Oecologia Montana 1999, **8**, 15 - 20

Morphological differences and habitat relationship of four common herb species of oak and pine forests of Central Himalaya

P.MEHROTRA, S.GARKOTI, Y.S. RAWAT, and S.P.SINGH

Department of Botany, Kumaun University Naini Tal, India

Abstract. The morphology of forest herbs was examined to determine how variation in growth form could relate to growth and survival in the forest. The four common herb species in both oak and chirpine forests were totally excavated in old growth forest in the Kumaun Himalaya. Both aboveground and belowground parts were measured oven dried and weighed. The different growth forms allow there species flexibility in exploiting the forest environment. The four species were different in rate of extension, growth and rooting depth in both forests. *A. vulgaris, G. gossypina, A. concinnum* and *O. contiguum* have difference in above and below ground growth within the species pairs and these differences in above and belowground growths often greatly effects the plant habitat, tolerances and competitive ability. The difference in growth form among the species help to explain their ability to survive and coexist in the heterogeneous forest floor environment and may be causal in determining distribution patterns..

Key-words: forest, herbs, belowground, mofphology, growth form

Introduction

The morphological differences in underground structures between the species examined are consistent with their distributional differences. Plants require few basic resources such as water and nutrients, which affect distribution and abundance of plants. Root structure is critical to the extraction of these resources and can determine environmental tolerances and out come of species interactions (Antos 1988). The nature of underground structure controls vegetative expansion and reproduction of species as well as their nutrients and water uptake (Weaver, 1919; Holch *et. al.* 1941). For a species to survive in a habitat variety of plant characteristics must be appropriate but of more interest than characteristics that allow a species to grow in a habitat are those that constrain it from growing elsewhere (Harper 1982). Underground morphology is relevant with some exceptions (Bell 1974, Hutching and Benkham 1976; Shireffs and Bell 1984, Pitelka *et. al.* 1988). The underground morphology of the Central Himalayan herbaceous plant forest has received inadequate attention. We examined morphology of four common herbs occurring both in oak and pine forests with emphasis on underground structures. Our specific objectives were(i) To document the differences in morphology of the species and changes that occur in them due to variations in site (ii) To evaluate the possible significance of various morphological features in relation to the growth and survival of the species in the forests.

Materials and Methods

The four common herb species of the two forest sites studied (oak and pine forest) were *Artemisia vulgaris* Sensu Hook F., *Gerbera gossypina* (Royle) Raisada and *Saxsena, Arisaema concinnum* Schoot and *Onychium contiguum* Wall. Oxhop.

The oak forest (*Quercus leucotrichophora* A. Camus) is located at 29°23' N lat. and 79°29'E long and chirpine forest (*Pinus roxburghii* Sarg.) at 29°22' N lat. and 79°26' E long. Both the site have south facing slopes. There are three well defined seasons in a year i.e. summer (April to mid-June), rainy (mid-June to September) and winter (November to February). May to June are the hottest months (27.4°C and 26.0°C mean temperature) and December and January are the coldest months (6.0° C and 3.5°C mean temperature). The annual rainfall is 2366 mm of which about 75% falls from mid-June to mid-September.

Oak and chir-pine forest have 80 and 60% crown density, respectively (Tewari and Singh 1982). Fire is quite frequent in chir-pine forest while it is rare in oak forest (Singh and Singh 1984). Shrub layer are common in oak forest but rare in chir-pine forest, largely due to frequent burning in Pine forest. So grasses formed a sizeable part of ground vegetation in chir-pine forest. The soil in oak and chir-pine forests of this region is residual brown earth derived from lime stones, quartzite, shales and sandy loam. The water holding capacity and pH of soil at 0-10 cm depth was relatively higher at oak forest site (66.3% and 6.30, respectively) than chir-pine forest (49.6% and 6.1, respectively) and the total nitrogen concentration was also relatively higher at oak forest (5.1%) than chir-pine forest (2.4%) (Table 1a).

The growth form and period of leaf development for four species are given in (Table 1b).

At each site five plants of each herb species were harvested in first week of October when plants had attained maximum biomass and were at reproduction stages. The plants were carefully excavated by hand and also by using some small digging implements. The below ground system was separated into rhizome/tuber/corm/taproot/ stolon and secondary roots. The above ground parts were also separated into different components (stem, leaves, inflorescence, flower and fruit, etc.). The number, and diameter (by using screwgauge) of main root, secondary root, stolon and stem length of four herb species at sites were measured. The leaf, flowers and fruits number were also recorded. The samples of all plant parts were dried separately in oven at 80°C till constant weight and weigh.

Results

Four herb species occurring at both pine and oak forests were compared for various morphological differences in different above and below ground parts.

Artemisia vulgaris an evergreen, erect form (Givnish 1987) with taproot system, occurred in forest gaps where stony rocks with thin soil were present. Plants were generally multistoryed in oak forest and had stolons which were generally not found in the pine forest's plants. The number of secondary roots (which were not dimorphic in nature) were more in plants growing in pine forest (21.6 number/plant) than in oak forest (14.2 number/plant). In pine forest roots also grew deeper. Leaves were comparatively fewer but larger in the oak forest plants. The total leaf area per plant was greater in chir pine forest, but values for many characters viz. specific leaf mass, canopy height, main root diameter and length were greater in oak forest. The species of oak forest had greater root:shoot ratio, leaf weight: below ground and leaf weight: total biomass than chir-pine forest plants. The percent allocation in stem and leaves of oak forest plants was also greater than in chir-pine forest plants, whereas, ratio between leaf weight; above ground biomass and percent allocation in main root and secondary roots were higher in chir-pine forest plants (Table 2a, Fig. 1).

Several aboveground parameters were significantly correlated with below ground biomass in oak forest plants (Table 2 b). In chir pine forest above ground parameters viz. plant height, aerial stem weight, leaf number and flower weight were significantly correlated with below around biomass. However, leaf weight and aerial stem diameter of plants were not significantly correlated.

Gerbera gossypina is a basal form (Givnish 1987) with radical leaves. The underground parts were tuberous. The upper surface of leaves was glaborus while lower surface was white tomentose and lobed. Leaf margins are minutely toothed. It grows commonly on shady places but occasionally occurs on dry slopes. The better growth was observed in oak forests. In this plant stem is pseudo-stem (leaf petioles give the appearance of stem by the overlapping of petiole bases). The below ground system consists of a single tuber running horizontally to the ground surface. However, secondary roots grew deep in soil up to 15.4 cm. in oak forest and 24.40 cm. in chirpine forest. All the components of plants in the oak forest showed more growth except secondary roots, which showed more growth in the pine forest. The ratio between leaf weight:below ground biomass, and leaf weight:total biomass, were higher in oak forest than pine forest. However, the root: shoot ratio of the plants was greater in chir pine forest than in oak forest. The total plant biomass was higher in oak forest (Table 2a, Fig. 1).

Positive significant correlation were observed between belowground biomass and different above ground parameters of plants in oak forest (Table 2b).

Arisaema concinnum: This herb species generally occurred in deeper shade and avoided open-crown sites (soil and free of stones). The plants deployed leaves from July to November thereafter stem died off. It had characteristically light cream coloured ball like below around structure called tuber from which unbranched stem with crown of leaves emerged. The plants of pine forest had comparatively higher canopy height than oak forest plants. Other parameters such as number of leaves, total leaf area, specific leaf mass, corm diameter and corm length, root depth and total biomass were greater in oak forest (Table 2a). The different plant component ratios in chir-pine forest were also higher (Table 2a, Fig. 1). Many positively significant correlations were observed between below ground and other parameters of above ground components in oak forest plants. The correlation between below ground biomass and leaf number (in both forests) and aerial shoot of pine forest plant were not significant (Table 2b).

Onychium contiguum: This species is rhizomatous fern. The stipes were stamineous but base invariably black and lamina was more pinnate in both the forests. This is one of the commonest terrestrial fern around Nainital. It grows near forest margins on soil which is rich in forest floor organic matter and grows never in open canopy area. This plant had tube like below ground structure which runs horizontal and from which numerous secondary roots emerged. The secondary roots were dimorphic in nature. The growth of above ground components of this species was greater in oak forest as compared to the pine forest (Table 2a, Fig. 1) The below ground component of this species in oak forest also showed higher growth than in chir-pine forest. The secondary root diameter had similar growth in both the forests (Table 2a). The total biomass and different ratios were also greater in oak forest than in pine forest. The plant height, aerial shoot weight, leaf weight, and sporophylls of plants in both forests showed positive correlation with below ground biomass (Table 2b).

Discussion

Comparison of the growth performance of herbs in the two study sites indicate that the growth of herb species was influenced by micro-

Parameters	Soil depth (cm)	*Q.leucotrichophora*	*P. roxburghii*
Fine soil	0-10	48.8±2.45	36.9±2.55
	10-20	41.1±2.39	33.0±2.30
	20-30	38.6±3.41	29.6±3.41
Bulk density	0-10	0.62±0.03	0.83±0.026
	10-20	0.79±0.04	0.94±0.023
	20-30	0.86±0.03	1.05+0.028
Water holding capacity %	0-10	66.3±3.72	49.5±5.05
	10-20	57.0±4.04	43.3±3.92
	20.30	54.0±2.88	38.9±3.12
pH	0-10	6.3±0.008	6.3±0.011
	10-20	6.0±0.000	6.1±0.011
	20.30	6.0±0.00	5.9±0.00
Carbon mg/g	0-10	44.1±0.63	36.3±0.11
	10-20	24.7±0.40	14.3±0.17
	20-30	30.4±0.20	13.7±0.43
Organic matters mg/g	0-10	76.0±1.09	62.5±0.20
	10-20	42.3±0.69	24.6±0.28
	20-30	35.0±0.39	23.6±0.72
Nitrogen concentration mg/g	0-10	5.1±0.23	2.4±0.17
	10-20	2.8±0.05	1.4±0.23
	20-30	2.2±0.11	1.1±0.20
Calcium mg/g	0-10	3.4±0.098	1.4±0.17
	10-20	2±0.28	1.0±0.11
	20-30	1.67±0.23	0.77±0.04
Sodium/mg/g	0-10	0.40±0.20	0.15±0.028
	10-20	0.19±.054	0.073±0.001
	20-30	.88±.019	0.048±0.004
Potassium mg/g	0-10	1.28±0.115	0.71±.005
	10-20	0.63±0.75	0.29±0.049
	20-30	0.30±0.057	0.15±0.031
Available Phosphorus mg/g	0-10	0.15±0.028	0.08±0.011
	10-20	0.09±0.17	0.05±0.005
	20-30	0.07±0.011	0.63±0.005

Table 1a. Physical and chemical properties of *Q. leucotrichophora and* *P. roxburhii* forests soils

Species	Growth Form	Seasonal Periodicity
1.*A.vulgaris*	Erect form. Taproot plant	Evergreen leaves, flowering in September last week to October
2.*G.gossypina*	Basal form parts belowground running horizontaly to the ground surface	Evergreen leaves. Flovering absent during study
3.*A.concinnum*	Unbranched stem rising from a corm tuber with a leaf crown (Leaves in same place)	Rainy season green. Flowering during study period
4.*O.contiguum*	Fern, basal form. rhizomatous plant	Rainy season green. Flowering during study period.

Table 1b. Species, growth form and their periodicity of growth

environmental factors and response to site variation varies from species to species. In *Artemisia* of chir-pine forest leaf number was significantly greater than in the oak forest, but no such difference was displayed by the other species except *Gerbera*. The leaf area of *Artemisia* increased markedly in the pine forest and that of the remaining three species declined. The rest three species seemed to be shade-loving.

The specific leaf mass of all herb species was in more shady environment of oak forest. In *Artemisia* the stolon was present only in individuals of oak forest indicating greater tendency for vegetative propagation. This is consistent with the observation that the proportion of the sophytes increases in more disturbed environment (Saxsena and Singh 1982). Fire, grazing and rapid soil erosion make a pine forest environment highly disturbed promoting the sophytic flora (Saxsena and Singh 1982). The dimorphic root system has been found only in *Onychium*. The dimorphic root system gives the clonal fragments considerable ability to integrate resource and take advantage of improvements in microsite

Parameters	*A. vulgaris* Oak Forest	*A. vulgaris* Pine Forest	*G. gossypina* Oak Forest	*G. gossypina* Pine Forest	*A. concinnum* Oak Forest	*A. concinnum* Pine Forest	*O. contiguum* Oak Forest	*O. contiguum* Pine Forest
1	2	3	4	5	6	7	8	9
Number of aerial stem/Plant	1.60*	1.00	-	-	1.00 NS	1.00	2.00*	1.00
Number of leaf/Plant	62.0**	115.40	18.40*	15.20	20.20	18.40	17.40 NS	17.60
Total leaf area (cm^2 / plant)	900.86**	1838.86	2001.92**	1306.136	460.57 NS	372.78	1257.32**	820.15
Specific leaf mass (gm/cm^2)	0.118**	0.004	0.009 NS	0.009	0.156 NS	0.013	0.008*	0.005
Plant height (cm)	138.00*	118.20	13.40 NS	12.60	102.40 NS	110.20	55.20*	46.40
Main root diameter (cm) (Tap/tuber/ rhizome)	1.08*	0.71 NS	1.38	1.24 NS	4.88	4.08 NS	1.18	1.02
Main root length (cm)	6.50**	4.00	8.16*	13.98	4.40 NS	3.46	11.60*	19.20
Number of Sec. root/plant	14.20*	21.60	21.30**	36.40	3.80**	15.40	175.00*	133.00
Secondary root diameter (cm)	0.17*	0.21	0.16 NS	0.20	0.15 NS	0.17	0.04 NS	.05
Secondary root length (cm)	15.20*	17.40	11.36*	18.66	4.50*	7.33	13.33*	8.00
Root depth (cm)	13.30*	22.00	15.14*	24.40	21.40*	13.60	16.60*	12.70
Stolen number	2	-	-	-	-	-	-	-
Stolen diameter (cm)	1.04	-	-	-	-	-	-	-
Stolen length (cm)	4.40	-	-	-	-	-	-	-
Total biomass (gm/plant)	50.701 NS	51.283	50.022**	47.865	215.28 NS	60.77	57.214*	39.746
Leaf wt and aboveground biomass ratio (%)	24.12	27.735	100	100	4.827	19.04	46.08	39.11
Leaf wt. and belowground biomass ratio (%)	64.915	31.42	62.72	37.19	10.856	13.811	30.50	19.18
Leaf wt and Total biomass ratio (%)	18	15	38.547	27	4	8	18	10
Root and shoot ratio	0.29	0.88	1.59	2.69	0.44	1.38	1.51	2.76

Table 2a. Means of plant Characteristics for four herb species common in both oak and pine forests. For each species at each site significant differences (T-test between species in pairs) are indicated by asterisk (*=P<0.05,**<0.001 and NS = non-significant)

condition (Antos 1988). According to Grime (1977) the dimorphic rhizome system allows plants to respond to both spatial and temporal variation in the forest floor environment and make the species stress tolerator. The minimal energy is invested by the plant to the below ground organs like Arisaema, where leaves constructed crown at the top of aerial shoot to utilise the maximum solar radiation and fine secondary roots are few in number. For this type of plant Antos (1988) gave explanation that these were all due to integrate resource and take advantage of improvements in microsite conditions. The microsite of plant which receives the filter light affects the growth of plants stolon system and also influence the branching system of plant. The microsite of plant slightly interfers the growth form. The major growth form characteristics remain more or less constant and can be used to evaluate habitat and distribution differences with in the species pairs (Antos 1988). Although the above ground characteristics of species, viz. differences in phenology (Mahall and Boramann 1978), leaf height (Givinsh 1982), and leaf physiology (Young and Smith 1979). often greatly affects the plants habitat tolerances competitive, the morphology of underground structures can also have important ecological consequences.

Weaver (1919, 1958 a, b) demonstrated that vertical root distribution of plant is an important variable affecting water relations among grassland herbs.

Bierzychudek (1982) said that the characteristics of underground organs may allow species to exploit resources differently. These characteristics of underground organs are still poorly understood in the field of ecological implications. So Weaver (1953) said that the detailed examination of the roots of grassland plants yielded explanations of many species responses, similar studies of forest plants would be illuminating.

References

Antos, J.A. 1988: Underground morphology and habitat relationships of three pairs of forest herbs *Amer. J. Bot.*, **(75) 1:** 106-113.

Bell, A.D. 1974: Rhizome organization in relation to vegetative spread in Medeola virginiana *J. Arnold Arbor.*, **55:** 458-468.

Bierazychudek, P. 1982: Life histories and demography of shade tolerant temperate forest herbs: a review *New Phytol.*, **90:** 757-776.

Grime, J.P. 1977: Evidence for the existence of three

S.N.	Species	Vegetative stage (r)		Reproductive stage (r)	
X	Y	Oak Forest	Pine Forest	Oak Forest	Pine Forest
1	2	3	4	5	6
		Artemisia	***vulgaris***		
(1) Tap root weight	Plant height	0.9308*	0.9208*	NS	0.9001*
(2) do	Aerial stem weight	0.8459*	0.9107*	NS	0.83002*
(3) do	Leaf weight	0.8841*	0.8655*	0.9721**	NS
(4) do	Leaf number	0.9281*	0.9472*	0.9727**	9828**
(5) do	Aerial stem diameter	0.9159*	0.9516*	0.9448*	NS
(6) do	Flower weight	-	-	0.8496*	0.8942*
		Gerbera	***gossypina***		
(1) Tuber weight	Plant height	0.8554*	0.8762*	NS	0.9062*
(2) do	Leaf weight per plant	0.9210*	NS	0.8840*	NS
(3) do	Leaf number	0.9748*	NS	0.9971**	NS
(4) do	Leaf area (cm^2 per leaf)	0.8444*	0.9337*	NS	
		Arisema	***concinnum***		
(1) Tuber weight	Plant height	0.8037*	0.9650**	0.8752**	0.9044*
(2) do	Aerial stem weight	0.9745 **	0.9555**	0.9812**	0.9681**
(3) do	Leaf weight	0.9600**	0.9513*	0.9383**	0/9121*
(4) do	Leaf number	0.9228*	0.9021*	NS	NS
(5) do	Aerial stem diameter	0.8966*	0.8517*	0.9282*	NS
(6) do	Fruit weight	-	-	0.9882**	0.9064*
		Onychium	***contiguum***		
(1) Rhizome weight	Plant height	0,9740**	0.8844*	0.9268*	0.9330*
(2) do	Aerial stem weight	0.9605**	0.9505*	0.9980**	0.9888**
(3) do	Leaf weight	0.9082*	0.8859*	0.9521*	0.9620*
(4) do	Aerial stem diameter	0.9273*	0.8321*	NS	NS
(5) do	Sporophyll	-	-	0.9367*	0.9094*

Table 2b Correlation (r) between taproot/ tuber/ rhizome and growth of above ground parts of herbs in oak and chir-pine forests

primary strategies in plants & its relevance to ecological and evolutionary theory *Am. Naturalist*, **11:** 1169-1194.

Givnish, T.J. 1982: On the adaptive significance of leaf height in forest herbs *Am. Naturalist*, **120:** 353-381.

Givnish, T.J. 1987: Comparative studies of leaf form assessing the relative roles of selective pressure and phytogenetic constraints. *New Phytol.*, **106** Suppl. 131 - 160.

Harper, J.L. 1982: After description In *The plant community as a working mechanism* (ed E.I. Newman) pp. 11-25 Blackwell scientific Publication Oxford.

Hutchings, M.J. and J.P. Barkham 1976: An investi gation of shoot interactions in *Mercurialis perennis* L, a rhizomatous perennial herb *J. Ecol.*, **64**: 723-743.

Holch, A.E., E.W. Hertel, W.O. Oakes and H.H. Well 1941: Root habits of certain plants of the foot hill & alpine belts of Rocky Mountain National Park. *Ecol. Monogr.*, **11:** 327-345.

Mahall, B.E. and F.H. Boramann 1978: A quantitative description of the vegetative phenology of herbs in a northern land wood forest *Bot. Gaz.*, **139:** 467-481.

Pitelka, L.F. 1988: Haissen and J.W. Ashmun 1985. Population biology of clintonia boreates I. Ramet and Root dynamics *J. Ecol.*, **73:** 169-183.

Saxsena, A.K. and Singh, J.S. 1982: A phytosociological analysis of woody species in forest communities of a part of Kumaun Himalaya *Vegetatio*, **50**: 3-22.

Shireffs, D.A. and A.D. Bell, 1984: The rhizome growth and clone development in *Anemone anemorosa* L. *Ann. Bot.*, **54**: 315-324.

Singh, J.S. and Singh, S.P.1984: An Integrated Ecological study of eastern Kumaun Himalaya with emphases on natural resources. Kumaun University, Nainital India, final report submitted to the Department of Science and Technology, New Delhi.

Tiwari, A.K., Tiwari J.C. and Singh, J.S. 1983: Application of aerial photo-analysis for assesment of vegetation in Kumaun Himalaya. II Kathgodam to Okhal kanda proc. *India Nati. Sci. Ada CB SC*, 421-435.

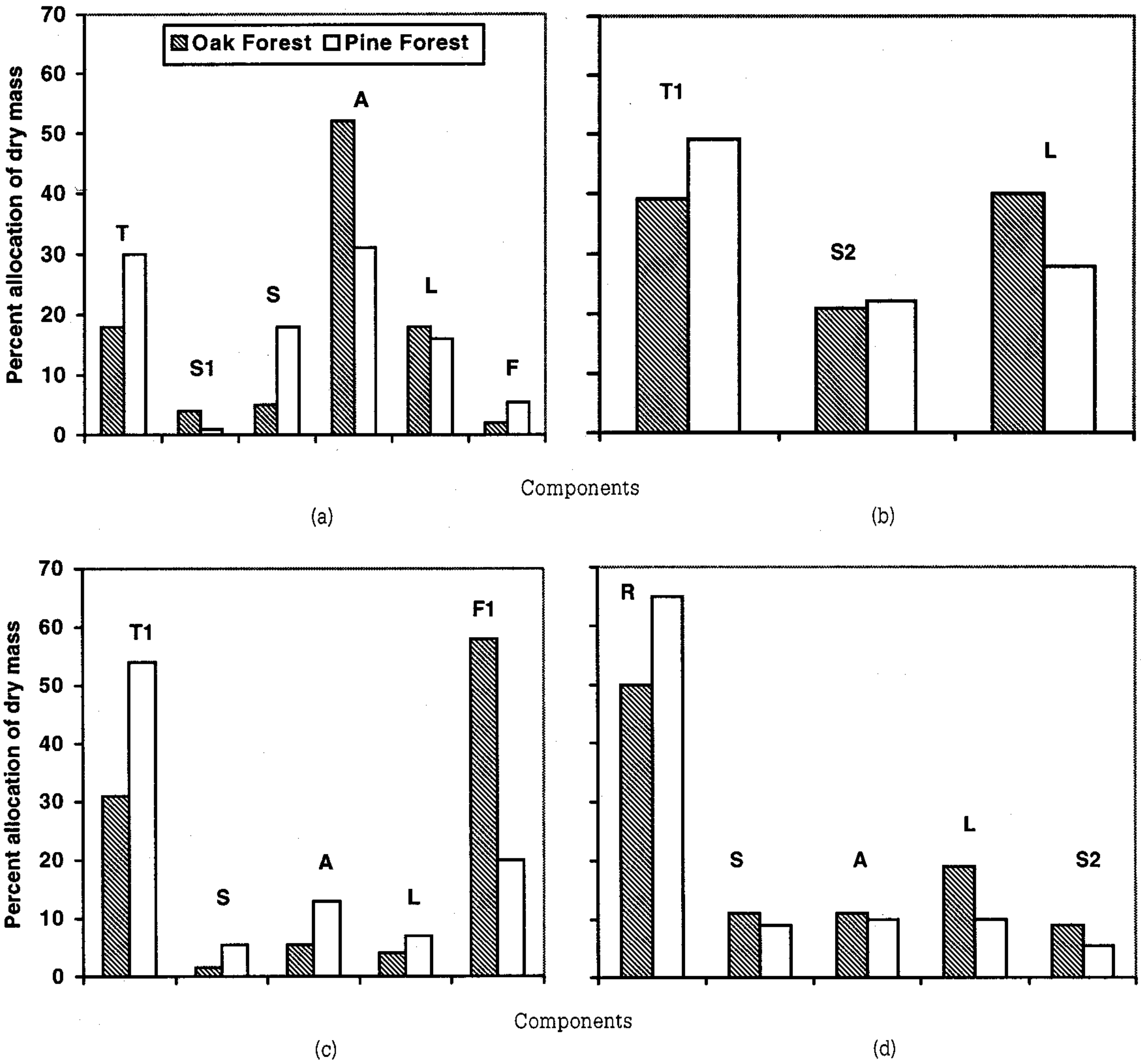

Fig. 1. Percent dry mass distribution in four pairs of forest herbs (a) *Artimisia vulgaris*, (b) *Gerbera gossypina*, (c) *Arisaema concinnum*, (d) *Onychium contiguum*.T - Taproot mass; S1 - Stolons mass; S - Secondary roots mass; A - Aerial stem mass; L - Leaves mass; F - Flowers mass; T1 - Tuber mass; F1 - Fruits mass; R - Rhizome mass; S2- Sporophylls mass

Weaver, J.E. 1919: The ecological relation of roots. Carnegee Institution of Washington Publication number 286.

Weaver, J.E. 1958a: Summary and interpretation of underground development in natural grass land communities *Ecol. Monogr.*, **28**: 55-78.

Weaver, J.E.1958b: Classification of root systems of forests of grassland and a consideration of their significance. *Ecology*, **39**: 393-401.

Young, D.R. and W.K. Smith 1970: Sunflecks on the temperature and water relations of two subalpine understory conquerors. *Oecologia*, **43**: 192-205.

Received 4 August 1998; revised 11 December 1998; accepted 4 April 1999.