EFFECT OF DIFFERENT TREE SPECIES ON MOISTURE DEPLETION PATTERN OF SOIL IN A DESERT ECOSYSTEM

by

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In

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H I S A R
1996

AFFECTIONATELY DEDICATED

TO

MY BELOVED PARENTS

CERTIFICATE-I

This is to certify that thesis entitled "Effect of different tree species on moisture depletion pattern of soil in a desert ecosystem" submitted for the degree of Master of Science, in the subject of Soil Science of Chaudhary Charan Singh Haryana Agricultural University, is a bonafide research work carried out by Mr. Mukesh Kumar Yadav under my supervision and that no part of this thesis has been submitted for any other degree.

The assistance and help received during the course of investigation have been fully acknowledged.

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CERTIFICATE-II

This is to certify that the thesis entitled "Effect of different tree species on moisture depletion pattern of soil in a desert ecosystem" submitted by Mr. Mukesh Kumar Yadav to Chaudhary Charan Singh Haryana Agricultural University, Hisar in partial fulfilment of the requirements for the degree of M.Sc., in the subject of Soil Science has been approved by the Student's Advisory Committee after an oral examination on the same, in collaboration with an External Examiner.

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(Mukesh Kumar Yadav)

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INTRODUCTION

CHAPTER-I

INTRODUCTION

The hot deserts of India are spread over six states, namely Rajasthan (61 % of the total desert of India), Gujarat (20 %), Andhra Pradesh (7 %), Punjab (5 %), Haryana (4 %) and Karnataka (3 %). These states cover about 12 per cent of the total geographical area of the country. In Haryana, the total forest area is 1,67, 300 ha i.e. 3.7 per cent of the total geographical area of the state. These soils are less productive, and in turn the economic condition of the inhabitants is very poor. The per capita forest area in the state is about 0.01 ha, which is the lowest in the country (Statistical Abstract of Haryana, 1993-94).

The forest plantation due to their deep growing roots have the capacity to improve physico-chemical conditions of the soil, extract bases from deep layers and return them to the surface. The vegetative cover protects soil from solar radiation, retards organic matter decay and provide suitable microclimate through lowering of temperature and reducing the evaporation losses, especially in arid and semi-arid regions. The rooting pattern, canopy type and quantity of litterfall of the tree vegetation have direct and indirect influence on the soil fertility and moisture status of the soil. Soil moisture affects the growth of the plants and soil properties, viz. consistency, stickiness and trafficability, air content and gaseous exchange, the activity of micro-organism and the chemical state of the soil (oxidation reduction potential).

The ability of a plant to obtain sufficient water supply depends, not only on its content but also upon soil factors (water retention, transmission, texture, structure), climatic factors (temperature, rainfall, evaporation, transpiration, evapotranspiration) and on plant factors (type of plant, age, genetic inheritance). Effect of root density and vegetative cover on moisture depletion was studied by David and Edwar (1983). The study on moisture depletion pattern of different tree species under different agro-climatic conditions will help in: (i) Screening of different tree species which are more efficient in water use, and (ii) Developing a suitable supplemental irrigation system under desert ecosystem.

The importance of systematic scientific study on effect of different tree species on moisture depletion pattern of soil in desert ecosystem is important and few studies have been carried out in many countries in this direction. However, the existing information on this subject is meagre. Therefore, the present piece of work was undertaken *with a single objective:*

To study the effect of different tree species on soil moisture depletion pattern under desert ecosystem.

REVIEW OF LITERATURE

CHAPTER-II

REVIEW OF LITERATURE

The literature pertaining to the problem entitled "Effect of different tree species on moisture depletion pattern of soil in a desert ecosystem" have been given in this chapter. Scanty work has been done on this aspect in India and abroad. However, an effort has been made to review the aforesaid parameters from evaluation point of view and whatever literature is available on the tree species taken (i.e. Dalbergia sissoo, Prosopis cineraria, Albizia lebbek, Azadirachta indica and Acacia tortilis) and other species related to the study besides some specific references on field crops have been reviewed under appropriate headings as under:

2.1 *Effect of different tree species on chemical characteristics of soil*

2.2 Moisture depletion pattern of soil under different tree species.

2.1 Chemical characteristcs of soil:

Kushalappa (1985) reported that there was higher oxidation of organic matter under Eucalyptus tereticornis plantation as compared to natural forests. Due to higher oxidation of organic matter the surface soil samples showed lower organic carbon, total-N (nitrogen), available-N, NH_4^--N and NO_3^--N under Eucalyptus tereticornis plantation. Weaver et al. (1985) estimated that under prairie vegetation, 31 tonnes/acre of organic matter was added to the surface soil of Nabraska (U.S.A.) while under deciduous forest, the amount of organic matter added was reduced by 5 per cent that of prairie vegetation. The prairie soils were found to be higher in bases than the forest soils, since they have developed from similar type of parent material. Choubey ét al. (1987) reported that organic carbon, N, P and K content were higher under teak plantation and values increased with the age of trees.

The values of organic matter content and P (Phosphorus) were higher under the cover of mixed plantation than that of monoculture. Available K (Potassium) was also higher under teak plantation followed by sal (Singh et al., 1987). Basu and Nandi (1988) reported that there was gradual increase in soil fertility with plantation age as shown by increase in organic carbon content. A slight increase in total nitrogen was observed under Eucalyptus tereticornis monoculture.

Bagatyrev (1990) reported that transformation process of plant residues on cutover area depend on the moisture conditions of the landscape, regenerated forest stand and ground cover vegetation. The studies conducted by Kumar and Deepu (1992) revealed that nitrogen ratio and decomposition rate of litter were higher in tropical forests than temperate forests. They also assessed that residual litter mass decreased linearly with time for all species (i.e Dillenia pentagyna, Terminalia paniculata, Grewia tillifolia, Pterocarpus massupium, Tectona grandis and Xylia xylocarpa) and the variation in mean concentration of N, P, K in litter amongst the dominant species. Wasemael et al. (1992) indicated considerable spatial variation in the amount of organic matter within the plots and was related to vegetation type. Kheiwtam (1993) reported that litterfall and its decomposition were very pronounced during monsoon season in contrast to conditions in other rainforests in the region. High levels of N (2.13 - 3.58 %), P (0.62 - 0.91 %) and K (0.45 - 1.98 %) were observed in the leaf litter of four dominant species (Engelhardatia spicata, Echimocarpus dosycarpus, Syzygium cuminii and Drimycarpus racenosus).

Nutrient analysis of logs in case of decomposition of silver maple (Acer saccharinum L.) woody debris indicated that P and K were released but N was significantly higher (Chueng and Brown, 1995).

2.2 Moisture depletion pattern of soil:

Vegetative cover affects the seasonal moisture change in the soil profile. The seasonal moisture changes are obtained to determine hydraulic gradient and soil water flux, which are the functions of the soil depths and time and are useful in the determination of depletion, evaporation and evapotranspiration from the land. Patric et al. (1965) indicated that most transpired water come from densely rooted soil surface, where matric potential is kept low by frequent rainfall. Although soil water well beyond rooting depth, returned to the surface during long periods without rain. Mader et al. (1973) reported that the removal of vegetation reduced the moisture depletion rates during summer months. Rogerson (1976) observed that summer increased the average depletion rate by 2.1 mm/day on the cut areas as compared to winter season. Average rainfall deficits for forested and cut area were spring, 23 mm and 16 mm; fall, 230 mm and 45 mm and winter, 108 mm and 24 mm, respectively.

Cable (1977) reported that in summer, the soil water was extracted by the plants within 2-3 weeks of rainfall at times when evapotranspiration was high but that extraction was slower during winter. Evapotranspiration was as effective (to a depth of 50 cm) as vegetation was removing soil moisture in case of Larrea divaricata and Ambroisa deltoides stands on fine gravelly sandy loam. Hart and Lomas (1979) showed that the seasonal water depletion was 20 to 25 cm less than on an uncut plot in the first season. This change, which represented a saving of water previously lost to evapotranspiration, is considerably greater than that reported for comparable studies in aspen pine. The effect of clear cutting on soil water depletion are expected to persist for as many as 50 years.

Arkley (1981) observed that moisture depletion occurred upto 274 cm depth. He also found that water use (soil moisture depletion + rainfall) during growing season appeared to be equal to the available water storage capacity during dry summer but was considerably increased in year with summer precipitation. So the survival of the forest depends on the moisture presence in deeper layer. Huber et al. (1985) found that during summer soil water reserves were considerably depleted down to a depth of 250 cm in the plantations and down to 100 cm in a natural Agrostis tenuis/Holcus lomatus meadow. They also reported that evapotranspiration amounted to 76 per cent of the net precipitation in the 26 years old and 9 years old silvo-pastural plantation, for the meadows, it was 23 per cent. Huber and Lopez (1993) made comparisons of seasonal and spatial variation on soil moisture content and water consumption in an adult stand (32 years old) of Pinus radiata, before and after falling and also in natural grass land (Agrostis capillaris and Holcus lamatus) and noticed that water reserves in the soil during summer changed to a depth of 280 cm in the stand, but only to 100 cm in grassland and in the felled area. Evapotranspiration and interception was 1031 mm in the stand, this was 80 % greater than in grassland, which in turn was 13 % more than in felled area. Evapotranspiration during this period was equivalent to 96.6 per cent of the total precipitation for the stand and 57.7 per cent for the grassland. Williams (1993) advocated that environmental conditions promoting low transpiration rates (shading, cloudiness) would cause a net increase in soil water potential as a result of reduced soil water depletion during the day and contributing water efflux from roots during the night.

Gardner (1964) reported that the relative distribution of roots with depth and water retaining and transmitting properties of the soil determined the main features of water uptake pattern. David and Edwar (1983) advocated that water uptake is related to root density. Rose (1967) showed that maximum rate of water withdrawal by root was between the soil surface i.e. 25 cm, and those rates were relatively below 30 cm. La Rue et al. (1968) observed that amount of water moving into or out of root zone was influenced by the irrigation. Johnston (1970) advocated that removing deep rooted aspen could reduce the average evapotranspiration by about six inches per year from a nine feet profile. Taylor et al. (1976) conducted an experiment to compare absorbing efficiency per centimetre of roots near the soil surface. Soil water content was determined with neutron probe and observed that the roots deep in the profile were probably more effective per centimetre of root for water uptake than shallow roots because they were younger. Nnymah and Black (1977) observed downward shift of the zone of maximum root water uptake as soil dried up. The fully developed root system of plant showed less hydrotropic pressure than the undeveloped root system. A good correlation between water uptake rate, rooting density and profile water depletion was noticed.

Rice (1975) reported that water uptake pattern changes rapidly near the surface during first few days after irrigation in soils under Bermunde grass.

Van Bavel et al. (1968) reported that depletion rates were always higher than the rate of loss to the atmosphere in case of bare soil as compared to the sorghum cropped field. Gupta (1975) studied that the moisture changes in the soil under permanent vegetative cover and concluded that moisture depletion rate was maximum in Eucalyptus forest and minimum in grassland. Moreover, Eucalyptus exploits sub-soil moisture and surface soil moisture remain unused and can be used by other species whose roots are confined to surface only. Wagorek (1987) observed that anti-erosion tree planting on slopes under agricultural utilization can decrease crop productivity mainly due to interception of underground waters thereby reducing soil moisture in lower fields. Sartz (1972) studied the soil water depletion under cut and uncut forests with neutron moisture meter and concluded that in latter case, the amount of depletion increased with depth. Thus cutting had a greater water removing effect on conservation of moisture in deeper layer. Rozhkov and Rozkoch (1985) studied the change in soil moisture content in scot pine stands of the mossy type and found that average moisture content was reduced by 31-33 per cent depending upon depth in case of 42 years old stands with or without recreational pressure and 18-20 per cent in 65-69 years old stands with or without recreational pressure, with values upto 45 per cent and 43 per cent, respectively on certain dates. Significant increase in surface runoff and associated soil erosion was also observed in heavily used areas. Jha and Rathore (1981) found that moisture depletion largely depends on the top (90 cm) of 180 cm of the soil profile depth and it is met from deeper and surface horizons in case of chir-pine and Eucalyptus forests of Dehradoon.

Conard (1986) showed that soil moisture depletion was more rapid under the deciduous species, indicating that these species were more severe competitors with conifers for soil moisture. Kucza and Sulinski (1991) studied utilization of ground soil water in related pine tree stands in the Niepolomice forest and reported that water utilization by stand was determined by age and mean water table depth. Maximum utilization was predicted at age 19-23 years, falling to a minimum at 63-77 years. Bartsch (1987) showed that plants in the acidic soil were limited in their ability to react to changes in water supply compared with plants in normal soil. Spruce seedlings were more limited than pine seedlings. Srivastva and Misra (1987) found that the fast growing forest species like Eucalyptus tereticornis consumed maximum amount of water where as Pongamia pinnata consumed the least amount of water. Thus the tested species on the basis of their water requirement could be grouped as: Eucalyptus tereticornis > Dalbergia sissoo > Acacia auriculiformis > Syzygium cumini > Albizia lebbek > Pongamia pinnata etc.

Dabral et al. (1965) recorded accretion and depletion ration by chir-pine as compared to other species like sal and teak upto a depth of 0-4 feet. Teak was found to have slightly lower depletion values. They also observed that available soil moisture was an important factor governing loss of water through evaporation and transpiration. Some preliminary observation on potential water requirement of forest trees were made by Dabral (1970) and suggested differential water consumption behaviour with species. He found that chir-pine (Pinus roxburghii) consumed more water than Eucalyptus tereticornis and Dalbergia latifolia. He also noticed that water consumed per unit gram of dry matter production was least for Eucalyptus and highest for chir-pine. Dabral and Subha Rao (1968) assumed that stem flow and interception losses ranged between 2 to 3.9 and 22.2 per cent, respectively of total rainfall. The corresponding figures, in respect of teak plantation where maximum number of trees were planted within diameter range of 15.2 mm to 30.5 mm were 2.5 to 7.9 and 18.9

to 29.4 per cent of the total rainfall. In 1969, they also reported that maximum interception was observed in dense canopied stand in case of sal and khair plantation. Harris (1974) reported that vegetative cover has important role in determining the soil moisture. Dmitriev et al. (1980) showed that the moisture content varied significantly and was found lower under sedge (caren) and fern than under spruce regeneration or Asparum europaecum, these differences obscured the generally known effect of canopy structure. Significant association with canopy gaps was also observed by them. Assenac and Granier (1988) reported that thinning reduced the severity and duration of soil water depletion by reducing evaporation, especially during 3 years after thinning. After 5 years, however, evapotranspiration was similar in both the thinned and adjacent unthinned stand. Malik et al. (1990) reported that moisture extraction decreased and crop productivity increased as a function of distance (upto 10 m) from a row of Eucalyptus tree under semi-arid supplemental irrigation in a agroforestry system. Norden (1991) studied depletion of soil water in two stands of Norway spruce (Picea abied (L) Karst) and showed that at the beginning of dry period the top soil was more efficiently dessicated than subsoil at both sides. This difference continued for all droughts at the southern site, and was explained by a higher root density in the top soil. At the northern site, there was difference in degree of dessication at different soil depths during an extended dessication period, while certain microsites tended to be more depleted than others. Leuning et al. (1993) predicted that tree with low stomatal sensitivity to water vapour pressure deficit (VPD) or with high Leaf Area Index (LAI) depleted soil water more rapidly than trees sensitive to VPD. or with low LAI.

MATERIALS AND METHODS

CHAPTER-III

MATERIALS AND METHODS

The study was carried out at the farm of National Agricultural Research Project (NARP), Balsamand (Hisar) during 1996. The details of methodology have been discussed in this chapter.

3.1 Location

The study site, NARP, Balsamand situated between 28°59' to 29°49'N latitude and 75°11' to 76°18' longitude at an elevation of 215.2 m above mean sea level, is 25 km away from Hisar on Hisar-Bhadra road.

3.2 Weather and climate

It has arid and semi-arid climate with hot and dry dessicating winds accompanied by frequent dust storms in summer, severe cold during winter and humid warm during monsoon months (July-September). Temperature varies largely during summer and winter months. Maximum temperature goes upto 48°C during summer and below freezing point accompanied by frost in winter season. The average rainfall is around 400 mm, most of which (80-85 %) is received from south-west monsoon during July, August and September. Wind velocity of 15-30 km/h are experienced in summer months but occasionaly very high wind velocity also occur. Total yearly U.S. open pan evaporation averages 2592 mm with maximum evaporation rate of 16 mm/day in the month of June. The annual potential evapotranspiration computed with modified Penman's equation of this region is about 1650 mm. Meteorological data of Hisar during observation time (Jan.- August, 1996) are presented in Table-1.

Table 1. Meteorological data for experimental site during observation period (January-August, 1996).

Month	Temperature (°C)		Mean R.H. (%)		Total rainfall (mm)
	Min.	Max	Mor.	Even.	
January	0.5	23.6	92	51	5.3
February	0.9	26.4	92	51	35.2
March	7.5	35.4	48	-	-
April	7.2	42.2	22	-	306.5
May	16.5	44.7	19	-	13.0
June	21.5	45.7	44	-	107.7
July	23.5	40.4	79	56	69.5
August	24.1	40.6	53	-	192.2

3.3. Physico-chemical properties of the experimental soil

The NARP, Balsamand has flat land with some sand dunal hummocks. The sand dunal height range from 4 to 8 m above the ground level. The physico-chemical properties of experimental site are presented in Table 2.

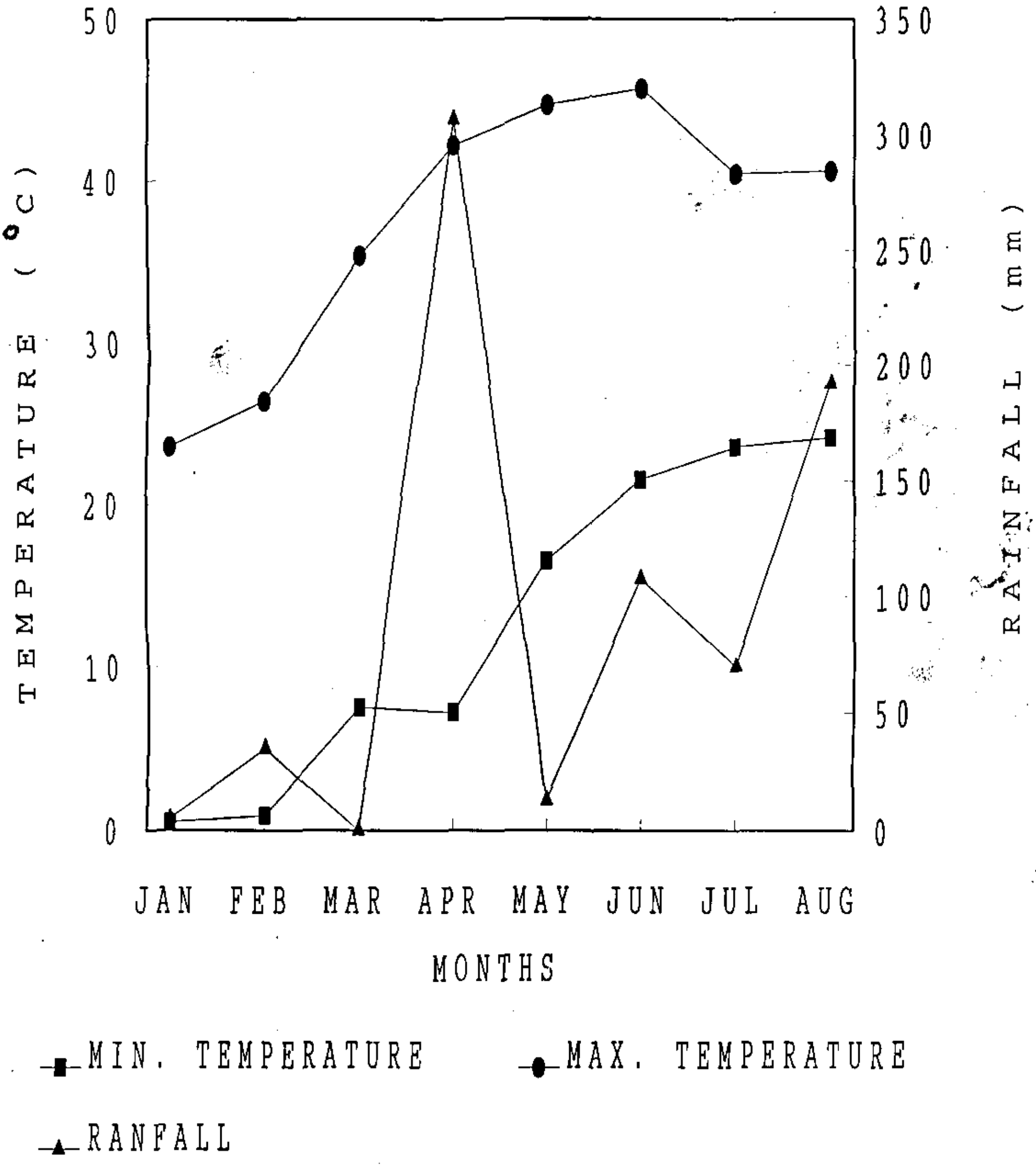


Figure 1. Meteorological data for experimental site from Jan.-Aug., 1996

Table 2. Physico-chemical properties of the soils of NARP farm Balsamand

Depth (cm)	Sand (%)	Silt (%)	Clay (%)	Textural class	Bulk density (mg m^3)	Hydraulic conductivity (cm h^{-1})	ECe (dS m^{-1})	pH	Organic carbon (%)	$Caco_3$ (%)	Soil moisture ($cm^3/100\ cm^3$ at different suction (Mpa) (0)	(0.01)	(1.5)
0-10	93.5	1.0	5.5	Sand	1.49	18.4	0.16	8.7	0.022	0.00	28.3	7.91	1.58
10-24	93.4	1.3	5.0	Sand	1.51	16.5	0.15	8.6	0.037	0.37	26.7	6.71	1.58
24-67	92.6	1.4	5.5	Sand	1.59	16.1	0.12	8.5	0.015	0.50	26.4	6.83	1.20
67-123	93.0	1.2	4.8	Sand	1.51	13.1	0.12	8.5	0.060	0.37	29.0	6.92	1.35
123-225	89.6	1.8	6.5	Sand	1.54	13.9	0.14	8.5	0.022	1.20	28.2	7.53	1.20
225-275	88.0	1.3	6.6	Sand	1.54	14.7	0.18	8.5	0.009	5.70	26.2	6.83	1.20
275-500	90.8	1.2	6.5	Sand	1.54	9.9	0.18	8.7	0.007	1.00	29.5	7.64	1.29

3.4 Vegetation

The vegetation in this region is scanty, xerophytic plant species classified as typical dry deciduous and thorny. The tree and grass species raised on NARP farm are presented in Table 3

Table 3. Common vegetation grown on NARP farm, Balsamand

Tree species	Grass species
Dalbergia sissoo	Cenchrus ciliaris
Azadirachta indica	Lasirus sindicus
Albizia lebbek	
Alianthus excelsa	
Prosopis cineraria	
Acacia tortilis	
Acacia albida	
Acacia catechu	
Acacia nilotica	
Acacia ferniciana	
Cassia siamea	
Tecomella undulata	
Prosopis juliflora	
Zizyphus mauritiana	
Embitica officinals	
Cardia myria	
Aegle mermedos	

3.5 Experimental details

For the present investigation 5 years old plantation of Dalbergia sissoo, Prosopis cineraria, Albizia lebbek, Azadirachta indica and 15 years old plantation of Acacia tortilis existing on the NARP farm were selected. The spacing of all the tree species was 6m x 6m. Different treatmets and layout of the experimental site is given in Table 4.

3.6 Tree characteristics

The following morphological characteristics of the existing tree species were recorded.

3.6.1 Tree height

The total height of the standing tree is the perpendicular distance from the top of the leading shoot to the ground level. The height of individual tree was measured with the help of Ravi's multimeter.

3.6.2 Diameter at breast height (dbh)

The diameter of the individual tree was recorded with the help of Tape/Vernier Caliper. Measurements were taken at breast height (1.37 m) from the ground level.

3.7 Soil characteristics

The soil samples from 1 m distance of tree trunk as well as from bare soil (control) at a depth interval of 5 cm up to 15 cm for organic carbon and 0-15 cm for available nitrogen, phosphorus and potassium were taken. The soil samples were air dried and analysed by using the methods as described by Kalra and Maynard (1991).

Table 4. Treatment and layout of the experimental site

Treatment	Tree spp.	Height (m)	Girth (dbh) (cm)
Dune Top	Dalbergia sissoo		
	R_1	6.70	7.30
	R_2	6.00	7.50
	R_3	6.10	7.60
	Prosopis cineraria		
	R_1	3.60	12.00
	R_2	0.55	1.11
	R_3	0.95	3.46
	Albizia lebbek		
	R_1	5.30	6.70
	R_2	4.90	7.60
	R_3	5.00	10.40
	Azadirachta indica		
	R_1	4.50	8.20
	R_2	4.15	7.00
	R_3	4.45	6.20
Interdune	Dalbergia sissoo		
	R_1	4.75	6.30
	R_2	5.20	9.40
	R_3	6.20	8.40
	Prosopis cineraria		
	R_1	0.90	1.48
	R_2	1.35	1.71
	R_3	0.70	0.96
	Albizia lebbek		
	R_1	3.70	4.60
	R_2	4.00	4.70
	R_3	4.40	2.40
	Azadirachta indica		
	R_1	3.95	5.00
	R_2	3.85	7.80
	R_3	3.75	3.50
	Acacia tortilis		
	R_1	8.50	22.60
	R_2	8.60	21.00
	R_3	7.40	20.00

3.8 Moisture depletion

For moisture depletion study, three tree species on dune top as well as on interdune were selected whereas Acacia tortilis trees exist on interdunal area were selected. Access tubes were installed at the distance of 1 m away from each tree trunk. Observations were started on 26th February, 1996 with the help of CPN Neutron moisture meter at an interval of 15 days upto the depth of 15-180 cm at 15 cm interval. In rainy season, the observations were taken at 5 days interval.

Soil moisture was also determined gravimetrically for calibration. The neutron counts were calibrated with the equation:

$$Y = mx + b$$

where Y = Number of counts

m = Slope of the line

x = Volumetric moisture

b = Intercept on Y-axis

The volumetric moisture content was calculated by the bulk densities given in Table 5 and the moisture contents observed gravimetrically were used for drawing the above equation.

Table 5 : Soil bulk densities of dune top and interdune soils upto 180 cm depth

Site	Depth (cm)											
	0-15	15-30	30-45	45-60	60-75	75-90	90-105	105-120	120-135	135-150	150-165	165-180
Dune Top (Db)	1.68	1.66	1.60	1.55	1.57	1.63	1.55	1.53	1.69	1.64	1.59	1.63
Interdune (Db)	1.71	1.67	1.63	1.60	1.62	1.55	1.59	1.59	1.59	1.64	1.63	1.65

Db : Bulk density

RESULTS AND DISCUSSION

CHAPTER-IV

RESULTS AND DISCUSSION

In order to study the effect of different tree species on moisture depletion pattern of soil in a desert ecosystem, studies were carried out at NARP farm, Balsamand (Hisar). The results of the present investigation are presented and illustrated under the following heads.

4.1 Chemical characteristics of soil

4.2 Moisture depletion characteristics

4.1 Chemical characteristics of soil

The chemical characteristics of the experimental field such as organic carbon, available nitrogen (N), available phosphorus (P) and available potassium (K) under different multipurpose tree species at dune top, interdune and the field devoid of trees (control) are presented in Table 6.

The data revealed that the organic carbon content of soil under the canopy of different tree species raised at dune top as well as in control was in order of Dalbergia sissoo > Prosopis cineraria > Albizia lebbek > Azadirachta indica > Control at all the depths. Similar trend was observed for trees raised at interdune except Acacia

Table 6. Chemical properties of experimental soil under different tree species (dune top and interdune)

Species	Depth (cm)	Organic carbon (%)		Available N (kg/ha) (0-15 cm)		Available P (kg/ha) (0-15 cm)		Available K (kg/ha) (0-15 cm)	
		Dune top	Interdune	Dune top	Interdune	Dune top	Interdune	Dune top	Interdune
A. tortilis	0-5	-	0.28						
	5-10	-	0.27	-	58.3	-	18.2	-	264.6
	10-15	-	0.24						
D. sissoo	0-5	0.21	0.16						
	5-10	0.20	0.15	56.5	55.7	14.7	13.5	256.7	214.3
	10-15	0.16	0.15						
P. cineraria	0-5	0.17	0.09						
	5-10	0.12	0.06	55.7	49.6	12.4	11.4	247.2	211.2
	10-15	0.07	0.05						
A. lebbek	0-5	0.09	0.07						
	5-10	0.07	0.06	48.9	36.6	10.3	10.1	239.2	188.2
	10-15	0.06	0.04						
A. indica	0-5	0.07	0.06						
	5-10	0.07	0.03	41.3	38.1	9.6	9.5	236.0	184.6
	10-15	0.05	0.03						
Control	0-5	0.06	0.02						
	5-10	0.05	0.01	27.2	20.0	5.3	5.0	183.4	182.4
	10-15	0.04	0.01						

tortilis. The soil organic carbon content was maximum under A. tortilis tree raised at interdune as compared to other species raised at dune top, interdune and the area without trees. The selected trees of A. tortilis exist at interdune only and were older than other tree species planted at dune top and interdune. The age of plant plays an important role in the accumulation of organic carbon under their canopy. The higher content of organic carbon at dune top than interdune except under A. tortilis may be due to more availability of moisture and fast growth of all the tree species (Table 4).

In general, the organic carbon content of soil was more in plantation area than the area devoid of trees. It decreased with increase in soil depth at all the sites. This is mainly due to deciduous nature of trees, addition of organic matter through litterfall and decay of fine roots. However, in barren lands due to low moisture availability and high temperature the burning of organic matter is more than their decomposition. Similar results have been reported earlier by Marin et al. (1985), Kushlappa (1985) and Kumar and Kumar (1991).

Similar trends as that of previous parameter was also noticed for available N, P and K for all the tree species as well as for control except A. indica and A. lebbek for K content at dune top and interdune. A. indica showed higher K content than A. lebbek at both the sites. Maximum and minimum content of nutrients (N, P and K) was observed at dune top and interdune, respectively under plantation as well as in the area devoid of trees. This may be ascribed due to fast growth of all the tree species at dune top (Table 4). In general the contents of N, P and K were higher in plantation area than the area without trees. These results corrobrate with the findings of Verma et al. (1982), Singhal (1986), Dowling et al. (1986), Choubey et al. (1987), Basu and Nandi (1988), Gupta et al. (1989) and Bahuguna et al. (1990).

4.2 Moisture depletion characteristics

Depth-wise moisture distribution under different tree species at different times have been included in appendix I to XII. Here only those results have been presented which were practically important and need discussion.

4.2.1 Profile moisture dynamics under different tree species

The changes in water storage were evaluated by determining water content, which varied with time and space [Acharya et al.(1979)].

The profile moisture status (PMS) with time under different tree species have been illustrated in Figures 2 to 9 and it was observed that the moisture content decreased linearly with time in both the cases viz. dune top and interdune under different tree species in summer as well as in rainy season.

Figures 2, 3, 6 and 7 proved that the PMS was maximum

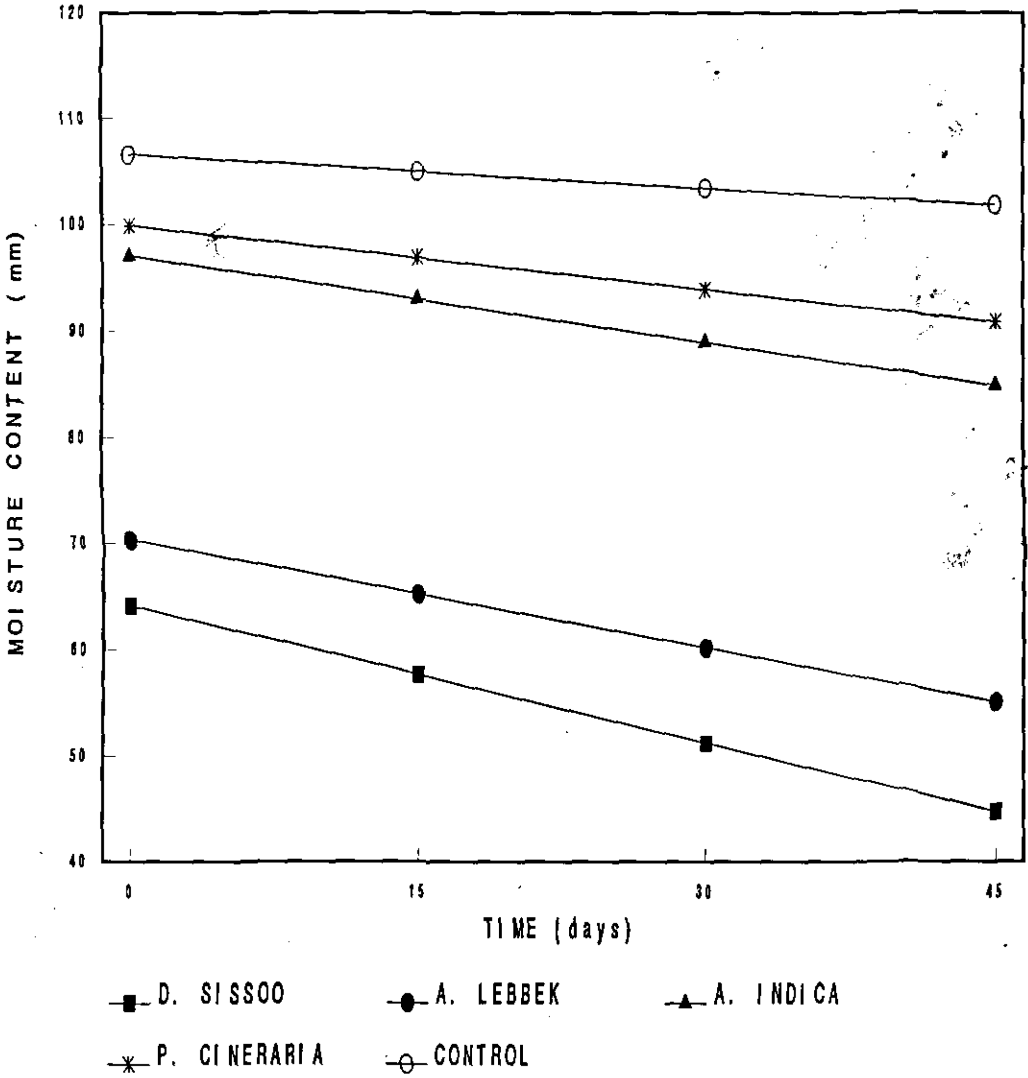


Figure 2 PROFILE MOISTURE STATUS UNDER DIFFERENT TREE SPECIES IN SUMMER SEASON (DUNE TOP)

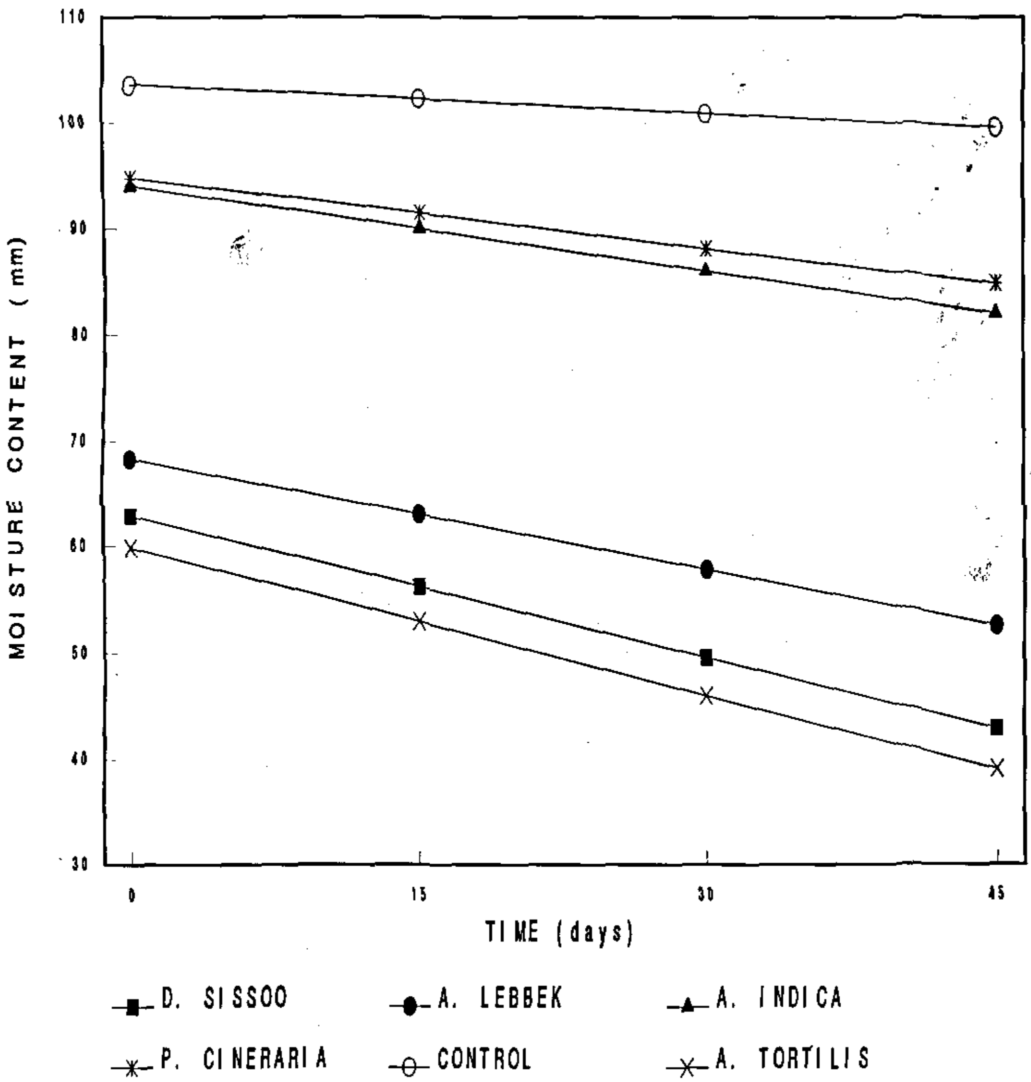


Figure 3 PROFILE MOISTURE STATUS UNDER DIFFERENT TREE SPECIES IN SUMMER SEASON (INTERDUNE)

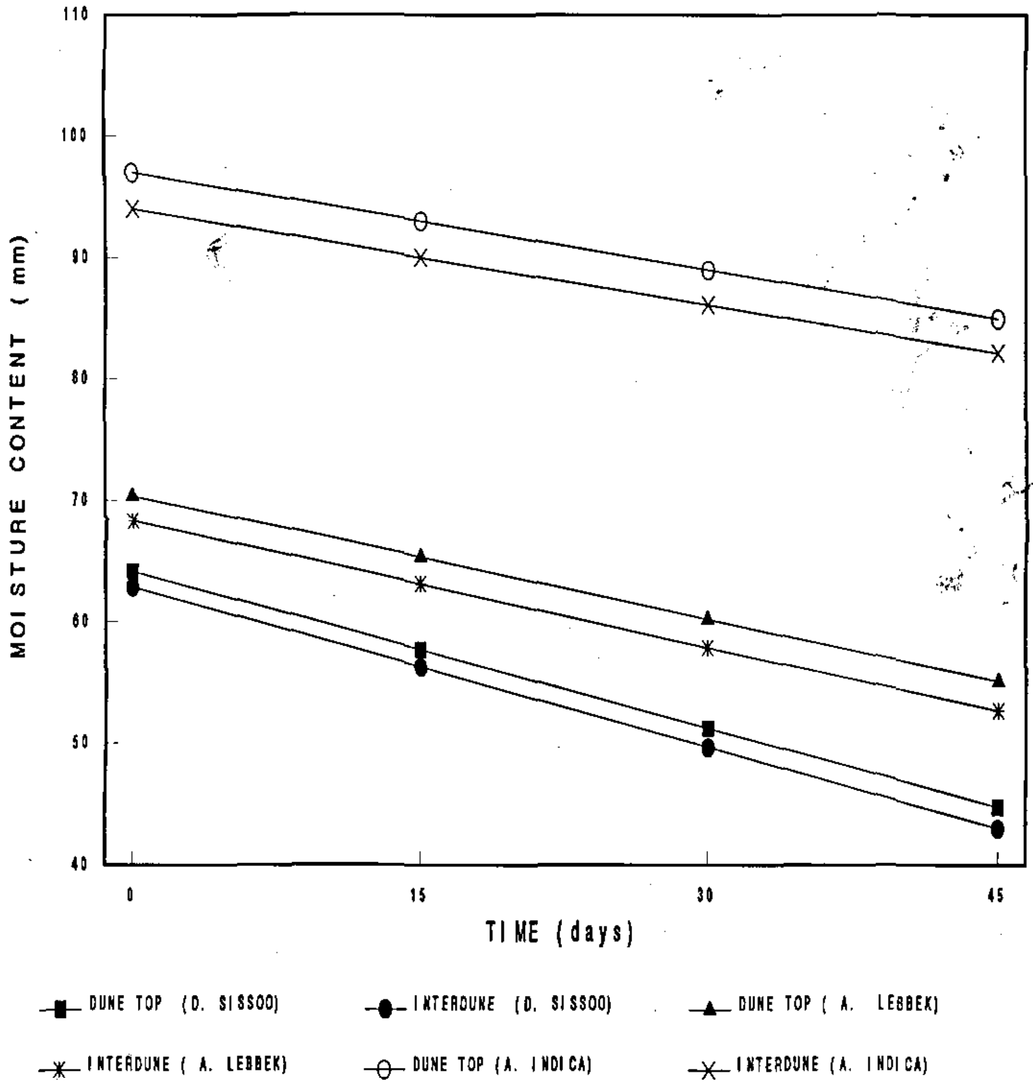


Figure 4 PROFILE MOISTURE STATUS UNDER DIFFERENT TREE SPECIES IN SUMMER SEASON (DUNE TOP VS. INTERDUNE)

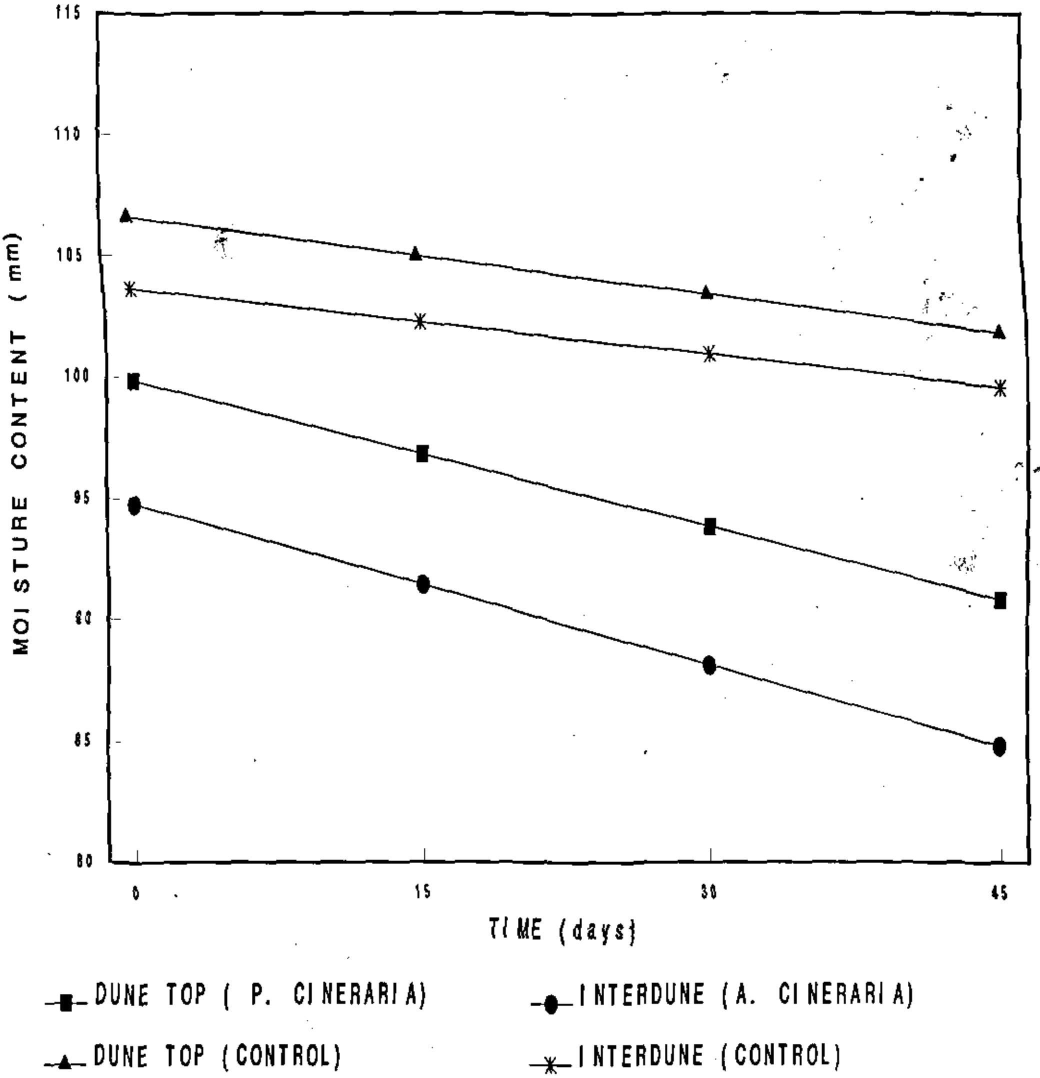


Figure 5 PROFILE MOISTURE STATUS UNDER DIFFERENT TREE SPECIES IN SUMMER SEASON (DUNE TOP VS. INTERDUNE)

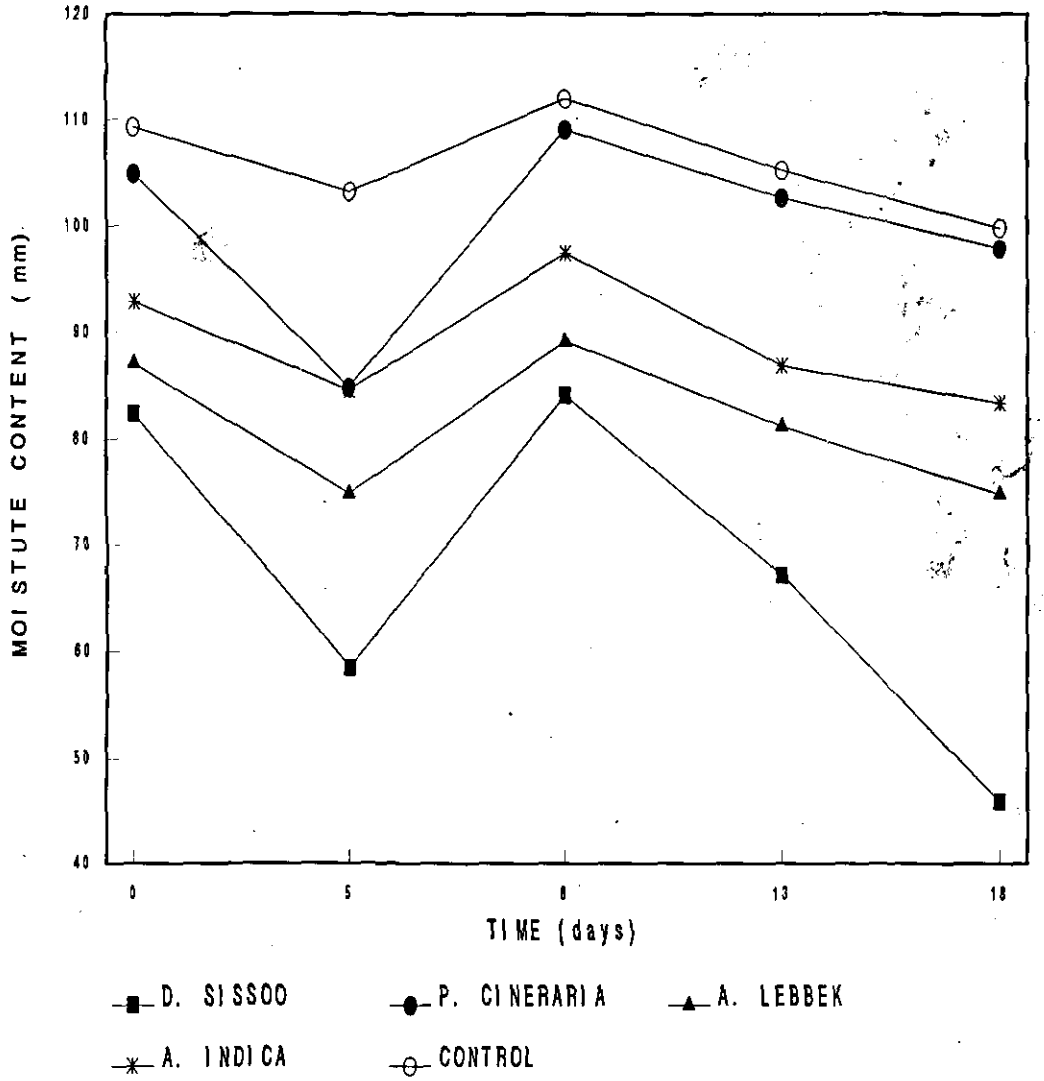


Figure 6 PROFILE MOISTURE STATUS UNDER DIFFERENT TREE SPECIES IN RAINY SEASON (DUNE TOP)

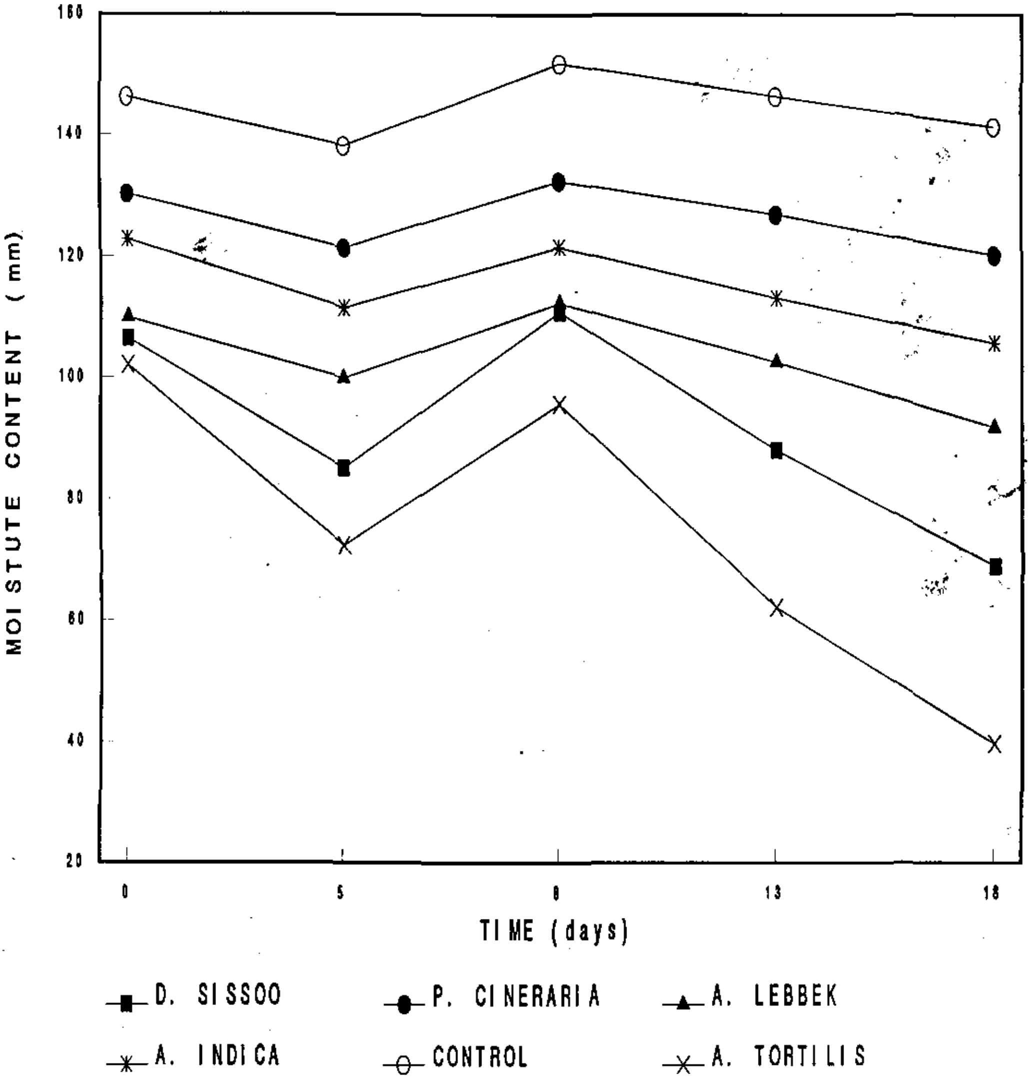


Figure 7 PROFILE MOISTURE STATUS UNDER DIFFERENT TREE SPECIES IN RAINY SEASON (INTERDUNE)

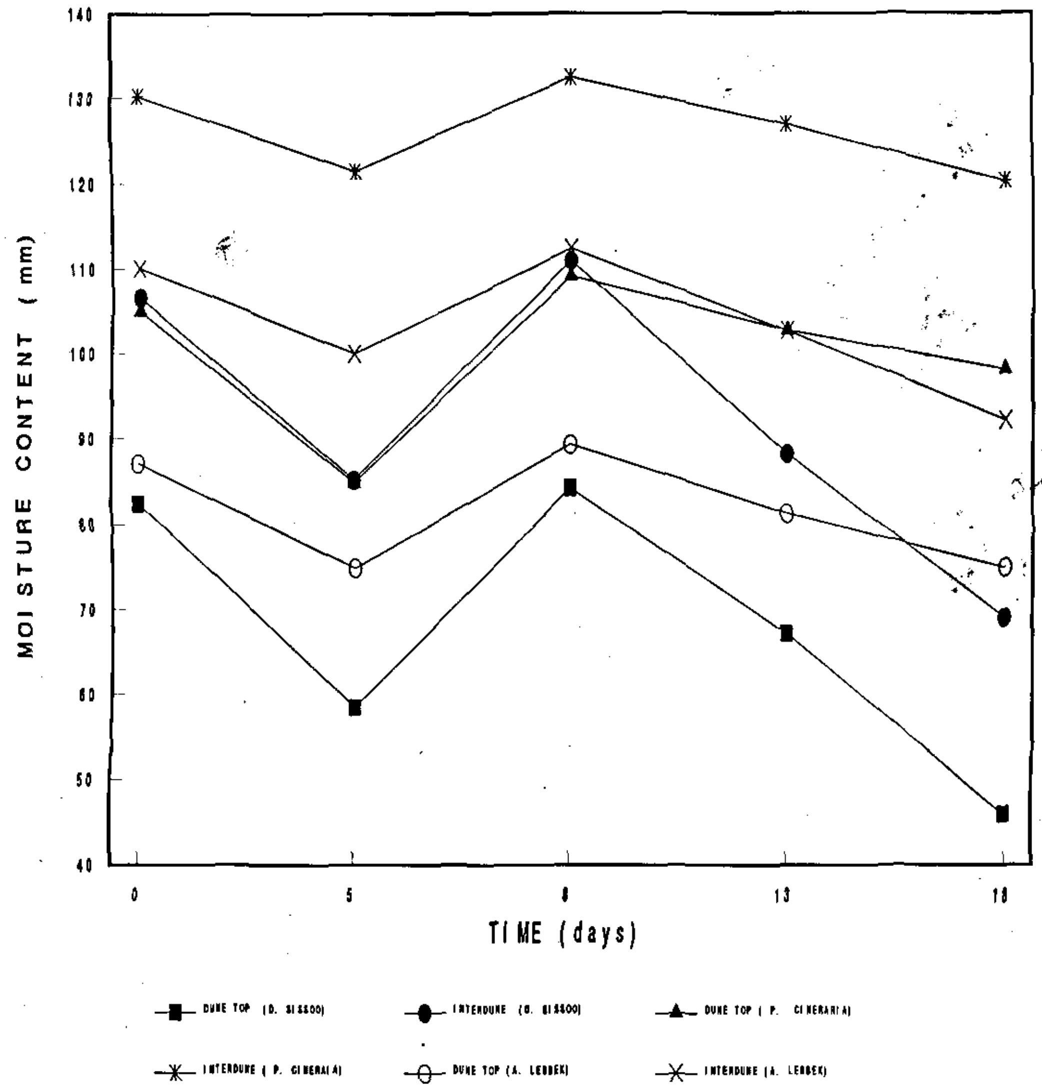


Figure 8 PROFILE MOISTURE STATUS UNDER DIFFERENT TREE SPECIES IN RAINY SEASON (DUNE TOP VS. INTERDUNE)

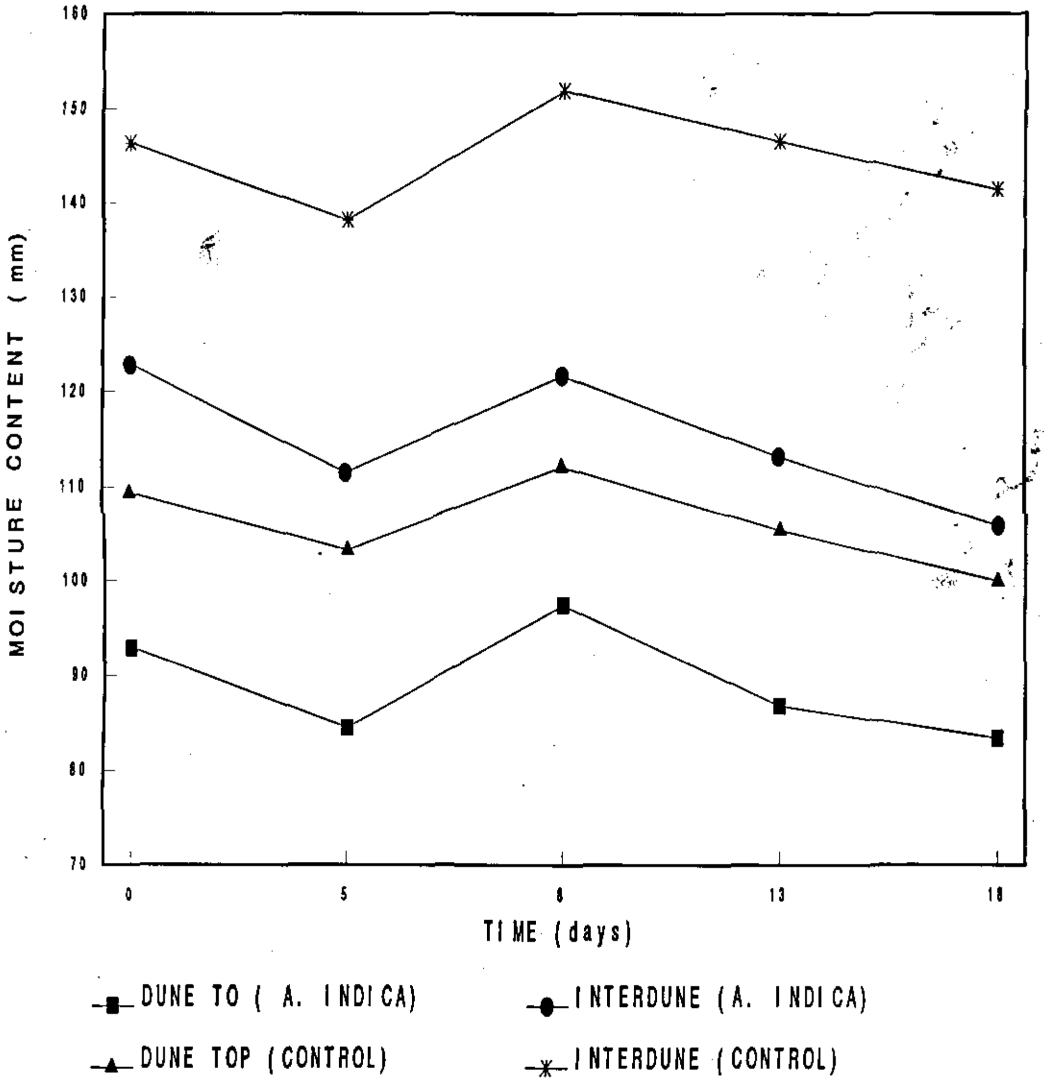


Figure 9 PROFILE MOISTURE STATUS UNDER DIFFERENT TREE SPECIES IN RAINY SEASON (DUNE TOP VS. INTERDUNE)

under control, minimum under Acacia tortilis and intermediate under Prosopis cineraria, Albizia lebbek and Dalbergia sissoo in both the seasons i.e. summer and rainy as well as in both the sites i.e. dune top and interdune. It was due to the water depletion rate of trees varied with different tree species according to their root system and nature of growth. On the basis of PMS, these tree species can be classified as: Control > Prosopis cineraria > Azadirachta indica > Albizia lebbek > Dalbergia sissoo > Acacia tortilis.

The PMS was more in dune top than in interdune in summer season (Figs. 4 and 5). This might be due to the reason that; i) The dune top was weed free site, so no moisture loss except depletion by trees took place; but at interdune, there was weed infestation, which caused the moisture loss. ii) Surface soil in dune top acts as a self mulch, which checks the evaporation losses. iii) Sand dune profile is deeper but interdune profile is limited to 2 m depth due to the presence of calcareous layer. Similar results on evaporation suppression by sand mulch were reported by Malik et al. (1978) and Modaihsh et al. *(1985)*.

It is seen from Figures 8 and 9 that the PMS was higher in interdune than dune top (which is reverse to the summer season), this was because of runoff accumulation in rainy season.

4.2.2 Depth-wise cumulative moisture depletion (DCMD) rate

It is evident from tables 7, 8, 9 and 10 that DCMD rate was higher in plantation area than the area devoid of trees in summer season as well as in rainy season. This might be due to the fact that in plantation soils, evapotranspiration process takes place but in case of control, there is only evaporation. Due to this evapotranspiration process, more soil moisture was depleted. The present results are in conformity with the findings of Mader et al. (1973) and Gupta et al. (1975).

From Tables 7 to 10, it was observed that in both the seasons (summer and rainy), the DCMD rate was maximum under Acacia tortilis followed by Dalbergia sissoo, Albizia lebbek, and Azadirachta indica and it was minimum under Prosopis cineraria. On the basis of these results, the multipurpose tree species according to their water requirement can be grouped as: Acacia tortilis > Dalbergia sissoo > Albizia lebbek > Azadirachta indica > Prosopis cineraria > Control. Similar results were also reported by Gupta et al. (1975), Jha and Rathore (1981) and Srivastava and Mishra (1987).

It was also seen that DCMD rate was more in rainy season as compared to summer season (Tables 7 to 10) in dune top as well as in interdune. It is mainly due to more evaporation and percolation losses because of higher saturation in rainy season. Similar results were

Table 7. Depthwise cumulative moisture depletion rate (mm/day) under different tree species in summer season (Dune top).

Soil depth	Tree species				Control
(cm)	D. sissoo	A. lebbek	A. indica	P. cineraria	
15-30	0.090	0.050	0.070	0.040	0.009
15-45	0.180	0.080	0.100	0.050	0.019
15-60	0.210	0.110	0.130	0.070	0.028
15-75	0.250	0.140	0.150	0.080	0.037
15-90	0.310	0.170	0.160	0.100	0.040
15-105	0.320	0.190	0.180	0.120	0.050
15-120	0.330	0.210	0.200	0.150	0.060
15-135	0.370	0.230	0.208	0.190	0.070
15-150	0.390	0.260	0.215	0.200	0.080
15-165	0.410	0.300	0.220	0.210	0.090
15-180	0.430	0.320	0.250	0.214	0.100

Table 8. Depthwise cumulative moisture depletion rate (mm/day) under different tree species in summer season (Interdune).

Soil depth	Tree species					Control
(cm)	A. tortilis	D. sissoo	A. lebbek	A. indica	P. cineraria	
15-30	0.060	0.040	0.030	0.008	0.150	0.014
15-45	0.110	0.070	0.070	0.098	0.160	0.021
15-60	0.130	0.130	0.080	0.100	0.165	0.029
15-75	0.170	0.150	0.100	0.110	0.170	0.037
15-90	0.220	0.170	0.130	0.120	0.174	0.044
15-105	0.250	0.200	0.160	0.140	0.179	0.052
15-120	0.290	0.220	0.190	0.150	0.183	0.053
15-135	0.320	0.260	0.230	0.160	0.188	0.066
15-150	0.350	0.310	0.260	0.170	0.192	0.074
15-165	0.400	0.350	0.270	0.190	0.195	0.082
15-180	0.450	0.380	0.300	0.210	0.200	0.090

Table 9. Depthwise cumulative moisture depletion rate (mm/day) under different tree species in rainy season (Dune top).

Soil depth	Tree species				Control
(cm)	D. sissoo	A. lebbek	A. indica	P. cineraria	
15-30	0.36	0.01	0.19	0.09	0.08
15-45	0.77	0.21	0.42	0.19	0.19
15-60	1.15	0.38	0.58	0.34	0.30
15-75	1.46	0.47	0.74	0.43	0.41
15-90	1.72	0.57	0.88	0.53	0.46
15-105	1.97	0.66	1.02	0.63	0.51
15-120	2.35	0.77	1.16	0.71	0.67
15-135	2.70	0.98	1.20	0.79	0.79
15-150	3.10	1.24	1.23	0.86	0.85
15-165	3.47	1.31	1.23	0.94	0.90
15-180	3.77	1.43	1.38	1.07	0.92

Table 10. Depthwise cumulative moisture depletion rate (mm/day) under different tree species in rainy season (Interdune).

Soil depth (cm)	Tree species					Control
	A. tortilis	D. sissoo	A. lebbek	A. indica	P. cineraria	
15-30	0.450	0.460	0.180	0.120	0.030	0.090
15-45	0.770	0.820	0.540	0.280	0.080	0.170
15-60	1.340	1.160	0.790	0.340	0.200	0.250
15-75	1.890	1.500	1.030	0.410	0.370	0.330
15-90	2.460	2.030	1.180	0.620	0.570	0.430
15-105	2.980	2.440	1.320	0.880	0.660	0.510
15-120	3.520	2.820	1.460	1.050	0.810	0.590
15-135	4.040	3.190	1.610	1.210	0.960	0.680
15-150	4.550	3.580	1.730	1.320	1.080	0.780
15-165	4.990	3.950	1.890	1.420	1.180	0.870
15-180	5.410	4.180	2.110	1.460	1.200	0.980

observed by Rogerson (1976).

4.2.3 Moisture depletion pattern

The per cent moisture loss by different tree species from 15-105 cm depth of 180 cm soil profile in summer season have been presented in Table 11. It is evident from the table that depletion of moisture by A. tortilis was maximum (66.20 %), whereas P. cineraria trees deplete only 41.67 per cent moisture for their normal growth. This was so because surface feeder roots (Primary, secondary and tertiary) of A. tortilis deplete more moisture from soil than P. cineraria which had deep root (tap root) system. The P. cineraria is also a slow growing specie and in the first six years establish its roots. Although, the growth of A. tortilis is much faster than slow growing P. cineraria. Similar results were reported by Mathur et al. (1988).

4.2.4 Cumulative Profile moisture depletion (CPMD)

The CPMD rate under different tree species in summer season have been illustrated in Figures 10 and 11 and it was found that CPMD rate of Acacia tortilis, Dalbergia sissoo and Albizia lebbek followed *linear relationship with time whereas* *Azadirachta indica* *and* Prosopis cineraria followed linear CPMD rate as a function of square root of time (In summer season, the soil moisture depletion is considered equal to evapotranspiration because percolation losses are not

Table 11. Moisture depletion pattern (%) of different tree species from 15-105 cm of 180 cm profile in summer season

Soil depth (cm)	A. tortilis	D. sissoo		A. lebbek		A. indica		P. cineraria		Control	
	Interdune	Dune top	Interdune	Dune top	Interdune	Dune top	Interdune	Dune top	Interdune	Dune top	Interdune
15-30	10.05	22.17	8.69	19.45	10.45	18.15	2.77	13.31	10.25	8.84	9.93
30-45	11.38	21.70	11.10	10.43	11.40	11.81	11.29	5.84	5.69	8.84	8.97
45-60	16.66	8.50	17.13	9.45	4.97	11.56	9.95	5.68	5.92	9.05	9.23
60-75	10.19	9.60	5.92	8.47	10.89	3.85	7.44	5.68	5.81	8.64	9.76
75-90	10.69	8.18	5.87	9.38	13.63	4.62	7.44	6.65	6.94	9.26	9.23
90-105	7.25	2.69	7.43	7.09	8.85	6.07	7.02	6.65	7.06	9.26	9.23
Total	66.2	72.84	56.14	64.27	60.19	56.06	45.91	43.81	41.67	53.89	55.67

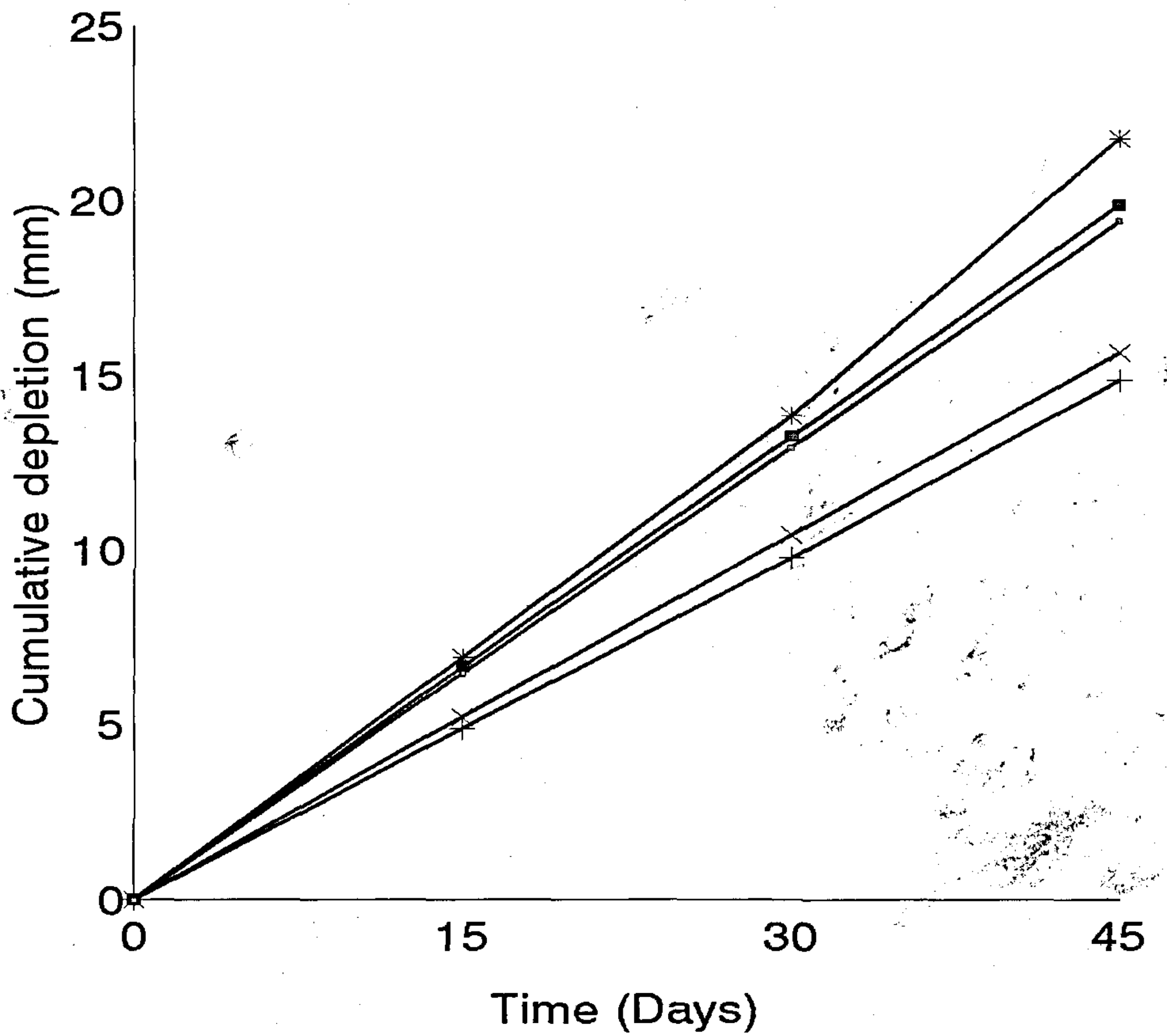
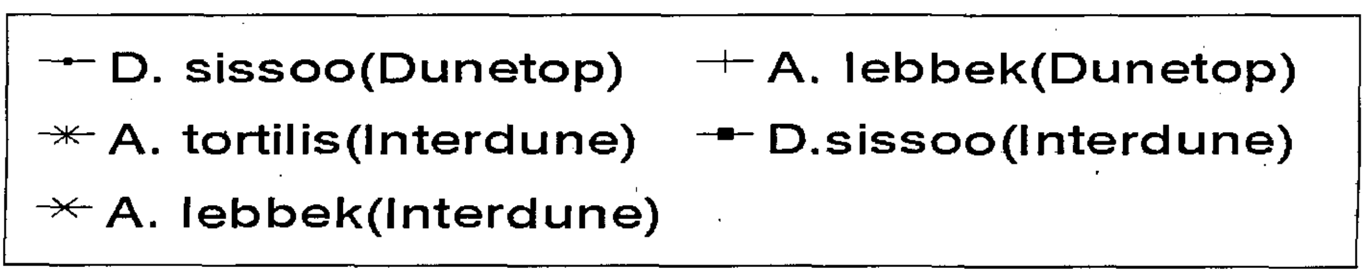


Fig. 10:- Cumulative profile moisture depletion under different tree species in summer season [Cumulative depletion v/s time (days)]



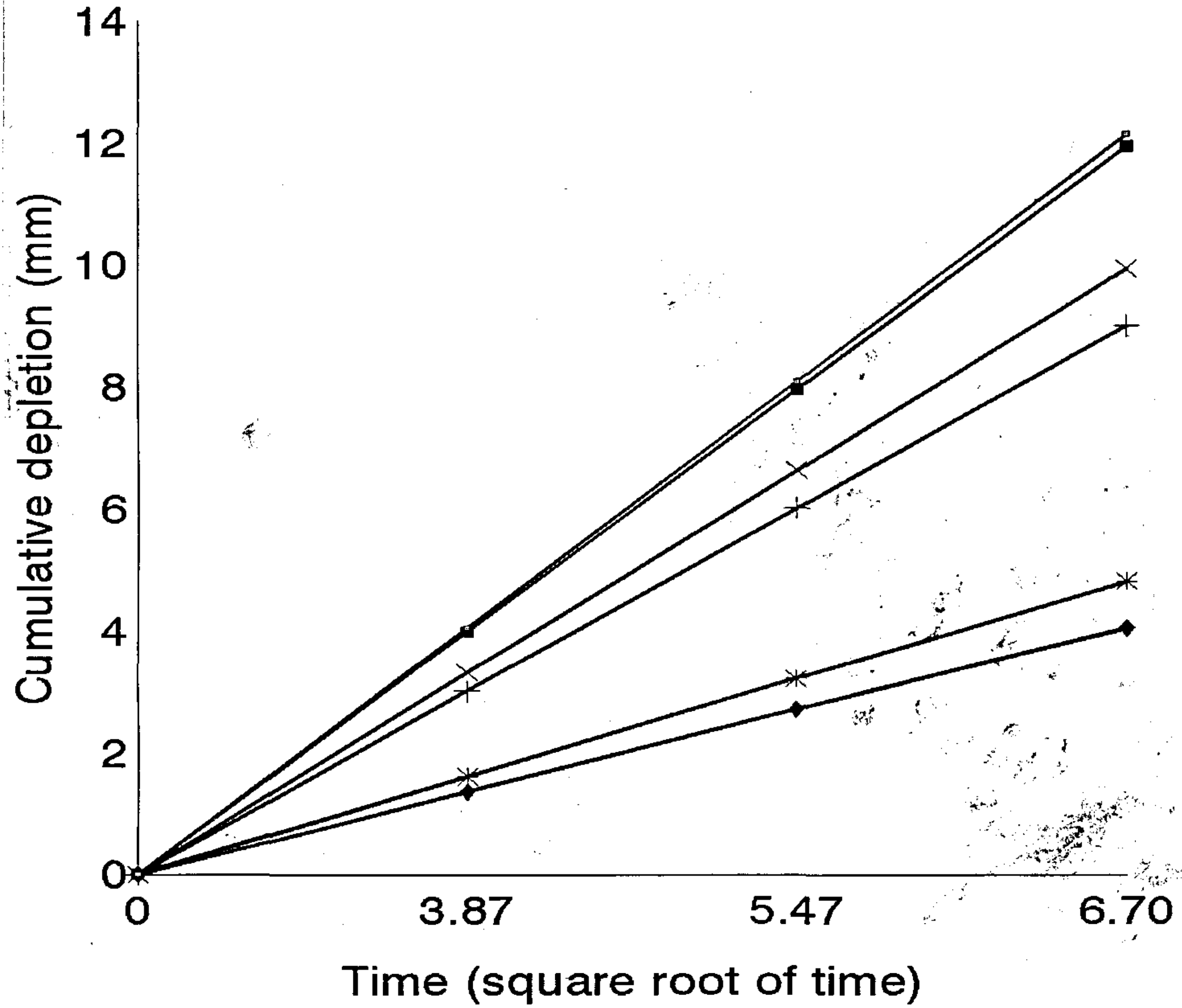


Fig. 11 Cumulative profile moisture depletion under different tree species in summer season (Cumulative depletion v/s square root of time)

A. indica(Dunetop)
P. cineraria(Dunetop)
Control(Dunetop)
A. indica(Interdune)
P. cineraria(Interdun)
Control(Interdune)

expected). The differences of behaviour among the tree species were according to their water requirement. In high water requiring trees, evapotranspiration has taken place as in case with pan evaporation but in low water requiring trees, only evaporation process has taken place as in case with cumulative evaporation from bare soil with time. Similar efforts were made by Hanks and Gardner (1965), Ekern (1966), Black et al. (1969) and Malik et al. (1992).

4.2.5 Moisture distribution pattern

Moisture distribution under D. sissoo and control in summer season has been illustrated in Fig 12 and for rainy season in Fig. 13. It is evident from the moisture content gradients that in summer season, the flux direction was upward but in rainy season, the moisture content of the deepest layer under D. sissoo (7.43 $cm^3/100\ cm^3$) and in control (9.62 $cm^3/100\ cm^3$) was above the field capacity (6.92 $cm^3/100\ cm^3$) as shown in figure 13. So there may be chances of percolation losses during rainy season.

Therefore, the depletion during rainy season is not entirely due to evapotranspiration but may include percolation losses. Hence we can not discuss distribution behaviour of depletion in rainy season from this limited data. These results corrobrate with the findings of Jha and Rathore (1981).

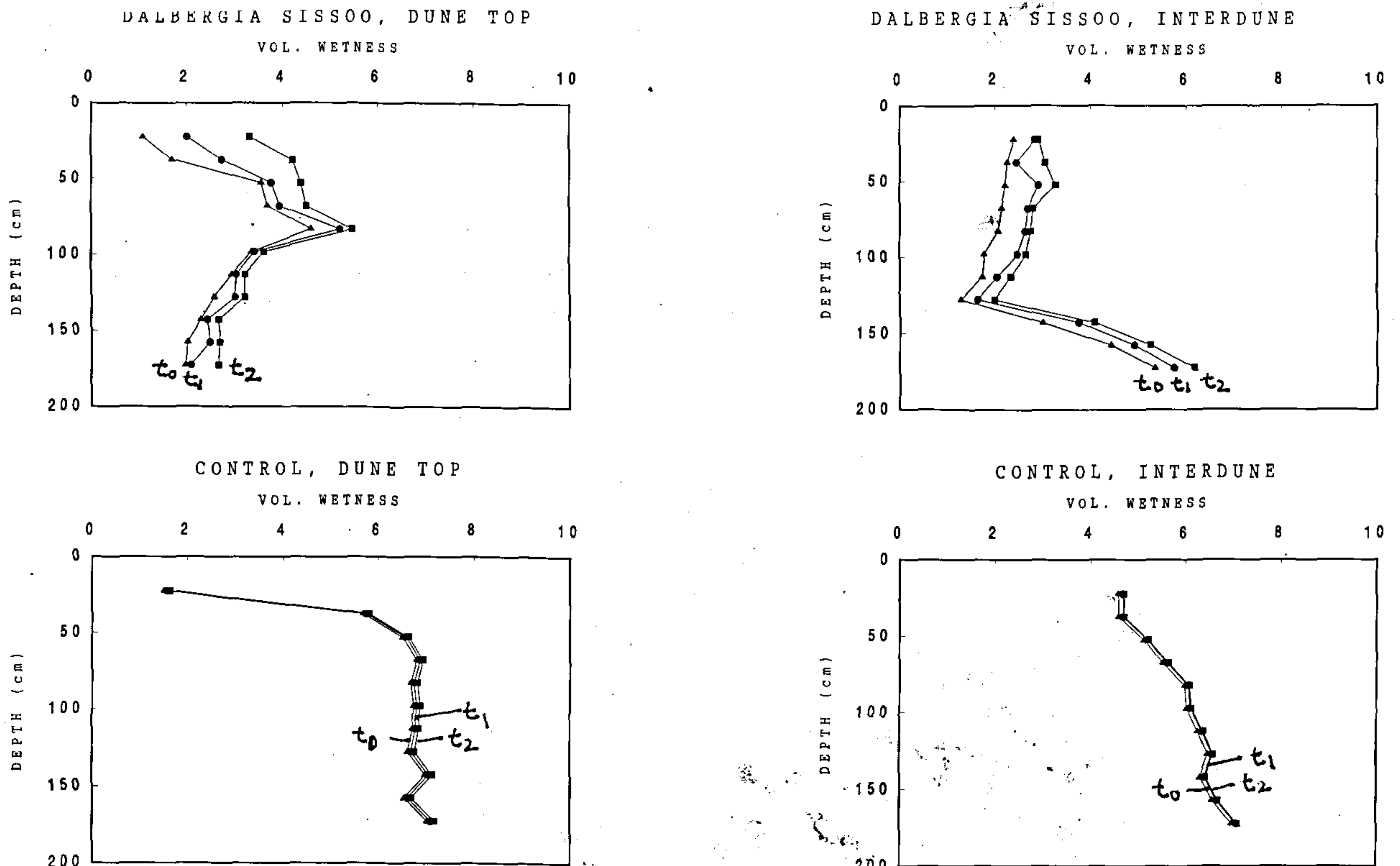


FIG. 12 MOISTURE DISTRIBUTION PATTERN IN DUNE TOP VS. INTERDUNE UNDER Dalbergia sissoo AND CONTROL DURING SUMMER SEASON

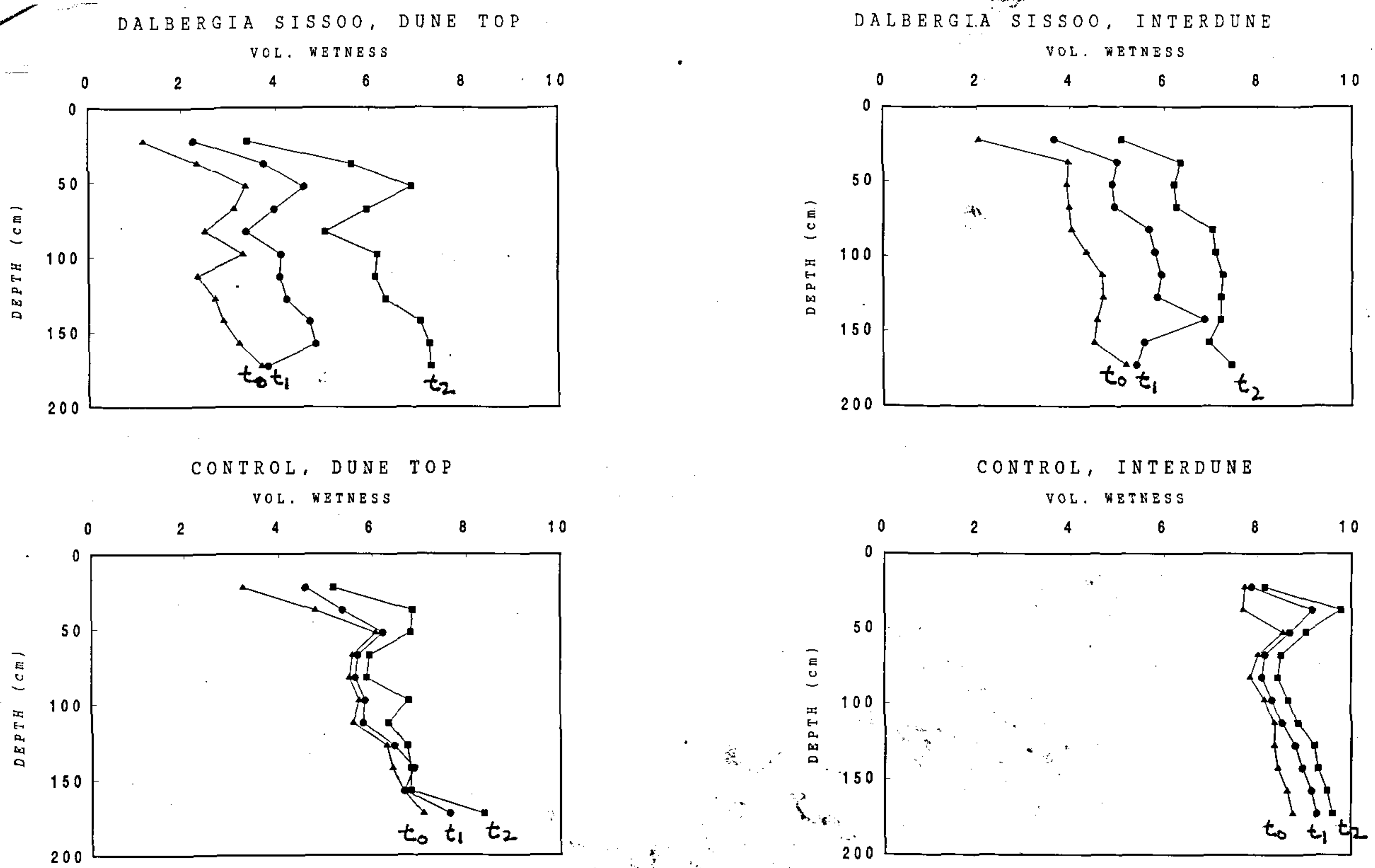


FIG. 13 MOISTURE DISTRIBUTION PATTERN IN DUNE TOP VS. INTERDUNE UNDER Dalbergia sissoo AND CONTROL DURING RAINY SEASON

SUMMARY AND CONCLUSION

CHAPTER-V

SUMMARY AND CONCLUSION

The present investigation entitled "Effect of different tree species on moisture depletion pattern of soil in a desert ecosystem" was carried out at NARP farm, Balsamand (Hisar). The results obtained are summarised and concluded below:

1. The soil of study site is extremely low in organic carbon and available nitrogen, low in available phosphorus but rich in available potassium.
2. Profile soil moisture content (15-180 cm) decreased with time under all the tree species in summer as well as in rainy season.
3. The moisture content was less in plantation area than the area devoid of trees.
4. The moisture status of 15-180 cm profile was higher at sand dune top than at interdune in summer season and reverse during rainy season.
5. Moisture depletion rate was more in rainy season as compared to summer season.
6. The soil moisture status at every time followed the order: Control > Prosopis cineraria > Azadirachta indica > Albizia

lebbek > Dalbergia sissoo > Acacia tortilis and reverse order was for moisture depletion rate.

7. Soil moisture depletion percentage was maximum in A. tortilis and minimum in P. cineraria, means A. tortilis is surface feeder and P. cineraria is deep feeder.

8. Cumulative depletion of moisture for A. tortilis, D. sissoo and A. lebbek increased linearly with time and for A. indica, P. cineraria and control it increased with square root of time.

9. The soil moisture loss in summer was due to evaporation and evapotranspiration but in rainy season, percolation losses have also occurred in addition to evaporation and evapotranspiration.

The practical application of the study may be that A. tortilis is not a beneficial tree under agroforestry system because it is a surface feeder and compete with the field crops for moisture and nutrients.

It further indicates that P. cineraria can be grown with agriculture crops in arid and semi-arid lands where water scarcity is main problem, it provides suitable microclimate to underneath crop and does not compete for moisture and nutrients. If the surface soil moisture is sufficient for germination, the tree growth may be better at sand dune top than at interdune because of more availability of moisture in deeper layer in summer season.

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APPENDICES

Appendix I

Profile moisture status under Acacia tortilis in summer season (Interdune)

Soil depth (cm)	26.02.96	11.03.96	26.03.96	10.04.96
15-30	4.45	4.02	2.32	2.26
30-45	4.68	4.25	2.55	2.20
45-60	4.87	4.33	3.90	3.24
60-75	6.43	5.57	4.99	4.21
75-90	6.96	5.66	5.08	4.63
90-105	5.74	5.14	4.88	4.16
105-120	5.62	5.05	4.53	3.97
120-135	5.25	4.95	4.49	3.94
135-150	5.19	4.84	4.49	3.44
150-165	5.46	4.56	4.45	3.56
165-180	5.31	4.59	4.38	3.49
Total	59.90	52.96	46.02	39.10

Appendix II

Profile moisture status under Dalbergia sissoo in summer season

Soil depth (cm)	Dune top				Interdune			
	Avearge moisture content (mm)							
	26.02.96	11.03.96	26.03.96	10.04.96	26.02.96	11.03.96	26.03.96	10.04.96
15-30	5.84	5.23	3.01	1.64	5.32	4.35	4.17	3.59
30-45	6.65	6.31	4.10	2.54	5.59	4.56	3.67	3.38
45-60	6.94	6.78	5.64	5.33	6.73	4.89	4.27	3.32
60-75	7.36	6.96	5.91	5.54	4.38	4.19	3.92	3.20
75-90	8.44	8.40	7.80	6.89	4.27	4.12	3.85	3.10
90-105	5.56	5.62	5.10	5.05	4.15	3.97	3.61	2.67
105-120	4.93	5.04	4.56	4.41	4.05	3.49	2.96	2.62
120-135	5.29	5.02	4.52	3.86	4.05	3.11	2.36	1.93
135-150	4.47	4.21	3.65	3.46	6.74	6.41	5.41	4.49
150-165	4.32	4.23	3.72	3.03	8.54	7.90	7.26	6.65
165-180	4.36	4.20	3.15	2.98	9.39	9.27	8.15	8.05
Total	64.16	57.68	51.20	44.73	62.90	56.26	49.63	43.00

Appendix III

Profile moisture status under Albizia lebbek in summer season

Soil depth (cm)	Dune top				Interdune			
	Avearge moisture content (mm)							
	26.02.96	11.03.96	26.03.96	10.04.96	26.02.96	11.03.96	26.03.96	10.04.96
15-30	6.27	5.60	5.26	4.83	5.85	5.83	4.97	4.21
30-45	6.54	5.65	5.51	4.87	6.03	5.96	4.57	4.24
45-60	6.57	5.92	5.57	5.05	6.10	6.10	5.65	5.32
60-75	6.92	6.45	6.04	5.55	5.80	5.28	5.03	4.09
75-90	7.07	6.54	6.05	5.56	5.75	4.28	4.02	3.61
90-105	5.94	5.64	5.14	4.78	5.54	4.70	4.32	4.15
105-120	5.85	5.58	5.07	4.60	5.54	4.73	4.35	4.08
120-135	5.75	5.56	4.99	4.57	5.50	5.30	4.99	3.98
135-150	5.68	5.46	4.89	4.43	6.65	5.82	5.50	5.06
150-165	5.60	4.99	4.20	3.86	7.29	7.33	7.06	6.82
165-180	8.12	7.86	7.49	6.96	8.27	7:76	7.40	7.07
Total	70.36	65.26	60.16	55.06	68.32	63.09	57.86	52.63

Appendix IV

Profile moisture status under Azadirachta indica in summer season

Soil depth (cm)	Dune top				Interdune			
	Avearge moisture content (mm)							
	26.02.96	11.03.96	26.03.96	10.04.96	26.02.96	11.03.96	26.03.96	10.04.96
15-30	7.74	6.92	5.63	4.42	7.67	7.15	5.72	4.35
30-45	7.80	7.00	6.90	6.42	7.92	7.22	6.72	6.57
45-60	7.98	7.27	7.03	6.63	8.01	7.24	7.03	6.82
60-75	7.96	8.03	7.99	7.51	7.35	6.80	6.76	6.46
75-90	8.16	8.14	8.08	7.62	8.17	8.00	7.60	7.28
90-105	8.47	8.53	8.46	7.76	8.20	8.10	7.68	7.36
105-120	8.64	8.54	8.48	7.90	8.35	8.18	7.74	7.40
120-135	8.80	8.86	8.81	8.40	8.51	8.42	8.23	8.13
135-150	9.88	9.91	9.57	8.58	8.47	8.29	8.23	8.13
150-165	9.13	9.14	8.85	8.66	9.80	9.65	9.30	9.21
165-180	10.65	9.64	10.09	9.63	11.54	10.35	10.52	10.33
Total	97.03	92.98	88.93	84.88	93.99	90.00	86.02	82.04

Appendix V

Profile moisture status under Prosopis cineraria in summer season

Soil depth (cm)	Dune top				Interdune			
	Avearge moisture content (mm)							
	26.02.96	11.03.96	26.03.96	10.04.96	26.02.96	11.03.96	26.03.96	10.04.96
15-30	3.71	2.50	2.15	1.70	4.64	4.55	4.16	3.66
30-45	6.91	6.59	6.22	5.96	6.25	6.18	5.91	5.64
45-60	9.43	9.38	9.00	8.79	6.77	6.71	6.44	6.14
60-75	9.42	9.36	9.41	8.78	7.98	7.93	7.66	7.36
75-90	9.74	9.67	9.29	9.04	8.28	8.23	7.86	7.56
90-105	9.71	9.64	9.40	9.01	8.15	8.05	7.70	7.40
105-120	9.78	9.73	9.40	9.11	8.20	8.13	8.07	7.87
120-135	9.93	9.78	9.43	9.13	9.28	8.83	8.17	7.88
135-150	10.05	10.01	9.66	9.38	11.15	11.09	10.82	10.48
150-165	10.55	10.50	10.15	9.61	11.01	10.87	10.60	10.34
165-180	10.70	10.57	10.21	9.91	12.15	10.96	10.74	10.49
Total	99.84	96.83	93.82	90.82	94.77	91.45	88.13	84.82

Appendix VI

Profile moisture status under control in summer season

Soil depth (cm)	Dune top				Interdune			
	Avearge moisture content (mm)							
	26.02.96	11.03.96	26.03.96	10.04.96	26.02.96	11.03.96	26.03.96	10.04.96
15-30	2.71	2.55	2.43	2.28	7.54	7.41	7.29	7.16
30-45	8.95	8.80	8.67	8.52	7.53	7.40	7.29	7.16
45-60	10.21	10.05	9.92	9.77	8.33	8.18	8.07	7.25
60-75	10.64	10.49	10.37	10.22	8.96	8.81	8.69	8.56
75-90	10.48	10.32	10.18	10.03	9.52	9.48	9.37	9.24
90-105	10.56	10.40	10.26	10.11	9.68	9.54	9.42	9.30
105-120	10.51	10.36	10.22	10.07	10.05	9.81	9.78	9.65
120-135	10.39	10.23	10.09	9.94	10.37	10.23	10.10	9.98
135-150	10.94	10.78	10.64	10.49	10.11	9.98	9.85	9.73
150-165	10.28	10.12	9.97	9.82	10.51	10.37	10.24	10.11
165-180	10.99	10.84	10.70	10.55	11.03	10.98	10.82	10.73
Total	106.63	105.02	103.41	101.80	103.63	102.27	100.92	99.57

Appendix VII

Profile moisture status (mm) under <u>Acacia</u> <u>tortilis</u> in rainy season

Soil depth (cm)	27.07.96	01.08.96	04.08.96	09.08.96	14.08.96
15-30	6.56	4.39	7.23	4.57	-
30-45	8.88	6.13	8.18	5.29	2.67
45-60	10.86	7.16	10.22	6.82	3.24
60-75	10.96	8.06	9.58	6.30	4.47
75-90	11.42	8.78	10.09	6.66	4.05
90-105	11.00	7.72	9.13	6.03	4.36
105-120	11.91	7.65	9.25	6.01	3.92
120-135	10.21	7.12	8.88	5.61	3.88
135-150	8.99	6.71	8.59	5.39	3.66
150-165	6.23	4.18	6.82	4.77	3.48
165-180	6.09	4.03	7.73	4.73	2.43
					3.52
Total	102.11	72.38	95.70	62.08	39.68

Appendix VIII

Profile moisture status (mm) under Dalbergia sissoo in rainy season

Soil depth (cm)	Dune					Interdune				
	27.07.96	01.08.96	04.08.96	09.08.96	14.08.96	27.07.96	01.08.96	04.08.96	09.08.96	14.08.96
15-30	4.91	3.05	5.44	3.40	1.81	6.92	4.87	7.65	5.49	3.06
30-45	7.01	5.18	7.68	5.63	3.52	10.69	6.81	9.51	7.51	5.94
45-60	7.95	6.39	8.90	6.88	5.01	10.74	6.57	9.29	7.32	5.87
60-75	7.89	5.48	7.83	5.93	4.65	10.14	6.64	9.38	7.41	5.96
75-90	7.48	4.09	6.36	5.04	3.74	10.38	7.79	10.53	8.53	6.05
90-105	7.74	5.19	7.47	6.16	4.94	10.41	7.87	10.64	8.72	6.53
105-120	7.72	5.12	7.40	6.12	3.51	9.87	8.16	10.86	8.91	7.03
120-135	7.55	5.30	7.58	6.33	4.05	9.80	8.14	10.81	8.80	7.06
135-150	8.03	6.05	8.33	7.07	4.33	9.62	8.31	10.81	8.79	6.87
150-165	8.16	6.26	8.54	7.26	4.84	9.10	7.95	10.44	8.41	6.78
165-180	8.10	6.32	8.58	7.28	5.52	8.99	12.05	11.15	8.14	7.81
Total	82.54	58.43	84.11	67.10	45.93	106.56	85.16		88.05	68.95

Appendix IX

Profile moisture status (mm) under Albizia lebbek in rainy season

Soil depth (cm)	Dune					Interdune				
	27.07.96	01.08.96	04.08.96	09.08.96	14.08.96	27.07.96	01.08.96	04.08.96	09.08.96	14.08.96
15-30	3.48	2.85	4.66	4.52	4.47	6.99	6.80	7.28	6.22	5.63
30-45	8.63	7.12	7.77	6.62	5.80	9.95	8.74	10.14	9.09	6.55
45-60	10.12	8.51	8.98	7.87	7.27	11.86	9.91	11.62	10.49	9.04
60-75	10.33	8.52	8.52	7.91	7.56	10.96	9.64	10.87	9.98	8.46
75-90	10.85	8.87	8.78	8.17	7.77	10.66	8.49	10.17	9.35	8.70
90-105	9.95	7.81	8.16	8.04	7.19	10.47	8.81	10.29	9.46	8.81
105-120	8.84	7.52	9.08	8.00	7.00	9.32	8.92	10.20	9.35	8.80
120-135	7.24	6.84	9.49	8.93	7.40	9.28	8.27	10.24	9.38	8.72
135-150	5.65	5.13	10.08	8.96	7.45	9.69	8.31	9.97	9.13	8.75
150-165	5.50	5.19	7.05	6.73	6.33	9.50	8.53	10.04	9.90	8.47
165-180	6.51	6.10	7.60	6.78	6.43	10.39	9.98	10.73	9.27	8.54
Total	87.10	74.86	89.17	81.18	74.79	109.07	99.48	110.55	100.90	90.41

Appendix X

Profile moisture status (mm) under Azadirachta indica in rainy season

Soil depth (cm)	Dune					Interdune				
	27.07.96	01.08.96	04.08.96	09.08.96	14.08.96	27.07.96	01.08.96	04.08.96	09.08.96	14.08.96
15-30	3.18	2.81	4.93	3.77	3.03	7.03	6.02	6.96	6.13	5.75
30-45	7.41	5.20	7.30	5.78	5.01	10.35	8.49	9.59	8.32	7.93
45-60	8.06	5.91	8.32	6.85	6.69	11.67	9.79	10.52	10.09	9.85
60-75	7.51	6.08	8.21	6.75	6.61	12.32	10.65	10.44	9.96	9.75
75-90	8.33	7.00	8.22	6.94	6.81	12.97	11.45	11.55	10.97	9.46
90-105	9.40	8.23	8.76	7.51	7.37	13.19	11.51	12.99	10.92	10.30
105-120	9.62	9.18	9.42	8.16	8.04	12.51	11.40	12.21	11.63	10.52
120-135	9.68	9.51	9.76	9.47	9.36	12.09	11.17	12.54	10.96	10.87
135-150	11.11	10.28	10.47	10.20	10.08	10.95	10.57	11.70	11.60	10.62
150-165	10.15	10.02	11.59	10.83	10.55	9.77	9.45	11.39	11.30	10.30
165-180	8.44	8.30	10.96	10.16	9.42	9.97	9.60	10.79	10.70	10.39
Total	92.89	84.51	97.44	86.82	83.38	122.82	111.48	121.59	113.08	105.74

Appendix XI

Profile moisture status (mm) in control in rainy season

Soil depth (cm)	Dune					Interdune				
	27.07.96	01.08.96	04.08.96	09.08.96	14.08.96	27.07.96	01.08.96	04.08.96	09.08.96	14.08.96
0-15	2.28	2.24	3.25	2.35	2.27	3.51	2.67	3.72	3.68	3.38
15-30	8.52	6.55	7.76	6.86	4.88	13.58	12.90	12.25	11.81	11.58
30-45	9.66	7.69	10.30	8.06	7.18	14.64	13.01	14.27	13.76	11.53
45-60	9.45	8.07	10.22	9.33	9.11	13.69	12.06	13.55	13.03	12.81
60-75	9.66	9.10	8.92	8.54	8.37	11.99	11.45	12.75	12.24	12.02
75-90	9.48	9.19	8.83	8.46	8.27	11.85	11.33	12.66	12.15	11.76
90-105	9.38	9.28	10.18	8.78	8.60	12.12	11.82	13.00	12.48	12.25
105-120	9.28	9.02	9.52	8.71	8.39	12.38	11.73	13.29	12.78	12.55
120-135	9.27	9.17	10.10	9.70	9.45	12.59	11.75	13.83	13.32	12.54
135-150	10.07	10.01	10.23	10.33	9.65	12.75	12.25	13.96	13.45	12.63
150-165	11.67	10.62	10.22	10.03	10.09	12.66	12.63	14.25	13.74	12.57
165-180	12.04	11.67	12.55	11.47	10.62	14.57	14.51	14.43	13.93	13.15
Total	107.08	100.97	108.83	102.91	97.56	142.82	135.44	148.16	142.77	137.91

Appendix XII

Profile moisture status (mm) under *Prosopis cineraria* in rainy season

Soil depth (cm)	Dune					Interdune				
	27.07.96	01.08.96	04.08.96	09.08.96	14.08.96	27.07.96	01.08.96	04.08.96	09.08.96	14.08.96
15-30	5.73	4.69	6.29	5.92	5.26	10.83	9.54	8.50	8.11	5.86
30-45	8.06	6.57	8.35	7.87	7.50	12.64	10.83	14.26	10.14	8.27
45-60	9.45	7.32	8.90	7.92	3.35	12.47	11.54	10.96	10.64	9.21
60-75	9.54	7.46	9.24	8.78	8.33	12.97	12.02	11.75	11.46	10.44
75-90	10.43	8.94	10.13	9.66	9.09	13.32	12.13	12.62	12.11	11.04
90-105	10.11	9.13	10.35	9.88	9.35	12.80	12.14	12.78	12.16	11.02
105-120	10.21	9.23	10.56	10.06	9.72	10.86	10.60	13.06	12.39	12.36
120-135	10.62	10.22	11.15	10.63	10.32	10.72	10.36	13.15	12.49	12.46
135-150	10.39	10.37	11.09	10.56	10.36	10.77	10.56	13.03	12.36	13.14
150-165	10.08	10.06	11.17	10.63	10.35	9.92	9.77	12.94	12.29	13.01
165-180	10.90	10.75	11.77	10.73	10.48	10.15	10.02	13.11	12.46	13.07
Total	105.02	94.86	109.00	102.62	97.91	127.45	119.71	131.99	120.80	120.18