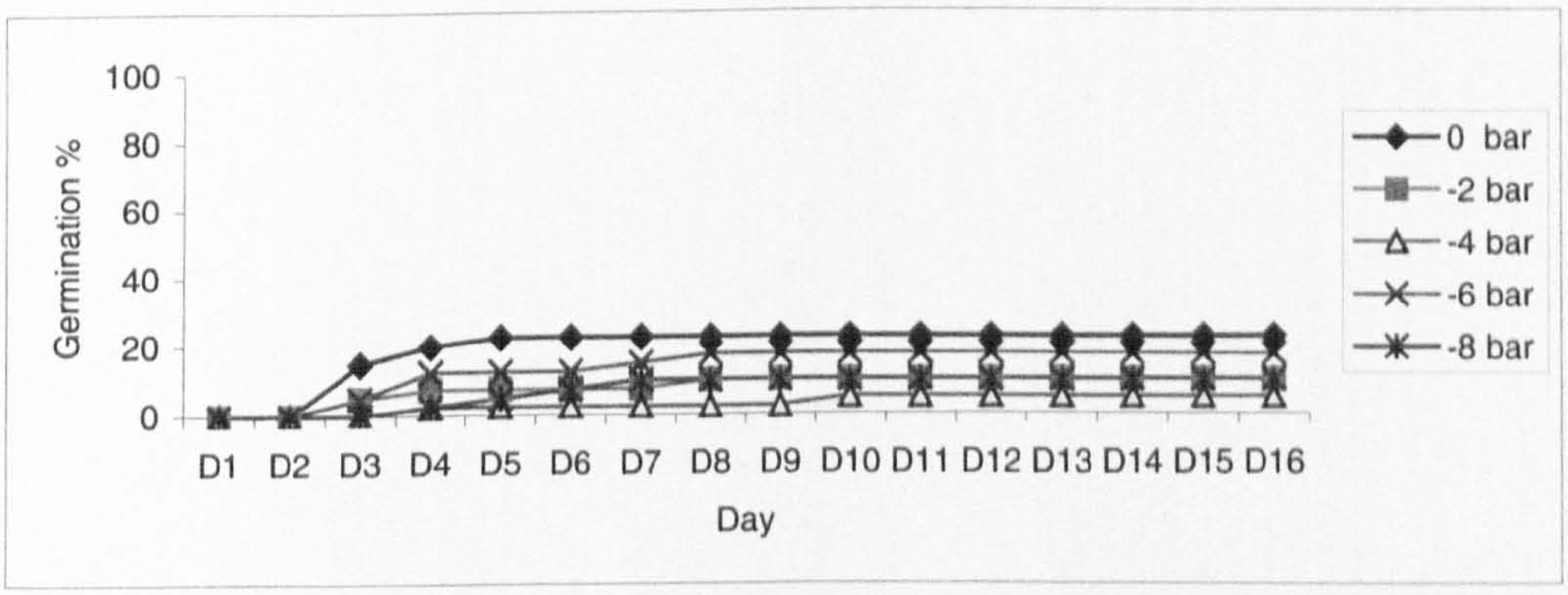

Fig. 6.3: Affect of moisture stress on germination percentage of *Abutilon pannosum*

6.3.2 *ACHILLEA FRAGRANTISSIMA*

Germination of *Achillea fragrantissima* was 87.5% in the control and slightly decreased in the potential treatments (-2, -4, -6 and -8 bar). Differences in germination percentage between untreated seed and all treatments were non-significant at (P>0.05).

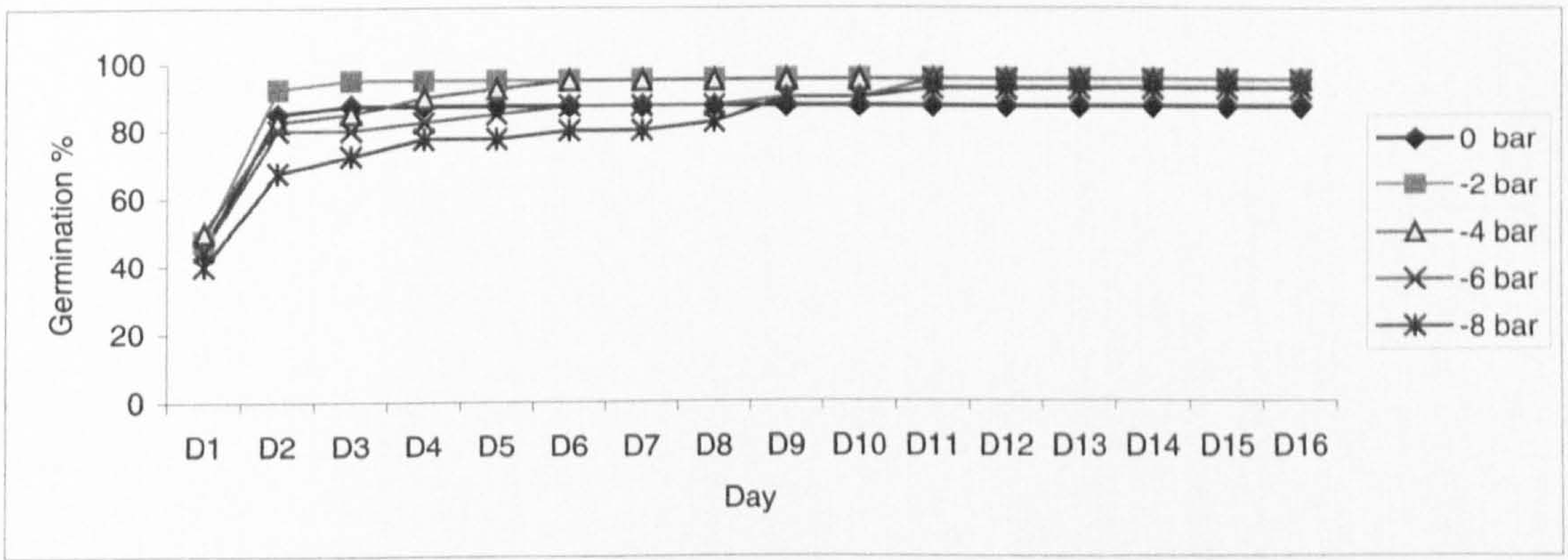

Fig. 6.4: Effect of moisture stress on germination percentage of *Achillea fragrantissima*

6.3.3 *AERVA JAVANICA*

Very low germination (approximately 2.5%) of *Aerva javanica* observed at with –8 bar water potential, rising to 35% at –2 bar. Germination of control seed was 70%. There was a significant difference in germination percentage between untreated and treated seeds at all comparisons.

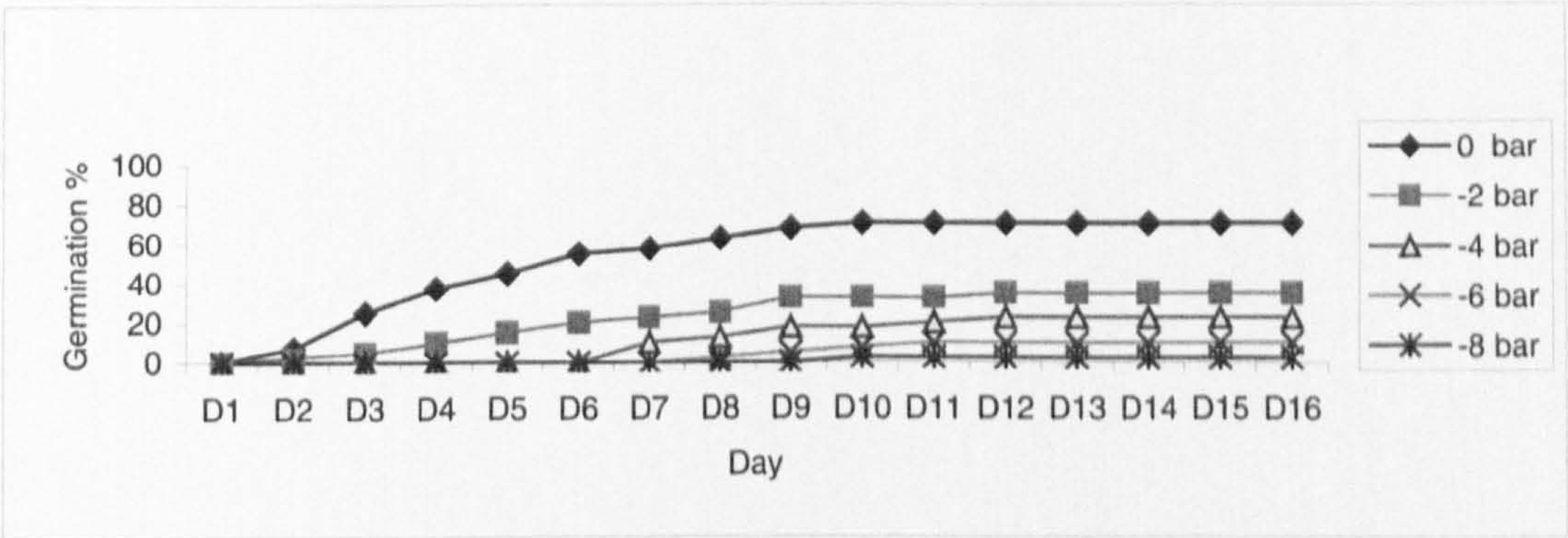

Fig. 6.5: Effect of moisture stress on germination percentage of *Aerva javanica*

6.3.4 *ALOE VERA*

It can be seen from Fig 6.6 that the germination percentage of *Aloe vera* at -2, -4 and -6 bar slightly decreased, and greatly decreased at –8 bar. There was non-significant difference in germination between the control and water potential –2 and –4 bar ($P>0.05$). Other differences (with -6 and –8 bar) were significant. Rate of germination was greatly reduced at –8 bar.

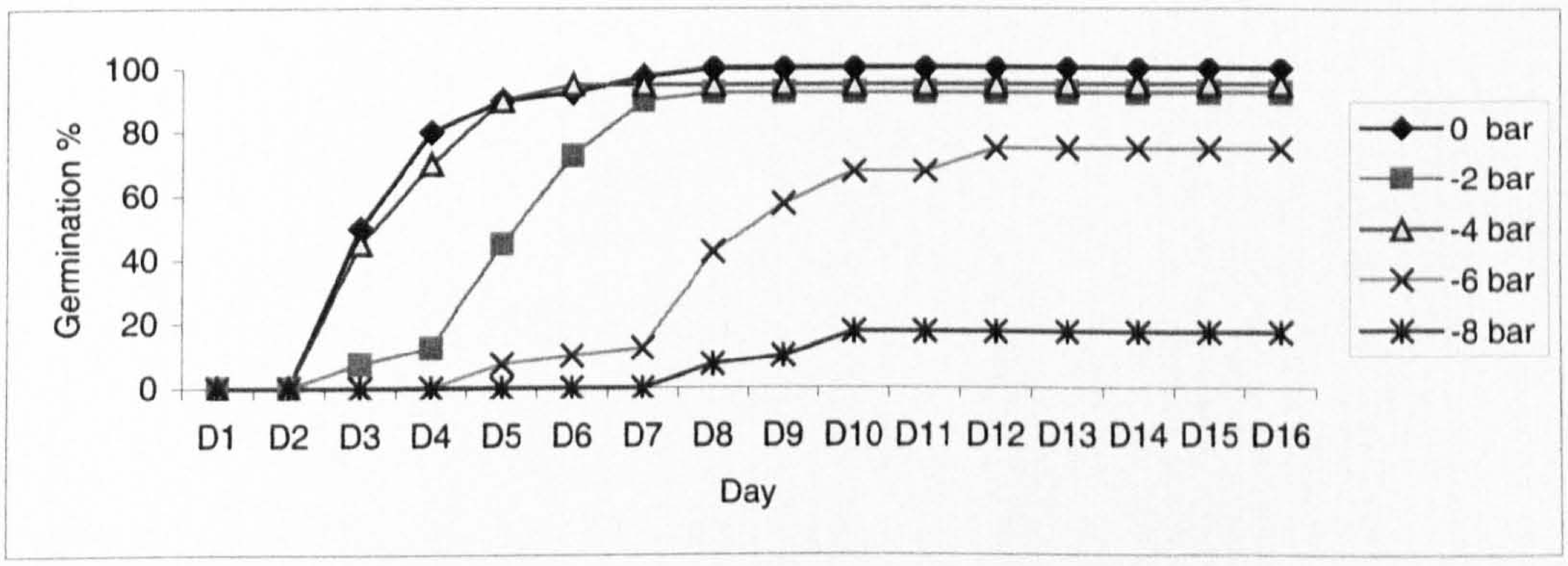

Fig. 6.6: Effect of moisture stress on germination percentage of *Aloe vera*

6.3.5 *ANVILLEA GARCINI*

Germination of untreated (control) seeds of *Anvilla garcini* was 30%. Most of the water potential treatments decreased this, but this was not statistically significant (P>0.05) for any of the treatments.

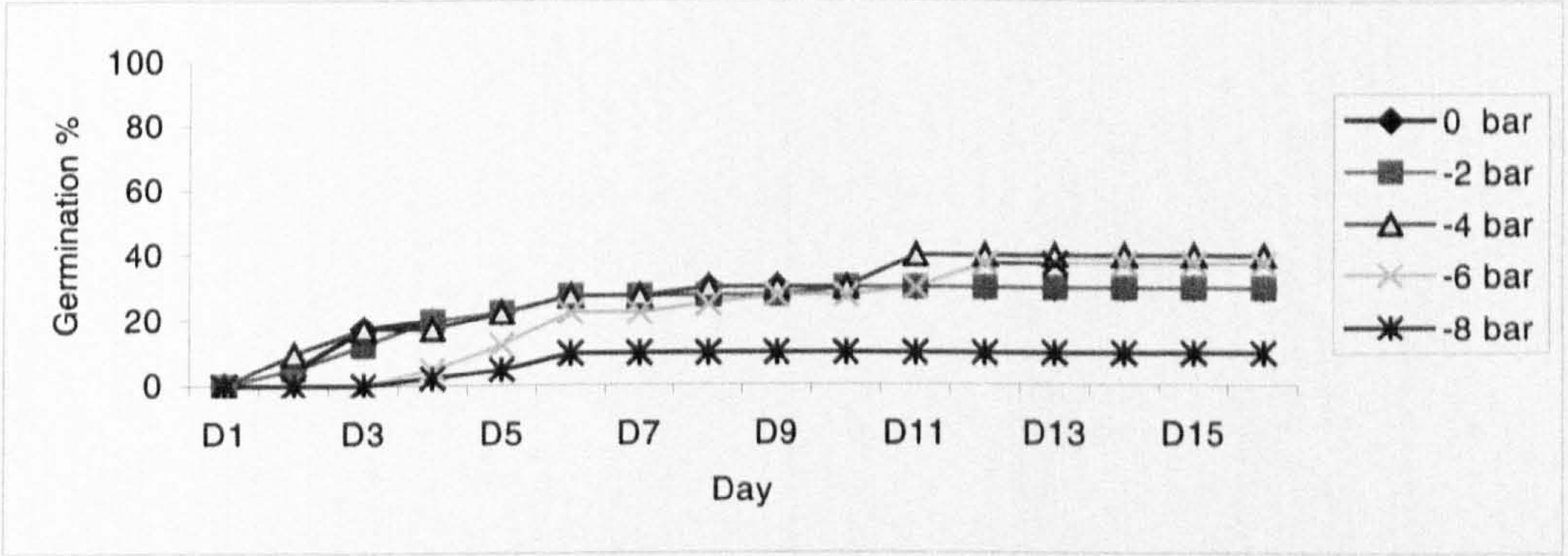

Fig. 6.7: Effect of moisture stress on germination percentage of *Anvilla garcini*

6.3.6 ARTEMISIA HERBA-ALBA

Low germination (approximately 22.5%) of *Artemisia herba-alba* was recorded at –8 bar. Germination increasing as water potential decreased was observed up to 70% at –2 bar. Germination of untreated seed was 65%. There was a significant difference in germination percentage between untreated (control) and –8 bar water potential. Other comparisons were not significant. Rate of germination was greatly reduced at –8 bar treatment.

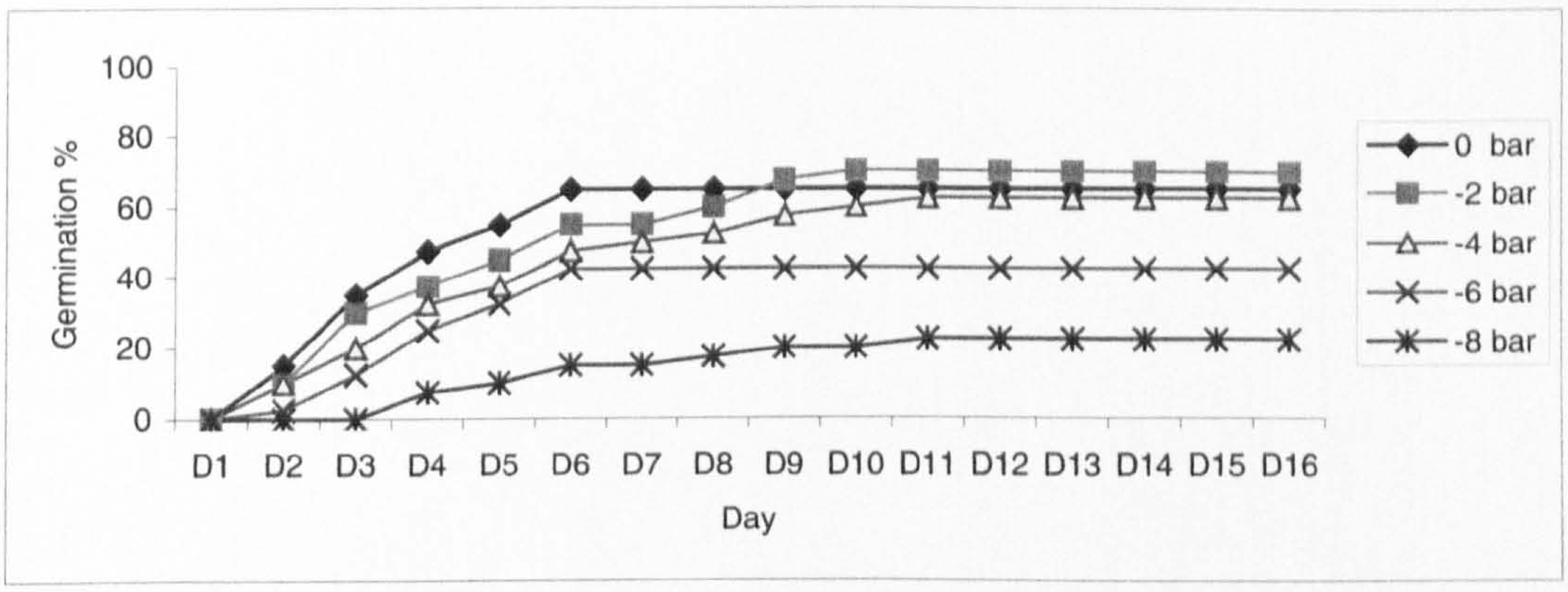

Fig. 6.8: Effect of moisture sterss on germination percentage of *Artemisia herba alba*

6.3.7 *ARTEMISIA JUDAICA*

Germination of *Artemisia judaica* as untreated (control) seeds and at water potentials of -2 and –4, was approximately 75%. At –6 bar treatment germination slightly decreased (65%), and was greatly reduced at –8 bar (23%). There was non-significant difference in germination percentage between untreated seeds with the water potentials of –2, -4 and –6 bar ($P>0.05$), with –8 bar significant at ($P<0.05$).

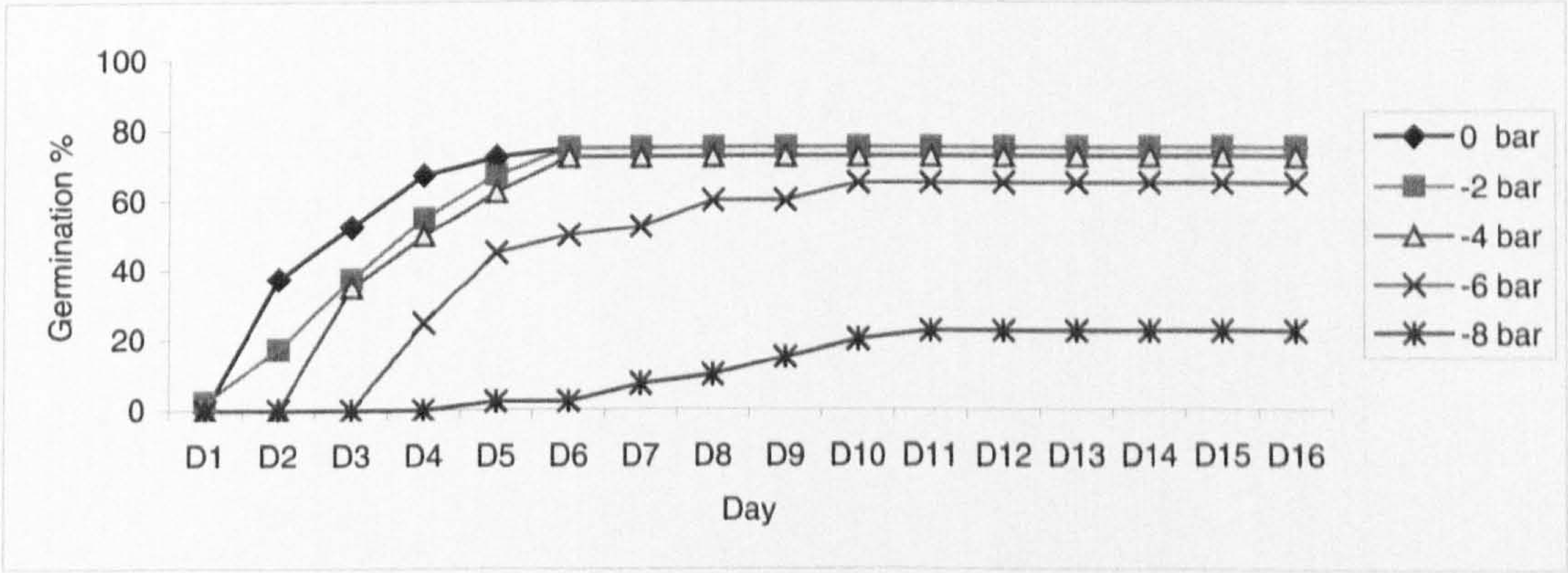

Fig. 6.9: Effect of moisture stress on germination percentage of *Artemisia judaica*

6.3.8 *ATRIPLEX HALIMUS*

It can be seen from Fig 6.5 that the germination percentage of *Atriplex halimus* at water potentials of -8 bar was 50%. Germination of untreated (control) seed was 25%. There was a non-significant difference in germination percentage between untreated and treated seeds.

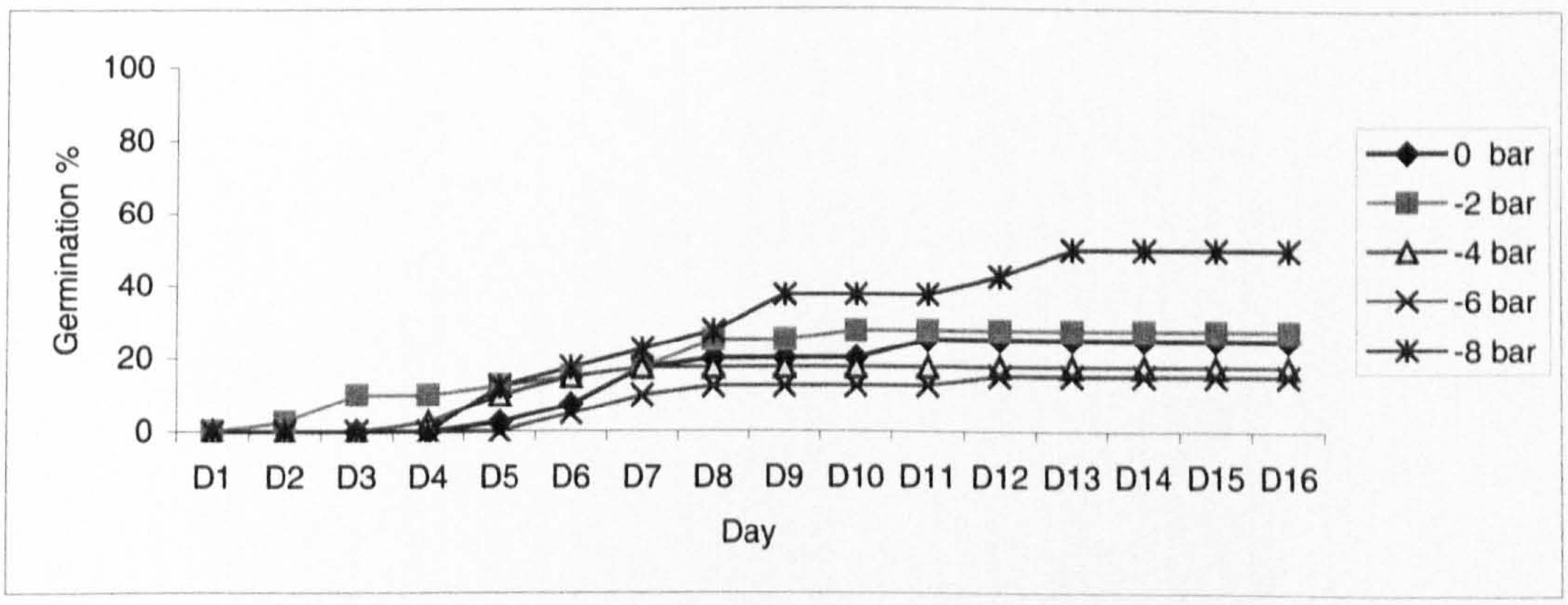

Fig. 6.10: Effect of moisture stress on germination percentage of *Atriplex halimus*

6.3.9 *ATRIPLEX LEUCOCLADA*

Germination of untreated (control) seed of *Atriplex leucoclada* was 40%, and with water potential treatments (-2, -4 bar) germination slightly decreased (approximately 22%), and greatly decreased at –6 and –8 bar to 15 and 13%. Differences in germination percentage between untreated seed and –2 and -4 bar were not significant ($P>0.05$), but significant ($P<0.05$) at –6 and –8 bar.

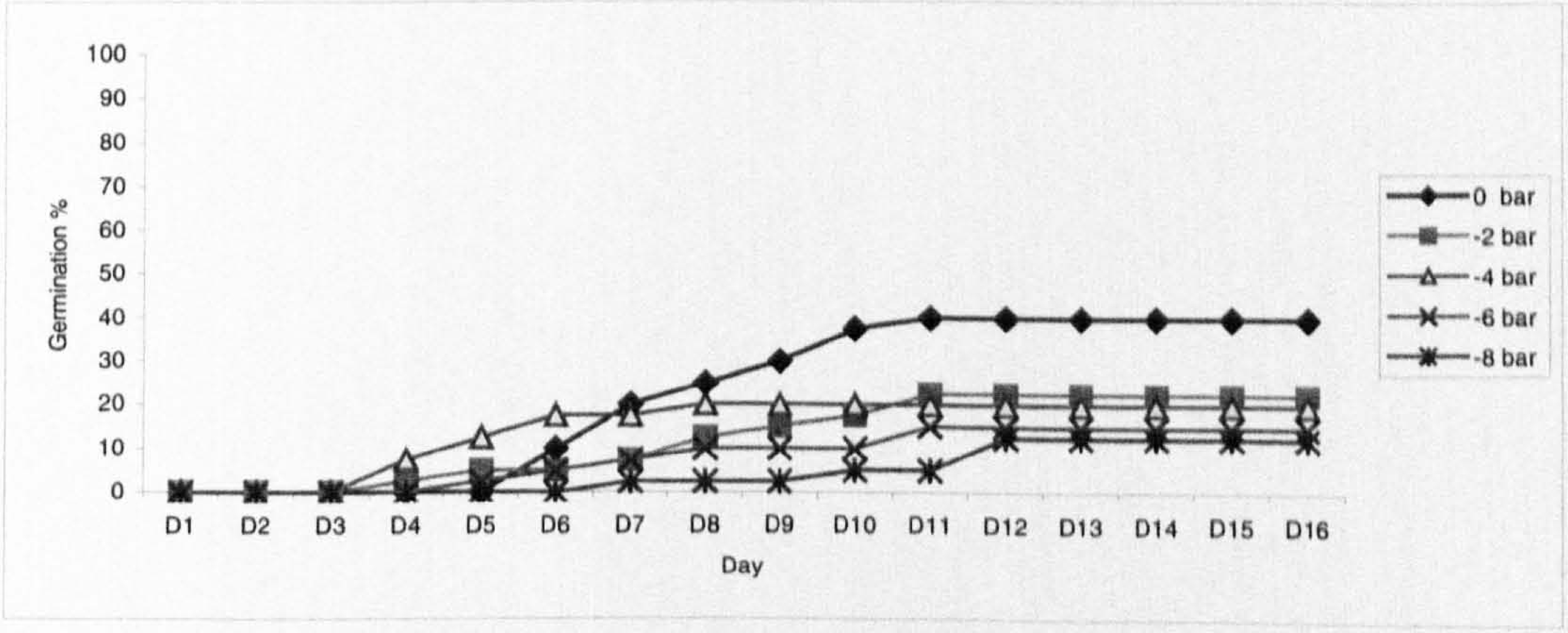

Fig. 6.11: Effect of moisture stress on germination percentage of *Atriplex leucoclada*

5.3.10 *CASSIA ITALICA*

Germination percentage of untreated (control) seeds of *Cassia italica* was 55%. At water potential of –4 bar germination was 58%, other treatments decreased germination. Differences in germination between treated and untreated seeds were non-significant (P>0.05).

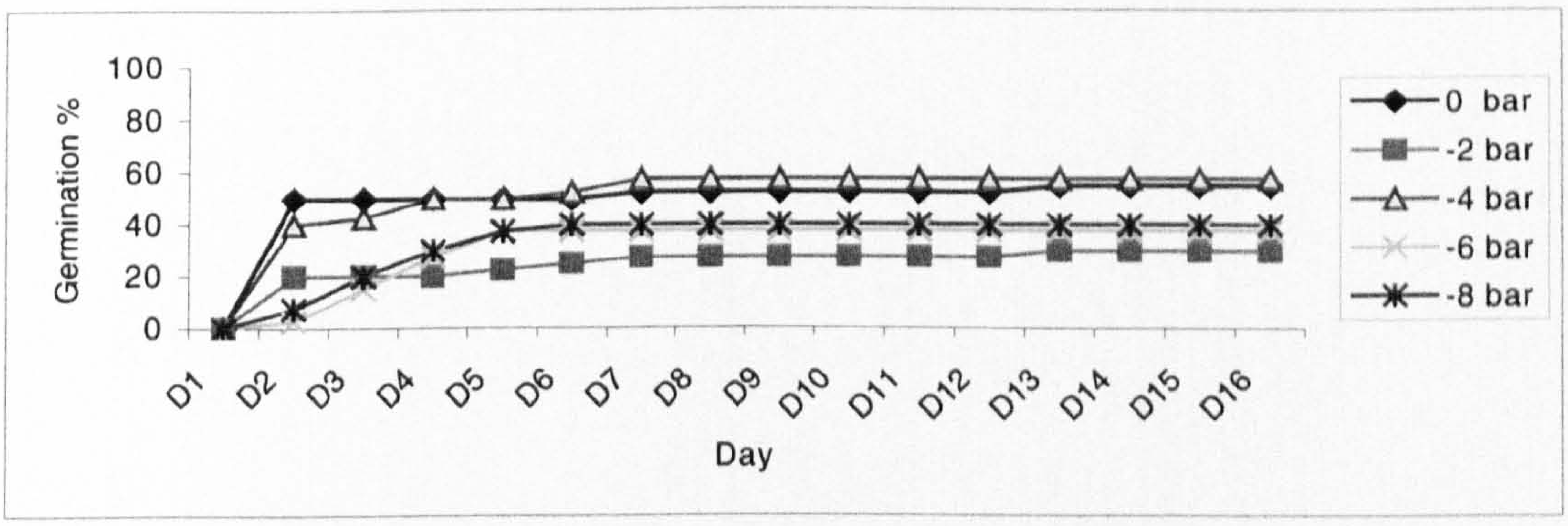

Fig. 6.12: Affect of moisture stress on germination percentage of *Cassia italica*

5.3.11 *CASSIA OCCIDENTALIS*

In *Cassia occidentalis* germination of seed in the control and at water potentials of -2 bar was 100%. At –4 and –6 bar germination slightly decreased (approximately 93%), and greatly decreased at –8 bar (47.5%). There was non-significant difference in germination percentage between untreated seeds and water potentials of –2, -4 and –6 bar (P>0.05), at –8 bar differences were significant (P<0.05). Rate of germination was also greatly reduced at –8 bar.

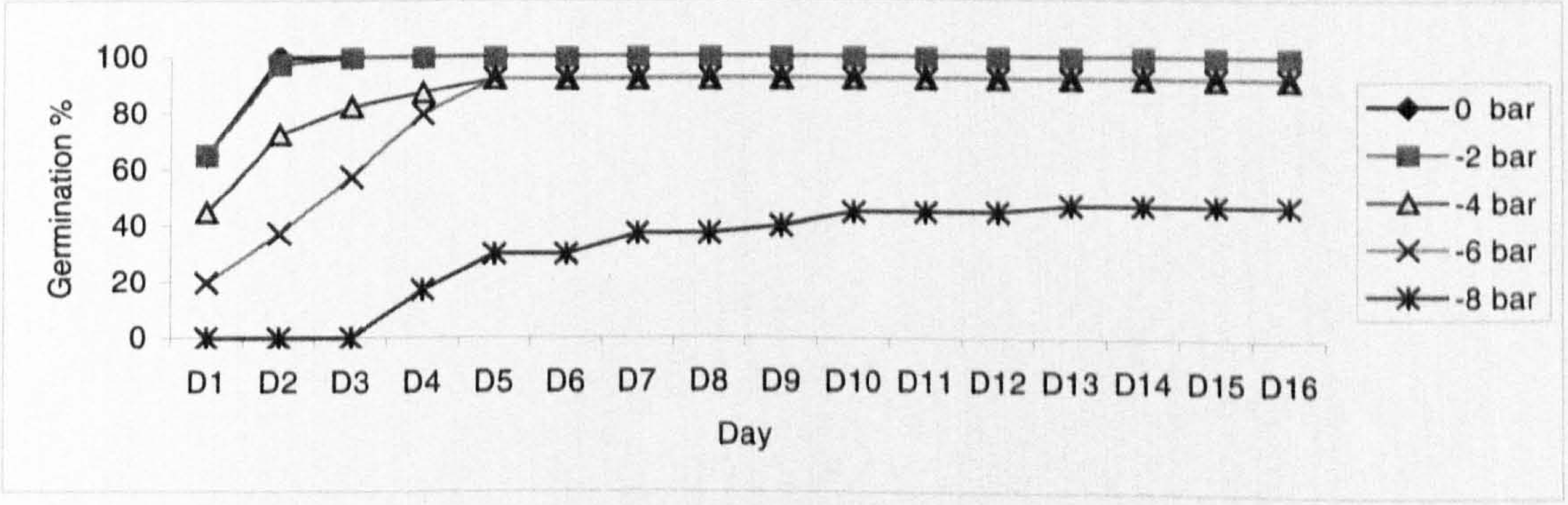

Fig. 6.13: Affect of moisture stress on germination percentage of *Cassia occidentalis*.

5.3.12 *CASSIA SENNA*

Minimum germination (approximately 33%) of *Cassia senna* was observed at –8 bar. Fifty eight % germination was observed at –6 bar, and it was 75% and 73% at –4 and –2 bar. Germination of untreated (control) seed was 65%. There was a significant difference in germination percentage between untreated seed and that at –8 bar water potential. Rate of germination was greatly reduced at –8 bar.

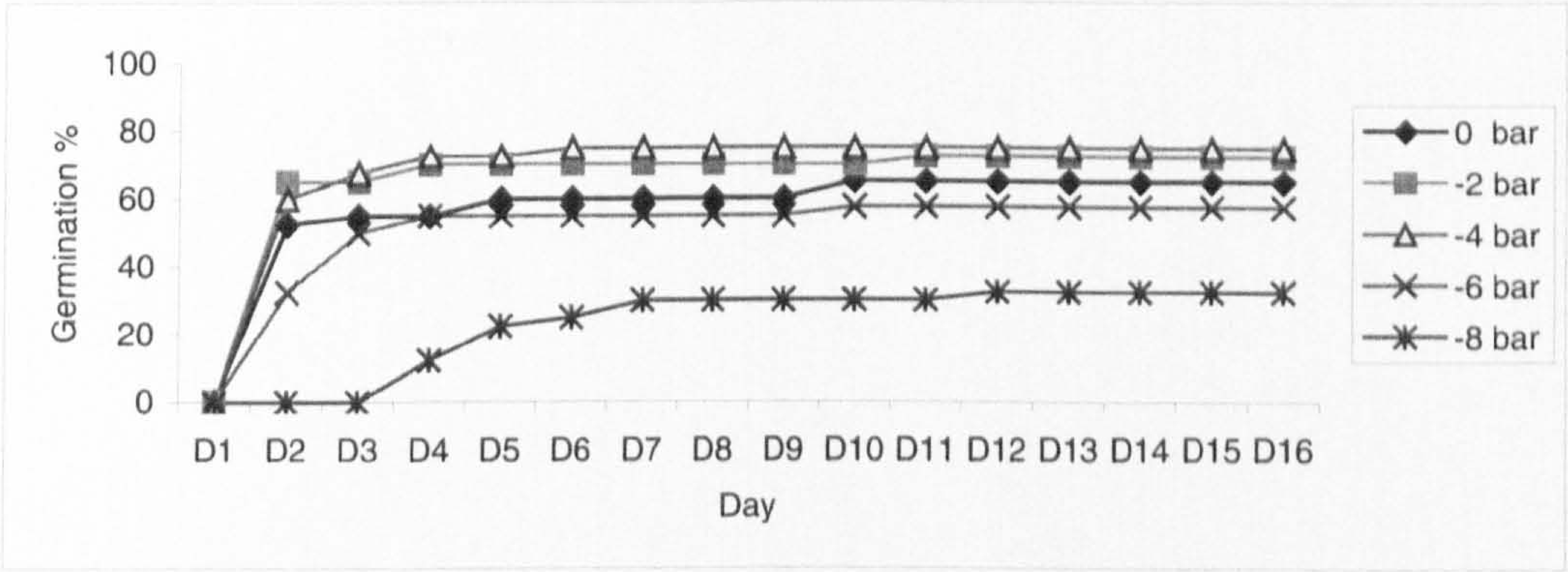

Fig. 6.14: Effect of moisture stress on germination percentage of *Cassia senna*

6.3.13 *DATURA INNOXIA*

The maximum germination of *Datura innoxia* at –2 and –4 bar water potential and in the control was 60%. Germination was zero at –6 and –8 bar. Germination at –2 and –4 bar water potential and untreated seed was not significantly different ($P>0.05$). There was a significant difference in germination at -6 and –8 bar water potential and the other treatments ($P<0.05$). Rate of germination was greatly reduced at –6 and –8 bar.

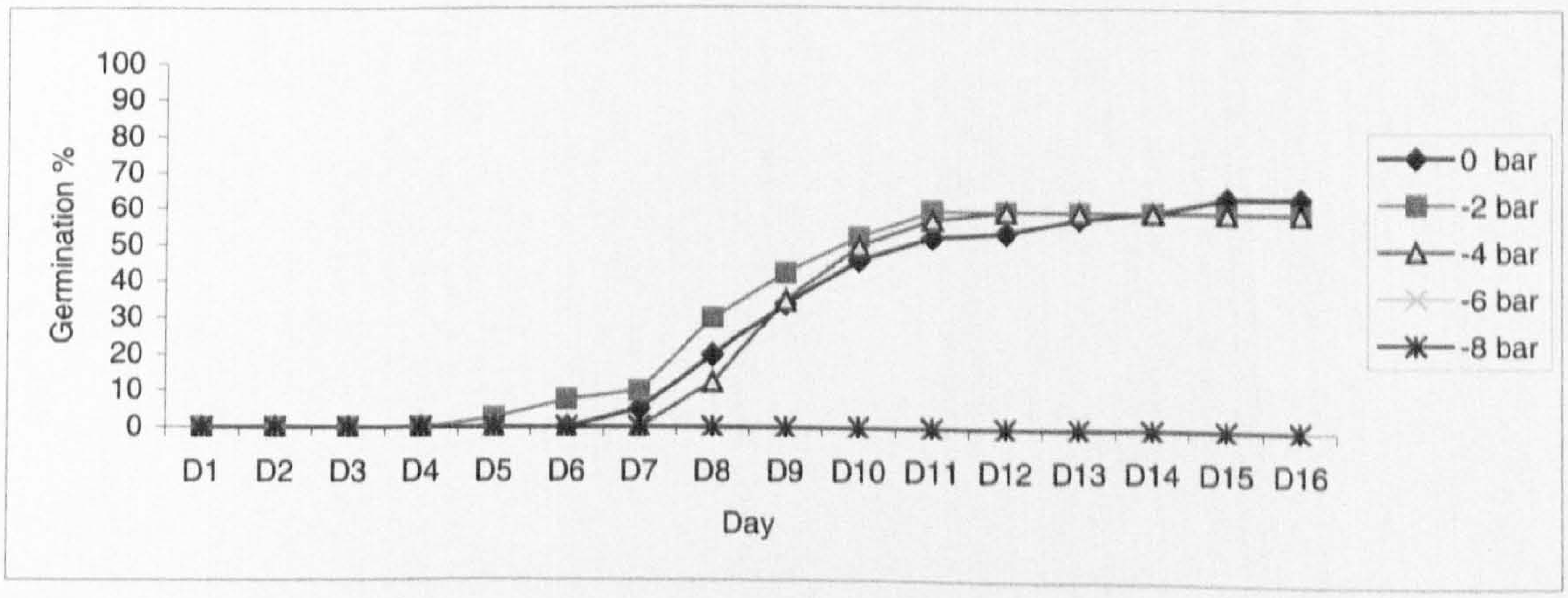

Fig. 6.15: Effect of moisture stress on germination percentage of *Datura innoxia*.

6.3.14 *DODONEA VISCOSA*

It can be seen from Fig 6.15 that the germination of *Dodondea viscosa* at water potentials below at –6 bar is greatly reduced. At –8 bar seed did not germinate. There was a significant difference in germination percentage between untreated (control) seeds and –6 and –8 bar (P<0.05). Rate of germination was greatly reduced with-6 at –8 bar treatments.

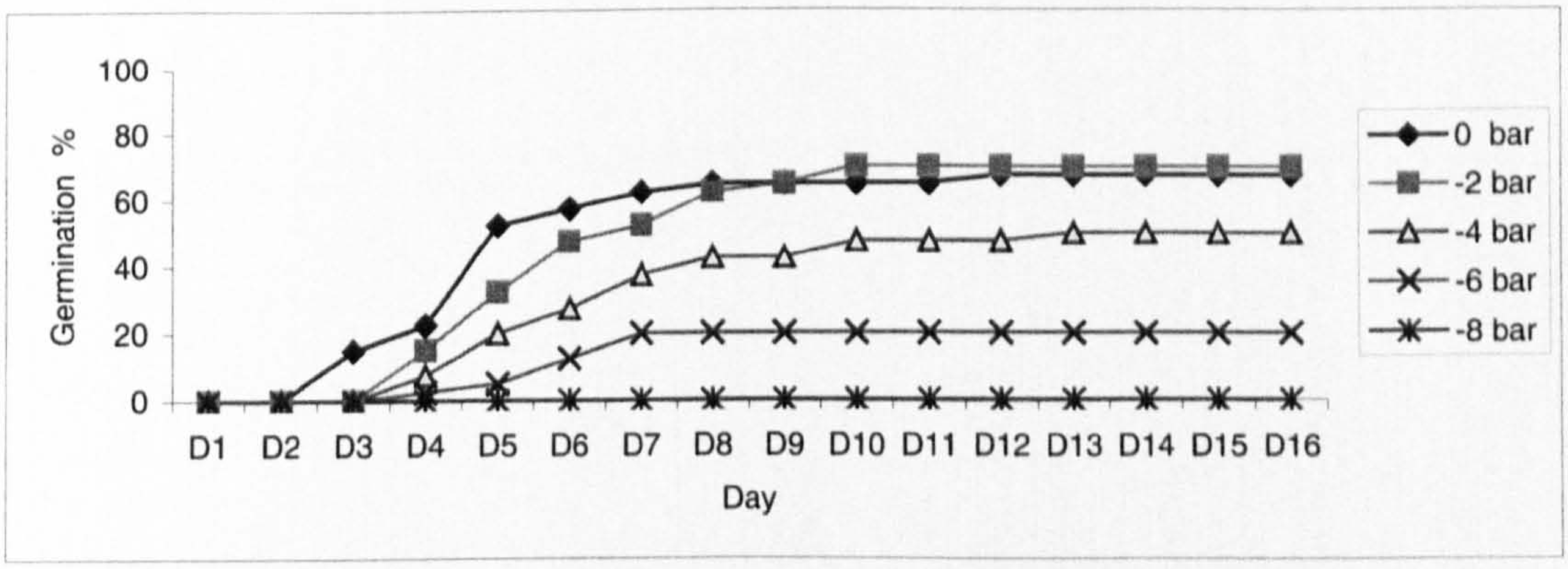

Fig. 6.16: Effect of moisture stress on germination percentage of *Dodonea viscosa*

6.3.15 FARSETIA AEGYPTIA

Farsetia aegyptia germination as untreated seed (control) and at a water potential of -2 was 97.5%. At –4 bar germination slightly decreased (92.5%), falling to 67.5% at –8 bar. There was a significant difference (P<0.05) in germination between untreated seeds and the –6 and–8 bar treatments.

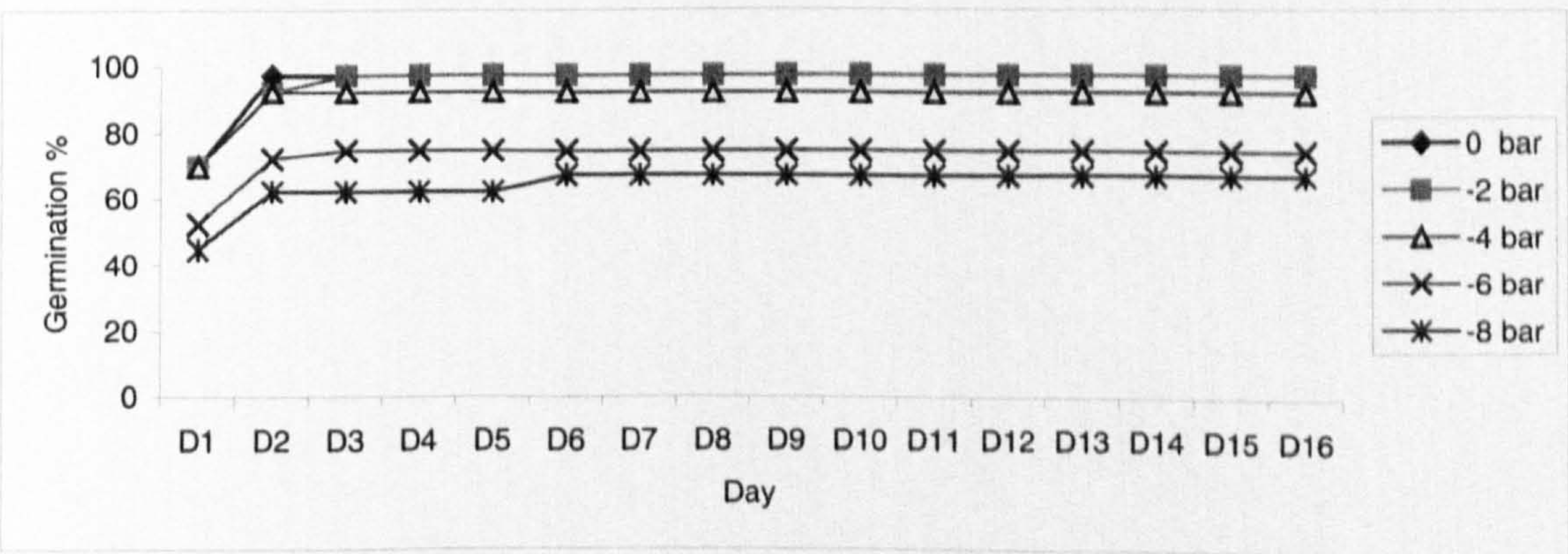

Fig. 6.17: Effect of moisture stress on germination percentage of *Farsetia aegyptia*

6.3.16 *LASIURUS SCINDICUS*

It can be seen from Fig 6.18 that the germination of *Lasiurus scindicus* decreased slightly at–2 bar and decreased greatly at –4, -6 and –8 bar. Germination in untreated seeds and water potentials of –2 was significantly greater than at –4,-6 and –8 bar.

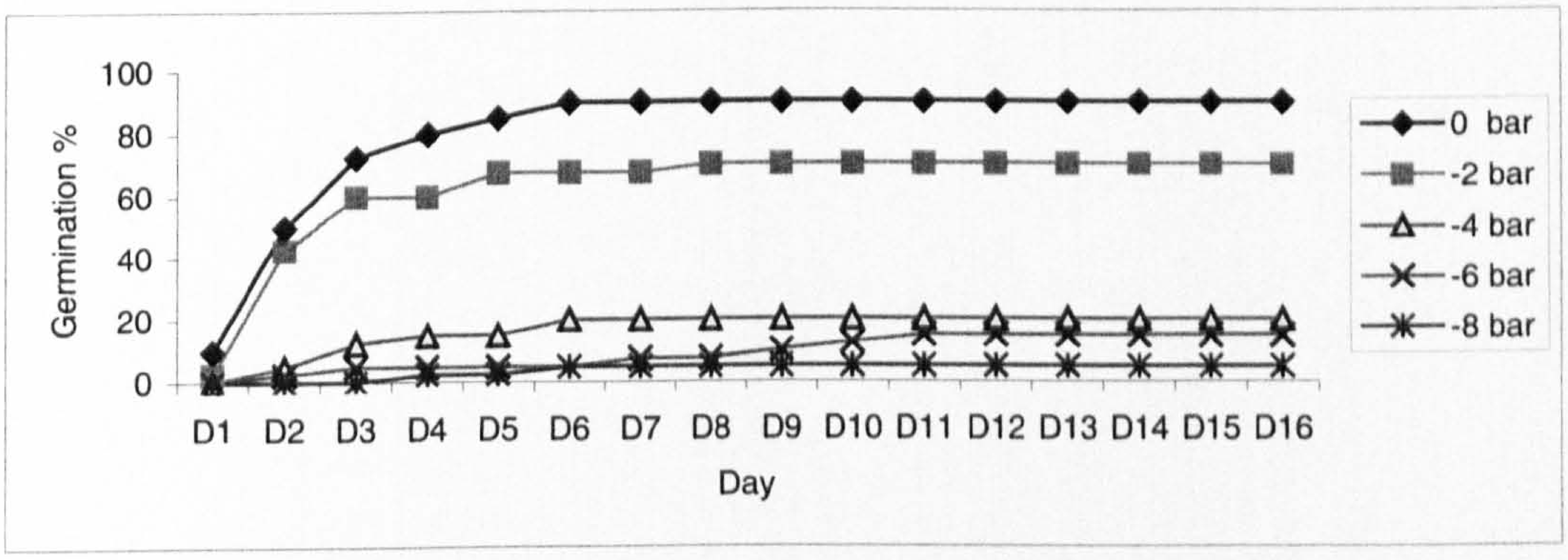

Fig. 6.18: Effect of moisture stress on germination percentage of *Lasiurus scindicus*

6.3.17 *LYCIUM SHAWII*

This species did not germinate at any of the water potentials.

6.3.18 *PEGANUM HARMALA*

Germination of untreated (control) seeds and seed at –2 bar water potential was 65%. At –8 bar this fell to 17.5%. Germination of –8 bar was significantly different to that at 0, –2, –4, and –6 bar ($P<0.05$).

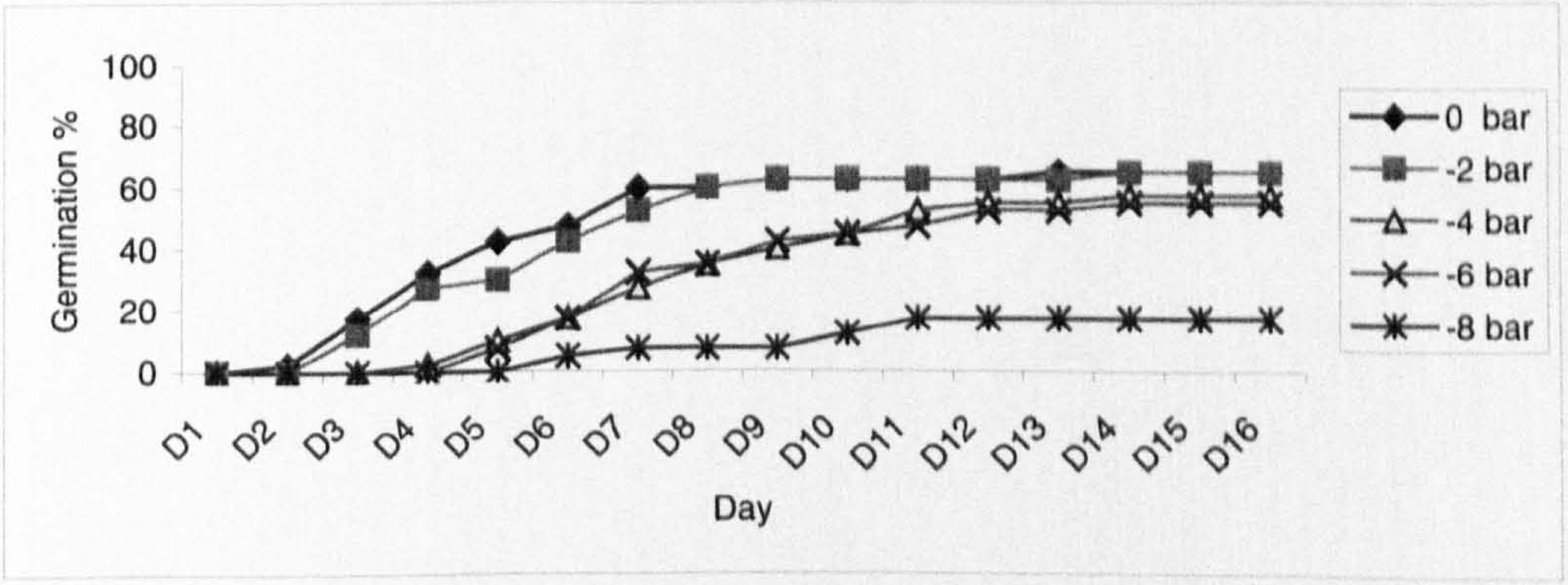

Fig. 6.19: Effect of moisture stress on germination percentage of *Peganum harmala*

6.3.19 *PULICARIA CRISPA*

The maximum germination of *Pulicaria crispa* at –8 bar water potential was 18%, rising to 75% in the control and –2 bar. Germination was 60 and 50% at –6 and –8 bar. There was a significant difference in germination between (–8 bar water potential) and the other treatments (P<0.05). Rate of germination was greatly reduced at–8 bar.

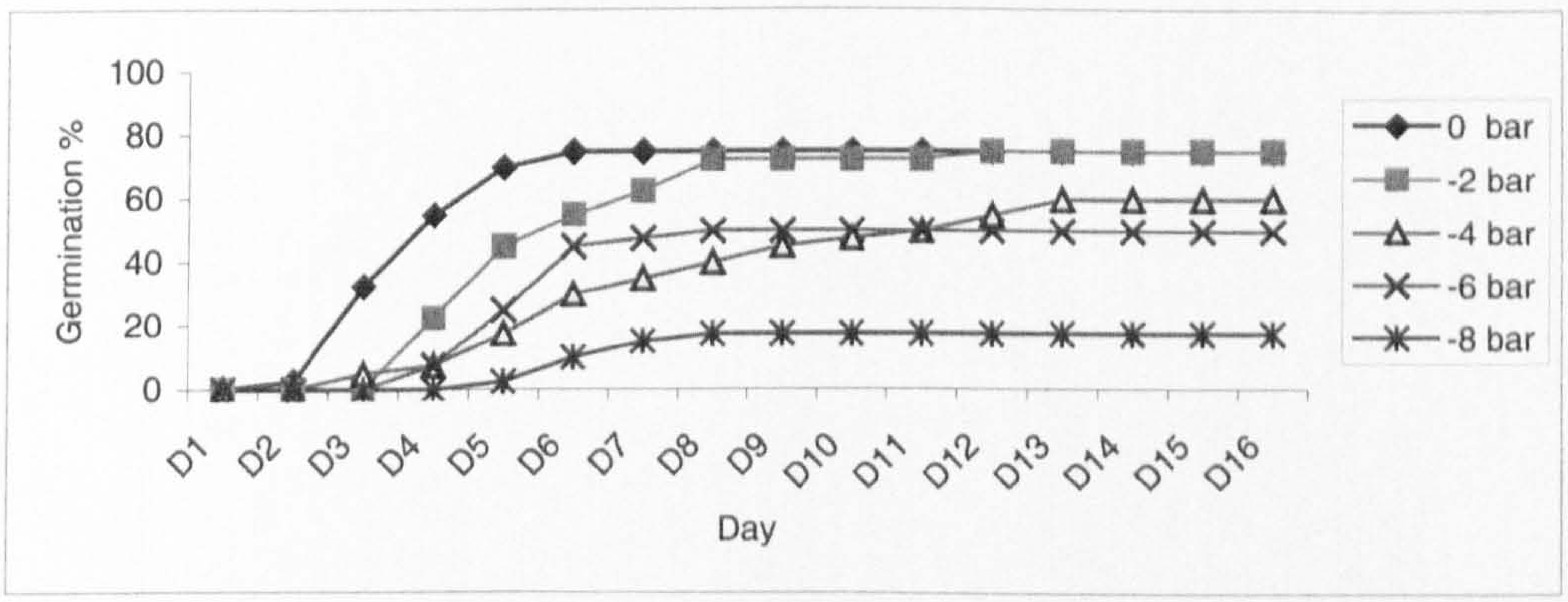

Fig. 6.20: Effect of moisture stress on germination percentage of *Pulicaria crispa*

5.3.20 *RHAZYA STRICTA*

Rhazya stricta germination in the control was 40%, and fell to 10 % at –8 bar. There was non-significant difference in germination percentage between the control and seeds at –2 and -4 bar (P>0.05), but the control comparisons with-6 and –8 bar was significant (P<0.05). Rate of germination was greatly reduced with -6 and –8 bar treatments.

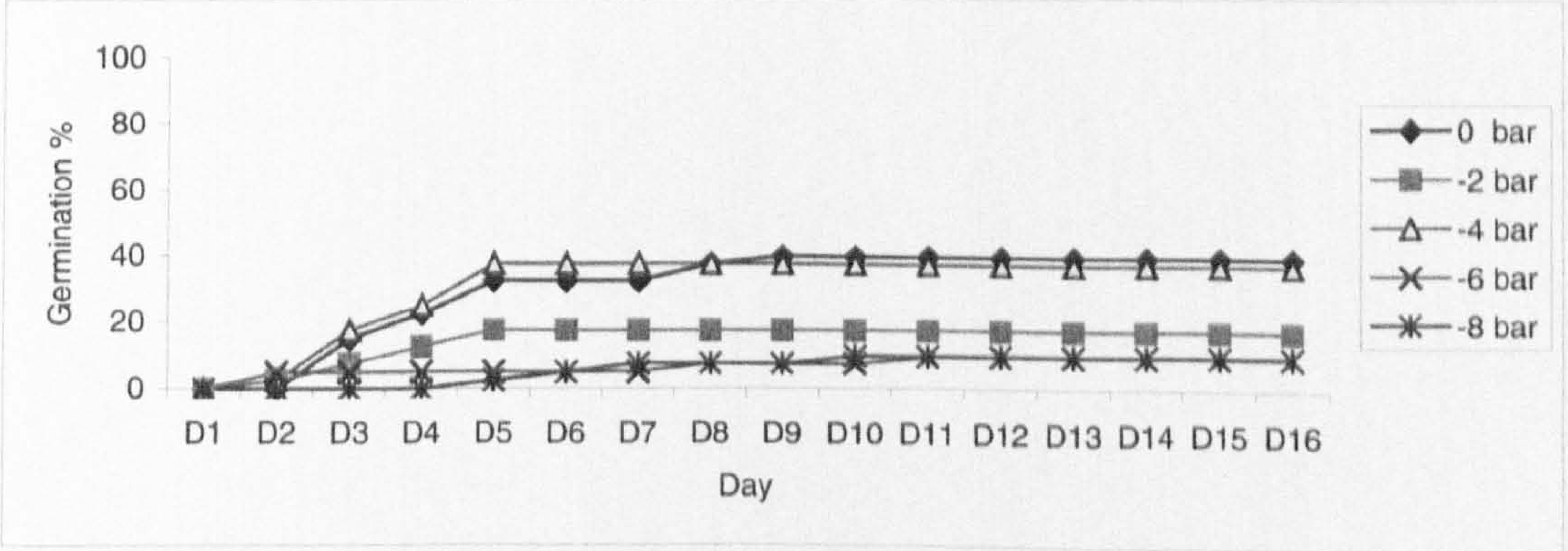

Fig. 6.21: Effect of moisture stress on germination percentage of *Rhazya stricta*

5.3.21 *RUMEX VILLOSA*

It can be seen from Fig. 6.22 that minimum germination (57.5 %) of *Rumex villosa* was at –8 bar water potential. Approximately 97 % germination was observed at –2 and –4 bar. Germination of untreated seed was 97.5%. There was a significant difference in germination percentage between untreated seed and –8 bar water potential. Other treatments were not significant.

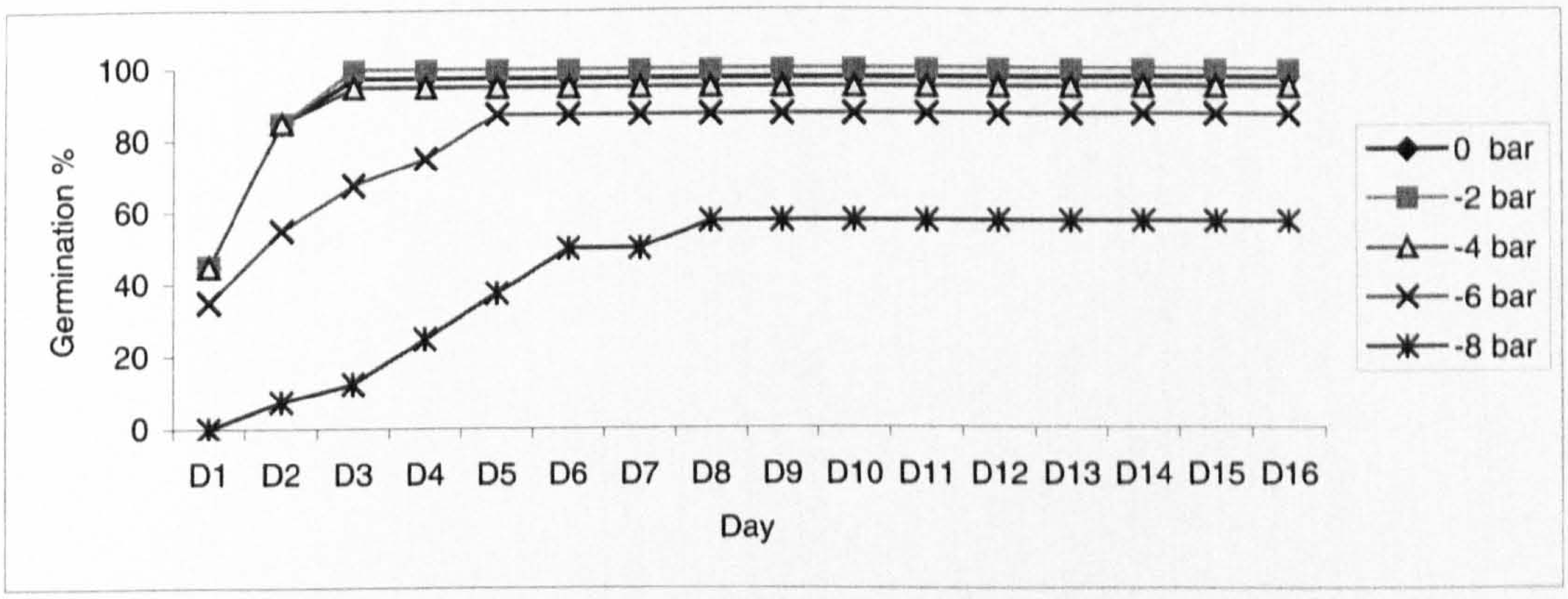

Fig. 6.22: Effect of moisture stress on germination percentage of *Rumex villosa*

5.3.22 *VERBESINA ENCELIOIDES*

Germination of untreated (control) seed of *Verbesina encelioides* was 80%, This decreased slightly at -4 and -6 bar, and greatly decreased at –8 bar. Differences in germination between untreated seeds and water potentials at –2, -4 and –6 were not significant ($P>0.05$). At –8 bar comparisons with other treatments were significantly different ($P<0.05$).

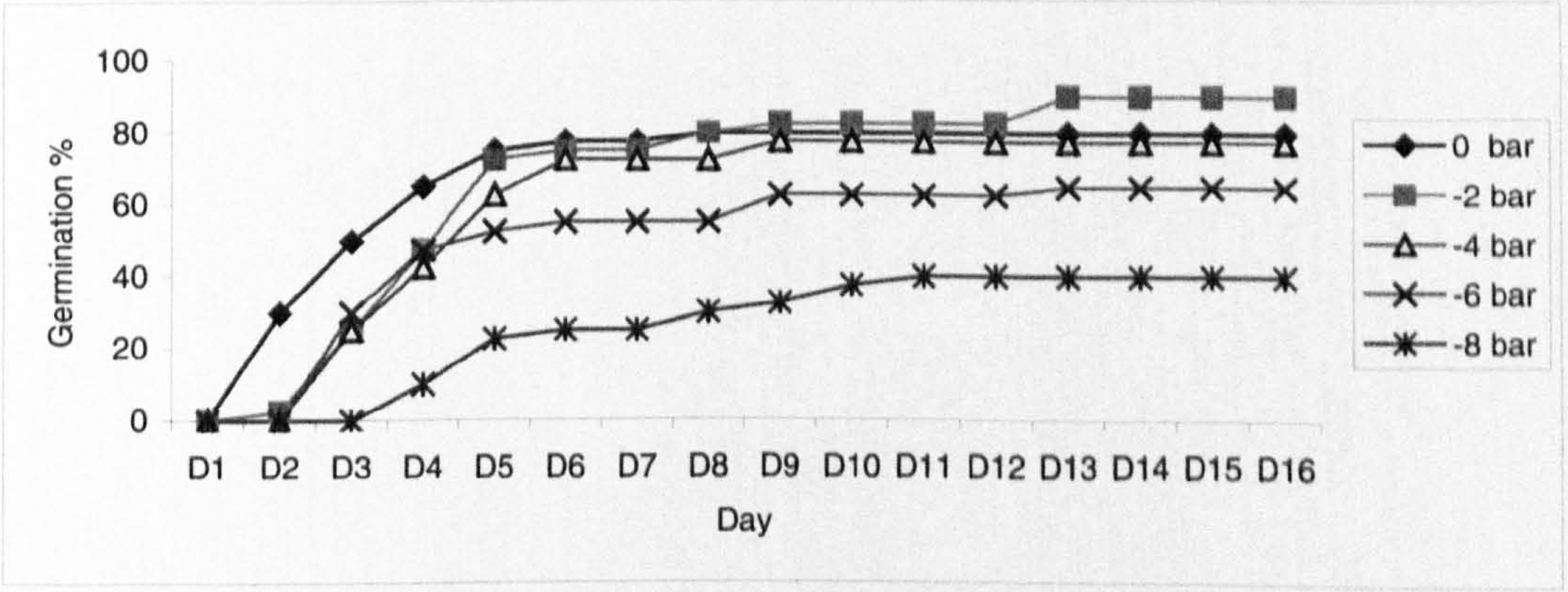

Fig. 6.23: Effect of moisture stress on germination percentage of *Verbesina encelioides*

5.4 DISCUSSION:

In general it can be seen from the results an increase in moisture stress resulted in a significant decrease in germination percentage of most species. This effect differed considerably from one species to another (Table 6.3).

From the Table 6.3 there were some species that were not statistically effected by –8 bar moisture stress. These include : *Abutilon pannosum, Achillea fragrantissima* and *Cassia italica.* The other species can be divided to three groups: -

- Highly moisture sensitive species: Species effected by –2 - -4 bar moisture stress:

Aerva javanic, Atriplex leucoclada and *Lasiurus scindicus*

- Moderately moisture sensitive species: Species effected by –4 - –6 bar moisture stress:

Aloe vera, Datura innoxia, Dodonea viscosa, Farsetia aegyptia, Farsetia aegyptia, and *Rhazya stricta*

- Slightly moisture sensitive species: Species effected by –8 bar or more moisture stress:

Artemisia herba alba, Artemisia judaica, Anvillea garcini, Cassia occidentalis, Cassia senna, Peganum harmala, Pulicaria crispa, Rumex villosa and *Verbesina encelioides.*

Table 6.3, Suggests how the combination of temperature and moisture stress may determine germination time in the field in Saudi Arabia.

	Germination at low temperature	Germination at high temperature
moisture sensitive	*Datura innoxia* (Could germinate in February?)	*Rhazya stricta* (Could germinate in March or April?)
Less moisture sensitive	*Anvillea garcini* (Could germinate in December?)	*Achillea fragrantissima, Cassia italica, Cassia occidentalis, Cassia senna and Peganum harmala.* (Could germinate in April or May?)

Table 6.3. Effect of temperature and moisture stress on likely germination dates.

	0 bar	-2bar	P*	-4bar	P*	-6bar	P*	-8bar	P*	%-8 bar to 0bar
ABUTLON PANNSOUM	22.5[a]	10[a]	0.524	5[a]	0.222	17.5[a]	0.967	10[a]	0.524	44.4
ACHILLEA FRAGRANTISSIMA	87.5[a]	95[a]	0.513	95[a]	0.513	95[a]	0.513	92.5[a]	0.817	105.7
AERVA JAVANICA	70[a]	35[b]	0.030	22.5[b]	0.003	10[b]	0.000	2.5[b]	0.000	3.6
ALOE VERA	100[a]	92.5[a]	0.676	95[a]	0.897	75[b]	0.004	17.5[b]	0.000	17.5
ANVILLEA GARCINI	30[a]	30[a]	1.000	40[a]	0.558	38[a]	0.778	10[b]	0.052	33.3
ARTEMISIA HERBA ALBA	65[a]	70[a]	0.990	62.5[a]	0.999	42.5[ab]	0.280	22.5[b]	0.010	34.6
ARTEMISIA JUDAICA	75[a]	75[a]	1.000	7.3[a]	0.999	65[a]	0.801	23[b]	0.000	30.7
ATRIPLEX HALIMUS	25[a]	27.5[ab]	0.998	17.5[a]	0.898	15[a]	0.762	50[b]	0.064	200.0
ATRIPLEX LEUCOCLADA	40[a]	23[b]	0.013	20[b]	0.029	15[b]	0.006	13[b]	0.002	32.5
CASSIA ITALICA	55[a]	30[a]	0.056	58[a]	0.998	38[a]	0.263	40[a]	0.401	72.7
CASSIA OCCIDENTALIS	100[a]	100[a]	1.000	92.5[a]	0.810	92.5[a]	0.810	47.5[b]	0.000	47.5
CASSIA SENNA	65[a]	73[a]	0.916	75[a]	0.798	58[ab]	0.916	33[b]	0.018	50.8
DATURA INNOXIA	64[a]	60[a]	0.989	60[a]	0.989	0[b]	0.000	0[b]	0.000	0.0
DODONEA VISCOSA	68[a]	70[a]	0.997	50[a]	0.185	20[b]	0.000	0[b]	0.000	0.0
FARSETIA AEGYPTIA	97.5[a]	97.5[a]	1.00	92.5[ab]	0.905	75[bc]	0.011	67.5[c]	0.001	69.2
LASIURUS SCINDICUS	90[a]	70[a]	0.155	20[b]	0.000	15[b]	0.000	5[B]	0.000	5.6
PEGANUM HARMALA	65[a]	65[a]	1.000	57.5[a]	0.936	55[a]	0.840	17.5[b]	0.002	26.9
PULICARIA CRISPA	75[a]	75[a]	1.000	60[a]	0.407	50[a]	0.058	18[b]	0.000	24.0
RUMEX VILLOSA	97.5[a]	100[a]	0.973	95[a]	0.973	87.5[a]	0.171	57.5[b]	0.000	59.0
RHAZYA STRICTA	40[a]	17.5[a]	0.066	37.5[a]	0.996	10[b]	0.006	10[b]	0.006	25.0
VERBESINA ENCELIOIDES	80[a]	90[a]	0.896	78[a]	0.999	65[ab]	0.674	40[b]	0.020	50.0

* Compared with deionised water (0 bar) treatment

Table 6.4: Effect of moisture on germination percentage of Saudi native species. P values for comparisons with 0 bar control are given in italic. Values within rows with the same superscript letter are not significant.

In conclusion, the results of the present work strongly suggest that some Saudi indigenous plants have a good degree of drought tolerance in germination stage.

CHAPTER 7

7. EFFECT OF COMPETITION IN A SOWN COMMUNITY OF SAUDI NATIVE SPECIES

CHAPTER 7

7. EFFECT OF COMPETITION IN A SOWN COMMUNITY OF SAUDI NATIVE SPECIES

7.1 -INTRODUCTION

The effects of competition between plants was probably first observed by Neolithic farmers. Any gardener knows that a great range of species can be grown in a garden as long as the competing species are grassed out. Some of the first scientific studies of the subject can be found in the work of De Crescentiis (1305) and DeCandolle (1820). Inspired by the logic of Malthus (1798), Darwin (1859) wrote extensively about competition as important selective agent for all types of organisms. Early botanists and vegetation ecologists considered interspecific competition to be an integral part of nature. Agricultural and forestry practices have long attempted to minimize the effects of competition from undesired plants. One of the first treatments of the subject was published by Clements (1929). This seminal work contains a detailed description of the early history of plant competition as well as a wealth of empirical information (Grace and Tilman 1990).

Over the past two decades, experimental field evidence has accumulated to show that competition between plants in natural communities is a common, although not ubiquitous phenomenon (Connell,1983; Schoener, 1983; and Fowler 1986). Yet there is still much debate over what determines which species will be successful in competition under different environmental conditions, and the relative importance of competition itself in determining the nature of plant communities (Newman, 1973; Grime, 1977; Tilman 1982, del Moral, 1983; Grime, 1987; Wilson and Keddy,1986; Thompson, 1987).
Many species seem to be restricted to habitats not because they grow better there but because that is the only habitat in which they escape competition sufficiently. Tolerance of extreme conditions often carries a sacrifice of growth rate and competitive ability (Sutherland et al., 1995). Competition occurs when adjacent plants are forced to share the

limited resources of a restricted area (de Wit 1960, Tilman 1982). Plants that first deplete resources may be considered superior competitors if they subsequently prevent adjacent plants from reaching their maximum potential productivity (de Wit 1960, Harper 1977, Grime 1979). Tilman (1987) emphasizes how ecological thought has been shaped primarily by quantitative models that summarize competitive effects in terms of plant size, without examining the underlying mechanisms

In most grassland ecosystems nutrient supply is one of the major factors affecting the species composition of the plant community (Kruijne et al. 1967, Elberse et al. 1983, Vermeer and Berendse 1983, Tilman 1984, 1988). An issue that has evoked much debate is the question of what plant features contribute to a high competitive ability under nutrient-poor conditions and what features do so in relatively nutrient-rich environments (e.g., Newman 1973 vs. Grime 1973, Thompson 1987 vs. Tilman 1987). Adaptation to environments where nutrient supply severely limits plant growth may follow two essentially different pathways: maximizing the assimilation of nutrients or minimizing the loss of nutrients. Tilman (1988) postulated that plant species adapt to nutrient-poor habitats by an increased biomass allocation to structures (i e, roots) that enhance nutrient absorption. Other authors have stressed the significance of plant features that reduce nutrient losses from the plant (Grime 1979, Chapin 1980, Berendse and Elberse 1990).

One of the techniques for investigating plant competition involves microcosm or "bottle" experiments. These have a long history in ecology, demonstrated by Woodruff's (1912) exploration of succession in hay infusion and Gause's (1934) studies on protozoan competition and predation. More recently, larger "microcosm" systems have allowed multi-generation experiments using simulated marine, stream, and terrestrial communities.

As biological models microcosms have played a central role in the development of contemporary ecological thought (Gause, 1934, Crombie 1945, Park 1948, 1954, Utida 1953, 1957, Huffaker 1958, Tilman 1977). From Gause's (1934) pioneering analysis of competitive exclusion to Huffaker's (1958) examination of a spatial resource and

Tilman's (1977, 1982) exploration of competitive mechanisms, microcosms analyses have provided essential insight into real-world ecology. Conversely, phenomena encountered in the field have been systematically examined in microcosms experiments, extending and refining understanding of both mechanism and process (e.g., Park 1954, Tilman 1977, Drake 1991, Lawer and Moring 1993). Extension of these model-driven insights to the field has been integral in the development of important themes within academic ecology. This interchange between laboratory and field studies is typified by recent microcosm models of competition (Tilman 1977, Kilham 1984. Tilman and Strener 1984, Prout and McChesney 1985, Grover 1988, Sommer 1991), predation (Utida 1957, Sommer 1988, Wilbur and Fauth 1990), community assembly (Hairston et al. 1968, Gilpin et al. 1986. Robinson and Dickerson 1987, Robinsons and Edgemon 1988, Drake 1991, Lawler and Morin 1993, Naeem et al. 1994), and landscape assembly (Drake et al. 1993, Drake et al. 1994, Grover and Lawton 1994).

It was only possible to undertaken this research in the UK on Saudi species by using microcosm models. However, numerous criticisms have been raised concerning the experimental disadvantages of microcosms (e.g., Grover and Lawton 1994, Carpenter 1996, Drake et al. 1996, Bogaard et al. 1998 and Lawton et al. 1998). Often these criticisms derive from several of the previously mentioned benefits of experimental microcosm, including simplification, control of scale and environmental effects, the lack of complexity and reduction in spatial heterogeneity.

All experimentation is conducted against a background of assumption. For example, many field experiments suffer from similar design constraints and are based on assumptions in a manner similar to microcosm studies. Inevitably experimentation hinges on controlling or reducing the number of variables under consideration to a manageable level. Criticisms of model studies, mathematical, biological or otherwise, based on arguments that nature can only be studied in situ (Drake et al. 1996). We acknowledge that when microcosm used as system-specific predictive models the inevitability of violating assumptions must be explicitly stated, and the resulting risk of error acknowledged.

An important factor in determining the creation of plant communities is competition for space and resources (Bullock 1996). Grime (1979) defined competition as:

"*The tendency of neighbouring plants to utilise the same quantum of light, ion of mineral nutrient, molecule of water, or volume of space*" These words define competition in terms of its mechanisms rather than effects.

According to (Newman 1973; Huston and Smith 1987; Tilman 1988) the nature of competition itself changes according to the prevailing conditions and the nature or the plants. The rapid establishment of competitive and undesirable species in the vegetation might prevent the colonisation of desirable species or out compete established species for resources (Hansson & Fogelfors, 1998).

Cover of established plants may also however protect seedlings from abiotic extremes, such as moisture stress or unsuitable temperature (Callaway 1995). Such facilitation can outweigh negative competitive effects of other plants (Brooker & Callaghan 1998). Nurse plants might help the establishment of sown species by suppressing more competitive species and /or ameliorating a harsh abiotic environment(Choi & wali 1995; Ray & Brown 1995). However practical experience and resent studies suggest that the presence of competitive nurse species is often undesirable.

A more difficult task is to recognize functional types that reflect the dynamic relationships of plants with other plants, with resources, with herbivores and with disruptive effects of climatic extremes and human interference on vegetation development. Attempts to achieve this objective can be classified into two types; two-strategy models, which propose two extremes of adaptive specialisation in plants and Three-strategy models (Grime, 2001). Involving (competitors (C), stress tolerators (ST), and ruderals (R)) of universal occurrence and with distinctive traits. The defining characteristic of C,ST and R can be seen in Table (7.1).

Table 7.1: Key characteristics of the three primary strategies of Grime (1976)

Strategy	Characteristics
Competitors	Vigorous vegetative growth where resources permit, often large growing, tall or widespreading, respond dramatically to nutrient addition may decline where local resource (water, nutrients, light) exhaustion occurs. Often depend more heavily in their habitats on vegetative spread than recruitment from seed.
Stress tolerators	Vegetation growth slow, plants tend to produce limited standing growth, response to nutrient addition far less marked. Naturally occur in habitats where resources required for growth are in limited supply.
Ruderals	Grow vigorously, but are short lived, often annuals persistence depends upon successful seed production and germination. Successful germination often requires significant habitat disturbance extensive underground storage organs are uncommon.

Grimes CSR theory can be summarized in Table 7.2 in terms of predicted competitive outcomes in vegetation, subject to varying intensities of disturbance and environmental stress.

Table 7.2: Predicted outcomes in vegetation using Grimes models:

	Productive regularly disturbed	Productive rarely disturbed	Non productive regularly disturbed	Non productive rarely disturbed
Ruderals	**Dominate**	Replaced by competitors	**Specialised spp. Dominate**	Decline except where specialised
Competitors	Held in check	**Dominate**	Eliminated	Held in check
Stress tolerators	Eliminated	Outcompeted by competitors	Only specialised spp.	**Dominate**

7/ EFFECT OF COMPETITION IN A SOWN COMMUNITY OF SAUDI NATIVE SPECIES

In this study the effects of competition of some indigenous Saudi Arabia species and common urban grass at different irrigation and nutrients regimes were studied to understand how these act on germination, emergence and growth, using microcosms as models within a glasshouse. This research was undertaken to provide base-line data for the creation Saudi native species as a sown community in nature-like landscapes. The study was based on the hypotheses that competition is likely to be most severe at high densities of grass under fertile and moist soil conditions. Specific objectives of the study were as follows:

- To investigate the growth and diversity of **a sown community** of Saudi native species in response to grass competition and different treatments of nutrients and irrigation frequency.
- To investigate the effect of grass competition, nutrients and irrigation frequency on the emergence, survival and growth of **each forb species** in the sown community.

It was anticipated that the results would indicate how these human made communities might be established and managed under actual Saudi conditions. The requirements for successful establishment of such communities are unknown at present.

7.2-MATERIAL AND METHODS

A microcosm approach was used to investigate competition in some mixes of Saudi native species (Table: 7.3), using species, which had been successfully germinated in earlier studies. *Lolium multiflorum* a common grass was included as grass component. A glasshouse environment was used to simulate the climatic conditions experienced in the Riyadh area of Saudi Arabia. An air temperature of between 20°C to 30°C was maintained which corresponds to the spring season in Saudi Arabia. Species were grown in 400 mm diameter pots filled with sharp sand. A drip irrigation system was established using spaghetti leads drip emitter in each pot (fig. 7.2).

The study looked at the outcome of competition in the first 5 months after sowing (from May 2001 to October 2001) across a series of treatment gradients. The treatment used were as follows, three different densities of grass competition (none, low and high), 3 nutrients treatments (low, medium and high) and 3 irrigation frequency (low, medium and high). This resulted in twenty-seven (3x3x3) treatment combination as shown in Table 7.4. Each treatment combination was replicated four times. The replicates were rotated within the glasshouse in a clockwise manner in weeks 5, 10 and 15.

Achillea fragrantissima	Small shrub	*Farsetia aegyptia*	Small shrub
Artemisia judaica	Small shrub	*Peganum harmala*	Perennial forb
Cassia italica	Small shrub	*Rumex villosa*	Annual forb
Cassia occidentalis	medium shrub	*Verbesina encelioides*	Annual forb
Cassia senna	Small shrub		
Datura innoxia	Annual forb	*Lolium multiflorum*	Annual grass

Table 7.3: Species in the experiment and their life form.

	Treatment(1)	Treatment(2)	Treatment(3)
Grass competition	0 seeds/pot	20 seeds/pot	40 seeds/pot
Nutrients	4 Tablets/pot*	8 Tablets/pot*	16 Tablets/pot
Irrigation frequency	once/3 weeks	once/fortnight	once/a week

* Broken in 16 perennials sub-tablets to improve evenness of nutrient distribution

Table 7.4 Treatments of the competition experiment.

Fig. 7.1 Osmocote plus tablet

In this experiment " *Osmocote plus" tablets* were used as the nutrient source. These tablets (N15+ P10+ K12 + Mg +Micro nutrients) were used provide six months of nutrient supply and were inserted 2.5 cm. under the sand surface. These tablets were inserted before sowing seeds, as at the rate of 0.5 tablet per litre sand (Each pot contained approximately 32 litres).

The seeds were collected between April 2000 until June 2000 in the Riyadh area of Saudi Arabia. As seeds were limited in number, a target number of four plants of each species per pot was decided upon, for ten species, forty plant in total excluding the grass in each pot. To achieve the target number of plants consideration was given to germination percentage of each species, plus an additional 50% for each species to avoid shortages. After emergence seedling numbers were corrected to four plants of each species by removal of additional plants (Table 7.5). *Cassia italica, Cassia occidentalis* and *Cassia senna* seeds were treated with sulphuric acid (98%) for 15 minutes prior to sowing.

The numbers of forbs present in all treatments were recorded at six-assessment dates (weeks 2,4,6,8,12,20). In week twenty above- and below-ground biomass were harvested and dried at 80°C to constant height and shoot and root were each weighed separately for each species.

	Seeds Treatment	Lab Ger. %	Seeds needed to get 4 plants	Seeds sown per pot (150%)	Seeds total for all pots
Achillea fragrantissima	None	87 %	5	$5 \times 1.5 \approx 8$	864
Artemisia judaica	None	50 %	8	$8 \times 1.5 = 12$	1296
Cassia italica	Sulp. Acid 15 min.	43.3%	10	10	1080
Cassia occidentalis	Sulp. Acid 15 min.	95 %	5	$5 \times 1.5 \approx 8$	864
Cassia senna	Sulp. Acid 15 min.	76.6 %	6	$6 \times 1.5 = 9$	972
Datura innoxia	None	83.3%	5	$5 \times 1.5 \approx 8$	864
Farsetia aegyptia	None	97 %	5	$5 \times 1.5 \approx 8$	864
Peganum harmala	None	96 %	5	$5 \times 1.5 \approx 8$	864
Rumex villosa	None	43 %	10	$10 \times 1.5 = 15$	1620
Verbesina encelioides	None	65%	7	$7 \times 1.5 \approx 11$	1188

Table 7.5 Number and treatment of sown seed.

Statistical analysis was undertaken using *SPSS version 10* to determine whether significant differences occurred at P=0.05, for the mean of all species at week 20. Data were square root transformed to improve normality and a two way ANOVA undertaken. Mean dry weights of the above and underground parts at the final harvest in October 2001, were subjected ANOVA, to determine whether significant differences occurred at P = 0.05. The means of shoot dry weight data were square root transformed, however the means of root dry weight data were $\log_e$ transformed, as were the means of plants height data. Where appropriate a post hoc test (LSD or Tukey Honestly significant difference) was undertaken to rank the means.

For individually species, statistical analysis was undertaken using *Microsoft Excel package* to determine whether significant differences occurred at P=0.05.
Data was square root transformed to improve normality and a two way ANOVA undertaken.

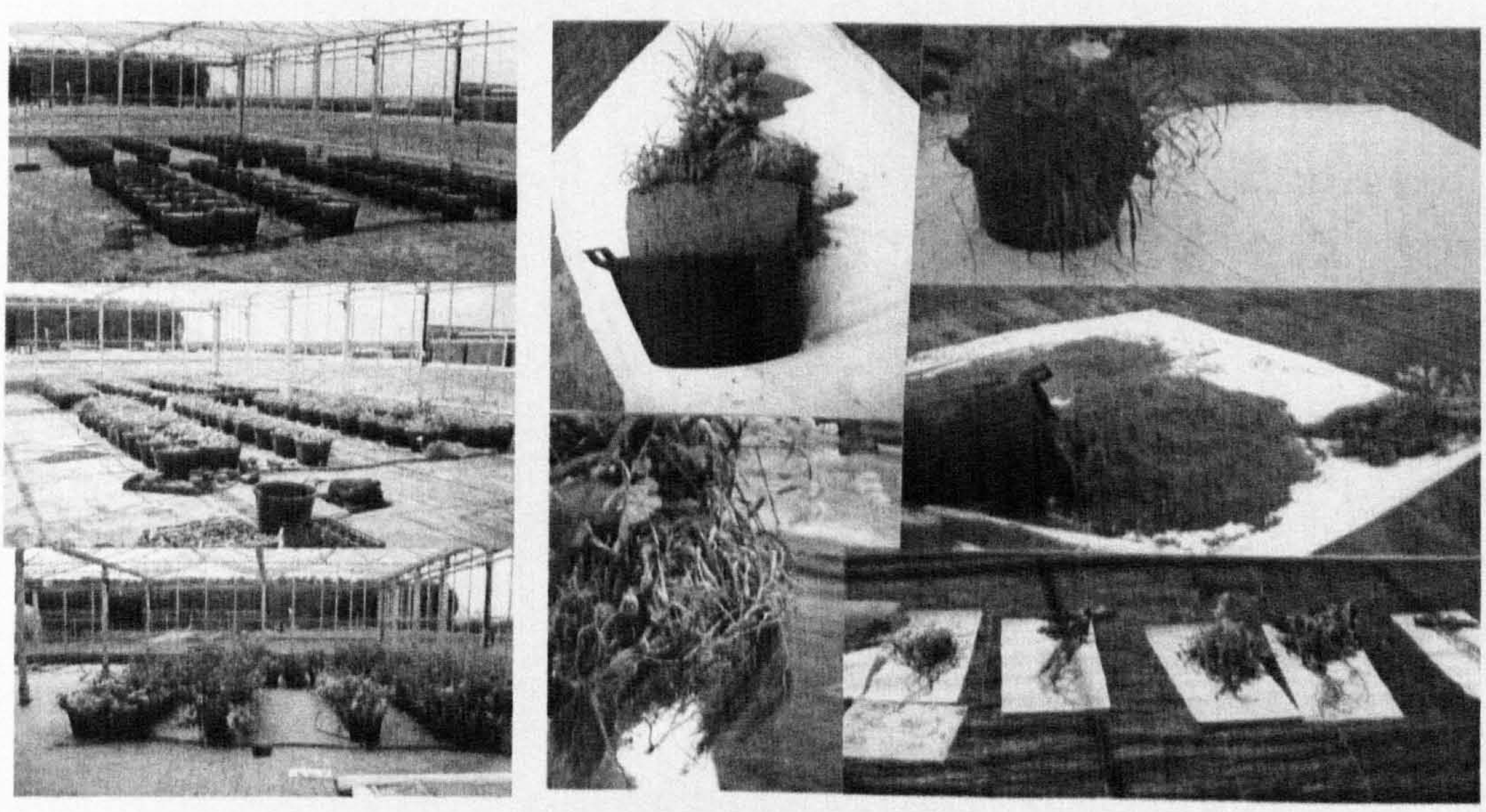

Fig. 7.2: The competition experiment.

7.3 RESULTS

7.3.1. MEAN OF ALL SOWN FORBS (THE COMMUNITY)

7.3.1.1 SEEDLING EMERGENCE AND SURVIVAL

i. Seedling numbers across the experiment

All of the species in this experiment had germinated successfully in previous studies. Seedling number, in terms of seedlings present at each assessment date were recorded from the second week in this experiment until biomass harvest in October 2001 at six-assessment date (week 2,4,6,8,12,20). It can be seen from Figures 7.3, 7.4 and 7.5 below, that the greatest number of seedling were present in the fourth week, with numbers declining until harvest. No attempt was made to distinguish between different emergence cohorts. In low and high grass treatments that were watered every twenty-one days, there was a sharp drop in seedling number after the sixth week (see Fig. 7.5).

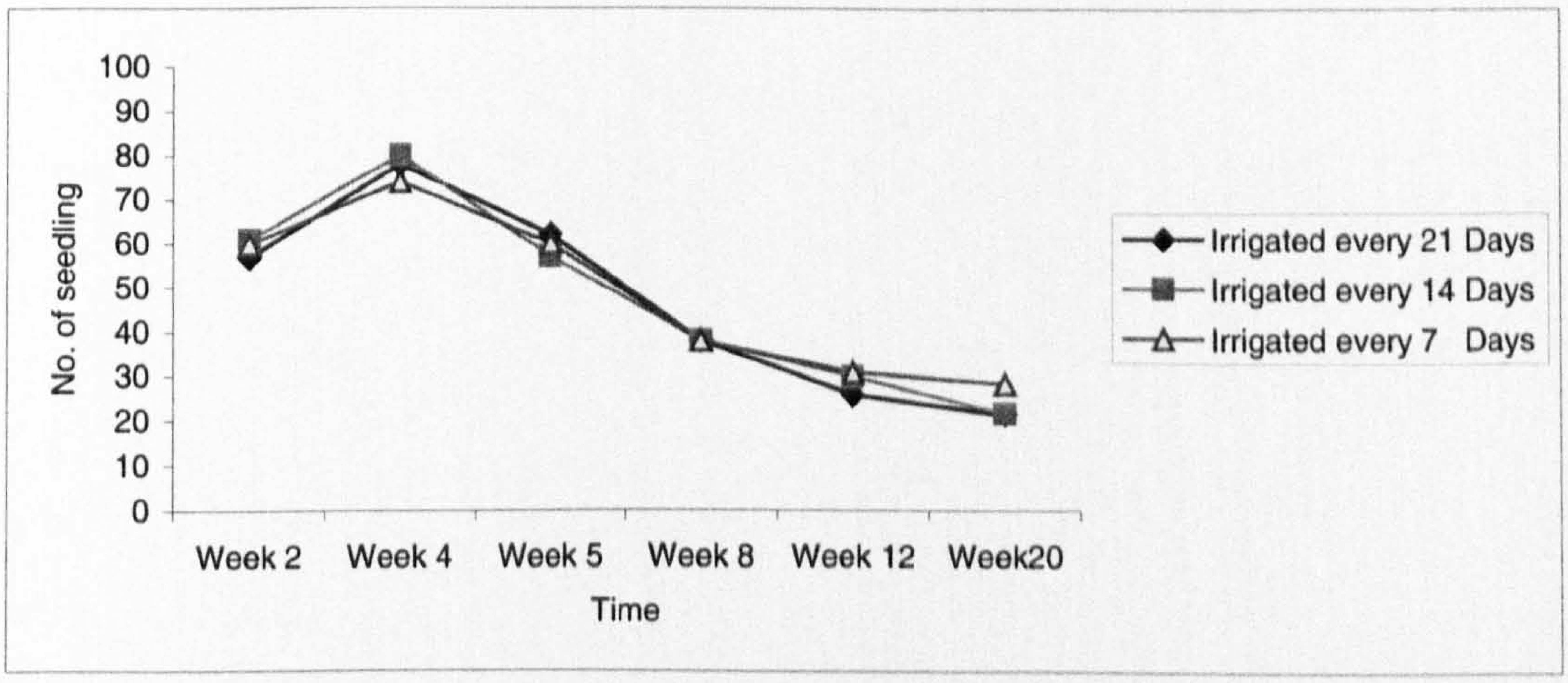

Fig.7.3: The mean number of sown forbs per pot in non-grass treatments, in weeks 2,4,6,8,12 and 20 of the experiment.

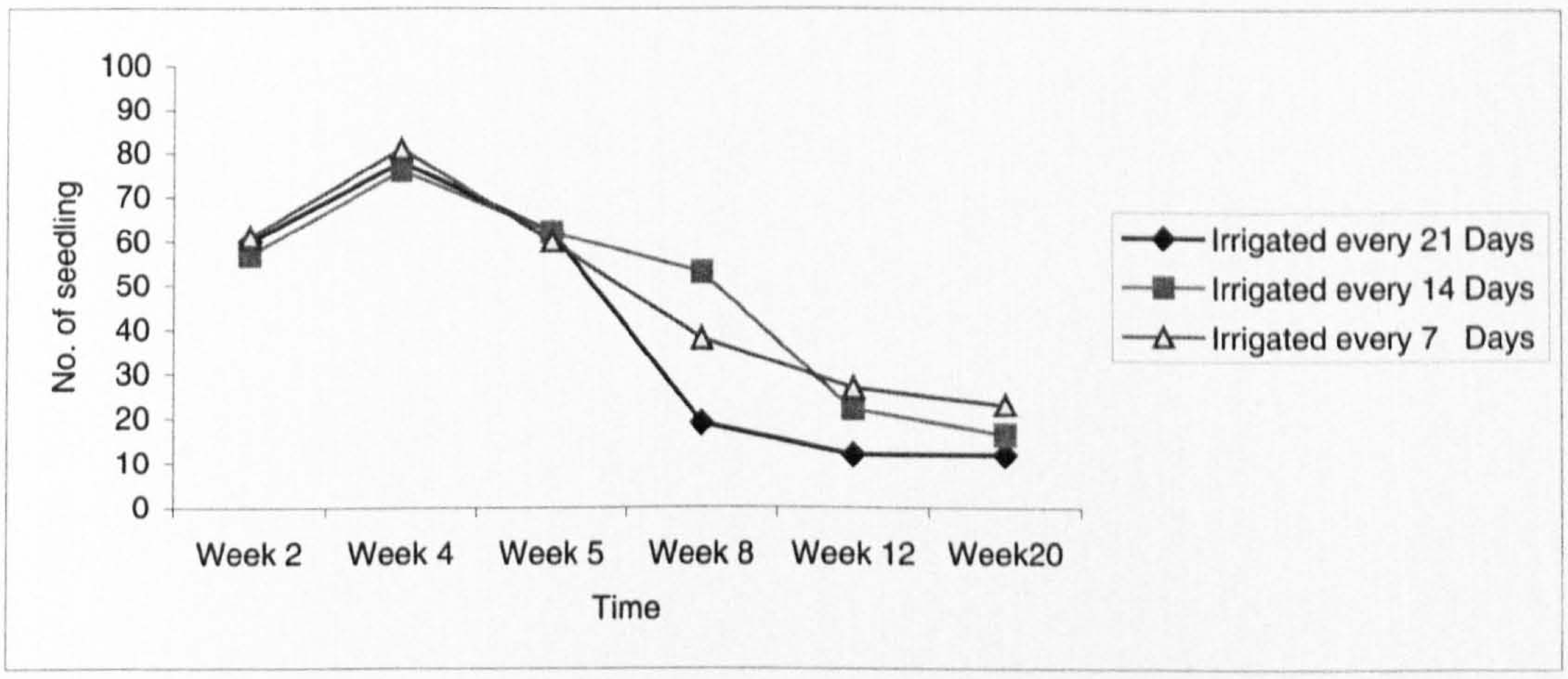

Fig.7.4: The mean number of sown forbs per pot in low grass treatments, in weeks 2,4,6,8,12 and 20 of the experiment.

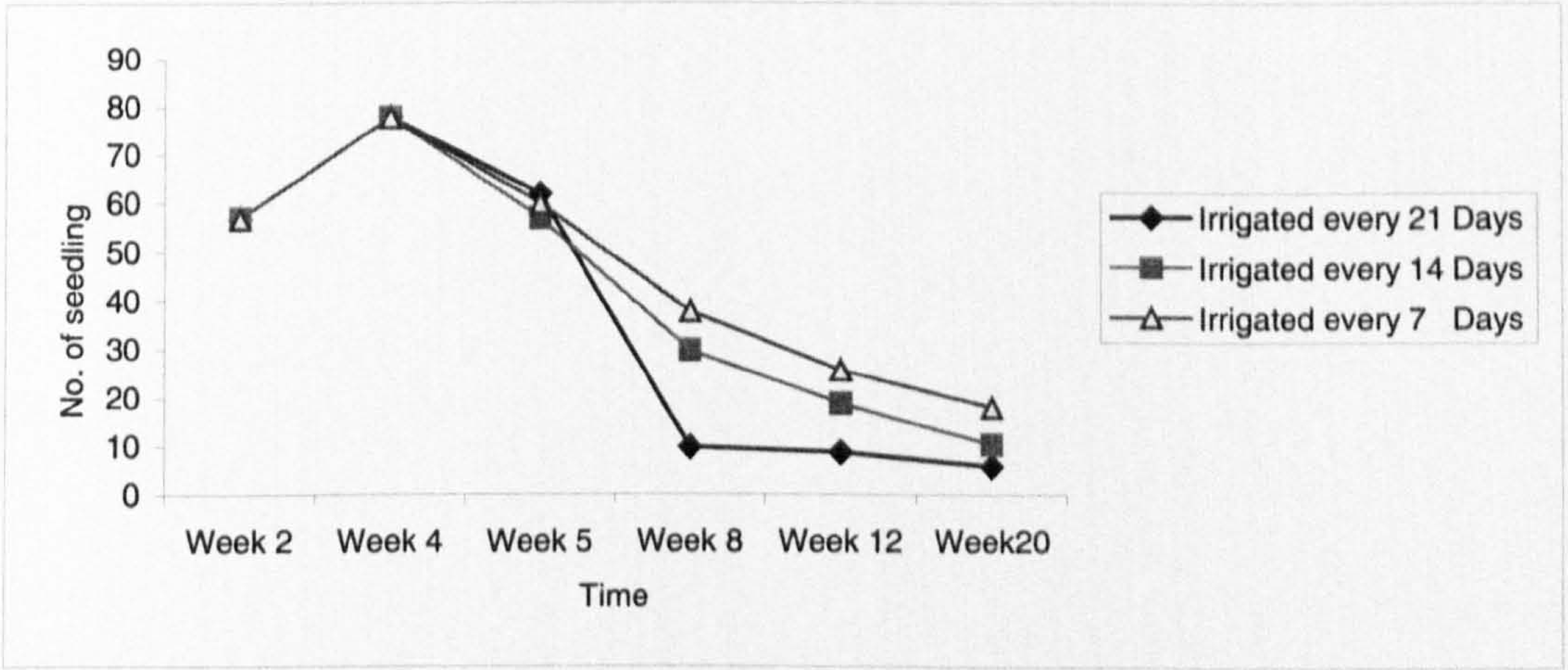

Fig. 7.5: The mean number of sown forbs per pot in high grass treatments, in weeks 2,4,6,8,12 and 20 of the experiment.

ii. Seedling survival at the end on the experiment

From Fig. 7.6 it can be seen that irrigation frequency has a significant impact on the mean number of sown forbs ($P<0.0001$). As irrigation frequency increases, more sown forbs survive. Grass have a significant effect on the mean number of sown forbs ($P < 0.0001$). As grass density increases the number of seedling sown forbs decreases. However the affect of nutrients on mean number of sown forbs was non-significant ($P > 0.05$).

In addition to mean data shown in figures 7.7 the effect of nutrients were also investigated statistically at different grass densities and irrigation frequencies. In all cases however nutrients were found not to have a significant effect ($p > 0.05$).

The greatest number of sown forbs was in the non-grass treatment watered every seven days, and the smallest number was in the high grass treatment watered every twenty-one days.

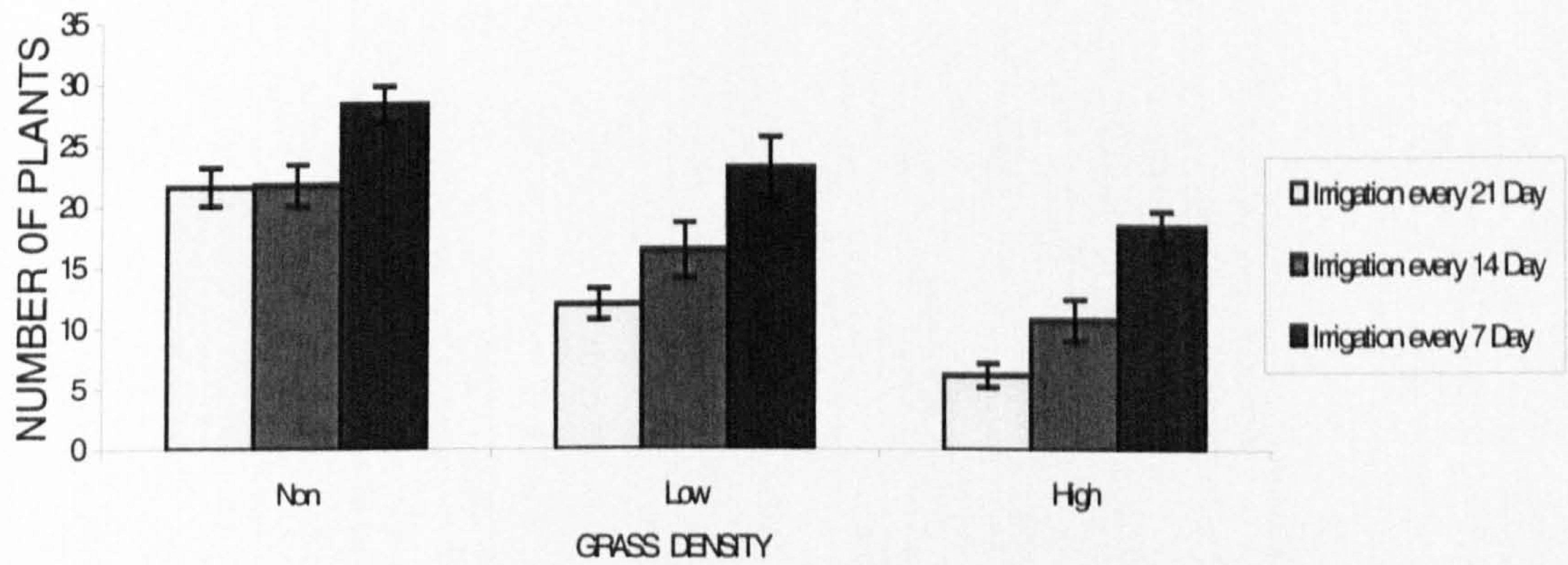

Fig 7.6: Effect of grass competition and irrigation frequency on number of surviving forbs (mean of all species). Error bars represent SEM

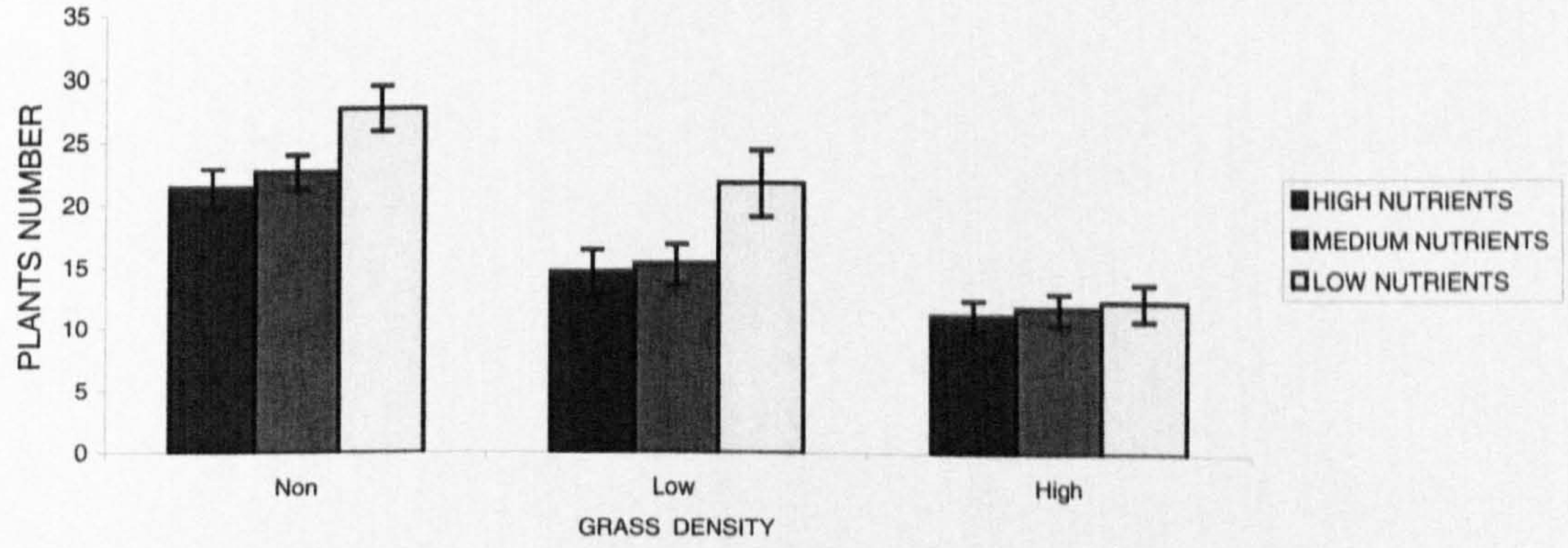

Fig 7.7: Effect of grass competition and nutrients on number of surviving forbs (mean of all species). Error bars represent SEM

iii. Percentage seedling survival

Survival of sown forbs (at week 20) as a percentage of the maximum number of emerged seedlings recorded (week four) can be seen from Fig. 7.8. Furthermore it can be seen that irrigation frequency has a significant positive impact on percentage of seedling survival of sown forbs ($P<0.0001$). As irrigation frequency increase, seedling survival increases. Grass have a significant negative effect on the percentage of seedling survival of sown forbs ($P < 0.0001$). As grass density increases percentage of seedling sown forbs decreases

Highest seedling survival of sown forbs was in the non-grass treatment watered every seven days, and the smallest percentage was in the high grass treatment watered every twenty-one days.

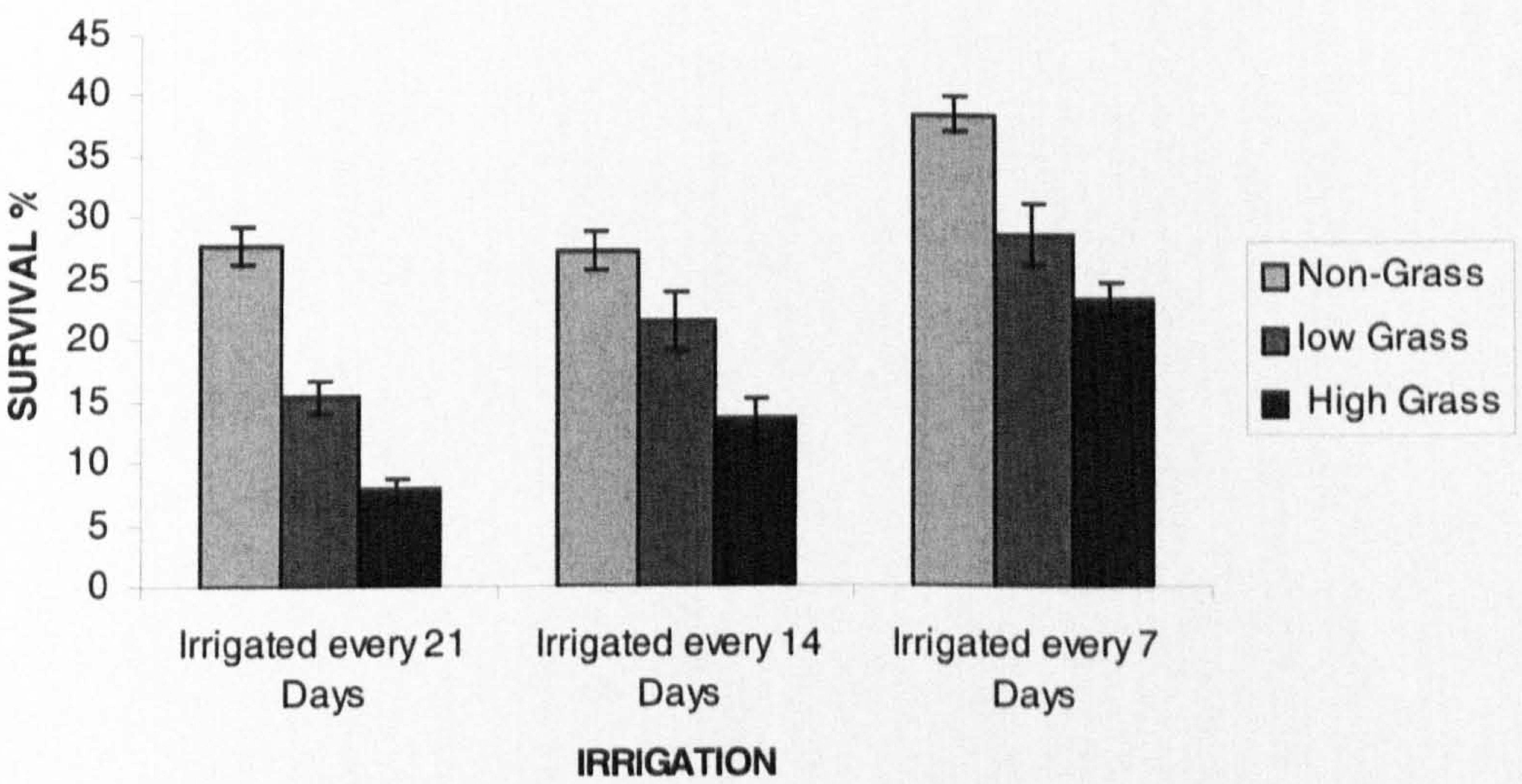

Fig 7.8: Mean survival of sown forbs (forbs presented at week 20 as a percentage of maximum number present (week 4). Error bars represent SEM

7.3.1.2 SEEDLING GROWTH

i. Shoot dry weight

From Fig. 7.9 it can be seen that irrigation frequency has a significant positive impact on the mean shoot dry weight of sown forbs ($P<0.0001$), as irrigation frequency increase, shoot dry weight increases. Grass had a significant negative effect on the mean of shoot dry weight of sown forbs ($P < 0.0001$). As grass density increases shoot dry weight of seedlings of sown forbs decreases. In addition, the affect of nutrients (Fig.7.10) on mean shoot dry weight of sown forbs was significant ($P < 0.0001$). The greatest shoot dry weight of sown forbs was in the non-grass treatment watered every seven days, and the smallest shoot dry weight was in the high grass treatment watered every twenty-one days.

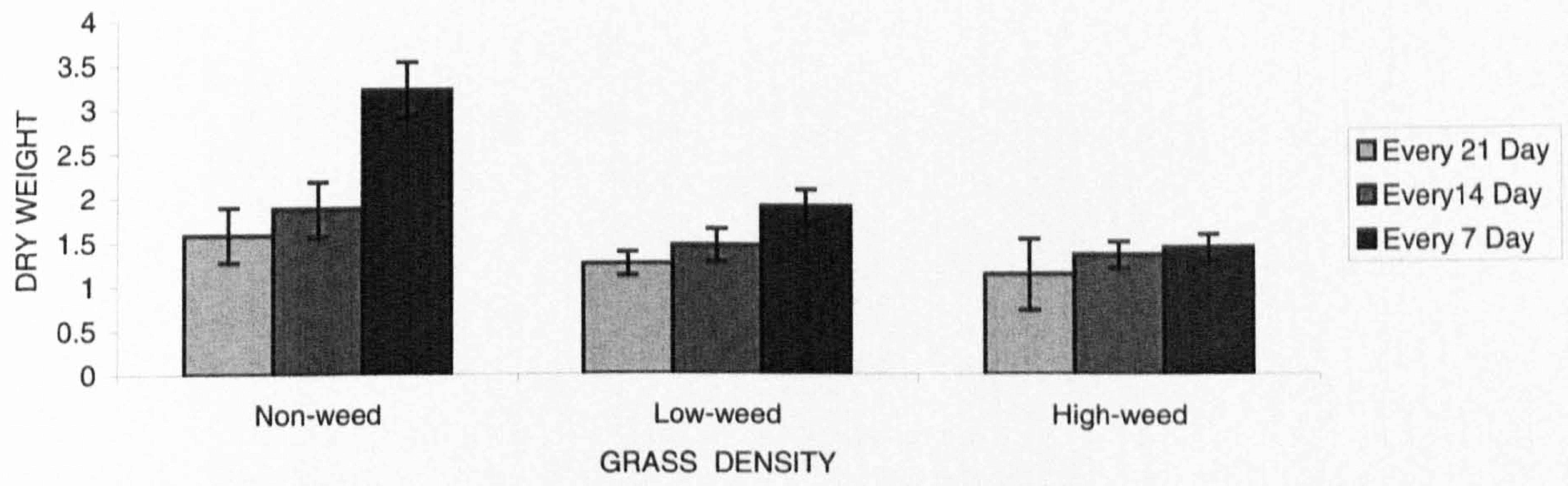

Fig 7.9: Effect of grass competition and irrigation frequency on shoot dry weight of sown forbs. Error bars represent SEM

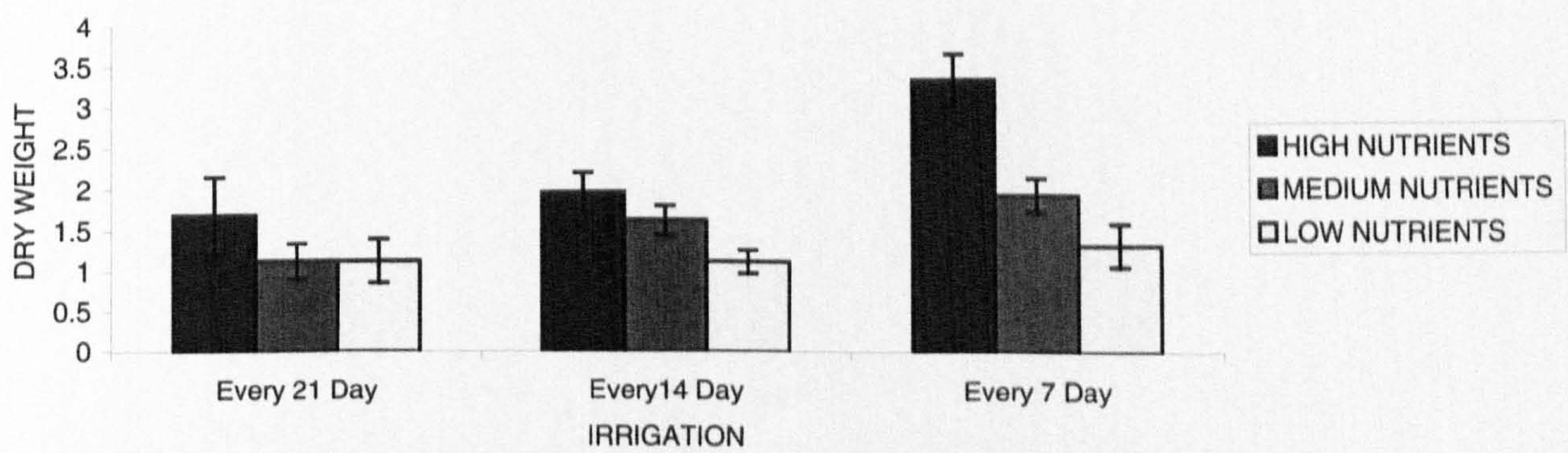

Fig 7.10: Effect of irrigation frequency and nutrients shoot dry weight of sown forbs. Error bars represent SEM.

ii. Root dry weight

From Fig. 7.11 it can be seen that irrigation frequency has a significant positive impact on mean root dry weight of sown forbs ($P<0.0001$), as irrigation frequency increases root dry weight increases. Grass had a significant negative effect on the mean root dry weight of sown forbs ($P < 0.0001$). As grass density increases root dry weight of seedling sown forbs decreases.

In addition, the affect of nutrients (Fig. 7.12) on mean root dry weight of sown forbs was significant ($P < 0.05$). The greatest root dry weight of sown forbs was in the non-grass treatment watered every seven days, and the smallest root dry weight was in the high grass treatment watered every twenty-one days.

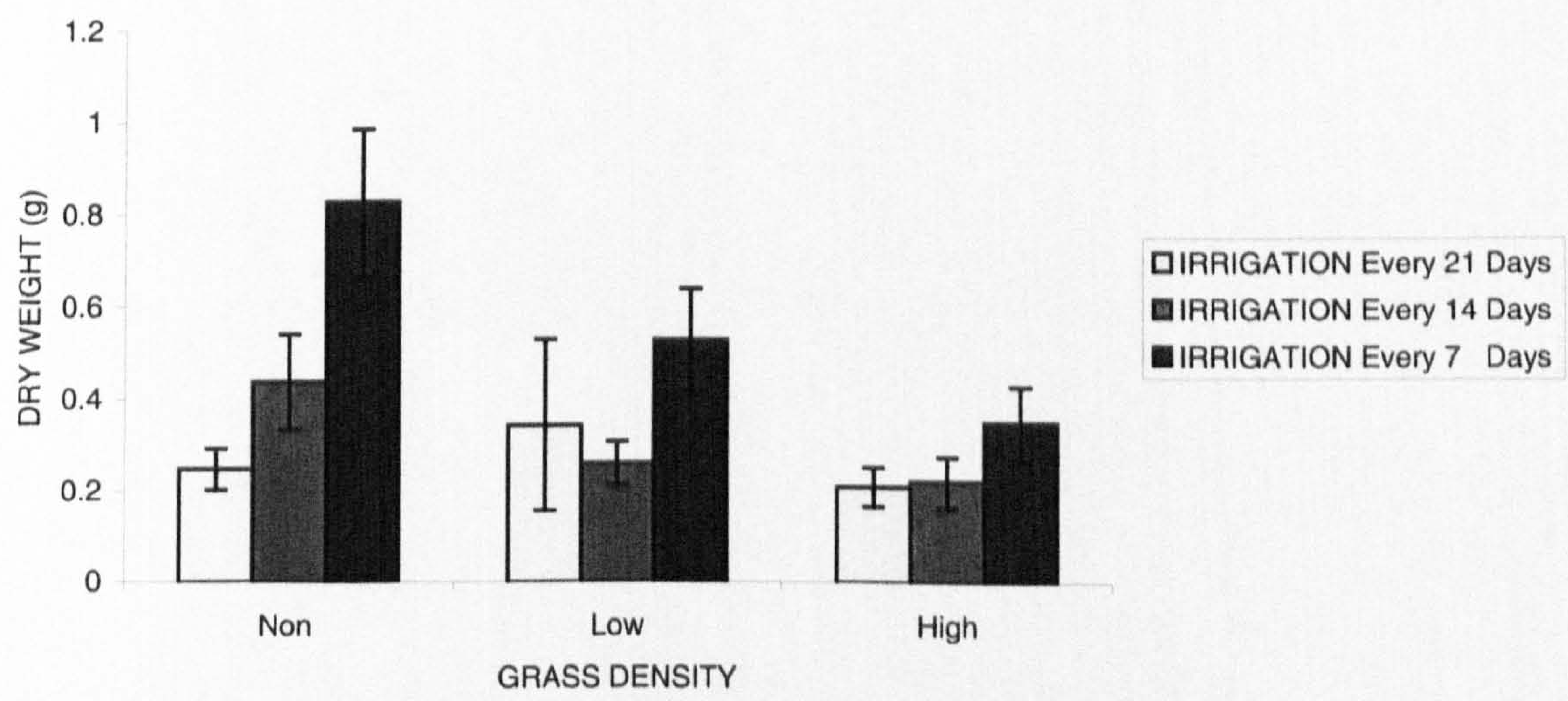

Fig 7.11: Effect of grass competition and irrigation frequency on root dry weight of sown forbs. Error bars represent SEM

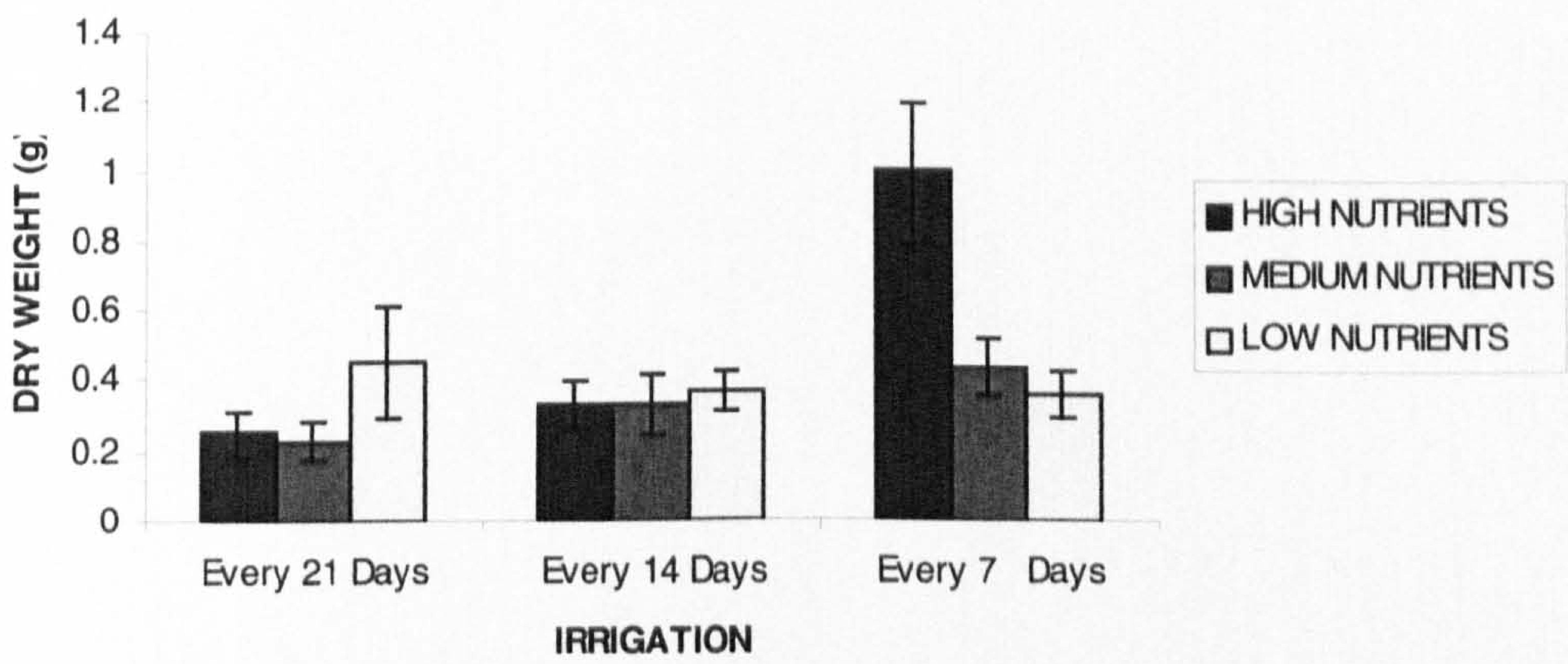

Fig 7.12: Effect of irrigation frequency and nutrients root dry weight of sown forbs. Error bars represent SEM.

iii. Plant height

From Fig.7.13 and 7.14 it can be seen that irrigation frequency has a significant positive impact on mean height of sown forbs ($P<0.0001$), as irrigation frequency increase, the height of sown forbs increases. In all cases however grass and nutrients were found not to have a significant effect on sown forb height ($p > 0.05$).

The tallest sown forbs were in the non-grass treatment watered every seven days, and the shortest plants were in the high grass treatment watered every twenty-one days.

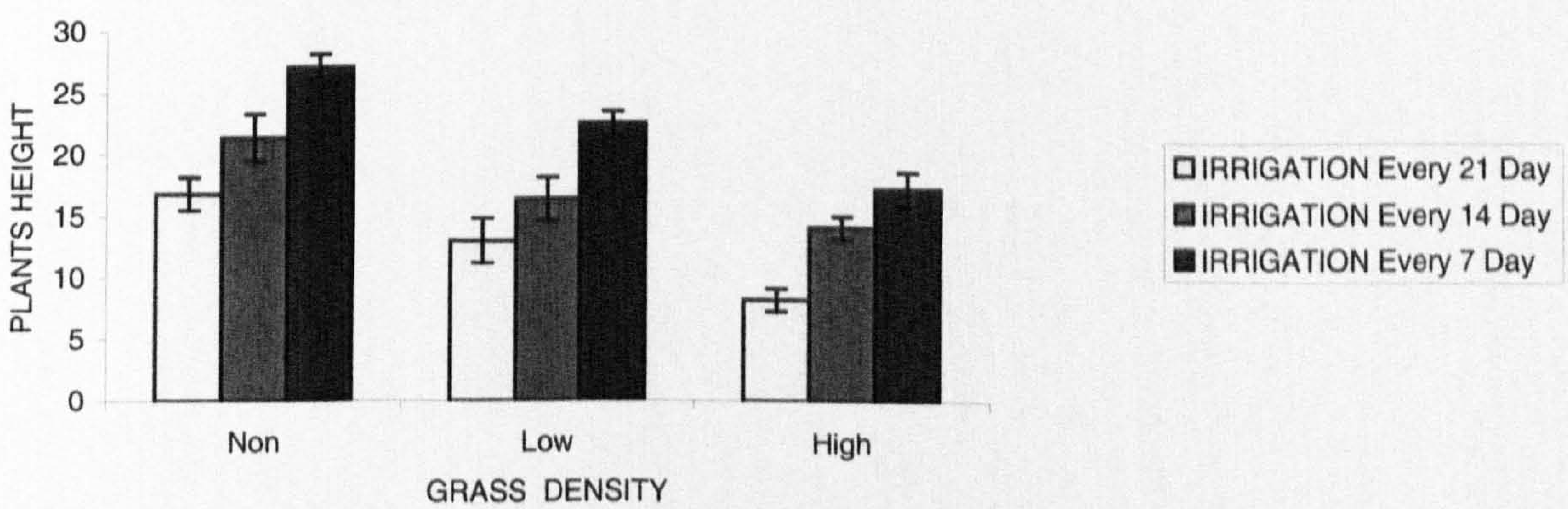

Fig 7.13: Effect of grass competition and irrigation frequency on height of sown forbs. Error bars represent SEM.

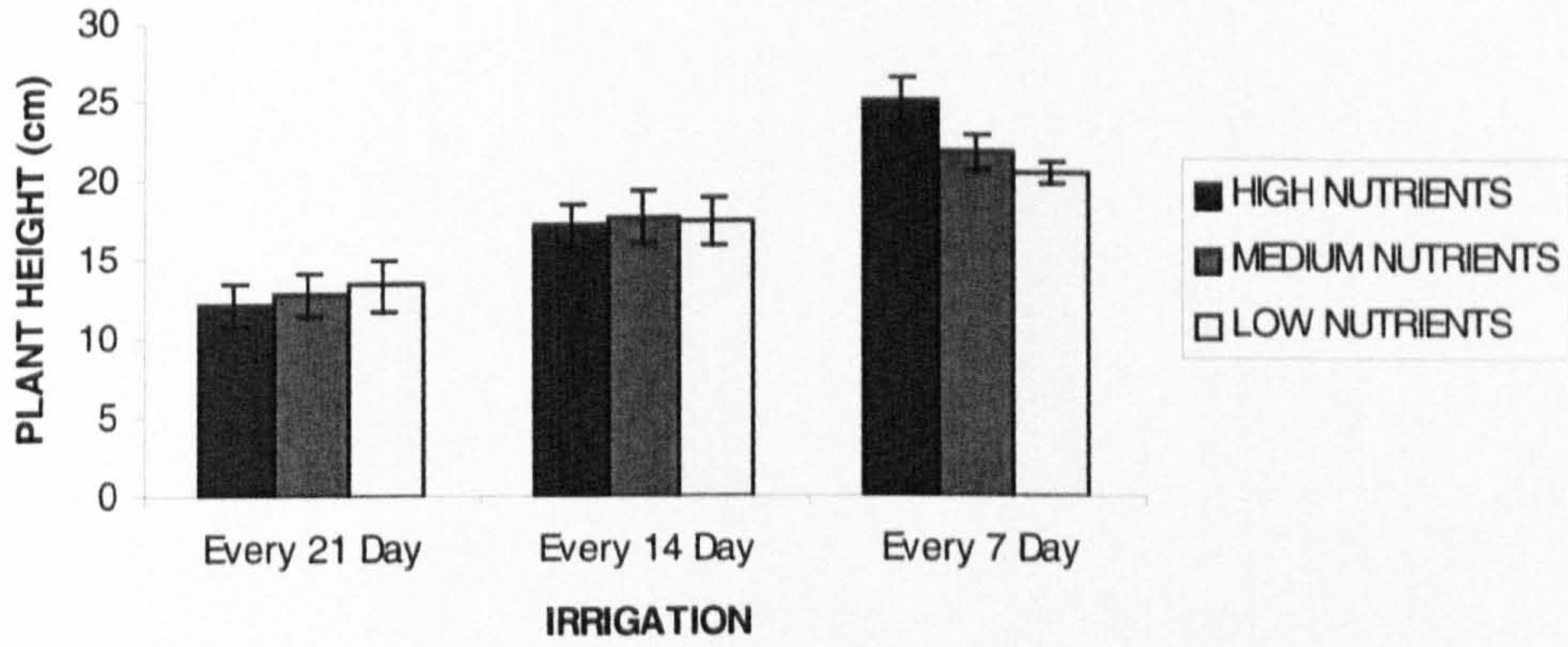

Fig 7.14: Effect of irrigation frequency and nutrients on height of sown forbs. Error bars represent confidence intervals

iv. Root : shoot ratio of sown forbs

In calculating mean root : shoot ratio for all sown forbs values for *Rumex* and *Verbesina* were excluded. These species are rapid growing ruderals and similar in many ways to the grass species used in the study. Irrigation frequency has a non-significant impact on the mean of root: shoot ratio of sown forbs ($p > 0.05$). Grass have significant negative impacts on the mean of root: shoot ratio of sown forbs ($p < 0.05$).

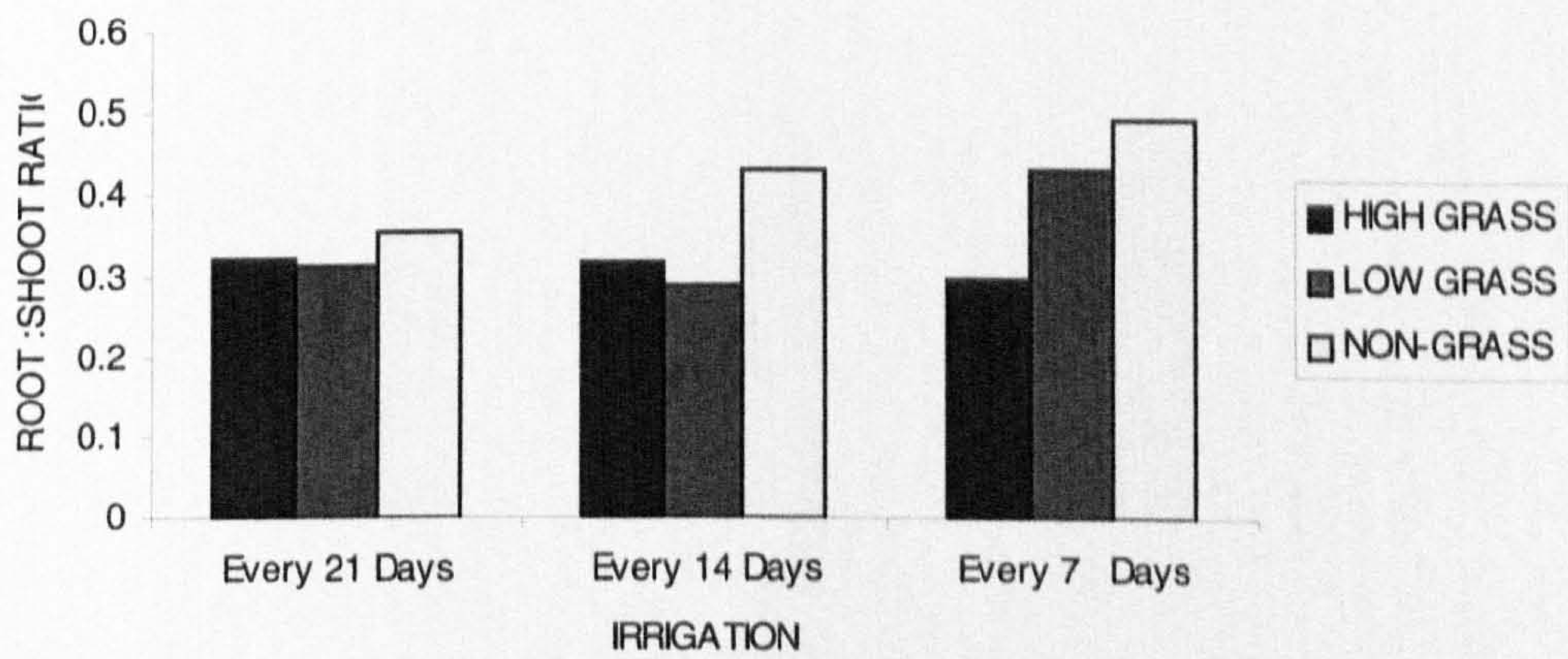

Fig 7.15: Effect of irrigation frequency and grass competition on root: shoot ratio of sown forbs. Error bars represent confidence intervals.

7.3.1.3 GRASS GROWTH

i. Grass shoot dry weight

From Fig.7.16 it can be seen that irrigation frequency has a significant positive impact on the mean shoot dry weight of the grass species used in the experiment (*Lolium multiflorum*) ($P<0.0001$). As irrigation frequency increases shoot dry weight increases. Density has a significant negative effect on mean shoot dry weight of individual grass ($P < 0.0001$). The greatest shoot dry weight of grass was in the low-grass treatment watered every seven days, and the smallest shoot dry weight was in the high grass treatment watered every twenty-one days.

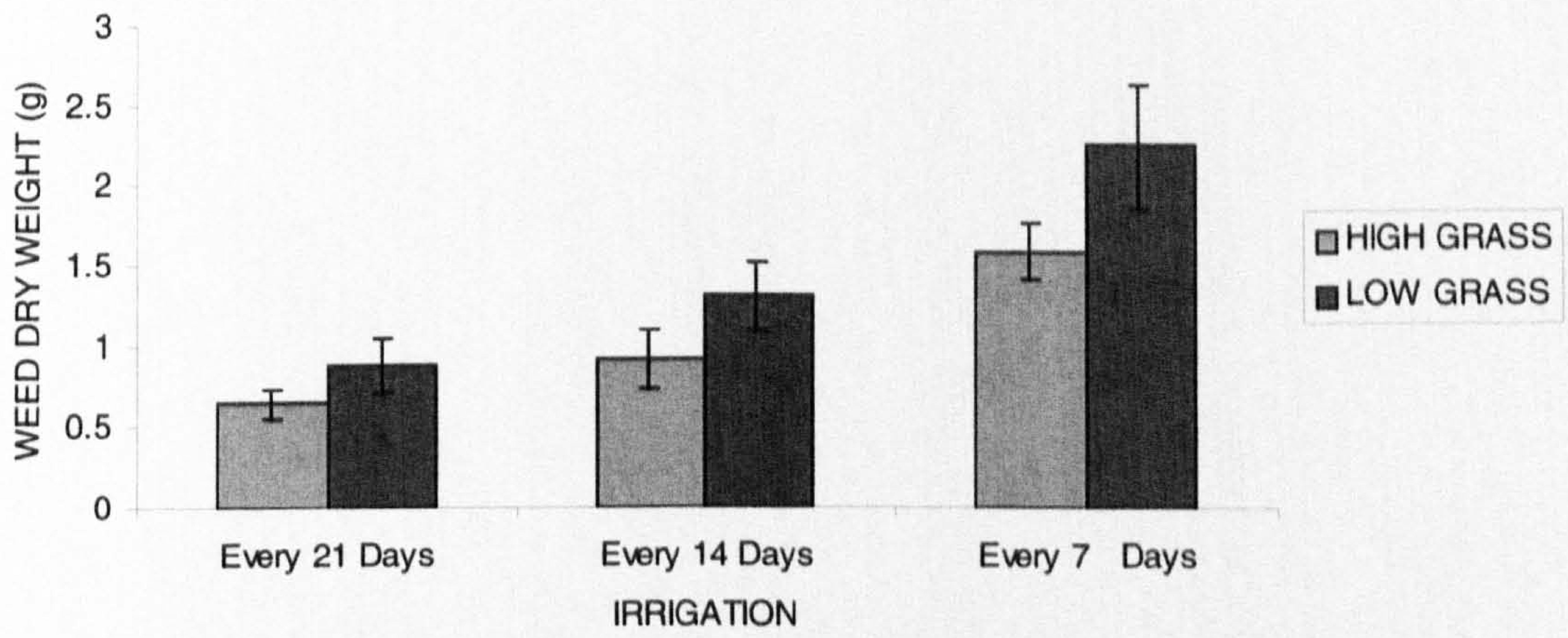

Fig 7.16: Effect of irrigation frequency and density on mean shoot dry weight per plant of *Lolium multiflorum*. Error bars represent confidence intervals

ii. Grass root dry weight

Irrigation frequency had a significant positive impact on mean root dry weight of grass ($P<0.0001$). As irrigation frequency increases, shoot dry weight increases. Density has a significant effect on the mean of root dry weight of grass ($P < 0.0001$). As grass density increases root dry weight of grass decreases (Fig.7.17).

The greatest root dry weight of grass was in the low-grass treatment watered every seven days, and the smallest root dry weight was in the high grass treatment watered every twenty-one days.

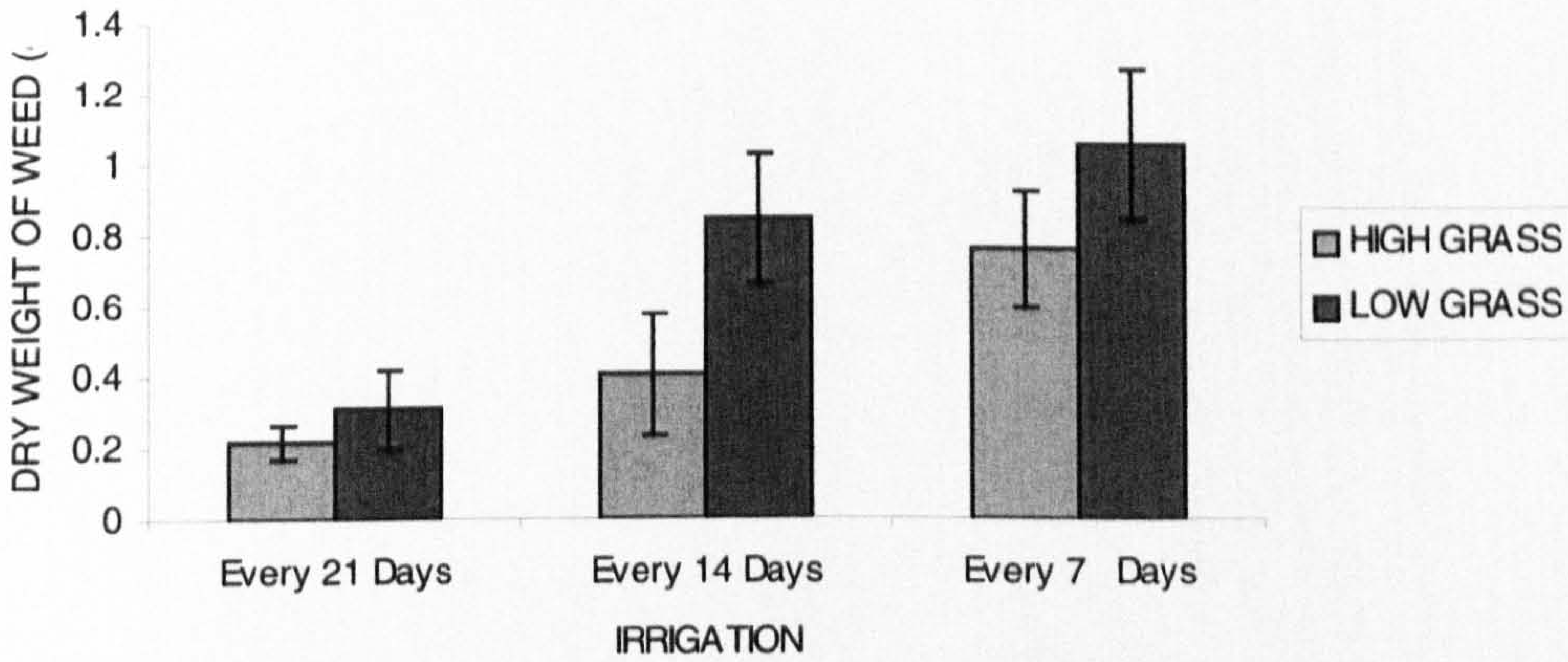

Fig (7.17): Effect of irrigation frequency and grass competition on mean root dry weight per plant of *Lolium multiflorum*. Error bars represent confidence intervals

7.3.1.4 GRASS AND SOWN FORBS

i. Shoot dry weight of grass and sown forbs

It can be seen from Fig. 7.18 that mean shoot dry weight of sown forbs responded much less to increasing irrigation than did the grass species.

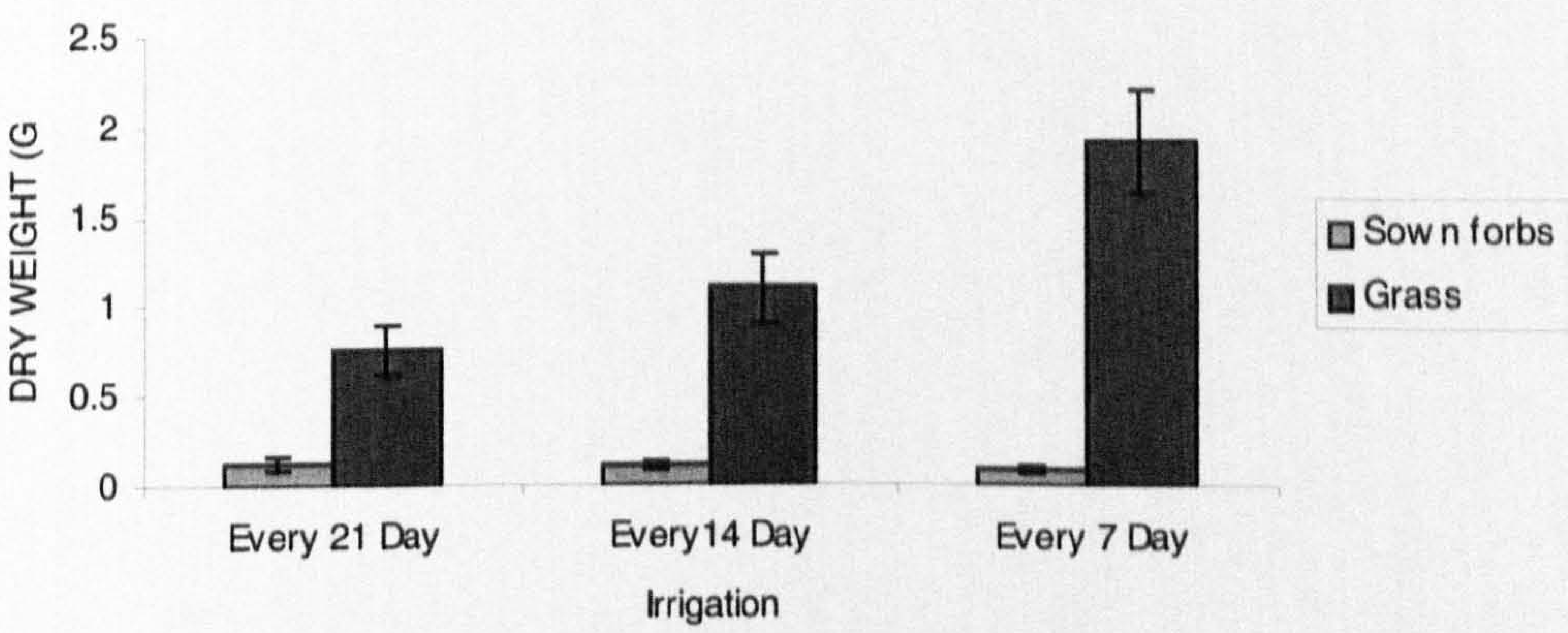

Fig. 7.18: The mean of shoot dry weight of sown forbs and grass (per plant) at the end of the experiment. Error bars represent SEM.

ii. Sown forb : grass ratio in terms of shoot dry weight

There were some differences between irrigation and grass treatments in shoot dry weight of sown forbs : grass ratio. It can be seen from Fig 7.19 below, that the treatment of high grass and irrigation frequency once every three week has the greatest sown forbs : grass ratio. The smallest ratio was with treatment of low grass and irrigation frequency once every week. In general as irrigation frequency increases the ratio of shoot dry weight of sown forbs : grass decreases.

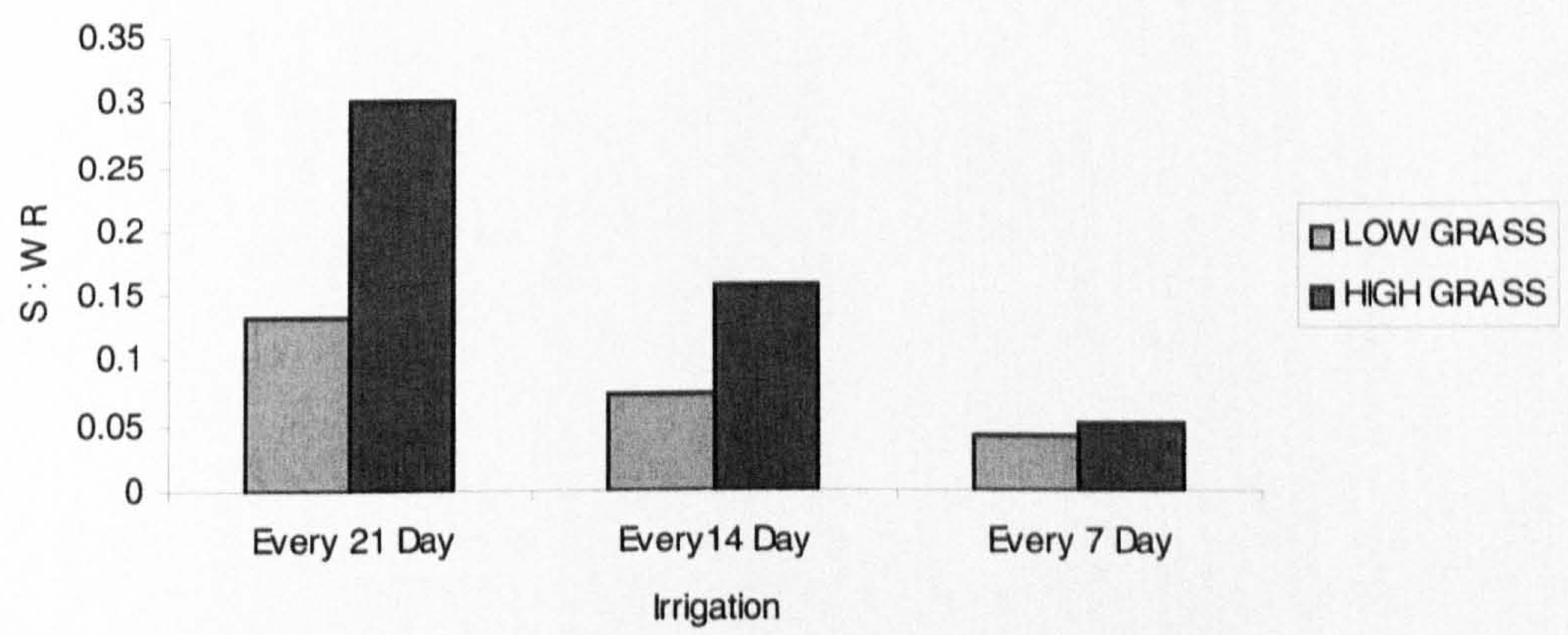

Fig. 7.19: The mean of shoot dry weight of sown forbs : grass ratio at the end of the experiment.

iii. Root dry weight of grass and sown forbs

It can be seen from Fig. 7.20 that mean of root dry weight of sown forbs at the end of the experiment was less in pots irrigated once every three week than in the other two treatments. Also the mean of root dry weight of grass was less in pots irrigated once every tree weeks than the other treatments. The greatest root dry weight of sown forbs was in pots irrigated once every week. The greatest of root dry weight of grass was in pots irrigated every week.

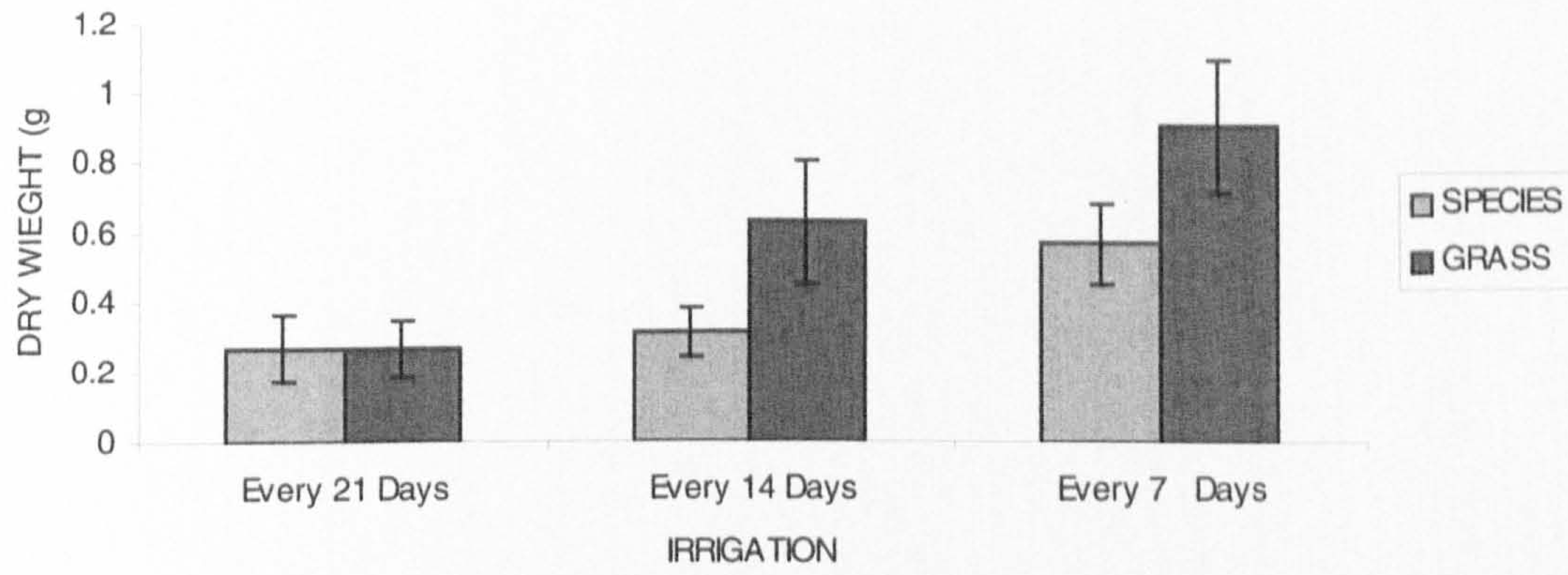

Fig. 7.20: The mean of root dry weight of sown forbs and grass (per plant) at the end of the experiment. Error bars represent SEM.

iv. Sown forb : grass ratio in terms of root dry weight

There were some differences between irrigation and grass treatments in terms of the ratio of root dry weight of sown forbs : grass. It can be seen from Fig 7.21 below, that the treatment of low grass and irrigation frequency once every two week has the greatest sown forbs : grass ratio. The smallest ratio was for low grass and irrigation frequency once every three week. In general as irrigation frequency increases root dry weight of sown forbs : grass ratio increases.

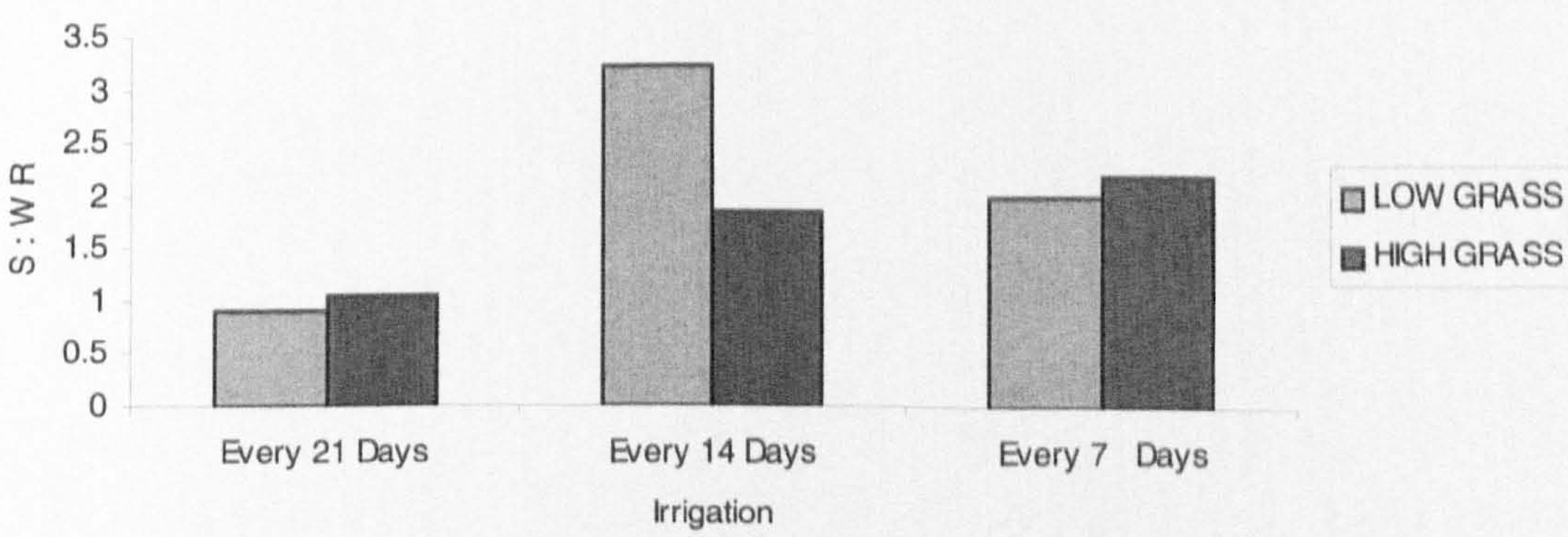

Fig. 7.21: The mean of shoot dry weight of sown forbs : grass ratio at the end of the experiment.

7.3.2. INDIVIDUAL SPECIES

7.3.2.1 SEEDLING SURVIVAL

i. Mean survival

There were large differences between sown forbs in terms of percentage mean survival. It can be seen from Figure 7.22, that the highest survival was in *Datura onnoxia* and the lowest survival was in *Peganum harmala*. The other species can be divided to three groups. First group of species (*Datura onnoxia, Rumex villosa,* and *Cassia occidentalis*) showed >70% survival. *Verbesina encelioides, Farsetia aegyptia,* and *Cassia senna* 65 – 35 %. The lowest group *Achillea fragrantissmia, Artemisia judaica, Cassia italica,* and *Peganum harmala* showed <15%.

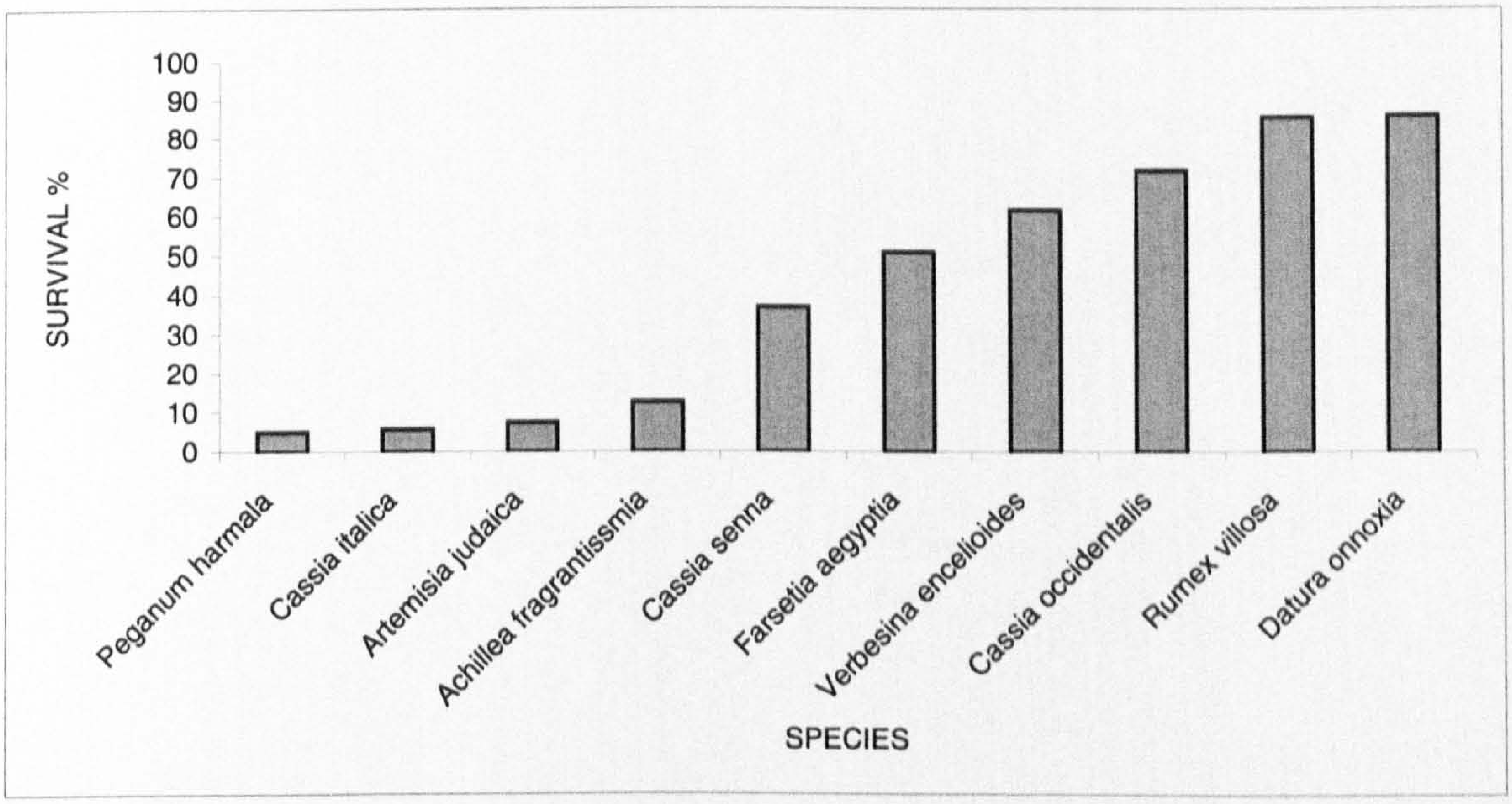

Fig. 7.22: Mean percentage survival of sown forbs.

7.3.2.2 SEEDLING GROWTH

i. Shoot dry weight

There were large differences between sown forbs in terms of shoot dry weight. Figure 7.23 showed, that the greatest shoot dry weight was in *Verbesina encelioides* and the smallest shoot dry weight was in *Peganum harmala*. It can also be seen that three species

(*Verbesina encelioides, Rumex villosa*, and *Datura onnoxia*) comprised most of the total dry weight of sown forbs at the end of the experiment.

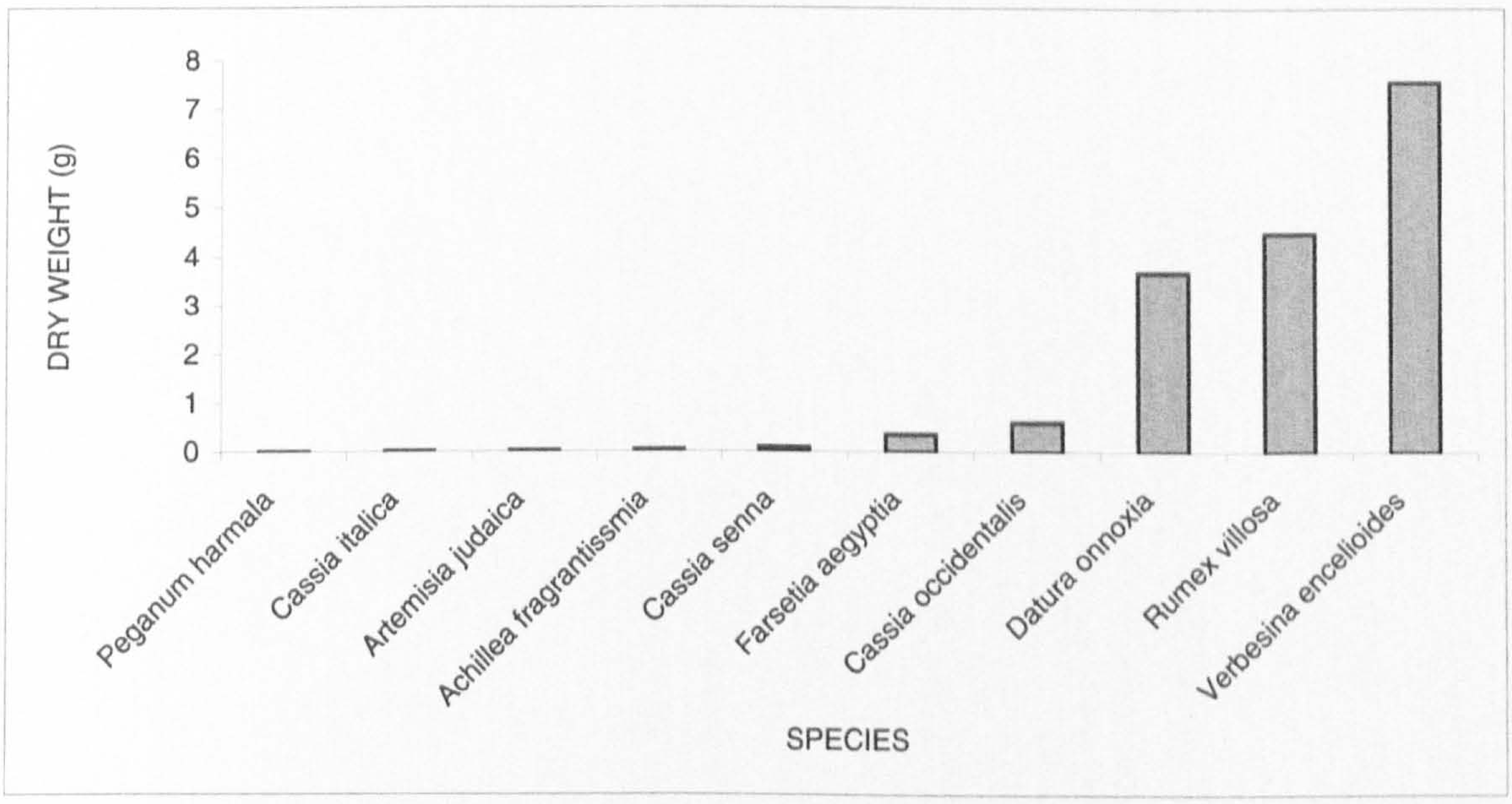

Fig. 7.23 : Mean of shoot dry weight of individual forbs.

ii. Root dry weight

Two species *Verbesina encelioides*, and *Datura onnoxia,* comprised most of the total root dry weight (Fig. 7.24).

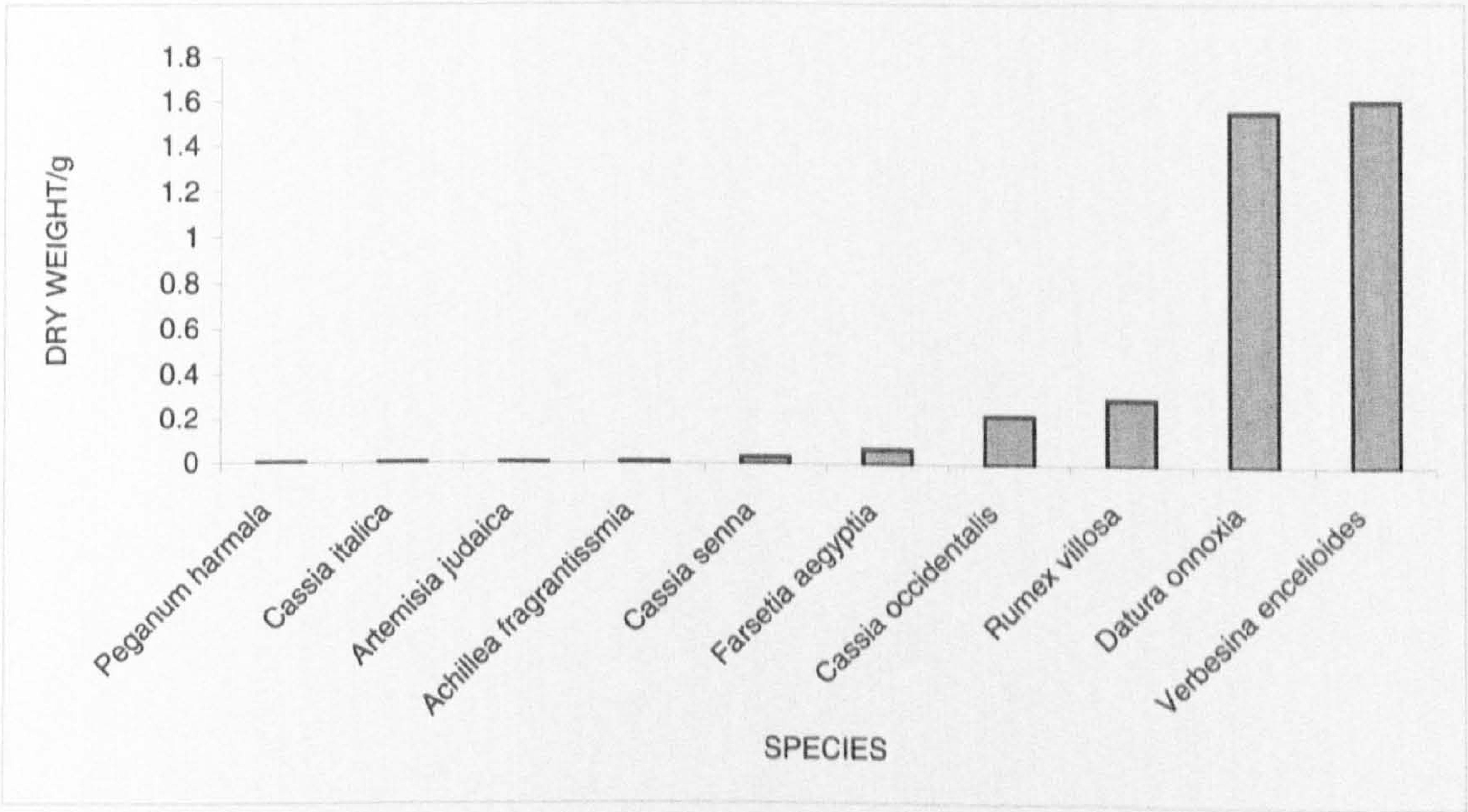

Fig. 7.24 : Mean of root dry weight of individual forbs.

iii. Plant height

Fig. 7.25 shows that sown forbs can be divided to three groups in bases of height. Group 1, (*Datura onnoxia, Rumex villosa*, and *Verbesina encelioides*) >30cm, Group 2, (*Cassia occidentalis* and *Farsetia aegyptia*) 10 – 30 cm. Group 3, <10cm.

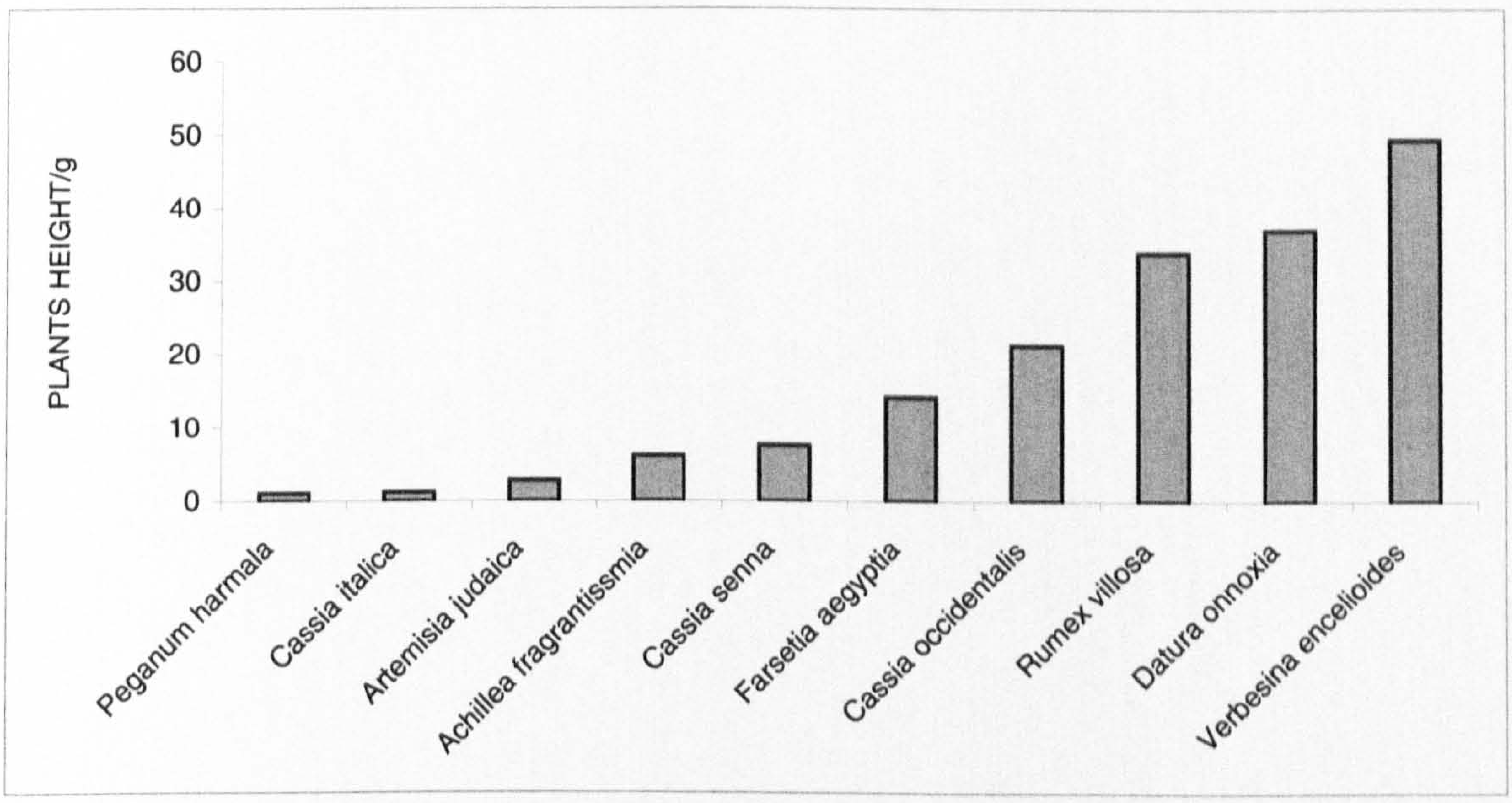

Fig. 7.25 : Mean height of individual forbs.

iv. Root : shoot ratio of all sown forbs

There were some differences between sown forbs in terms of root : shoot ratio. It can be seen from Fig 7.26, that *Datura onnoxia* has the greatest root : shoot ratio, (0.4). *Rumex villosa* had the smallest ratio (0.08).

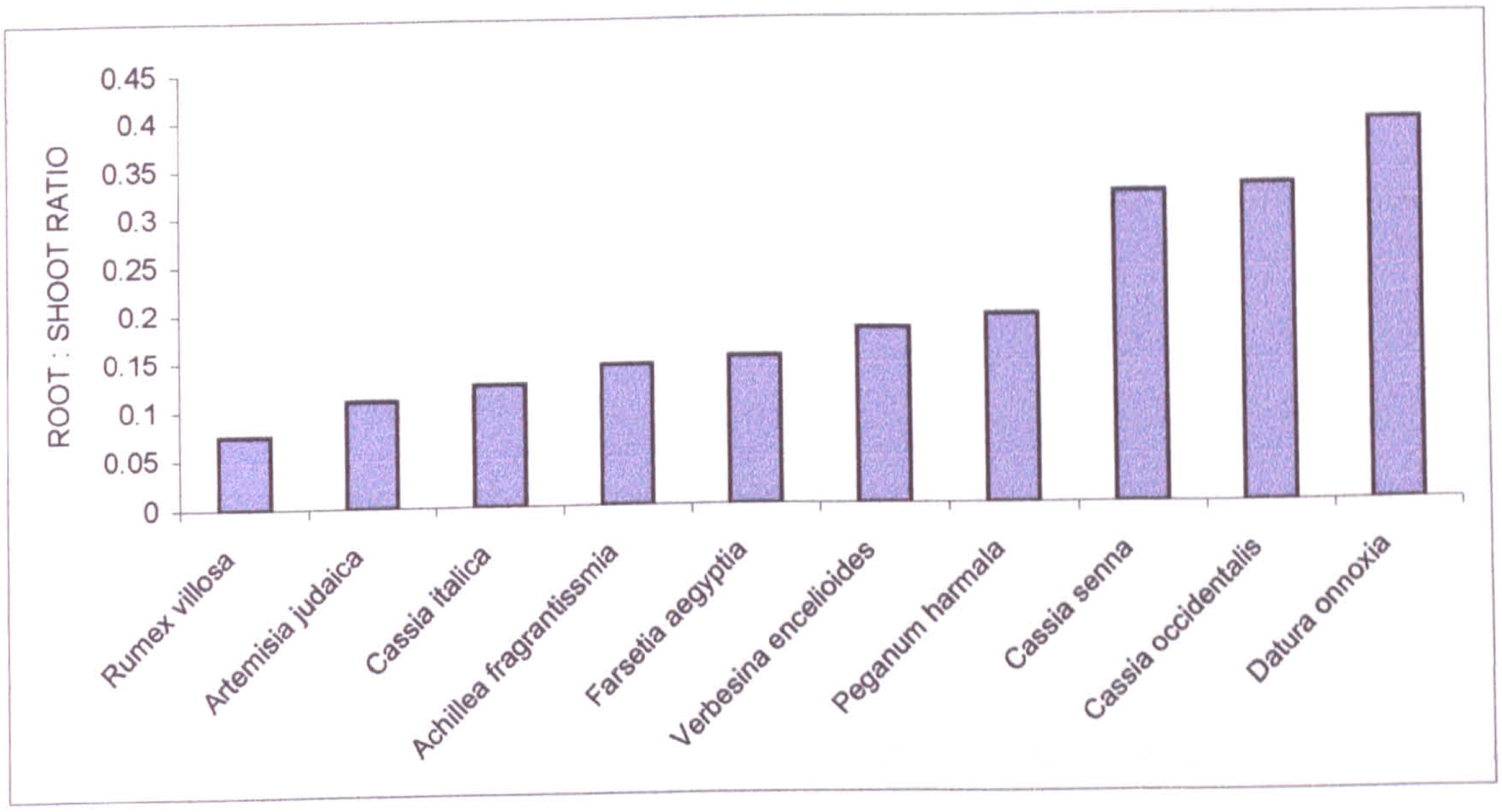

Fig. 7.26: Mean root : shoot ratio of individual forbs

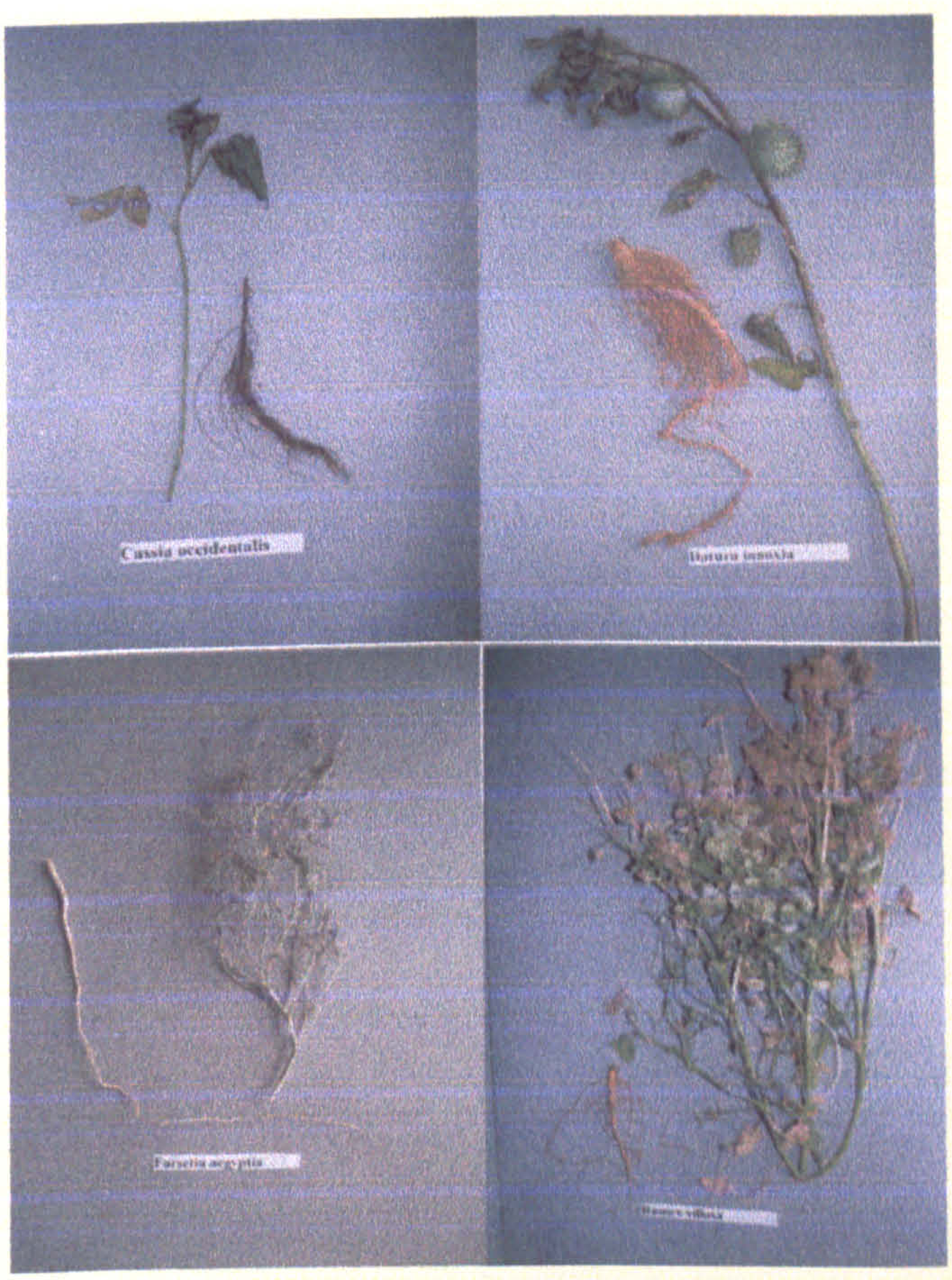

Fig. 7.27 Shoot and root system of some species (*Cassia occidentalis, Datura innoxia Farsetia aegyptia and Rumex villosa)*.

7.3.2.3 EMERGENCE AND GROWTH OF INDIVIDUAL SPECIES

Data was generally analysed via two way ANOVA. Interactions between factors are only mentioned when significant.

i. *Achillea fragrantissmia*

a) Seedling numbers across the experiment

It can be seen from Table 7.6 that the greatest number of (*Achillea fragrantissmia)* seedlings were present in the fourth week, with numbers declining by harvest time. There were significantly fewer seedlings at the end of the experiment in pots irrigated once every 3 weeks (P<0.05) than in the other two irrigation treatments Although seedling numbers at the end of the experiment were less in the grass treatments than the non-grass treatment, these differences were not significant at P=0.05.

		W2	W4	W6	W8	W12	W20
Non-grass	irrigated every 3 week	4.0	4.0	2.0	1.0	1.0	0.6
	irrigated every fortnight	4.0	4.0	3.0	3.0	2.0	1.3
	irrigated weekly	4.0	4.0	4.0	3.0	2.0	1.5
Low grass	irrigated every 3 week	4.0	4.0	2.0	1.0	1.0	0.1
	irrigated every fortnight	4.0	4.0	3.0	1.0	1.0	0.1
	irrigated weekly	4.0	4.0	3.0	2.0	1.0	0.9
High grass	irrigated every 3 week	4.0	4.0	3.0	0.0	0.0	0.0
	irrigated every fortnight	4.0	4.0	3.0	0.0	0.0	0.0
	irrigated weekly	4.0	4.0	3.0	1.0	1.0	0.2

Table 7.6: The mean number of *Achillea fragrantissmia* in weeks 2,4,6,8,12 and 20 of the experiment.

b) Percentage seedling survival

Survival of *Achillea fragrantissmia* at week twenty as a percentage of the maximum number of emerged seedling recorded (week four) can be seen from the chart below (Fig.7.28). Irrigation frequency had a significant impact on *Achillea fragrantissmia* survival (P< 0.05). Again grass had a highly significant effect on *Achillea fragrantissmia* survival (P< 0.0001).

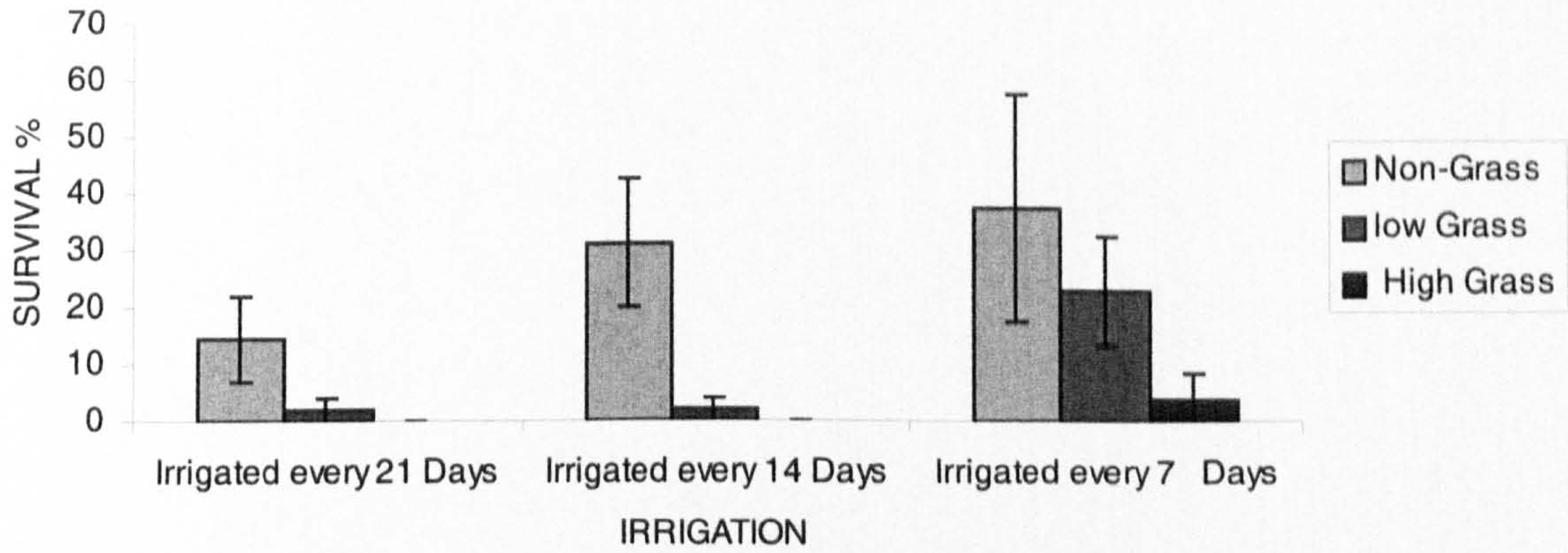

Fig 7.28: Percentage seedling survival of *Achillea fragrantissmia* at the end of the experiment.

c) Shoot dry weight

Irrigation frequency has a significant, positive impact on shoot dry weight of *Achillea fragrantissmia* ($P < 0.05$) (Fig.7.29). As irrigation frequency increases, shoot dry weight increases. Grass had a highly negative effect on the shoot dry weight ($P < 0.05$). As grass density increases shoot dry weight of *Achillea fragrantissmia* decreases.

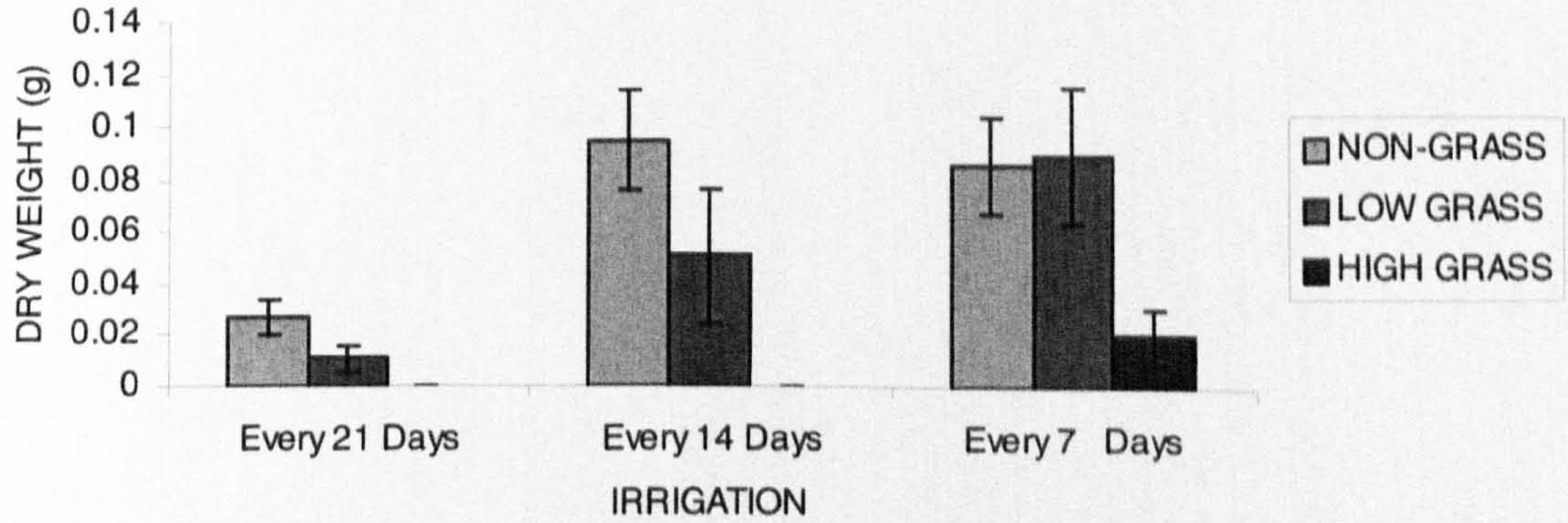

Fig. 7.29: Mean shoot dry weight of *Achillea fragrantissmia* at the end of the experiment.

d) Root dry weight

From the chart below (Fig.7.30) it can be seen that irrigation frequency has a significant positive impact on root dry weight of *Achillea fragrantissmia* (P< 0.02).As irrigation frequency increases, root dry weight increases. Grass have a highly negative significant effect on the shoot dry weight of *Achillea fragrantissmia* (P< 0.001). As grass density increases root dry weight decreases.

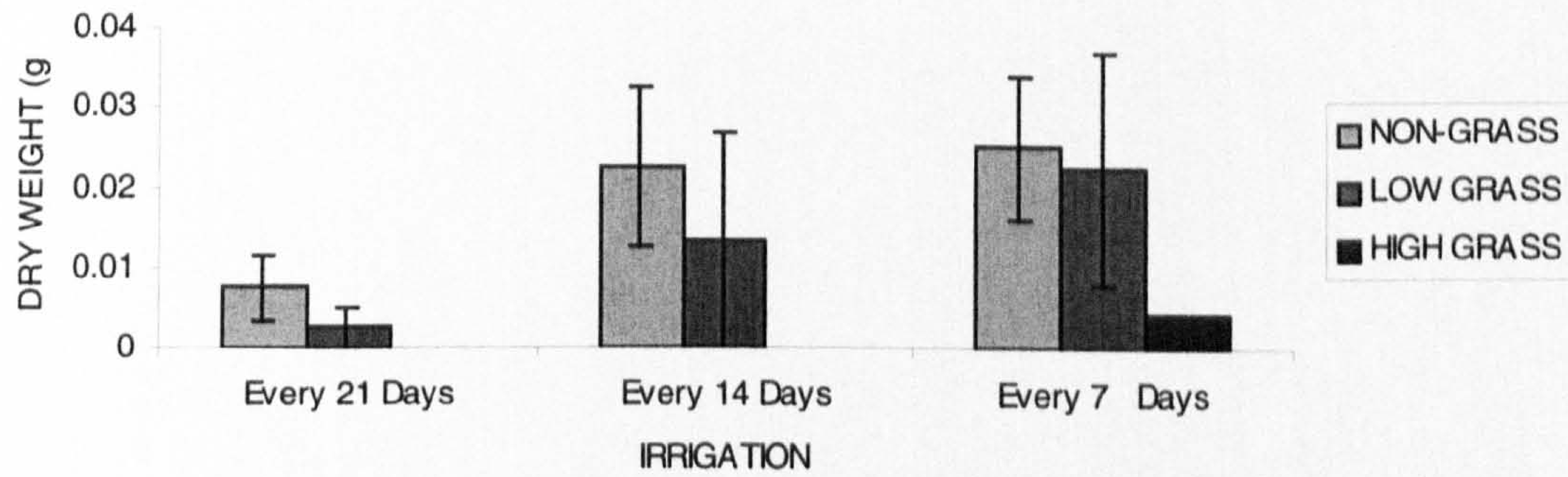

Fig. 7.30: Mean root dry weight of *Achillea fragrantissmia* at the end of the experiment.

e) Plant height

It can be seen from the chart below (Fig.7.31) that irrigation frequency has a significant impact on the height of *Achillea fragrantissmia* (P< 0.001). As irrigation frequency increases, plants height increases. Grass also have a high significant effect on height of *Achillea fragrantissmia* (P< 0.001). As grass density increases plants height decreases.

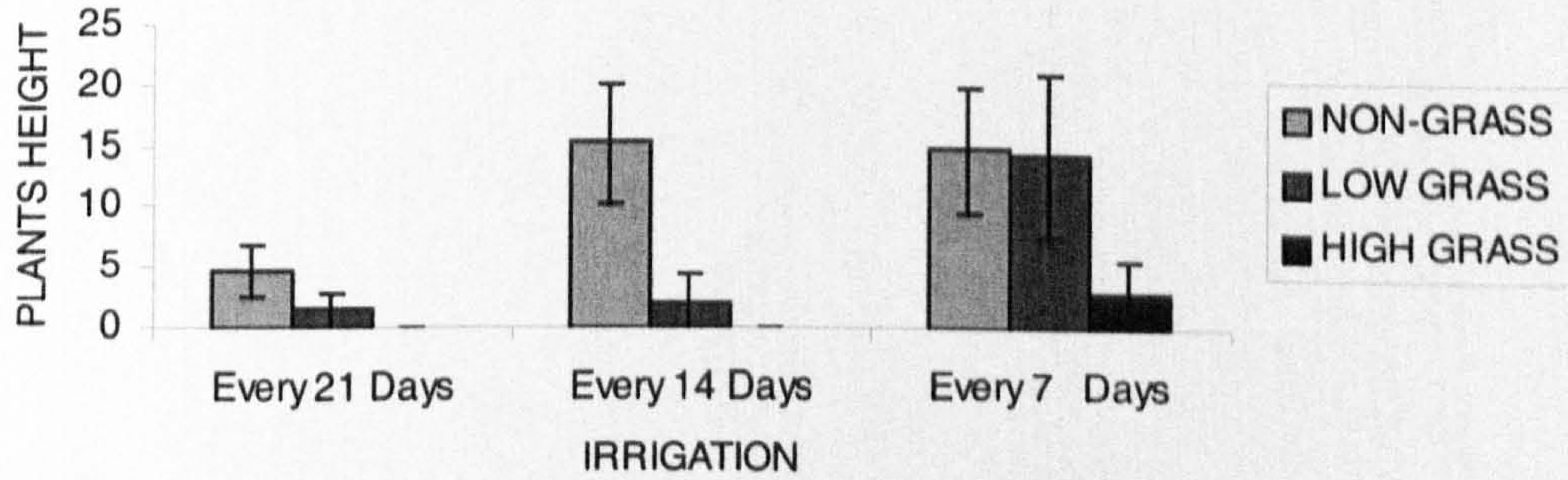

Fig. 7.31: Mean plants height of *Achillea fragrantissmia* at the end of the experiment.

f) Root : shoot ratio

Irrigation frequency and grass density has a non-significant impact on root : shoot ratio of *Achillea fragrantissmia* (P> 0.05) (Fig.7.34).

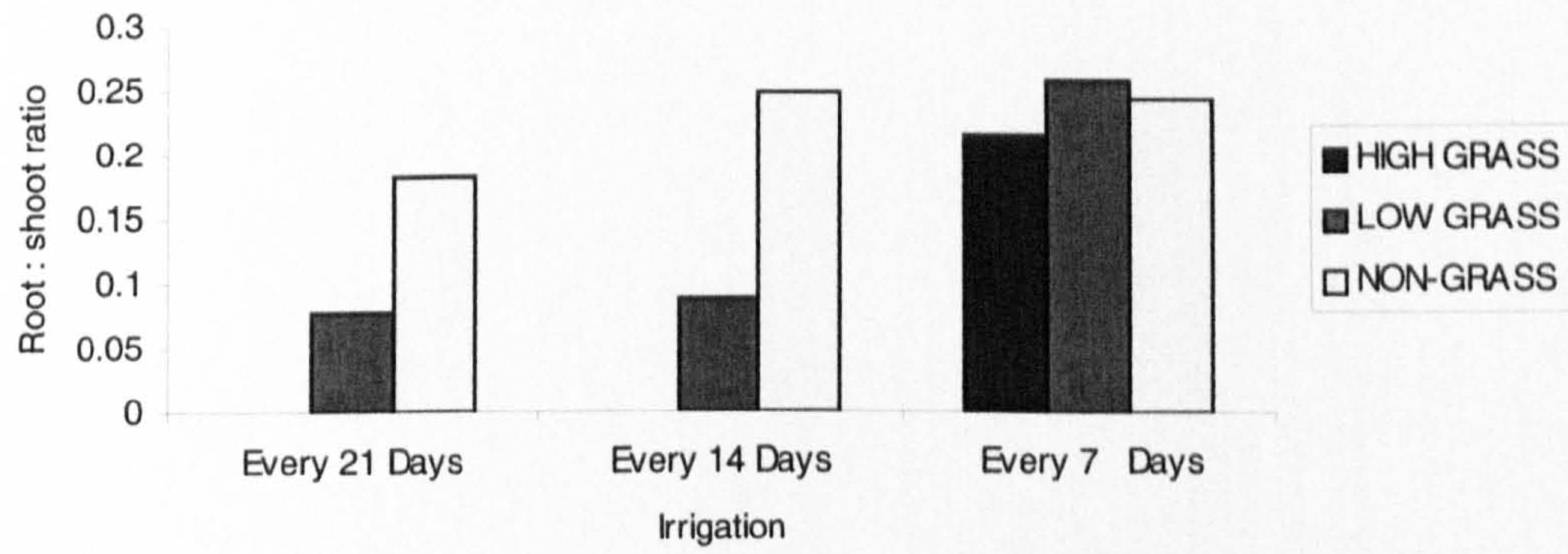

Fig. 7.32: The mean of root : shoot ratio of *Achillea fragrantissmia*

ii. *Artemisia judaica*

a) Seedling numbers across the experiment

Numbers of *Artemisia judaica* seedlings declined by harvest time. There were significantly fewer seedlings at the end of the experiment in pots irrigated once every three weeks (P<0.05) than in the other two irrigation treatments. Although seedling numbers at the end of the experiment was less in the grass treatments than the non-grass treatment, these differences were not significant at P=0.05.

		W2	W4	W6	W8	W12	W20
Non-grass	irrigated every 3 week	4.0	4.0	2.0	1.0	1.0	0.7
	irrigated every fortnight	3.0	3.0	3.0	2.0	1.0	0.4
	irrigated weekly	4.0	4.0	3.0	3.0	2.0	0.8
Low grass	irrigated every 3 week	4.0	4.0	4.0	2.0	1.0	0.3
	irrigated every fortnight	4.0	4.0	2.0	2.0	1.0	0.1
	irrigated weekly	4.0	4.0	3.0	3.0	2.0	0.3
High grass	irrigated every 3 week	3.0	3.0	2.0	0.0	0.0	0.0
	irrigated every fortnight	4.0	4.0	3.0	1.0	0.7	0.0
	irrigated weekly	4.0	4.0	3.0	0.0	0.0	0.0

Table. 7.7: The mean number of *Artemisia judaica* in weeks 2,4,6,8,12 and 20 of the experiment

b) Percentage seedling survival

Survival of *Artemisia judaica* at week twenty as percentage of the maximum number of emerged seedling recorded (week four) is shown in Fig.7.33. Irrigation frequency had non-significant impact on *Artemisia judaica* survival (P> 0.05). Grass have a non-significant effect on *Artemisia judaica* survival (P> 0.05).

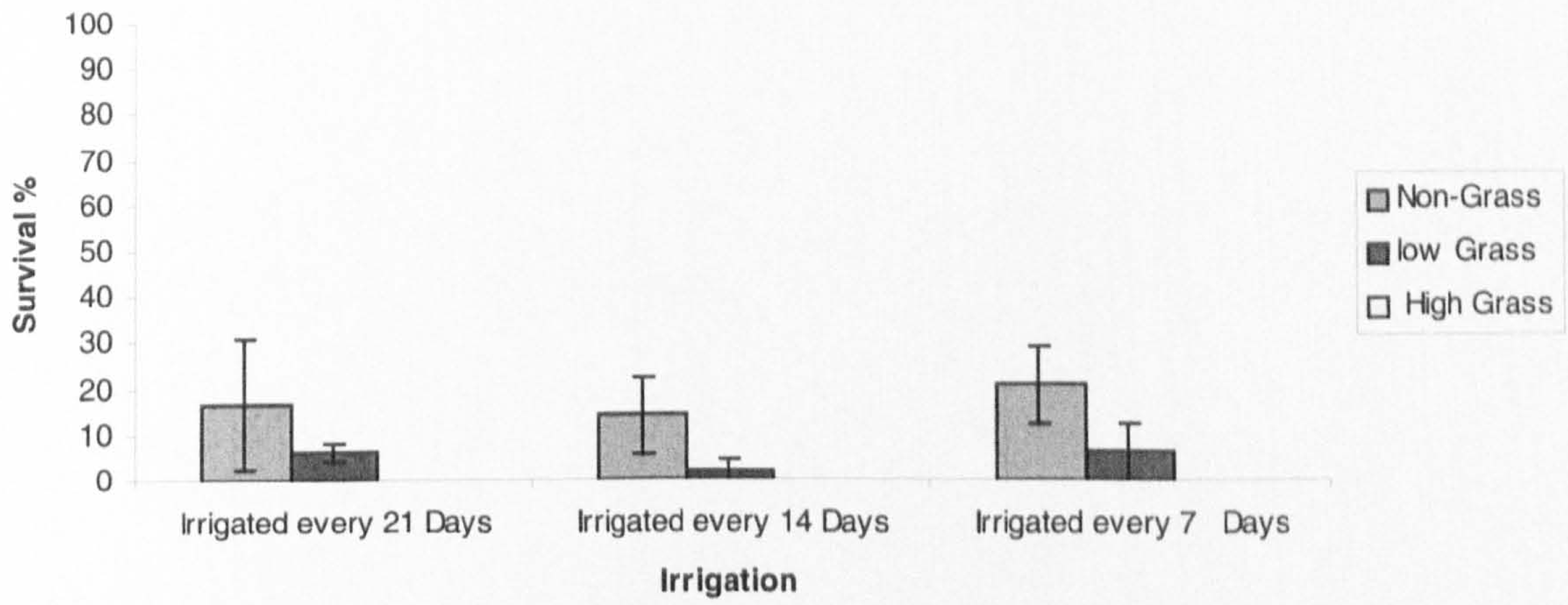

Fig 7.33: Percentage seedling survival of *Artemisia judaica* at the end of the experiment.

c) Shoot dry weight

Irrigation frequency has a non-significant impact on shoot dry weight of *Artemisia judaica* (P> 0.05) (Fig.7.34). Grass have a significant effect on the shoot dry weight of *Artemisia judaica* (P< 0.007). As grass density increases shoot dry weight decreases.

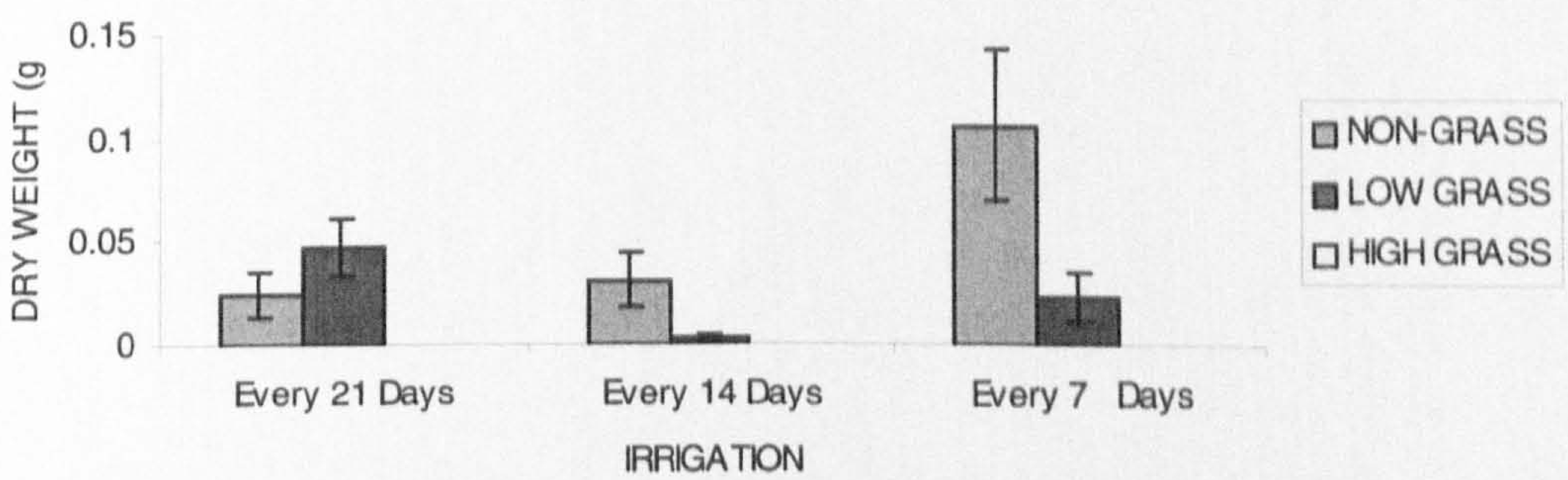

Fig. 7.34: Mean shoot dry weight of *Artemisia judaica* at the end of the experiment. Error bars represent SEM.

d) Root dry weight

Irrigation frequency has a non-significant impact on root dry weight of *Artemisia judaica* (P> 0.05) (Fig.7.35). Grass have a significant effect on the shoot dry weight of *Artemisia judaica* (P< 0.05). As grass density increases root dry weight decreases.

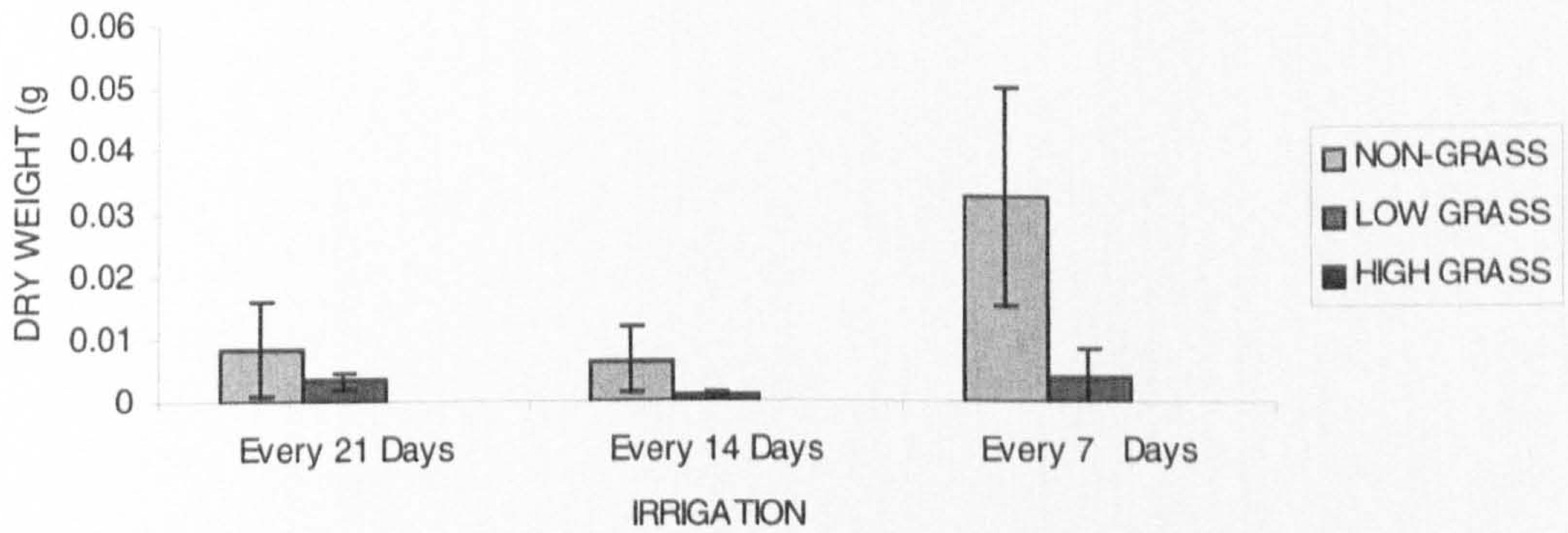

Fig. 7.35: Mean root dry weight of *Artemisia judaica* at the end of the experiment. Error bars represent SEM.

e) Plant height

Irrigation frequency has a non-significant impact on plant height of *Artemisia judaica* (P> 0.05) (Fig.7.36). Grass had a significant effect on plant height of *Artemisia judaica* (P< 0.05). As grass density increases plants height decreases.

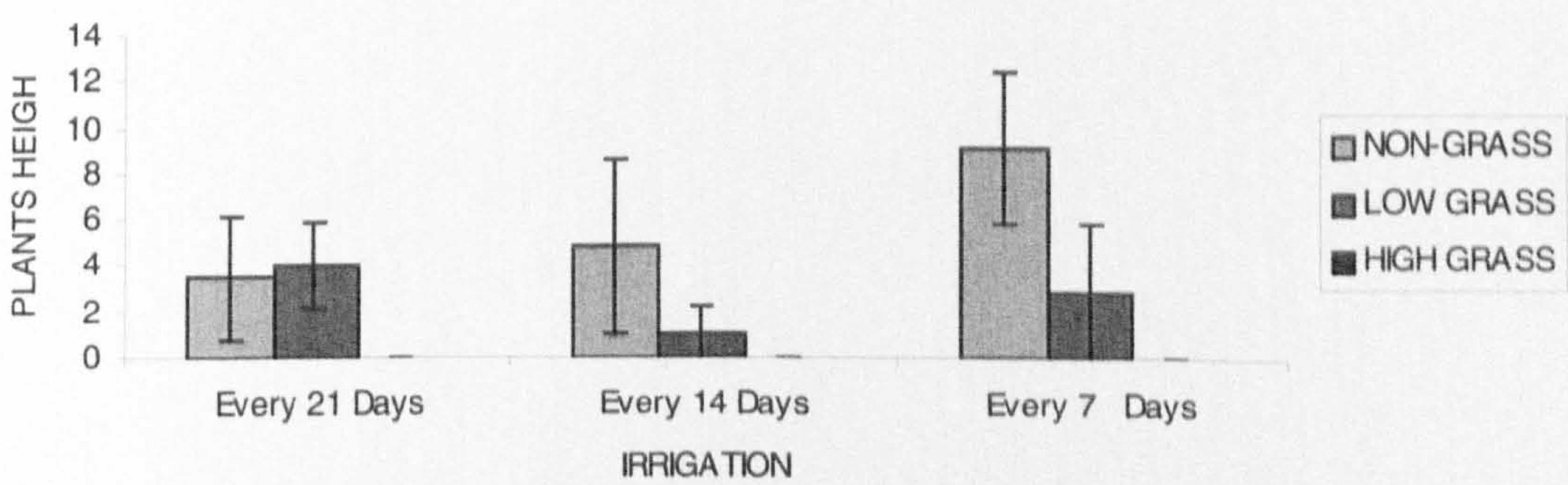

Fig. 7.36: Mean plant height of *Artemisia judaica* at the end of the experiment. Error bars represent SEM.

f) Root : shoot ratio

Irrigation frequency has a non-significant impact on root : shoot ratio of *Artemisia judaica* (P> 0.05) (Fig.7.37). Grass have a significant effect on root : shoot ratio of *Artemisia judaica* (P< 0.05).

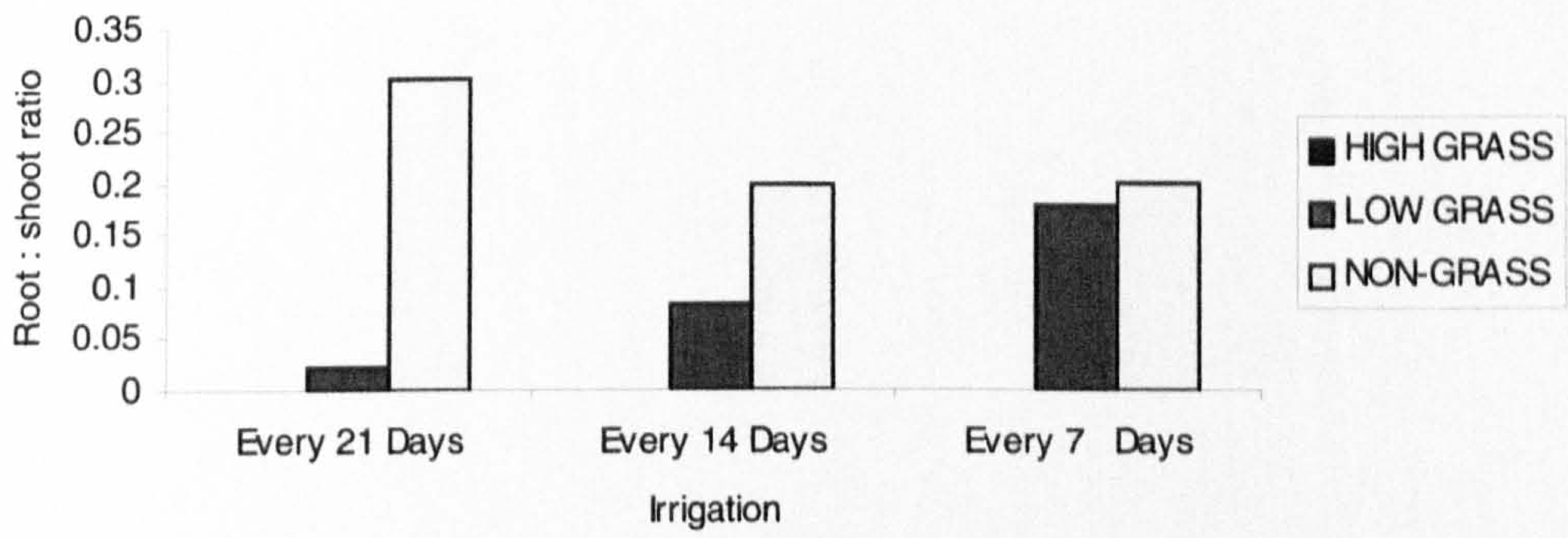

Fig. 7.37: Mean root : shoot ratio of *Artemisia judaica* at the end of the experiment.

iii. *Cassia italica*

a) Seedling numbers across the experiment

It can be seen from Table 7.8 that the greatest number of *Cassia italica* seedling was present in the fourth week, with numbers declining by harvest. Neither grass nor irrigation significantly effected numbers of seedlings present at the end of the experiment (P>0.05).

		W2	W4	W6	W8	W12	W20
Non-grass	irrigated every 3 week	4.0	4.0	3.0	3.0	2.0	0.2
	irrigated every fortnight	4.0	4.0	3.0	3.0	2.0	0.2
	irrigated weekly	4.0	4.0	4.0	4.0	1.0	0.4
Low grass	irrigated every 3 week	4.0	4.0	3.0	2.0	0.0	0.3
	irrigated every fortnight	4.0	4.0	3.0	2.0	1.0	0.3
	irrigated weekly	4.0	4.0	3.0	3.0	1.0	0.6
High grass	irrigated every 3 week	4.0	4.0	2.0	0.0	0.0	0.0
	irrigated every fortnight	4.0	4.0	2.0	1.0	1.0	0.0
	irrigated weekly	4.0	4.0	2.0	1.0	1.0	0.2

Table 7.8: The mean number of *Cassia italica* in weeks 2,4,6,8,12 and 20 of the experiment.

b) Percentage seedling survival

Survival of *Cassia italica* at week twenty as percentage of the maximum number of emerged seedling recorded (week four) can be seen from Fig.7.38. Irrigation frequency had a non-significant impact on *Cassia italica* survival (P> 0.05). Grass also have a non-significant effect on *Cassia italica* survival (P> 0.05).

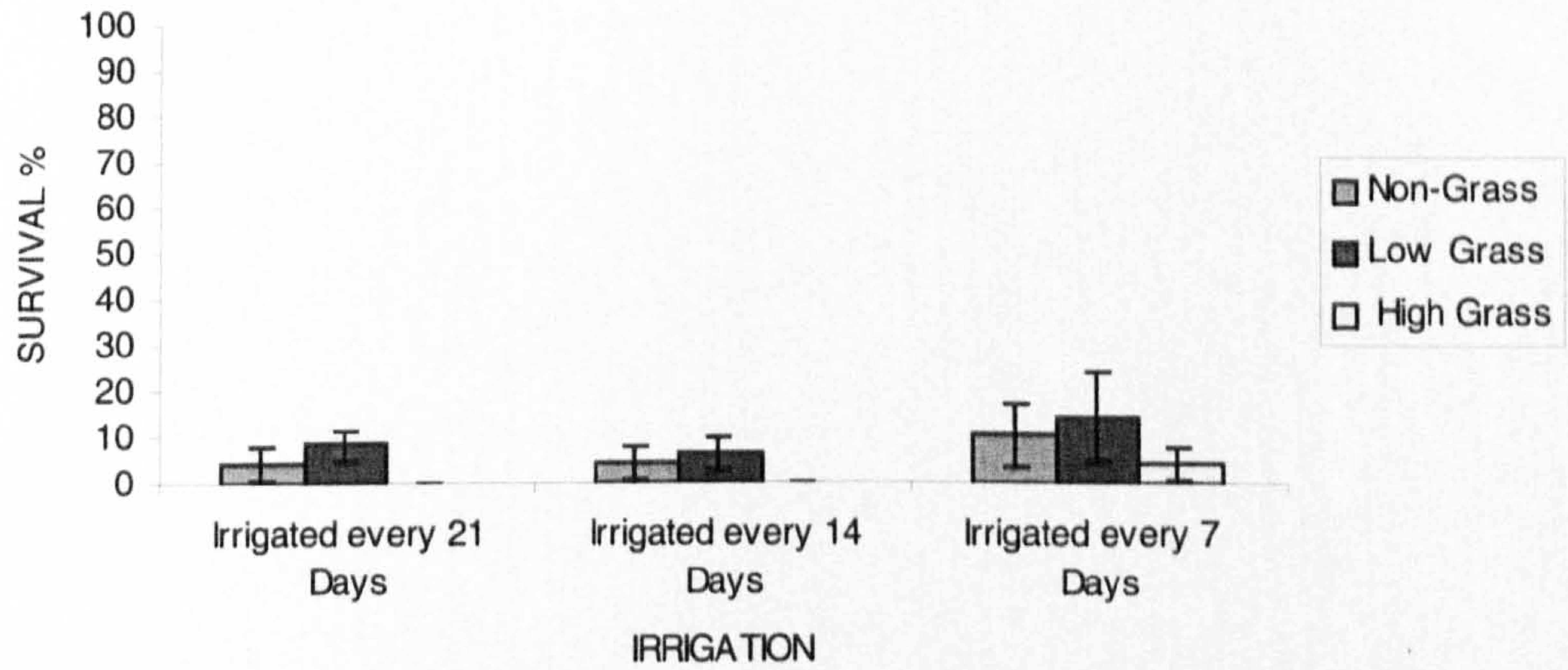

Fig 7.38: Percentage seedling survival of *Cassia italica* at the end of the experiment.

c) Shoot dry weight

Irrigation frequency has a non-significant impact on shoot dry weight of *Cassia italica* (P> 0.05) (Fig. 7.39). Grass have a significant effect (P< 0.05). As grass density increases shoot dry weight decreases.

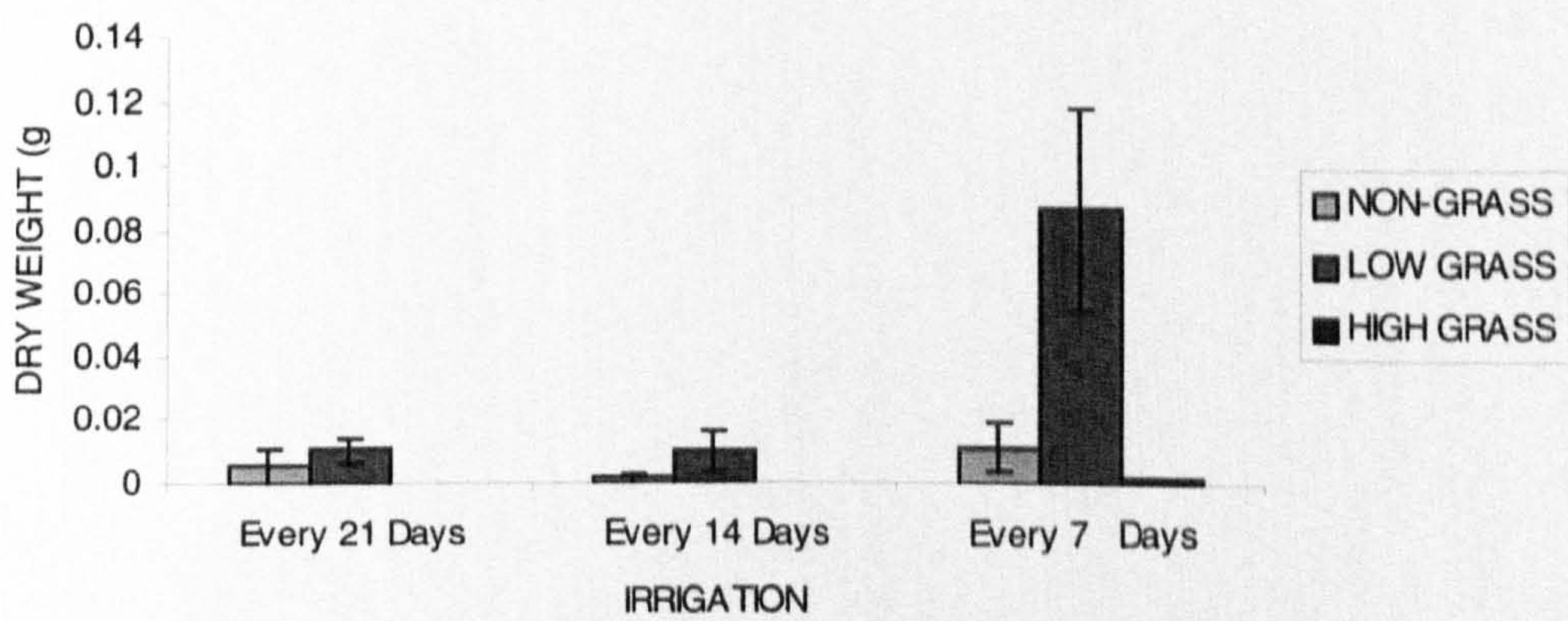

Fig. 7.39 : The mean of shoot dry weight of *Cassia italica* at the end of the experiment. Error bars represent SEM

d) Root dry weight

Irrigation frequency has a non-significant impact on root dry weight of *Cassia italica* (P> 0.05) (Fig.7.40). Grass have a significant effect on the shoot dry weight of *Cassia italica* (P< 0.05). As grass density increases root dry weight decreases.

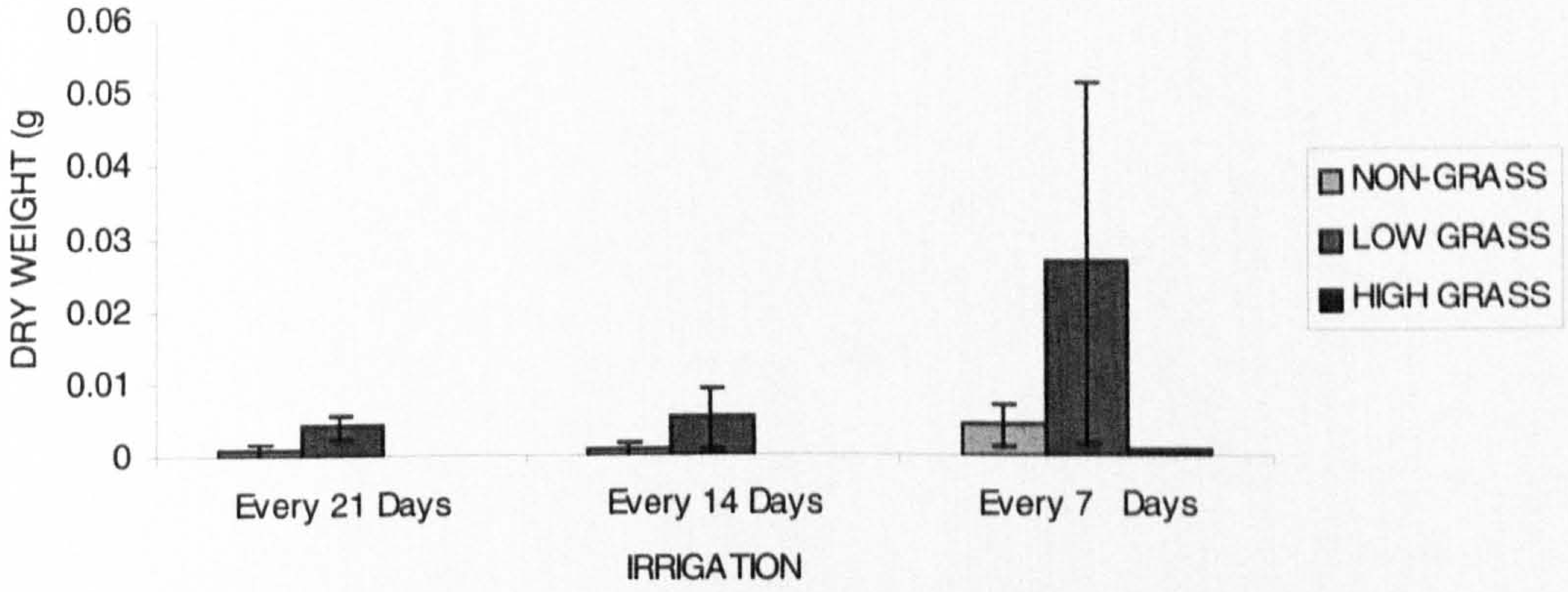

Fig. 7.40: The mean root dry weight of *Cassia italica* at the end of the experiment. Error bars represent SEM

e) Plant height

Irrigation frequency has a non-significant impact on plants height of *Cassia italica* (P> 0.05) (Fig.7.41). Grass have a non- significant effect on plant height of *Cassia italica* (P> 0.05).

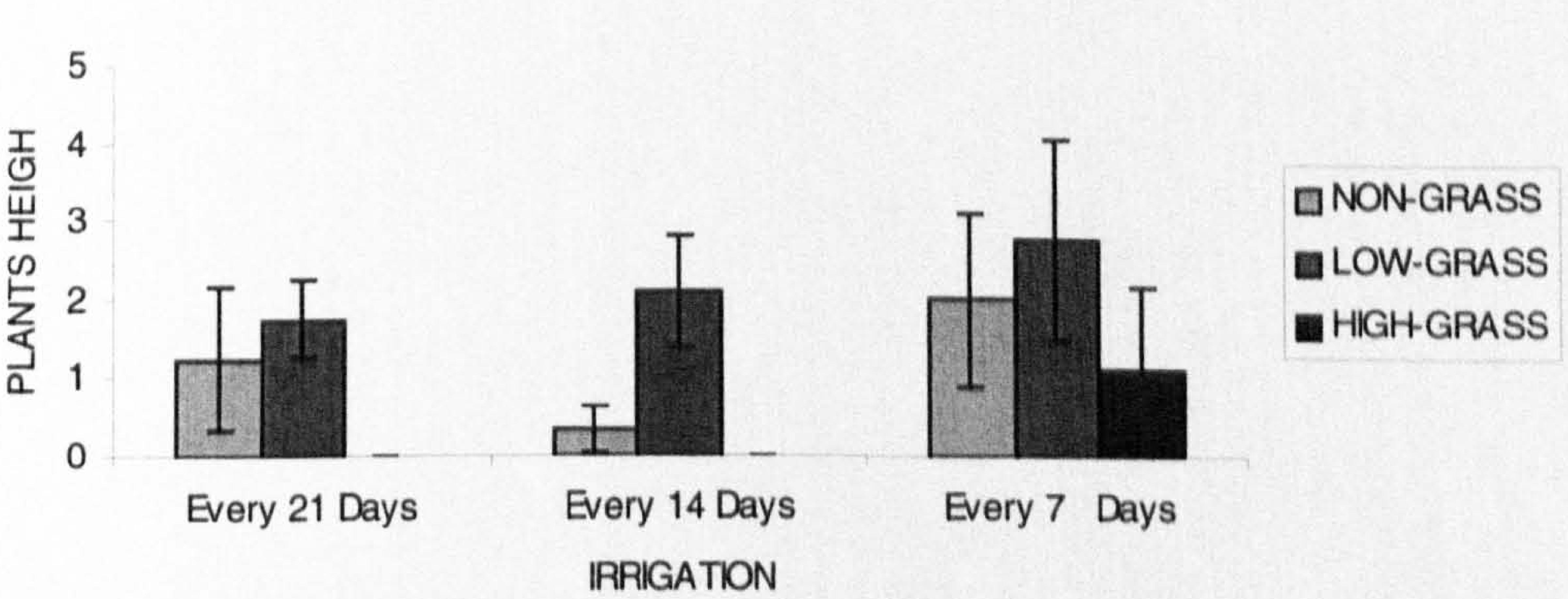

Fig. 7.41: The mean height of *Cassia italica* at the end of the experiment. Error bars represent SEM

f) Root : shoot ratio

Irrigation frequency has a significant impact on root : shoot ratio of *Cassia italica* (P< 0.05). Grass have a significant effect on root : shoot ratio of *Cassia italica* (P< 0.05).

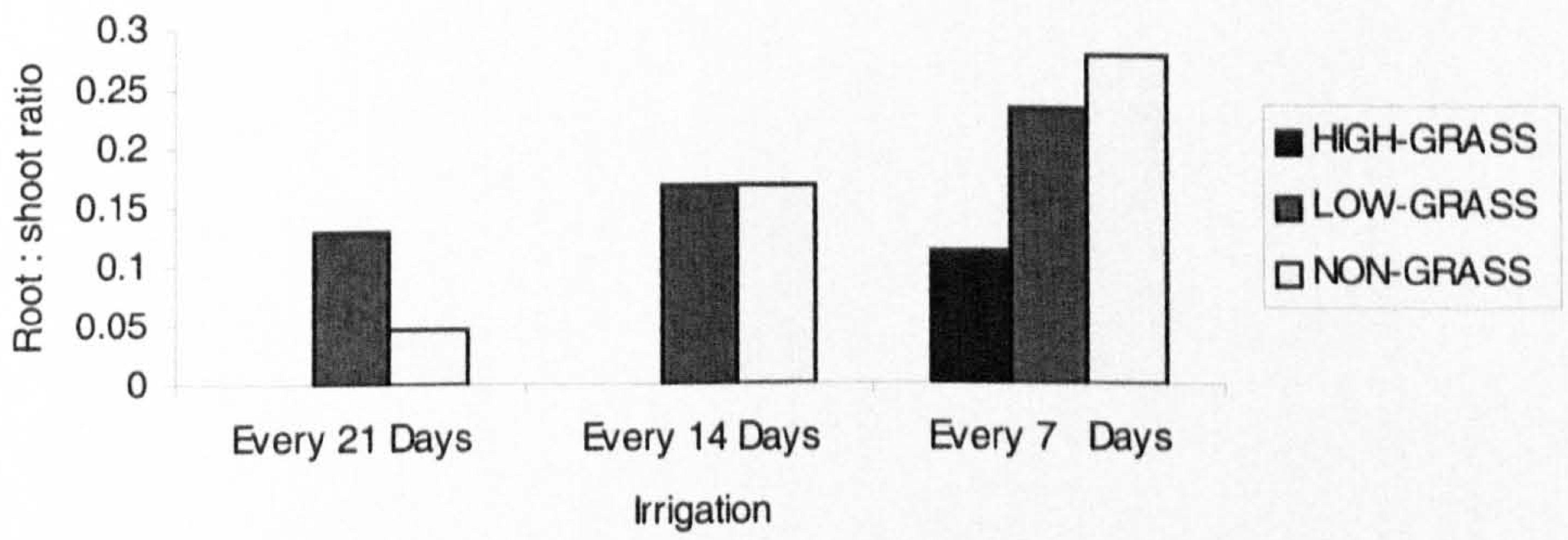

Fig. 7.42: The mean of root : shoot ratio of *Cassia italica* at the end of the experiment.

iv. *Cassia occidentalis*

a) Seedling numbers across the experiment

It can be seen from Table 7.9 that the greatest number of *Cassia occidentalis* seedlings were present in the sixth week, without significant decline in numbers of seedling in the weekly irrigation treatment. Within other irrigation treatments numbers declined by harvest time. There were significantly fewer seedlings at the end of the experiment in pots irrigated once every 3 weeks (P<0.05) than in the other two irrigation treatments. Although seedling numbers at the end of the experiment were less in the grass treatments than the non-grass treatment, these differences were not significant at P=0.05.

		W2	W4	W6	W8	W12	W20
Non-grass	irrigated every 3 week	4.0	4.0	5.0	5.0	5.0	4.5
	irrigated every fortnight	4.0	4.0	5.0	5.0	5.0	4.2
	irrigated weekly	4.0	4.0	6.0	6.0	6.0	5.8
Low grass	irrigated every 3 week	4.0	4.0	4.0	2.0	2.0	1.7
	irrigated every fortnight	4.0	4.0	4.7	4.3	3.7	3.7
	irrigated weekly	4.0	4.0	5.8	4.5	4.5	4.5
High grass	irrigated every 3 week	4.0	4.0	2.0	1.0	0.5	0.5
	irrigated every fortnight	4.0	4.0	3.7	3.3	2.5	2.5
	irrigated weekly	4.0	4.0	5.0	4.5	4.5	4.3

Table 7.9: The mean number of *Cassia occidentalis* in weeks 2,4,6,8,12 and 20 of the experiment.

b) Percentage seedling survival

Survival of *Cassia occidentalis* at week twenty as a percentage of the maximum number of emerged seedling recorded (week six) is shown in Fig.7.43. Irrigation frequency had a highly significant impact on *Cassia occidentalis* survival (P< 0.0001). Grass had a highly significant effect on *Cassia occidentalis* survival (P< 0.0001).

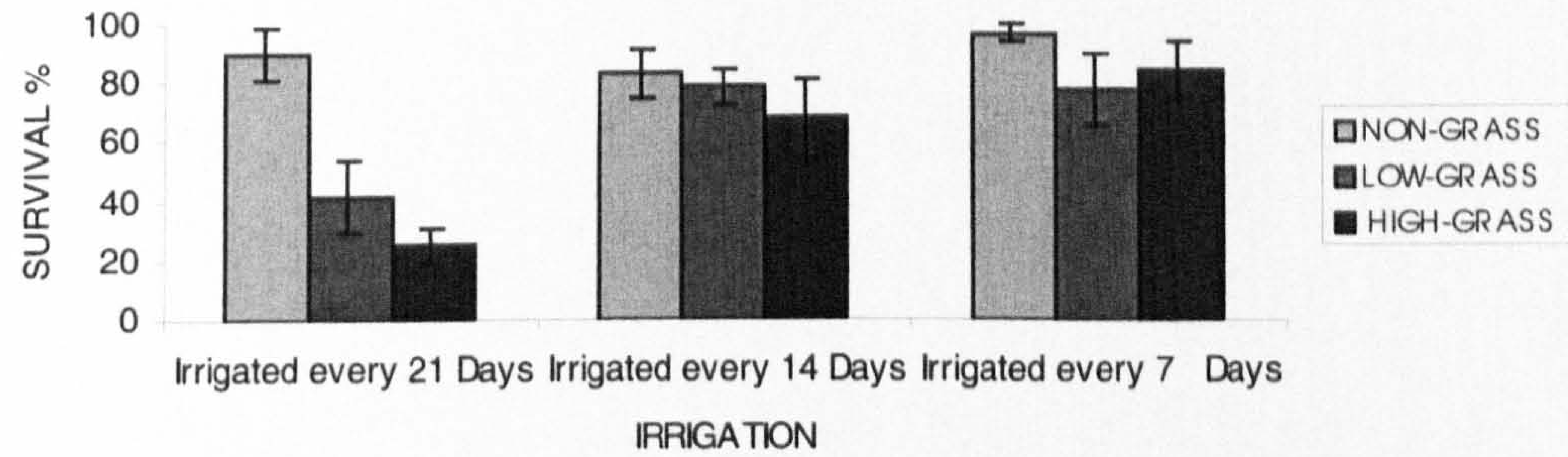

Fig 7.43: Percentage seedling survival of *Cassia occidentalis* at the end of the experiment.

c) Shoot dry weight

Irrigation frequency had a highly significant impact on shoot dry weight of *Cassia occidentalis* (P< 0.0001) (Fig. 7.44). As irrigation frequency increases, shoot dry weight increases. Grass have a highly significant effect on the shoot dry weight of *Cassia occidentalis* (P< 0.0001). As grass density increases shoot dry weight decreases.

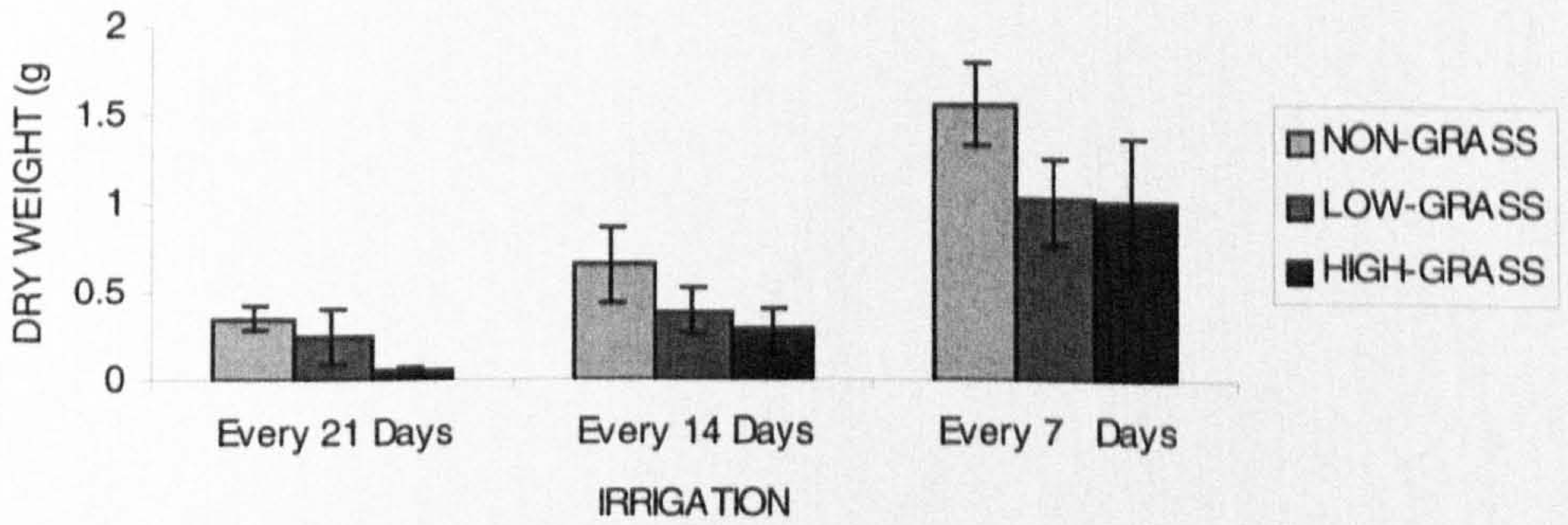

Fig. 7.44: The mean of shoot dry weight of *Cassia occidentalis* at the end of the experiment. Error bars represent SEM

d) Root dry weight

Irrigation frequency has a highly significant impact on root dry weight of *Cassia occidentalis* (P< 0.0001) (Fig.7.45). As irrigation frequency increases, root dry weight increases. Grass have a highly significant effect on the root dry weight of *Cassia occidentalis* (P< 0.0001). As grass density increases root dry weight decreases.

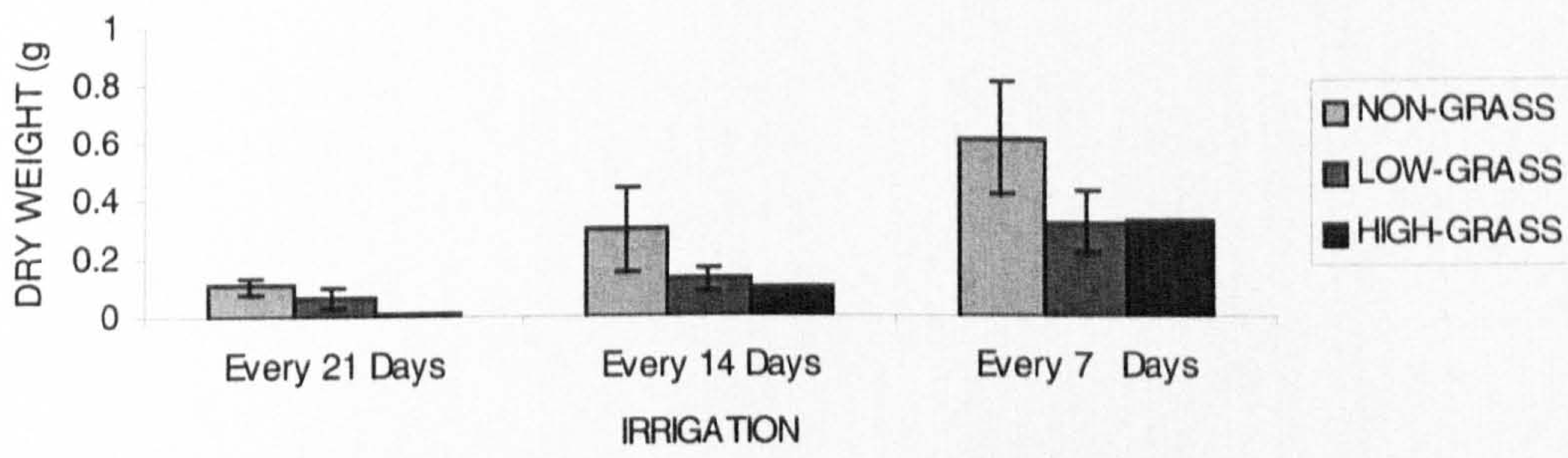

Fig. 7.45: Mean root dry weight of *Cassia occidentalis* at the end of the experiment. Error bars represent SEM

e) Plants height

Irrigation frequency has a significant impact on plants height of *Cassia occidentalis* (P< 0.05) (Fig.7.46). As irrigation frequency increases plant height increases. Grass have a significant effect on plant height of *Cassia occidentalis* (P< 0.05). As grass density increases plant height decreases.

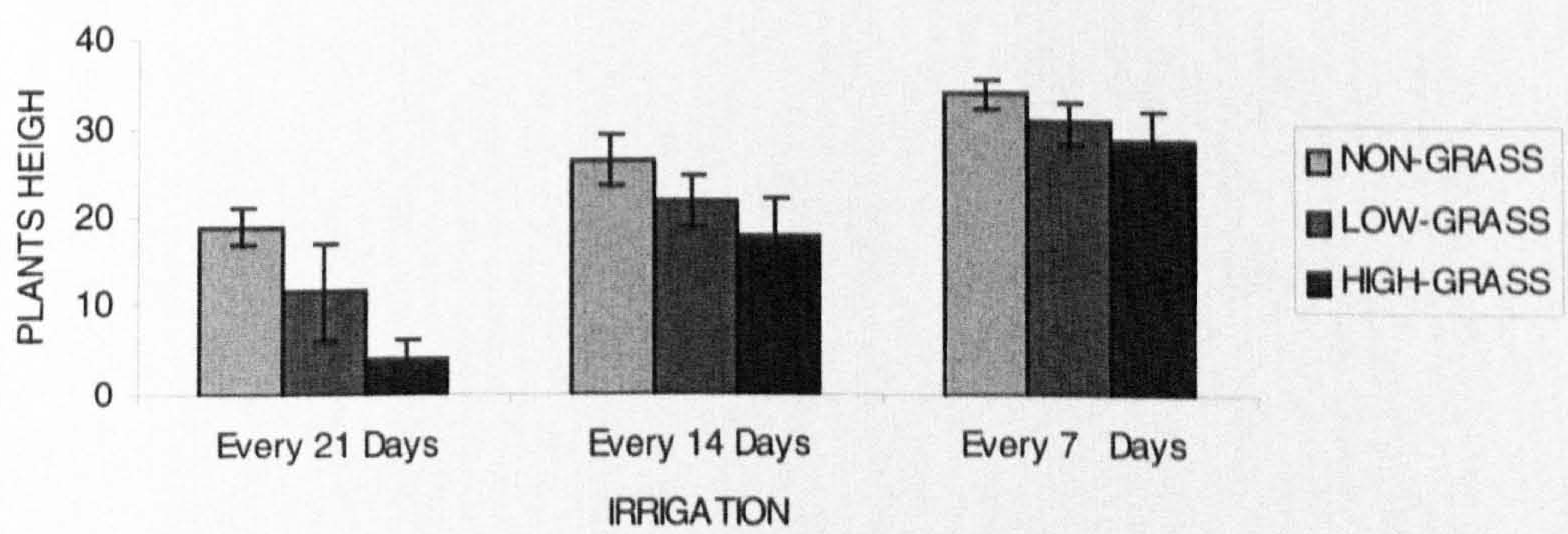

Fig. 7.46: The mean height of *Cassia occidentalis* at the end of the experiment. Error bars represent SEM

f) Root : shoot ratio

Irrigation frequency has a significant impact on root : shoot ratio of *Cassia occidentalis* ($P < 0.05$) (Fig.7.47). Grass also have a significant effect on root : shoot ratio of *Cassia occidentalis* ($P < 0.05$).

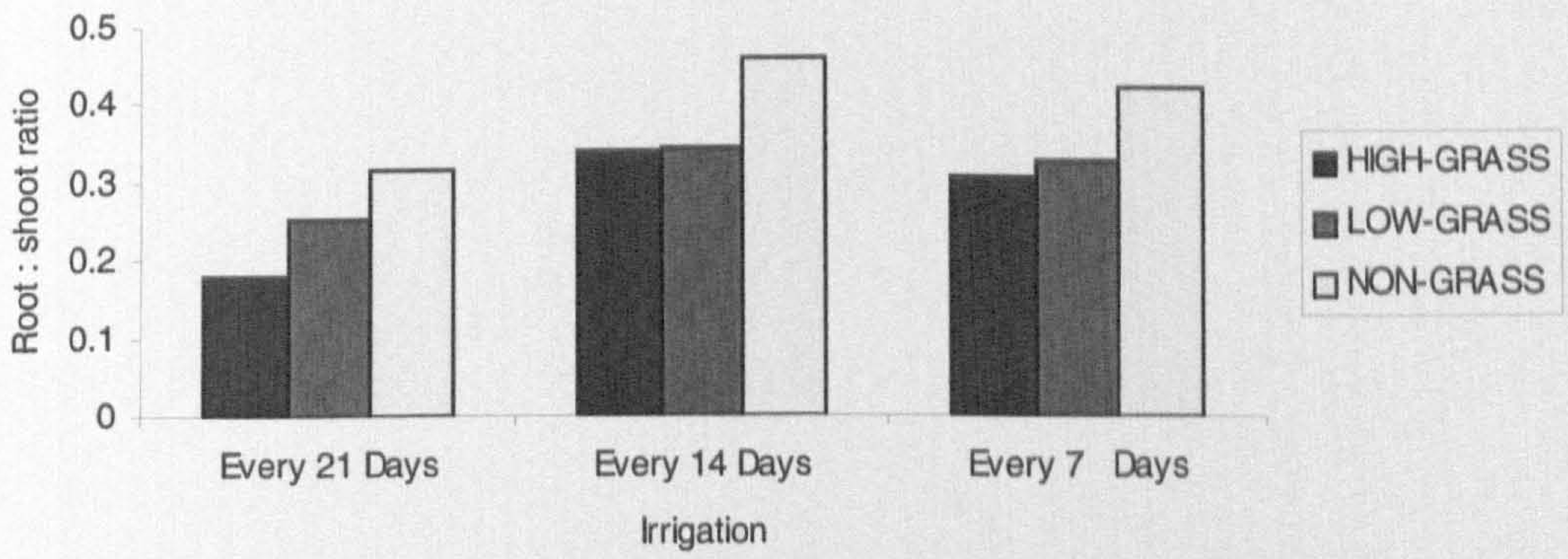

Fig. 7.47: The mean of root : shoot ratio of *Cassia occidentalis* at the end of the experiment.

v. ***Cassia senna***

a) Seedling numbers across the experiment

It can be seen from Table 7.10 that the greatest number of *Cassia senna* seedlings was present in the fourth week, with numbers declining by harvest time. There were significantly fewer seedlings at the end of the experiment in pots irrigated once every 3 weeks ($P<0.05$) than in the other two irrigation treatments. Although seedling numbers at the end of the experiment was less in the grass treatments than the non-grass treatment, these differences were not significant at $P=0.05$.

		W2	W4	W6	W8	W12	W20
Non-grass	irrigated every 3 week	4.0	4.0	3.0	3.0	2.0	1.9
	irrigated every fortnight	4.0	4.0	4.0	3.0	2.0	1.8
	irrigated weekly	4.0	4.0	4.0	4.0	4.0	3.5
low grass	irrigated every 3 week	4.0	4.0	2.0	2.0	1.0	0.3
	irrigated every fortnight	4.0	4.0	3.0	2.0	2.0	1.1
	irrigated weekly	4.0	4.0	3.0	3.0	3.0	2.6
High grass	irrigated every 3 week	4.0	4.0	1.0	0.0	0.0	0.0
	irrigated every fortnight	4.0	4.0	2.0	1.0	1.0	0.2
	irrigated weekly	4.0	4.0	3.0	2.0	2.0	2.0

Table 7.10: The mean number of *Cassia senna* in weeks 2,4,6,8,12 and 20 of the experiment.

b) Percentage seedling survival

Survival of *Cassia senna* at week twenty as a percentage of the maximum number of emerged seedling recorded (week four) can be seen in Fig.7.48. Irrigation frequency has a highly significant impact on *Cassia senna* survival (P< 0.0001). Grass have a highly significant effect on *Cassia senna* survival (P< 0.0001).

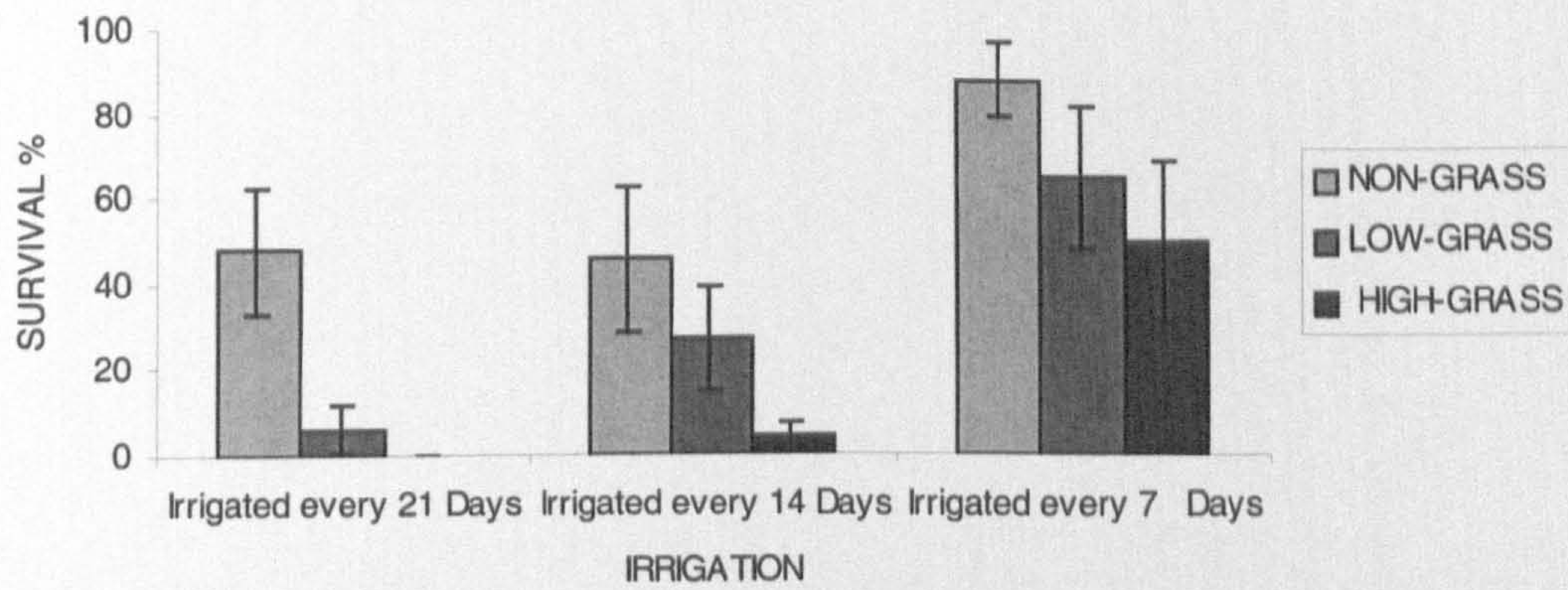

Fig 7.48: Percentage seedling survival of *Cassia senna* at the end of the experiment.

c) Shoot dry weight

Irrigation frequency has a highly significant impact on shoot dry weight of *Cassia senna* (P< 0.0001) (Fig.7.49). As irrigation frequency increases, shoot dry weight increases. Grass have a highly significant effect on the shoot dry weight of *Cassia senna* (P< 0.0001). As grass density increases shoot dry weight decreases.

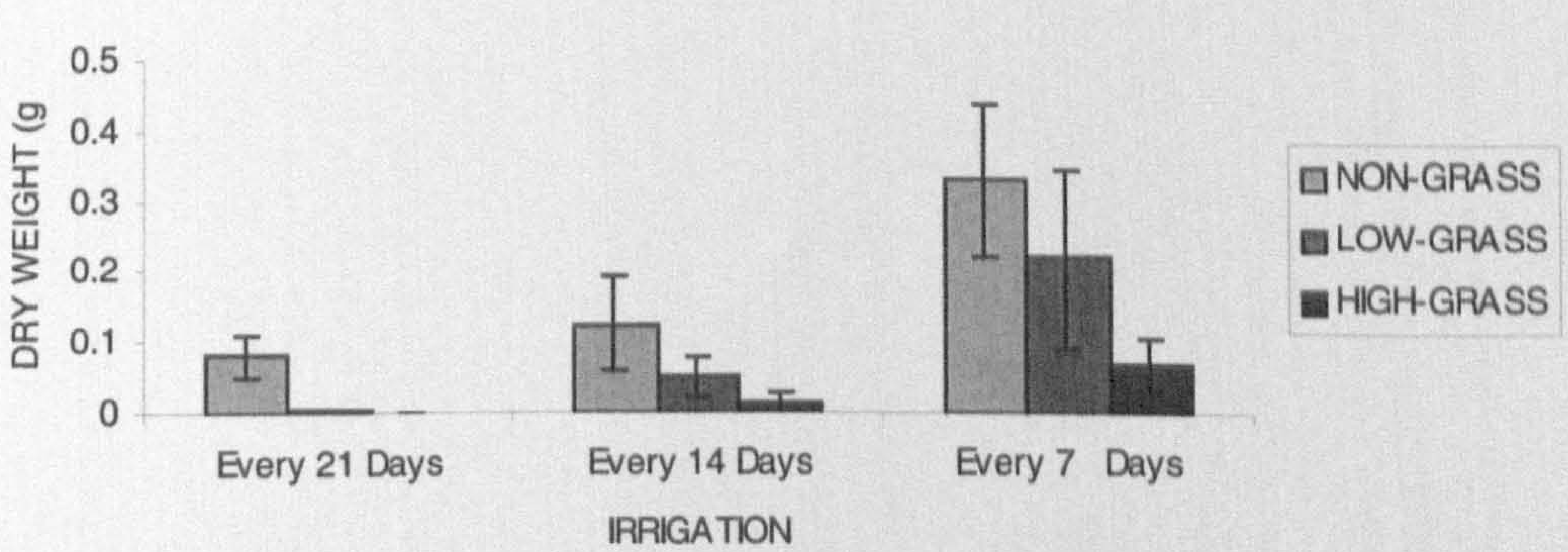

Fig. 7.49: The mean shoot dry weight of *Cassia senna* at the end of the experiment. Error bars represent SEM.

d) Root dry weight

Irrigation frequency has a highly significant impact on root dry weight of *Cassia senna* ($P < 0.0001$) (Fig.7.50). As irrigation frequency increases, root dry weight increases. Grass have a highly significant effect on the root dry weight of *Cassia senna* ($P < 0.0001$). As grass density increases root dry weight decreases.

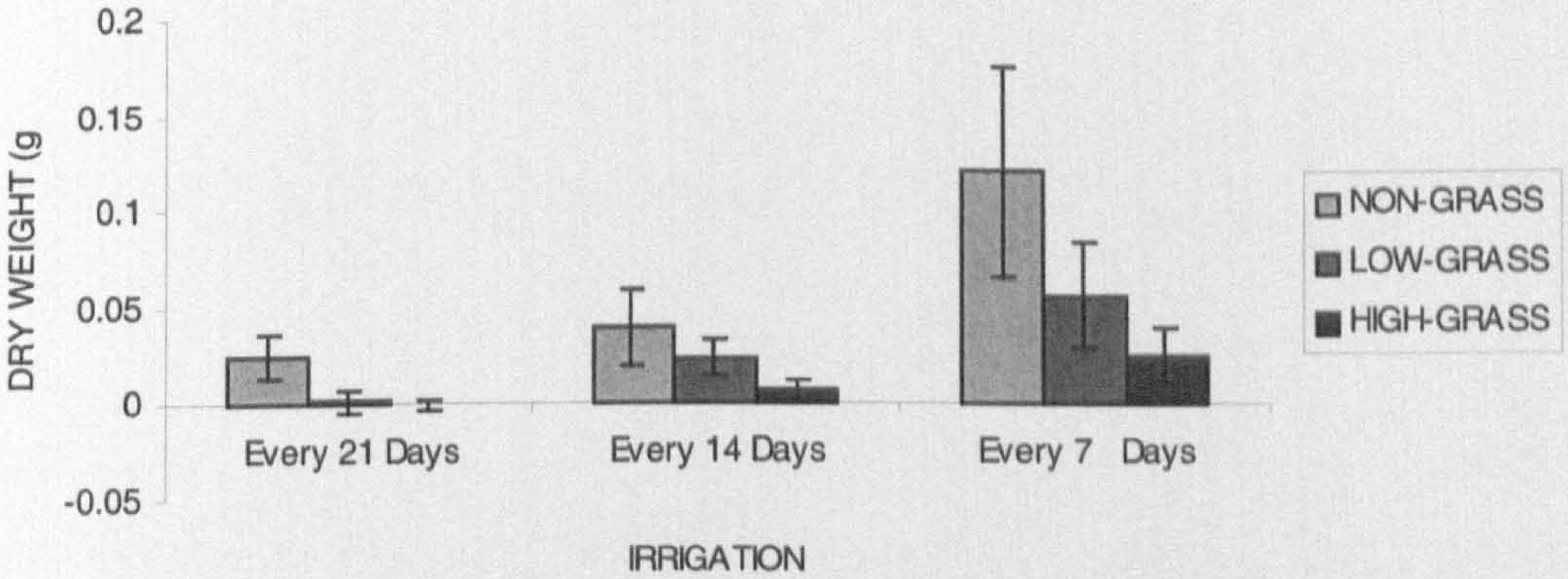

Fig. 7.50: The mean of root dry weight of *Cassia senna* at the end of the experiment. Error bars represent SEM.

e) Plant height

Irrigation frequency has a significant impact on height of *Cassia senna* ($P < 0.0001$) (Fig.7.51). As irrigation frequency increases, plants height increases. Grass have a highly significant effect on plant height of *Cassia senna* ($P < 0.0001$). As grass density increases plants height decreases.

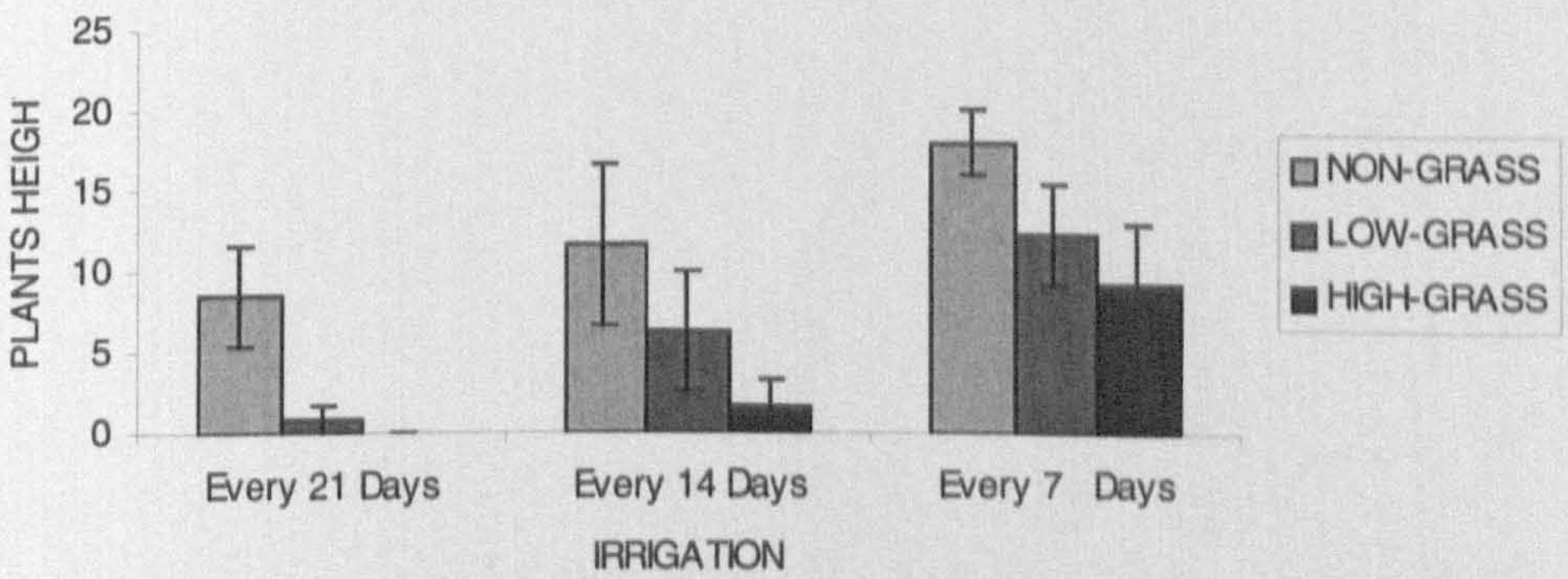

Fig. 7.51: The mean height of *Cassia senna* at the end of the experiment. Error bars represent SEM.

f) Root : shoot ratio

Irrigation frequency has a non-significant impact on root : shoot ratio of *Cassia senna* (P> 0.05) (Fig.7.52). Grass have a non-significant effect on root : shoot ratio of *Cassia senna* (P> 0.05).

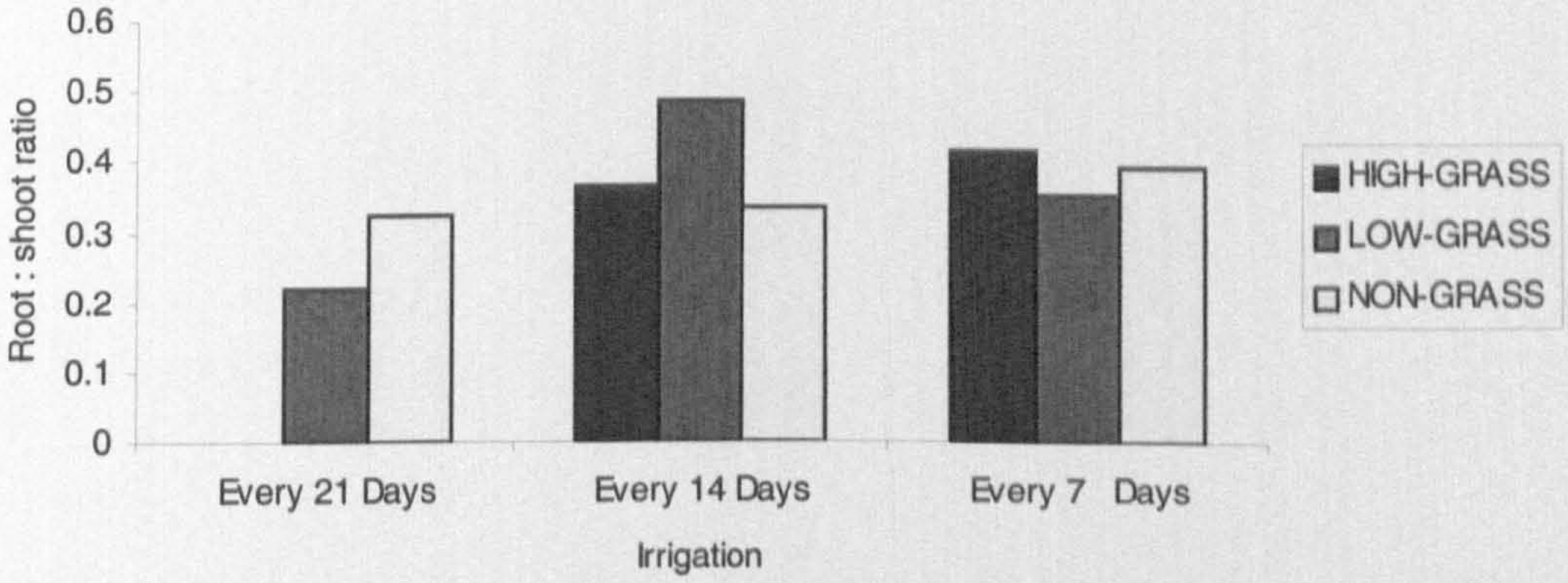

Fig. 7.52: The mean of root : shoot ratio of *Cassia senna* at the end of the experiment

vi. *Datura innoxia*

a) Seedling numbers across the experiment

It can be seen from Table 7.11 that the greatest number of *Datura innoxia* seedling was present in the sixth week, with numbers declining between week twelve and harvest time. There was a non-significant difference in number of seedling in response to irrigation frequency treatments at the end of the experiment (p > 0.05). Grass did not have a significant affect on number of *Datura innoxia* seedling (p > 0.05).

		W2	W4	W6	W8	W12	W20
Non-grass	irrigated every 3 week	4.0	4.0	4.0	4.0	4.0	3.1
	irrigated every fortnight	4.0	4.0	4.0	4.0	4.0	3.3
	irrigated weekly	4.0	4.0	5.0	5.0	5.0	4.3
Low grass	irrigated every 3 week	4.0	4.0	4.0	4.0	4.0	4.0
	irrigated every fortnight	4.0	4.0	5.0	5.0	5.0	4.1
	irrigated weekly	4.0	4.0	4.0	4.0	4.0	3.6
High grass	irrigated every 3 week	4.0	4.0	4.0	4.0	4.0	3.3
	irrigated every fortnight	4.0	4.0	4.0	4.0	4.0	3.3
	irrigated weekly	4.0	4.0	4.0	4.0	4.0	3.8

Table 7.11: The mean number of *Datura innoxia* in weeks 2,4,6,8,12 and 20 of the experiment.

b) Percentage seedling survival

Survival of *Datura innoxia* at week twenty as a percentage of the maximum number of emerged seedling recorded (week six) can be seen in Fig.7.53. Irrigation frequency had a non-significant impact on *Datura innoxia* survival (P> 0.05). Grass also had a non-significant effect on *Datura innoxia* survival (P> 0.05).

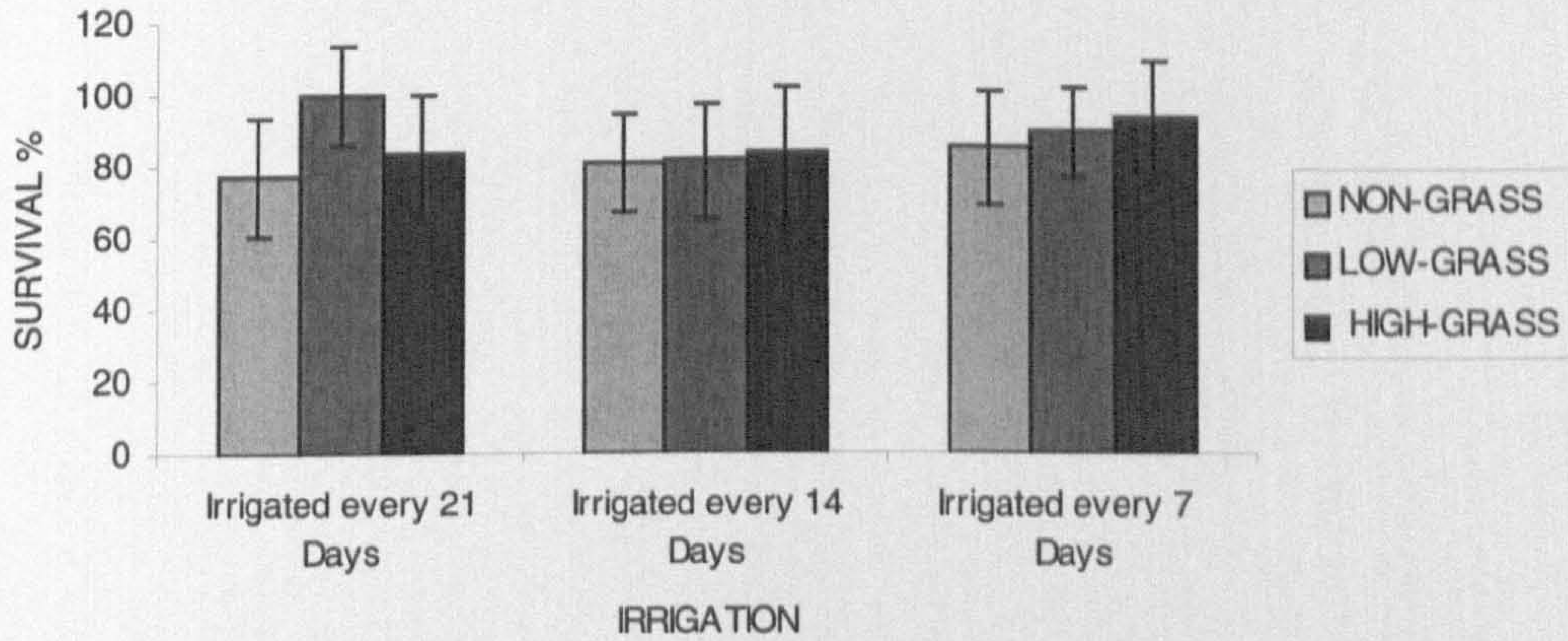

Fig. 7. 53: Percentage seedling survival of *Datura innoxia* at the end of the experiment.

c) Shoot dry weight

Irrigation frequency had a non-significant impact on shoot dry weight of *Datura innoxia* (P> 0.05) (Fig. 7.54). Grass also had a non-significant effect on the shoot dry weight of *Datura innoxia* (P> 0.05).

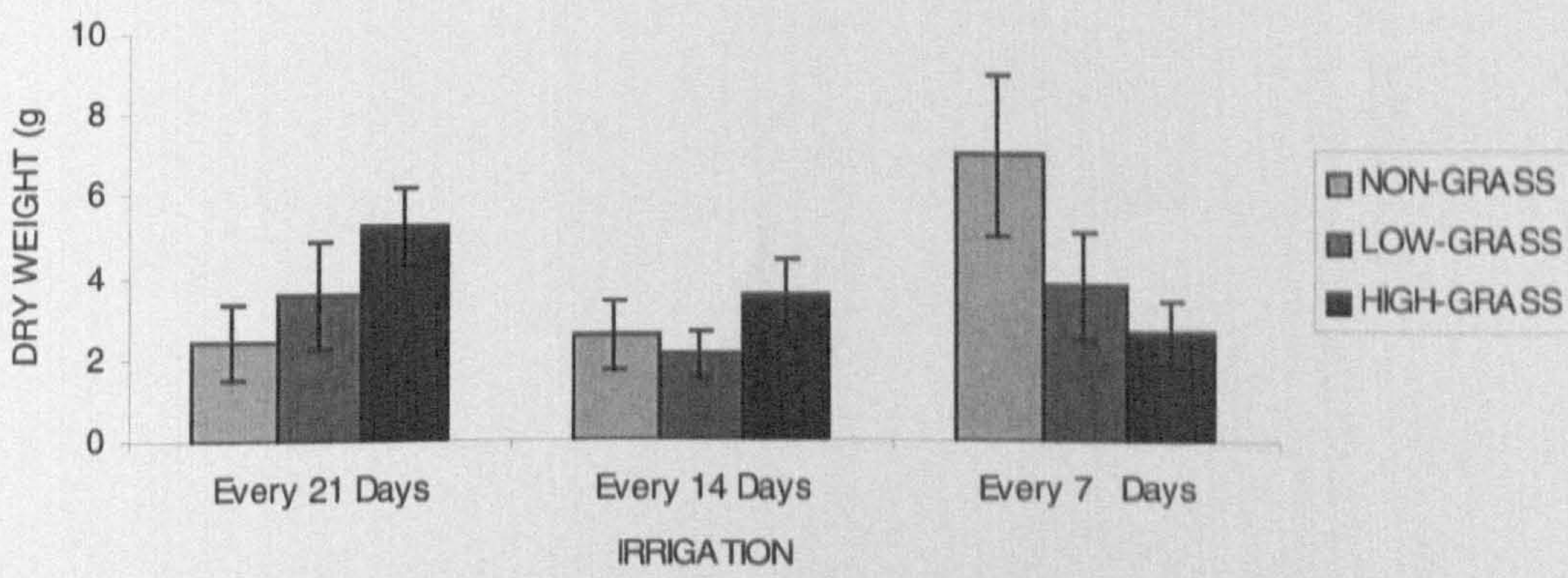

Fig. 7.54: Mean shoot dry weight of *Datura innoxia* at the end of the experiment. Error bars represent SEM

d) Root dry weight

Irrigation frequency had a non-significant impact on root dry weight of *Datura innoxia* (P> 0.05) (Fig. 7.55). Grass had non-significant effect on the root dry weight of *Datura innoxia* (P> 0.05).

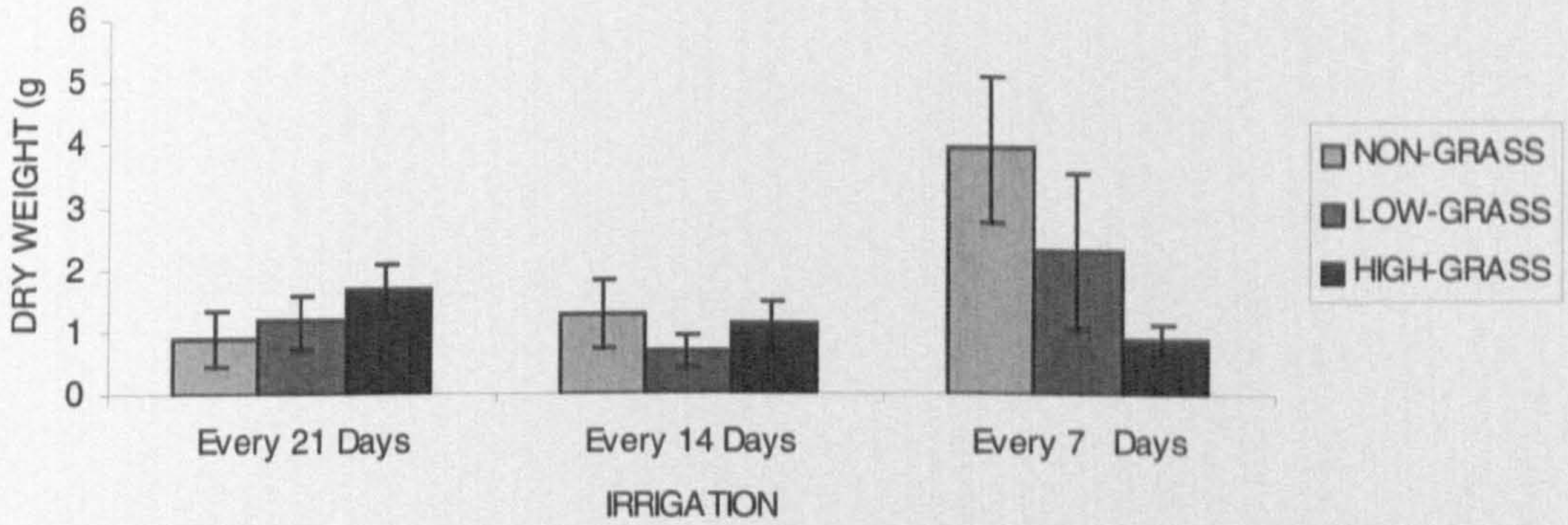

Fig. 7.55: Mean root dry weight of *Datura innoxia* at the end of the experiment. Error bars represent SEM.

e) Plant height

Irrigation frequency had a non-significant impact on plants height of *Datura innoxia* (P> 0.05) (Fig. 7.56). Grass also had a non-significant effect on plant height of *Datura innoxia* (P> 0.05).

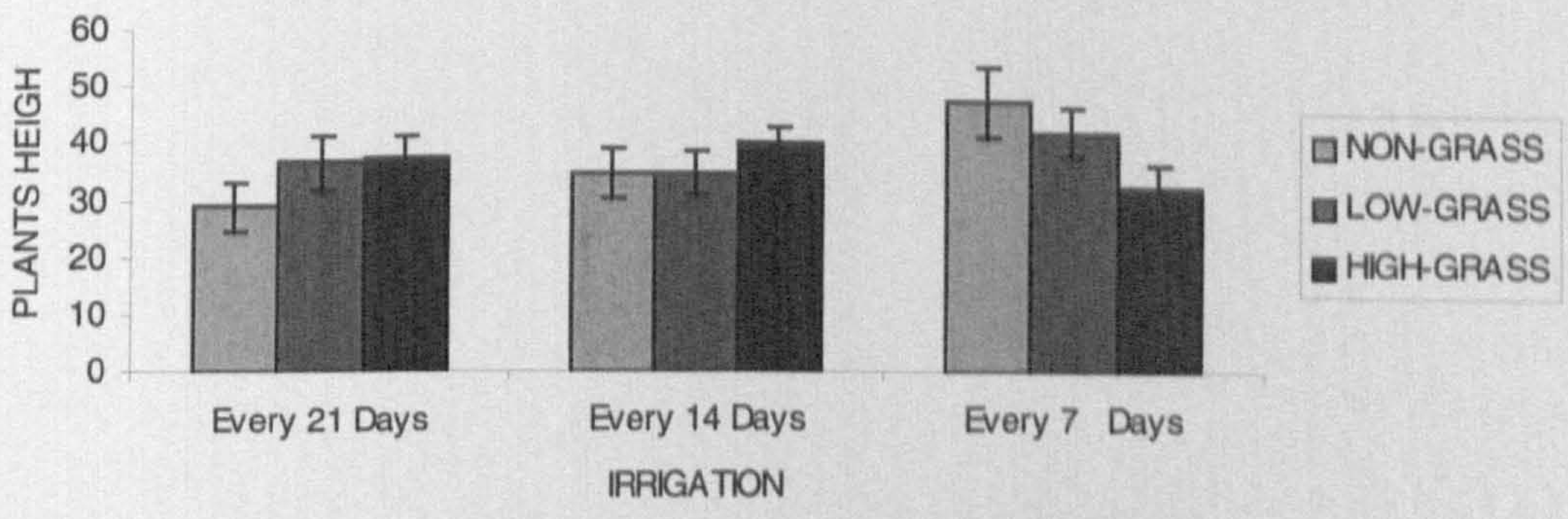

Fig. 7.56: Mean height of *Datura innoxia* at the end of the experiment. Error bars represent SEM.

f) Root : shoot ratio

Irrigation frequency had a non-significant impact on root : shoot ratio of *Datura innoxia* (P> 0.05) (Fig. 7.57). Grass had a significant effect on root : shoot ratio of *Datura innoxia* (P< 0.05).

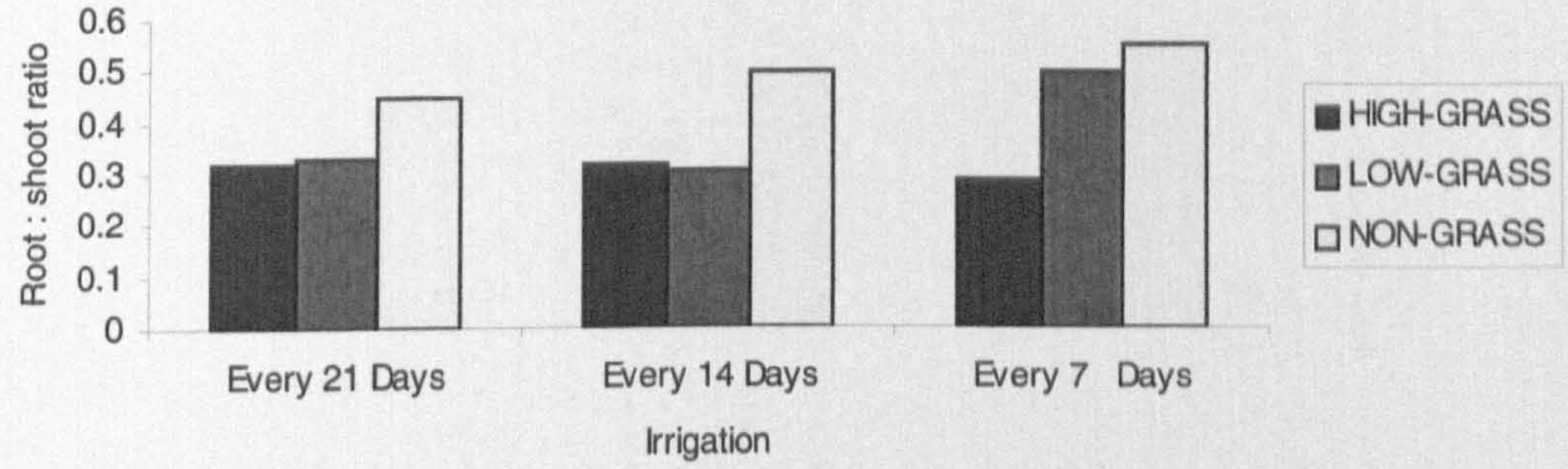

Fig. 7.57: Mean root : shoot ratio of *Datura innoxia* at the end of the experiment.

vii. *Farsetia aegyptia*

a) Seedling numbers across the experiment

It can be seen from Table 7.12 that the greatest number of *Farsetia aegyptia* seedlings was present in the sixth week, with numbers declining between week six and harvest. There were significantly fewer seedlings at the end of the experiment in pots irrigated once every 3 weeks (P<0.05) than in the other two irrigation treatments. Although seedling numbers at the end of the experiment were less in the grass treatments than the non-grass treatment, these differences were not significant at P=0.05.

		W2	W4	W6	W8	W12	W20
Non-grass	irrigated every 3 week	4.0	4.0	5.0	5.0	5.0	4.5
	irrigated every fortnight	4.0	4.0	5.0	5.0	5.0	4.2
	irrigated weekly	4.0	4.0	5.0	5.0	5.0	4.9
Low grass	irrigated every 3 week	4.0	4.0	3.0	2.0	2.0	1.0
	irrigated every fortnight	4.0	4.0	4.0	3.0	2.0	1.3
	irrigated weekly	4.0	4.0	5.0	4.0	4.0	3.3
High grass	irrigated every 3 week	4.0	4.0	2.0	1.0	0.0	0.0
	irrigated every fortnight	4.0	4.0	3.0	2.0	1.0	0.1
	irrigated weekly	4.0	4.0	4.0	3.0	3.0	2.0

Fig. 7.12: The mean number of *Farsetia aegyptia* in weeks 2,4,6,8,12 and 20 of the experiment.

b) Percentage seedling survival

Survival of *Farsetia aegyptia* at week twenty as a percentage of the maximum number of emerged seedling recorded (week six) is shown in Fig. 7.58. Irrigation frequency had a significant impact on *Farsetia aegyptia* survival (P< 0.05). Grass had a highly significant effect on *Farsetia aegyptia* survival (P< 0.0001).

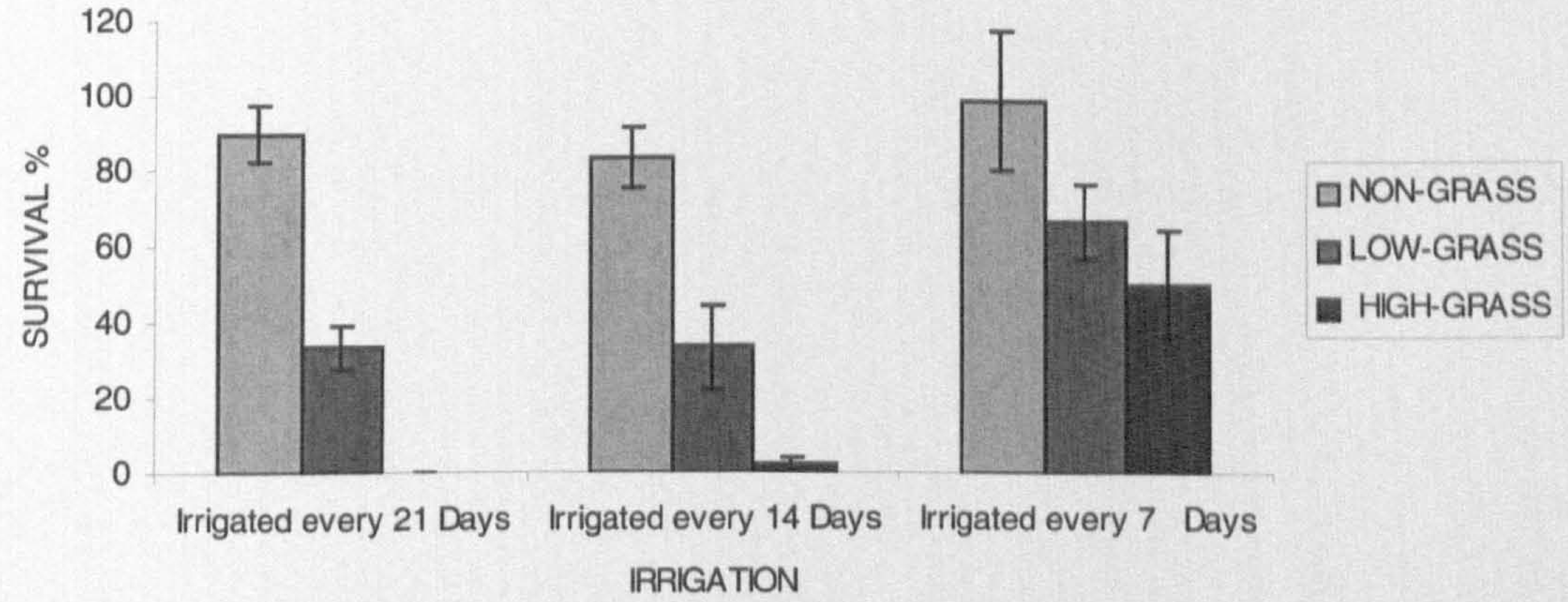

Fig 7.58: Percentage seedling survival of *Farsetia aegyptia* at the end of the experiment.

c) Shoot dry weight

Irrigation frequency has a non- significant impact on shoot dry weight of *Farsetia aegyptia* (P> 0.05) (Fig. 7.59). Grass had a highly significant effect on the shoot dry weight of *Farsetia aegyptia* (P< 0.0001). As grass density increases shoot dry weight decreases.

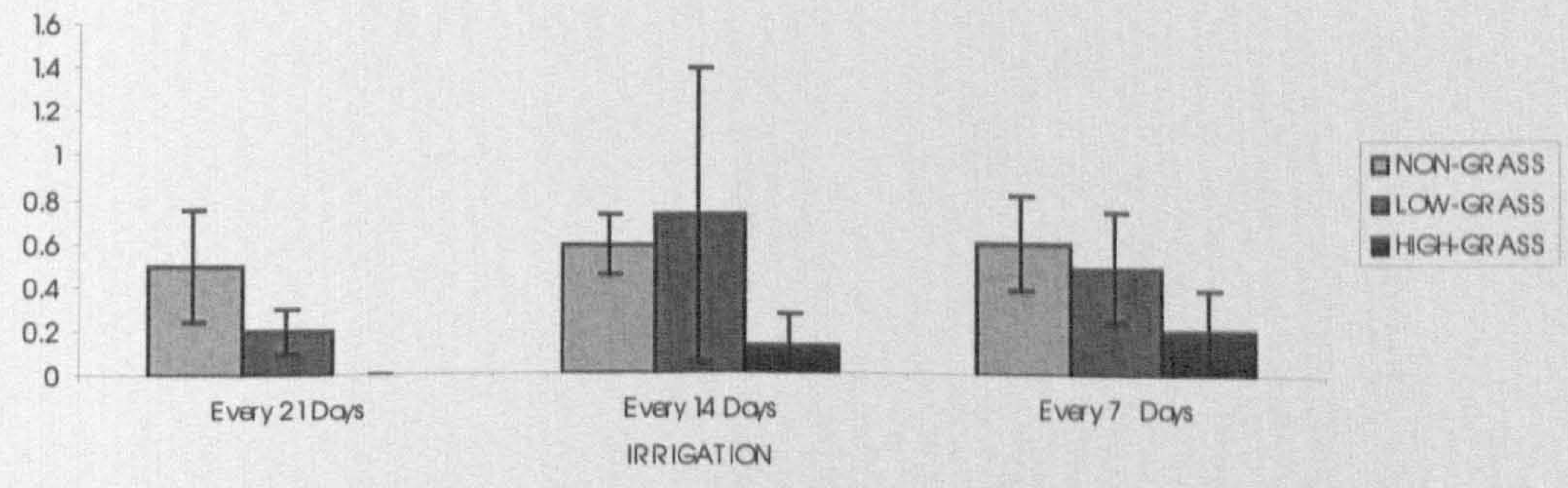

Fig. 7.59: The mean shoot dry weight of *Farsetia aegyptia* at the end of the experiment. Error bars represent SEM.

d) Root dry weight

Irrigation frequency had a non-significant impact on root dry weight of *Farsetia aegyptia* (P> 0.05) (Fig. 7.60). Grass had a highly significant effect on the root dry weight of *Farsetia aegyptia* (P< 0.0001). As grass density increases root dry weight decreases.

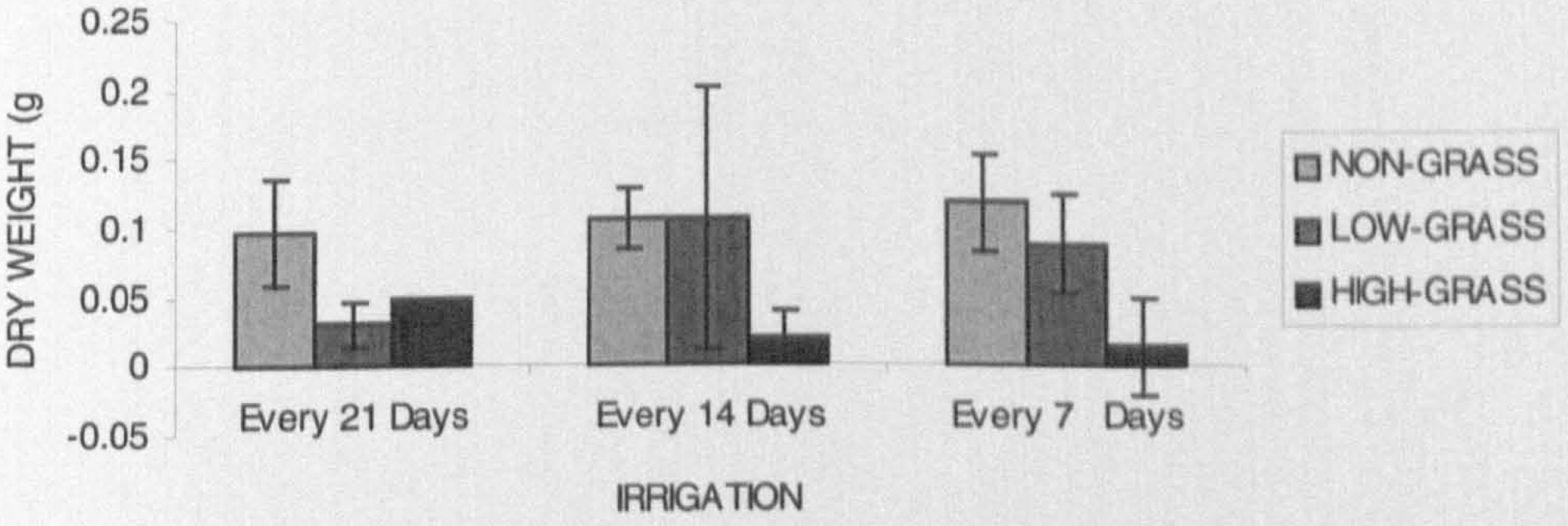

Fig. 7.60: Mean root dry weight of *Farsetia aegyptia* at the end of the experiment. Error bars represent SEM

e) Plants height

Irrigation frequency had a significant impact on plants height of *Farsetia aegyptia* (P< 0.0001) (7.61). As irrigation frequency increases, plant height increases. Grass had a highly significant effect on plants height of *Farsetia aegyptia* (P< 0.0001). As grass density increases plants height decreases.

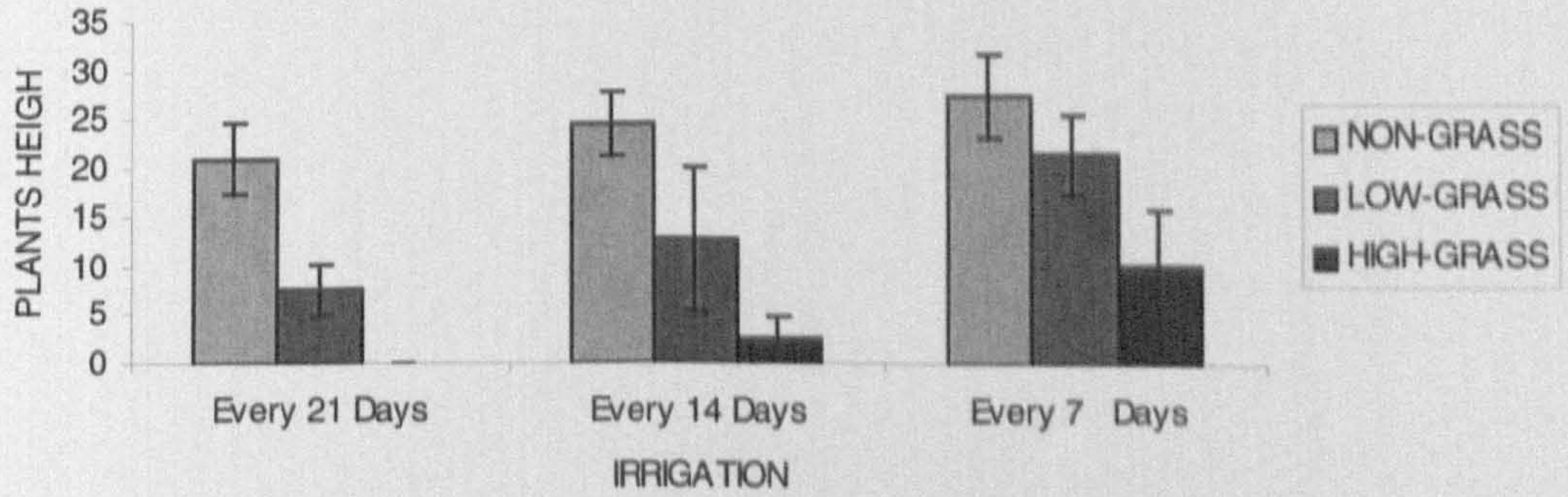

Fig. 7.61: Mean plants height of *Farsetia aegyptia* at the end of the experiment. Error bars represent SEM.

f) Root : shoot ratio

Irrigation frequency has a non-significant impact on root : shoot ratio of *Farsetia aegyptia* (P> 0.05) (7.62). Grass have a significant effect on root : shoot ratio of *Farsetia aegyptia* (P< 0.05).

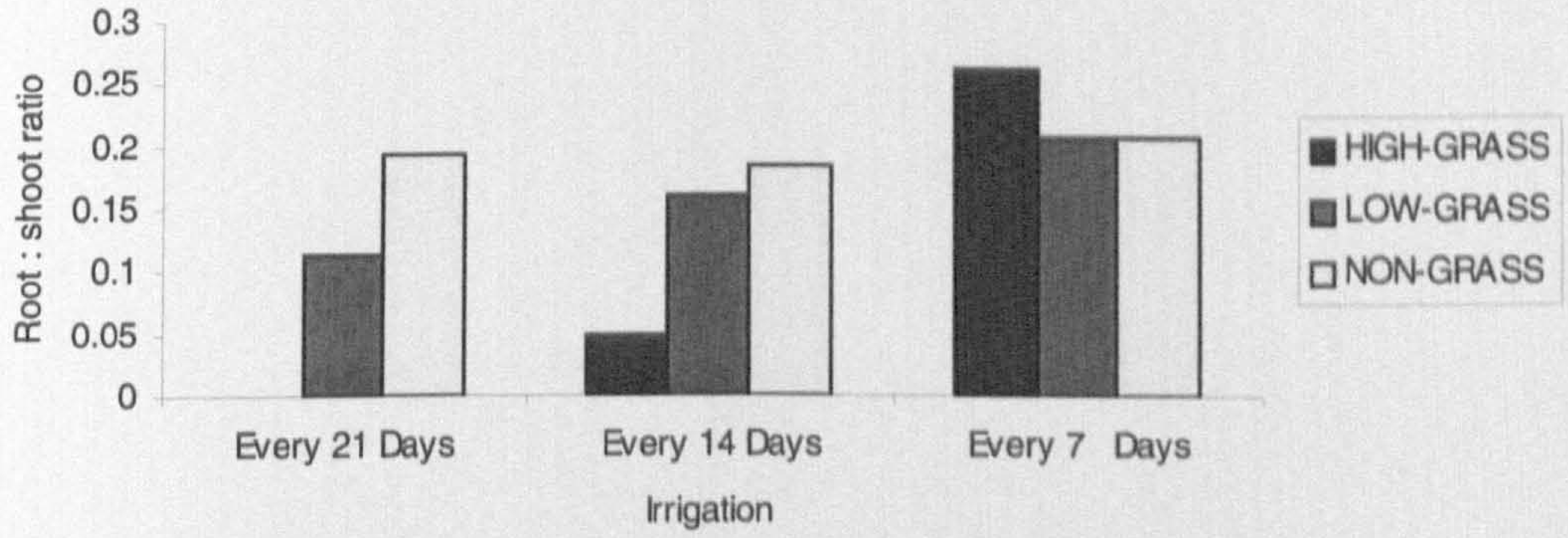

Fig. 7.62: Mean root : shoot ratio of *Farsetia aegyptia* at the end of the experiment.

viii. Peganum harmala

a) Seedling numbers across the experiment

It can be seen from Table 7.13 below, that the greatest number of *Peganum harmala* seedlings was present in the fourth week, with numbers declining from week five to harvest. There was a non-significant difference between irrigation frequency treatments at the end of the experiment (P > 0.05). Grass had a significant affect on number of *Peganum harmala* seedling (P < 0.05).

		W2	W4	W6	W8	W12	W20
Non-grass	irrigated every 3 week	4.0	4.0	2.0	2.0	2.0	0.3
	irrigated every fortnight	3.0	3.0	3.0	2.0	2.0	0.3
	irrigated weekly	4.0	4.0	3.0	3.0	3.0	0.3
Low grass	irrigated every 3 week	4.0	4.0	2.0	1.0	1.0	0.1
	irrigated every fortnight	4.0	4.0	2.0	2.0	1.0	0.3
	irrigated weekly	4.0	4.0	3.0	3.0	2.0	0.5
High grass	irrigated every 3 week	3.0	3.0	1.0	1.0	0.0	0.0
	irrigated every fortnight	4.0	4.0	2.0	1.0	0.0	0.0
	irrigated weekly	3.0	3.0	2.0	2.0	1.0	0.0

Table 7.13: The mean number of *Peganum harmala* in week 2,4,6,8,12 and 20 of the experiment.

b) Percentage seedling survival

Survival of *Peganum harmala* at week twenty as a percentage of the maximum number of emerged seedling recorded week four is shown in Fig. 7.63. Irrigation frequency has a non- significant impact on *Peganum harmala* survival (P> 0.05). Grass have a significant effect on *Farsetia aegyptia* survival (P< 0.05).

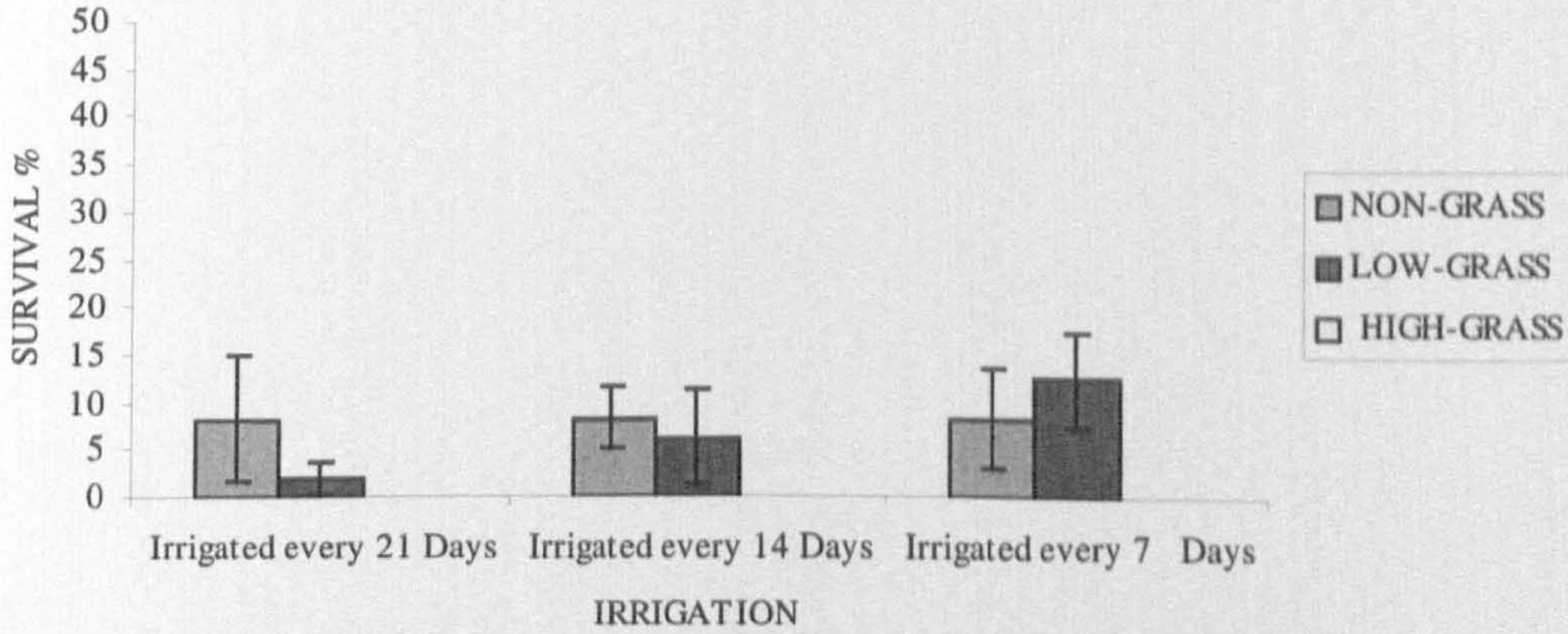

Fig 7.63: Percentage seedling survival of *Peganum harmala* at the end of the experiment.

c) Shoot dry weight

Irrigation frequency had a non- significant impact on shoot dry weight of *Peganum harmala* (P> 0.05) (Fig. 7.64). Grass had a significant effect on the shoot dry weight of *Peganum harmala* (P< 0.05). As grass density increases shoot dry weight decreases.

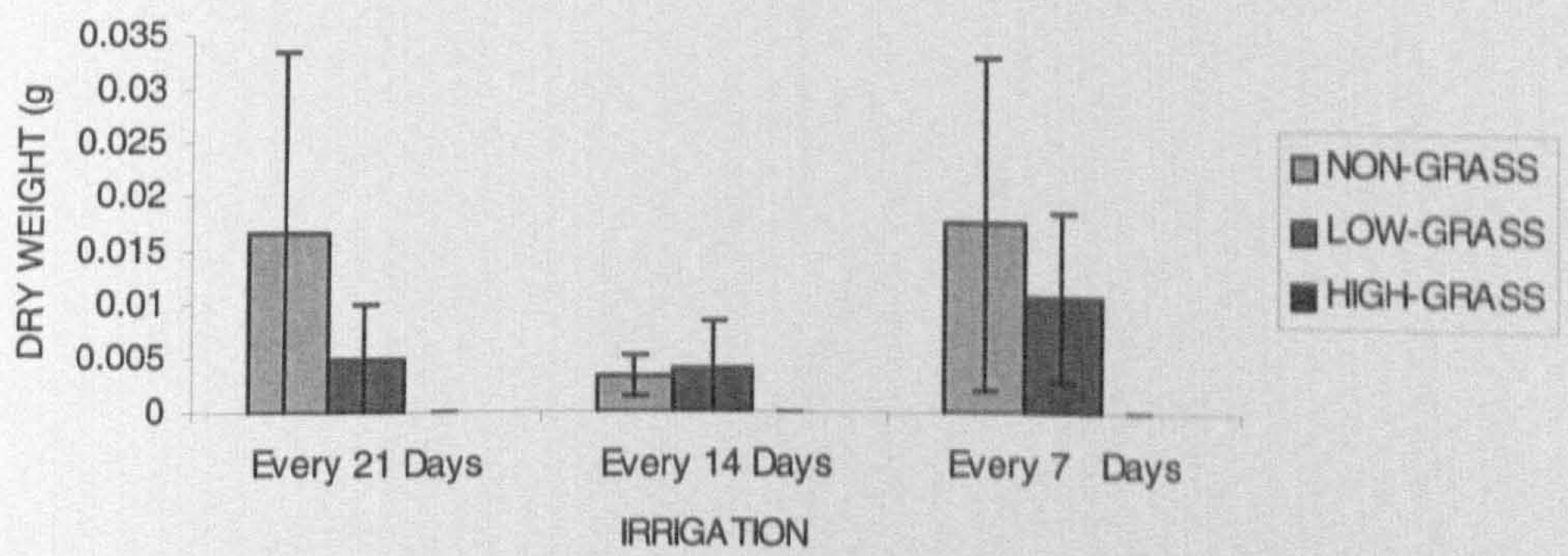

Fig. 7.64: Mean shoot dry weight of *Peganum harmala* at the end of the experiment. Error bars represent SEM

d) Root dry weight

Irrigation frequency had a non-significant impact on root dry weight of *Peganum harmala* (P> 0.05) (Fig. 7.65). Grass had a significant effect on the root dry weight of *Peganum harmala* (P< 0.05). As grass density increases root dry weight decreases.

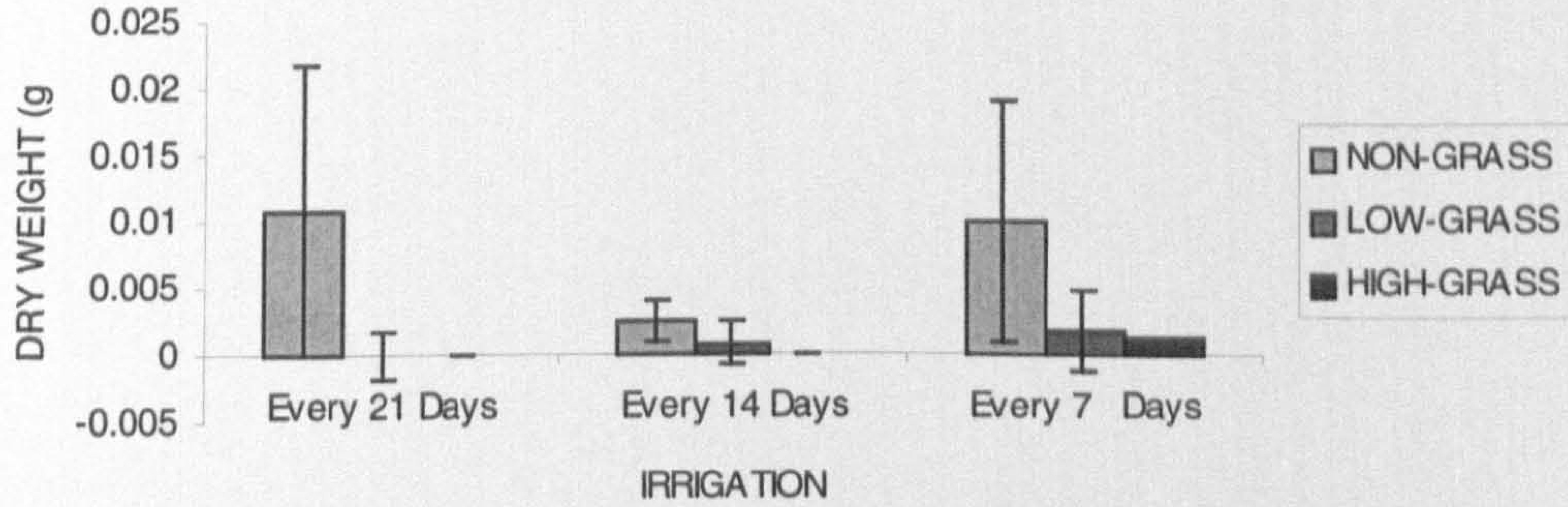

Fig. 7.65: Mean root dry weight of *Peganum harmala* at the end of the experiment. Error bars represent SEM

e) Plant height

Irrigation frequency had a non-significant impact on plants height of *Peganum harmala* (P> 0.05) (7.66). Grass had a significant effect on plants height of *Farsetia aegyptia* (P< 0.05). As grass density increases plants height decreases.

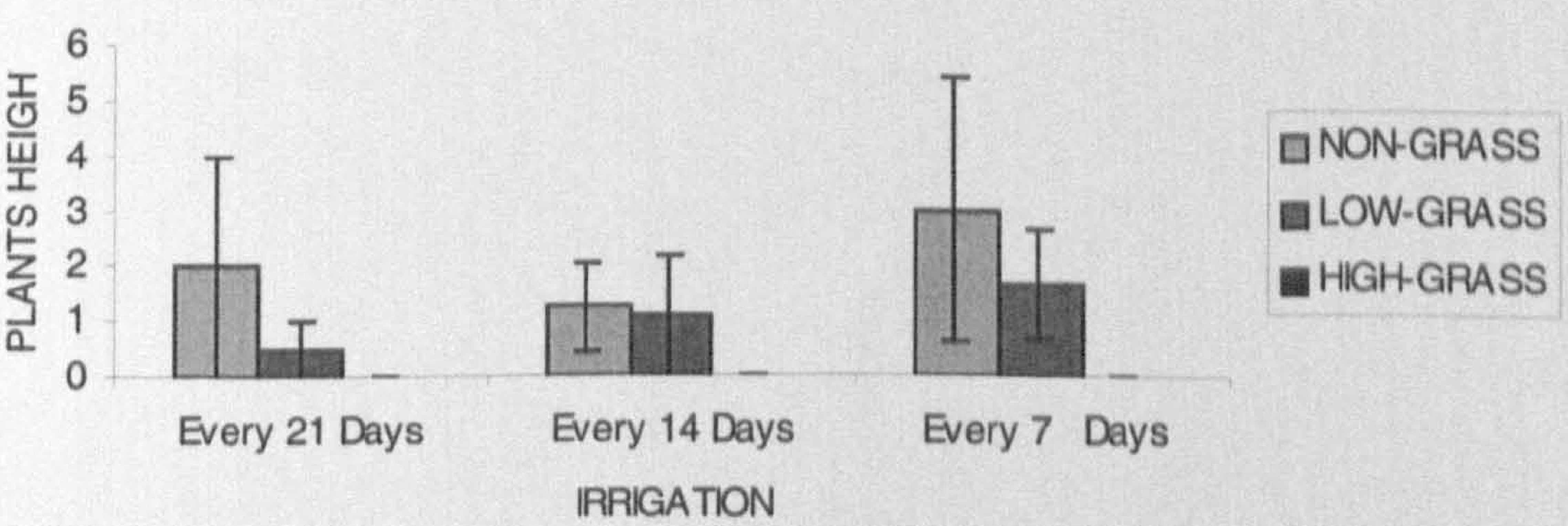

Fig. 7.66 : Mean plants height of *Peganum harmala* at the end of the experiment. Error bars represent SEM

f) Root : shoot ratio

Irrigation frequency had a non-significant impact on root : shoot ratio of *Peganum harmala* (P> 0.05) (7.67). Grass have a significant effect on root : shoot ratio of *Peganum harmala* (P< 0.05).

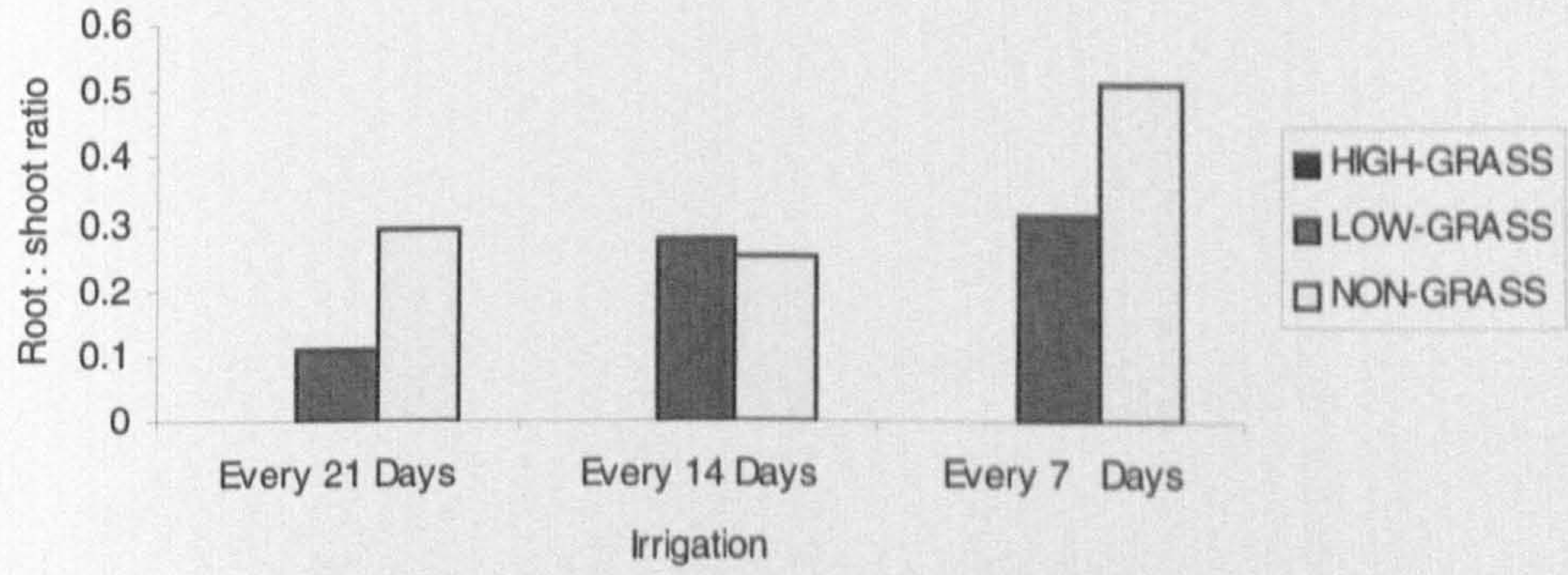

Fig. 7.67: Mean root : shoot ratio of *Peganum harmala* at the end of the experiment. Error bars represent SEM

ix. *Rumex villosa*

a) Shoot dry weight

Irrigation frequency had a non- significant impact on shoot dry weight of *Rumex villosa* (P> 0.05) (Fig. 7.68). Grass had a significant effect on the shoot dry weight of *Rumex villosa* (P< 0.05). As grass density increases shoot dry weight decreases.

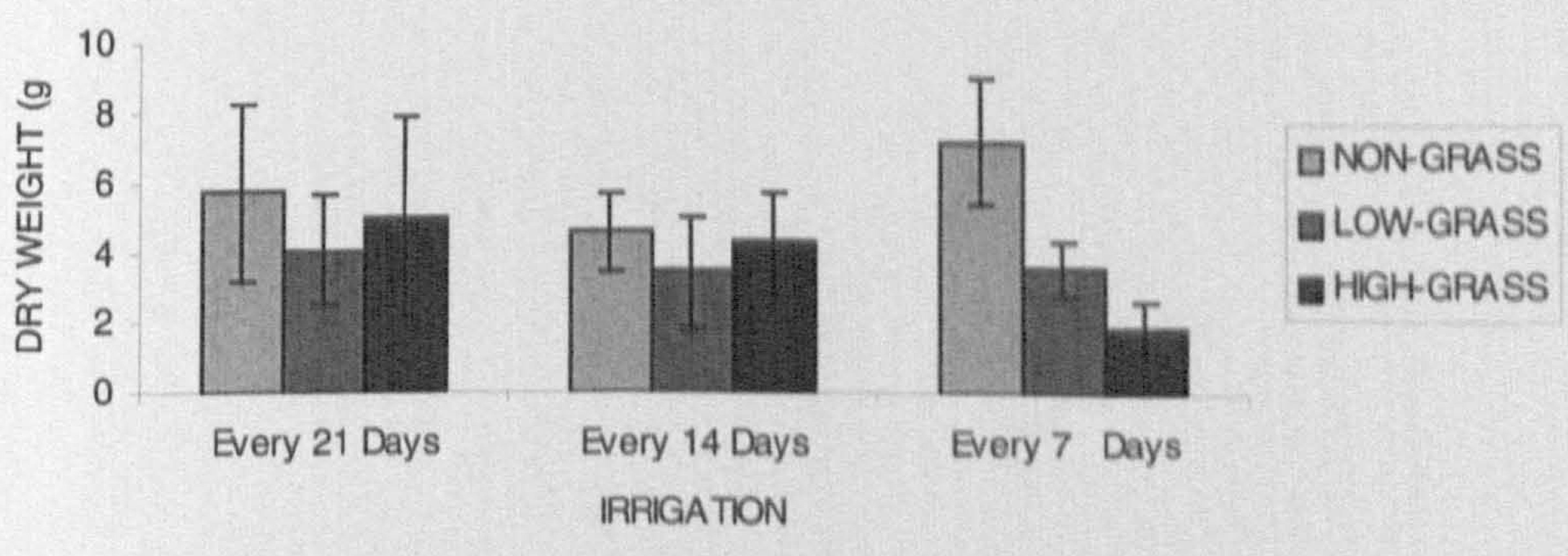

Fig. 7.68: Mean shoot dry weight of *Rumex villosa* at the end of the experiment. Error bars represent SEM

b) Root dry weight

Irrigation frequency had a non-significant impact on root dry weight of *Rumex villosa* (P> 0.05) (Fig. 7.69). Grass had a significant effect on the root dry weight of *Rumex villosa* (P< 0.05). As grass density increases root dry weight decreases.

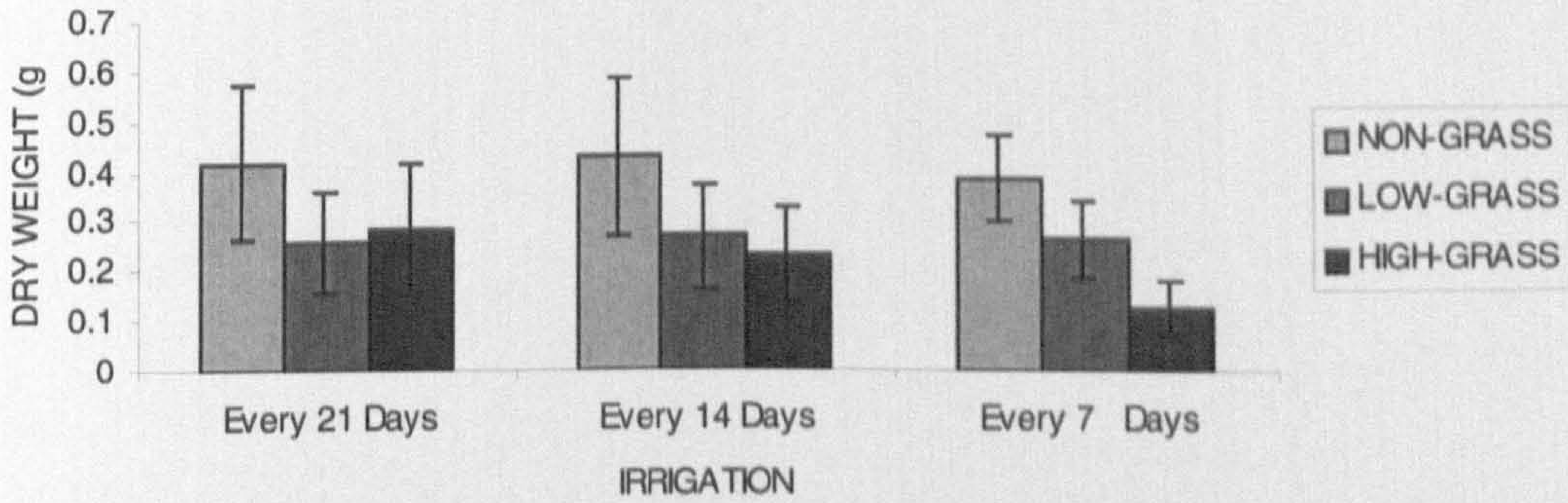

Fig. 7.69: Mean root dry weight of *Rumex villosa* at the end of the experiment. Error bars represent SEM

c) Plant height

Irrigation frequency has non-significant impact on plants height of *Rumex villosa* (P> 0.05) Fig. 7.70. Grass had non-significant effect on plant height of *Rumex villosa* (P> 0.05). As grass density increases plants height decreases. .

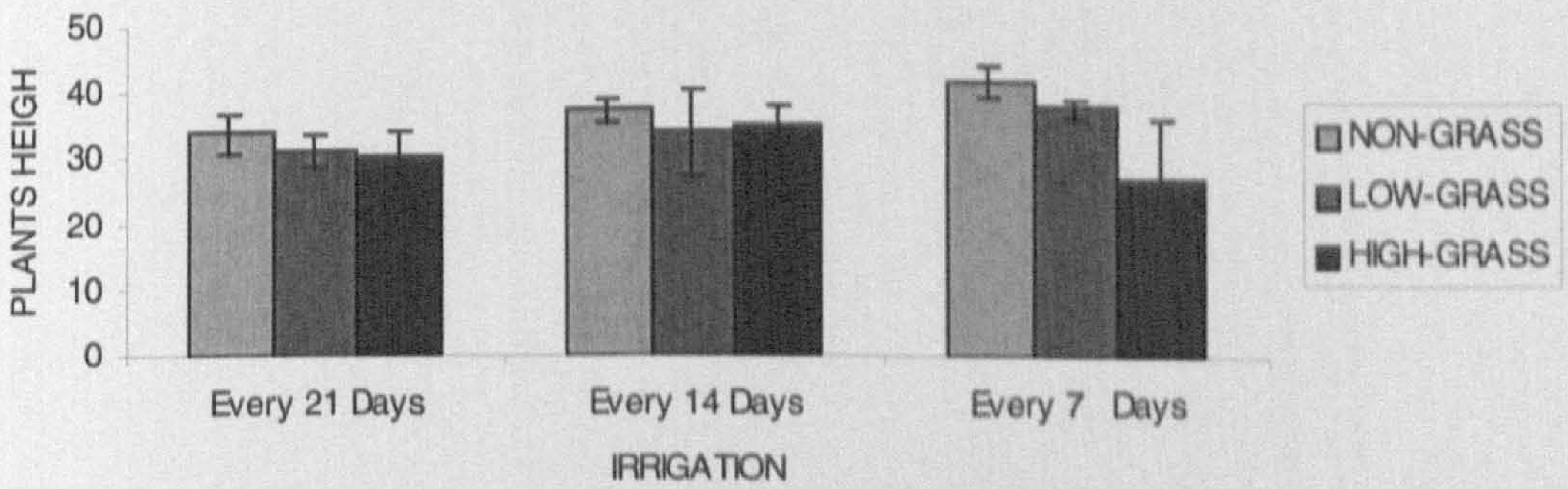

Fig. 7.70: Mean height of *Rumex villosa* at the end of the experiment. Error bars represent SEM

d) Root : shoot ratio

Neither irrigation frequency nor grass density had a significant impact on root : shoot ratio of *Rumex villosa* ($P > 0.05$) (7.71).

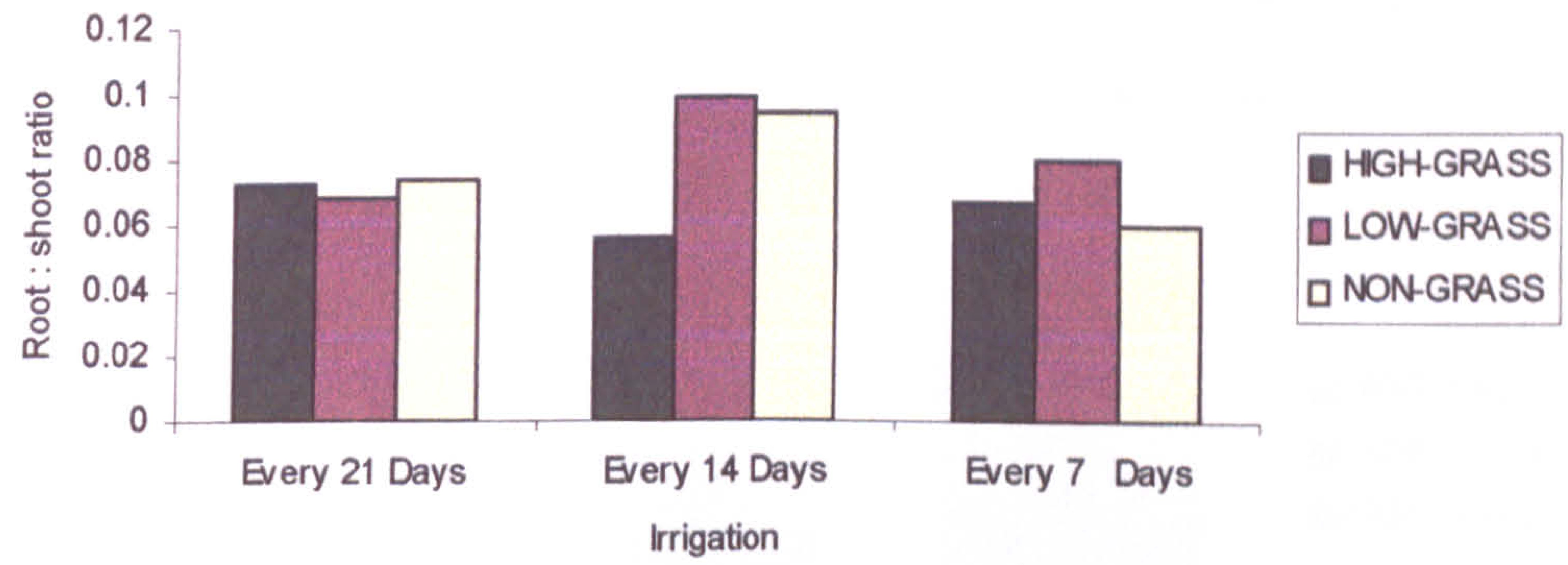

Fig. 7.71: The mean root : shoot ratio of *Rumex villosa* at the end of the experiment.

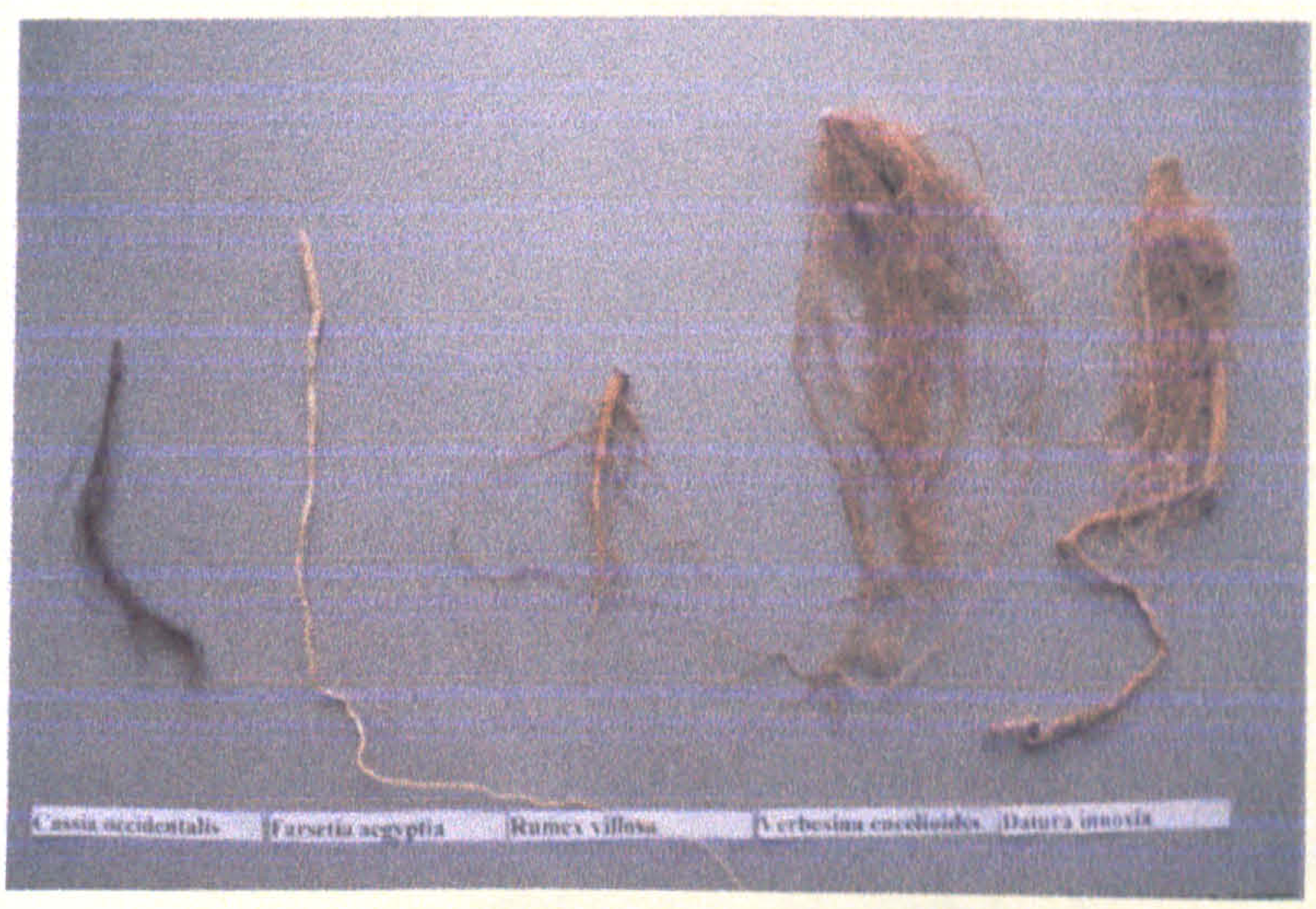

Fig. 7.72 Root system of *Cassia occidentalis, Farsetia aegyptia, Rumex villosa, Datura innoxia* and *Verbesina encelioides*.

x. ***Verbesina encelioides***

a) Shoot dry weight

Irrigation frequency has a highly significant impact on shoot dry weight of *Verbesina encelioides* ($P < 0.0001$) (Fig. 7.73). As irrigation frequency increases, shoot dry weight increases. Grass had a significant effect on the shoot dry weight of *Verbesina encelioides* ($P < 0.05$). As grass density increases shoot dry weight decreases.

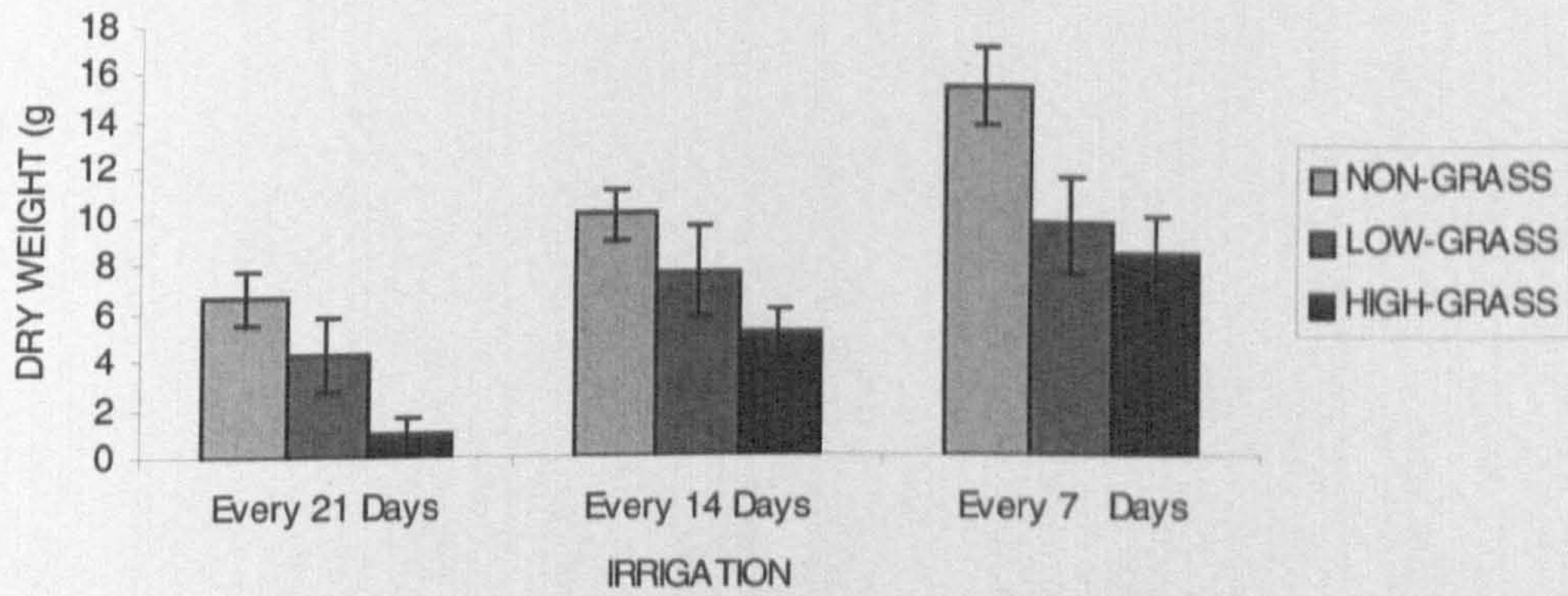

Fig. 7.73: Mean shoot dry weight of *Verbesina encelioides* at the end of the experiment. Error bars represent SEM

b) Root dry weight

Irrigation frequency had a highly significant impact on root dry weight of *Verbesina encelioides* ($P < 0.0001$) (Fig. 7.74). As irrigation frequency increases, root dry weight increases. Grass had a significant effect on the root dry weight of *Verbesina encelioides* ($P < 0.05$). As grass density increases root dry weight decreases.

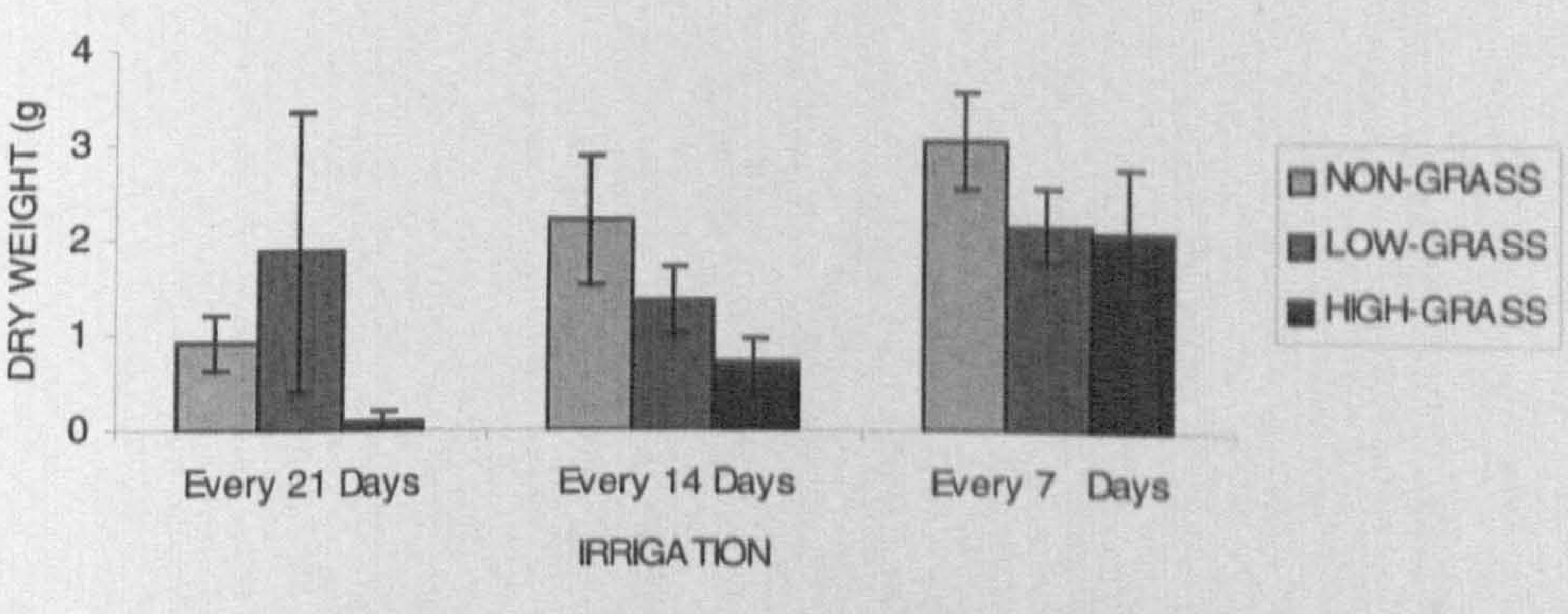

Fig. 7.74: Mean root dry weight of *Verbesina encelioides* at the end of the experiment. Error bars represent SEM

c) Plant height

Irrigation frequency had a highly significant impact on plants height of *Verbesina encelioides* (P< 0.0001) (7.75). As irrigation frequency increases, plant height increases. Grass had a significant effect on plant height of *Verbesina encelioides* (P< 0.05). As grass density increases plants height decreases.

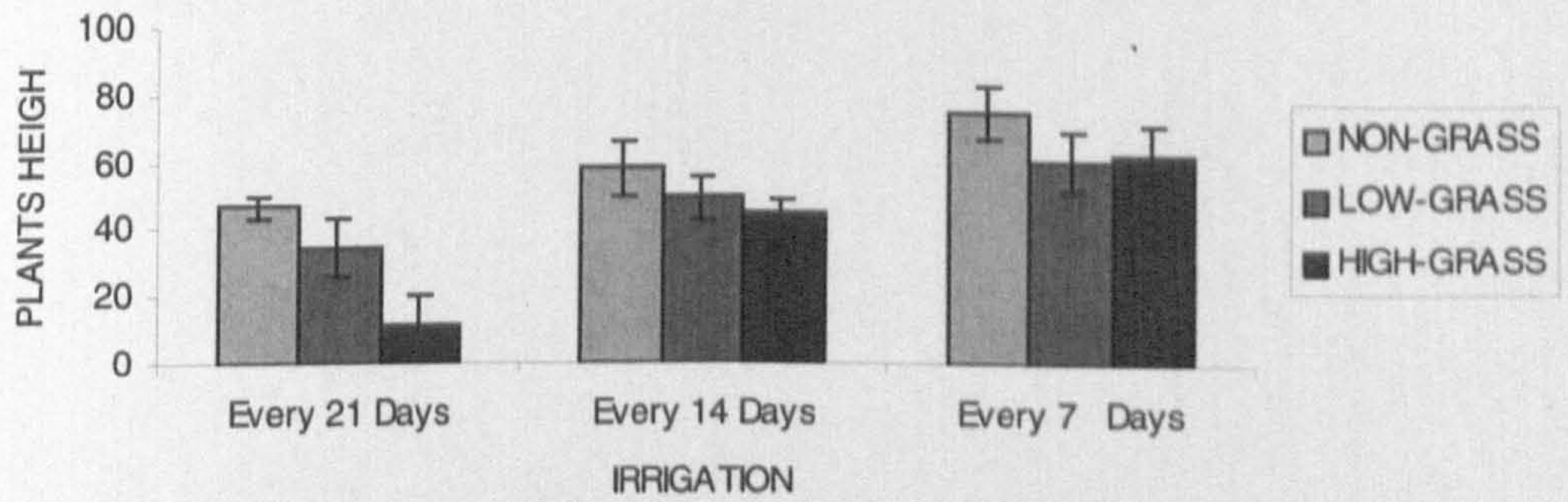

Fig. 7.75: Mean plant height of *Verbesina encelioides* at the end of the experiment. Error bars represent SEM

d) Root : shoot ratio

Irrigation frequency had a non-significant impact on root : shoot ratio of *Verbesina encelioides* (P> 0.05) (7.76). Grass had a non-significant effect on root : shoot ratio of *Verbesina encelioides* (P> 0.05).

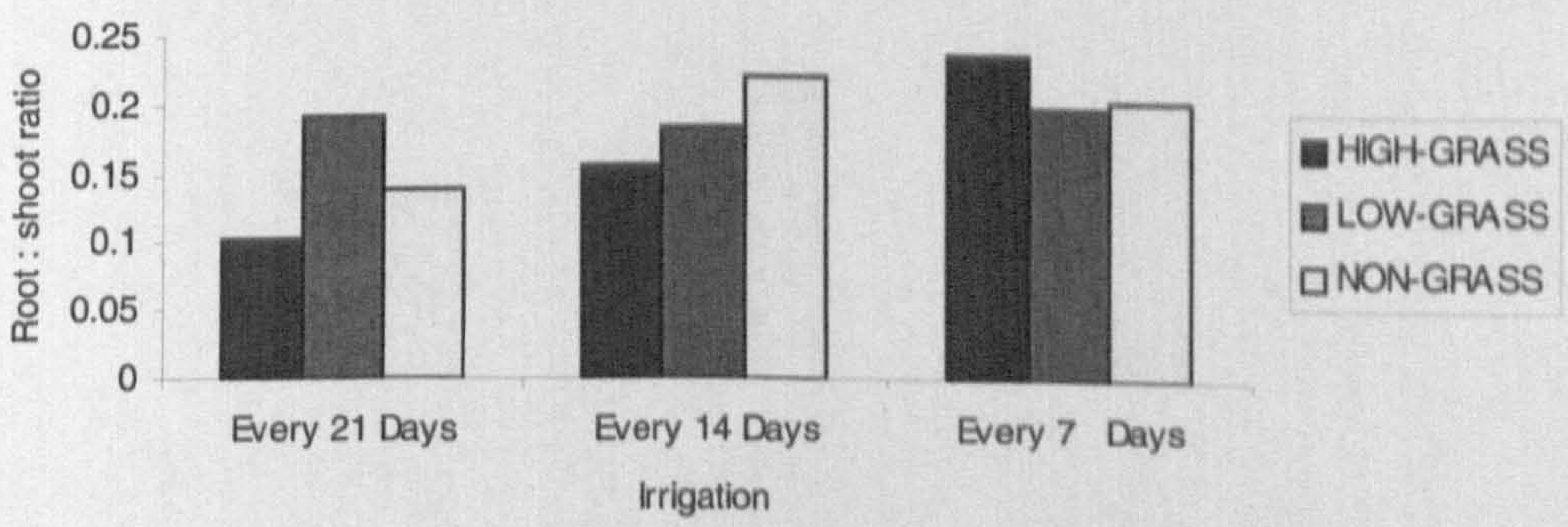

Fig. 7.76 : The mean of root : shoot ratio of *Verbesina encelioides* at the end of the experiment.

7.4 DISCUSSION

All of the species studied in this experiment have some adaptation in this micro-habitat and emerged, but with different emergence percentages as we expected. From the results there were some differences between sown forbs in terms of effect of grass competition and irrigation frequency on seedling emergence and growth, and the competition between these species. Some of these differences were significant (Table 7.3). A summary of our results are as follows:

Species	Treatment	Survival	Shoot D.W.	Root D.W.	Height	R : S Ratio
MEAN OF ALL SOWN FORBS	Grass	***	***	***	ns	*
	Irrigation	***	***	***	***	ns
Achillea fragrantissmia	Grass	***	*	***	***	ns
	Irrigation	*	*	**	***	ns
Artemisia judaica	Grass	ns	*	*	*	*
	Irrigation	ns	ns	ns	ns	ns
Cassia italica	Grass	ns	*	*	ns	*
	Irrigation	ns	ns	ns	ns	*
Cassia occidentalis	Grass	***	***	***	*	*
	Irrigation	***	***	***	*	*
Cassia senna	Grass	***	***	***	***	ns
	Irrigation	***	***	***	***	ns
Datura innoxia	Grass	ns	ns	ns	ns	*
	Irrigation	ns	ns	ns	ns	ns
Farsetia aegyptia	Grass	***	***	***	***	*
	Irrigation	*	ns	ns	***	ns
Peganum harmala	Grass	*	*	*	*	*
	Irrigation	ns	ns	ns	ns	ns
Rumex villosa	Grass	-	*	*	*	ns
	Irrigation	-	ns	ns	*	ns
Verbesina encelioides	Grass	-	*	*	*	ns
	Irrigation	-	***	***	***	ns

= significant at P=0.05 (= 0.05, ** = 0.01, *** = 0.001), ns = not significant, - = no data

Table 7.14: Effect of grass and irrigation on measured characteristics

7.4.1. SEEDLING EMERGENCE AND SURVIVAL

It has frequently been emphasized that early seedling growth is the most critical period in the life cycle of a plant and that susceptibility toward physical hazards is high (Grime and Curtis, 1976; Ryser, 1993; Morgan, 1998). In field studies, high seedling mortality during the summer months is often due to drought and competition with existing vegetation

(Grime and Curtis, 1976; Grace and Tilman, 1990; Biewer, 1997; Grime, 2001). The effect of irrigation and grass on seedling survival is clear, from many studies done by authors in different vegetation types Grime and Curtis, (1976); Klinhamer, (1988); Ryser (1993). The auther had expected that survival would be lowest at highest grass density and more frequent irrigation and highest at lowest grass density and least frequent irrigation as result of competitive displacement. Our investigation revealed a complex picture with some species behaving as expected, whilst others did not do so.

7.4.1.1 MEAN OF ALL SOWN FORBS (THE COMMUNITY AS A WHOLE)

After week four, irrespective of treatment seedling numbers decreased rapidly by harvest. Decline was greatest at infrequent irrigation suggesting that soil moisture stress was the major factor determining survival. Similar results are reported by Morgan (1995). Decline was greater in the grass treatment rather than when grass were absent. Again this suggests that the greater competition for moisture in the grass treatment further exacerbated seedling loss. Also where grass were present differences between irrigation treatments are obvious from week five. Where grass were absent these effects were much less obvious. It is clear that grass would be a problem in practice in the field in dry climates.

From the mean of all species we can observe that in week eight, competition had less effect on the mean number of surviving forb seedling in low grass treatment with irrigation every 14 days. Seedling numbers were less when irrigated every 7 or 21 days. This may be due to competition posed by the grass grass at the most frequent irrigation regime reducing growth of forbs in this treatment. As irrigation frequency decreases the soil is too dry for the grass to compete effectively however seedling numbers are smaller due to losses as result of infrequent irrigation. Also more irrigation may increase the size of the fast growing forb species (annuals) sown, therefore this may reduce the survival of some slow growing species as a result of the effect of the shade generated by the annual forbs.

At the end of the experiment, by increasing irrigation frequency seedling survival increases, presumably as result of decreasing competition for water with the grass.

However, in grass free treatments there was a very little effect of irrigation frequency on seedling survival because may most of these species are strongly stress tolerant. The effect of grass on seedling survival was clearer with severe water stress (pots irrigated every 21 days). This may be because in most of these species growth was slow compared to grass growth. Reduced irrigation did not improve survival by acting selectively on the less stress tolerant grass species as expected. This unexpected result may be due to *Lolium multiflorum* (a mediterranean annual) possessing greater stress tolerant than anticipated. On the other hand, survival of sown forbs was better at low nutrients with nil and low grass competition because of the positive effect of nutrients on the growth of annual forbs and grass, therefore subjecting more stress tolerants forbs to more competition.

7.4.1.2. INDIVIDUAL SPECIES

There were large differences between sown forbs in terms of survival. Some of these species have high survival such as *Datura onnoxia* (>90%) whilst others have low survival such as *Peganum harmala (<10%). Datura innoxia, Rumex villosa* and *Verbesina encelioides* seedling number was not affected by competition within all grass and irrigation frequency treatments; these species are all rapid growing annual forbs. This suggests that these species can be established in grassy sites and almost independent of irrigation or rainfall frequency.

In *Farsetia aegyptia* the effect of grass competition was more marked in response to water stress. This might be because this species grows relatively fast in response to irrigation therefore the effect of grass competition will be less. By contrast *Achillea fragrantissmia, Artemisia judaica, Cassia occidentalis, Cassia senna* and *Peganum harmala* were greatly affected by the presence of grass. Where grass were absent, there were very few difference in survival between different irrigation frequencies. These species appear more water stress tolerant, but in practice grass will have a negative effect on these species establishment. This may also be because they are more intolerant of shading by grass than species like *Farsetia aegyptia.*

7.4.2 SEEDLING GROWTH

7.4.2.1 SHOOT DRY WEIGHT

i. Mean of all sown forbs

Grass decreased mean shoot dry weight of sown forbs, whilst irrigation increased dry weight. However fig. 7.9 suggests that in terms of applying this to practice at high grass densities some seedlings of some forb species do not benefit from more frequent irrigation. Therefore on very grassy sites irrigation would not be valuable in practice. At high water stress, grass are less competitive than under low water stress and have less effect on shoot dry weight of sown forbs. At high water stress nutrients have less effect on shoot dry weight of sown forbs than under low water stress. This may be because of the mechanism of osmocote tablets, which was used in this experiment, they release more fertilizer under moister conditions, as well as the reduced uptake of nutrients in dry soils. In terms of shoot dry weight, the sown forbs : grass ratio in the high grass treatment, water stress disadvantaged competition from grass more than at low water stress.

ii. Individual species

In *Achillea fragrantissmia, Artemisia judaica* and *Cassia senna,* grass decrease shoot growth, whilst irrigation increases growth. However Fig. 7.31, 7.36 and 7.51 suggest that in practice at high grass densities seedlings of sown forbs cease to benefit from frequent irrigation. Therefore on very grassy sites irrigation would not be a valuable in practice. In *Datura innoxia,* grass decrease the growth of this species, in the high irrigation treatments however in low irrigation treatments and high grass density, growth increases. Fig. 7.56 suggests that in practice this species does not benefit from more frequent irrigation but it can grow well in grassy sites. This is assumed to be because it possesses ruderal characteristics; rapid growth and high capacity to compete for resources.

In *F. aegyptia* and *P. harmala* grass decrease growth. Irrigation did not increase growth in the absence of grass (Fig.7.61) these species are very slow growing and are likely to be stress tolerators (Grime et al 1988). Their strategy is to grow very slow and have limited capacity to respond to addition resources. In *Rumex villosa,* grass decreased growth at high irrigation treatment however at low irrigation frequency grass did not decrease growth (Fig. 7.70). Again this suggests that such species would be most readily established utilizing natural soil moisture stress post germination to suppress competition from grassy species that establish from the soil seed bank.

7.4.2.2 ROOT DRY WEIGHT

i. Mean of all sown forbs

The most common pattern observed was for root dry weight increase with irrigation. But as grass competition increases these effects are reduced. Generally the effect of irrigation are reduced at low nutrients. To achieve maximum root dry weight forbs must grow at low grass densities, so grass control is important. At low nutrients and infrequent irrigation root dry weight of sown forbs was proportionally higher, because stress increase the root shoot ratio, in line with models predicting how species competitive capacity is affected by these factors. Tilman (1988) postulated that plant species that are adapted to nutrient-poor habitats show increased biomass of root issue.

ii. Individual species

In *Achillea fragrantissmia, Artemisia judaica, Cassia occidentalis* and *Cassia senna* grass decrease root system size. Irrigation increases root mass. However Fig. 7.32, 7.37, 7.47 and 7.52 suggest that in practice at high grass densities seedlings of these forbs do not benefit from more frequent irrigation. In *Datura innoxia,* grass decrease root system mass at high irrigation frequencies however with low irrigation frequency, high grass density does not decrease root system size. Fig. 7.57 suggests that in practice root mass in this species does not benefit from more frequent irrigation and it can grow well in grassy sites. In *Farsetia aegyptia, Peganum harmala* and *Rumex villosa* irrigation does not increase root system size in the absence of grass (Fig.7.62, 7,67 and 7.71). This suggests these species are stress tolerators.

7.4.2.3 ROOT : SHOOT RATIO

i. Mean of all sown forbs

When grass are absent irrigation increases the root : shoot ratio of sown forbs as whole. With water stress the ratio decreases presumably because some of the species continue to make more leaves than roots. This is somewhat contrary to what might be expected; many studies suggest root : shoot ratios increase with moisture stress. This results may be due to the preponderance of ruderals in the community, at respond to drought stress in the opposite manner to more conservative perennial species.

ii. Individual species

It is clear in some species such as *Artemisia judaica* in non-grass treatments, root : shoot ratio increases with water stress, as photosynthates are selectively diverted to root production to improve water capture. In *Farsetia aegyptia* and *Peganum harmala* (at irrigation every fortnight and every three weeks treatments only) in non-grass treatment also show root : shoot ratio increases with water stress. In *A. fragrantissmia, C. italica* and *C. senna*, in non-grass treatment root: shoot ratio decreases with moisture stress, plants continue to make more leaves than roots. Irrigation and grass do not have any impact on roots : shoots ratios in *Rumex villosa* and *Verbesina encelioides*. Both of these species have strong ruderal tendencies.

7.4.2.4 PLANT HEIGHT

In *Verbesina encelioides* grass competition decreased plant height within the low irrigation treatment however with high irrigation treatment, plant height did not decrease. Fig. 7.76 suggests that in practice at high grass densities height of *V. encelioides* benefits from more frequent irrigation, and it can grow well in grassy sites as might be expected of vigorous ruderal species. In *R. villosa* grass and irrigation neither increase or decrease its height. In species such as *Peganum harmala,* grass decrease the plant height however increasing irrigation frequency does not lead to a corresponding increase. This lack of response to environmental factors in this stress tolerating species has previously been commented on.

Unfortunately, there are no specific published studies in terms of the effect of grass competition and irrigation frequency on the establishment of these species within plant community. Our results are however broadly supported by previous studies such as; Grimes CSR theory which is summarized in Table 7.2, as well as Newmans, 1973, study into how soil fertility influences the nature of competition. At low nutrient availability, competition tends to be below-ground; however on more fertile sites shading may be more significant. Tilman (1988) postulated that plant species adapted to nutrient-poor habitats by an increased root biomass. According to Newman (1973), Huston and Smith (1987) and Tilman (1988) the nature of competition itself changes according to the prevailing conditions and the nature or the plants. Benayas *et al.* (2002) suggest that competition between seedlings and grass is primarily for water rather than for light.

The CSR model proposes that plants have evolved three major life history strategies (competitive, ruderal, and stress tolerant) for different kinds of environments (Grime 1977). This functional classification has been developed for the established (adult) and regenerative (juvenile) phases of the life-history. However the results of our experiments in this thesis involved seedling which may behave very differently from adults (established plants), nevertheless it gives an indication of how these species may behave under different conditions in the establishment phase.

Overall, the result suggested most of these species have high physiological or morphological tolerance of moisture stress. However this is expressed through different ecological strategies. Grass competition is likely to be a significant constraint on the successful establishment of many of these Saudi native species especially those that are poorly adapted to fertile conditions such as *Peganum harmala*. Control of grass should be considered explicitly when developing a restoration plan, as well as ensuing enough moisture for adequate germination of sown seed.

CHAPTER 8

8. A FURTHER STUDY OF COMPETITION IN SOME NATIVE SPECIES

CHAPTER 8

8. A FURTHER STUDY OF COMPETITION IN SOME NATIVE SPECIES

8.1 -INTRODUCTION

Competition from more established vegetation is major factor limiting the successful establishment of species in the landscape. It is of particular importance when trying to establish native species on disturbed sites where seed banks are dominated by aggressive weed species. A common assumption about productive or fertile soil is that competition is mainly for light with little competition for nutrients. Wilson (1988) reviewed 23 studies that investigated root and shoot competition and found that on balance root competition was usually more important than shoot competition.

Grime (1973) stated that "the terminal role of shading in competition on fertile soils should not be allowed to obscure the fact that in such circumstances competition for nutrients is severe and may be of critical importance". This view is supported in the classic experiment of Donald (1958) in which the competitive superiority of *Lolium perenne* over *Phalaris aquatica* under conditions of high soil fertility, was pronounced only in treatments which allowed root competition. The mechanisms that facilitate successful recruitment and the relative importance of competition aboveground (for light) and belowground (for nutrients or water) are poorly understood.

Belowground competition is measured by quantifying the extent that root interactions reduce resource uptake, vegetative growth, or fecundity. Population or community level approaches generally estimate below-ground competition from biomass increases when interactions with neighboring roots are prevented through the use of root exclusion tubes, trenching or neighbor removal (Casper and Jackson 1997).

Root exclusion tubes are frequently employed in population or community level studies. Typically cylindrical steel or plastic partitions are inserted into the soil to separate the roots of target individuals, usually transplanted seedlings, from those neighboring plants. Root competition is determined by comparing the growth or survival of target plants inside the partitions with those whose root systems can interact freely with neighboring vegetation (Cook and Ratcliff 1984).

Environmental gradients are a powerful tool for studying the relationship between competition and environmental factors (Keddy 1991). However, variation in competition intensity, defined as the degree to which a plant is reduced by the presence of neighbours (Keddy 1991) increases along a gradient of increasing of plant biomass and nutrient availability. However, the intensity of competition does not vary predictably with biomass and nutrients in mixed-grass prairie (Wilson and Shay 1990).

Existing models and theories make contrasting predictions about changes in competition intensity along gradients. One view predicts an increase in both root and shoot competition along a gradient of increasing soil resources and the co-occurring gradient of increasing plant biomass (Grime 1973, 1979). The opposing view (e.g. Tilman 1985, 1987) says that the root competition should decrease and shoot competition should increase along a gradient of increasing soil resources whereas total competition should remain constant (i.g. there is a trade-off for above- and below-ground resources and root shoot competition are inversely related). Wilson and Tilman (1991) found that competition is primarily below-ground in less productive sites and is both below- and above-ground in more productive sites. Also Wilson and Tilman (1993) found that total competition intensity (below- and above-ground) did not vary with fertility and the intensities of below- and above-ground competition were significant.

In the study described in this chapter there are three parts. The first experiment was an extension of the experiment described in component Chapter 7 into the effect of cutting on the establishment of a sown community of Saudi native species. The second experiment was also an extension of an experiment described in this previous chapter about the effect of competition in a sown community of Saudi native species. In the new experiment only four species plus a weed species were used in contrast to nine species in the previous experiment. The main aim of this experiment to was look more carefully by eliminating the effect of fast growing ruderal species (*Verbesina encelioides* and *Rumex villosa),* and which in the previous experiment may have acted as "weed" species in addition to *Lolium multiflorum.*

The third new experiment considered underground and aboveground competition. The aim was to investigate the competition between two indigenous Saudi species and a common urban weed of arid landscapes to understand how this acts on these species.

8.2-MATERIAL AND METHODS

8.2.1 EXPERIMENT 1; EFFECT OF CUTTING ON COMPETITION IN A SOWN COMMUNITY OF SAUDI NATIVE SPECIES

The basis of this experiment has previously been described in chapter seven, but this experiment was undertaken using one treatment with four replicates. The treatment was cutting (approximately 7cm above surface every two weeks) started from week five. The study looked at the outcome of competition with cutting in the first 5 months after sowing (from May 2001 to October 2001). A glasshouse environment was used to simulate the climatic conditions experienced in the Riyadh area of Saudi Arabia. An air temperature of between 20°C to 30°C was monitored which corresponds to spring season in Saudi Arabia. Species were grown in 400 mm diameter pots filled with sharp sand. The experiment involved nutrients at level 2 (8 Osmocote Tablets each pot see page 154). Irrigation frequency was once a fortnight. Weeds at level 3 (40 seeds each pot). Further details of these treatments levels have previously been provided in chapter seven.

For the cutting experiment mean dry weights (above and under ground parts) at the final harvest in October 2001, were subjected to analysis of variance (ANOVA), to determine whether significant differences occurred at $P = 0.05$. The means of shoot dry weight data were square root transformed, however the means of root dry weight data were $\log_e$ transformed.

8.2.2 EXPERIMENT 2; EFFECT OF COMPETITION IN A SOWN COMMUNITY OF FOUR SAUDI NATIVE SPECIES

Four species (*Cassia occidentalis, Farsetia aegyptia, Achillea fragrantissima,* and *Artemisia judaica*) were sown in 234mm (9") pots filled with sharp sand plus essential nutrients. The research looked at competitive outcomes in the first 10 weeks after sowing across a series of management gradients involving different densities of weed competition (non, low and high), plus three irrigation frequencies (low, medium and high). The nine treatment combinations are shown in Table 8.1 There were four replicates, giving rise to 36 (4x9) experimental units in total.

No	Treatment	No	Treatment	No	Treatment
1	I. 1 + W. 1	4	I. 2 + W. 1	7	I. 3 + W. 1
2	I. 1 + W. 2	5	I. 2 + W. 2	8	I. 3 + W. 2
3	I. 1 + W. 3	6	I. 2 + W. 3	9	I. 3 + W. 3

I = Irrigation frequency (1=low (once/3 weeks), 2=medium (once/fortnight), 3= high (once/week)). W = Weeds (1= Non (0 seeds/unit), 2= low (5 seeds/unit), 3=high (10 seeds/unit)).

Table 8.1. The nine treatment combination in the experiment.

A glasshouse environment was used to regulate as closely as possible the climatic conditions experienced in the Riyadh area of Saudi Arabia with daytime temperatures between 20°C to 30°C. At the end of the experiment; shoot dry weight and root dry weight were taken as previously described.

8.2.3 EXPERIMENT 3; ABOVE-GROUND AND UNDERGROUND COMPETITION EXPERIMENT

Two Saudi native species; *Datura innoxia* (an annual with fast growth) and *Peganum harmala* (a perennial with slow growth) were studied to determine the outcome of competition by comparing the growth and survival of these species. *Lolium multiflorum* was included as a weed species. This experiment had three components; root and shoot competition, shoot competition and root competition. The full range of treatment combinations are shown in Table 8.2.

In all cases four plants of each species were established by sowing in each pot according to the protocol in Table 8.2. For the root exclusion tubes approach plants were sown in cylindrical plastic PVC pipe (50mm) after these cylinders were inserted into the soil to a depth of 16cm in 12 L pots filled with sand plus essential nutrients. For the root competition treatments four plants of each species were grown individually inside a weld mesh cone (10cm in height with a cone hole diameter of 2cm at the bottom). Roots were freely able to interact with neighboring species, but shoot were kept separate in space. For root and shoot competition treatment there were no aboveground weld mesh or underground tubes.

The experiment looked at competitive outcomes in the first 10 weeks after sowing. As in the previous studies the glasshouse environment was regulated as closely as possible to the climatic conditions experienced in the Riyadh area of Saudi Arabia. At the end of the experiment; shoot dry weights were taken as previously discussed. Statistical analysis was undertaken using [*SPSS version 10 package*] to determine whether significant differences occurred at P=0.05.

(1) shoot competition			
By separating underground parts only using cylindrical PVC 50mm diameter pipe	D & L (R1) D & L (R2) D & L (R3) D & L (R4)	D & P (R1) D & P (R2) D & P (R3) D & P (R4)	P & L (R1) P & L (R2) P & L (R3) P & L (R4)
(2)root competition			
By separating aboveground parts only using mesh cone	D & L (R1) D & L (R2) D & L (R3) D & L (R4)	D & P (R1) D & P (R2) D & P (R3) D & P (R4)	P & L (R1) P & L (R2) P & L (R3) P & L (R4)
(3) root and shoot competition			
No separation for underground or aboveground	D & L (R1) D & L (R2) D & L (R3) D & L (R4)	D & P (R1) D & P (R2) D & P (R3) D & P (R4)	P & L (R1) P & L (R2) P & L (R3) P & L (R4)
D = *Datura innoxia*, P = *Peganum harmala*, L = *Lolium multiflorum* R1 - R4 = replicates			

Table 8.2. The treatment combinations and species use in the experiment

For the effect of competition in a sown community of Saudi native species plus the above-ground and under-ground competition experiments, mean shoot and root dry weights at the final harvest in August 2002 were subjected to analysis variance (ANOVA), to determine whether significant differences occurred at P = 0.05. Means were separated and ranked by the LSD test. Where appropriate a post hoc test (Tukey Honestly significant difference) was undertaken to rank the means. The means of shoot dry weight data were square root transformed.

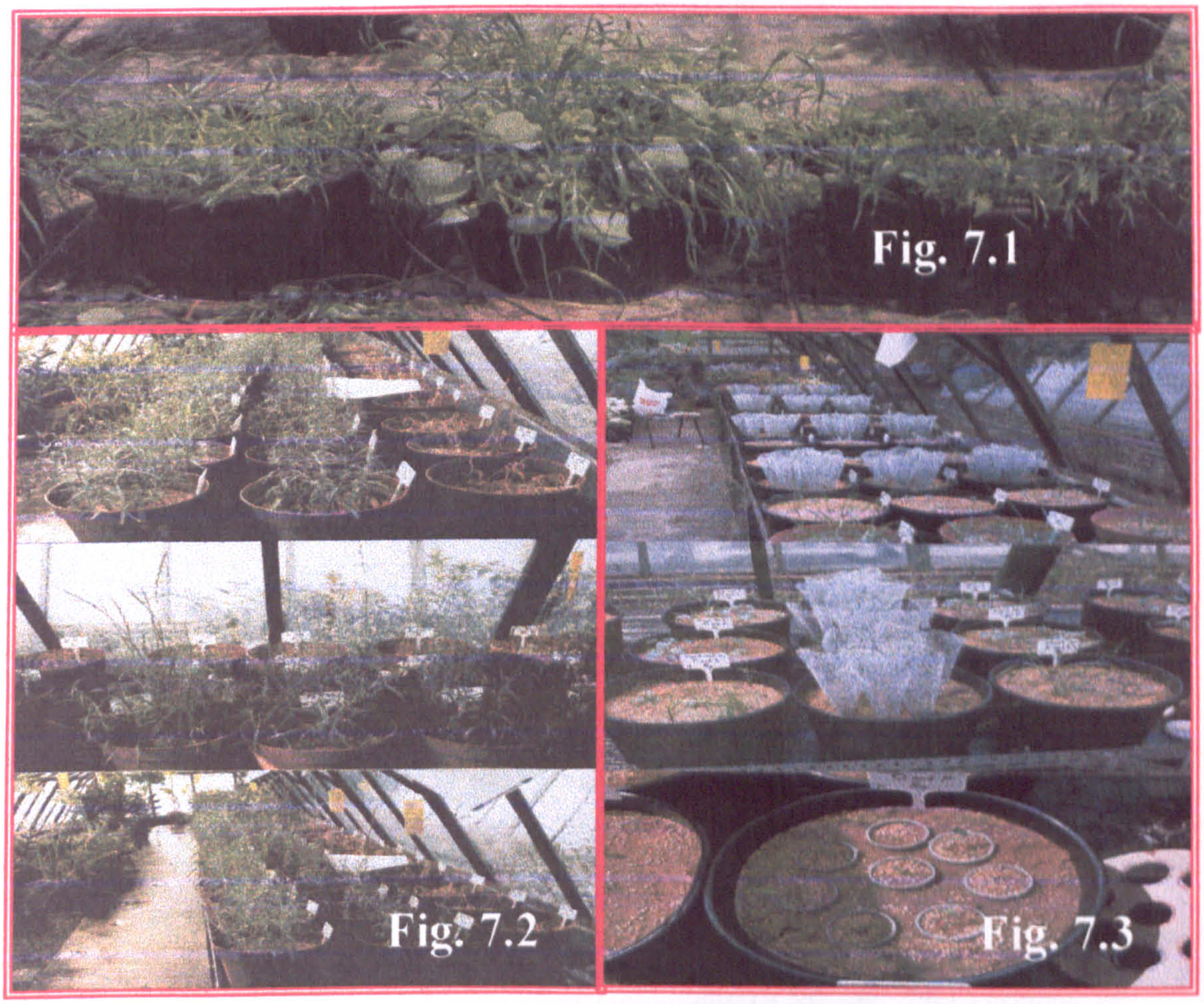

Fig. 7.1: Experiment 1; Effect of cutting on competition in a sown community of Saudi native species

Fig. 7.2: Experiment 1; Effect of cutting on competition in a sown community of Saudi native species

Fig. 7.3: Experiment 3; Above-ground and under-ground competition experiment

8.3 RESULTS

8.3.1 EXPERIMENT 1; EFFECT OF CUTTING ON COMPETITION IN SOME MIXES OF SAUDI NATIVE SPECIES

8.3.1.1 MEAN OF ALL SOWN FORBS

i. Seedling survival at the end of the experiment

From Fig. 8.4 it can be seen that cutting had a non- significant impact on the mean number of sown forbs ($P > 0.05$) at the end of the experiment.

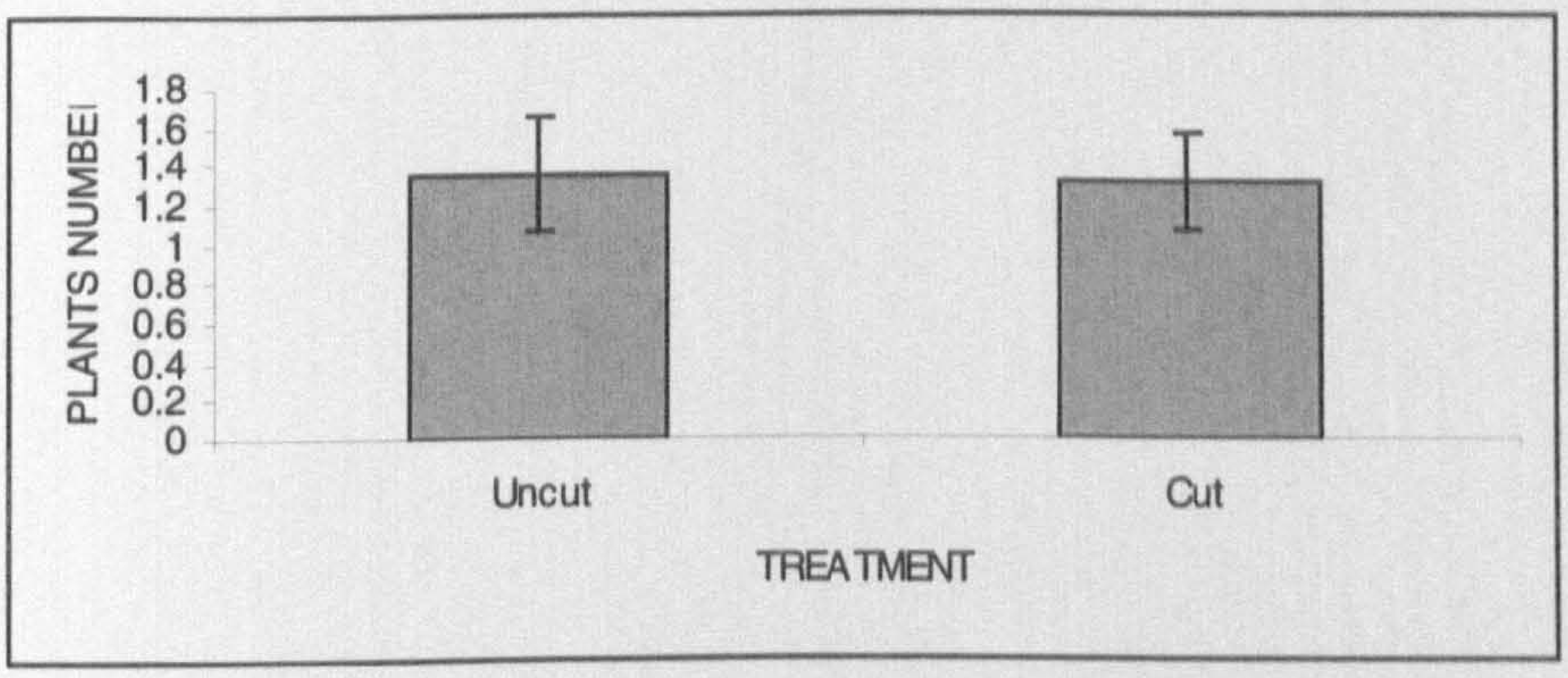

Fig 8.4: Effect of cutting on the number of surviving forbs (mean of all species). Error bars represent standard errors.

ii. Percentage seedling survival

Survival of sown forbs (at week twenty) as a percentage of the maximum number of emerged seedlings recorded (week four) can be seen from the chart below (Fig. 8.5). Furthermore it can be seen that cutting has a non-significant impact on the percentage survival of sown forbs ($P>0.05$).

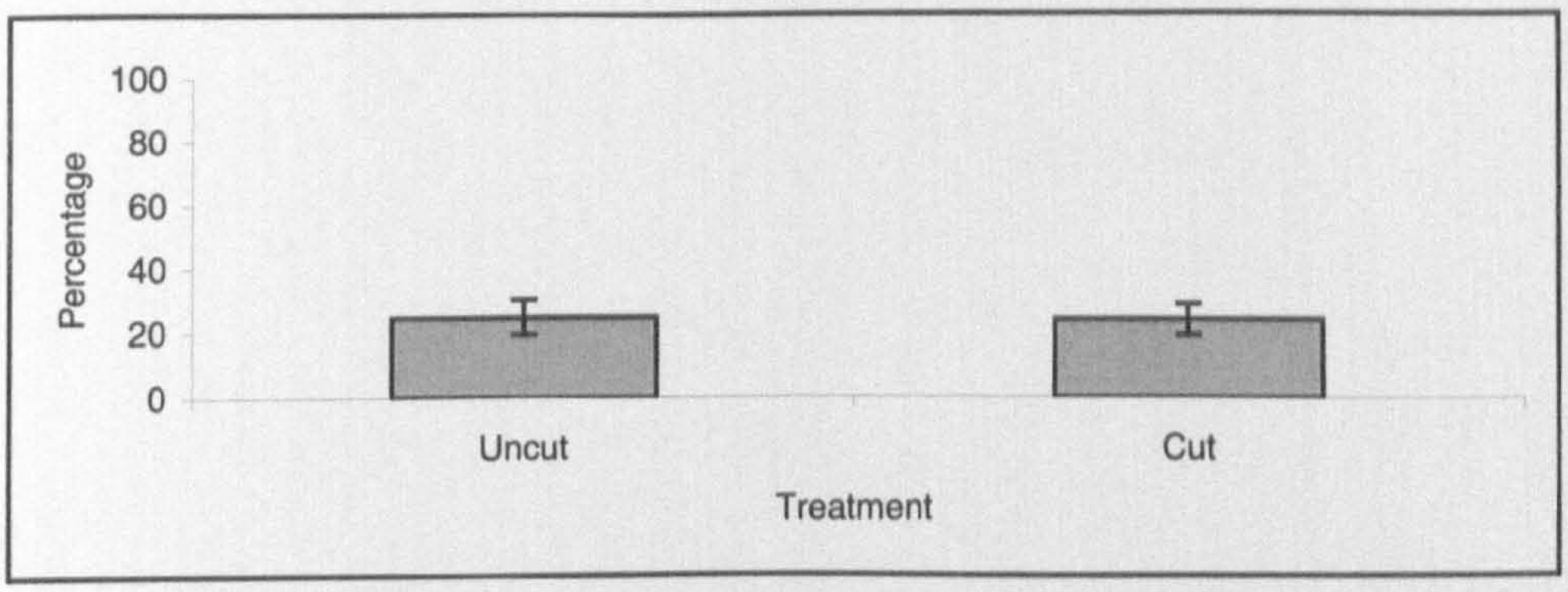

Fig. 8.5: Effect of cutting on percentage of surviving forbs (mean of all species).

iii. Shoot dry weight

From the chart below (Fig. 8.6) it can be seen that as expected cutting has a significant impact on the mean shoot dry weight of sown forbs ($P<0.05$).

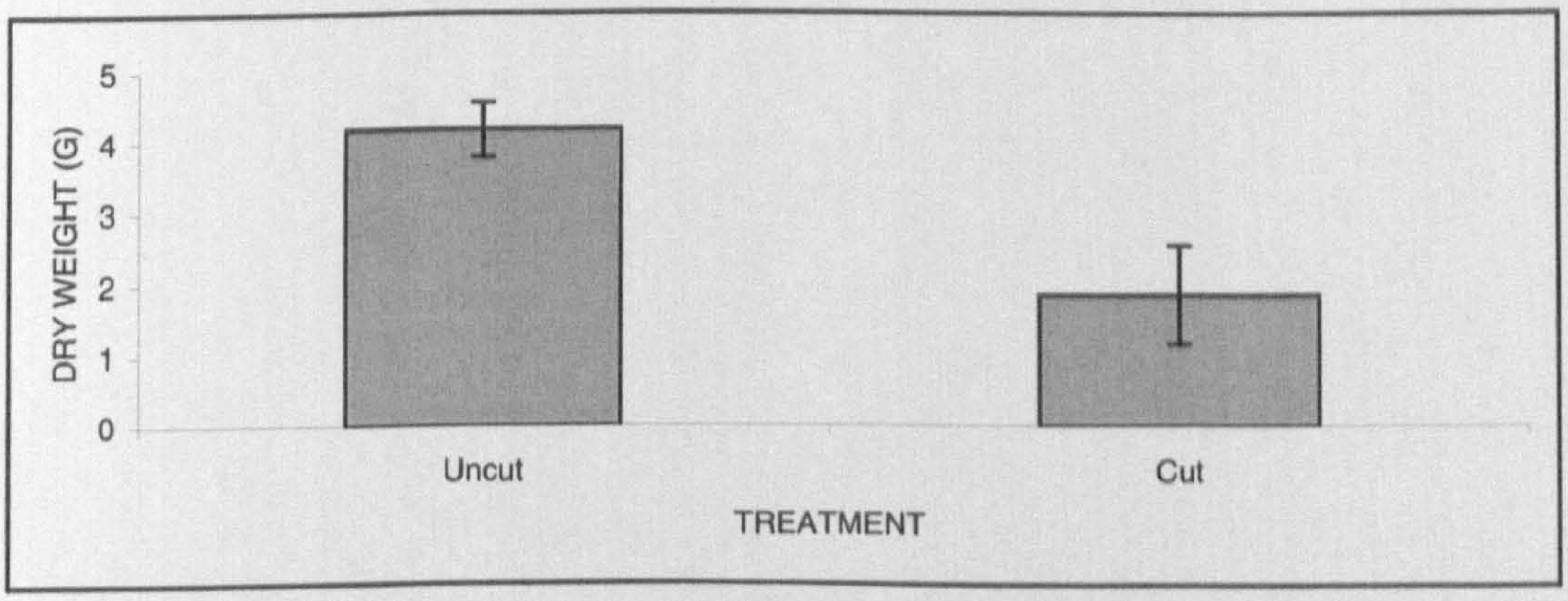

Fig 8.6: Effect of cutting on shoot dry weight of sown forbs. Error bars represent 1 standard error

iv. Root dry weight

From the chart below (Fig. 8.7) it can be seen that cutting has a non-significant impact on the mean root dry weight of sown forbs ($P>0.05$). However the mean root dry weight of sown forbs which were cut was considerably less.

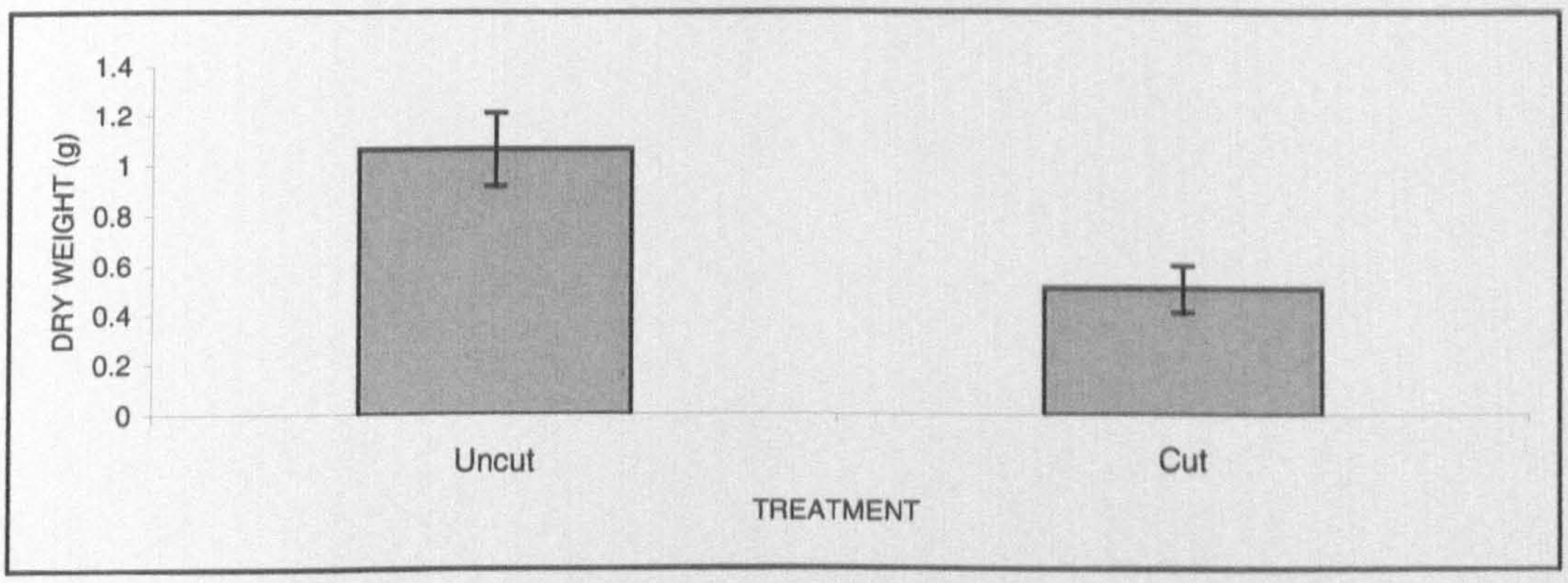

Fig 8.7: Effect of cutting on root dry weight of sown forbs. Error bars represent 1 standard error

8.3.1.2 INDIVIDUAL SPECIES

i. Seedling survival at the end of the experiment

From Fig. 8.8 it can be seen that cutting has a significant positive impact on the mean seedling survival of *Farsetia aegyptia ($P<0.05$).* It has a significant negative effect on the mean of shoot dry weight of *Verbesina encelioides* ($P < 0.05$). With other species cutting has no significant effect on seedling survival.

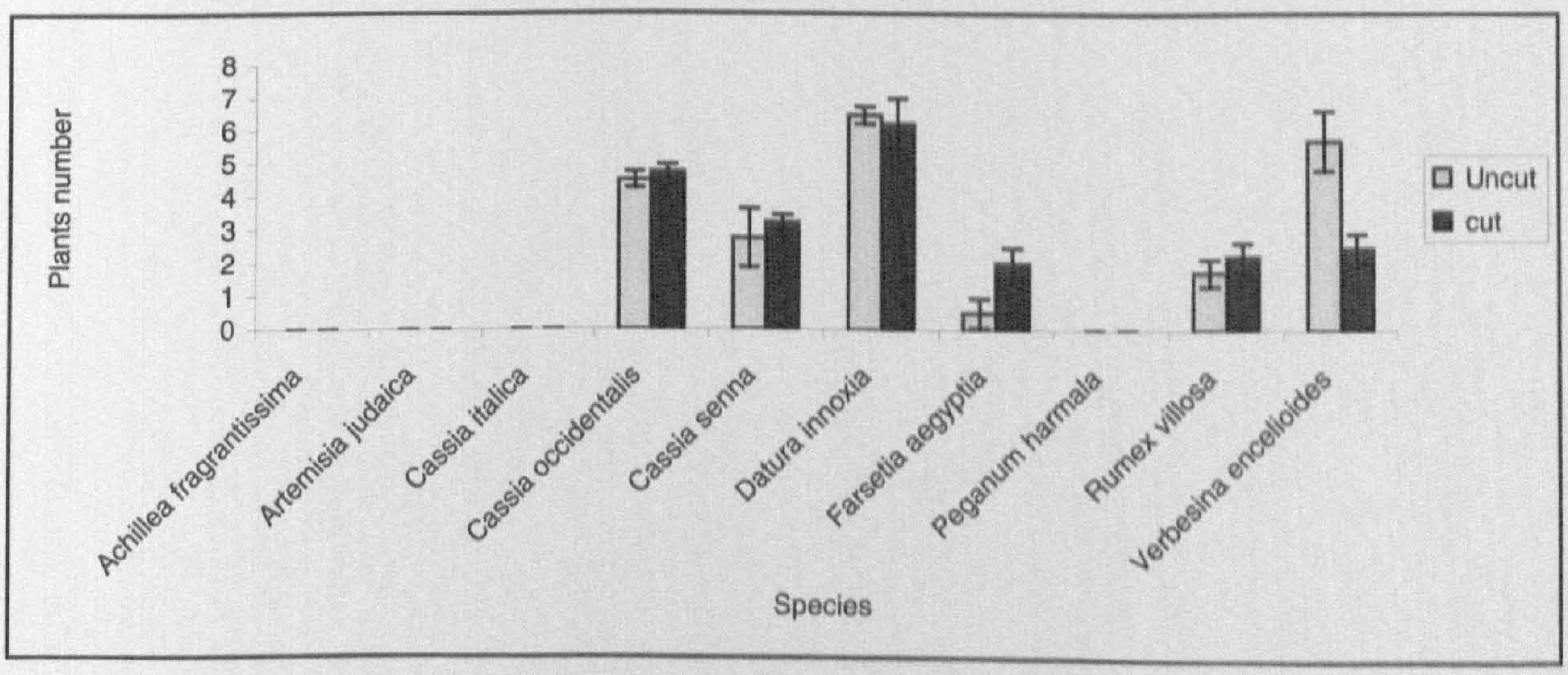

Fig 8.8: Effect of cutting on the number of surviving forbs

ii. Shoot dry weight

From Fig. 8.9 it can be seen that cutting has a small positive (but non-significant) impact on the mean shoot dry weight of *Rumex villosa.* It has a significant negative effect on the mean of shoot dry weight of *Datura innoxia* and *Verbesina encelioides* ($P < 0.05$). With other species cutting has no significant effect.

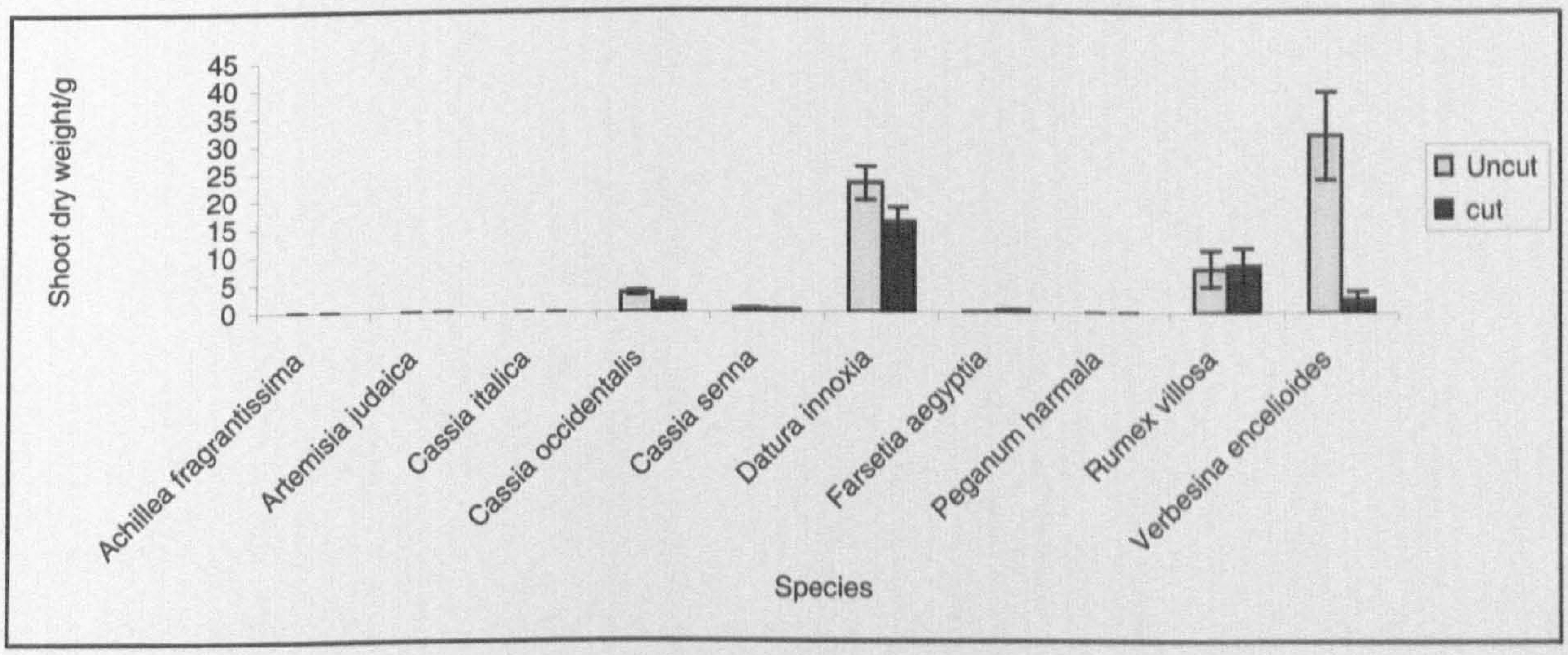

Fig 8.9: Effect of cutting on shoot dry weight of sown forbs

iii. Root dry weight

Cutting has a significant negative effect on the mean root dry weight of *Datura innoxia* and *Verbesina encelioides* ($P < 0.05$). With other species cutting did not have a significant effect (Fig 8.10).

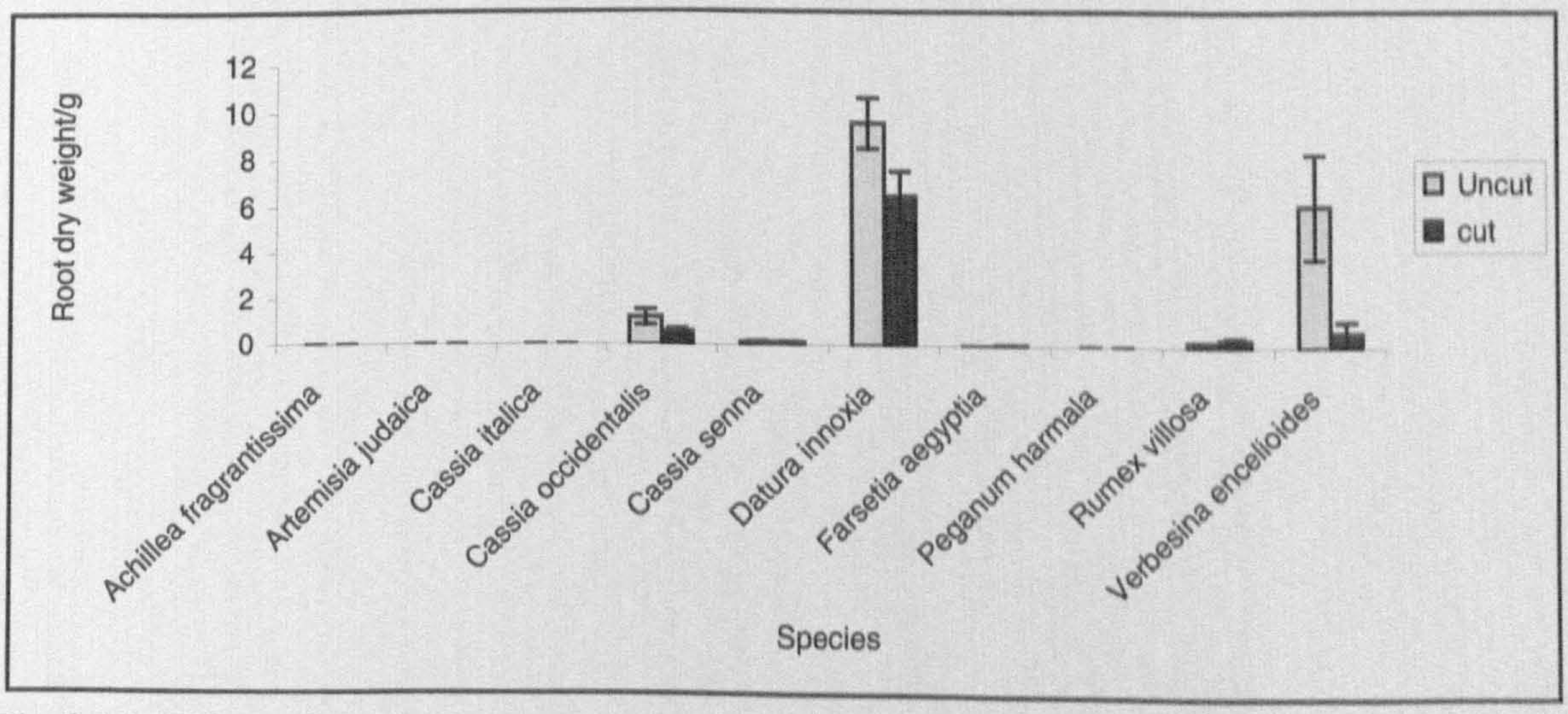

Fig 8.10: Effect of cutting on root dry weight of sown forbs. Error bars represent 1 standard error

8.3.2 EXPERIMENT 2; COMPETITION IN SOME MIXES OF FOUR SAUDI NATIVE SPECIES

8.3.2.1 MEAN OF ALL SOWN FORBS

i. MEAN SHOOT DRY WEIGHT

A two way ANOVA shows that, irrigation frequency has a significant impact on the mean shoot dry weight of sown forbs ($P<0.05$), as irrigation frequency increases, shoot dry weight increases. Weeds (Fig.8.11) had non-significant effects on the mean of shoot dry weight of sown forbs ($P > 0.05$). The greatest shoot dry weight of sown forbs was in the non-weed treatment watered every seven days, and the smallest shoot dry weight was in the high weed treatment watered every twenty-one days.

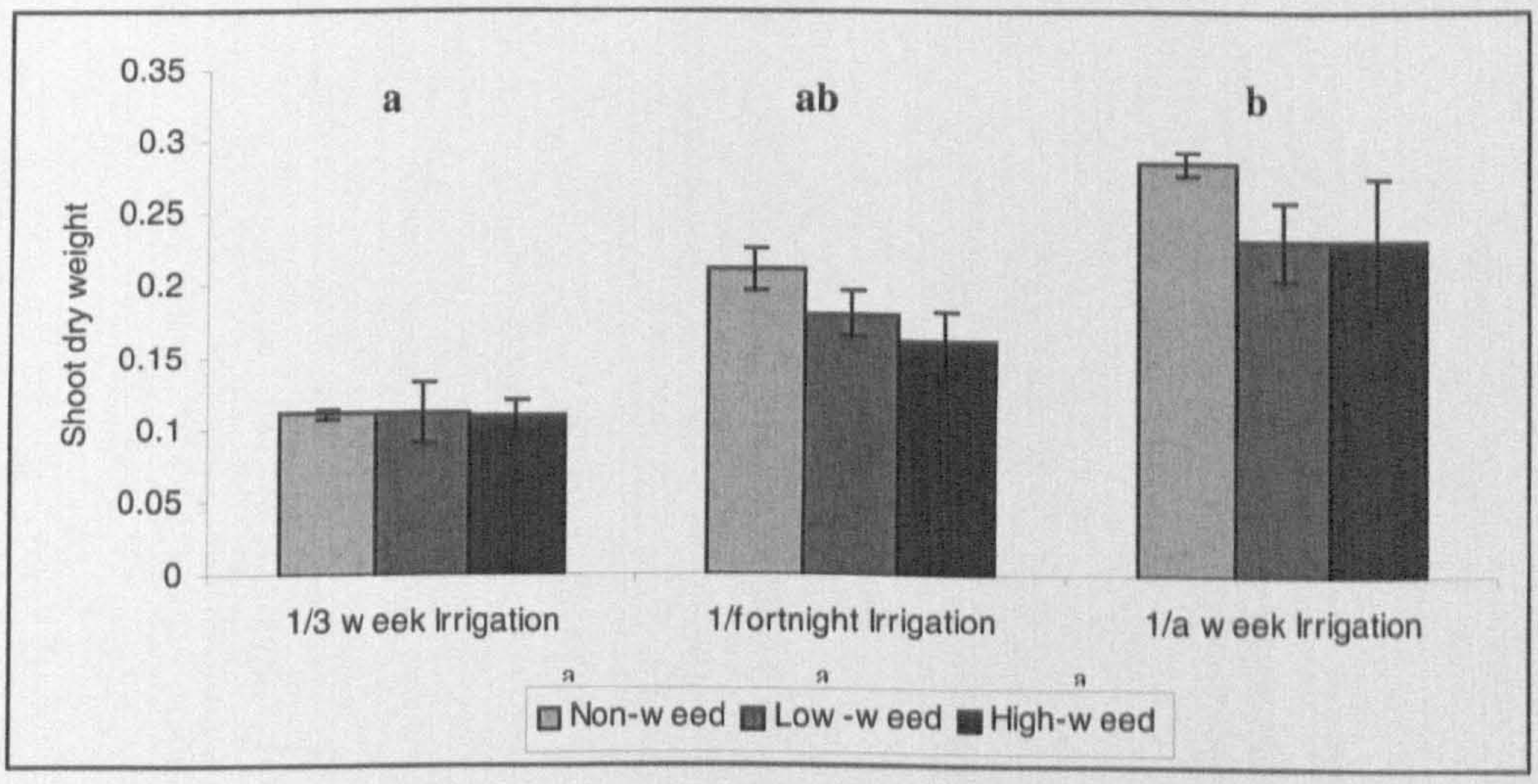

Fig (8.11): Effect of irrigation frequency and weed competition on shoot dry weight of sown forbs. Groups of bars and legends with different letters are statistically different at $P = 0.05$ (Tukey HSD). Error bars represent 1 standard error.

ii. MEAN ROOT DRY WEIGHT

Irrigation frequency has a significant impact on mean root dry weight of sown forbs ($P<0.05$), as irrigation frequency increase root dry weight increases. Weeds (Fig. 8.12) have non-significant effect on the mean root dry weight of sown forbs ($P > 0.05$).
The greatest root dry weight of sown forbs was in the non-weed treatment watered every seven days, and the smallest root dry weight was in the high weed treatment watered every twenty-one days.

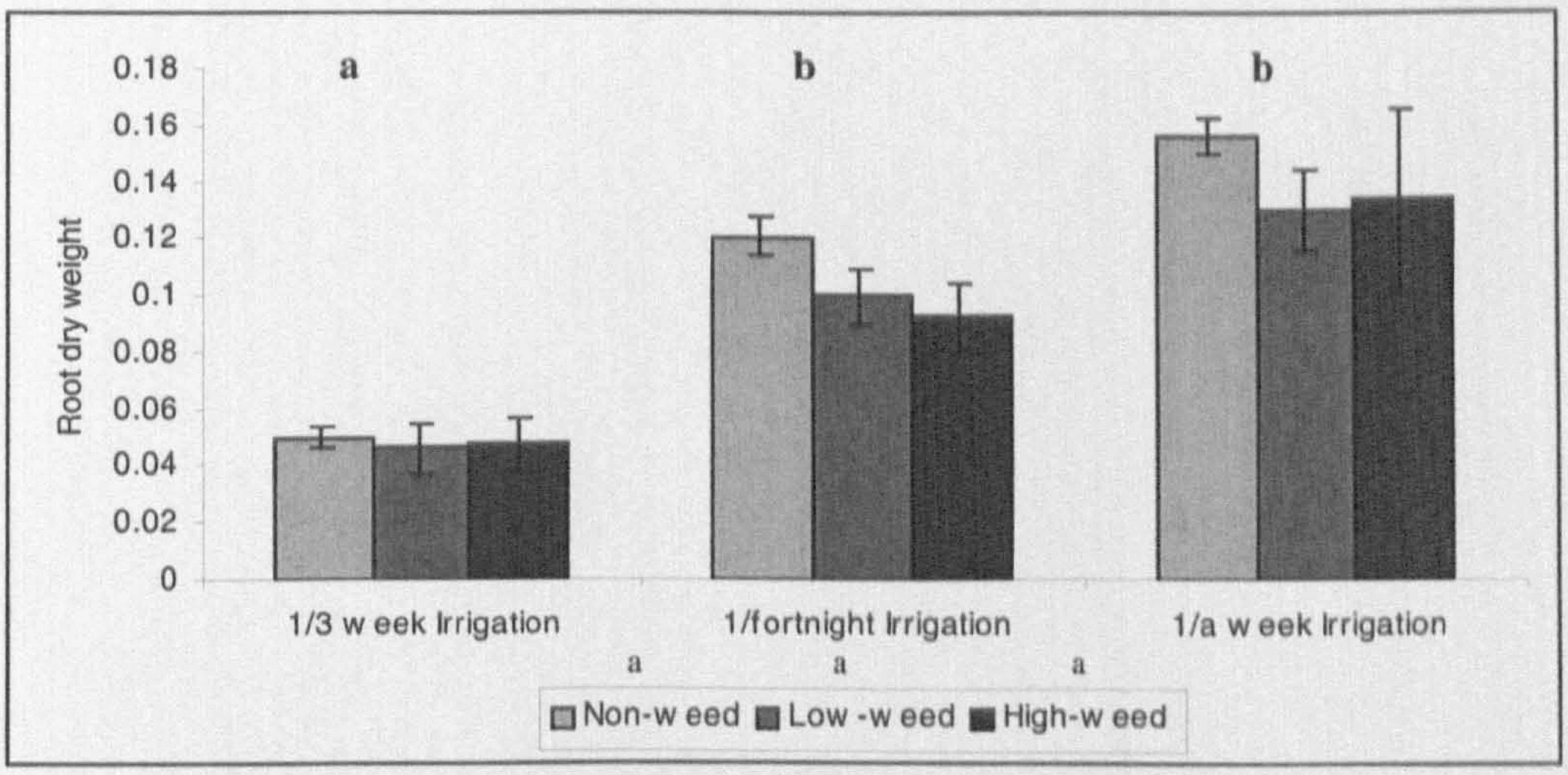

Fig (8.12): Effect of irrigation frequency and weed competition on root dry weight of sown forbs. Groups of bars and legends with different letters are statistically different at P = 0.05 (Tukey HSD). Error bars represent 1 standard error.

iii. MEAN ROOT : SHOOT RATIO

Irrigation frequency has a significant impact on the mean root: shoot ratio of sown forbs ($p < 0.05$). Weeds have non-significant impacts on the mean of root: shoot ratio of sown forbs ($p > 0.05$) (Fig. 8.13).

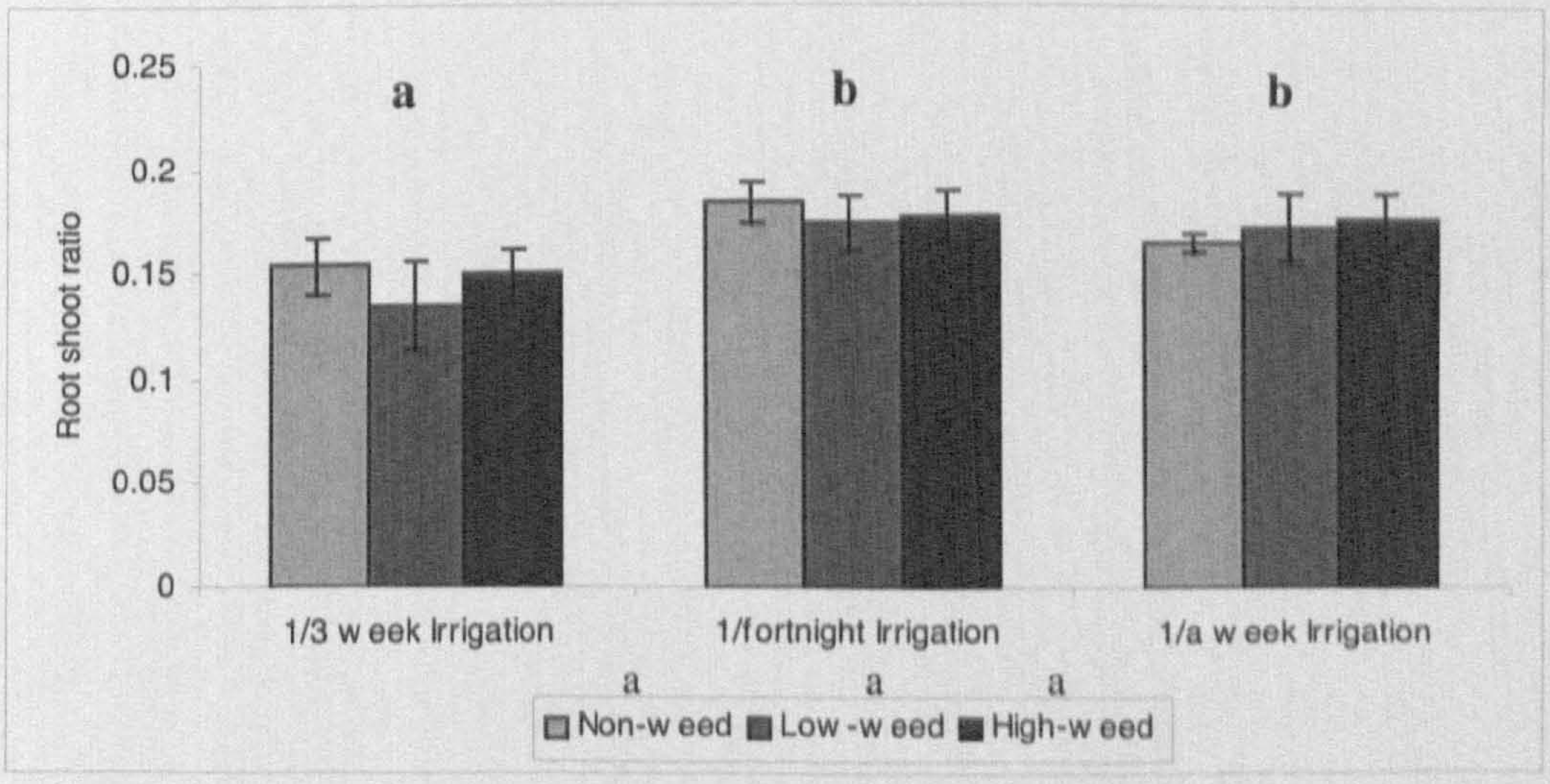

Fig. 8.13: Effect of irrigation frequency and weed competition on root: shoot ratio of sown forbs. Groups of bars and legends with different letters are statistically different at P = 0.05 (Tukey HSD).

8.3.2.2 SEEDLING GROWTH OF EACH SPECIES

i. Shoot dry weight

The greatest shoot dry weight was in *Farsetia aegyptia* and the smallest shoot dry weight was in *Achillea fragrantissima*. It can also be seen from Fig. 8.14 that there were large difference between *Farsetia aegyptia* and the three other species (*Cassia occidentalis, Achillea fragrantissima, and Artemisia judaica*) in terms of shoot dry weight at the end of the experiment.

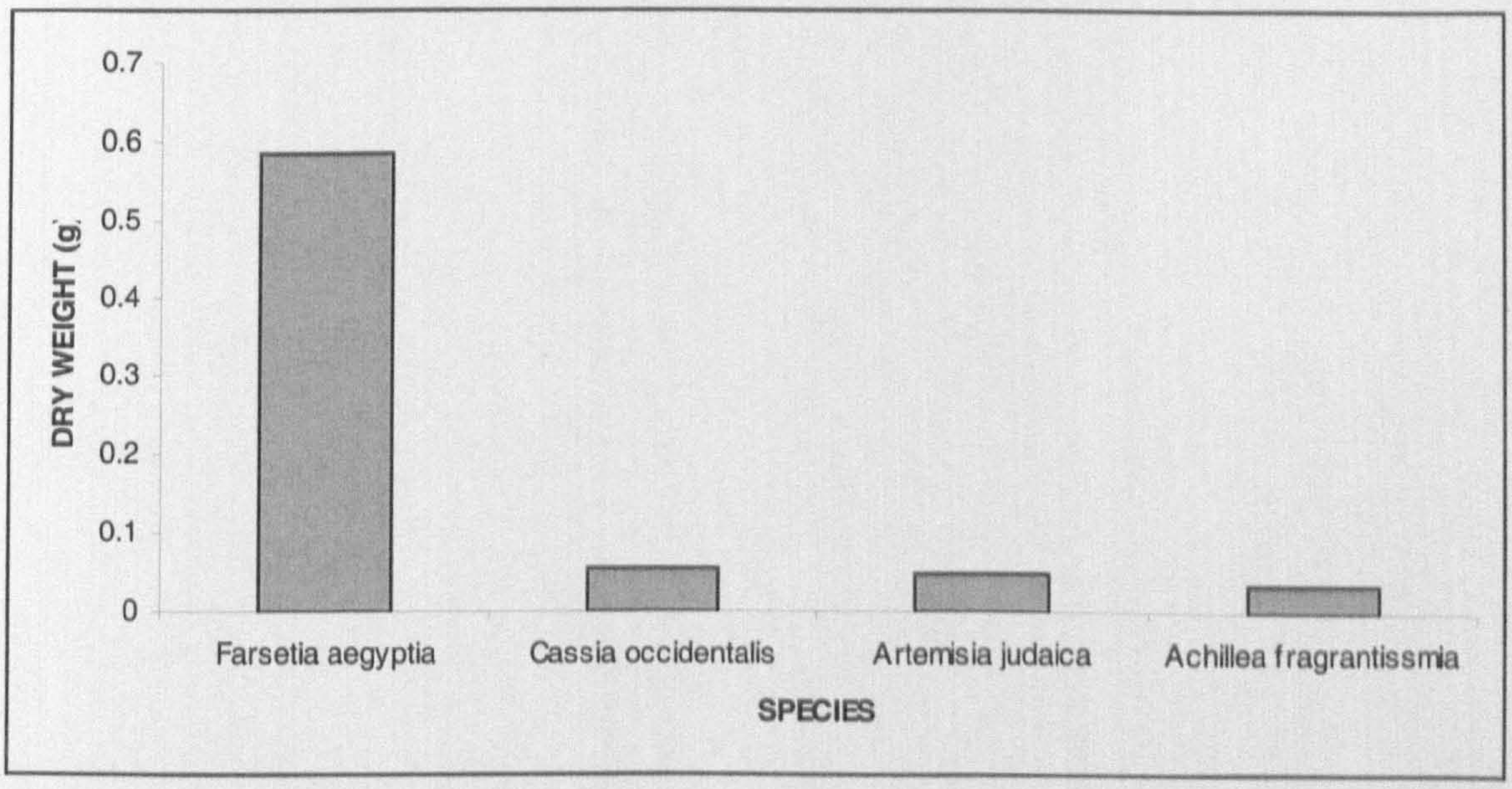

Fig. 8.14 : Mean of shoot dry weight of individual forbs (mean of all treatments).

ii. MEAN OF ROOT DRY WEIGHT

Farsetia aegyptia comprised most of the total root dry weight (Fig. 8.15). The smallest root dry weight was in *Achillea fragrantissima,* with *Cassia occidentalis* and *Artemisia judaica* intermediate.

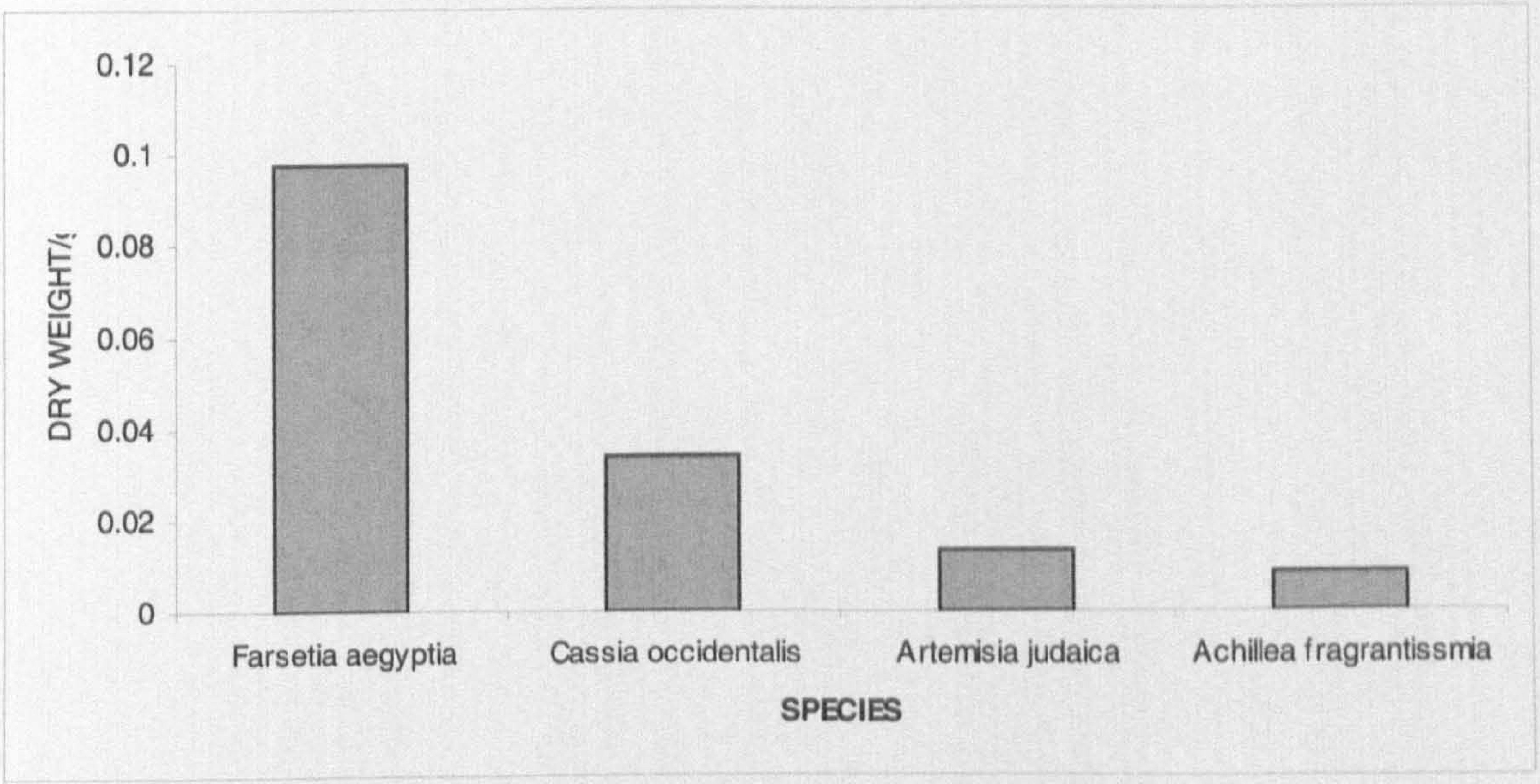

Fig. 8.15 : Mean of root dry weight of individual forbs (mean of all treatments).

iii. THE MEAN ROOT : SHOOT RATIO

There were some differences between sown forbs in terms of root : shoot ratio. It can be seen from Fig 8.16, that *Cassia occidentalis* has the greatest root : shoot ratio, (0.6). *Farsetia aegyptia* had the smallest ratio (0.16).

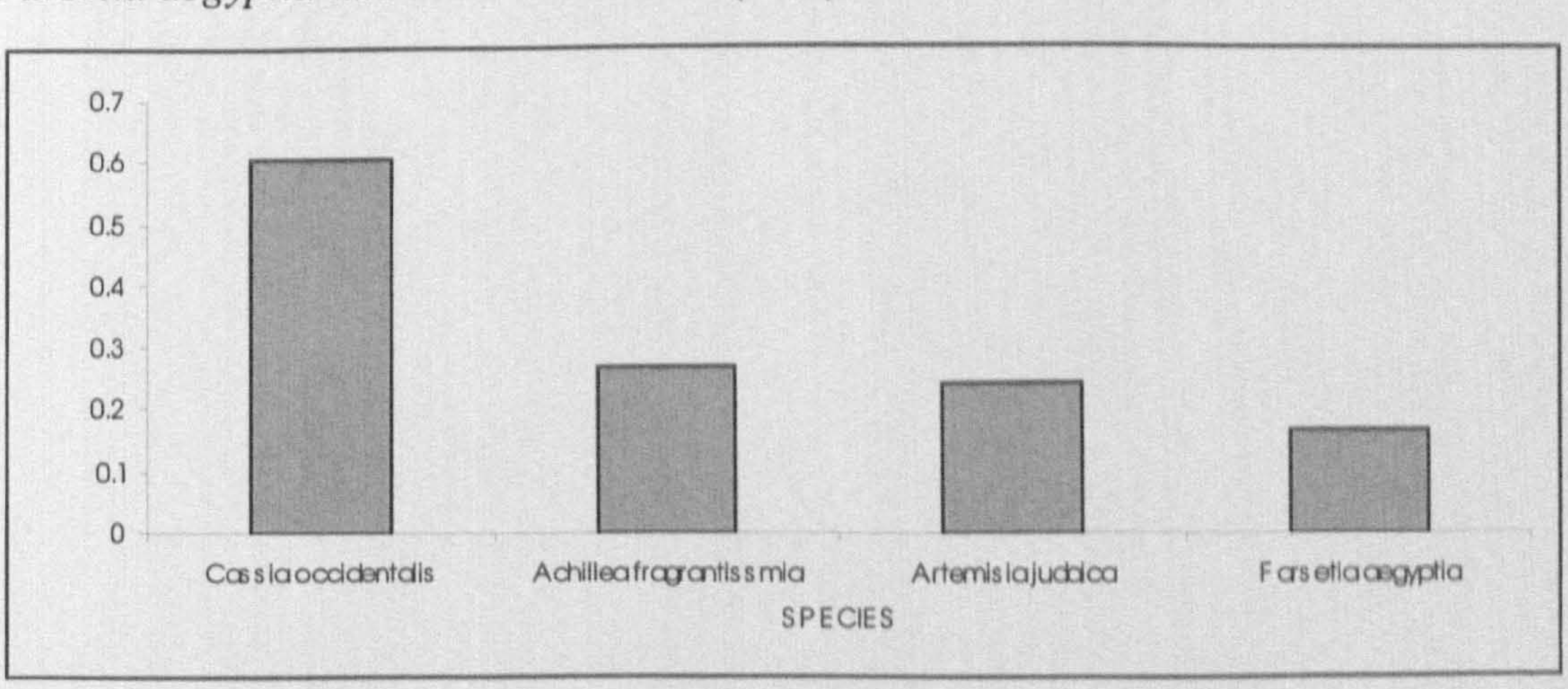

Fig. 8.16: Mean root : shoot ratio of individual forbs (mean of all treatments).

8.3.2.3 GROWTH OF SEEDLING OF INDIVIDUAL SPECIES

i. ACHILLEA FRAGRANTISSIMA

a) MEAN OF SHOOT DRY WEIGHT

From Fig. 8.17 it can be seen that irrigation frequency has a significant impact on the mean shoot dry weight of *Achillea fragrantissima* ($P<0.05$), as irrigation frequency increases, shoot dry weight increases. Weeds have non-significant effect on the mean of shoot dry weight of sown forbs ($P > 0.05$).

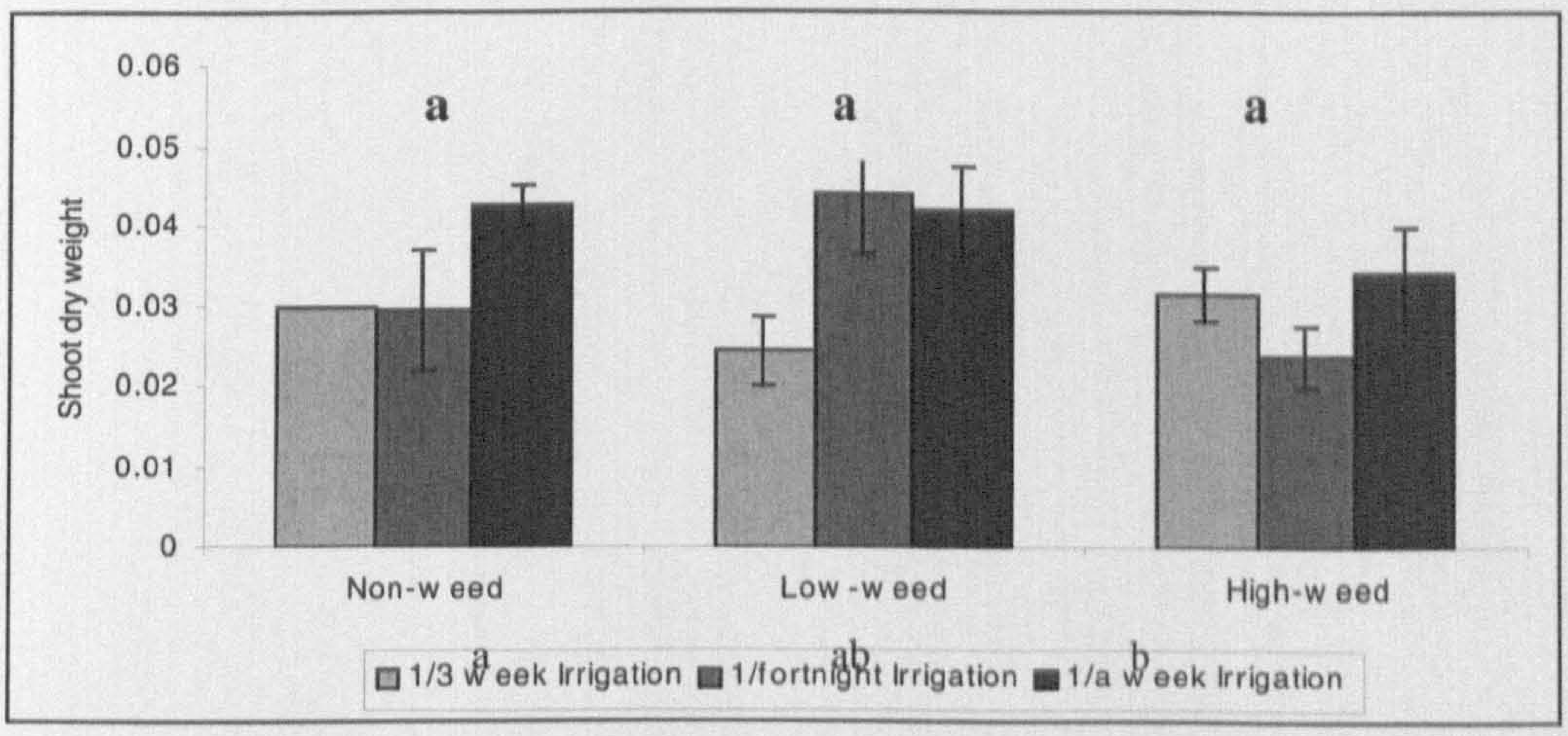

Fig (8.17): Effect of weed competition and irrigation frequency on shoot dry weight of *Achillea fragrantissima*. Groups of bars and legends with different letters are statistically different at P = 0.05 (Tukey HSD). Error bars represent 1 standard error.

b) MEAN OF ROOT DRY WEIGHT

Irrigation frequency and weeds (Fig.8.18) have non-significant impact on mean root dry weight of *Achillea fragrantissima* ($P>0.05$).

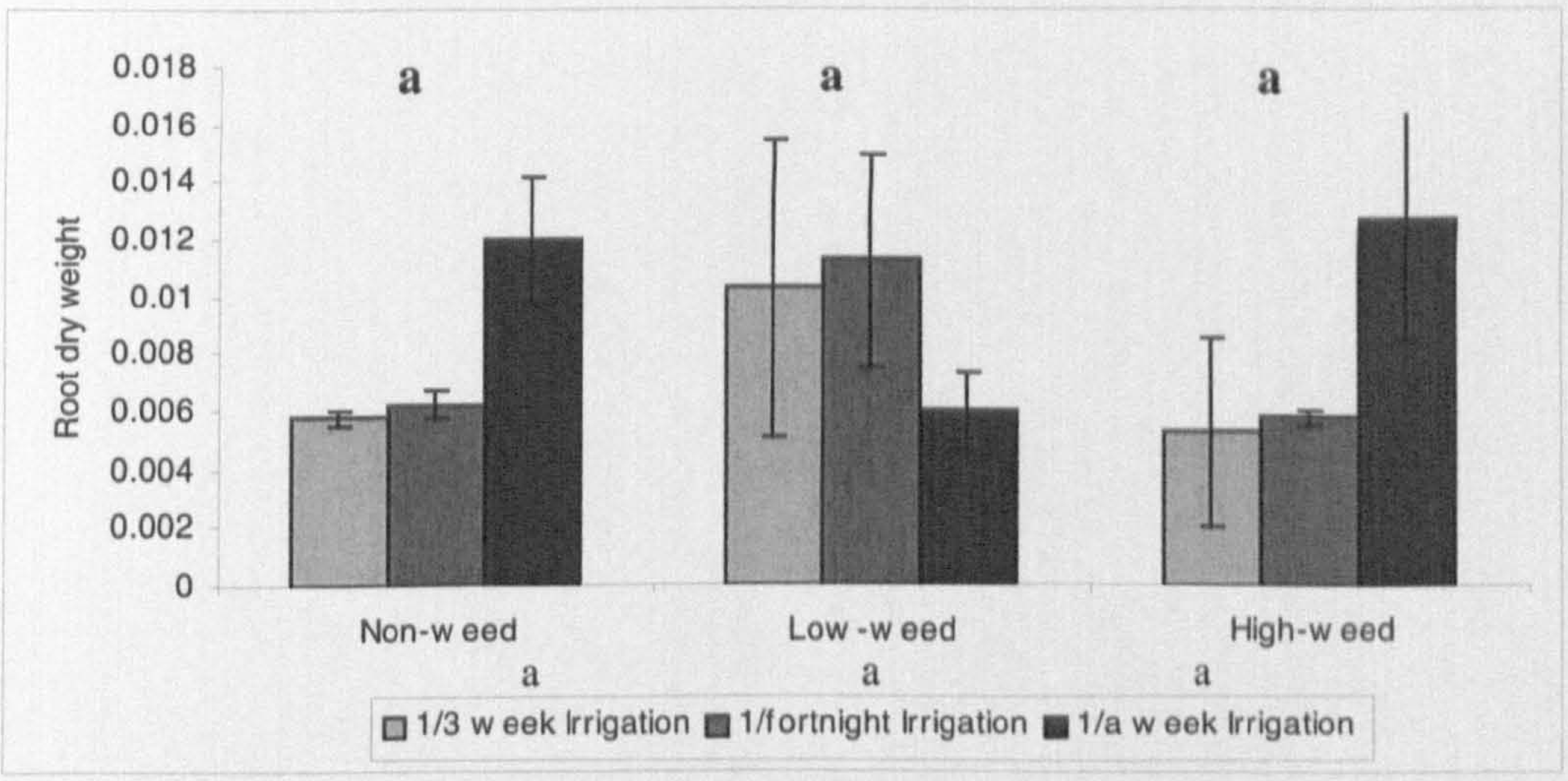

Fig (8.18): Effect of weed competition and irrigation frequency on root dry weight of *Achillea fragrantissima*. Groups of bars and legends with different letters are statistically different at P = 0.05 (Tukey HSD). Error bars represent 1 standard error.

c) THE MEAN ROOT : SHOOT RATIO

Irrigation frequency and weed have non-significant impact on the mean of Root: shoot ratio of *Achillea fragrantissima* ($p > 0.05$). (Fig. 8.19).

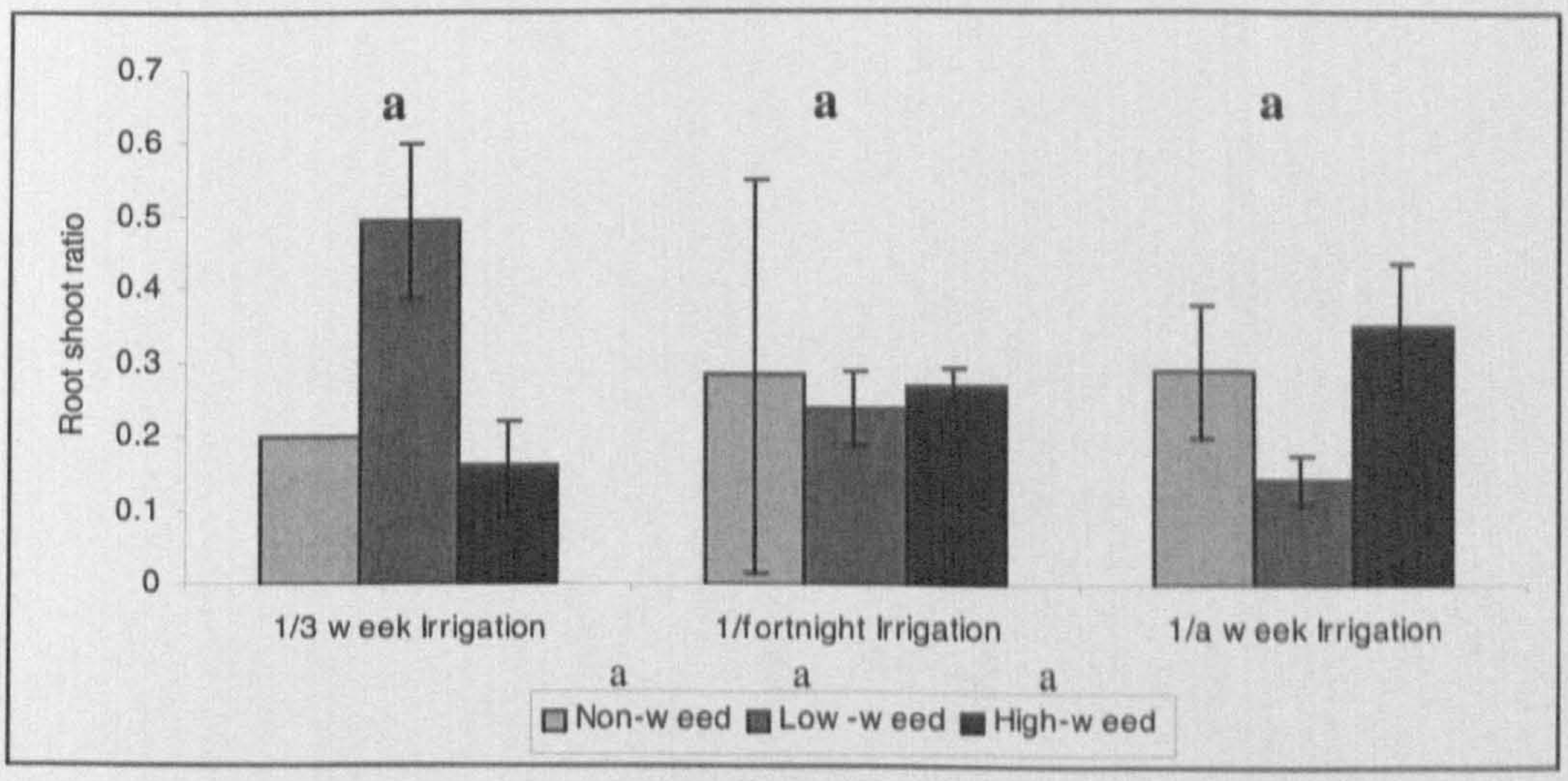

Fig. 8.19: Effect of irrigation frequency and weed competition on root: shoot ratio of *Achillea fragrantissima*. Groups of bars and legends with different letters are statistically different at P = 0.05 (Tukey HSD).

ii. ARTEMISIA JUDAICA

a) MEAN SHOOT DRY WEIGHT

As be seen from Fig. 8.20 irrigation frequency has a significant impact on the mean shoot dry weight of *Artemisia judaica* ($P<0.05$), as irrigation frequency increases, shoot dry weight increases. Weeds (Fig.8.20) have non-significant effect on the mean of shoot dry weight of sown forbs ($P > 0.05$).

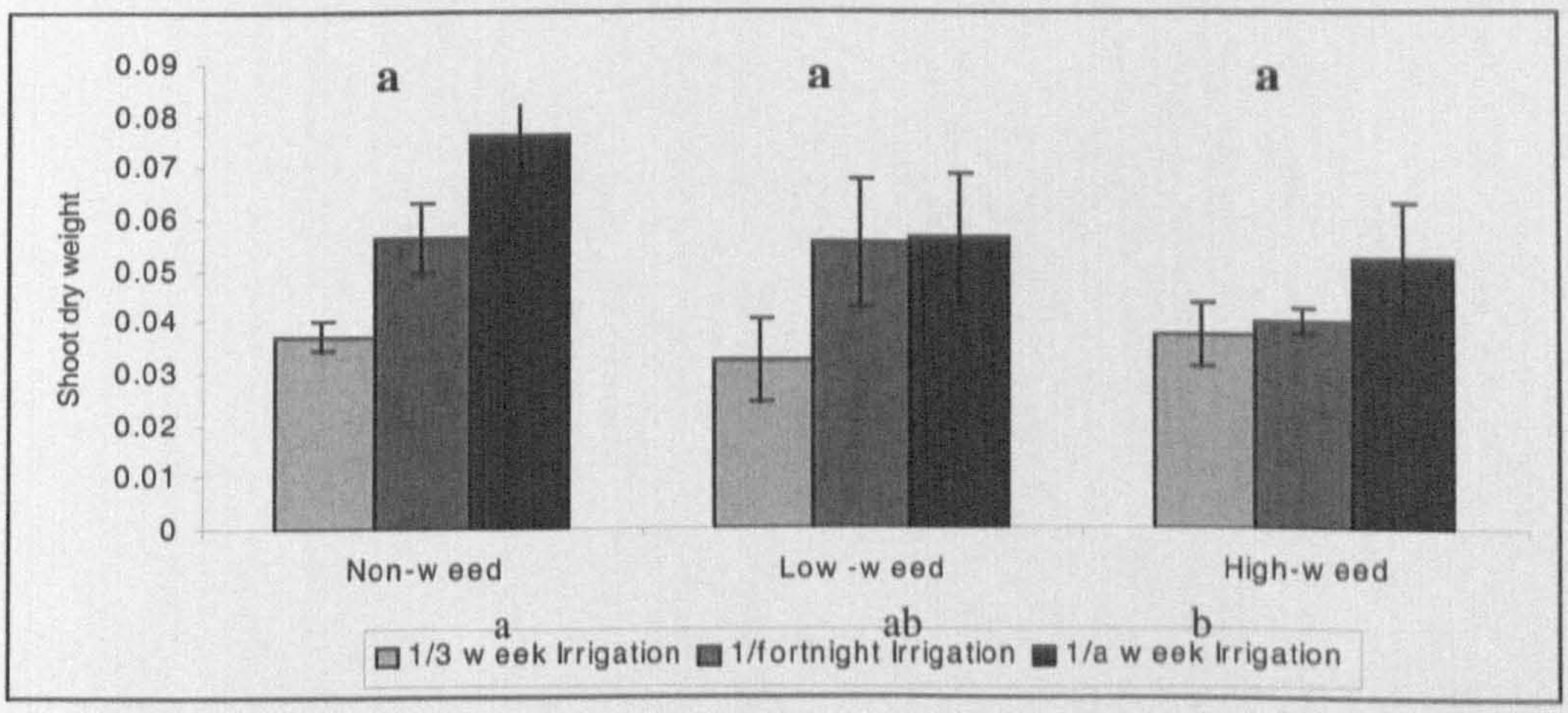

Fig 8.20: Effect of weed competition and irrigation frequency on shoot dry weight of *Artemisia judaica*. Groups of bars and legends with different letters are statistically different at $P = 0.05$ (Tukey HSD). Error bars represent 1 standard error.

b) MEAN ROOT DRY WEIGHT

Irrigation (Fig.8.21) has a significant impact on mean root dry weight of *Artemisia judaica* ($P<0.05$), as irrigation frequency increase root dry weight increases. Weeds (Fig. 8.23) have non-significant effect on the mean root dry weight of sown forbs ($P > 0.05$).

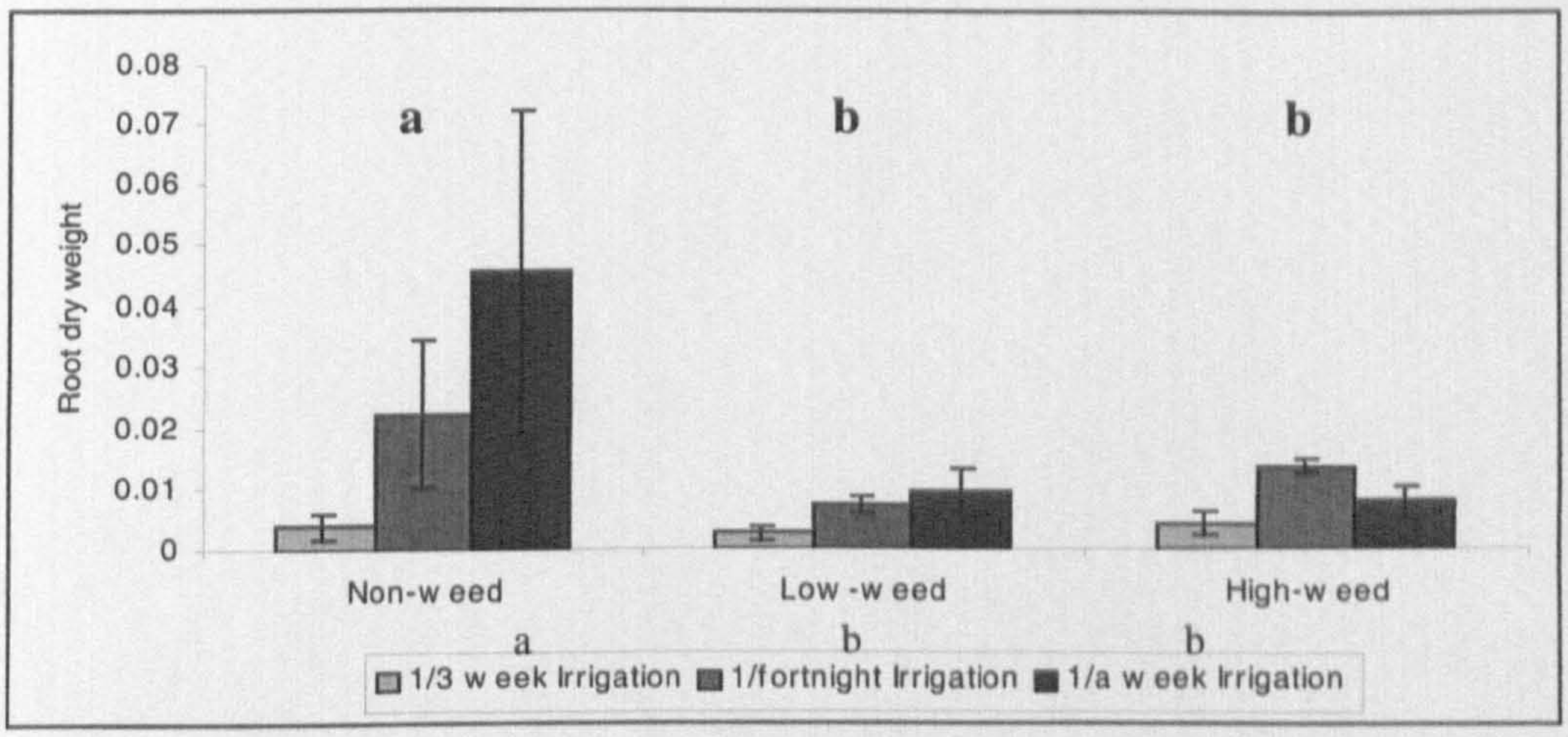

Fig (8.21): Effect of weed competition and irrigation frequency on root dry weight of *Artemisia judaica*. Groups of bars and legends with different letters are statistically different at P = 0.05 (Tukey HSD). Error bars represent 1 standard error.

c) MEAN ROOT SHOOT : RATIO OF *ARTEMISIA JUDAICA*

Irrigation frequency has a significant impact on the mean of root: shoot ratio of *Artemisia judaica* ($p < 0.05$). Weeds have non-significant impacts on the mean of root: shoot ratio of sown forbs ($p > 0.05$) (Fig.8.22).

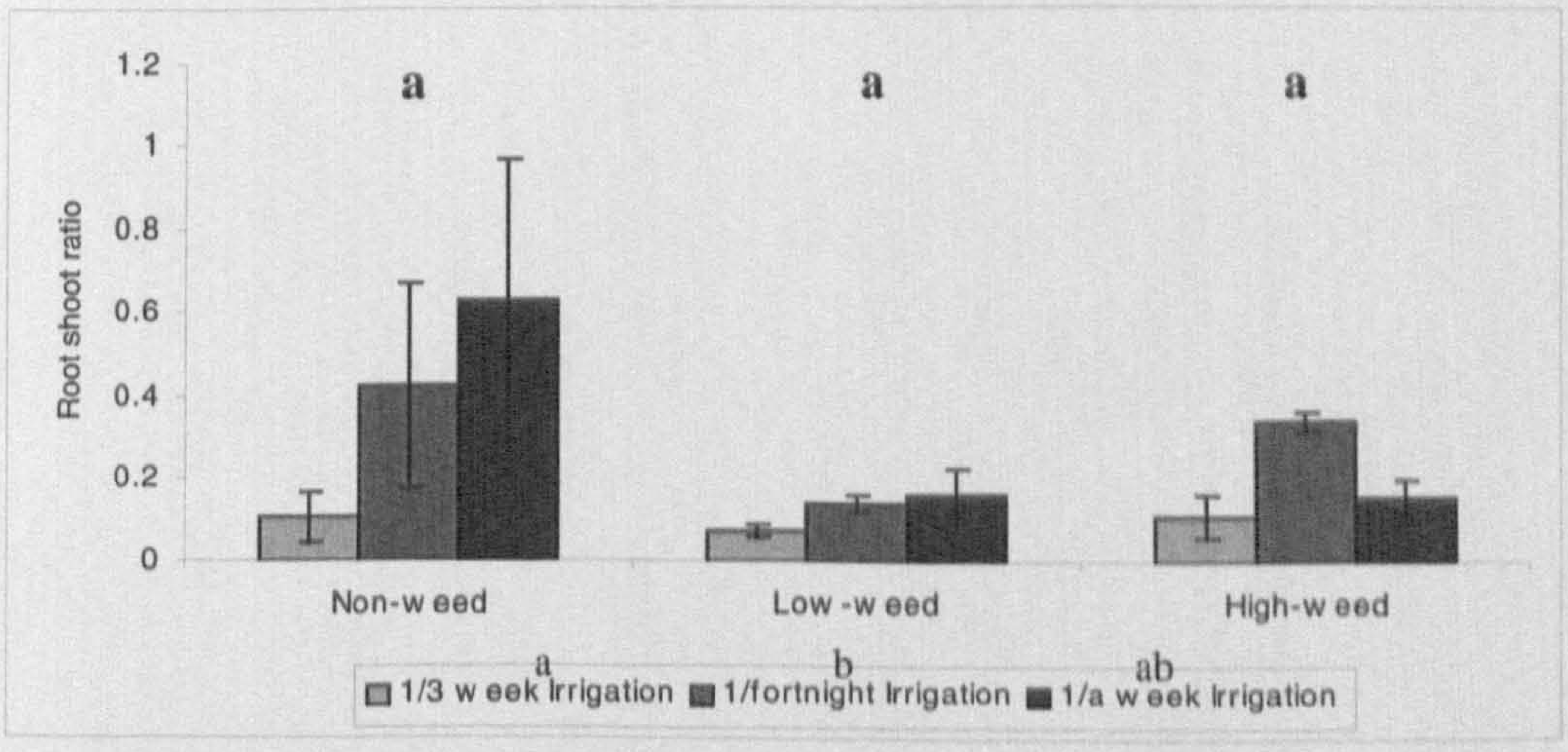

Fig. 8.22: Effect of irrigation frequency and weed competition on root: shoot ratio of *Artemisia judaica*. Groups of bars and legends with different letters are statistically different at P = 0.05 (Tukey HSD).

iii. *CASSIA OCCIDENTALIS*

a) MEAN SHOOT DRY WEIGHT

From the charts below (Fig. 8.23) it can be seen that weeds and irrigation frequency have a non-significant impact on the mean shoot dry weight of *Cassia occidentalis* ($P>0.05$).

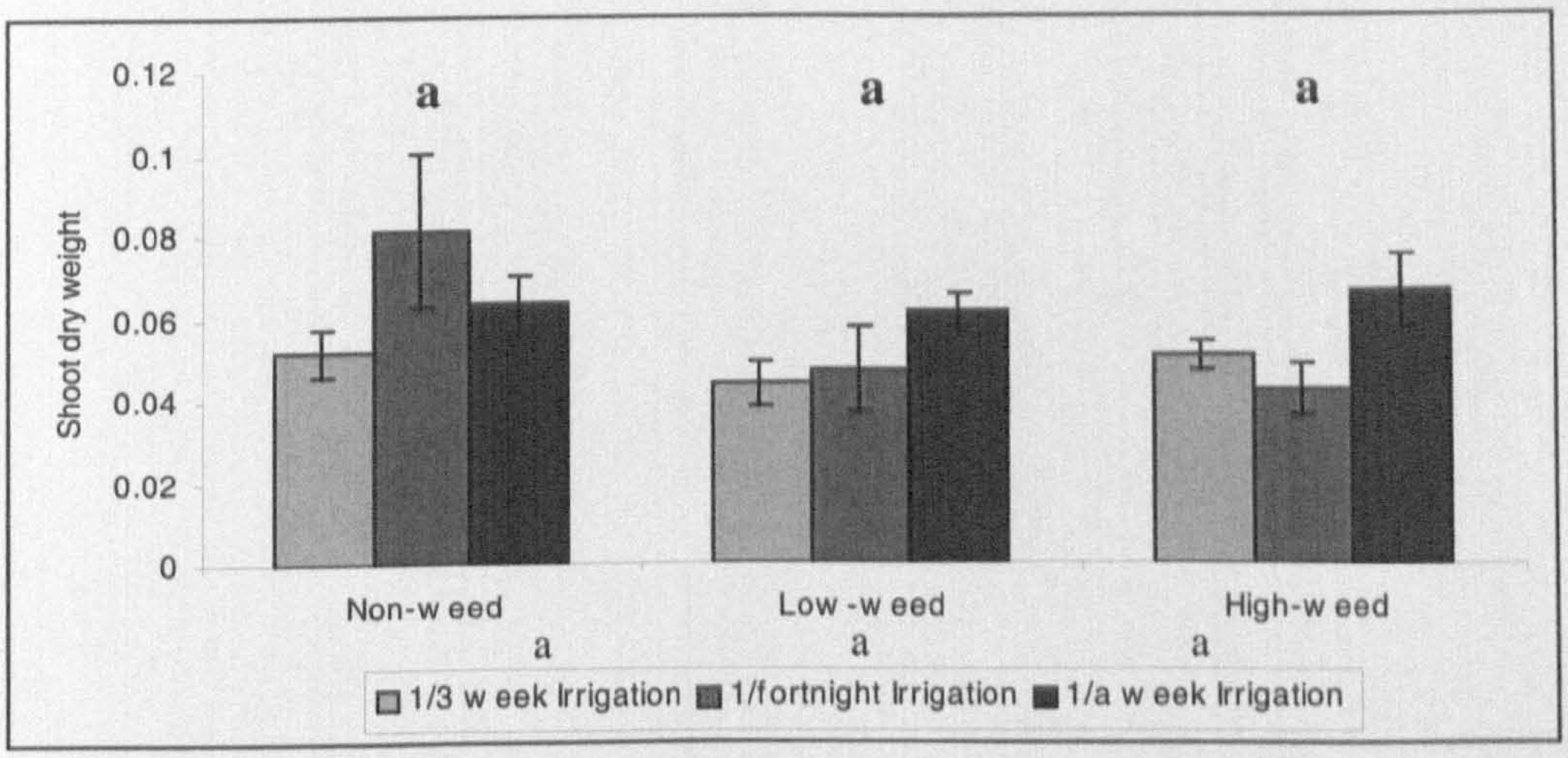

Fig (8.23): Effect of weed competition and irrigation frequency on shoot dry weight of *Cassia occidentalis*. Groups of bars and legends with different letters are statistically different at P = 0.05 (Tukey HSD). Error bars represent 1 standard error.

b) MEAN ROOT DRY WEIGHT

Irrigation frequency (Fig.8.24) has a significant impact on mean root dry weight of *Cassia occidentalis* ($P<0.05$). Weeds have a significant effect on the mean root dry weight of sown forbs ($P < 0.05$).

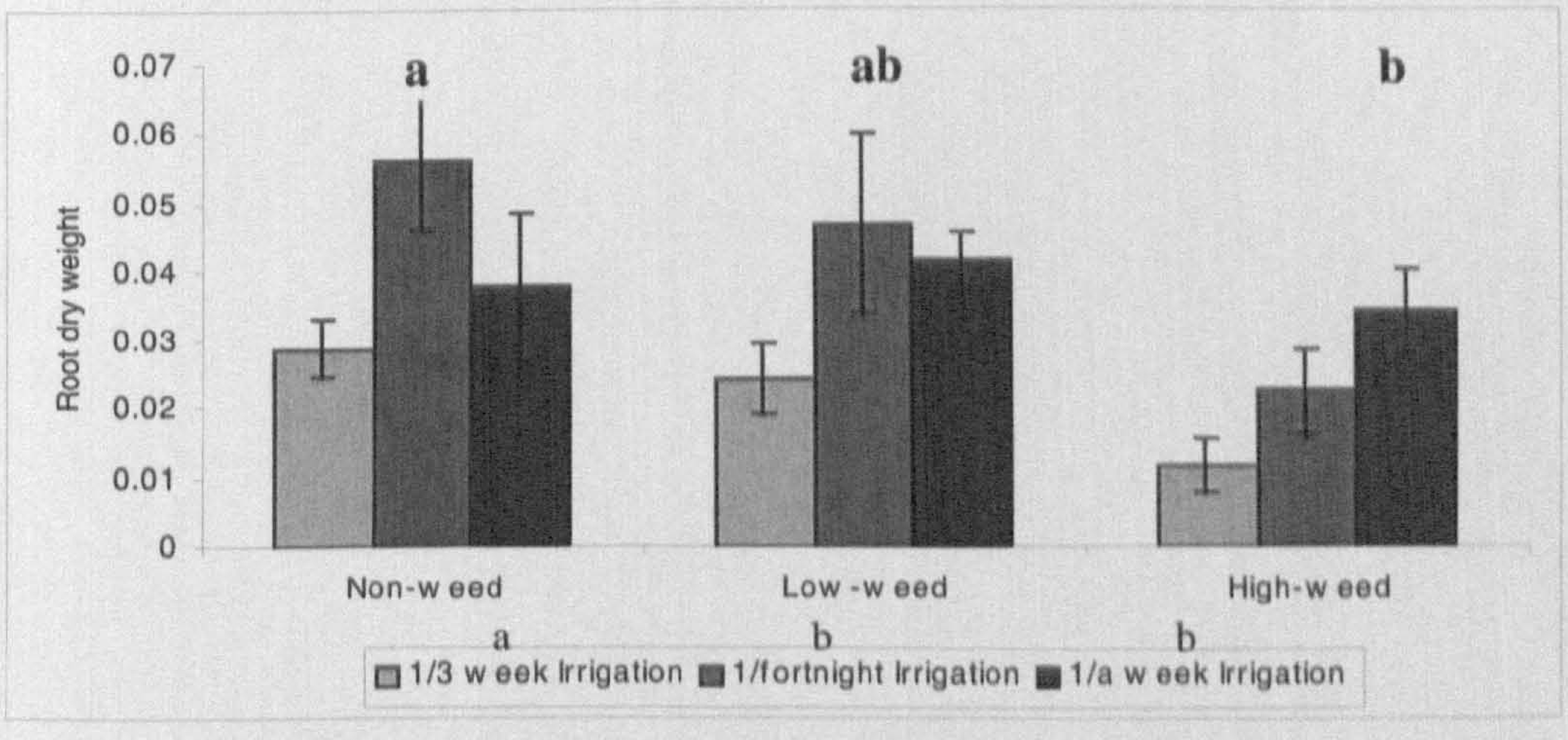

Fig (8.24): Effect of weed competition and irrigation frequency on root dry weight of *Cassia occidentalis*. Groups of bars and legends with different letters are statistically different at P = 0.05 (Tukey HSD). Error bars represent 1 standard error.

c) MEAN ROOT SHOOT RATIO

Irrigation frequency has a significant impact on the mean of root: shoot ratio of *Cassia occidentalis* ($p < 0.05$). Weeds also have a significant impacts on the mean root: shoot ratio ($p < 0.05$) (Fig. 8.25).

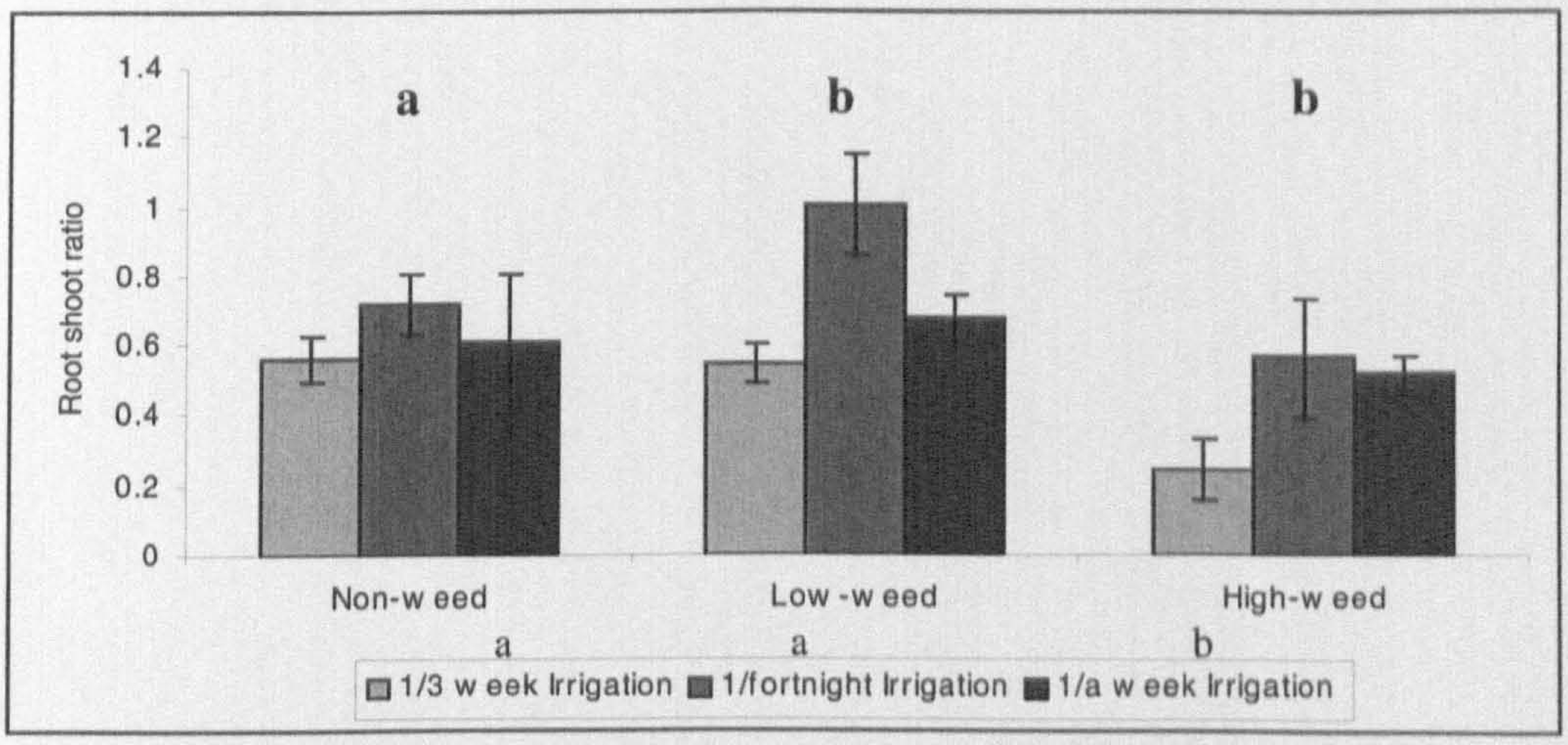

Fig. 8.25: Effect of irrigation frequency and weed competition on root: shoot ratio of *Cassia occidentalis*. Groups of bars and legends with different letters are statistically different at P = 0.05 (Tukey HSD).

iv. FARSETIA AEGYPTIA

a) MEAN SHOOT DRY WEIGHT

From the chart below (Fig. 8.26) it can be seen that irrigation frequency has a significant impact on the mean shoot dry weight ($P<0.001$), as irrigation frequency increase, shoot dry weight increases. Weeds have a non-significant effect on shoot dry weight ($P > 0.05$). The greatest shoot dry weight was in the non-weed treatment watered every seven days, and the smallest shoot dry weight was in the high weed treatment watered every twenty-one days.

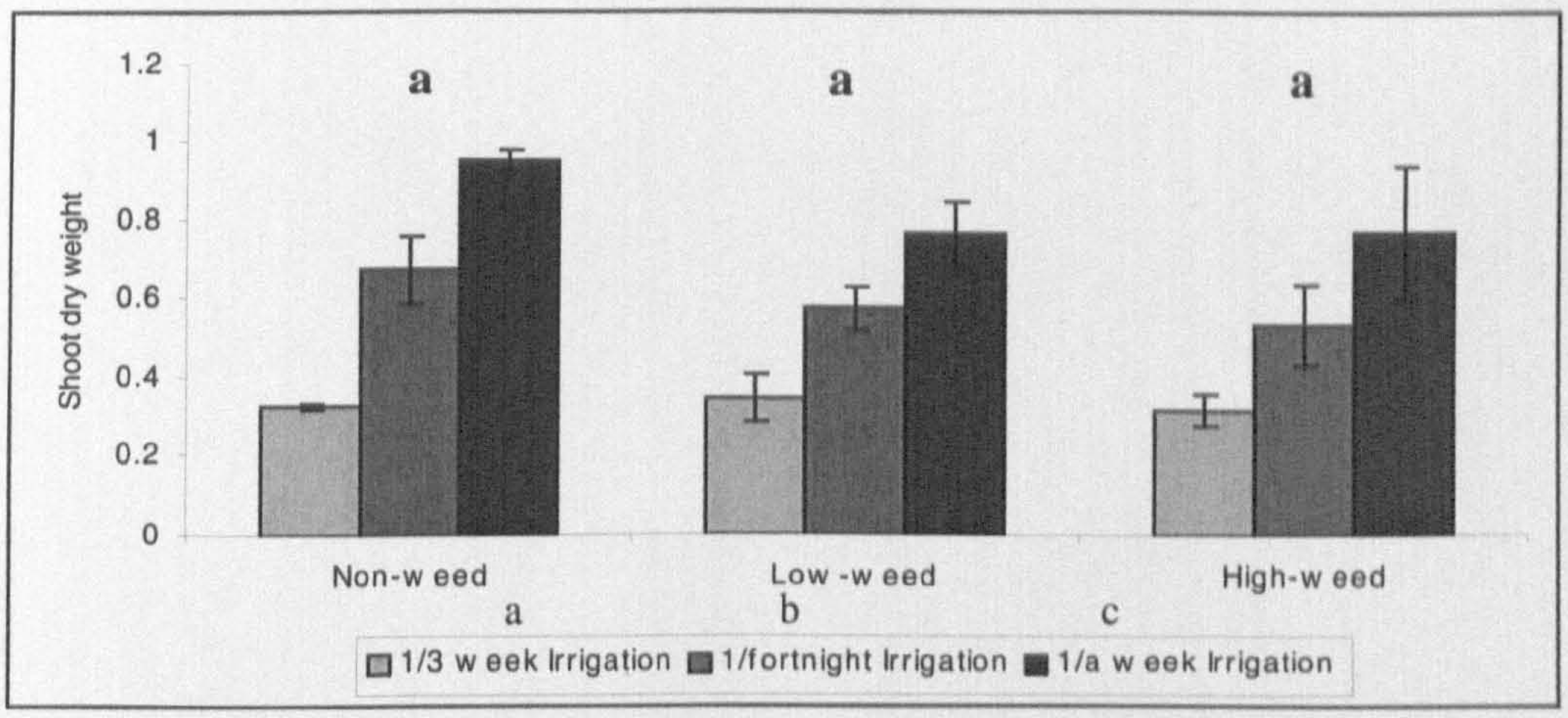

Fig (8.26): Effect of weed competition and irrigation frequency on shoot dry weight of *Farsetia aegyptia*. Groups of bars and legends with different letters are statistically different at P = 0.05 (Tukey HSD). Error bars represent 1 standard error.

b) MEAN ROOT DRY WEIGHT

Irrigation frequency (Fig.8.27) has a significant impact on mean root dry weight of *Farsetia aegyptia* ($P<0.001$), as irrigation frequency increase root dry weight increases. Weeds have a non-significant effect on the mean root dry weight ($P > 0.05$).

The greatest root dry weight of sown forbs was in the non-weed treatment watered every seven days, and the smallest root dry weight was in the high and low weed treatments watered every twenty-one days.

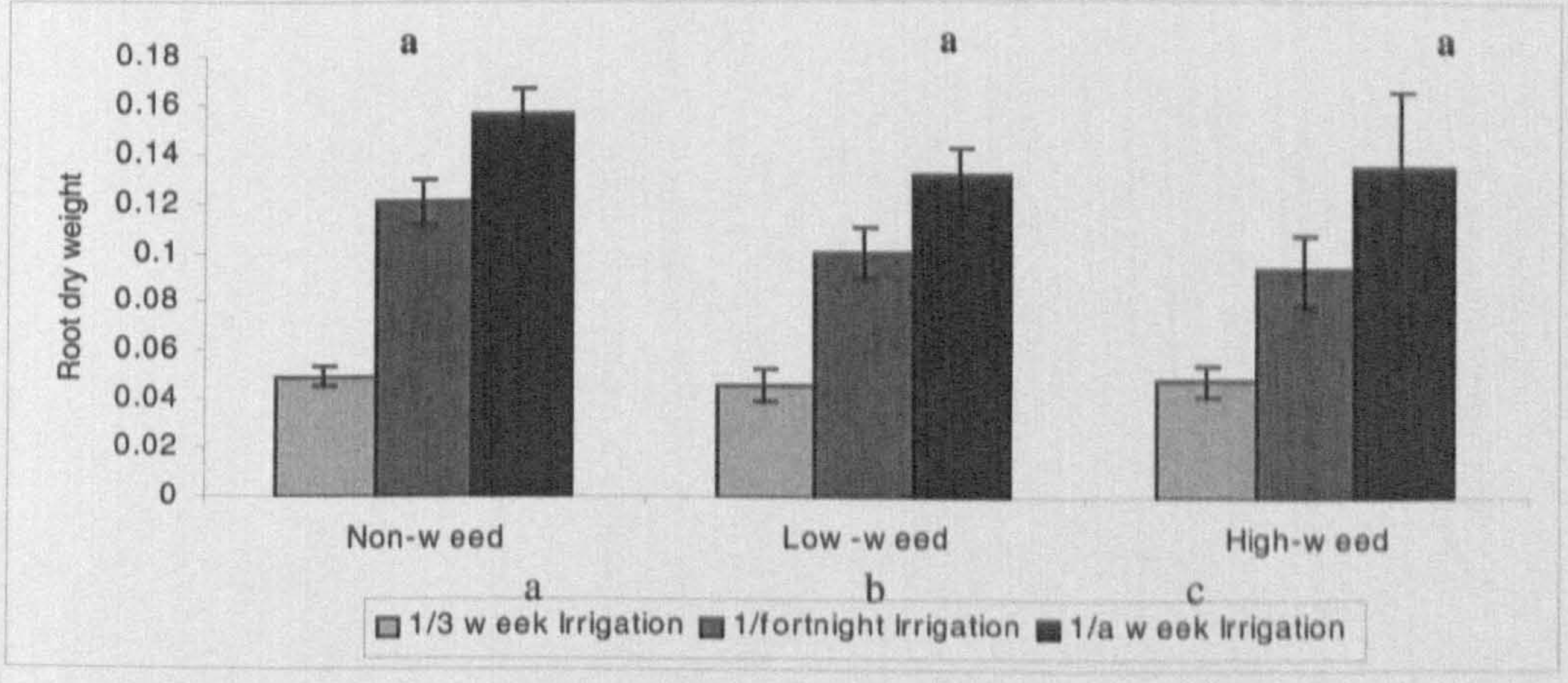

Fig (8.27): Effect of weed competition and irrigation frequency on root dry weight of *Farsetia aegyptia*. Groups of bars and legends with different letters are statistically different at P = 0.05 (Tukey HSD). Error bars represent 1 standard error.

c) MEAN ROOT SHOOT RATIO

Irrigation frequency has a significant impact on the mean of root: shoot ratio of *Farsetia aegyptia* ($p < 0.05$). Weeds have non-significant impacts on the mean of root: shoot ratio of sown forbs ($p > 0.05$) (Fig.8.28).

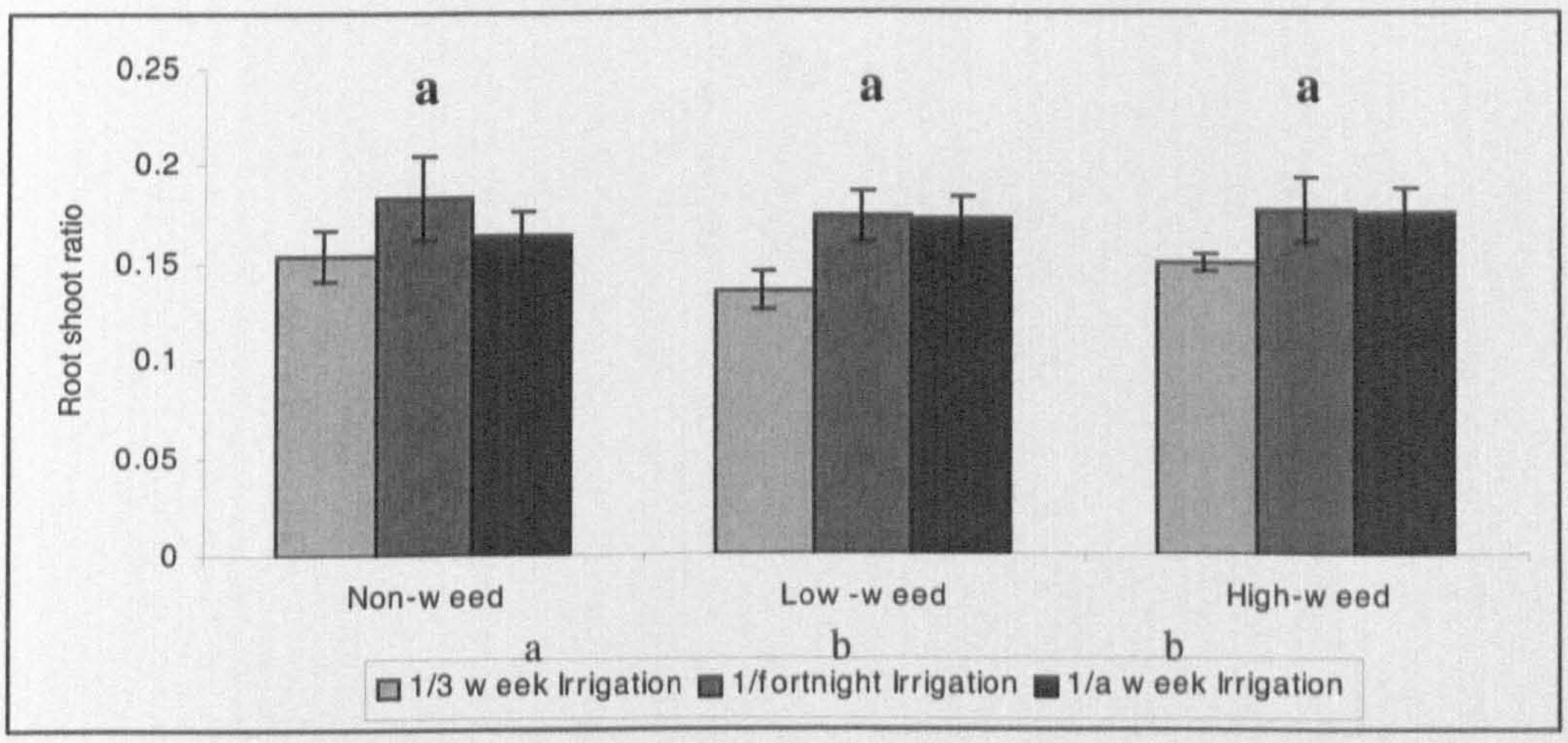

Fig. 8.28: Effect of irrigation frequency and weed competition on root: shoot ratio of *Farsetia aegyptia*. Groups of bars and legends with different letters are statistically different at P = 0.05 (Tukey HSD).

8.3.3 EXPERIMENT 3; ABOVE AND BELOW-GROUND COMPETITION

8.3.3.1.SHOOT DRY WEIGHT RATIO OF *PEGANUM HARMALA* TO *LOLIUM MULTIFLORUM*

These studies showed some differences in ratio of shoot dry weight ratio of *Peganum harmala* to *Lolium multiflorum* across the three treatments (Shoot competition, root competition and root and shoot competition). It can be seen from Fig.8.29 that the greatest shoot dry weight ratio (i.e. when shoot growth of *P harmala* was greatest relative to *L multiflorum*) was in the shoot competition treatment and the smallest shoot dry weight ratio in the root competition. However the shoot dry weight ratio between the three treatments were not significantly different (P>0.05).

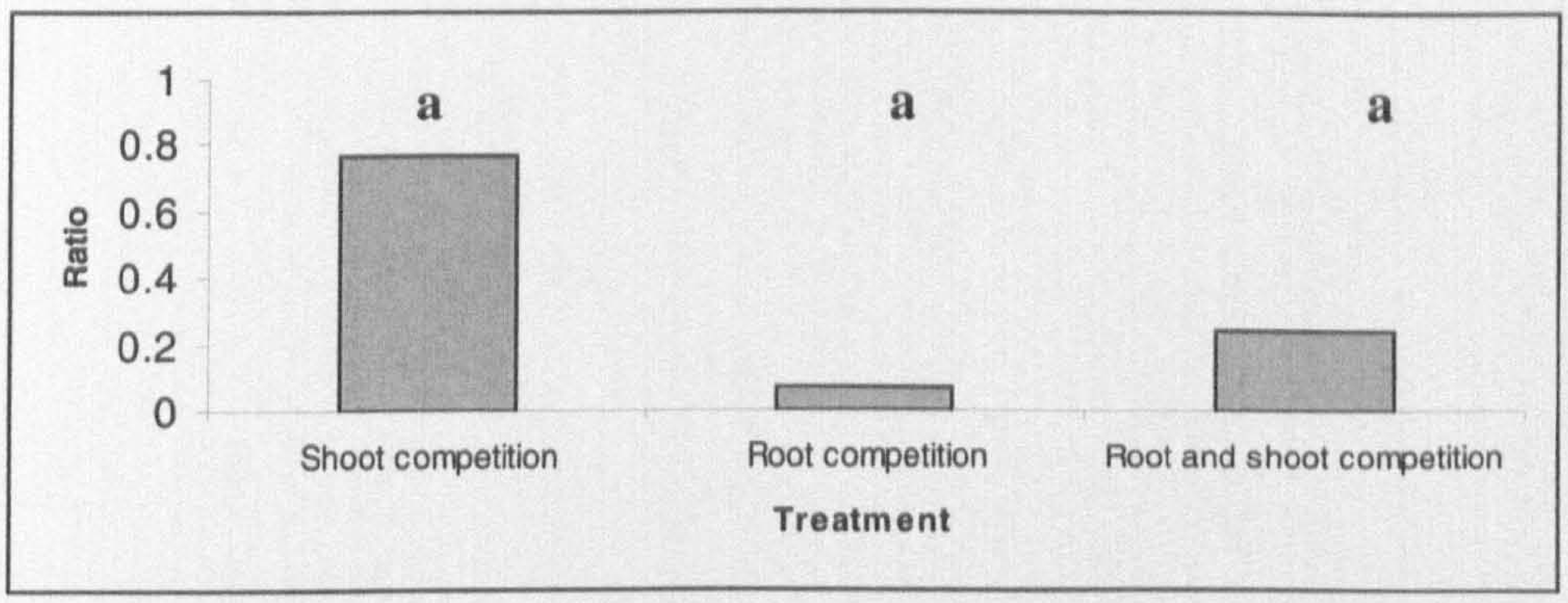

Fig. 29: Dry weight ratio of shoot of *Peganum harmala* to *Lolium multiflorum*. Bars with different letters are statistically different at P = 0.05 (Tukey HSD).

8.3.3.2.SHOOT DRY WEIGHT RATIO OF *PEGANUM HARMALA* TO *DATURA INNOXIA*

In terms of the dry weight ratio of shoots of *Peganum harmala* to *Datura innoxia*, there were some differences within the shoot competition, root competition and root and shoot competition treatments. As be seen from Fig.8.30 the greatest shoot dry weight ratio (i.e. when shoot growth of *Peganum harmala* was greater relative to *Datura innoxia*) was found in the shoot competition treatment, and the smallest shoot dry weight ratio in the root competition treatment. There were significant differences in shoot dry weight ratios between the three treatments (P< 0.05).

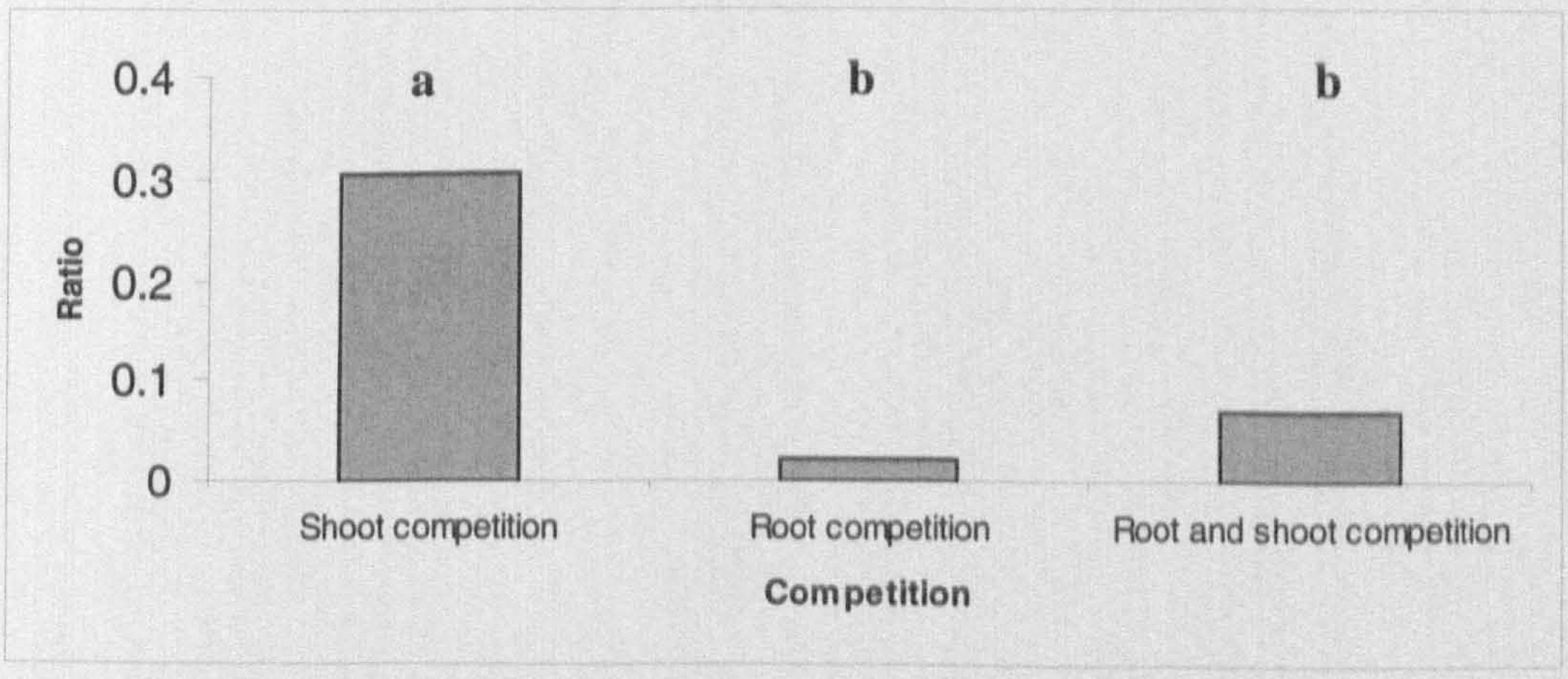

Fig. 8.30: Dry weight ratio of shoots of *Peganum harmala* to *Datura innoxia*. Bars with different letters are statistically different at P = 0.05 (Tukey HSD).

8.3.3.3.SHOOT DRY WEIGHT OF *DATURA INNOXIA* RATIO TO *LOLIUM MULTIFLORUM*

There were some differences in shoot dry weight ratio of *Datura innoxia* to *Lolium multiflorum*. Fig.8.31 shows that the greatest shoot dry weight ratio (i.e. when shoot biomass of *D innoxia* was greatest relative to *L multiflorum*) was in the root and shoot competition treatments, and the smallest shoot dry weight ratio in the shoot competition. These differences were however non-significant.

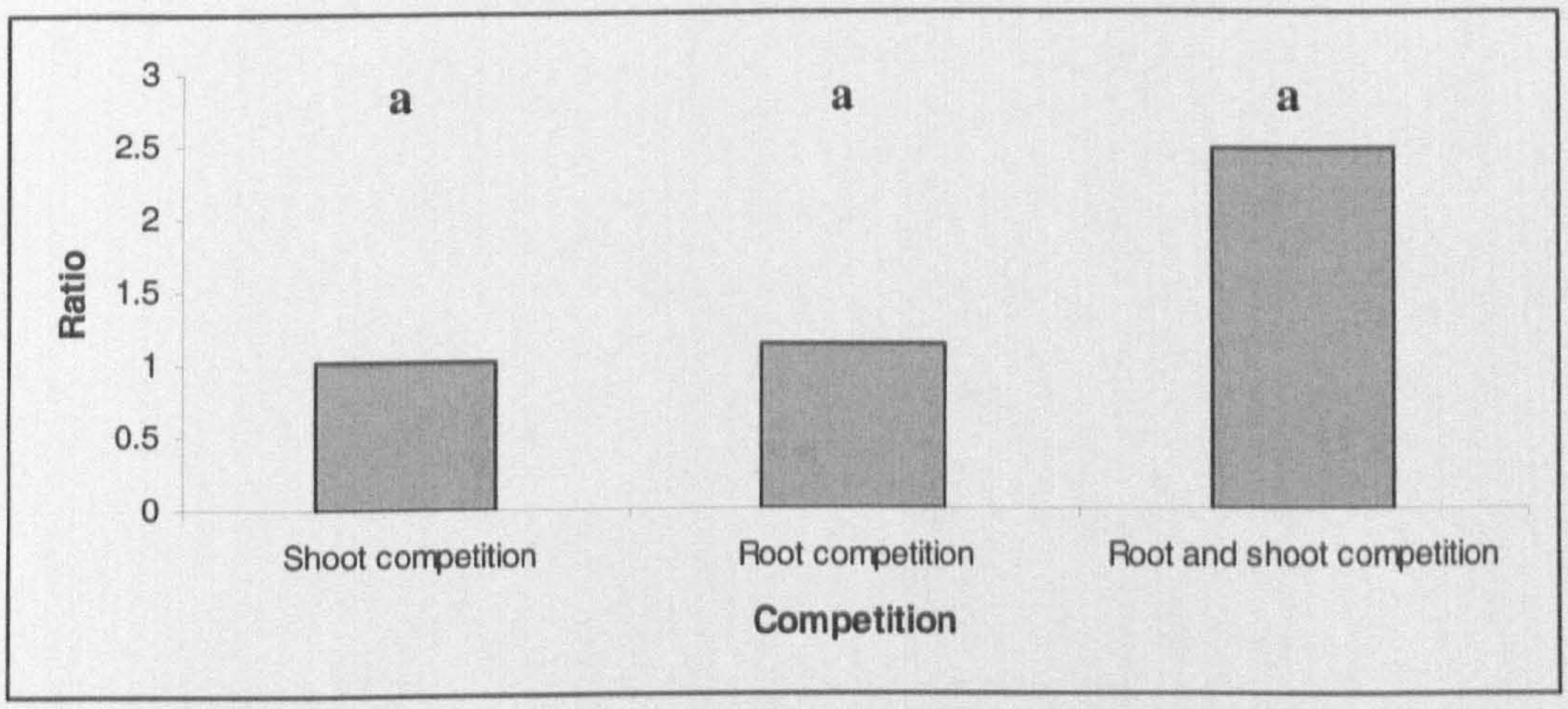

Fig. 8.31: Dry weight ratio of shoot of *Datura innoxia* to *Lolium multiflorum*. Bars with different letters are statistically different at P = 0.05 (Tukey HSD).

8.4 DISCUSSION

8.4.1 EXPERIMENT 1; EFFECT OF CUTTING ON COMPETITION IN SOME MIXES OF SAUDI NATIVE SPECIES

8.4.1.1 MEAN OF ALL SOWN FORBS

The results shows that cutting did not have a significant effect on the mean of all species in terms of seedling survival. It was originally assumed that by reducing dominance cutting would increase coexistence and raise percentage survival. At a community level this did not occur for the following reasons:

- *Lolium multiflorum* produce too much growth at ground level even when not cut.

- Cutting benefits the survival of some species such as *Farsetia aegyptia* and disadvantages the survival of other species e.g. *Verbesina encelioides;* hence mean survival is similar between uncut and cut.

8.4.1.2 INDIVIDUAL SPECIES

Cutting increases seedling survival of *Cassia occidentalis, Cassia senna* and *Farsetia aegyptia* although only by small amount. This is as result of decreasing the effect of competition on these species by having a negative effect on the weed species and ruderals such as *Verbesina encelioides.* This suggests cutting may helpful for these species establishment within that community in weedy sites.

8.4.2 EXPERIMENT 2; EFFECT OF COMPETITION IN A SOWN COMMUNITY OF FOUR SAUDI NATIVE SPECIES

This experiment was a continuation of the experiment mentioned in chapter seven. As can be seen from Table 8.3, there were a number of significant differences in the effect of weed competition and irrigation frequency on sown forbs.

Species	Treatment	Shoot dry weight	Root dry weight	Root : shoot ratio
MEAN OF ALL SOWN FORBS	Weed	ns	ns	ns
	Irrigation	*	*	*
Achillea fragrantissmia	Weed	ns	ns	ns
	Irrigation	*	ns	ns
Artemisia judaica	Weed	ns	ns	ns
	Irrigation	*	*	*
Cassia occidentalis	Weed	ns	*	*
	Irrigation	ns	*	*
Farsetia aegyptia	Weed	ns	ns	ns
	Irrigation	***	***	*

= significant at P=0.05 (= 0.05, ** = 0.01, *** = 0.001)
ns = not significant

Table 8.3: Effect of Weeds and Irrigation on growth of sown forbs.

Weeds did not effect the mean growth of sown forbs significantly. This may be because the duration of the experimental period (about ten weeks) was too short, they may need more time to make sufficient shoots to be able to shade more the sown forbs from the light. In the previous experiment weeds had a more significant impact on mean of all sown forbs growth because plant density was greater and the period was longer. Also the presence of fast growing forbs such as *Verbesina encelioides* in the previous experiment contributed to the effects of the weeds. In common in the other experiments in this thesis no attempt was made to maintain constant density when weeds were included as treatment. As consequence the results may be an artifact of increased seedling density rather than the grass weed *per se.*

The species whose growth was most effected by irrigation was *Farsetia aegyptia.* This is also the most rapid growing species of the four forbs. The reduced effect of irrigation on the other three forbs suggests that they are more strongly stress tolerant and can not respond as ruderals to increasing resources. This suggests that establishment of these three species will favoured by drier conditions post germination.

In the mean shoot and root dry weight, irrigation increases growth. Weed decreases growth. However, the effect of weed competition with water stress (pots irrigated every 21 days) disappeared, but with irrigation frequency every fortnight weed competition was more evident. This may because of the positive effect of water stress on the weeds, and suggested that drought stress might benefit these species by reducing weed competition.

In the root : shoot ratios we can observe that this ratio was always greater in fortnightly irrigation treatments than in every week treatment. This may because shoots were growing more quickly with more irrigation (every week) rather than root system.
In some species such as *Achillea fragrantissima* the effect of weed competition and irrigation frequency was not clear, this may because this species is very slow growing and was very small at harvest time. This species germinated later than the other species and may be affected more if the experiment was run for longer than the other species.

In *Artemisia judaica* the effect of irrigation frequency on shoot and root dry weight is more demonstrated clearly within non-weed treatments rather than other treatments. This suggests that in this species irrespective of irrigation regimes, weeds are more effective competitors for water than the species. However the growth of *Artemisia judaica* is uneffected by irrigation frequently when weeds are present. When weeds are absent *A judaica* show the expected increased in growth in response to irrigation frequently. This indicates that in a field situation irrigation of sown communities of *Artemisia judaica* would tend to lead to the competitive elimination of this species where weeds are present. The mean root : shoot ratio of *Cassia occidentalis* with irrigation every fortnight was greater than with every week treatment, because of the fast growth of shoots rather than roots. The mean of root : shoot ratio of *Farsetia aegyptia* was little affected by weed competition and irrigation frequency. It is not entirely clear why this species is responding in this way.

8.4.3 EXPERIMENT 3; ABOVEGROUND AND UNDERGROUND COMPETITION EXPERIMENT

In this experiment, the greatest values for the shoot dry weight ratio of *Peganum harmala* growing in mixture with *Lolium multiflorum* was in the shoot competition treatment where roots were partitioned. With partitioned shoots (root competition treatment) the ratio was less than without partitions (shoot and root competition treatment). This suggested that that competition is primarily for soil resources. This is also continued in the shoot partitioning treatment; the ratio of *Peganum harmala* to *Lolium multiflorum* decreased markedly when roots were able to interact. However the root competition treatment was anticipated to produce a ratio that would be approximately intermediate between the shoot competition treatment and the root and shoot competition treatment; this was not so however in this experiment. It appears that the metal cones used to separate the foliage canopies in the root competition treatment may have had generated adverse effects. Alternatively as the negative effect of the cone are restricted to *P harmala* the smallest species used, it may simply be that the cone actually shaded the young seedling of this species in the first few weeks.

The shoot dry weight ratio of *Peganum harmala* growing in mixture with *Datura innoxia* within the root competition treatment provides similar results. It would appear that *Datura innoxia* is similar as a competitor to *P. harmala* as *Lolium multiflorum.*
The greatest shoot dry weight ratio of *Datura innoxia* in mixture with *Lolium multiflorum* was with root and shoot competition, that may because these two species growth is very fast and approximately equivalent (ratio ≅ 1.0 for shoot and root competition). There is however some evidence in the root competition treatment that *Datura innoxia* is better able to compete for soil resources than *Lolium multiflorum.* The canopy of *Datura innoxia* in the shoot competition treatment may have been restricted by the limited sand volume available in this treatment due to root partitioning. In the root and shoot competition treatment *Datura innoxia* exerts its dominance over the *Lolium multiflorum.* The broad horizontal foliage of *Datura innoxia* is ideally suited to shade its neighbours.

Table 8.4: Factors restricting the growth and competition ability of the three species:

	Peganum harmala	*Datura innoxia*	*Lolium multiflorum*
Root competition most important	✔ (all competitions)	✔ (with *L multiflorum)*	✔ (with *P harmala)*
Shoot competition most important		✔ (with *P harmala)*	✔ (with *D innoxia)*

It appears that which is most important in terms of competition differs from species to species and also according to the characteristics of the other species in the competition.

CHAPTER 9

9. THE PROCESS OF USING INDIGENOUS PLANTS IN DESIGNED LANDSCAPE AND OVERALL DISCUSSION AND CONCLUSION

CHAPTER 9

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9.1 THE PROCESS OF USING INDIGENOUS PLANTS IN DESIGNED LANDSCAPE

9.1.1 -INTRODUCTION

The previous chapters establish important data about indigenous plants of Saudi Arabia, which provides the basic information, needed to start specifying native species and plant communities as substitutes for more conventional plantings or non-indigenous plants. These native plant communities can be used in extensive landscape design in Riyadh with in a nature design style. McHarg (1969) first introduced the phrase "Design with Nature". It is assumed here that the best way to fulfil the concept of 'Design with Nature' is to design the way nature does, i.e. in terms of ecological laws.

Thorne (1991) stated that the "*ecological aesthetic can be viewed as the union between aesthetic appeal and landscape ecological integrity*" with the latter referring to the overall health of the landscape, involving different environmental and cultural factors. Lucas (1991) emphasized the necessity of a natural appearance, conformity of forest form to the land form, visual and habitat diversity, blending of the forest with landscape, a natural appearance of the distribution of species within the forest, and a dominant species within the forest landscape.

In this chapter, the author speculates on how to use the native species that succeeded in the establishment experiments in a typical landscape project and how they might satisfy various landscape design roles in Riyadh and equally importantly to contribute Saudi social life. Planting designs may be derived from evaluation of thousands of different species, plus topographic and soil variables. In this chapter only the twenty species discussed earlier in this thesis will be considered for use in Saudi landscapes via two different methods (The target species method and Target community method). These methods were derived from studies of Salama (1990), Al-mahdi (1994) as options for using plants in landscape.

The target species method seems most appropriate for intensive urban landscape. In this method the site will largely have lost its original ecological character (as in most of Riyadh designed landscapes at present). Here the approach is to examine the environmental, social and use factors and match particular target species to these conditions and elements. From a list of suitable species, the landscape architect designs a composition to match the special character and needs of the site. In the target community method for nature parks and extensive landscape the process for each site is different. In this method the landscape architect use whole communities, either one or more. Here the given site almost completely controls the choice of community to be use. There must be a close match between the two if success is to be guaranteed. (Fig. 9.1)

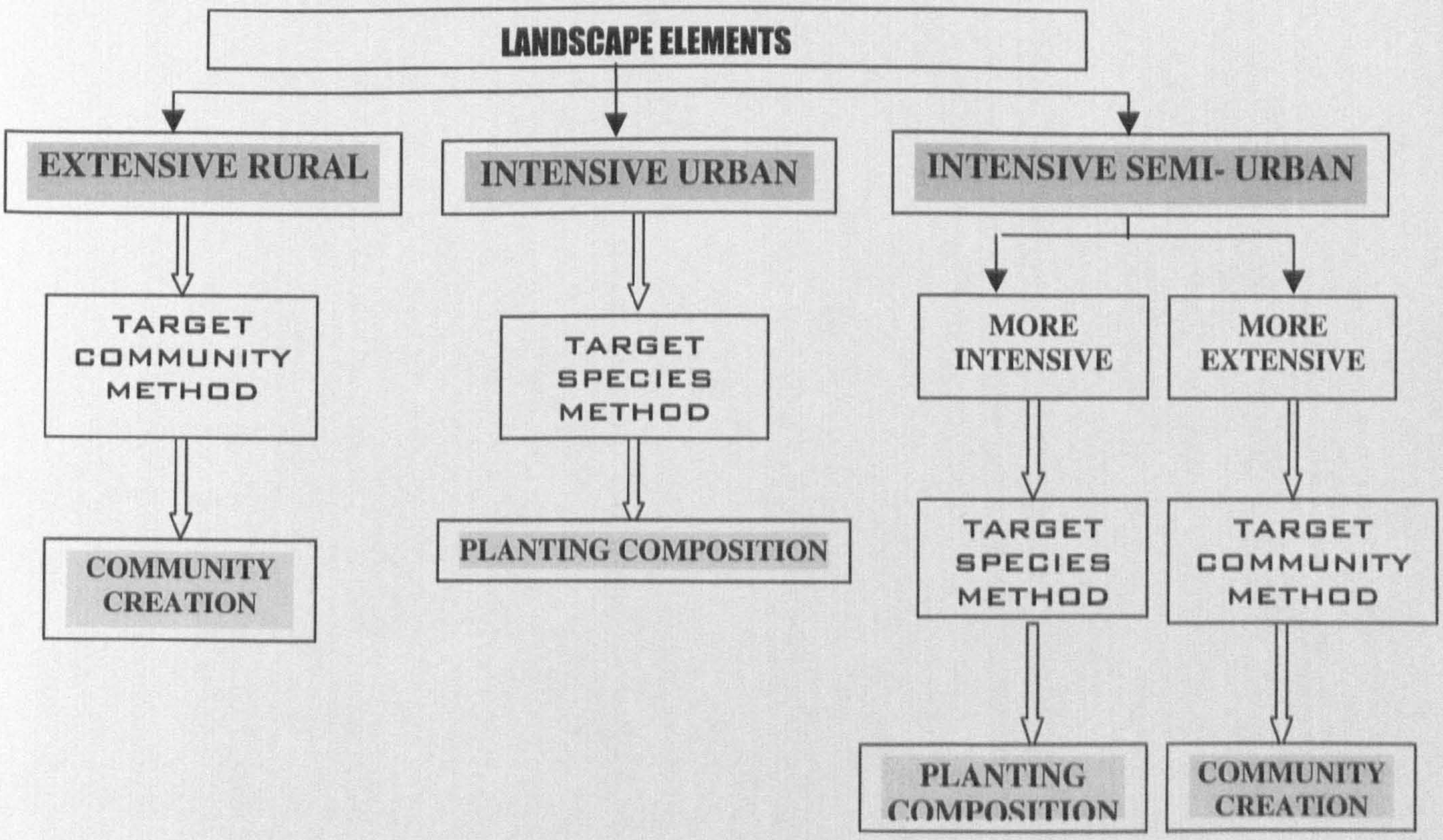

Fig. 9.1 Options for using native plants in landscape in Saudi Arabia

In the target community method in which the propose is generally to establish large areas of semi-nature landscape, the following objectives are generally inherent:

- **Conserving nature:** Conserving nature involves many issues; the key ones in these kinds of design are the maintenance of a site's natural topography and establish suitable native plants community.

- **Establishing a sustainable ecosystem:** Sustainability is a complex concept. A simple version sufficient for this study involves:
  - Selecting native species community suitable for Riyadh's climate and areas use
  - Placing the individual plants at suitable location within the site with the target species method.
  - Ensuring compatibility between the species, through selection of an appropriate plant palette from a native community.

- **Achieving natural appearance.** This is related to personal philosophy and aesthetics and is thus rather more subjective than the previous two criteria. In the present context it is assumed to involve:-
  - A diversity of species
  - A sense of unity achieved through planting the different species in proportions similar to those the original (model) native plant community
  - Organic (informal) distribution of the species.
  - Blending of the site into the surrounding semi- natural.

All of the above objectives can be realized by selecting a plant palette from a native plant community suitable for the climate and soil of the project site, and placing the individual plants according to the specific topographic and soil characteristics of the particular locations within the site. These issues have been discussed at length by authors such as; Sepahi (2000) and Thompson (1998).

9.1.2 THE PROCESS OF USING TARGET SPECIES METHOD

For urban and suburban projects, planting work associated with buildings and general intensive usage, the target species method highlighted earlier is often most appropriate. According to their shapes and character, which was derived from studies of (Migahid, (1974), Al-Zoghet, (1989) Heemstra, Al Hassan and Al Minwer (1990), Salama (1990) Al-Zoghet and Al-Alsheikh (1999), and Chaudhary & Al-Jowaid (1999), approximately twenty species were proposed to be suitable for landscape use within the urban fabric of the Riyadh area. Table 9.1 displays information on each species character. Table 9.2 represents examples of urban landscape projects and the species most suited for each. It is very critical for landscape architect to understand those species they are using in a planting design (see appendix).

Table 9.1 Characteristics of twenty species that can be used in the Riyadh urban landscape.

Plants name	Life form	Horticultural character	Size (cm)	Growth	Flower				
					F.	W.	Sp.	Su.	Colour
Achillea fragrantissima	S. Shrub	Fragrant	60	Fast			x		Yellow
Aerva javanica	Forb------	Perennial	50	Very fast			x		
Aloe vera	Succulent	Perennial	50	Medium			x	x	Yellow
Anvillea garcini	Shrub	Perennial	40	Medium			x		Yellow
Artemisia herba alba	Shrub	Dwarf	60	Medium					
Artemisia judaica	Shrub	Aromatic	70	Medium					
Atriplex halimus	Shrub	Evergreen	250	Very fast					
Atriplex leucoclada	Shrub	Evergreen	70	Fast					
Cassia italica	Shrub	Dense	50	Fast				x	Yellow
Cassia occidentalis	Shrub	Evergreen	150	Very fast				x	Red-yellow
Cassia senna	Shrub	Dense	70	Very fast				x	Yellow
Datura innoxia	Forb------	Annual	70	Very fast				x	white
Dodonea viseosa	Shrub	Evergreen	180	Very fast				x	Green
Farsetia aegyptia	Shrub	Grey bushy	50	Fast			x		Purple
Lasiurus scindicus	Grass	Thick clump	50	Fast			x		White
Peganum harmala	Forb------	Perennial	50	Medium			x		White- Yellow
Pulicaria crispa	Shrub	Perennial	60	Fast			x		Yellow
Rhazya stricta	Shrub	Evergreen	100	Fast				x	White
Rumex villosa	Forb------	Annual	50	Very fast			x		Pale red
Verbesina encelioides	Forb------	Annual	70	Very fast			x		Yellow

STREET ELEMENTS	SUITABLE SPECIES		
DEFINING PEDESTRIAN PATHS	*Atriplex halimus*	*Cassia occidentalis*	*Dodonea viseosa*
SHADING CAR PARKS	None of these species		
STREET ISLANDS	*Achillea fragrantissima* *Aerva javanica* *Aloe vera* *Artemisia herba alba*	*Artemisia judaica* *Atriplex halimus* *Atriplex leucoclada* *Cassia italica*	*Cassia senna* *Farsetia aegyptia* *Lasiurus scindicus* *Pulicaria crispa*
ROUND-ABOUT	*Achillea fragrantissima* *Aerva javanica* *Aloe vera* *Artemisia herba alba*	*Artemisia judaica* *Atriplex halimus* *Atriplex leucoclada* *Cassia italica*	*Cassia senna* *Farsetia aegyptia* *Lasiurus scindicus* *Pulicaria crispa*
URBAN PARKS			
PLAY GROUND AND ACTIVE AREAS	*Achillea fragrantissima* *Anvillea garcini* *Artemisia herba alba* *Artemisia judaica* *Atriplex halimus*	*Atriplex leucoclada* *Cassia italica* *Cassia occidentalis* *Cassia senna* *Dodonea viseosa*	*Pulicaria crispa* *Rumex villosa* *Verbesina encelioides*
TRAILS AND PATHES	*Atriplex halimus*	*Cassia occidentalis*	*Dodonea viseosa*
SHADING (SITTING ZONES)	None of these species		
AS A VISUAL BARRIER TO SATISFY PRIVACY	*Atriplex halimus*	*Cassia occidentalis*	*Dodonea viseosa*
GROUND COVER	*Achillea fragrantissima* *Aerva javanica* *Aloe vera* *Anvillea garcini* *Artemisia herba alba* *Artemisia judaica*	*Atriplex leucoclada* *Cassia italica* *Cassia senna* *Datura innoxia* *Farsetia aegyptia* *Lasiurus scindicus*	*Peganum harmala* *Pulicaria crispa* *Rhazya stricta* *Rumex villosa* *Verbesina encelioides*
HEDGES	*Atriplex halimus*	*Dodonea viseosa*	
BEDDING PLANT	*Anvillea garcini* *Datura innoxia*	*Rumex villosa*	*Verbesina encelioides*

Table 9.2: Examples of species suitable for landscape use within Riyadh area urban fabric

9.1.3 THE PROCESS OF USING THE TARGET COMMUNITY METHOD

9.1.3.1 –INTRODUCTION

The target community method is the most appropriate solution for more extensive landscape projects, which in Riyadh are associated with greening the edge of the city, developing the wadi system and landscaping large areas. The method can be described as a man made environmental succession that is indigenous in approach and result. Salama (1990) proposed that require the following:

> *"Extensive projects are likely to be designed, administrated and constructed by highly qualified consultants and contractors. Also the client is usually a government agent, who is likely to have a technical committee from the highest academic ranks. This implies a better understanding of success than with a private developer or small intensive landscape project. The landscape consultant for such project should have knowledge of habitat design and management and possess an understanding of Riyadh area ecosystem. The design team should contain an ecologist knowledgeable in arid ecosystem"*

The creation of nature-like landscape using target community method often involves the sowing of seed in sites where the plants are to grow (Fig 9.2). This approach has many advantages comparing with planting nursery grown transplants, such as it is inexpensive, the cost of implementation is low, it produces very fluid, high densities of plants and complicated planting plans are not required. However there are also disadvantages in this method such as; it requires specialized skills to weigh out small quantities of seed, need contractors with some experience of establishing vegetation by sowing in sites, timing of sowing sometimes has major impact upon success, it requires good control of the germination environment, and weed control is more complex and critical.

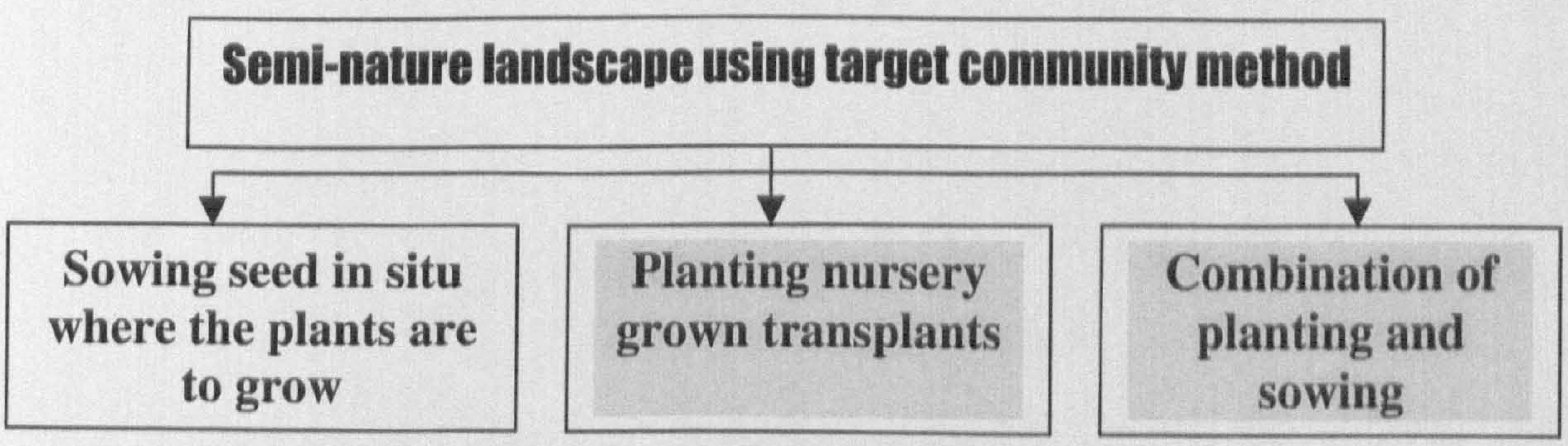

Fig. 9.2 Methods of semi-natural landscape creation using target community method

In this method individual species are not established in clearly defined groups or blocks. All sown plants are typically surrounded by 3-4 neighbours of a different species which expand to fill the space available. Loss of one species is an opportunity for other desirable species as much as it is for invading weeds. After the species are chosen the degree of establishment success will often depend upon soil moisture and weed competition. Also the vegetation selected must be expected to change with the site, there is no exact plant composition to achieved in contrast to traditional planting design. For this reason the community creation will be given by the author in this chapter is as example.

9.1.3.2 CREATION OF SEMI-NATURAL LANDSCAPE USING TARGET COMMUNITY METHOD GUIDELINE IN PRACTICE

Successful habitat creation depends on the careful consideration of several basic factors before seed are sown or plants selected. These factors can be summarized in general group topics as following:-

Site context: it is important to relate to the nature of the adjacent habitats and how the site functions in the wider ecological landscape.

The location of the site: how it is to be managed, and its potential use by people.

Soil and water which plants can sensibly be established in response to these conditions.

The design process: it is necessary to consider questions of shape, scale, habitat type, species and implementation (see fig. 9.3). (Gilbert and Anderson 1998)

Overall considerations to create semi-natural landscape using target community method can be summarized as following:-

i. Design context

Setting of objectives is an essential pre-requisite to semi-natural landscape creation. It assists in the design of the most-appropriate set of communities and provides an all important reference point against which the degree of success can be judged at the later stage. Also in most instances, the site is earmarked before a project begins. However, where there is choice, it is productive to consider the landscape ecology of an area: the pattern, linkages relative size and dispersion of existing habitat patches of different types. Furthermore it is very important understanding the soil and water characteristics of the site, there are a number of aspects to consider such as nutrient, moisture, salinity, pH and hydrology which variables over time.

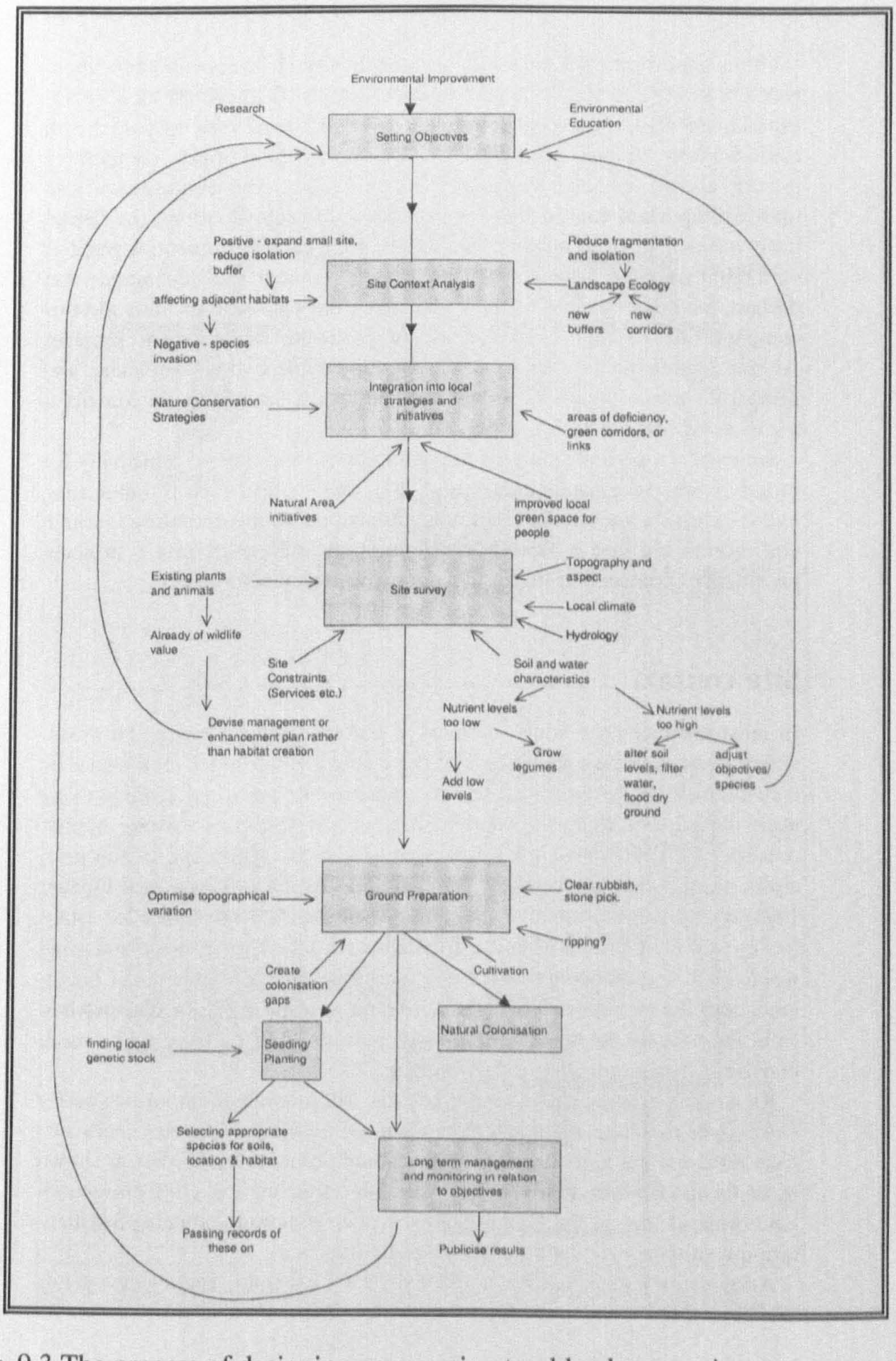

Fig. 9.3 The process of designing new semi-natural landscape using target community method (Gilbert and Anderson 1998)

ii. Choice of the community species

The type of species for plant community creation chosen should reflect the likely need and expectations of uses, the overall design context, and the environmental conditions. When dealing with rural or urban fringe situations only native species are likely to be considered. In this study we have used only native species because these are the overwhelming determinant of Riyadh rural landscape character. Additional reasons to support the use of native species have been discussed in chapter one. It can be seen from Table (9.3) an example of community seed mix formulated using the species studied in this thesis, with different numbers of target plants for each species considering the species size, shape and character, in addition to functional requirements. Furthermore, to formulate a seed mix for a sown community according to these seeds establishment percentage in laboratory the difference between this percentage and that in the field must be considered. Consequently we used 50% of laboratory percentage as field establishment percentage although in many case actual field establishment will be lower than this.

Species	No. of seed /g	% laboratory establishment	% field establishment (50%)	Target plants /m^2	g/seeds/m^2 to achieve this	Total amount of seed required for 1000 m^2 (g/ m^2x total area)
Achillea fragrantissima	3468.2	87	43.5	8	0.006	5.517
Artemisia judaica	6818.2	50	25	6	0.002	2.400
Cassia italica	34.979	43	21.5	6	0.798	798.140
Cassia occidentalis	54.088	95	47.5	0.4	0.016	15.579
Cassia senna	44.537	76	38	6	0.355	355.263
Datura innoxia	72.115	83	41.5	8	0.268	267.952
Farsetia aegyptia	352.53	97	48.5	6	0.035	34.639
Peganum harmala	317.63	96	48	8	0.052	51.667
Rumex villosa	352.53	43	21.5	10	0.130	130.233
Verbesina encelioides	381.19	65	32.5	10	0.080	80.000
Aerva javanica	4545.5	86	43	6	0.003	2.791
Anvillea garcini	1739.1	87.5	43.75	8	0.011	10.971
Artemisia herba alba	6250	77.5	38.75	6	0.003	3.097
Lasiurus scindicus	191.14	97	48.5	10	0.107	107.216
Pulicaria crispa	20000	80	40	6	0.001	0.750
Rhazya stricta	149.85	65	32.5	0.3	0.006	6.185
Total				104.7	1.872	1872.399

Table 9.3 An example of community seed mix formulated using the species studied in this thesis to achieve designed plant community.

iii. Establishment practice

- **Time of sowing**

The most important factor that determines successful germination and establishment of temperate forbs is soil moisture (Fuller, 1987; Wilson and Gerry 1995), and it seems likely that this is also the case for Saudi forbs and shrubs. For this reason the optimal time for sowing these seeds will generally be the months of reasonable rainfall that are warm enough for germination to occur. In Riyadh the best month for this is November especially since it is following by five months when Riyadh receives the highest amount of rainfall. How ever although Saudi Arabia has low rainfall, nevertheless Saudi soils are not always sands, some of these soils are clays which are highly fertile and therefore when moist subject plants to extreme competition especially after rainfall when the nutrient increases as result of organic matter breakdown. However some Saudi soils are infertile and dry out quickly. For this reason tropical annual species grow very quickly to complete their life cycle, and perennial species, for the most part, naturally occur at low densities to avoid extreme competition on dry infertile soils.

- **Seed dormancy**

Some seed of Saudi indigenous species may subject to dormancy and fail to germinate ever when provided with appropriate conditions to do so. To break seed dormancy, choosing a technique is very important factor. In the community mix shown in Table 9.3 there are only three species will need dormancy breaking treatment as following:-

Species	**Treatment**	**Post treatment Ger. % (In lab.)**
Cassia italica	Sulphuric Acid 15 min.	43.3%
Cassia occidentalis	Sulphuric Acid 15 min.	95%
Cassia senna	Sulphuric Acid 15 min.	76.6%
Rhazya stricta	Leaching	65%

Table 9.4 Techniques for breaking of seed dormancy.

Commonly used techniques to break Saudi indigenous species seed dormancy have been discussed in chapter Three.

- **Counting seed required per m^2**

It is very important when making up seed mix to establish new semi-nature plant community to set a target number of plants per m^2 for individual species and for all species together to know the amount of seed required. In temperate forbs-grass community the total number of plants aimed at is usually between 100 and 200 plants/ m^2. These values depend on the size of plants at maturity, the visual characteristics required and the weediness of the site. However, in arid environment this may be less than 100 plants/ m^2, especially with soil water shortages which will limit survival of more plants.

- **Site preparation**

This treatment includes weed control, soil cultivation. They are fundamental requirements for successful semi-nature landscape establishment and long-term community development. For that reason in weedy sites higher sown forb seedling densities and less watering frequency are required.

- **Sowing practice**

To achieve semi-nature landscape with predictable visual characteristics, effectivs and uniform distribution of seed must be considered. The calibration process for sowing must be considered to sow the right weight of seed per m^2 (1.872g/m^2 as we specify earlier), this can be made quicker by adding one handful seed sowing carrier (e.g. sand) for every m^2 of area. Sowing can be undertaken by hand for small scale or by machine for large scales.

iv. Long-term management

Management of semi-nature landscape needs consideration at the earliest stages of project planning, to achieve a satisfactory balance between maintenance costs and the appearance and persistence of sown species. The practice of management and maintenance is in effect to maintain a plant community within acceptable limits in a state of suspended animation (Hitchmough, 2002).

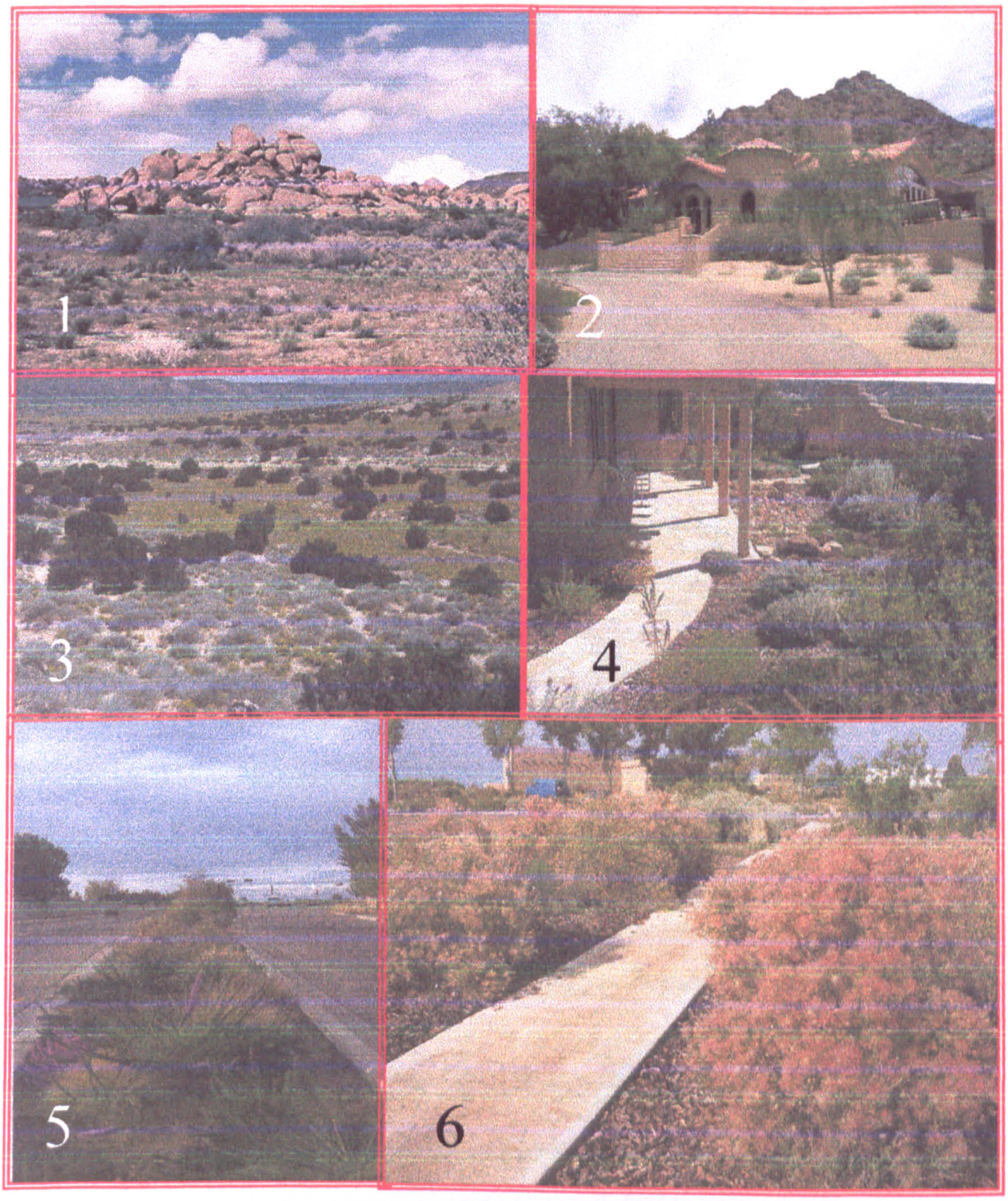

Fig. 9.4. Some examples of using native plants in urban landscape within target species method (Photos 2 and 4) and target community method (Photos 1,3.5 and6) in Arizona, USA

9.2 OVERALL DISCUSSION

9.2.1 INTRODUCTION TO USE OF INDIGENOUS PLANTS IN THE DESIGNED LANDSCAPE

Throughout the world increasing use is being made of native plants in urban landscapes, both to preserve regional visual character, conserve native biodiversity and to reduce energy inputs in the urban landscape. In Saudi Arabia most designed urban landscapes employ non-indigenous species of plants. This use of non-indigenous plants is sometimes problematic, as these species often require considerably more water and maintenance than indigenous plants. Indigenous plants have evolved in response to a harsh climate, drifting sands, high salinity and long periods of hyperaridity. The beauty and values of wild plants are only now being fully appreciated, but Saudi people have had a close relationship with wild plants and natural landscape from early times when they lived in the desert with these plants.

Using native plants in designed landscapes as a reconstruction of indigenous communities is often viewed as a relatively recent phenomenon. The concept has further developed and been applied to the design of urban public open space. Therefore the overall aim of this study is to better understand the ecology behind methods to establishing semi-natural vegetation in urban landscape in the Riyadh area of Saudi Arabia, and to produce preliminary guidelines for landscape practice in Saudi Arabia on how to use native species in these types of landscape projects.

9.2.2 SPECIES SELECTION AND LABORATORY WORK

In this study approximately 40 common species indigenous to the desert areas in Saudi Arabia including the Riyadh area have been selected, and their seed collected in the wild. All of these species are small-medium shrubs, grasses and forbs, which range in height from 30cm to > 150cm. The results of germination studies showed that some species could be sown in the landscape without any dormancy breaking treatments, such as *Achillea fragrantissima, Aerva javanica, Aloe vera, Artemisia herba alba, Cenchrus ciliaris, Datura innoxia, Farsetia aegyptia, Lasiurus scindicus, Ocimum sp, Peganum* *harmala, Pulicaria crispa* and *Verbesina encelioides*. Their germination percentages must however be considered when seeds mixes are being prepared for sowing.

In other species seeds were heavily dormant, but according to the tetrazolium test many species had high viability regardless the low germination percentages. Seed dormancy is very widespread amongst seed of wild plants. Therefore we investigated the influence of some pre-sowing treatment to understand the best methods to break the dormancy of these seeds.

The results of the dormancy experiments have showed that some of these species have potentially high germination percentages. With sulphuric acid (15 minutes) treatment *Cassia italica, Cassia occidentalis, Cassia senna* and *Dodonaea viscosa* demonstrated high germination percentage. Furthermore with sulphuric acid (60 minutes) treatment *Abutilon pannosum* also showed significant germination. Germination percentage of *Calligonum comosum* and *Malva parviflora* increased significantly with sulphuric acid (120 minutes) treatment. *Anthemis deserti* has given significant germination results with seed scarification (40 second) treatment. In addition *Rhazya stricta* germination percentage increased significantly with leaching. These results will allowed practitioners to chose the right methods to break these seeds dormancy in terms of establishing semi-natural vegetation in urban landscape.

One factor that contributes to synchronised germination is adequate soil moisture and temperature. The influence of temperature upon germination percentage was studied at seven constant temperatures over the range 5-35 °C, using temperature gradient bars. Results obtained from these experiments show that in the absence of other limiting factors (e.g. water stress) the germination of these Saudi native species is significantly controlled by temperature, also there were some differences between species in the optimum germination temperature (Fig. 3.25). For most of these species the maximum germination percentage was at the temperatures between 20 °C and 30 °C. For this reason the optimal time for sowing the seeds in Riyadh is likely November especially as it is followed by five months when Riyadh receives the highest amount of rainfall.

Salt tolerance at germination and during early growth is critical for plant survival and growth especially in arid regions such as Saudi Arabia. In a part of this study seed germination of some species were studied to understand how salinity effects percentage seed germination. Results show that in general an increase in salinity resulted in a significant decrease in germination percentage of all species. Some species were less tolerant of salinity such as *Artemisia judaica, Lasiurus scindicus, Lycium shawii, Pulicaria crispa, and Rhazya stricta.* Other species were high tolerant of salinity such as *Abutilon pannosum, Achillea fragrantissima, Atriplex halimus, Cassia italica, Cassia senna, Rumex vesicarius* and *Verbesina encelioides.* These results will allow landscape architects to select species and to chose the right sites which can be use for establishing a sown community and whether it is necessary to reduce topsoil salinity before sowing by pre-irrigation to leach the soil surface.

Soil moisture stress is a particularly important ecological factor in hot semi-arid climates such as that of Saudi Arabia where the indigenous species grown a hostile environment. In part of this study seed germination of some Saudi species were studied under water stress induced by *PEG-8000* (Polyethylene glycol) solutions. The results show that in general an increase in moisture stress resulted in a significant decrease in germination percentage of most species. There were some species that were not affected by –8 bar or greater moisture stress such as: *Abutilon pannosum, Achillea fragrantissima and Cassia italica.* However *Aerva javanica* and *Atriplex leucoclada* were affected by –2 bar or more moisture stress. Most other species were effected by moisture stress between –6 bar and –8 bar. This suggest that most Saudi indigenous species were highly tolerant of moisture stress at germination. Again these results will allow landscape architect to chose the optimal time for sowing these seeds.

9.2.3 GLASSHOUSE WORK

9.2.3.1 EFFECT OF COMPETITION IN A SOWN COMMUNITY OF SAUDI NATIVE SPECIES

The effects of competition of some indigenous Saudi Arabia species and common urban weeds at different irrigation and nutrients regimes were studied to understand how these act on these species emergence and growth to provide base-line data for the creation of Saudi native species as a sown community as nature-like landscapes. The result show that there were some differences between sown forbs in terms of the effect of weed competition and irrigation frequency on seedling emergence and growth. Survival as the mean of all species suggested that soil moisture stress was the major factor determining survival. Competition for moisture was greatest in the weedy treatment. It is clear that weeds would be a problem in practice in the field in dry climate. On the other hand, survival of sown forbs was better at low nutrients at nil and low weed competition because of the stimulating effect of nutrients on the growth of annual forbs and weeds.

In appears that *Datura innoxia, Rumex villosa* and *Verbesina encelioides* can be established in weedy sites and almost independent of irrigation or rainfall frequency In these species seedling number was not affected by competition within all weed and irrigation frequency treatments. *Farsetia aegyptia* grows relatively fast in response to irrigation; consequently the effect of weed competition was more marked when water stress was severe. *Achillea fragrantissmia, Artemisia judaica, Cassia occidentalis, Cassia senna* and *Peganum harmala* are very slow growing species that appear more water stress tolerant. These species however were intolerant of shading by weeds; in practice weeds will have a negative effect on these species establishment.

In terms of mean shoot dry weight, some forb species do not benefit from more frequent irrigation at high weed densities. At high water stress, weeds are less competitive than under low water stress. Therefore on very weedy sites irrigation would not be a valuable in practice. Also at high water stress nutrients have less effect on shoot dry weight of sown forbs than under low water stress. In *Achillea fragrantissmia, Artemisia judaica* and *Cassia senna,* weeds decrease shoot growth, whilst irrigation increases growth. However *Datura innoxia,* possesses ruderal characteristics and does not benefit from more frequent irrigation but it can grow well in weedy sites. *F. aegyptia* and *P. harmala* appear to be stress tolerators, weeds decrease growth markedly. Irrigation did not increase the growth of these species in absent of weeds.

Generally to achieve maximum mean root dry weight; sown forbs must grow at low weed densities, so weed control is important. At infrequent irrigation root dry weight of sown forbs was proportionally higher, because stress increase the root : shoot ratio. *Achillea fragrantissmia, Artemisia judaica, Cassia occidentalis* and *Cassia senna* do not benefit from more frequent irrigation, and weeds decrease root system size. In *Datura innoxia,* root mass does not benefit from more frequent irrigation and it can grow well in weedy sites. In *Farsetia aegyptia, Peganum harmala* and *Rumex villosa* irrigation does not increase root system size in absent of weed. This suggests that they are stress tolerators. The latter species functions as a stress tolerant ruderal.

In terms of mean of all sown forbs, root : shoot ratio in the presence of weeds irrigation decreases this ratio. This is somewhat contrary to what might be expected; many studies suggest root : shoot ratios increase with moisture stress. This results may be due to the preponderance of ruderal in the community. In some species such as *A. fragrantissmia Artemisia judaica, C. italica* and *C. senna*, *Farsetia aegyptia* and *Peganum harmala* root shoot ratio increases with water stress, plants continue to make more leaves than roots. Irrigation and weeds do not however have any impact on root : shoot ratios in *Rumex villosa* and *Verbesina encelioides.* Both of these species have strong ruderal tendencies, and skewed the root : shoot ratio data in this experiment.

Overall, the result suggested most of these species have high physiological or morphological tolerance of moisture stress. However this is expressed through different ecological strategies. Weed competition is likely to be a significant constraint on the successful establishment of many of these Saudi native species especially those that are poorly able to respond to fertile conditions such as *Peganum harmala.* Control of weeds should be considered explicitly when developing a restoration plan, as well as ensuing enough moisture for adequate germination of sown seed.

9.2.3.2 EFFECT OF CUTTING ON COMPETITION IN A SOWN COMMUNITY OF SAUDI NATIVE SPECIES

The basis of this experiment corresponded to a previous experiment, but this experiment was undertaken using a treatment of cutting starting from week five. The aim was to investigate the effect of cutting on the establishment of a sown community of Saudi native species. The results show that at a community level cutting did not benefit the forb species perhaps because of the weed species used and the fact that cutting disadvantages the survival of some forb species and benefits the survival of others such as *Cassia occidentalis, Cassia senna* and *Farsetia aegyptia.* This suggests cutting may helpful for these latter species establishment in weedy sites.

9.2.3.3 EFFECT OF COMPETITION IN A SOWN COMMUNITY OF FOUR SAUDI NATIVE SPECIES

As an extension of main experiment, this experiment was about the effect of competition in a sown community of four Saudi native species only. The main aim of this experiment to was look more carefully by eliminating the effect of ruderal species which grow very fast (*Verbesina encelioides* and *Rumex villosa),* and which in the previous experiment may have acted as "weed" species in addition to *Lolium multiflorum.* The results show that weeds did not significantly affect the mean growth of sown forbs. This may be because the short duration of the experimental period (about ten weeks). *Farsetia aegyptia* was the most rapid growing species of the four forbs, and it was the most affected by irrigation in terms of growth. The reduced effect of irrigation on the other three forbs suggests that they are more strongly stress tolerant, and their establishment will be favoured in the presence of weeds by drier conditions post germination.

9.2.3.4 ABOVE-GROUND AND UNDER-GROUND COMPETITION EXPERIMENT

The third experiment considered underground and aboveground competition. The aim was to investigate the competition between two indigenous Saudi species and a common urban weed of arid landscapes to understand how this acts on these species. The results show that in the first part of the experiment (*Peganum harmala* growing in mixture with *Lolium multiflorum*) the greatest value of the shoot dry weight ratio was in where root partitioned occurred. With partitioned shoots the ratio was less than without partitions. This suggested that competition is primarily for soil resources. In the second part of the experiment (*Peganum harmala* growing in mixture with *Datura innoxia*) would appear that *Datura innoxia* is similar as a competitor to *P harmala* as *Lolium multiflorum*. In the third part of the experiment (*Datura innoxia* in mixture with *Lolium multiflorum*) the greatest shoot dry weight ratio was with root and shoot competition, that may because these two species growth is very fast and approximately equivalent.

9.3 CONCLUSION

Most plants respond differently when left to compete with other plants than when grown under controlled conditions. These differences between plants are seldom reflected in conventional landscape, species usually are selected more for ornamental value than for their physiology. As a result, many must be nursed along with regular maintenance, to be ready to use in landscape within the target species method. With this approach all of the Saudi indigenous species can be use in designed landscape especially where plants are traditionally grown individually or in groups from one or two species. The same approach to planting would produce extensive failures in a sown community in a semi-nature landscape, in which plants are allowed to grow or die with minimal management. Establishment conditions and competition must be considered much more when the target community method is used.

In this study to establish a basic understanding of the establishment of approximately twenty Saudi indigenous plants for use as sown communities for semi-nature landscape, we have investigated suitable methods for breaking dormancy and the germinating of these species. We have also selected the most appropriate time for germination by defining the optimal germination temperature of each species. Moreover understanding the affect of moisture and salinity on the germination of these species seeds has been investigated. In general most of these species were found they have adaptation to water stress and salinity. For most of these species the maximum germination percentage was at the temperatures between 20 °C and 30 °C. In Riyadh the best month for sowing may be November as it is typically followed by five months when Riyadh receives the highest amount of rainfall.

After building this basic data about these species establishment, competition is the next most important factor, which controls the success of a sown community. Therefore we have investigated the establishment of species in mixture under simulated Saudi conditions using microcosm competition experiments within communities of native species. The results show that in the survival of sown species soil moisture stress was the major factor determining survival. Greater competition for moisture was demonstrated in the weedy treatment. It is clear that weeds would be a problem in practice in the field in dry climate. On the other hand, survival of sown forbs was better at low nutrients with nil and low weed competition because of the stimulatory effect of nutrients on the growth of annual forbs and weeds. In terms these species growth, most of the forbs do not benefit from more frequent irrigation at high weed densities. At high water stress, weeds are less competitive than under low water stress. Therefore on very weedy sites irrigation would not be valuable in practice. Cutting may be helpful for these species establishment within that community in weedy sites.

Overall, the results of these studies demonstrate that there is potential to use these twenty Saudi indigenous plants within the target community method for creating communities in practice in semi-natural landscape projects in Saudi Arabia.

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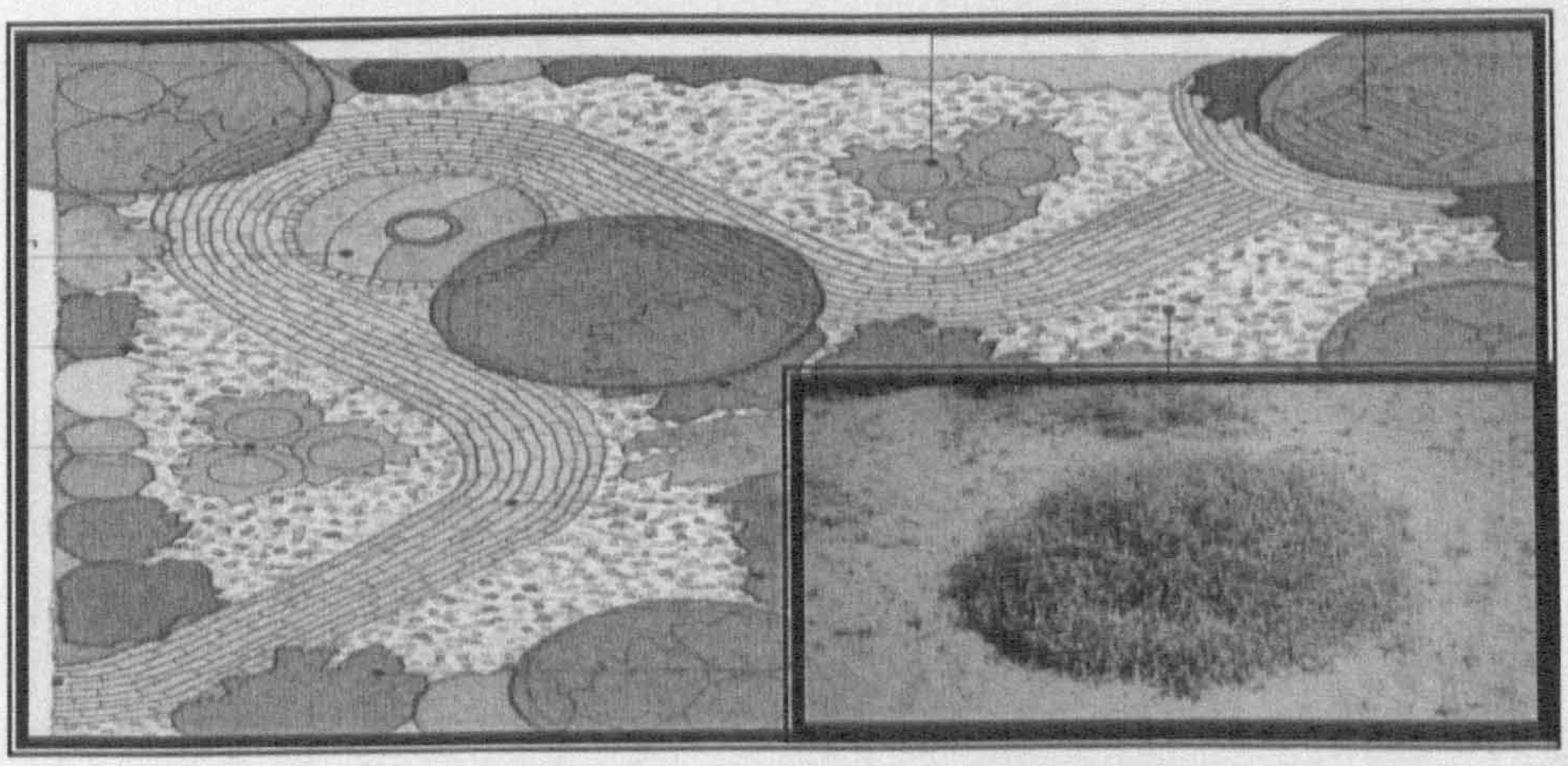
APPENDIX

A BRIEF GUIDE ON APPLICATION OF TWENTY NATIVE PLANTS IN DESIGNED LANDSCAPE IN SAUDI ARABIA
USING THE TARGET SPECIES METHOD



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* Garden plans were derived from: Bradley and Newbury (2001). *Constructing a garden*. Collins & brown. London.

Plant name:	**Locale name**	**Family:**	**No.**
Achillea fragrantissima	Kaisom	*Compositae*	1

Form:

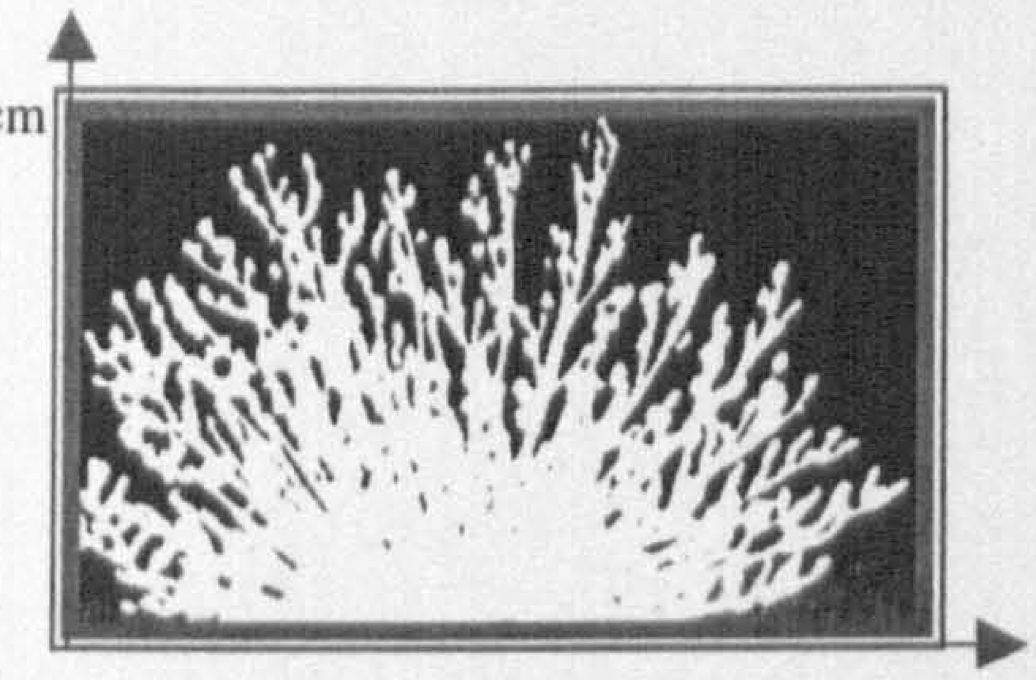
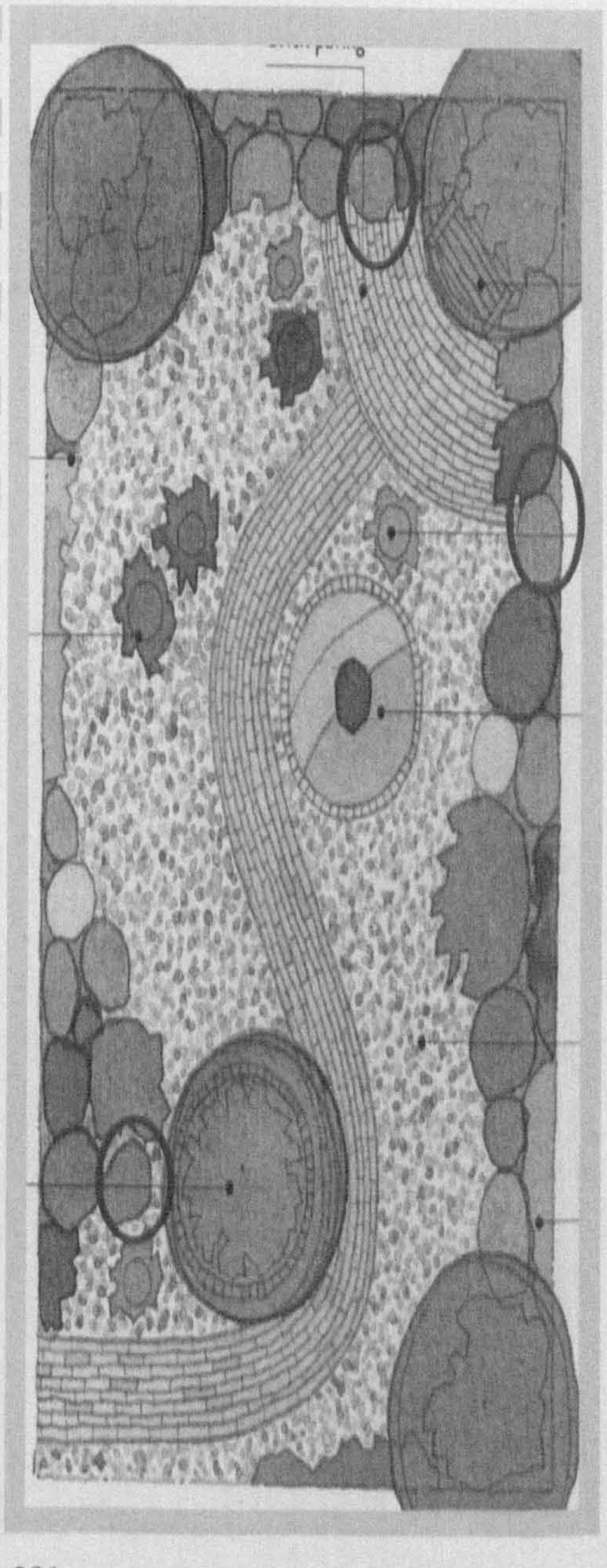


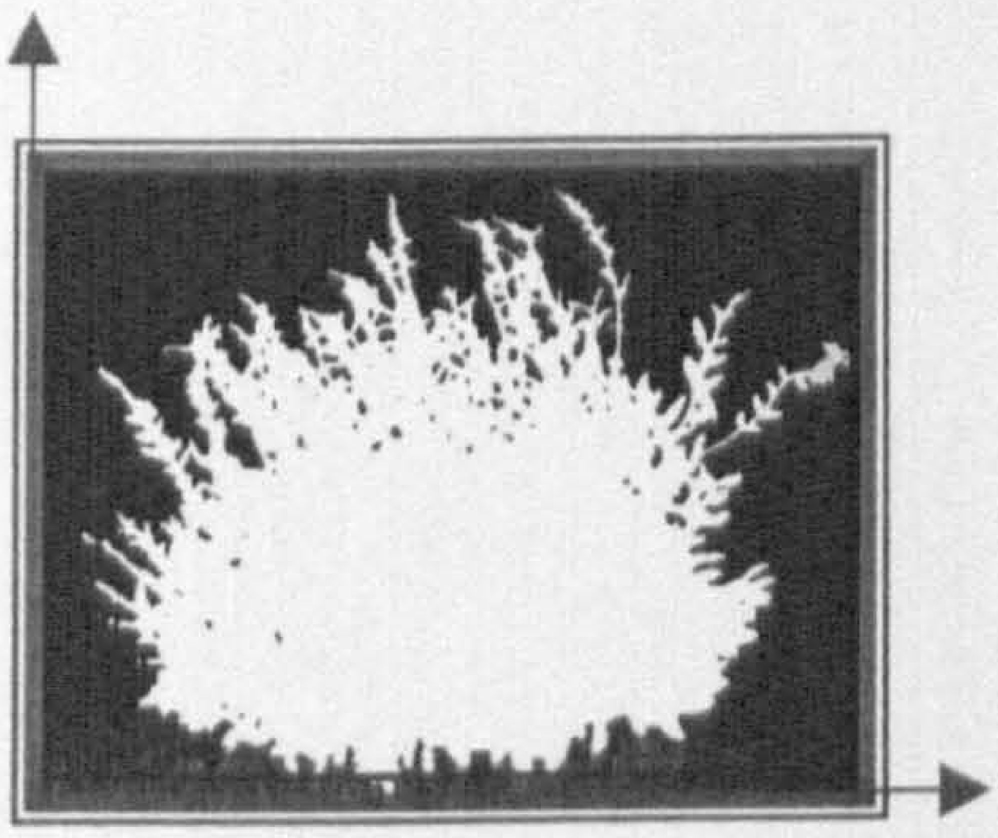
Photo:

Character	Annual forb	
	Perennial forb	
	Small shrub	
	Med. shrub	✔
	Large shrub	
	Grass	
Foliage colour:	Grey / blue green	
	Yellow green	
	Med. green	
	Dark green	
	Light green	✔
	Showy green	
Flower colour:	White	
	Yellow	✔
	Pink	
	Red	
	....	
Growth:	Fast	✔
	Med.	
	Slow	
Landscape uses:	Ground cover	✔
	Bedding plant	✔
	Hedges	
	Ornamental plant	✔
	Afforestation	
	For long road	
	Windbreaks	
	Shade	
	Erosion sand control	



Plant name:	**Locale name:**	**Family:**	**No.**
Aerva javanica	Taref	*Amaranthaceae*	2

Form:



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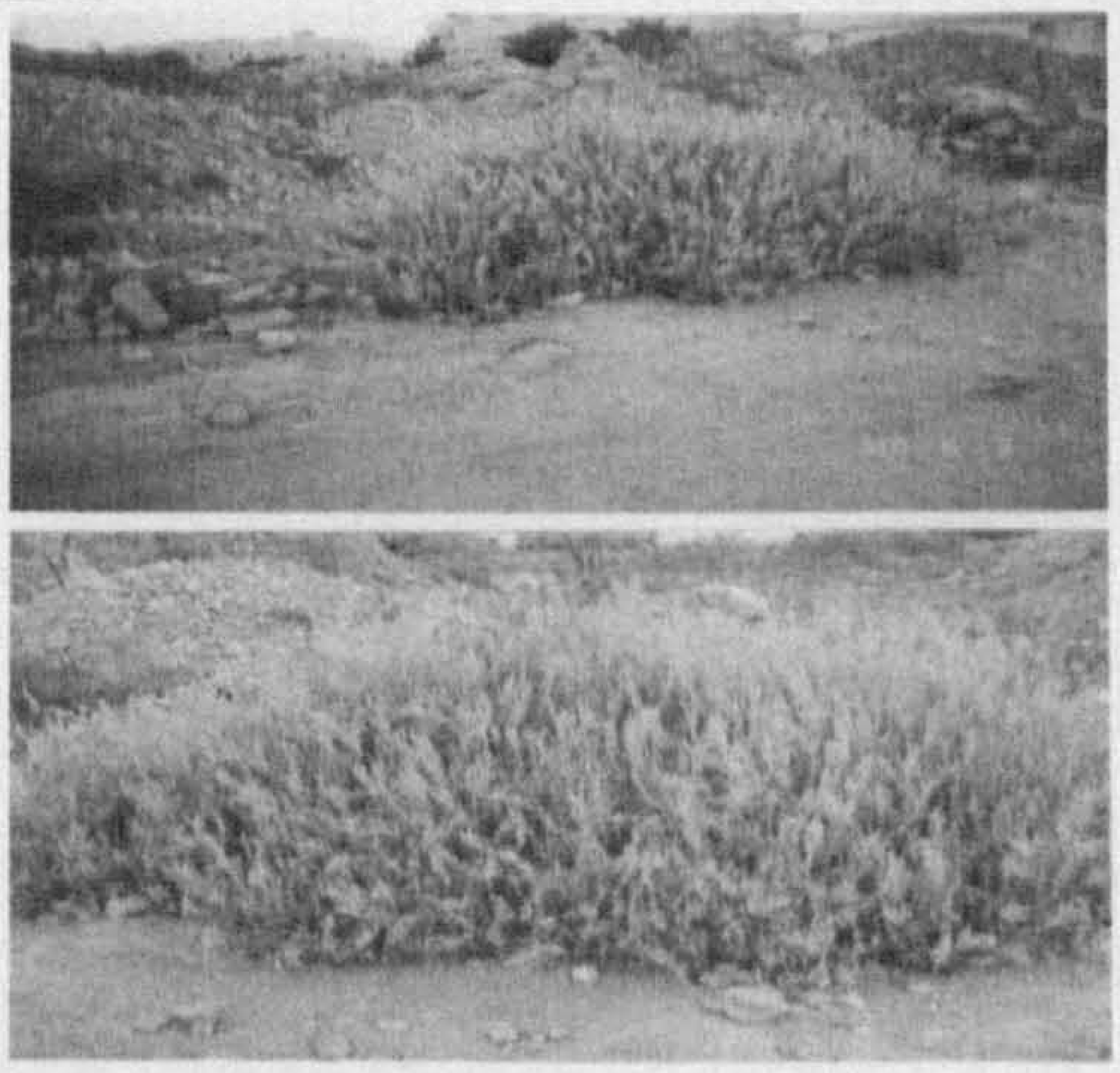
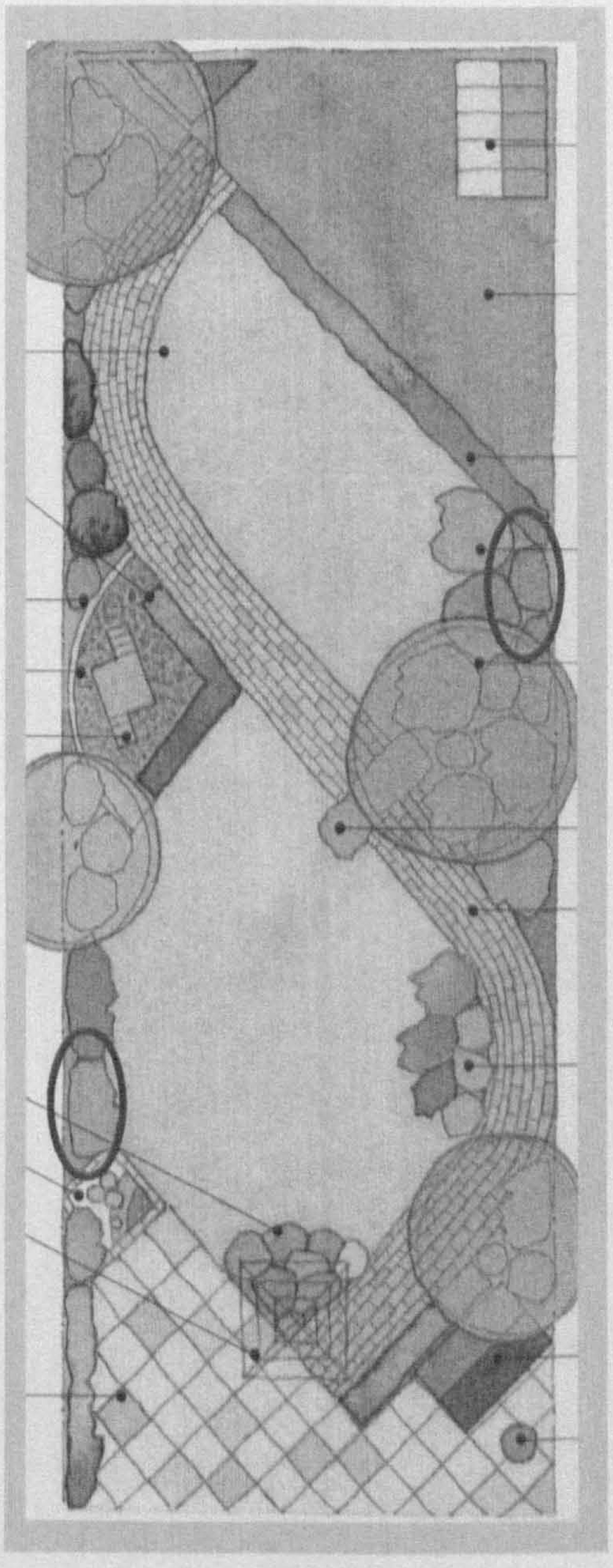
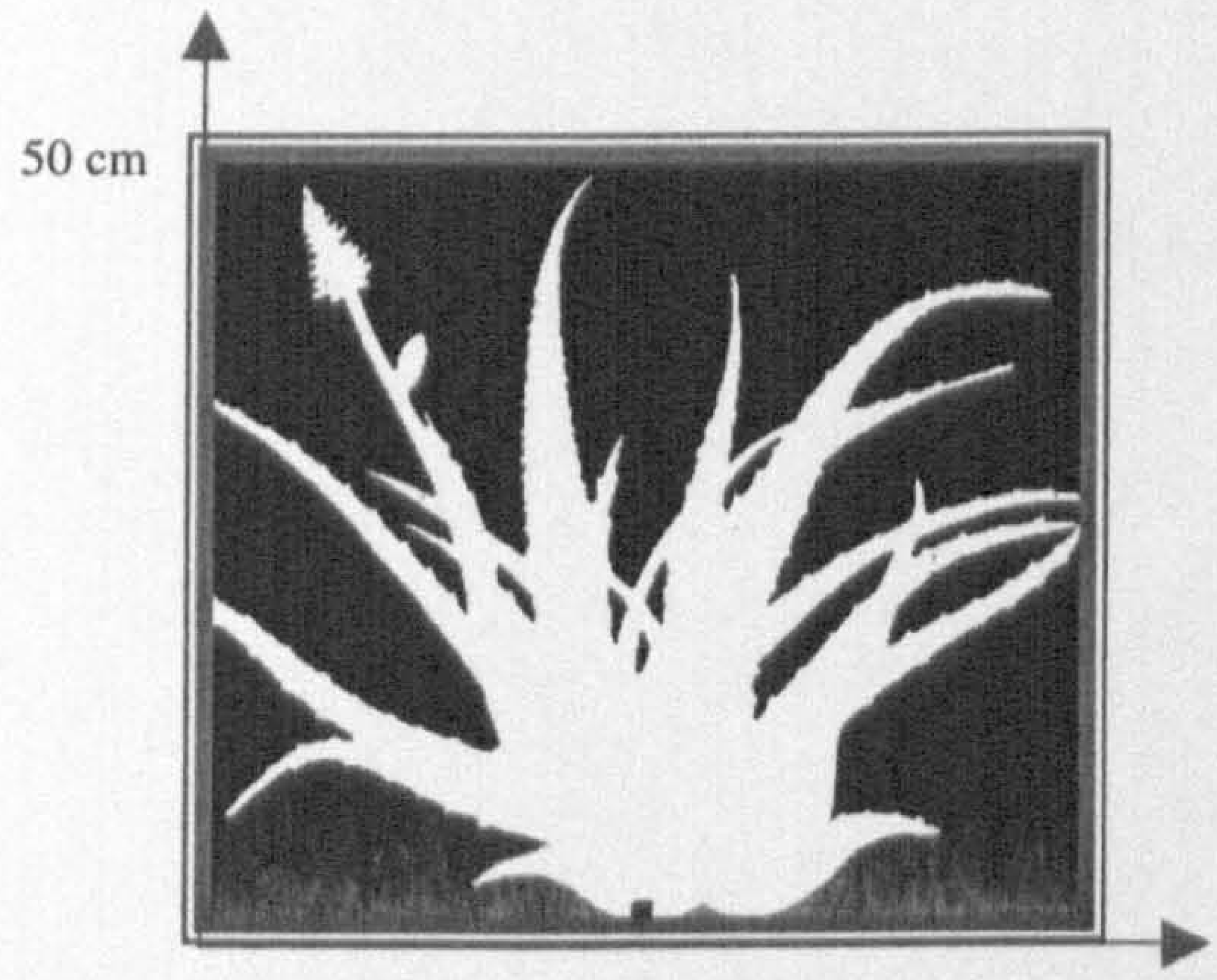


Character	Annual forb	
	Perennial forb	✔
	Small shrub	
	Med. shrub	
	Large shrub	
	Grass	
Foliage colour:	Grey / blue green	
	Yellow green	
	Med. green	
	Dark green	
	Light green	✔
	Showy green	
Flower colour:	White	✔
	Yellow	
	Pink	
	Red	
	....	
Growth:	Fast	✔
	Med.	
	Slow	
Landscape uses:	Ground cover	✔
	Bedding plant	✔
	Hedges	
	Ornamental plant	✔
	Afforestation	
	For long road	✔
	Windbreaks	
	Shade	
	Erosion sand control	



Plant name:	**Locale name:**	**Family:**	**No.**
Aloe vera	Sabar	*Liliaceae*	3

Form:



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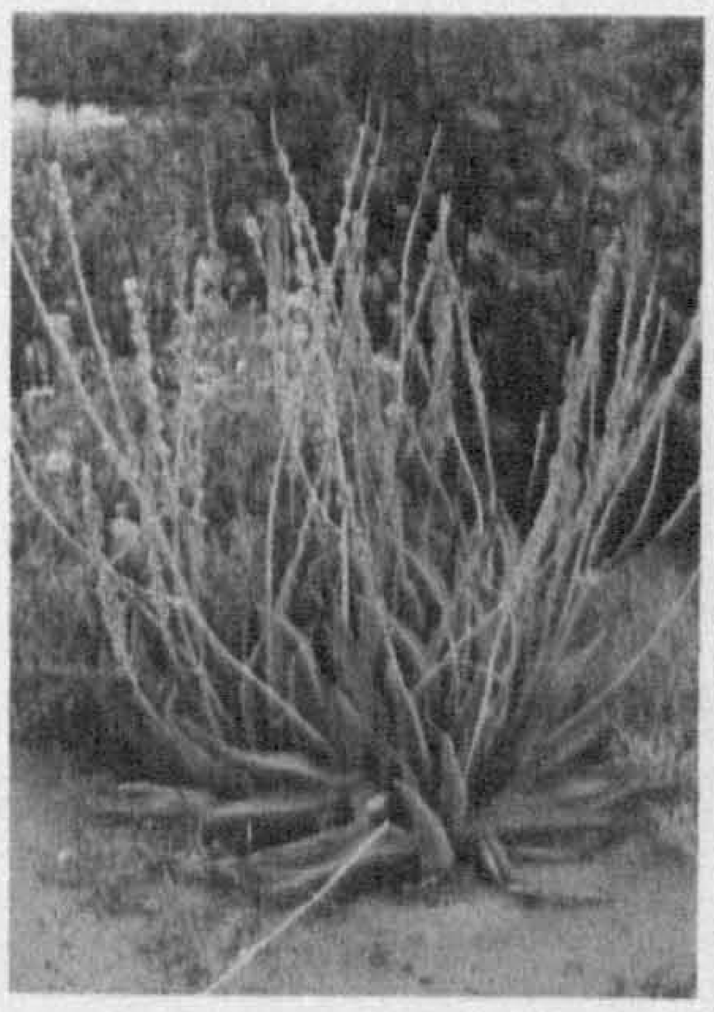
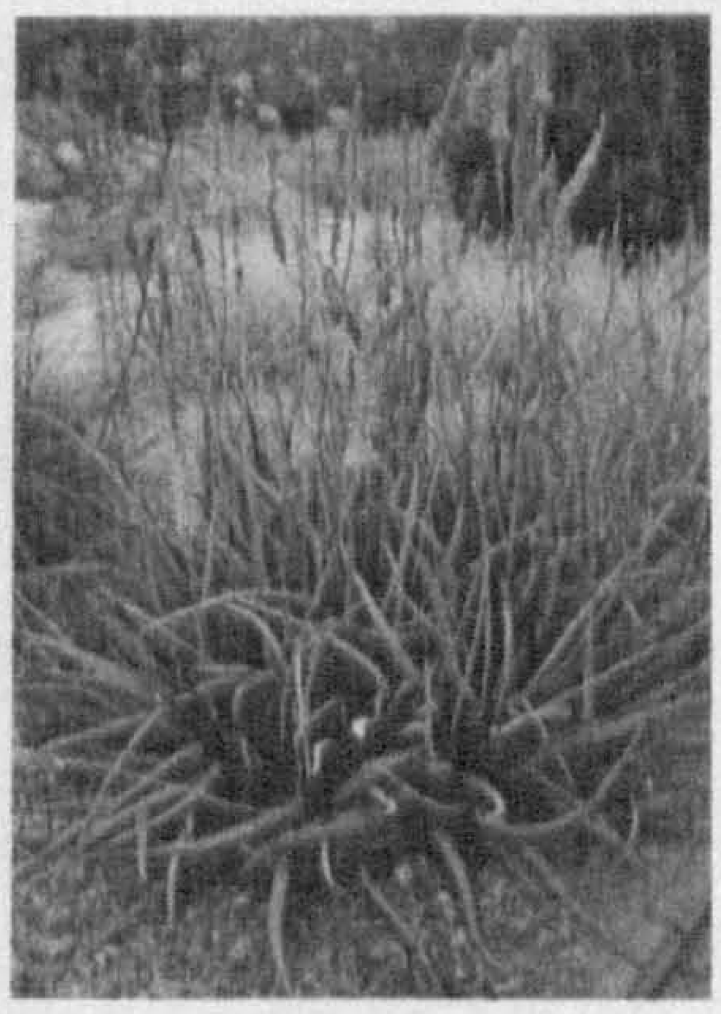
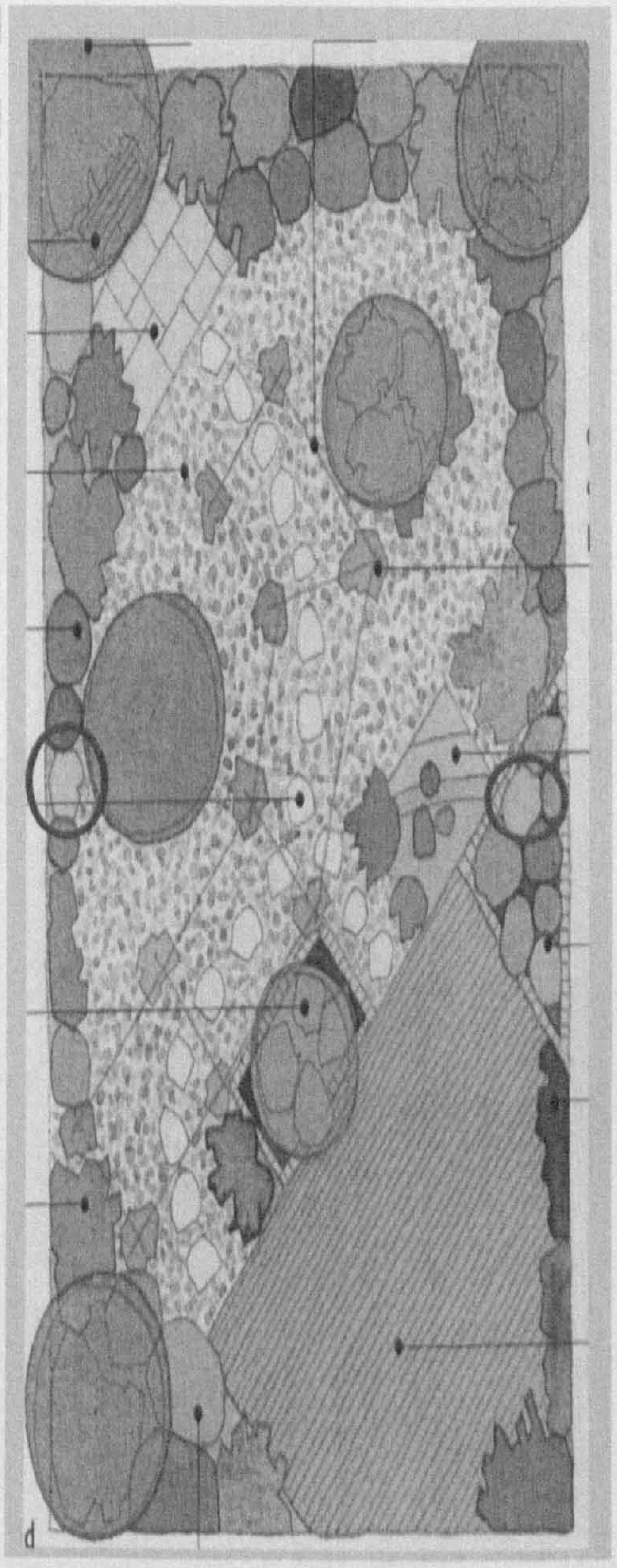


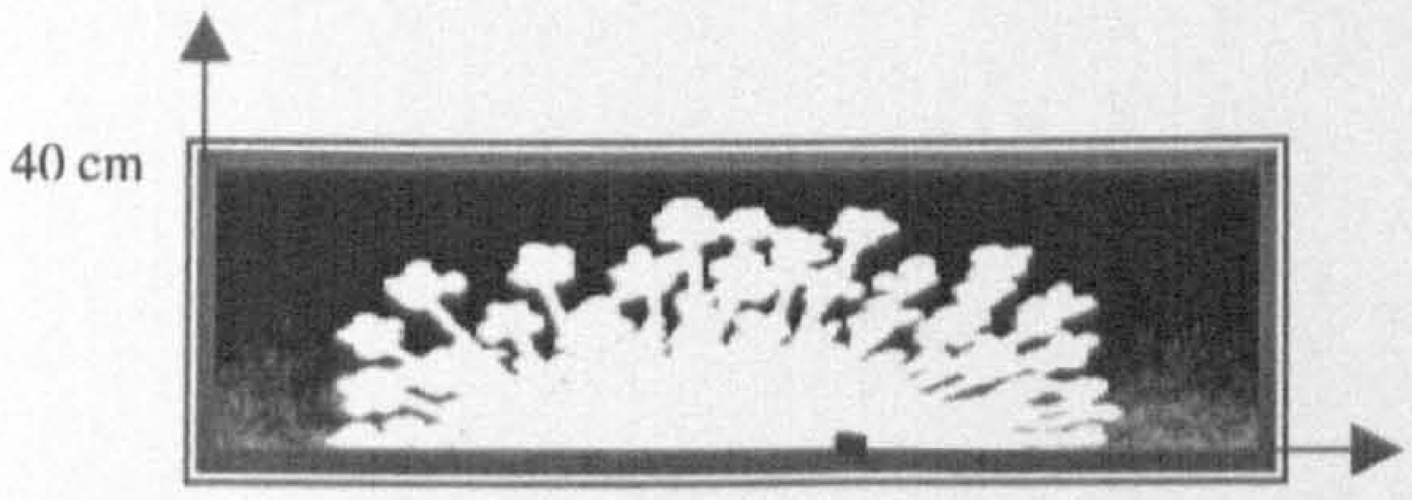


Character	Annual forb	
	Perennial forb	✔
	Small shrub	
	Med. shrub	
	Large shrub	
	Grass	
Foliage colour:	Grey / blue green	
	Yellow green	
	Med. green	
	Dark green	✔
	Light green	
	Showy green	
Flower colour:	White	
	Yellow	✔
	Pink	
	Red	✔
	Purple	
Growth:	Fast	
	Med.	✔
	Slow	
Landscape uses:	Ground cover	✔
	Bedding plant	✔
	Hedges	
	Ornamental plant	✔
	Afforestation	
	For long road	
	Windbreaks	
	Shade	
	Erosion sand control	



Plant name:	Locale name:	Family:	No.
Anvillea garcini	*Nagaid*	*Compositae*	4

Form:



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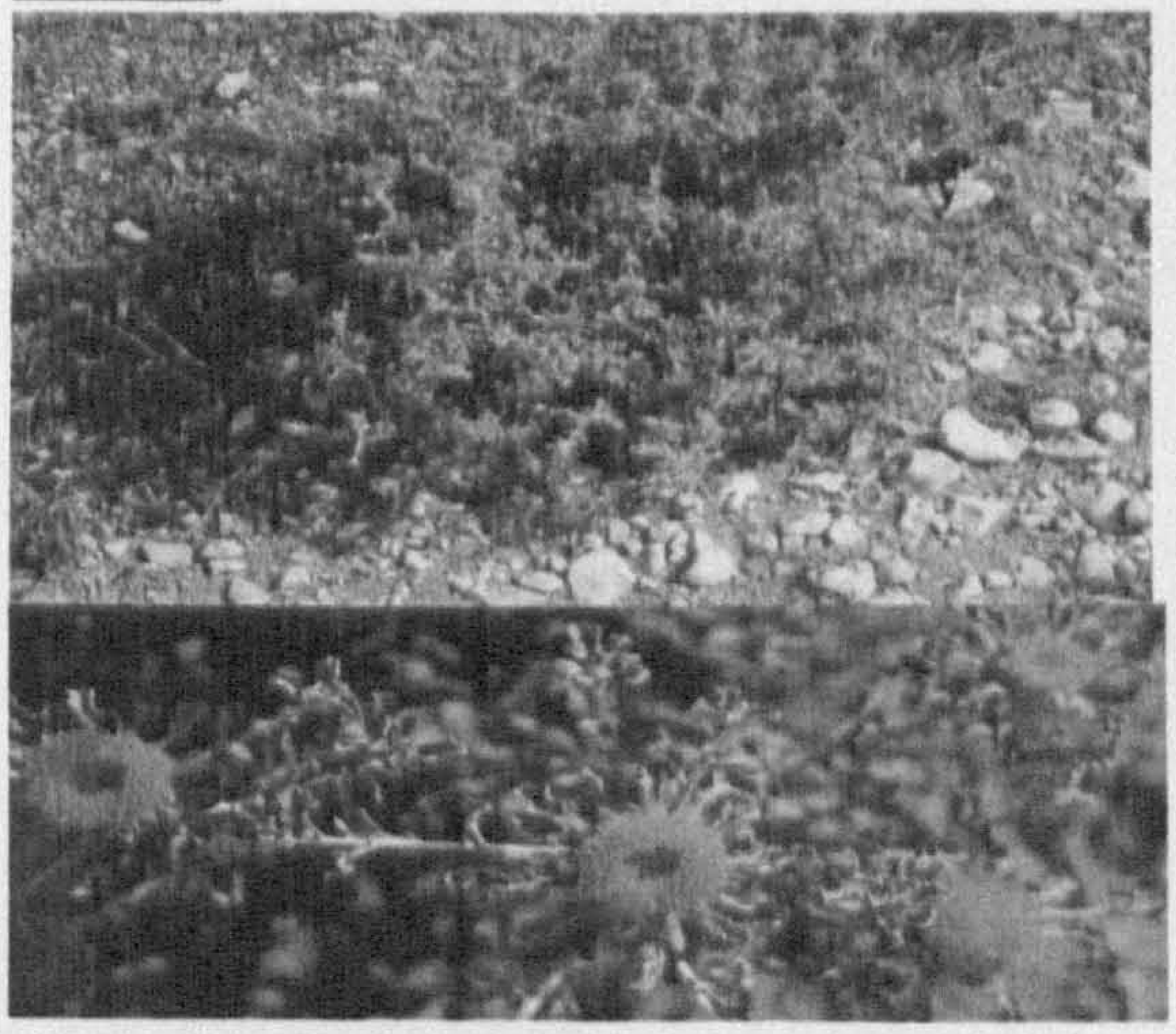
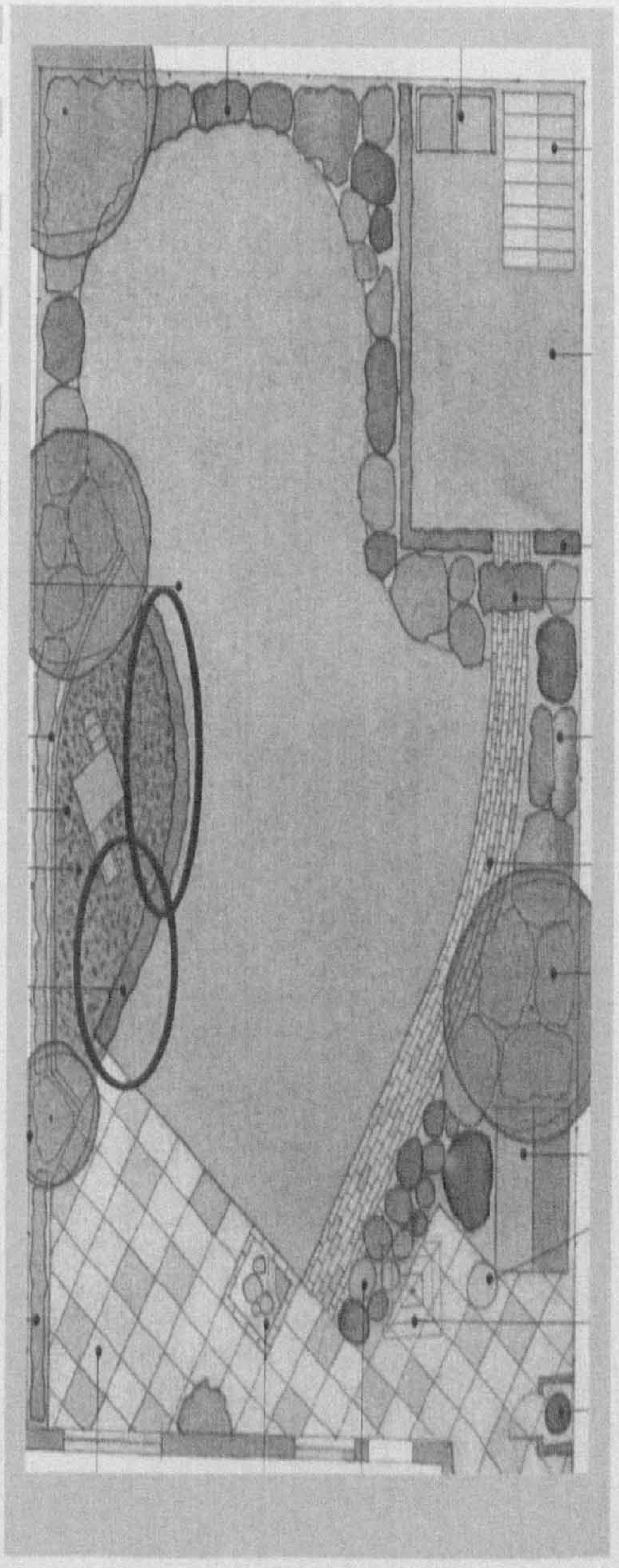
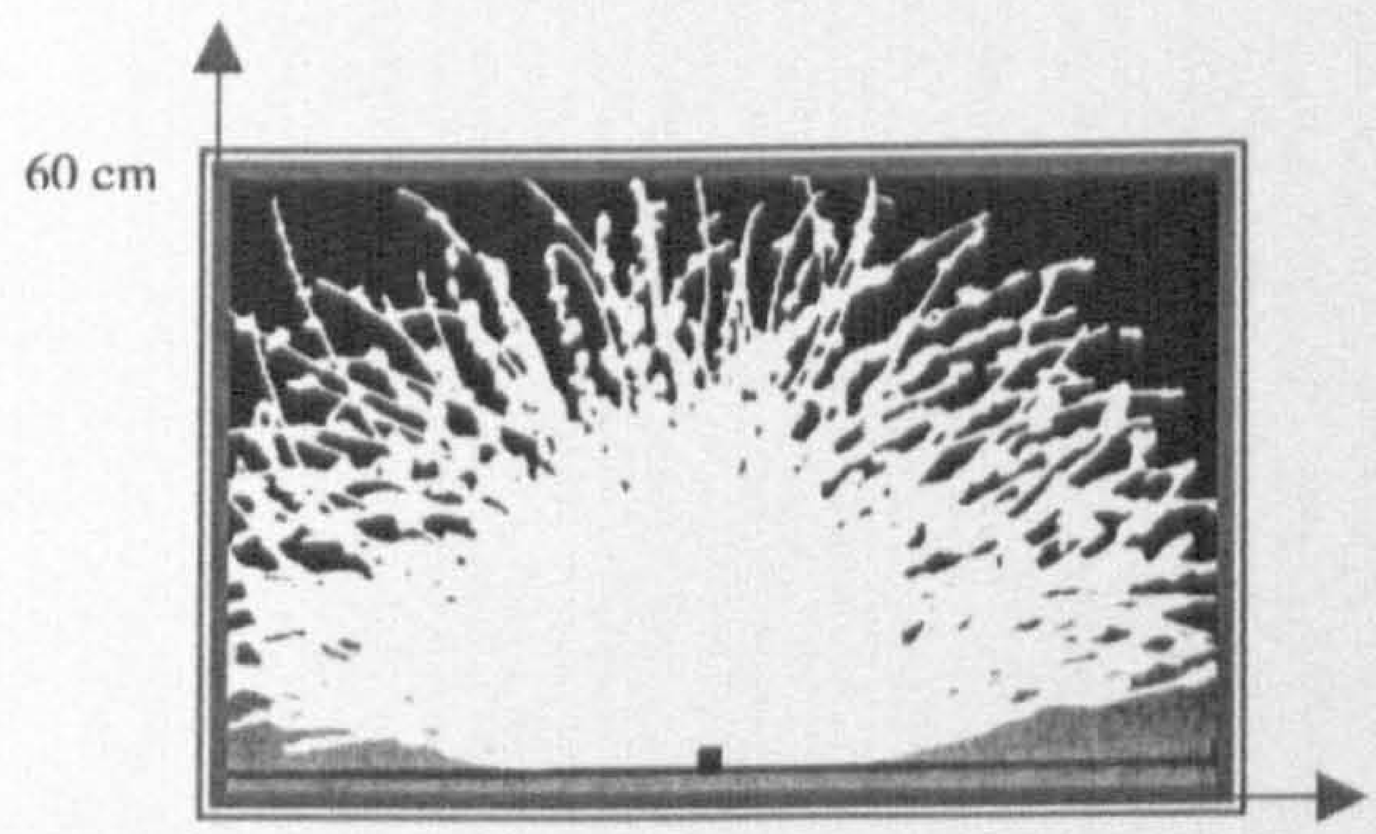


Character	Annual forb	
	Perennial forb	✔
	Small shrub	
	Med. shrub	
	Large shrub	
	Grass	
Foliage colour:	Grey / blue green	✔
	Yellow green	
	Med. green	
	Dark green	
	Light green	
	Showy green	
Flower colour:	White	
	Yellow	✔
	Pink	
	Red	
	Purple	
Growth:	Fast	
	Med.	✔
	Slow	
Landscape uses:	Ground cover	✔
	Bedding plant	✔
	Hedges	
	Ornamental plant	✔
	Afforestation	
	For long road	✔
	Windbreaks	
	Shade	
	Erosion sand control	



Plant name:	**Locale name:**	**Family:**	**No.**
Artemisia herba alba	Shaih	*Compositae*	5

Form:



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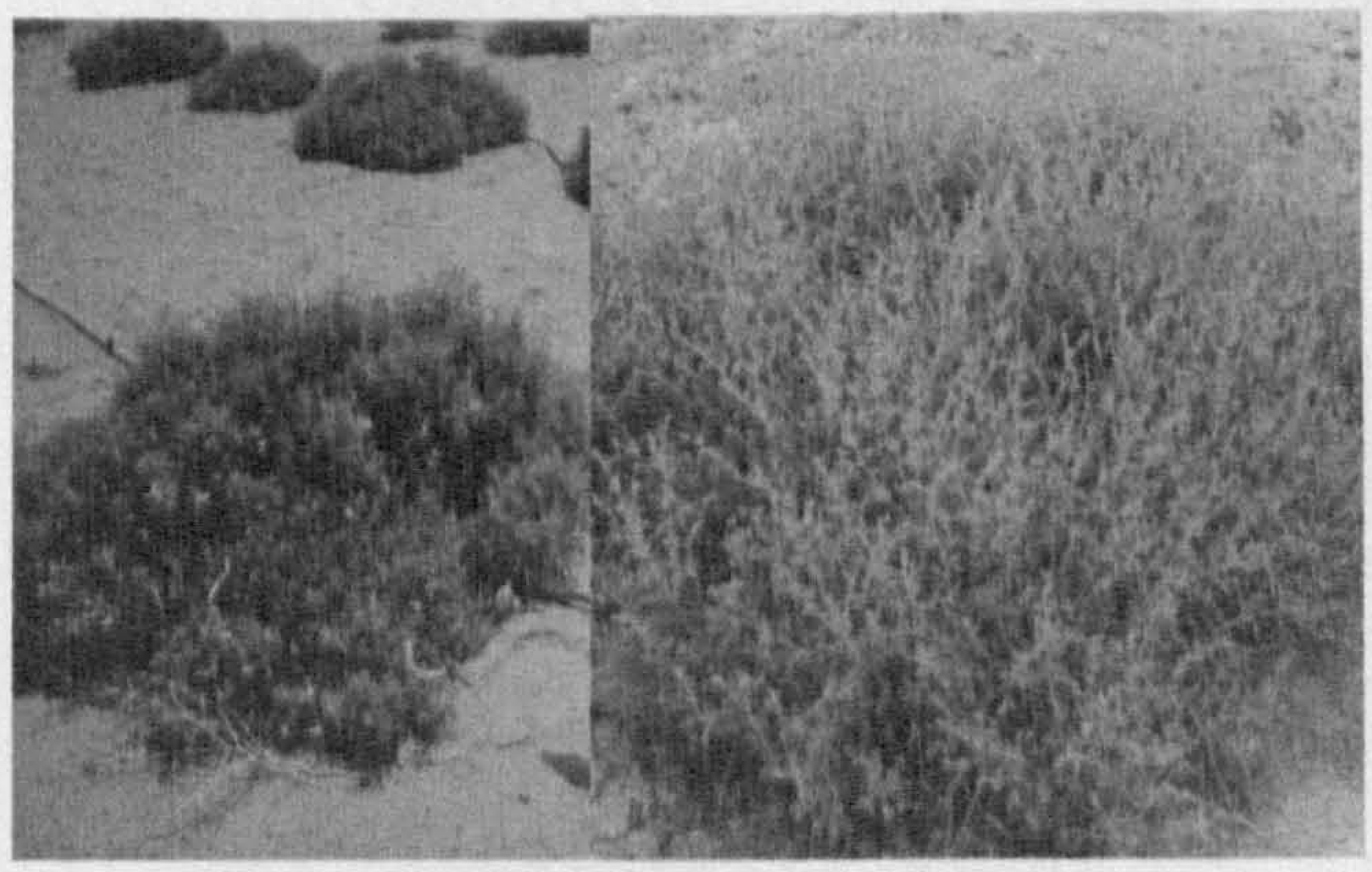
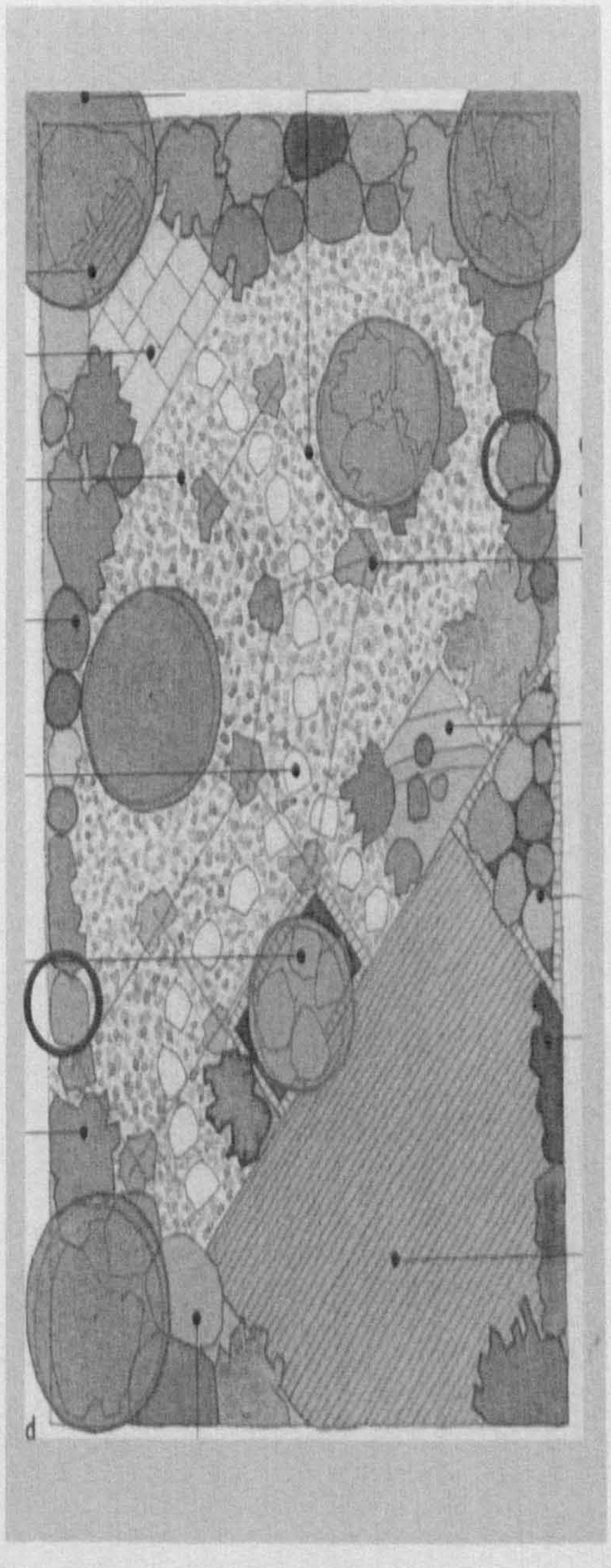


Character	Annual forb	
	Perennial forb	✔
	Small shrub	
	Med. shrub	
	Large shrub	
	Grass	
Foliage colour:	Grey / blue green	✔
	Yellow green	
	Med. green	
	Dark green	
	Light green	
	Showy green	
Flower colour:	White	
	Yellow	
	Pink	
	Red	
	....	
Growth:	Fast	
	Med.	✔
	Slow	
Landscape uses:	Ground cover	✔
	Bedding plant	✔
	Hedges	
	Ornamental plant	✔
	Afforestation	
	For long road	✔
	Windbreaks	
	Shade	
	Erosion sand control	



Plant name:	**Locale name:**	**Family:**	**No.**
Artemisia judaica	Buaithiran	*Compositae*	6

Form:

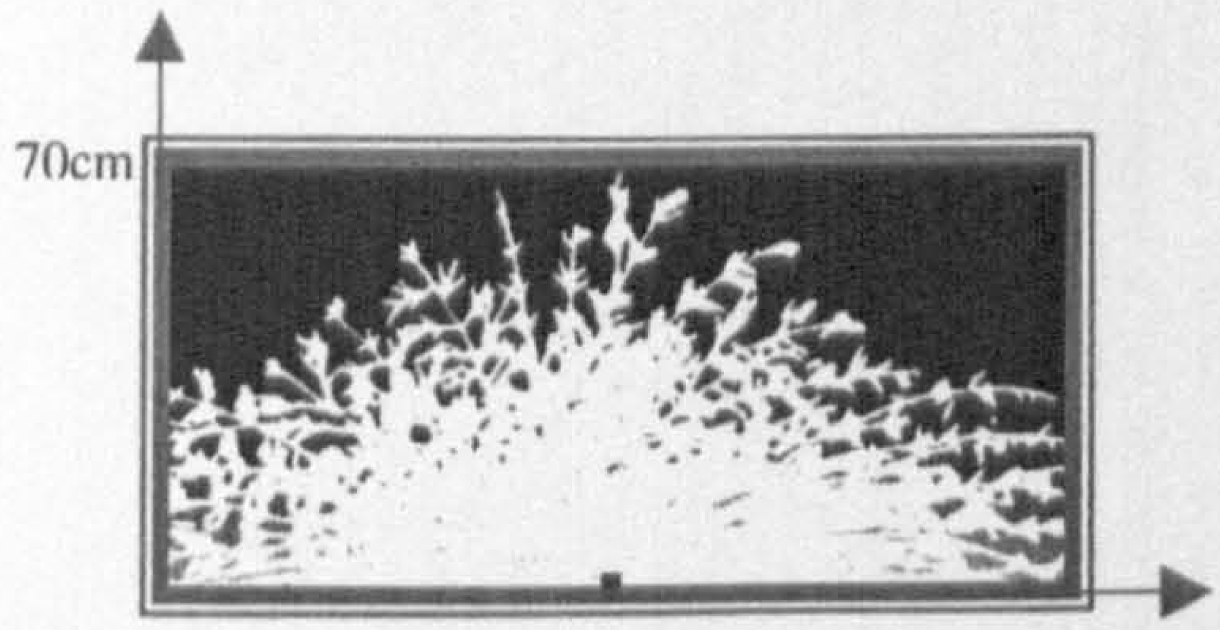
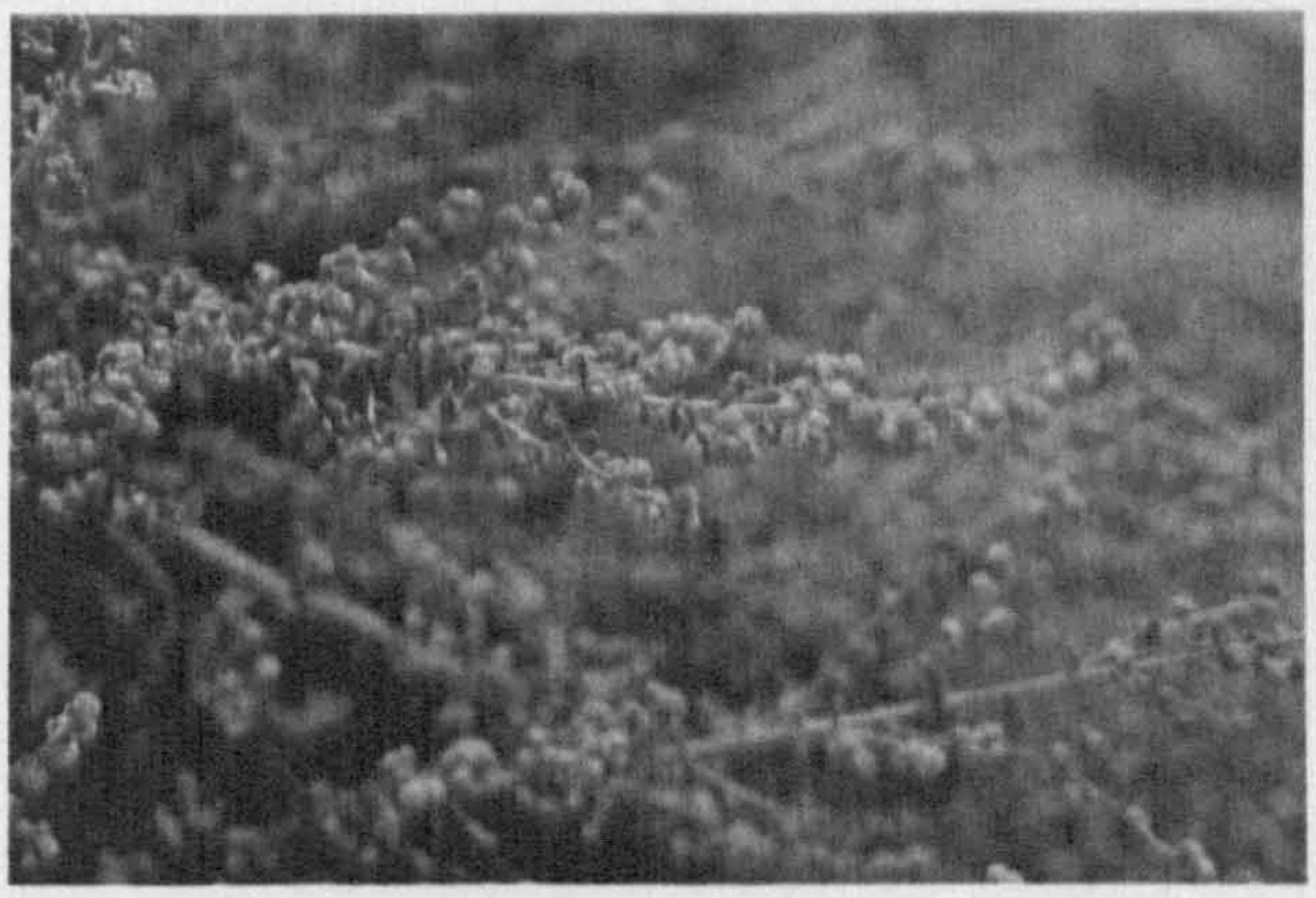
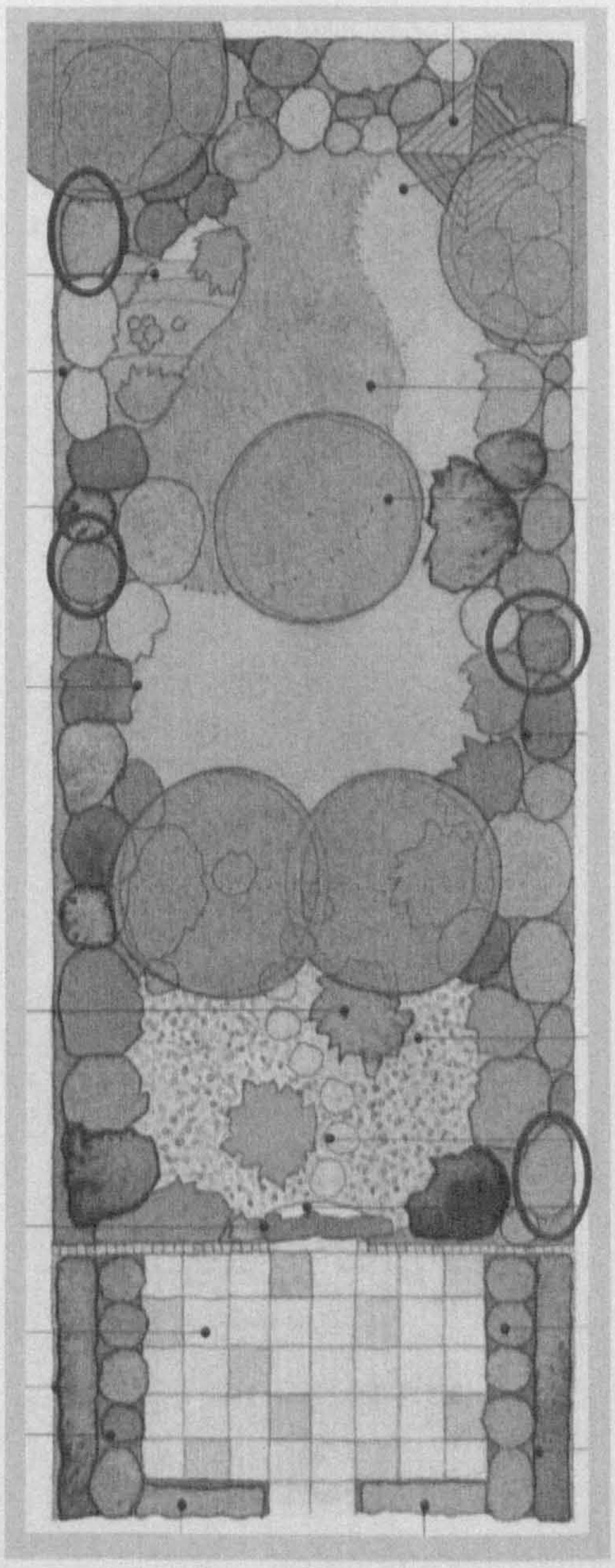


Photo:



Character	Annual forb	
	Perennial forb	
	Small shrub	✔
	Med. shrub	
	Large shrub	
	Grass	
Foliage colour:	Grey / blue green	✔
	Yellow green	
	Med. green	
	Dark green	
	Light green	
	Showy green	
Flower colour:	White	
	Yellow	✔
	Pink	
	Red	
	…….	
Growth:	Fast	
	Med.	✔
	Slow	
Landscape uses:	Ground cover	✔
	Bedding plant	✔
	Hedges	
	Ornamental plant	✔
	Afforestation	
	For long road	✔
	Windbreaks	
	Shade	
	Erosion sand control	



Plant name:	**Locale name:**	**Family:**	**No.**
Atriplex halimus	Khatef	*Chenopodiaceae*	7

Form:

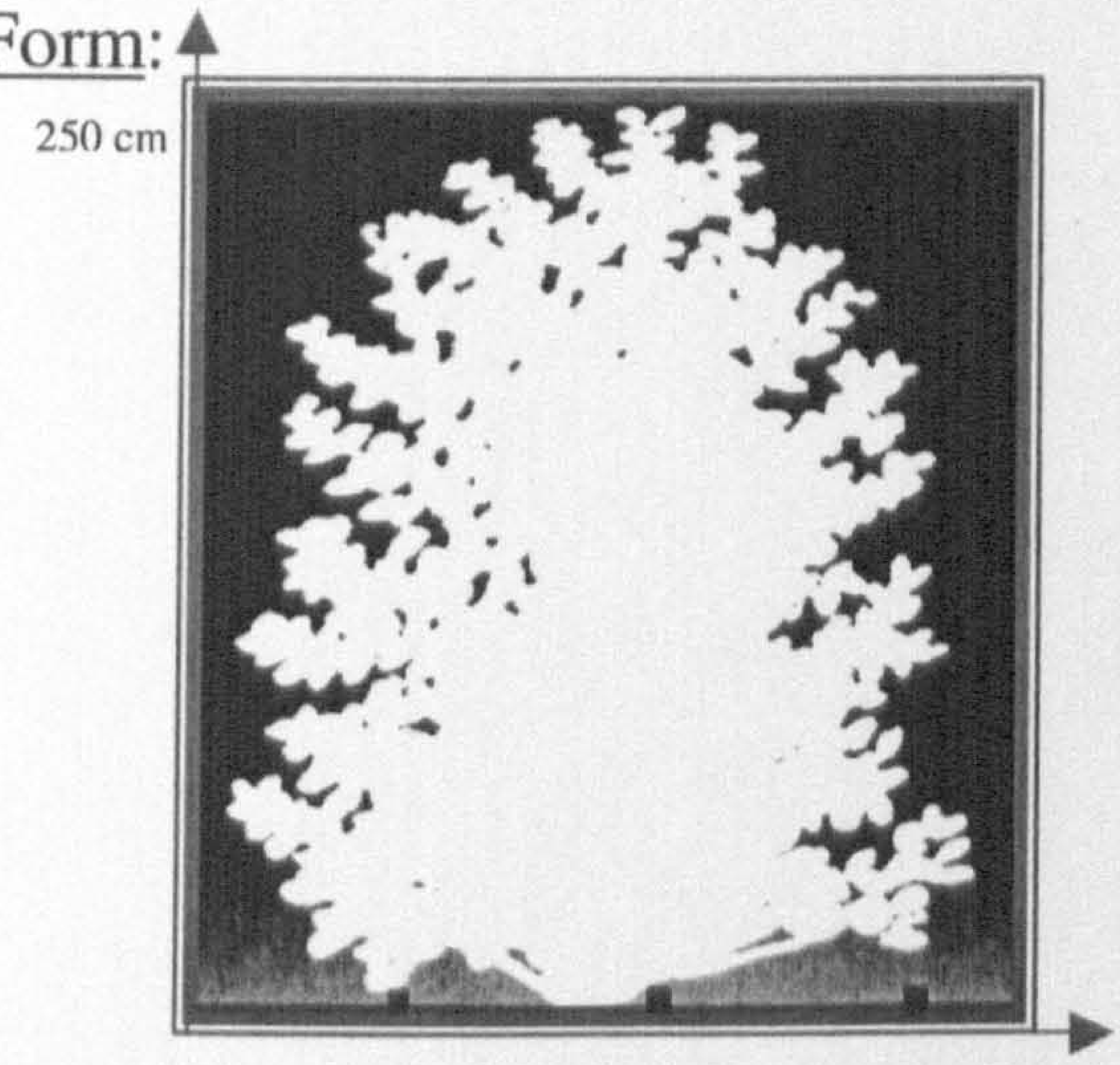
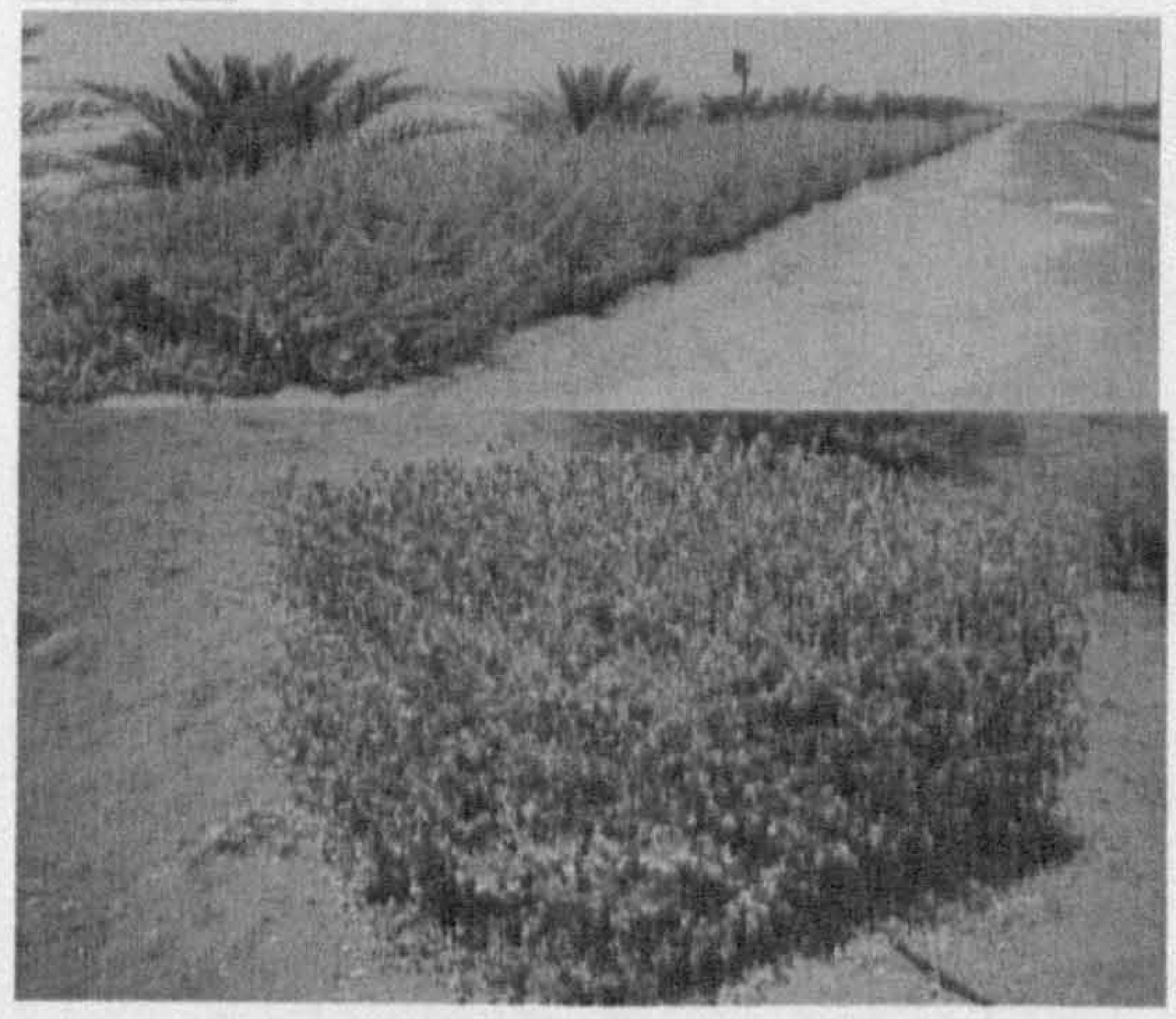
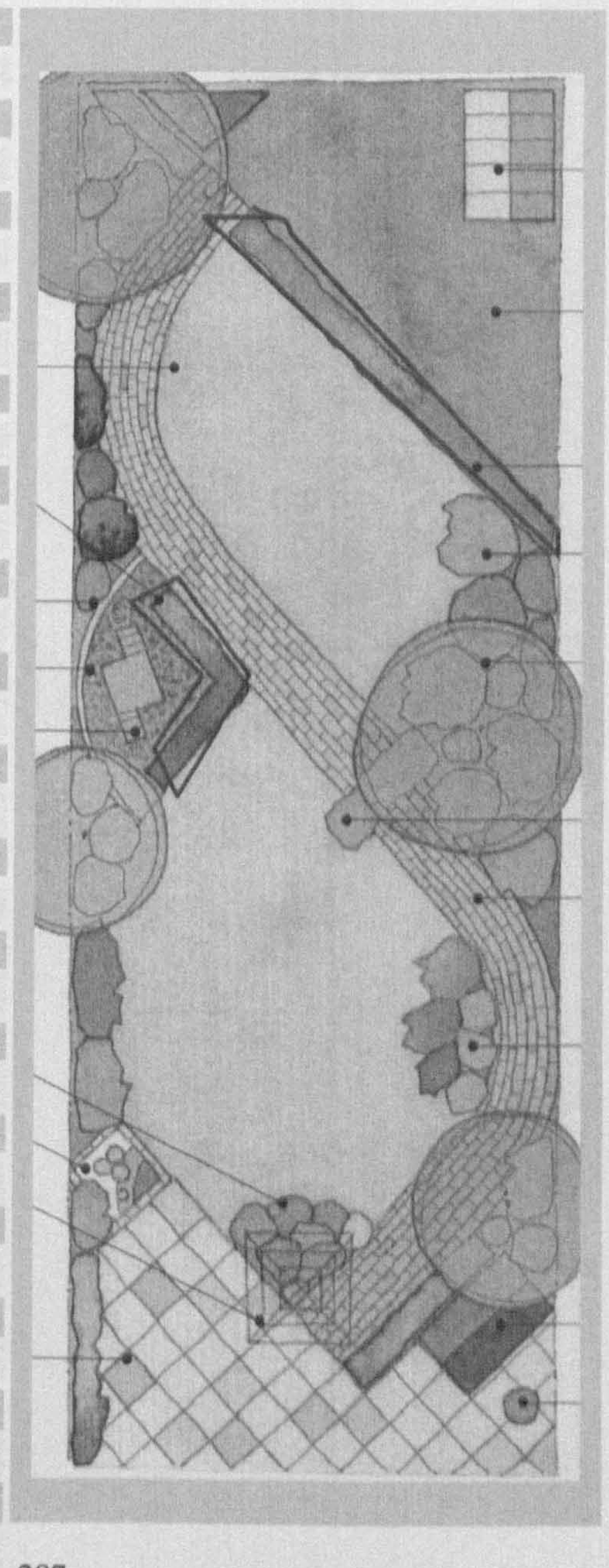


Photo:



Character	Annual forb	
	Perennial forb	
	Small shrub	
	Med. shrub	
	Large shrub	✔
	Grass	
Foliage colour:	Grey / blue green	✔
	Yellow green	
	Med. green	
	Dark green	
	Light green	
	Showy green	
Flower colour:	White	✔
	Yellow	
	Pink	
	Red	
	Purple	
Growth:	Fast	✔
	Med.	
	Slow	
Landscape uses:	Ground cover	✔
	Bedding plant	
	Hedges	✔
	Ornamental plant	✔
	Afforestation	
	For long road	✔
	Windbreaks	
	Shade	
	Erosion sand control	



Plant name:	**Locale name:**	**Family:**	**No.**
Atriplex leucoclada	Raghel	*Chenopodiaceae*	8

Form:

70 cm

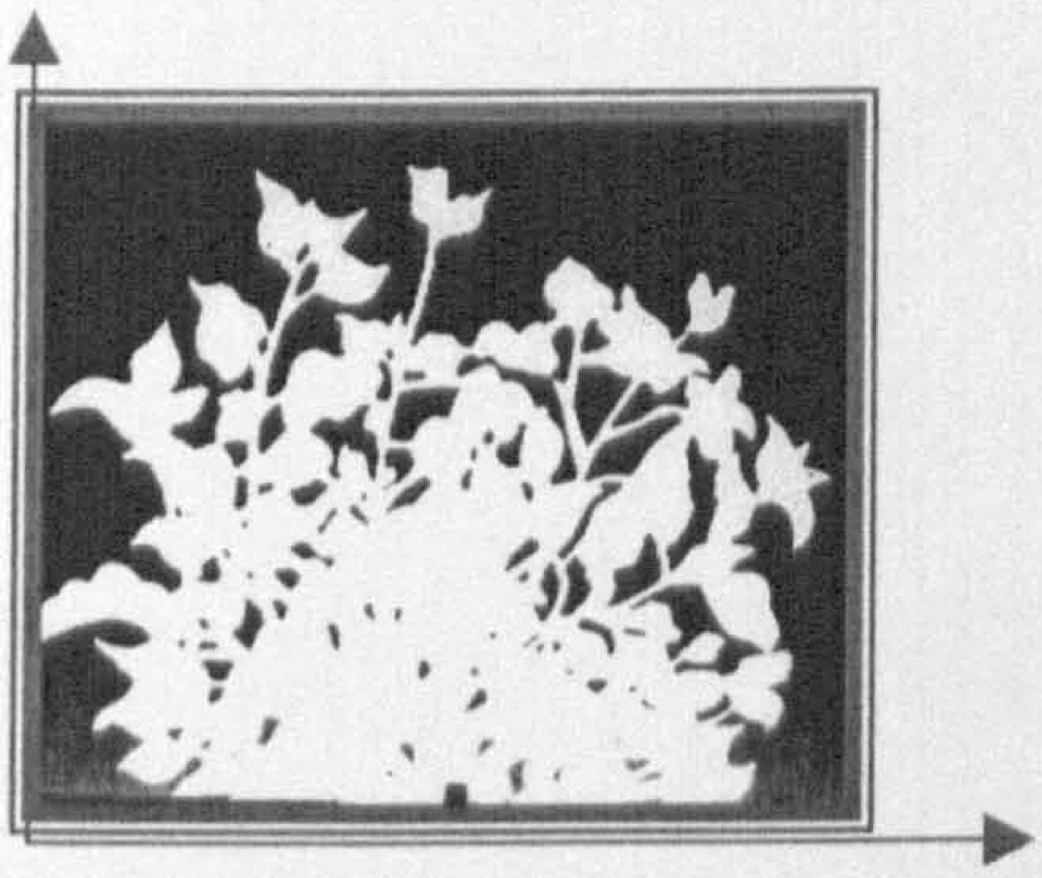
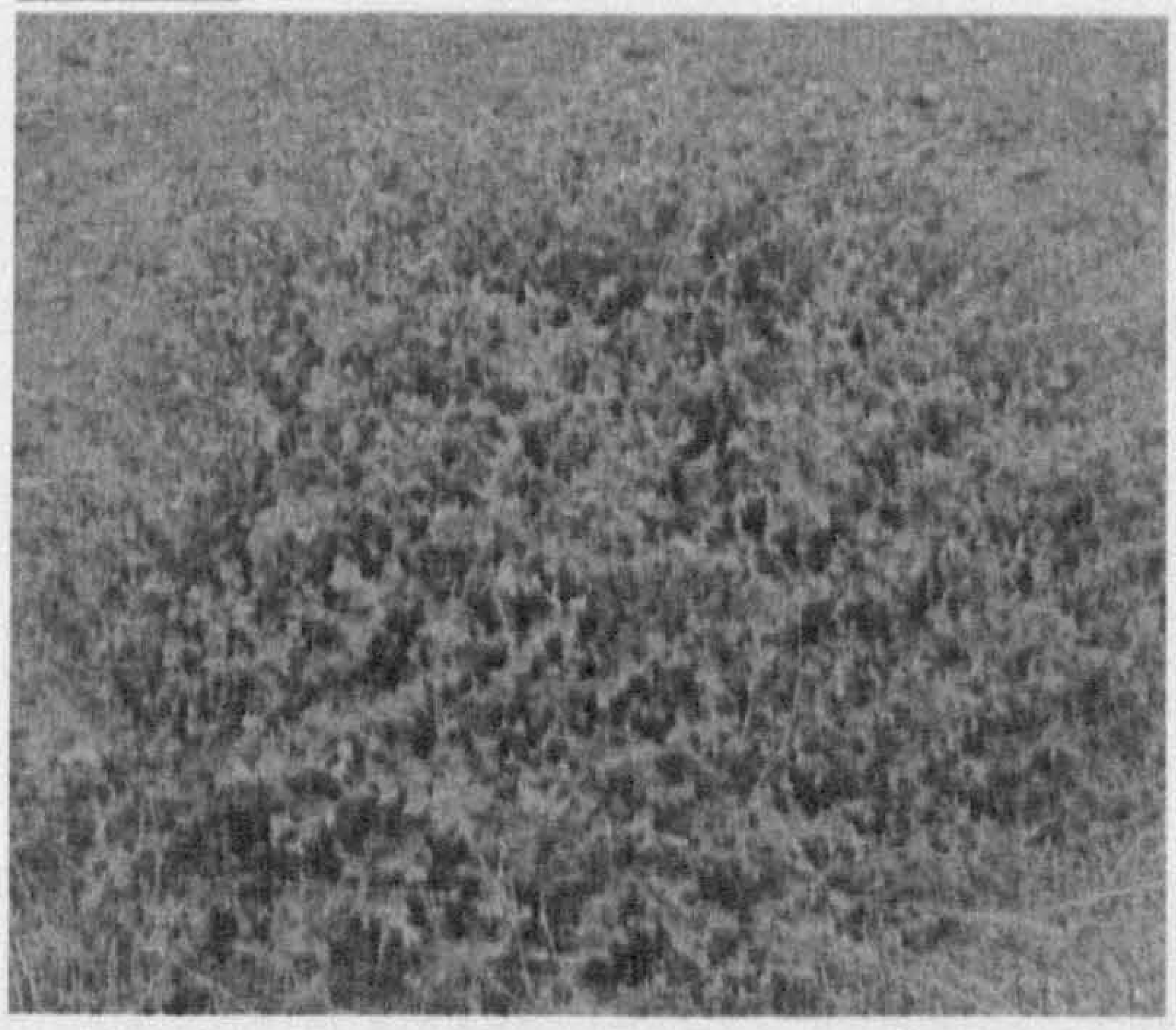
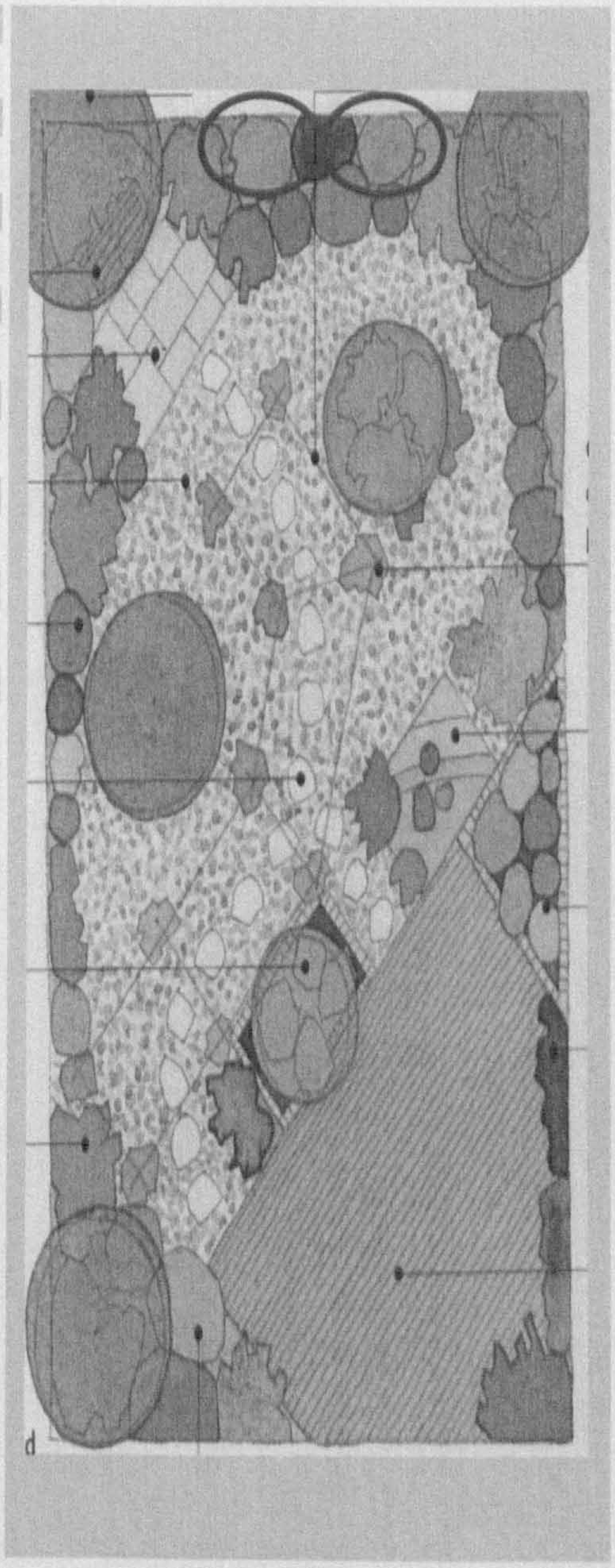


Photo:



Character	Annual forb	
	Perennial forb	
	Small shrub	
	Med. shrub	✔
	Large shrub	
	Grass	
Foliage colour:	Grey / blue green	✔
	Yellow green	
	Med. green	
	Dark green	
	Light green	
	Showy green	
Flower colour:	White	✔
	Yellow	
	Pink	
	Red	
	Purple	
Growth:	Fast	✔
	Med.	
	Slow	
Landscape uses:	Ground cover	✔
	Bedding plant	
	Hedges	✔
	Ornamental plant	✔
	Afforestation	
	For long road	✔
	Windbreaks	
	Shade	
	Erosion sand control	



Plant name:	**Locale name**	**Family:**	**No.**
Cassia italica	Ashrk	*Caesalpiniaceae*	9

Form:

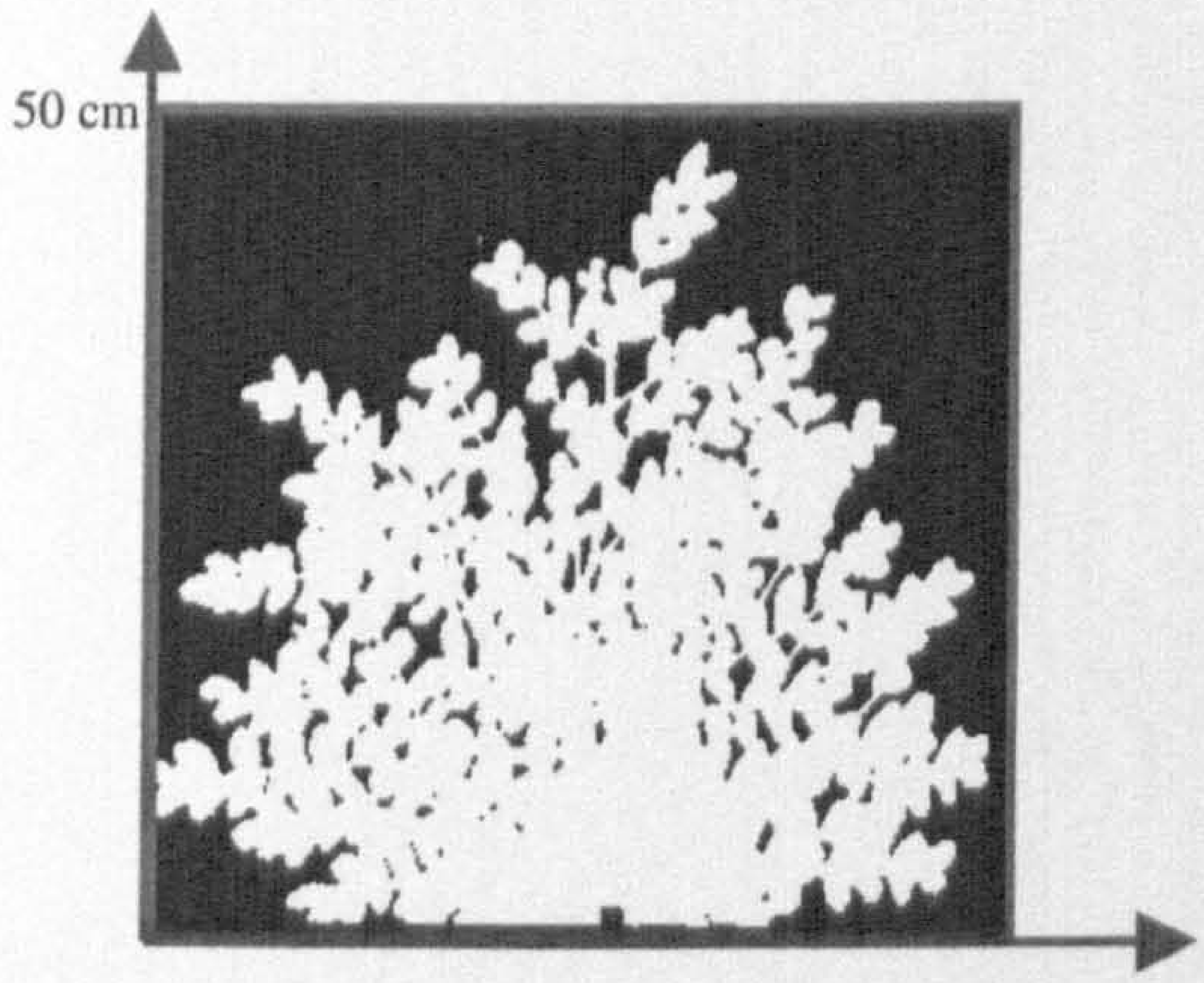
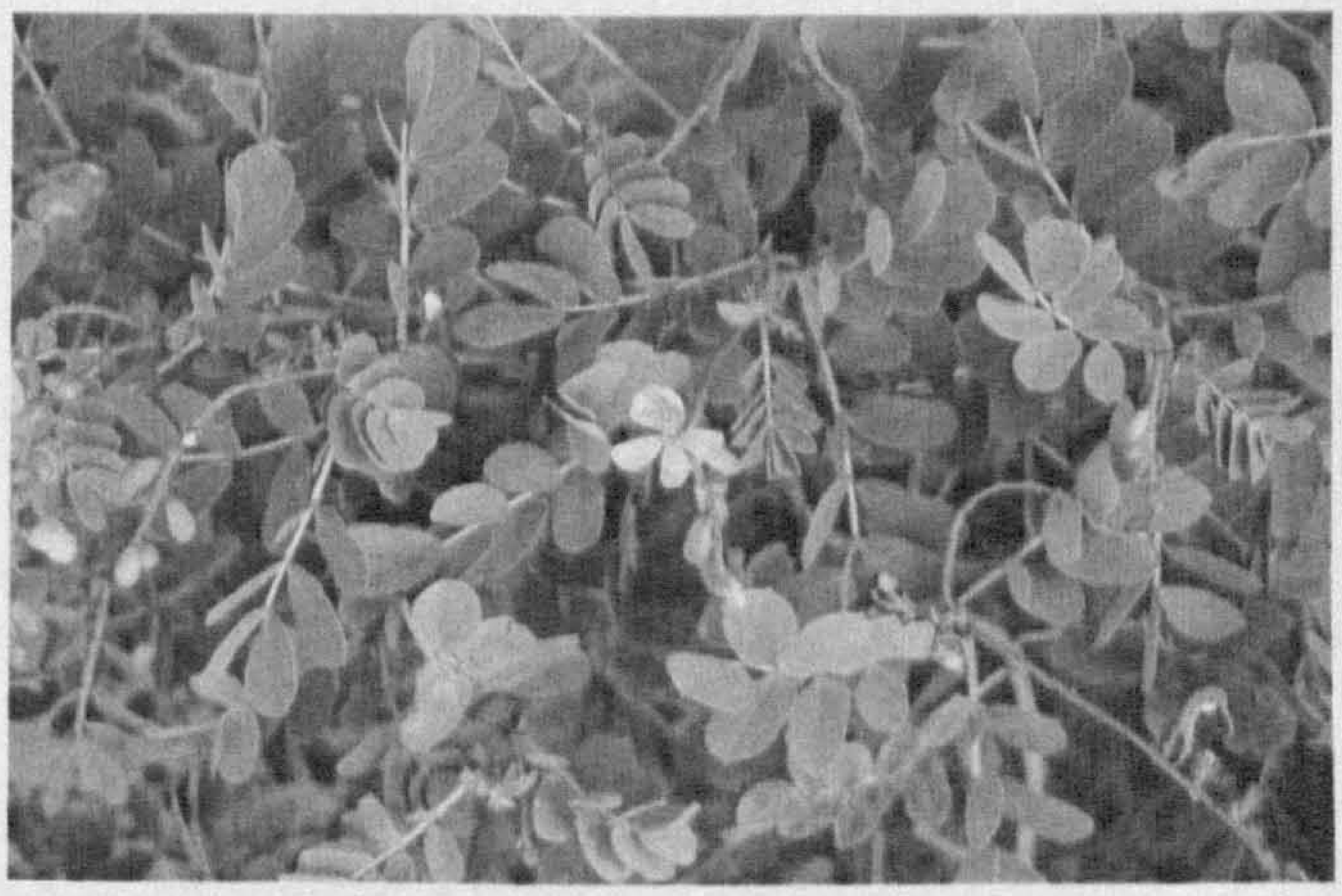
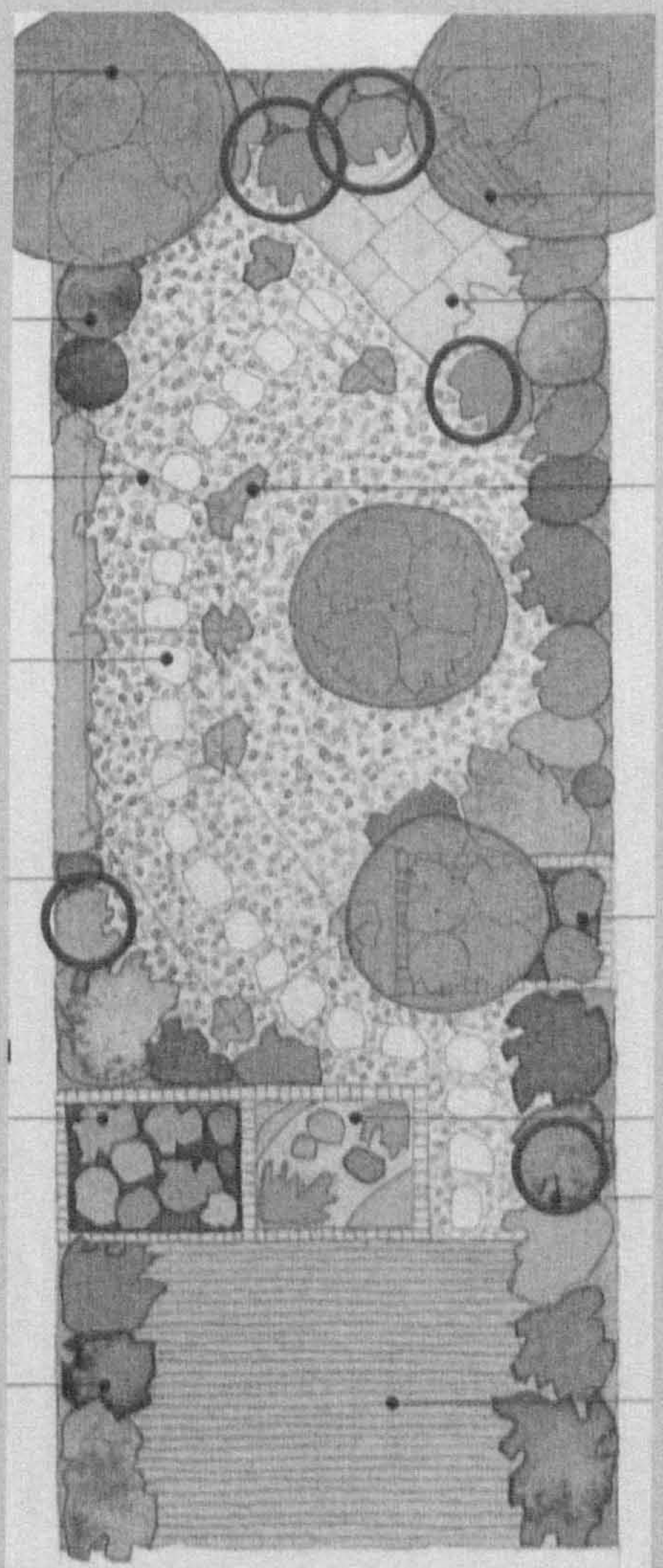


Photo:



Character	Annual forb	
	Perennial forb	
	Small shrub	✔
	Med. shrub	
	Large shrub	
	Grass	
Foliage colour:	Grey / blue green	
	Yellow green	
	Med. green	✔
	Dark green	
	Light green	
	Showy green	
Flower colour:	White	
	Yellow	✔
	Pink	
	Red	
	………	
Growth:	Fast	✔
	Med.	
	Slow	
Landscape uses:	Ground cover	✔
	Bedding plant	✔
	Hedges	
	Ornamental plant	✔
	Afforestation	
	For long road	✔
	Windbreaks	
	Shade	
	Erosion sand control	



Plant name:	Locale name:	Family:	No.
Cassia occidentalis	Saiseban	*Caesalpiniaceae*	10

Form:

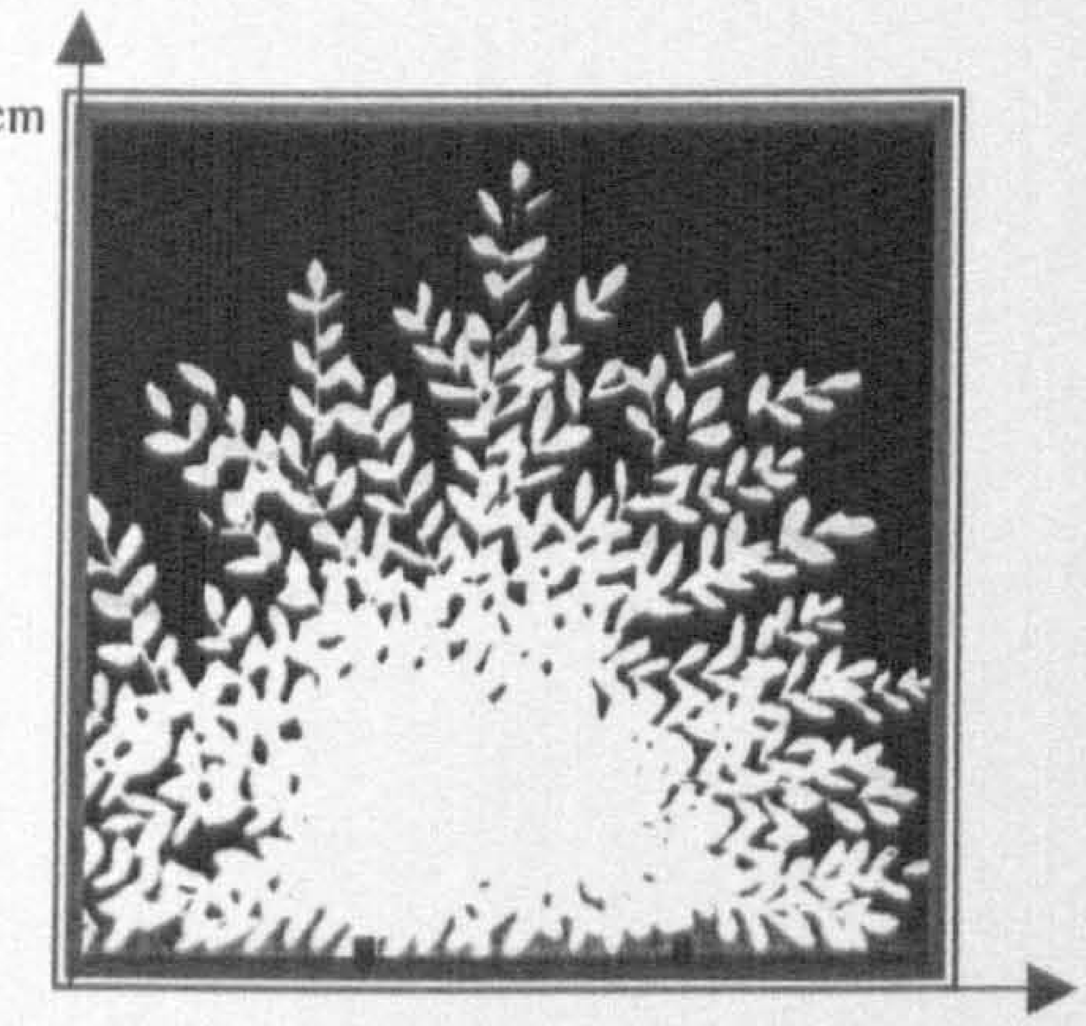
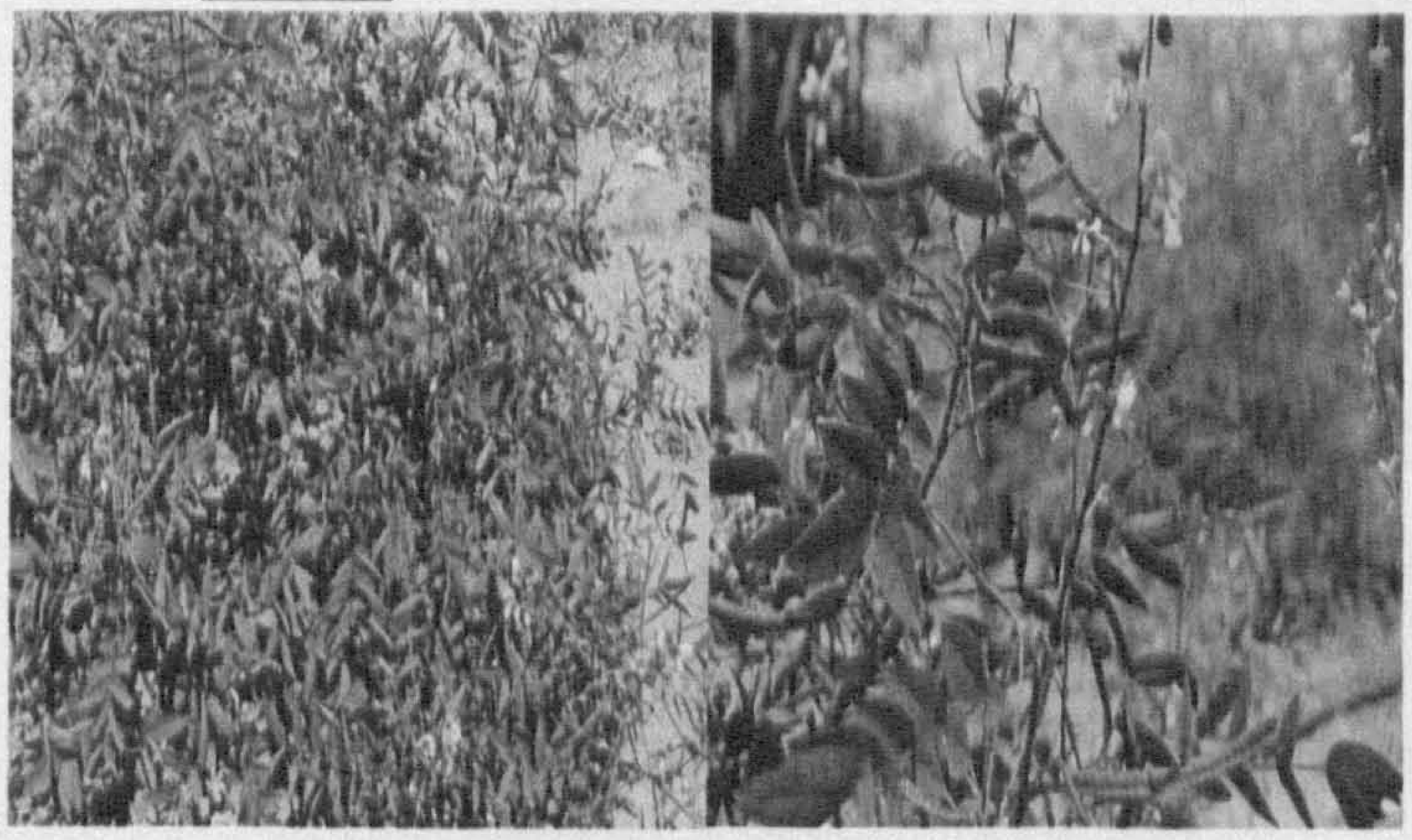
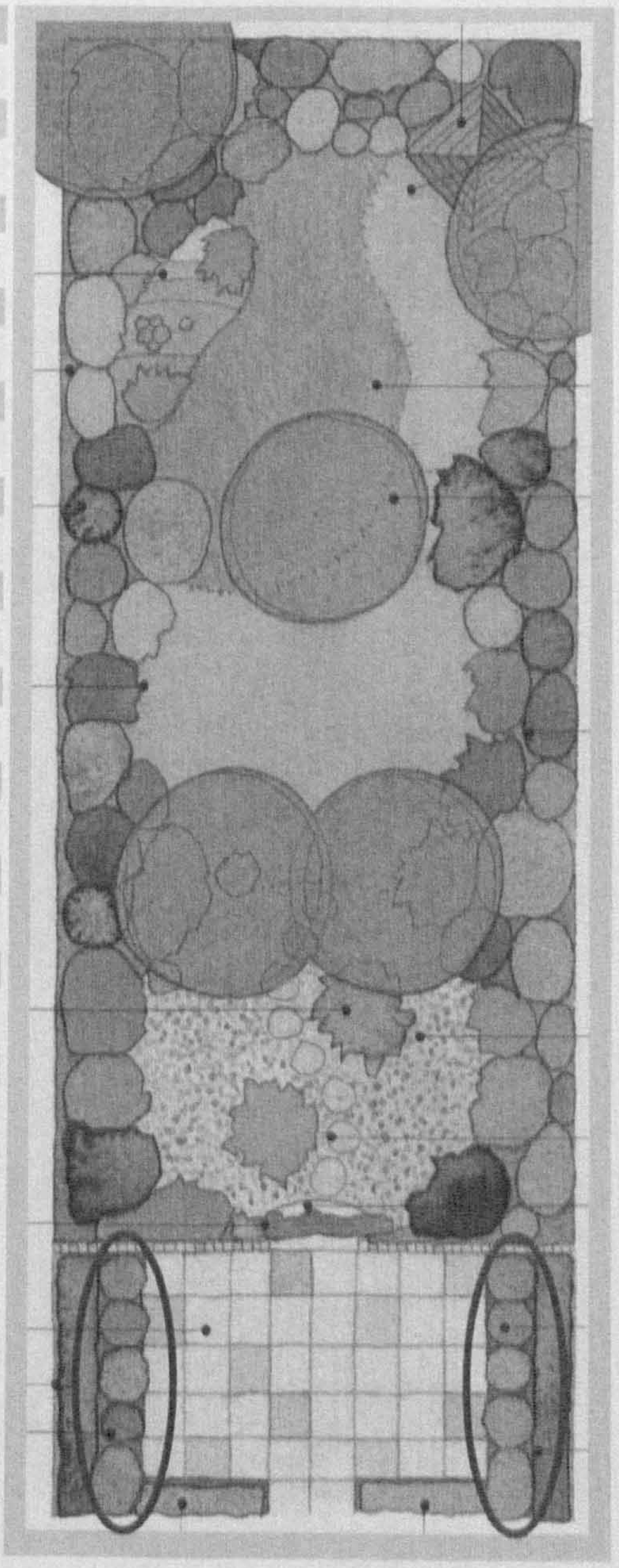


Photo:



Character	Annual forb	
	Perennial forb	
	Small shrub	
	Med. shrub	✔
	Large shrub	
	Grass	
Foliage colour:	Grey / blue green	
	Yellow green	
	Med. green	
	Dark green	✔
	Light green	
	Showy green	
Flower colour:	White	
	Yellow	✔
	Pink	
	Red	✔
	…….	
Growth:	Fast	✔
	Med.	
	Slow	
Landscape uses:	Ground cover	✔
	Bedding plant	✔
	Hedges	
	Ornamental plant	✔
	Afforestation	
	For long road	
	Windbreaks	
	Shade	
	Erosion sand control	



Plant name:	**Locale name:**	**Family:**	**No.**
Cassia senna	Sana Makka	*Caesalpiniaceae*	11

Form:

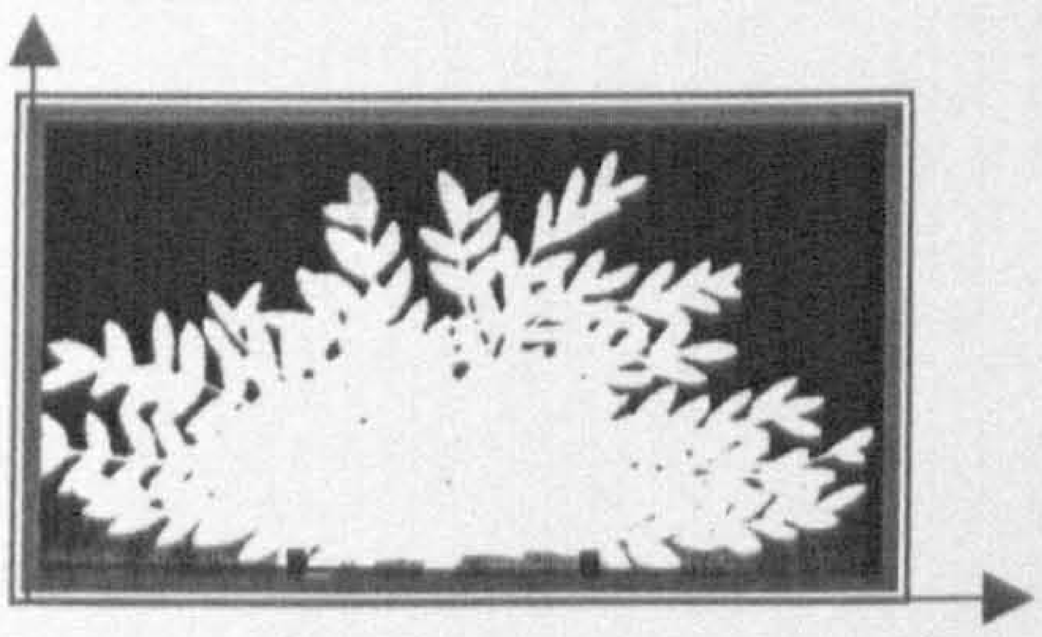
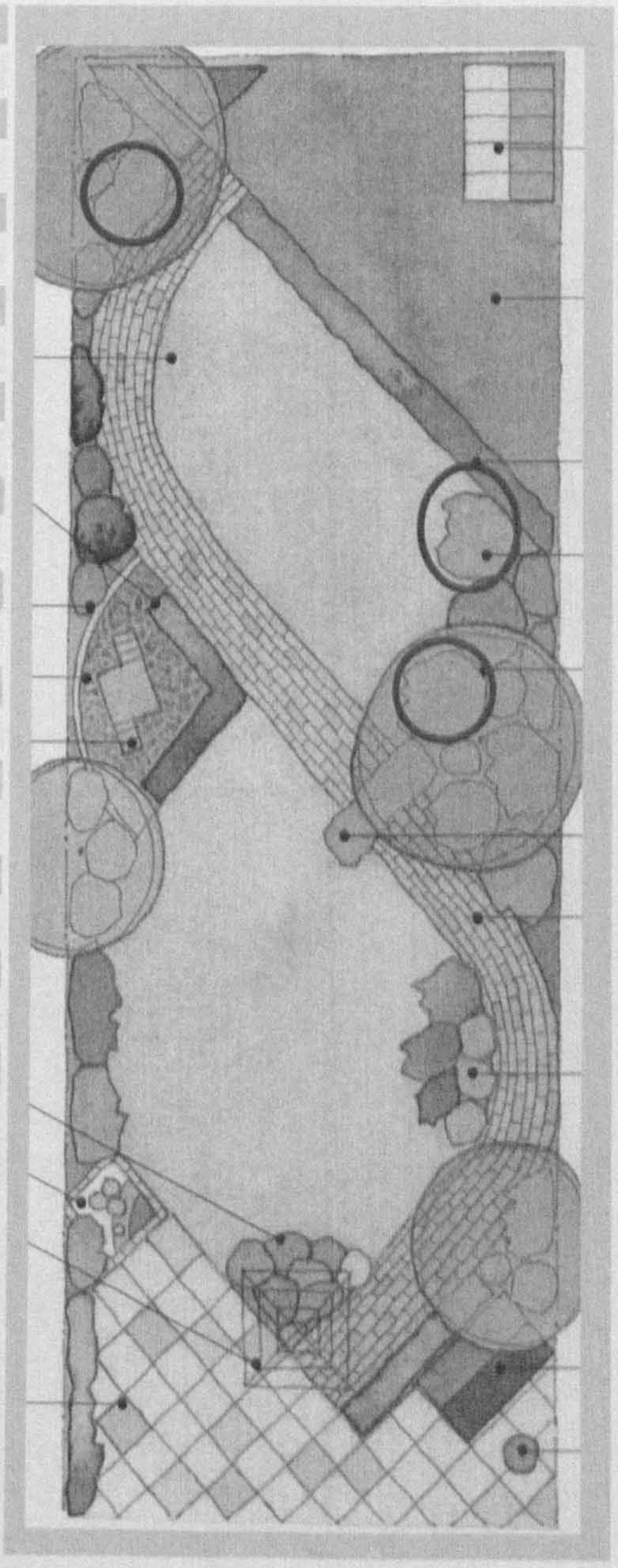


Photo:

Character	Annual forb	
	Perennial forb	
	Small shrub	✔
	Med. shrub	
	Large shrub	
	Grass	
Foliage colour:	Grey / blue green	
	Yellow green	
	Med. green	
	Dark green	✔
	Light green	
	Showy green	
Flower colour:	White	
	Yellow	✔
	Pink	
	Red	
	....	
Growth:	Fast	✔
	Med.	
	Slow	
Landscape uses:	Ground cover	✔
	Bedding plant	✔
	Hedges	
	Ornamental plant	✔
	Afforestation	
	For long road	✔
	Windbreaks	
	Shade	
	Erosion sand control	



Plant name:	**Locale name:**	**Family:**	**No.**
Datura innoxia	Banje	*Solanaceae*	12

Form:

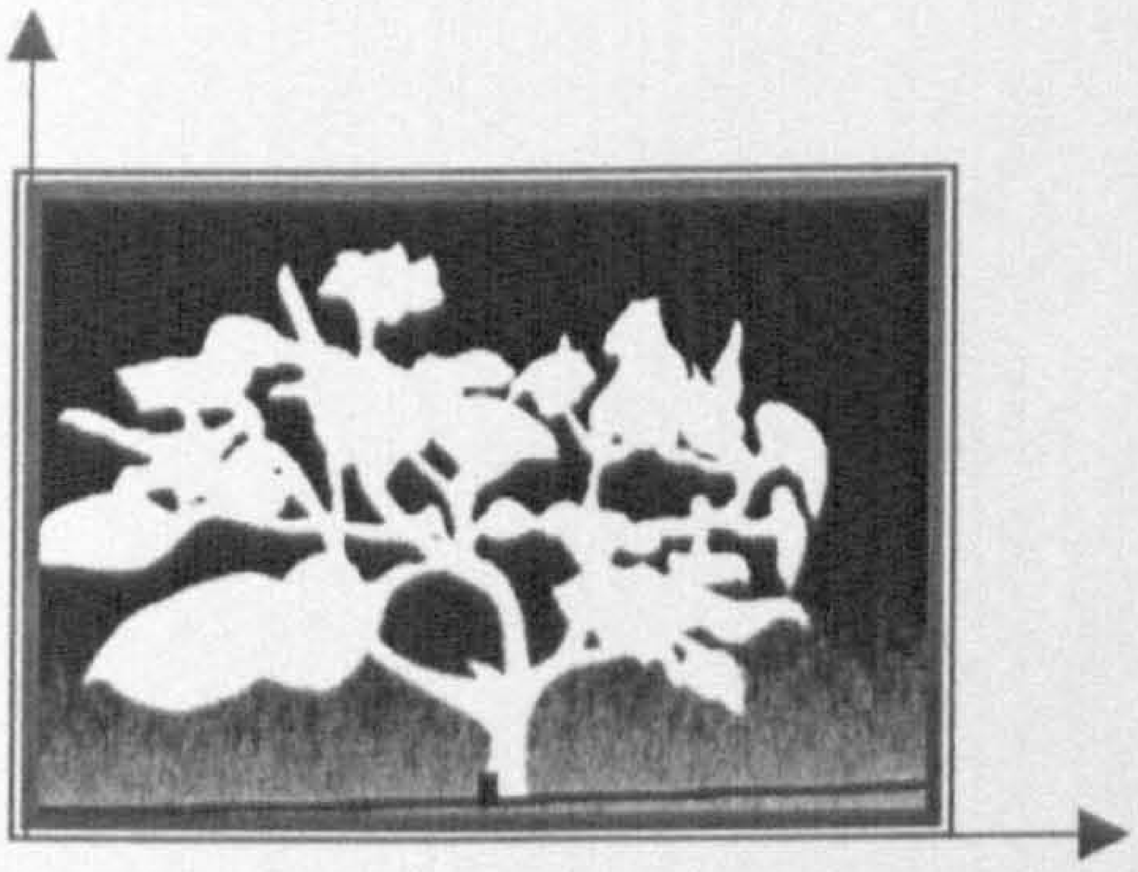
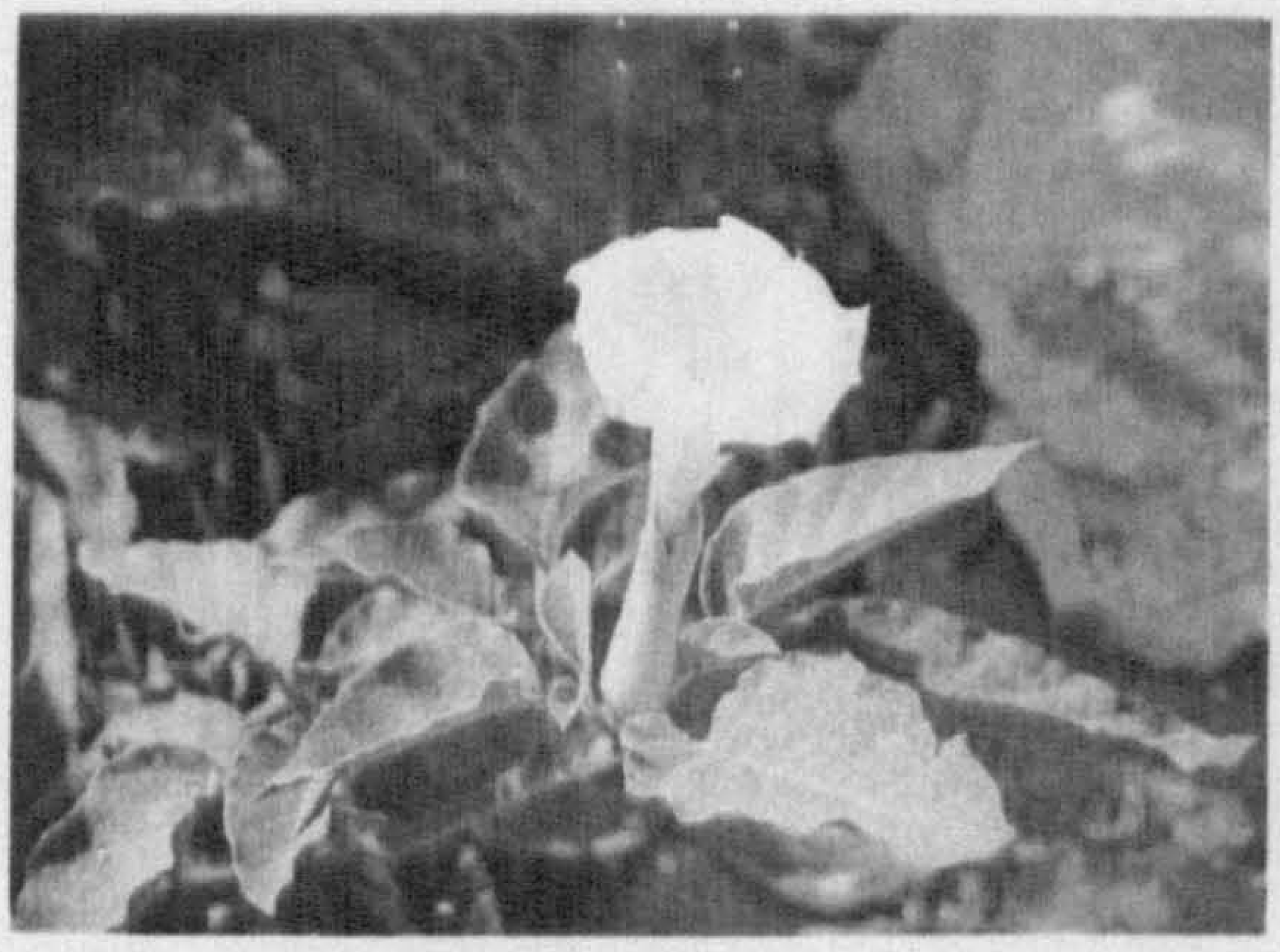
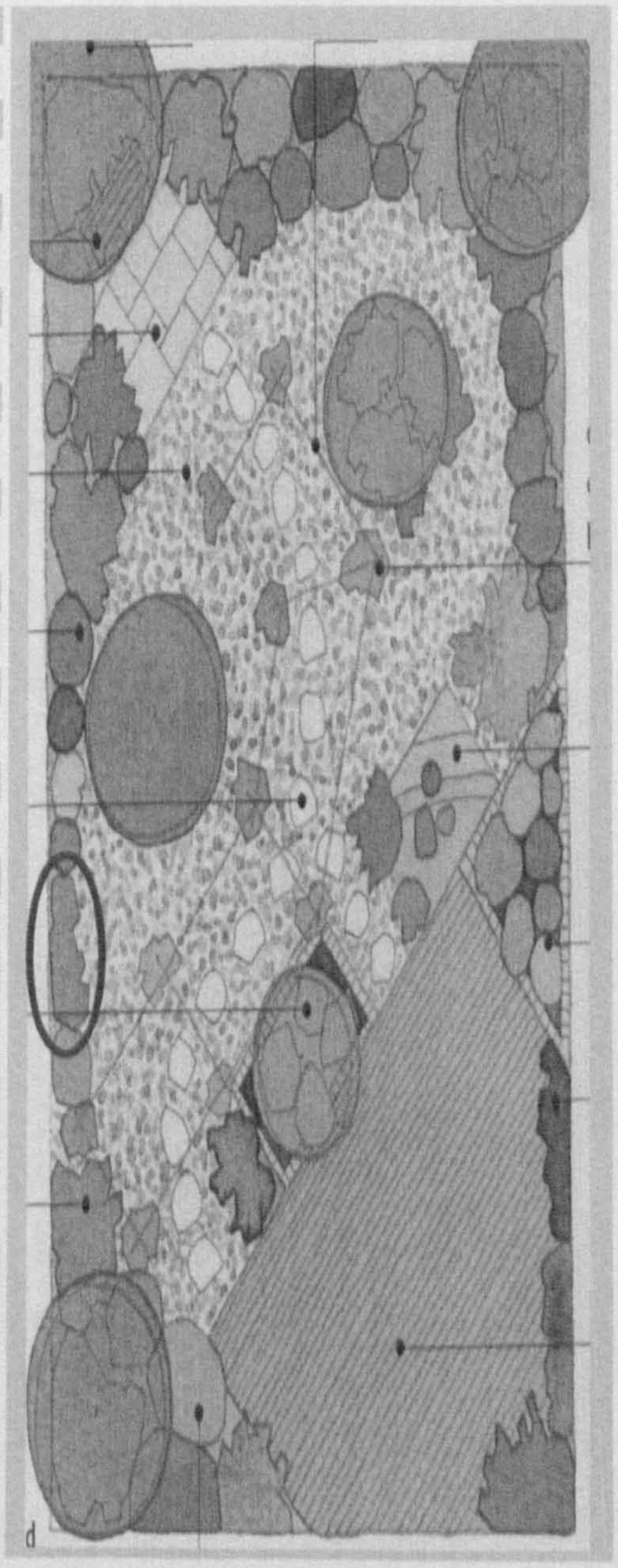


Photo:



Character	Annual forb	✔
	Perennial forb	
	Small shrub	
	Med. shrub	
	Large shrub	
	Grass	
Foliage colour:	Grey / blue green	
	Yellow green	
	Med. green	
	Dark green	✔
	Light green	
	Showy green	
Flower colour:	White	✔
	Yellow	
	Pink	
	Red	
	Purple	
Growth:	Fast	✔
	Med.	
	Slow	
Landscape uses:	Ground cover	✔
	Bedding plant	✔
	Hedges	
	Ornamental plant	✔
	Afforestation	
	For long road	
	Windbreaks	
	Shade	
	Erosion sand control	



Plant name:	**Locale name:**	**Family:**	**No.**
Dodonea viseosa	Saiseban	*Sapindaceae*	13

Form:

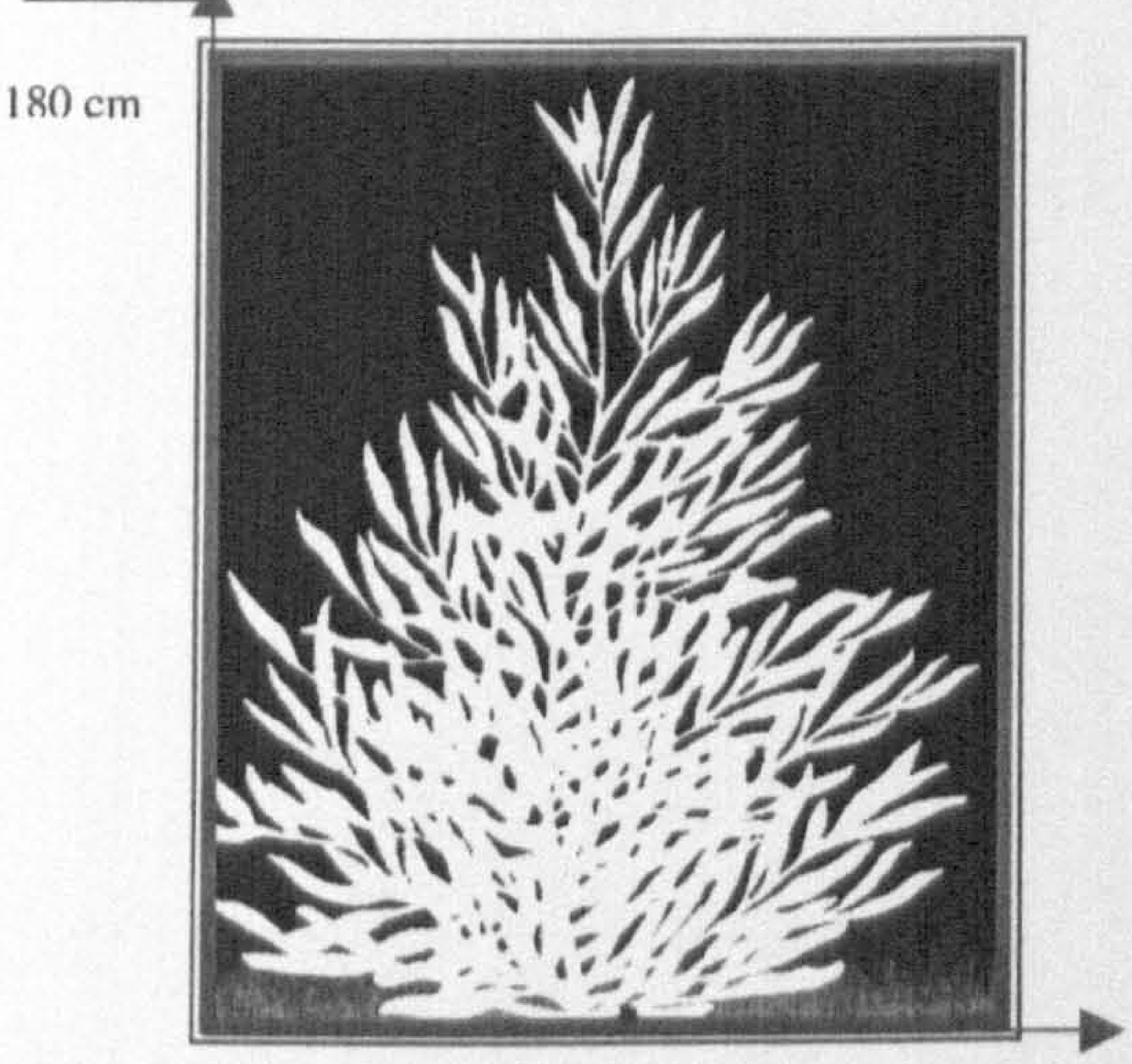
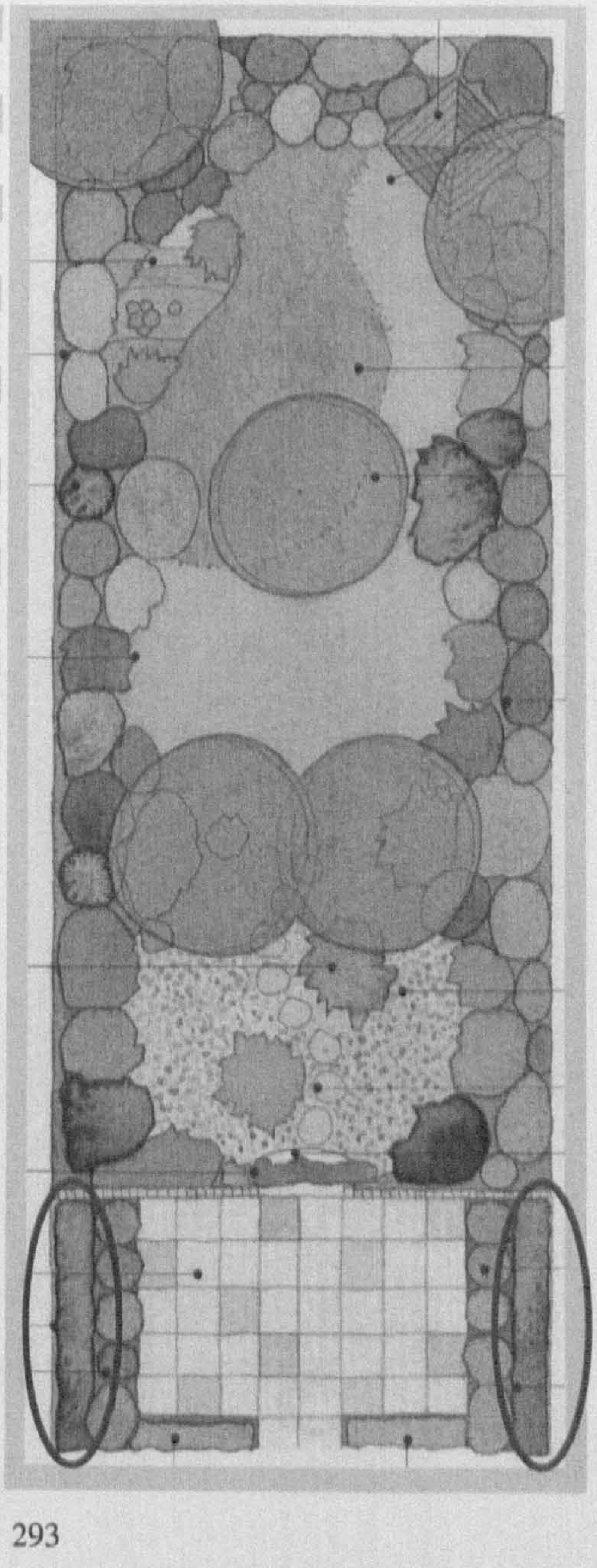


Photo:

Character	Annual forb	
	Perennial forb	
	Small shrub	
	Med. shrub	
	Large shrub	✔
	Grass	
Foliage colour:	Grey / blue green	
	Yellow green	
	Med. green	✔
	Dark green	
	Light green	
	Showy green	
Flower colour:	White	
	Yellow	
	Pink	
	Red	
	…….	
Growth:	Fast	✔
	Med.	
	Slow	
Landscape uses:	Ground cover	✔
	Bedding plant	
	Hedges	✔
	Ornamental plant	✔
	Afforestation	
	For long road	✔
	Windbreaks	
	Shade	
	Erosion sand control	



Plant name:	**Locale name:**	**Family:**	**No.**
Farsetia aegyptia	Jerbah	*Cruciferae*	14

Form:

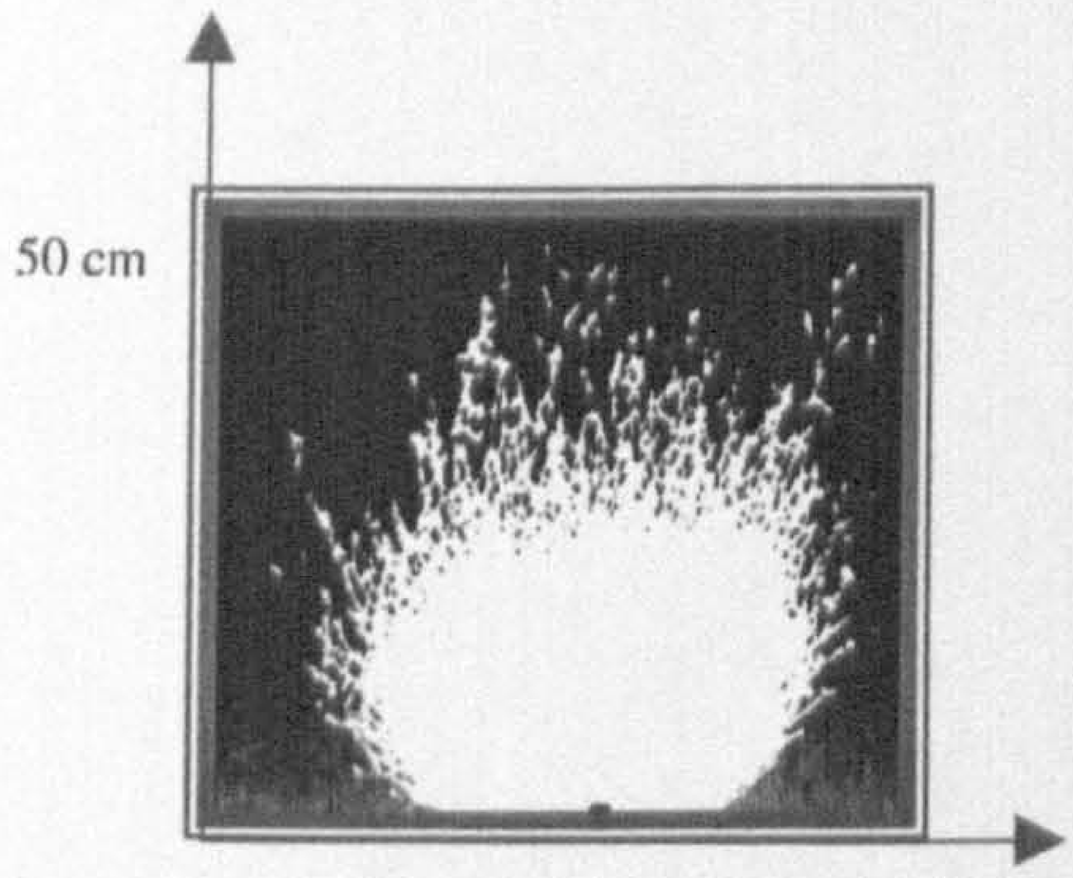
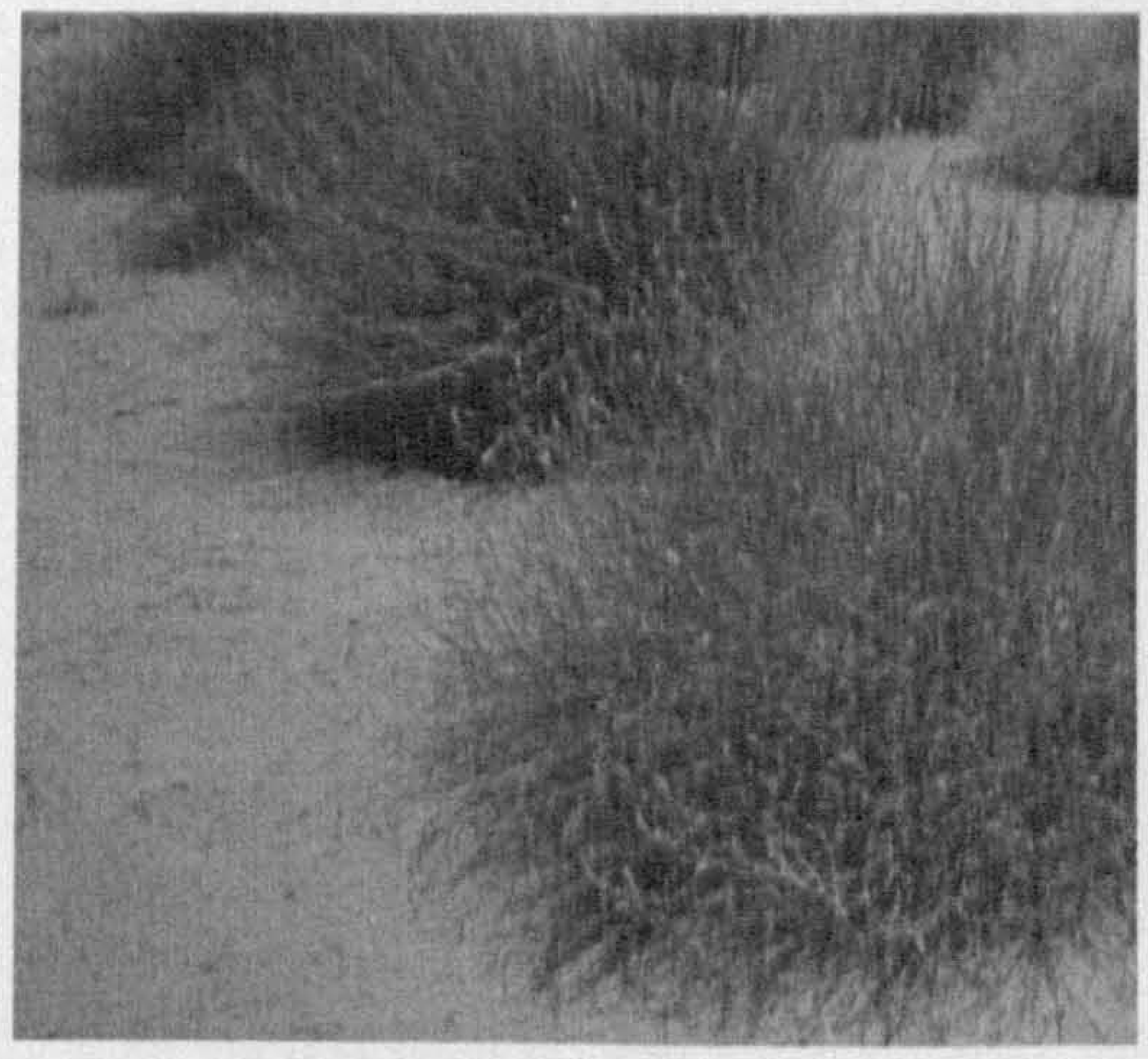
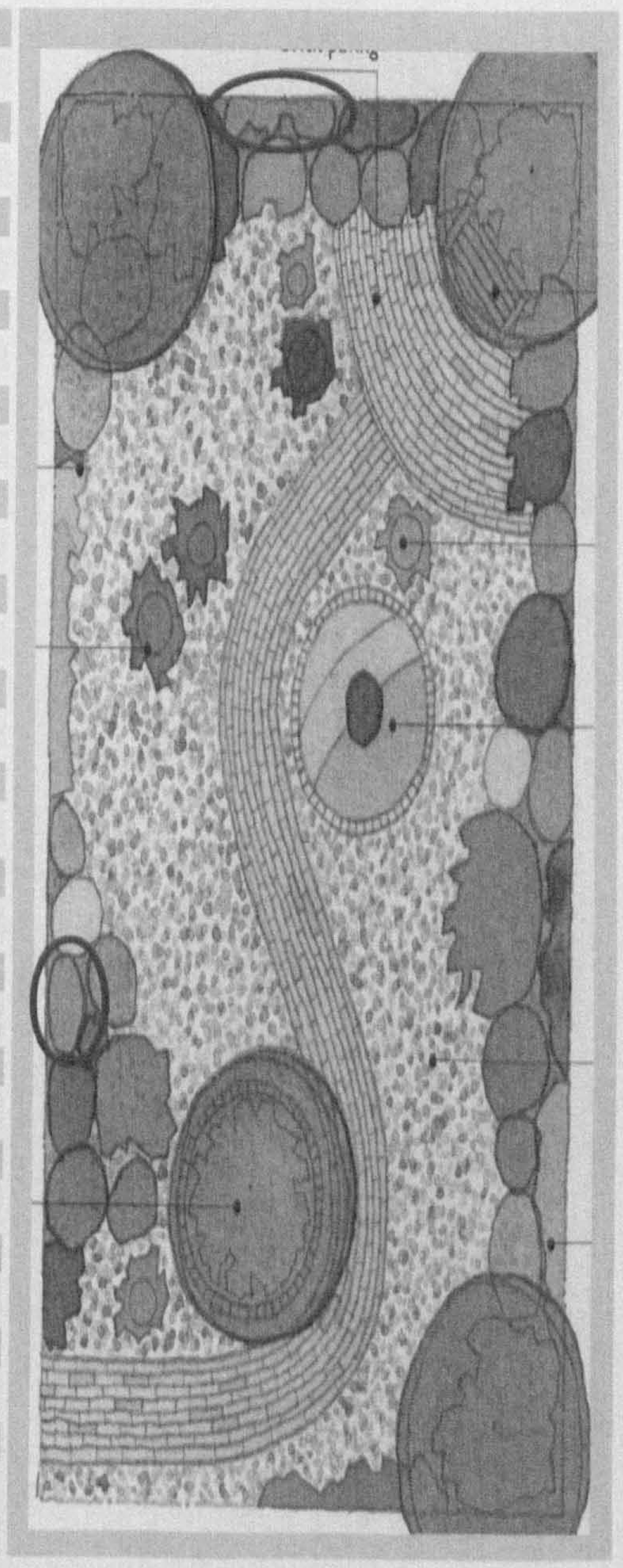


Photo:



Character	Annual forb	
	Perennial forb	
	Small shrub	✔
	Med. shrub	
	Large shrub	
	Grass	
Foliage colour:	Grey / blue green	✔
	Yellow green	
	Med. green	
	Dark green	
	Light green	
	Showy green	
Flower colour:	White	
	Yellow	
	Pink	
	Red	
	Purple	✔
Growth:	Fast	✔
	Med.	
	Slow	
Landscape uses:	Ground cover	✔
	Bedding plant	✔
	Hedges	
	Ornamental plant	✔
	Afforestation	
	For long road	✔
	Windbreaks	
	Shade	
	Erosion sand control	



Plant name:	**Locale name:**	**Family:**	**No.**
Lasiurus scindicus	Daah	*Gramineae*	15

Form:

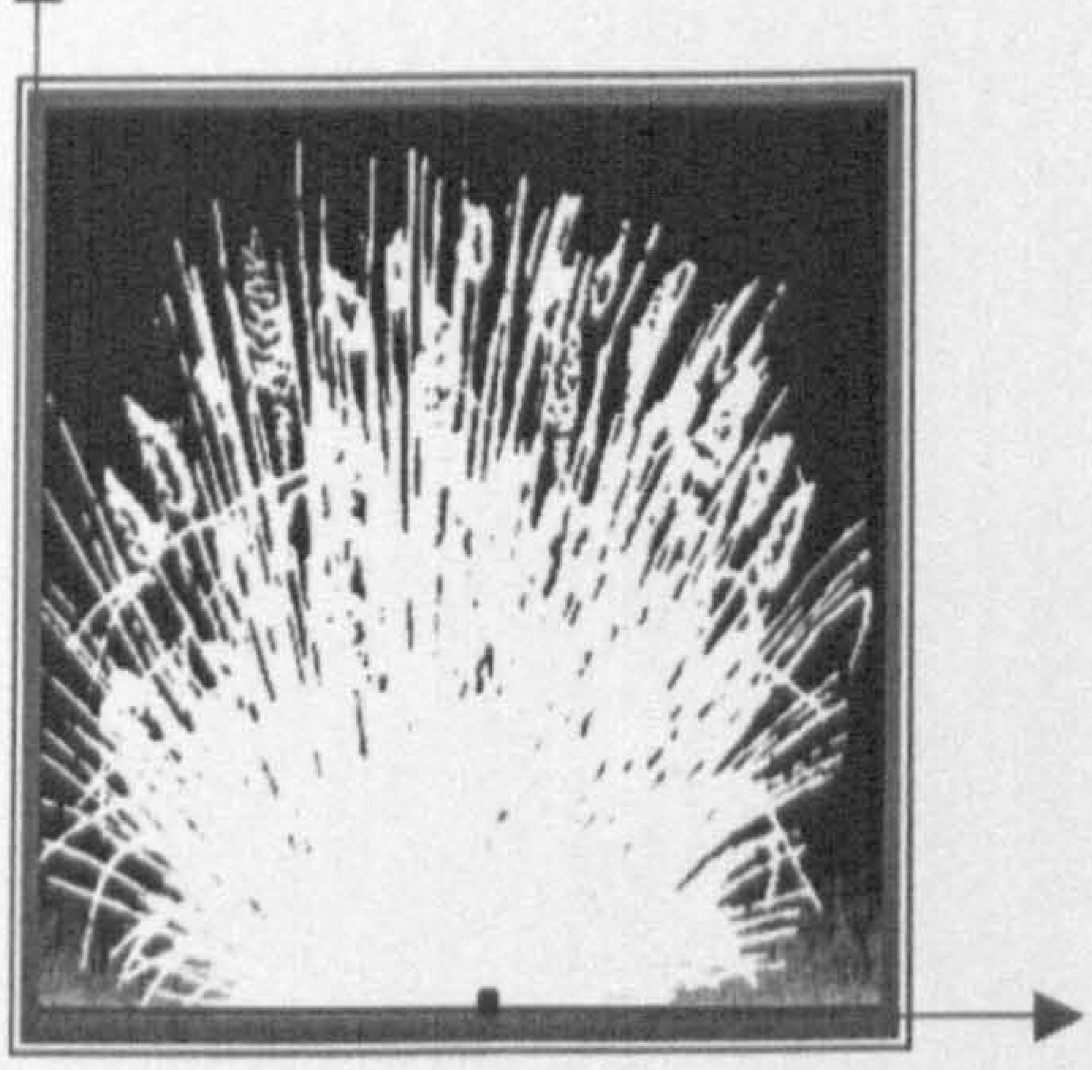
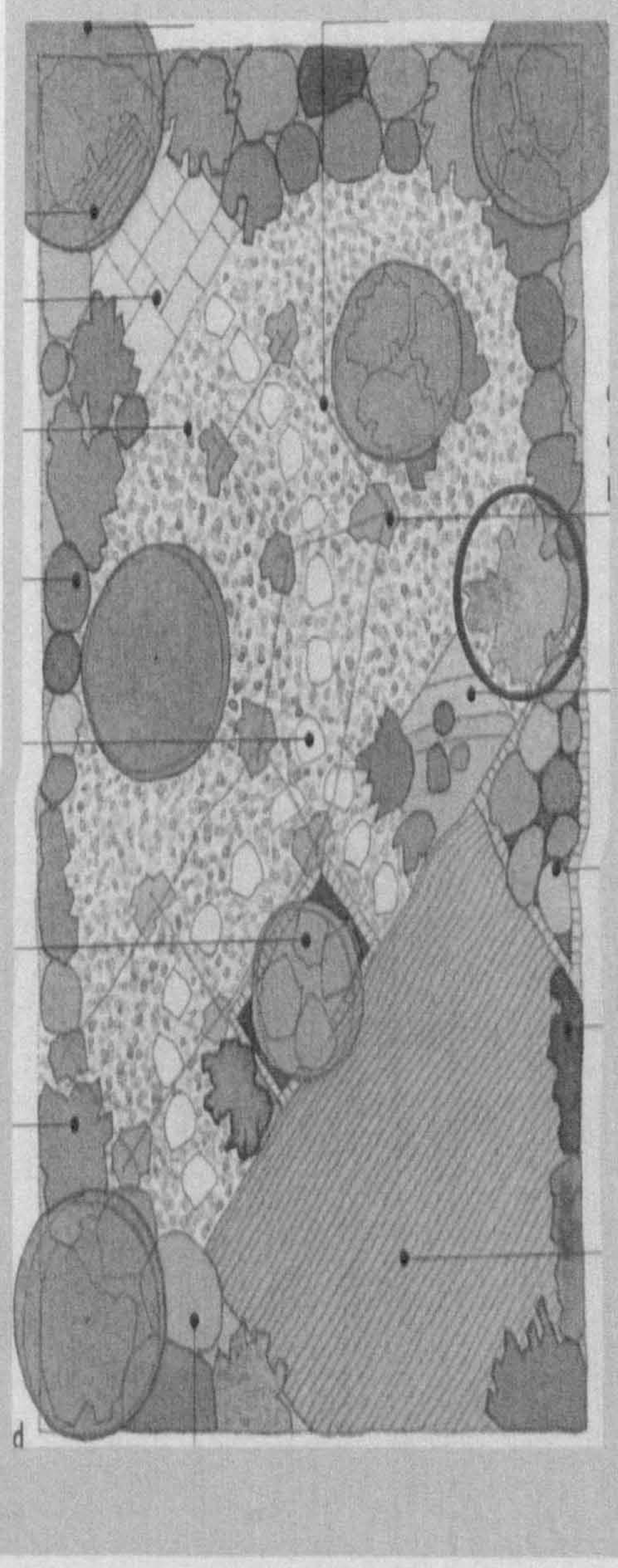


Photo:

Character	Annual forb	
	Perennial forb	
	Small shrub	
	Med. shrub	
	Large shrub	
	Grass	✔
Foliage colour:	Grey / blue green	✔
	Yellow green	
	Med. green	
	Dark green	
	Light green	
	Showy green	
Flower colour:	White	✔
	Yellow	
	Pink	
	Red	
	Purple	
Growth:	Fast	✔
	Med.	
	Slow	
Landscape uses:	Ground cover	✔
	Bedding plant	
	Hedges	
	Ornamental plant	
	Afforestation	
	For long road	✔
	Windbreaks	
	Shade	
	Erosion sand control	



Plant name:	**Locale name:**	**Family:**	**No.**
Peganum harmala	*Harmal Al-shamal*	*Gramineae*	16

Form:

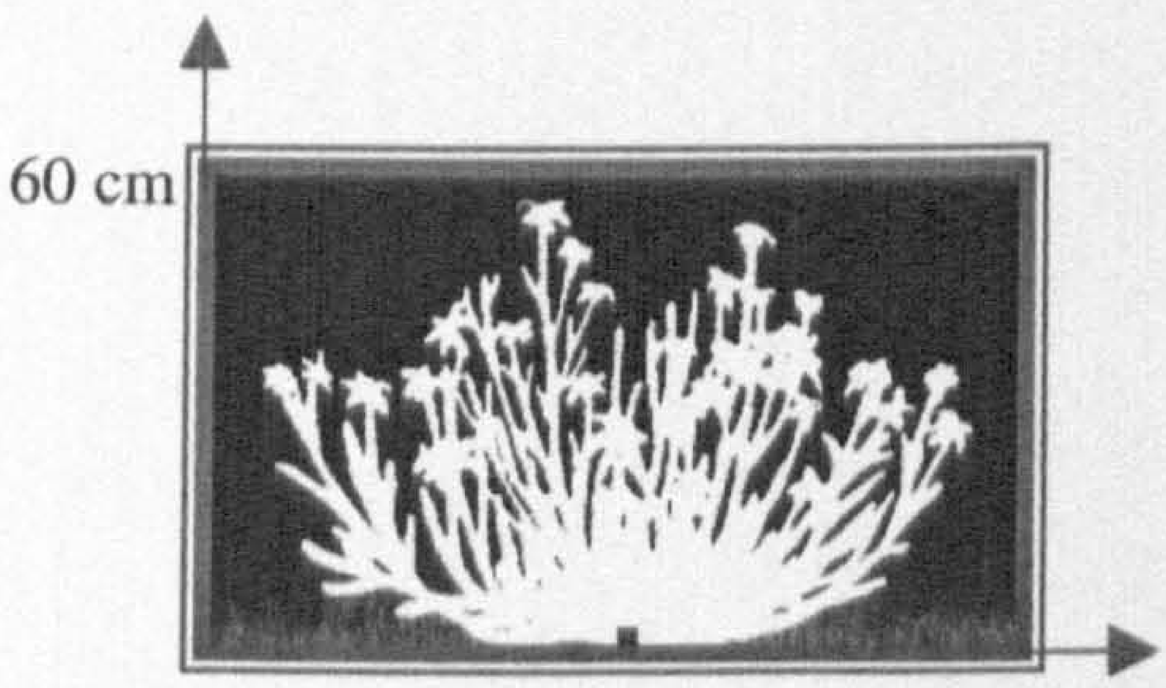
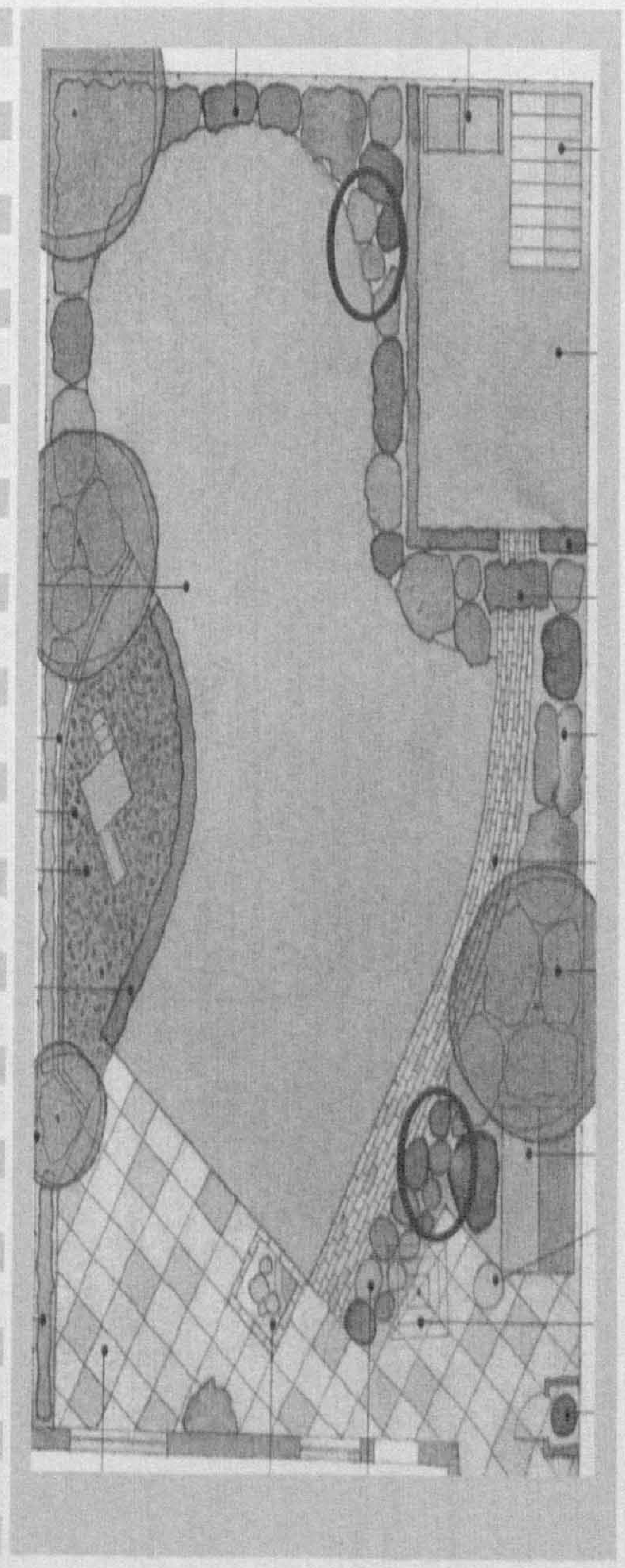


Photo:

Character	Annual forb	
	Perennial forb	✔
	Small shrub	
	Med. shrub	
	Large shrub	
	Grass	
Foliage colour:	Grey / blue green	
	Yellow green	
	Med. green	✔
	Dark green	
	Light green	
	Showy green	
Flower colour:	White	✔
	Yellow	✔
	Pink	
	Red	
	Purple	
Growth:	Fast	✔
	Med.	
	Slow	
Landscape uses:	Ground cover	✔
	Bedding plant	✔
	Hedges	
	Ornamental plant	✔
	Afforestation	
	For long road	✔
	Windbreaks	
	Shade	
	Erosion sand control	



Plant name:	**Locale name:**	**Family:**	**No.**
Pulicaria crispa	Jethjath	*Conipositae*	17

Form:

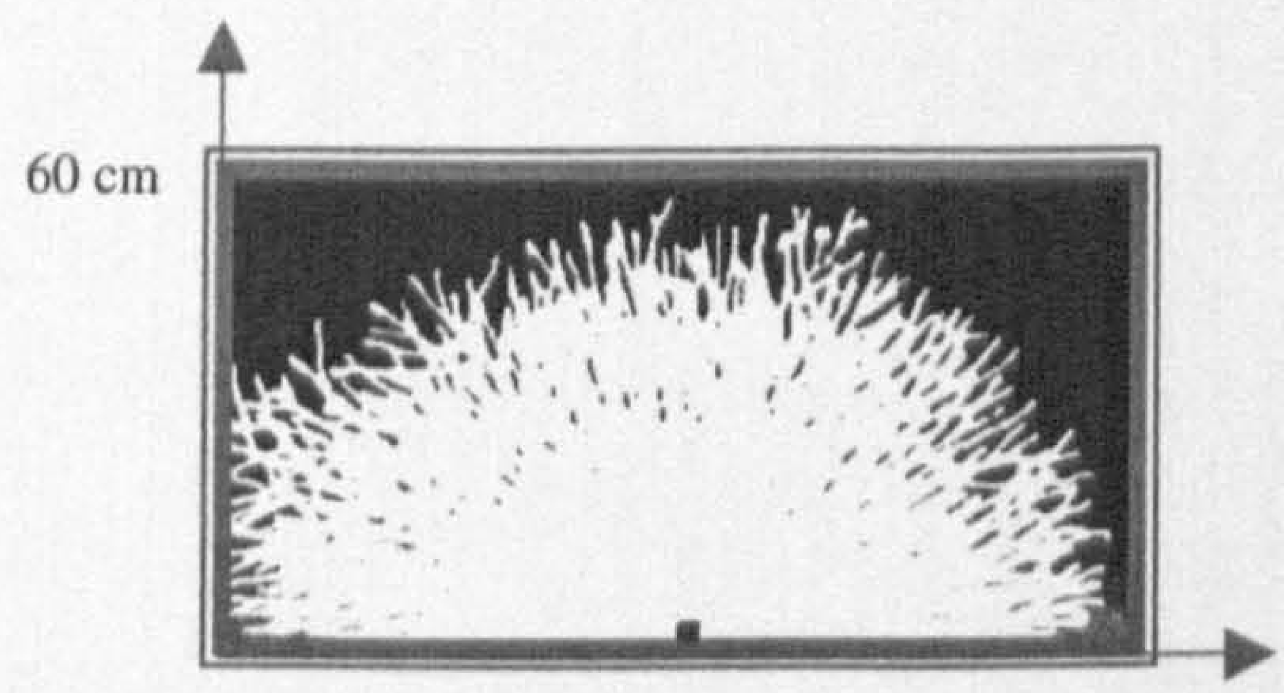
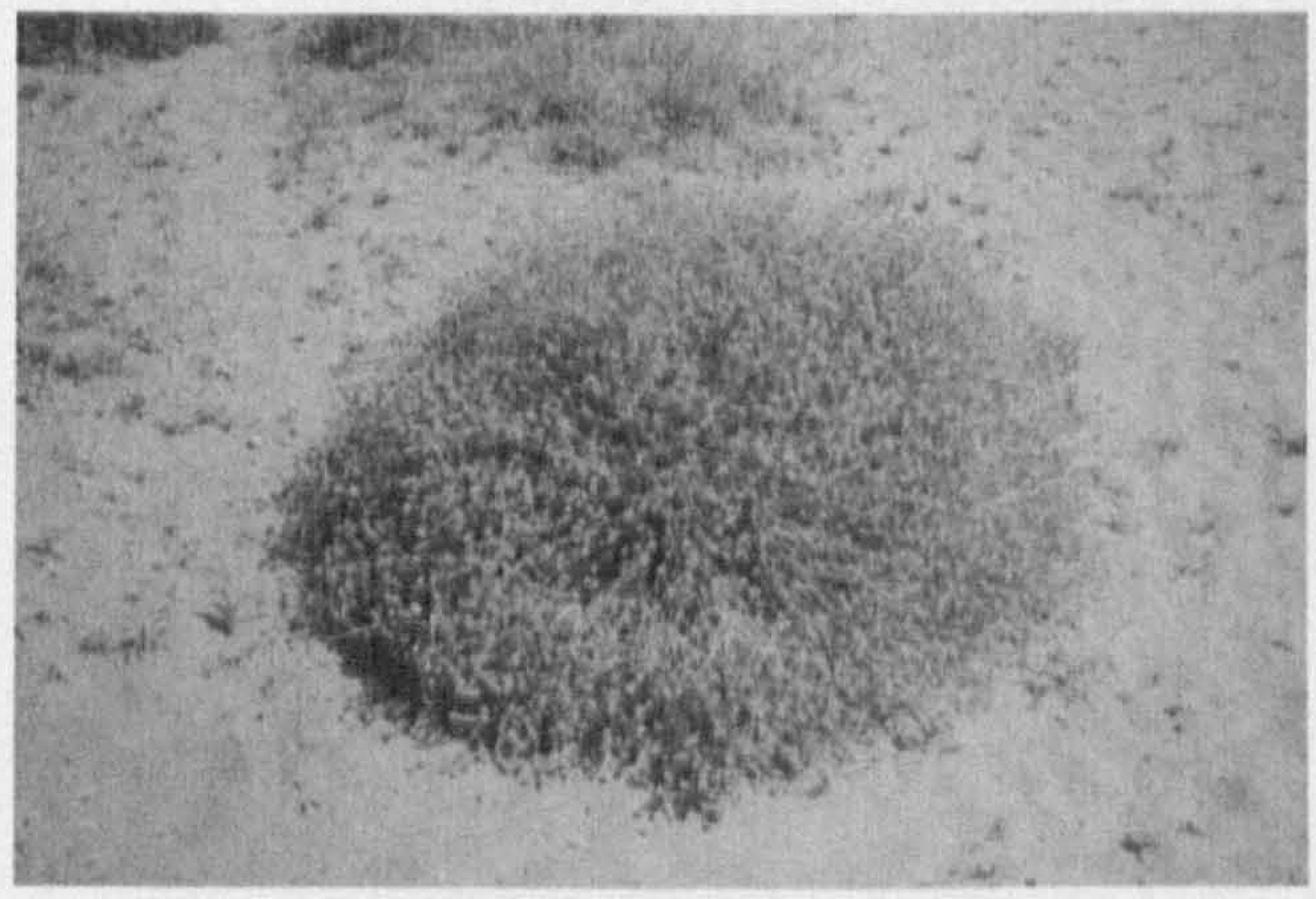
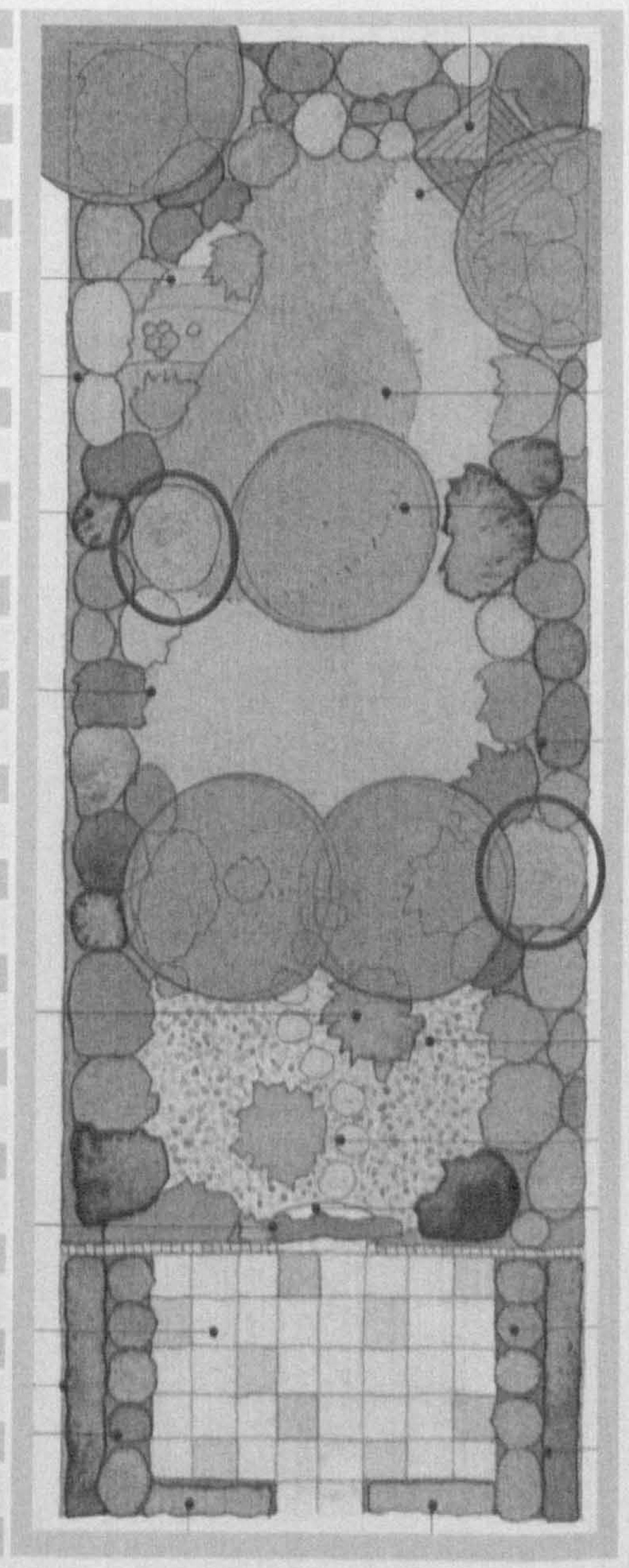


Photo:



Character	Annual forb	
	Perennial forb	
	Small shrub	✔
	Med. shrub	
	Large shrub	
	Grass	
Foliage colour:	Grey / blue green	✔
	Yellow green	
	Med. green	
	Dark green	
	Light green	
	Showy green	
Flower colour:	White	
	Yellow	✔
	Pink	
	Red	
	....	
Growth:	Fast	✔
	Med.	
	Slow	
Landscape uses:	Ground cover	✔
	Bedding plant	✔
	Hedges	
	Ornamental plant	✔
	Afforestation	
	For long road	✔
	Windbreaks	
	Shade	
	Erosion sand control	



Plant name:	Locale name:	Family:	No.
Rhazya stricta	Harmal	*Apocynaceae*	18

Form:

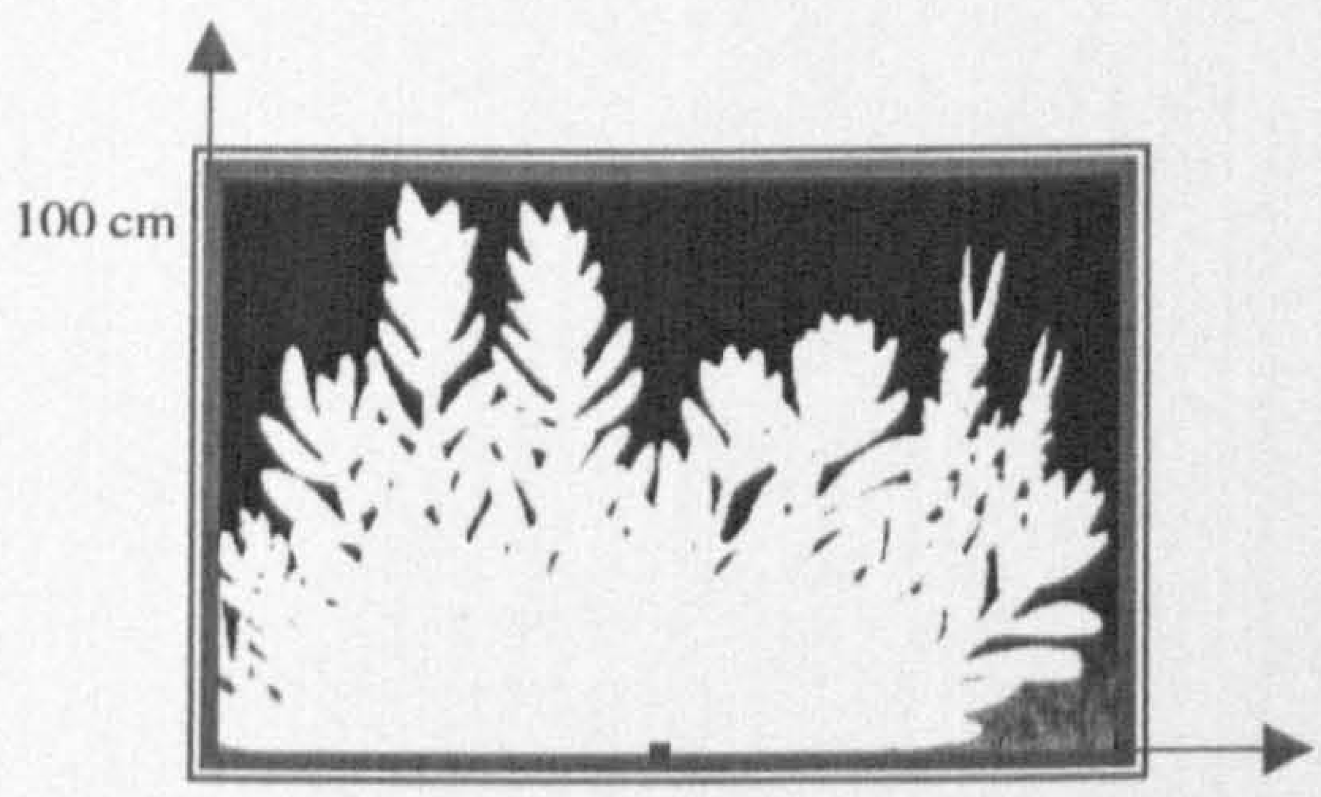
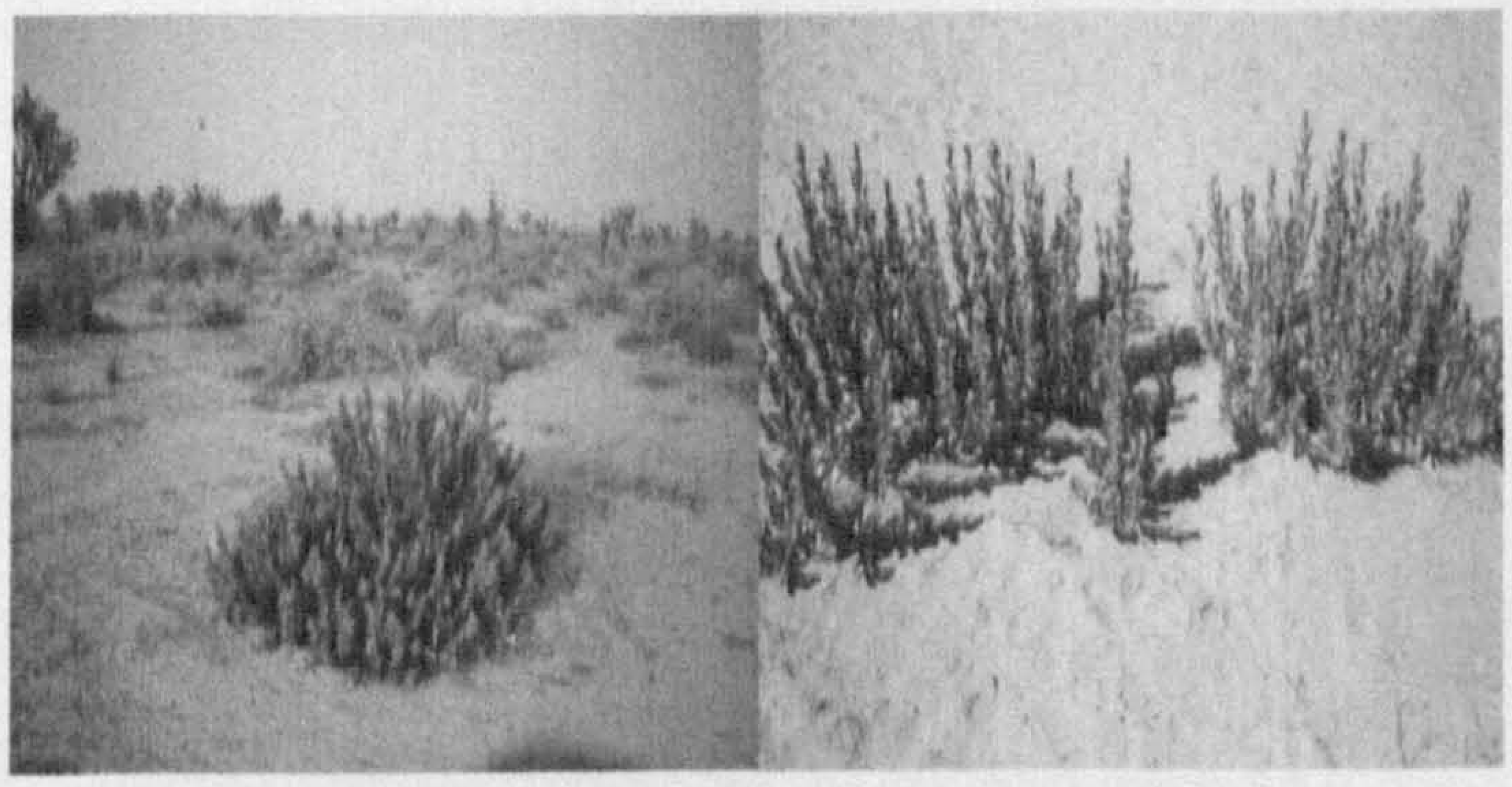
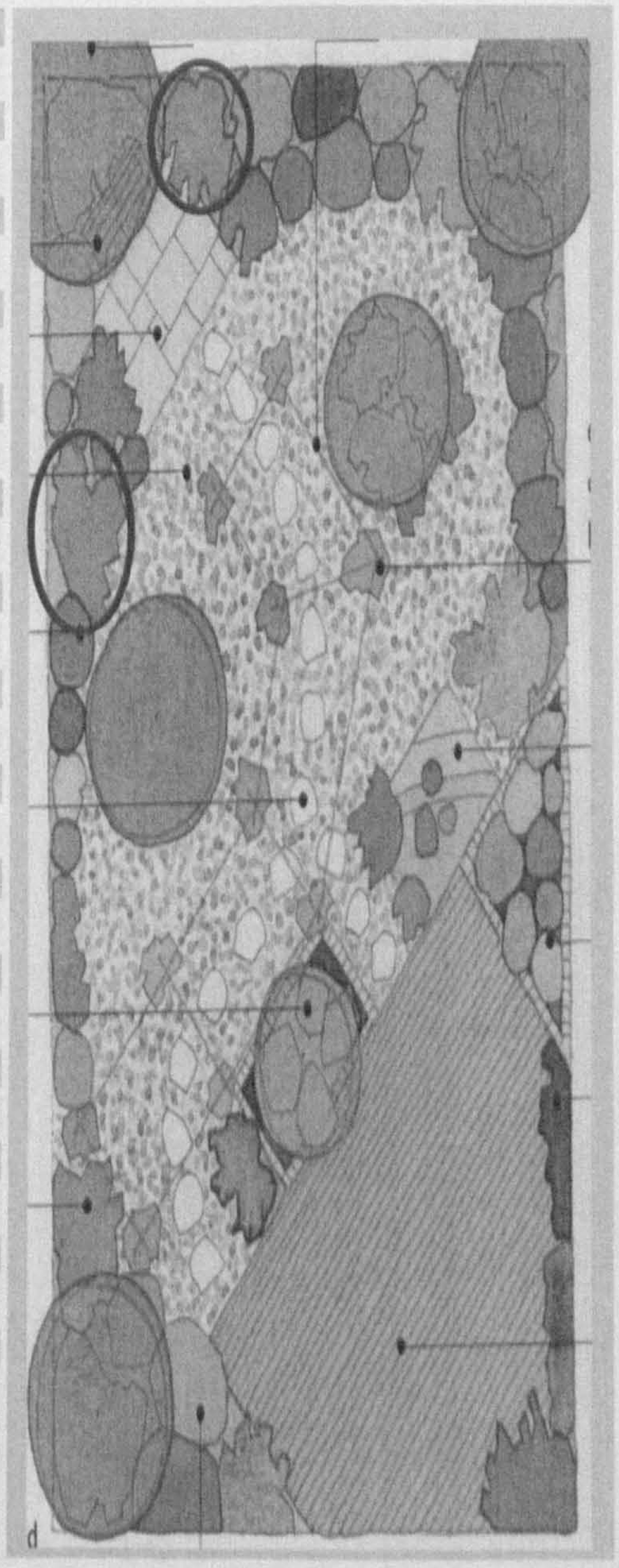


Photo:



Character	Annual forb	
	Perennial forb	
	Small shrub	
	Med. shrub	✔
	Large shrub	
	Grass	
Foliage colour:	Grey / blue green	
	Yellow green	
	Med. green	✔
	Dark green	
	Light green	
	Showy green	
Flower colour:	White	✔
	Yellow	
	Pink	
	Red	
	Purple	
Growth:	Fast	✔
	Med.	
	Slow	
Landscape uses:	Ground cover	✔
	Bedding plant	✔
	Hedges	✔
	Ornamental plant	✔
	Afforestation	
	For long road	✔
	Windbreaks	
	Shade	
	Erosion sand control	✔



Plant name:	**Locale name:**	**Family:**	**No.**
Rumex villosa	Homaid	*Polygonaceae*	19

Form:

50 cm

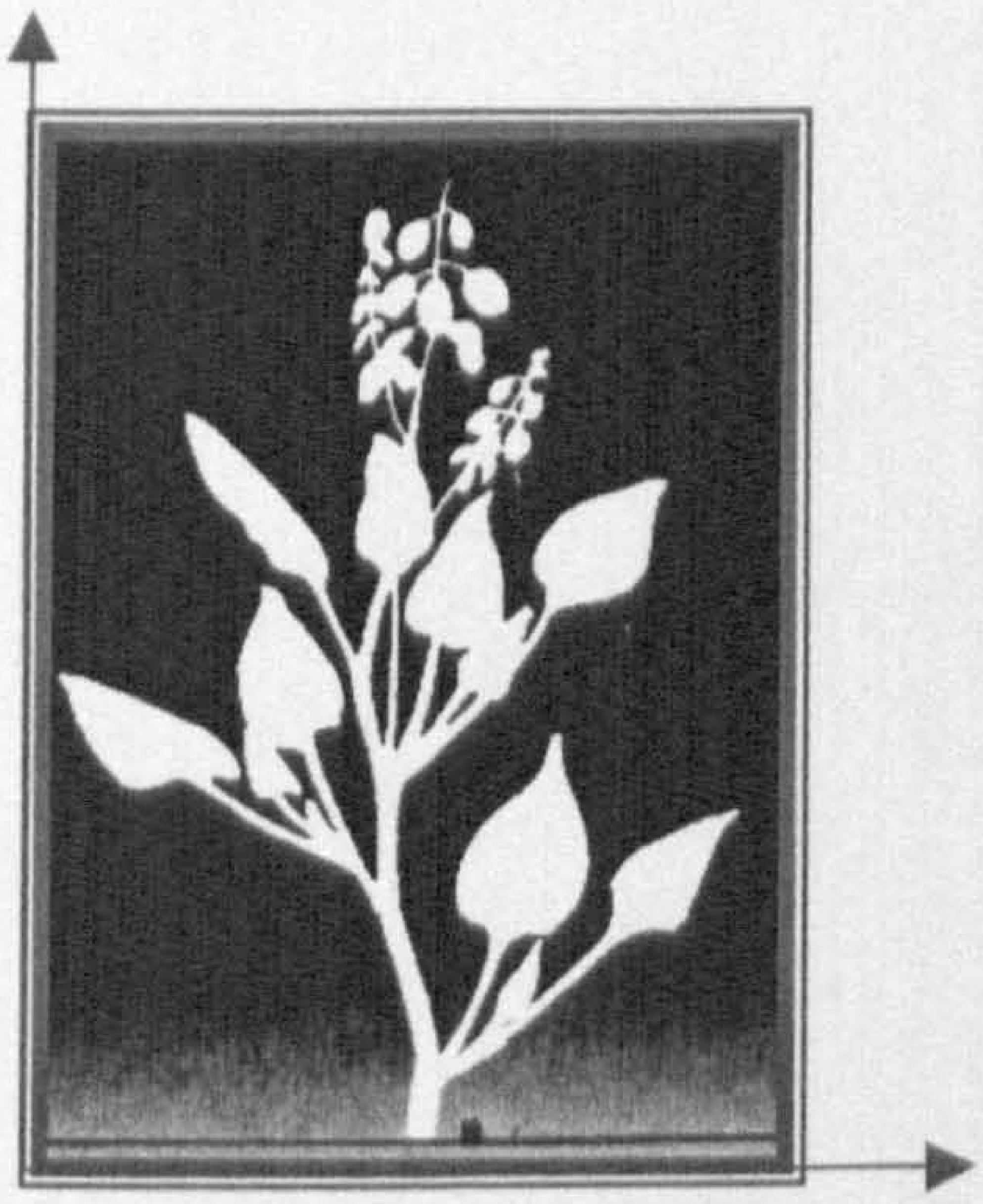
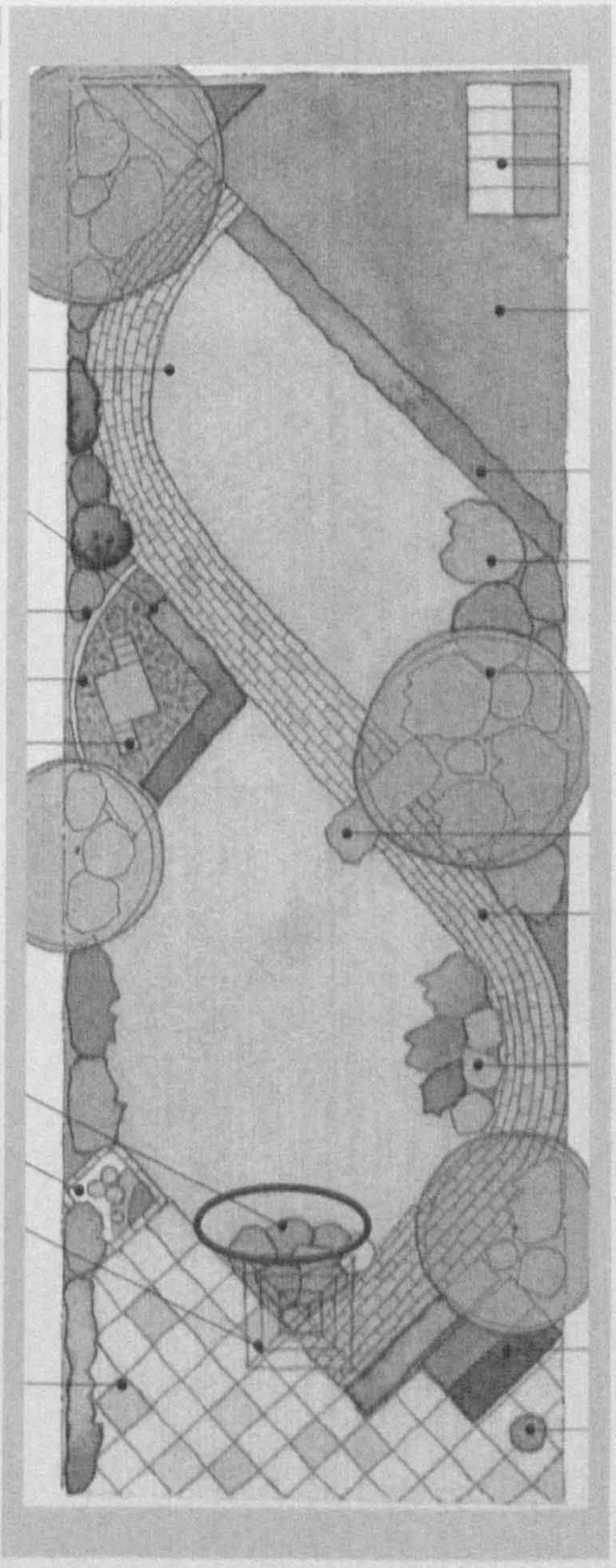


Photo:

Character	Annual forb	✔
	Perennial forb	
	Small shrub	
	Med. shrub	
	Large shrub	
	Grass	
Foliage colour:	Grey / blue green	
	Yellow green	
	Med. green	✔
	Dark green	
	Light green	
	Showy green	
Flower colour:	White	
	Yellow	
	Pink	
	Red	✔
	Purple	
Growth:	Fast	✔
	Med.	
	Slow	
Landscape uses:	Ground cover	✔
	Bedding plant	✔
	Hedges	
	Ornamental plant	
	Afforestation	
	For long road	✔
	Windbreaks	
	Shade	
	Erosion sand control	



Plant name:	**Locale name:**	**Family:**	**No.**
Verbesina encelioides	Safra	*Conipositae*	20

Form:

70 cm

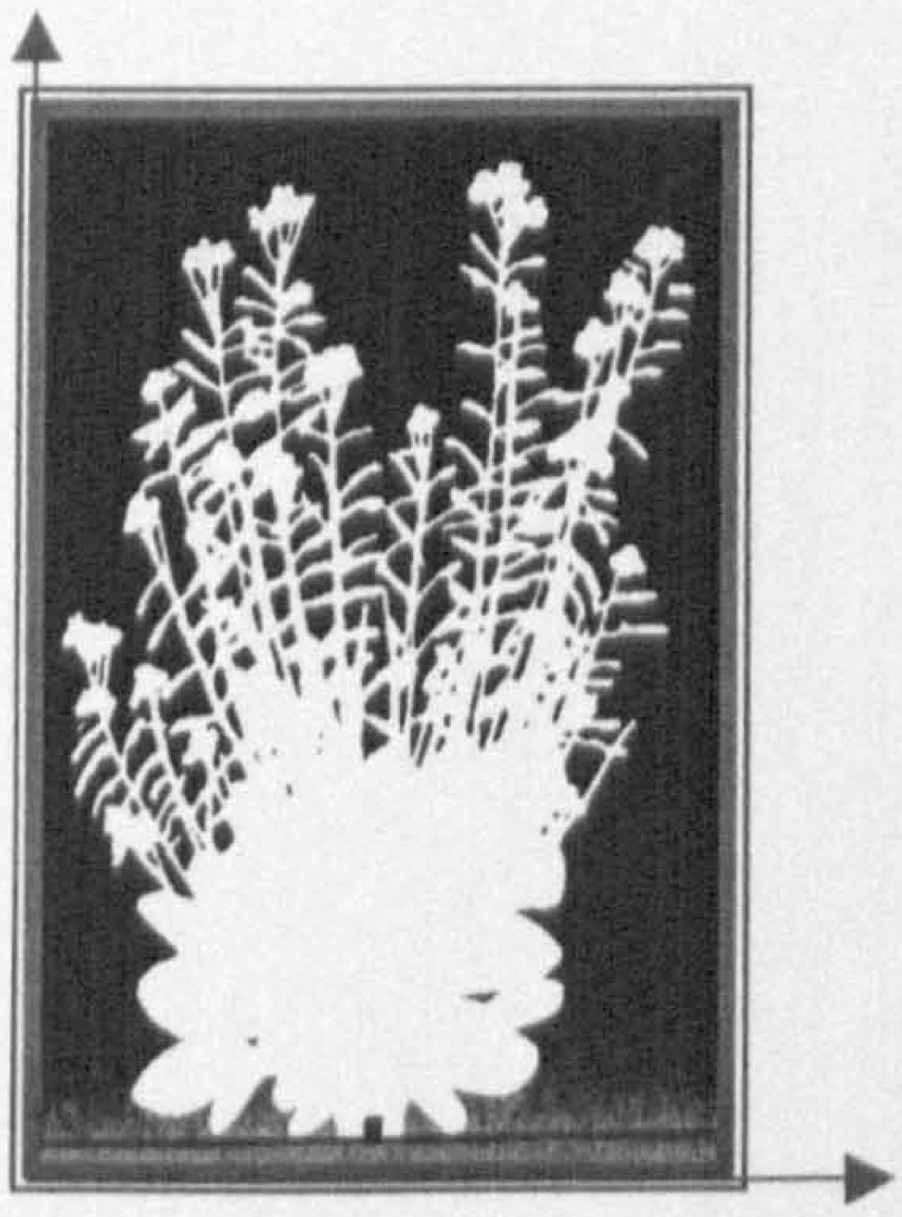


Photo:

Character	Annual forb	✔
	Perennial forb	
	Small shrub	
	Med. shrub	
	Large shrub	
	Grass	
Foliage colour:	Grey / blue green	
	Yellow green	
	Med. green	✔
	Dark green	
	Light green	
	Showy green	
Flower colour:	White	
	Yellow	✔
	Pink	
	Red	
	....	
Growth:	Fast	✔
	Med.	
	Slow	
Landscape uses:	Ground cover	✔
	Bedding plant	✔
	Hedges	
	Ornamental plant	✔
	Afforestation	
	For long road	
	Windbreaks	
	Shade	
	Erosion sand control