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Composition of Understory Vegetation in Major Shrub Species of Cholistan Desert, Pakistan

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Abstract: Current study was done in Cholistan desert (27° 42' and 29° 45' North and longitudes 69° 52' and 75° 24' East) to study the understory vegetation of major shrub species. Phytosociological as well as soil chemistry were analysed to find the association among various plant species forming understory vegetation of shrubs. Quadrats (1 m^2) sampling given the species data forming the plant communities underside the canopies of shrubs and then cover, relative cover, relative frequency, relative density, importance value index and some dominant ratios of each plant species were calculated following standard methods. Field guides were used for the identification of the plant species and study was repeated for three times. Understory soil chemistry varied among all shrubs species and there was no consistency among various physico-chemical parameters. Two grass species (*C. ciliaris* and *S. plumose*) and one shrub (*S. baryosma*) were noted to be most frequent and form good association among the other understory plant species. Other understory plant species found to have little associations with other understory plant species. Plant eco-physiological studies are needed to find the indepth phenomenon of plant communities formation among the plants.

Key words: Cholistan desert · Quadrat · Shrubs · Phytosociology · Plant species

INTRODUCTION

Vegetation is a driving force of all kind of life in any ecological area. Plant species with different life forms from grasses, forbs, shrubs and trees growing in any particular area specifically to a rangelands serve as an important sources of fodder to the herbivorous fauna [1], hence it is thought as a natural and an important phenomenon to maintain carrying capacity of any rangelands [2]. Grazing animals, both wild and domesticated, have great impacts in a rangeland in various ways including remove vegetation cover, compacting the soil by hoof actions, roughing up, addition of minerals and nutrients by droppings and by the animal carcass etc [2]. A well organised and properly managed grazing practices improve the floristic structure, habitat structure for dwelling wildlife, reduces invading extrinsic weeds, seed dispersal for restoration, reduce mulch accumulation, add organic matter and reduce fuel loads that reducing wildfire [3]. Due to over grazing and lack of efficient management strategies abolish native flora, shorten the ground water table, enhance soil erosion, increase weed invasion that lead to alter plant community composition to a less desirable state [3,4].

Generally vegetation is on decline in Pakistan, but in Southern Punjab specifically Cholistan desert, is a small piece of land (26,000 km^2), is severely suffering prolonged droughts, less precipitation, over grazing and ultimately the vegetation loss, hence thinning the vegetation cover. The area bears typically arid xerophytic plant species, which are prone to extreme seasonal temperatures, moisture fluctuation and different edaphic conditions as

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well [5]. The whole area is divided in to two regions i.e., Eastern region (200 mm rainfall zone) have better vegetation cover compared to Southern region (100 mm rainfall zone) [3]. The soil topography and chemical composition is playing an important role in plant distribution in the area, which are different in different areas. The association of certain plant species to certain soils at different places is very common [5,6].

Research shows that an increase in incident solar energy also cases an increase in understory biomass [7]. Gilliam and Turrill 1993 describe that the reduction of light intensity and nutrients availability, also affect understory layer i.e. when canopy is very thick and stratified [8]. Accessibility of soil nutrients and soil properties like pH and net nitrification is greatly dependent on the different nutrient requirements by the species in a stand and their relative contributions to the chemistry litter [9]. Overstory-understory relationship is very complex but it has also been found that this relationship is dependent on the surface deposit. The form of canopy also plays a great role in the determination of composition of understory [10]. All the communities are considered as the indicators of land's biological resources or mirrors of landmass they and also has influence on these factors but the best indicators of environments and economic potentialities of the area is only considered as the plant communities [11]. So it is necessary to take the positive steps for conservation such precious plant species of the area and scientific inventory of rangelands, which can be done by the obtaining of basic information of the plant communities including threatening factors, associations among various plant types viz. trees, shrubs, herbs and grasses, with soil and other eco-geographical attributes. Involvement of specific plant with specific soil is considered as very common but the association of different plant communities at different soil type has also been studied [5,6,12].

In Cholistan desert, pH and the salinity have been studied as main factors for plant communities-soil association and vegetation distribution [6,13]. Some researchers showed that phytosociological groups which determine the soil type have more influence on the vegetation than other factors. In this area community structure and colonization of plant have been studied but physical environmental threats are still needed a deep study as the reason for the survival of plant communities in these threats is still unknown [4]. Present work was conducted with the objective to determine the impacts of shrub species on composition of understory vegetation and structure of the plant communities underside the shrub species.

MATERIALS AND METHODS

The composition of understory vegetation of the 6 shrub species was conducted at 10 different random sites in the Cholistan desert (27° 42' and 29° 45' North and longitudes 69° 52' and 75° 24' East) (Figure 1). For the present study we selected major shrub species, *Acacia jacquemontii*, *Leptadenia pyrotechnica*, *Calligonum polygonoides*, *Capparis decidua*, *Haloxylon salicornicum*, *Aerva javanica*, *Salsola baryosma* are included. Quadrat method was used to record understory vegetation [14,15]. Three quadrats measuring 1x1 m2 were randomly taken from underside of the canopy of each shrub species. The study was repeated for three times.

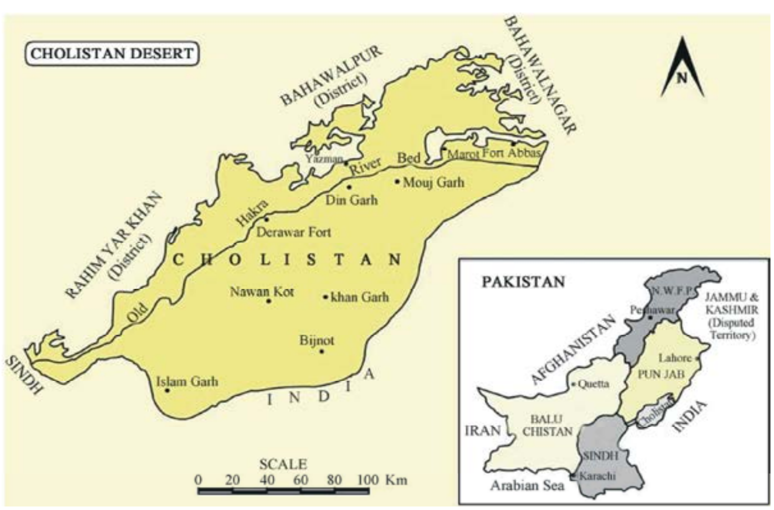

Fig. 1: Map of Cholistan desert

The plant species were identified in the field with field guide [4,16-18]. Frequency, density and plant cover were recorded, whereas relative frequency, relative density and relative cover for each of the plant species was computed following the methods described by Hussain [19]. Importance value index (IVI) was calculated by the direct summation of relative frequency, relative density and relative cover of each plant species [15,20,21]. The species having the highest IVI were considered as the leading dominant plant species of understory vegetation. Soil samples from underside of each plant were also taken and were transferred to Soil Testing Lab., for complete soil assay to judge the effect of plant canopy on the soil enrichment. Chemical analysis conducted included soil pH, organic matter (Walkley-Black method), Phosphorus (Bray-2 method) and exchangeable cations, viz. sodium (Na), potassium (K), calcium (Ca) and magnesium (Mg). The exchangeable cations were extracted by leaching the sample soil with normal ammonium acetate and analyzed spectrophotometrically. The soil chemical analyses were done in triplicate to verify the results.

RESULTS AND DISCUSSION

The results of soil samples collected from underside the canopies of *A. jacquemontii*, *L. pyrotechnica*, *C. polygonoides*, *C. decidua*, *H. salicornicum*, *A. javanica* and *S. baryosma* are presented in Table 1. The texture of the soil was sandy and the soil was found to be moderately alkaline. The pH range is not highly diverse but the highest pH 8.63 in the soil collected from underside the canopy of *A. jacquemontii*, while minimum pH 8.26 was noted in the soil samples collected from underside the canopy cover of *C. decidua* (Table 1). The electrical conductivity (E.C.) was maximum (1.476 ds/m) in the soil samples from underside the canopy of *S. baryosma*. Minimum E.C. (1.21 ds/m) was recorded in the soils from underside the canopy of A. *jacquemontii*. The soil samples collected from underside the canopy of shrubs in Cholistan desert were analyzed for soluble ions (Table 1). The maximum phosphorus contents (5.53 ppm) were recorded in the soil collected from underside the canopy cover of *A. jacquemontii*, while minimum phosphorus contents (3.63 ppm) was noted in the soil sample from underside the canopy of *C. polygonoides*. The results for Potassium contents in soil samples of different pattern from the above as, maximum potassium contents (118.66 ppm) were recorded in soil samples underside the canopy of *S. baryosma* and minimum 101.0 ppm underside the canopy of *C. decidua*. The results of the exchangeable cations (Ca, Mg, Na) measured in the different soil samples collected from underside the canopy cover of all the seven shrub species and varied greatly (Table 1). The maximum amount of these exchangeable cations were noted in the soil underside the canopy of *S. baryosma* (Ca 0.923 meq/l), *A. javanica* (Mg 0.713 meq/l) and *A. jacquemontii* (Na 0.386 meq/l); while minimum amount of Ca (0.556 meq/l) was recorded in the soils from *A. javanica*, Mg (0.27 meq/l) in *A. jacquemontii* and Na (0.176 meq/l) in *S. baryosma*. The accumulation of organic matter was meagre in all the soil samples collected underside the canopies of studied shrub species (Table 1). Highest organic matter (0.35 %) was recorded in the soil from underside the canopy cover of *A. javanica* and minimum (0.24%) under *C. decidua*.

The cover of the plant species recorded under side of the canopy of shrub species varies enormously from one species to the other. Overall occurrence, forming the highest and lowest cover values are given in Table 2. *C. polygonoides* and *S. baryosma* are two plant species, that make the highest cover (97.5%) inside the understory of shrub species more than once. Highest RD values was observed for *Stipagrostis plumosa* remains highest underside of all the shrub species, while the other plant species that showed the least RD values include *A. javanica, A. jacquemontii, P. antidotale, L. scindicus, L. pyrotechnica, L. procumbens, P. cineraria*, *C. polygonoides* and *H. salicornicum* (Table 2). The relative cover was found to be the highest (26.0) given by both *P. cineraria* and *C. polygonoides* in the same canopy type while the lowest (0.67) RC was given by *S. sesuvioides* under the same canopy type (Table 2).

Relative frequesncy (RF) data also varied for different shrub species (Table 2). S. baryosma has the highest (25.81) RF value under A. jacquemontii canopies while next to it *S. plumosa* (22.58 RF). While *T. terrestris* and *A. jacquemontii* make the lowest (3.22) RF under the *A. jacquemontii* canopy. RF for the plants underside of *L. pyrotechnica*, *S. baryosma* showed the maximum (22.73) RF value while the lowest value RF value (4.54) was shown by five plant species as mentioned in Table 2. *S. baryosma* again make the highest (22.86) RF under the *C. poligonoides* canopy, while lowest RF of 2.86 was among five plant species. Under the canopies of *C. decidua* and *S. baryosma*, *C. ciliaris* is the dominant species with RF value of 12.12 and 22.86 respectively, but *O. compressa* also have the same RF like *C. ciliaris* under *C. decidua* canopy. Table 2 shows the pattern of change in the importance value of understory plant species

Table 1: Soil analysis collected from underside the canopies of shrub species of Cholistan desert, Pakistan

Soil parameter	*A. jacquemontii*	*L. pyrotechnica*	*C. polygonoides*	*C. decidua*	*S. baryosma*
pH	8.63	8.43	8.3	8.26	8.33
E.C.(dS/m)1:10	1.26	1.32	1.453	1.296	1.476
Available-P (ppm)	5.53	5,23	3.63	4.73	4.733
Available-K (ppm)	109.33	108.3	103.66	101	118.66
Ca meq/l 1:10	0.603	0.68	0.70	0.87	0.923
Mg meq/l 1:10	0.27	0.43	0.51	0.243	0.376
Na meq/l 1:10	0.386	0.213	0.243	0.183	0.176
O.M. %	0.276	0.266	0.253	0.24	0.303
Texture	Sandy Loam				

Table 2: Summary of understory vegetation analysis of major shrub species in Cholistan desert. RD, Relative density; RF, Relative frequency; RC Relative cover; IVI, Importance Value Index; SDR, Some Dominant Ratio

Canopy	Plant Species	Cover	R.C.	R.D.	R.F.	IVI	SDR
A. jacquemontii	*Salsola baryosma*	37.5	7.54	23.27	25.81	56.62	18.87
	Stipagrostis plumosa	15.0	3.01	35.64	22.58	61.23	20.41
	Haloxylon salicornicum	62.5	12.56	1.98	6.45	20.99	6.996
	Cenchrus ciliaris	37.5	7.54	33.17	16.13	56.84	18.95
	Aerva javanica	97.5	19.60	0.99	6.45	27.04	9.01
	Tribulus terristris	15.0	3.01	0.49	3.22	6.72	2.24
	Acacia jacquemontii	97.5	19.60	0.49	3.22	23.31	7.77
	Calligonum polygonoides	97.5	19.60	1.48	9.68	30.76	10.25
	Dipterigium glaucum	37.5	7.54	2.47	6.45	16.64	5.49
L. pyrotechnica	*Salsola baryosma*	97.5	16.74	6.14	22.73	45.61	15.20
	Stipagrostis plumosa	15.0	2.58	76.53	13.64	92.75	30.92
	Haloxylon salicornicum	97.5	16.74	6.86	18.18	41.78	13.93
	Cenchrus ciliaris	37.5	6.44	7.22	22.73	36.39	12.13
	Panicum antidotale	97.5	16.74	0.36	4.54	21.64	7.21
	Tribulus terrestris	15.0	2.58	1.44	4.54	8.56	2.85
	Lasiurus scindicus	62.5	10.73	0.36	4.54	15.63	5.21
	Suaeda fruiticosa	62.5	10.73	0.72	4.54	15.99	5.33
	Leptadenia pyrotechnica	97.5	16.74	0.36	4.54	21.64	7.21
C. polygonoides	*Salsola baryosma*	62.5	16.67	24.28	22.86	63.81	21.27
	Stipagrostis plumosa	15.0	4.0	39.02	17.14	60.16	20.05
	Launea procumbens	2.5	0.67	0.29	2.86	3.82	1.27
	Cenchrus ciliaris	15.0	4.0	28.03	20.00	52.03	17.34
	Citrulus colocynthis	15.0	4.0	1.73	2.86	8.59	2.86
	Tribulus terristris	15.0	4.0	0.87	5.71	10.58	3.53
	Prosopis cineraria	97.5	26.0	2.60	14.28	42.88	14.29
	Calligonum polygonoides	97.5	26.0	0.87	5.71	32.58	10.86
	Cenchrus setigerus	15.0	4.0	0.58	2.86	7.44	2.48
	Sessuvium sesuvioides	2.5	0.67	1.16	2.86	4.69	1.56
	Ochthocloa compressa	37.5	10.0	0.58	2.86	13.44	4.48
C. decidua	*Salsola baryosma*	97.5	23.49	21.86	9.09	54.44	18.15
	Stipagrostis plumosa	15.0	3.61	24.89	3.03	31.53	10.51
	Cenchrus ciliaris	62.5	15.06	4.98	12.12	32.16	10.72
	Chenopodium album	15.0	3.61	0.43	3.03	7.07	2.36
	Launea procumbens	37.5	9.04	13.85	15.15	38.04	12.68
	Alhaji morarum	37.5	9.04	2.81	9.09	20.94	6.98
	Lasiurus scindicus	15.0	3.61	1.73	9.09	14.43	4.81
	Panicum antidotale	37.5	9.04	2.16	9.09	20.29	6.76
	Launea nudicaulis	15.0	3.61	3.46	6.06	13.13	4.38
	Ochthocloa compressa	37.5	9.04	7.14	12.12	28.3	9.43
	Prosopis cineraria	15.0	3.61	0.22	3.03	6.86	2.29
	Cynodonn dactylon	15.0	3.61	15.80	6.06	25.47	8.49
	Sonchus asper	15.0	3.61	0.65	3.03	7.29	2.43

Table 2: Continued

S. baryosma	*Salsola baryosma*	15.0	21.43	11.16	11.43	44.02	14.67
	Stipagrostis plumosa	2.5	3.57	24.79	14.28	42.64	14.21
	Cenchrus ciliaris	15.0	21.43	21.90	22.86	66.19	22.06
	Haloxylon salicornicum	2.5	3.57	0.41	2.86	6.84	2.28
	Calligonum polygonoides	2.5	3.57	0.41	2.86	6.84	2.28
	Lasiurus scindicus	2.5	3.57	4.13	5.71	13.41	4.47
	Ochthocloa compressa	2.5	3.57	10.74	11.43	25.74	8.58
	Suaeda fruiticosa	15.0	21.43	1.24	5.71	28.38	9.46
	Acacia nilotica	2.5	3.57	5.79	2.86	12.22	4.07
	Leptadenia pyrotechnica	2.5	3.57	0.83	2.86	7.26	2.42
	Launea procumbens	2.5	3.57	14.46	8.57	26.6	8.87
	Launea nudicaulis	2.5	3.57	3.30	5.71	12.58	4.19
	Prosopis juliflora	2.5	3.57	0.83	2.86	7.26	2.42

growing as common associates under the canopy cover of shrub species. According to the IVI value 92.75 *S. plumosa* appeared as dominant plant species occurring under *L. pyrotechnica*, whereas *L. procumbens* appeared as the rare plant with importance value 3.82 under the *C. polygonoides* canopy.

The shrub species in the present study were of almost same height but this introduces a bias while comparing the effect of the shrub canopies on the understory vegetation. The composition of understory vegetation underside the canopy cover differ from one shrub species to another one as the canopy of tree species had a great influence on shrub and herb cover underside it [1,22]. This may be due the fact that there occurs competition among understory plant species for soil moisture, soil nutrients or may be to escape high solar radiation and heat stress to avoid excessive transpiration as there is already scarcity of water in deserts.

Underside of plant canopy soil chemistry is the most outstanding feature that shape the ground flora and organic matter availability also effect under canopy vegetation [23,24]. *S. baryosma* had higher amounts of soil organic matter under its canopy as compared to other shrub species and this might be due to the easily decomposeable litter produced by falling leaves as reported the similar results in other plants by Gower and Son [25]. Top soil pH and other earth-alkaline cations (Na, Mg, Ca) were not consistent in any particular shrub species rather they are unevenly distrusted among various species, similar results reported by Naz *et al*. [26]. All of these shrubs are highly stress tolerable (salinity and drought), thus incorporate different salts into the twigs and leaves, when fallen on the ground return them again to the soil but to different proportion as many different kind of understory plants taken up these salts in different proportion, hence uneven distribution of these salts in the underside soil. Similar trend was observed for the phosphorus and potassium contents. *C. decidua* and *S. baryosma* given the highest species richness and diversity underside the canopy cover. *S. plumosa*, *S. baryosma* and *C. ciliaris* are the most frequent plant species forming the understory composition of vegetation. Some scientists reported the same canopy cover effects on understory vegetation [27] while many others reported that the effect of tree canopy cover on understory vegetation diversity was much low [28,29]. This diversity in understory vegetation might be due to thick litter deposition or some plant species are sensitive to it [30-32].

It is concluded from the present study that shrub species are able to modify the soil chemistry beneath the canopy cover thus defining the underside vegetation communities. *S. plumosa*, *S. baryosma* and *C. cilaris* appeared as most frequent plant species forming the understory flora of shrub species due to their close association with other plants in the Cholistan desert. Other plant species also take part in forming the understory vegetation of shrub species but to some less extent.

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REFERENCES

1. Nisar, M.F., F. Jaleel, M. Waseem, S. Ismail and M. Arfan, 2013. Composition of understory vegetation in tree species of Cholistan desert, Pakistan. J. Eco. Nat. Env., 5(10): 278-284.
2. Akhtar, R. and M. Arshad, 2006. Arid rangelands in the Cholistan desert (Pakistan). Sécheresse, 17: 210-217.

3. Nisar, M.F., S. Iram, Y. Akhtar, A. Majeed, S. Ismail and F. Lin, 2010. AFLP based analysis of genetic diversity in buffle grass. World Appl. Sci. J., 10(5): 560-567.
4. Rao, A.R., M. Arshad and M. Shafiq, 1989. Perennial grass germplasm of Cholistan desert and their phytosociology. Cholistan Institute of Desert Studies, Islamia University of Bahawalpur, pp: 84.
5. Arshad, M., A. Hussain, M.Y. Ashraf, S. Naureen and M. Moazzam, 2008. Edaphic factors and distribution of vegetation in the Cholistan desert Pakistan. Pak. J. Bot., 40(5): 1923-1931.
6. Abdullah, M., R.A. Khan, S. Yaqoob and M. Ahmad, 2013. Community structure of browse vegetation in Cholistan rangelands of Pakistan. Pak. J. Agri. Sci., 50(2): 237-247.
7. Zavitkovski, J., 1976. Ground vegetation biomass, production and efficiency of energy utilization in some northern Wisconsin forest ecosystems. Ecology, 57: 694-706.
8. Gilliam, F.S. and N.L. Turrill, 1993. Herbaceous layer cover and biomass in a young versus a mature stand of a central Appalachian hardwood forest. Bul. Torrey Bot. Club, 120: 445-450.
9. Ste-Marie, C. and D. Pare, 1999. Soil, pH and N availability effects on net nitrification in the forest floors of a range of boreal forest stands. Soil Biol. Biochem., 31: 1579-1589.
10. Legare, S., Y. Bergeron and D. Pare, 2001. Comparison of the understory vegetation in boreal forest types of southwest Quebec. Canadian J. Botany, 79: 1019- 1027.
11. Arshad, M. and G. Akbar, 2002. Benchmark of plant communities of Cholistan desert. Pak. J. Biol. Sci., 5: 1110-1113.
12. Arshad, M., M.Y. Ashraf, M. Ahmad and F. Zaman, 2007. Morpho-genetic variability potential of *Cenchrus ciliaris* L., from Cholistan desert, Pakistan. Pak. J. Bot., 39: 1481-1488.
13. Arshad, M., 2003. Cholistan desert ecosystem monitoring for future management. Annual Technical report of a project sponsored by WWF-Pakistan. (Unpublished).
14. Oosting, H.J., 1957. Study of plant community. Freeman Co., 2nd Ed. 62-64, 3050.
15. Chul, K.S. and K. Moody, 1983. Comparison of some methodologies for vegetation analysis in transplanted rice. Korean J. Crop Sci., 28: 310-318.
16. Chaudhary, S.A., 1969. Flora in Lyallpur and the adjacent canal-colony districts. West Pakistan Agricultural University, pp: 214.
17. Chaudhary, S.A., 1989. Grasses of Saudi Arabia. Ministry agriculture and water, Riyadh, pp: 465.
18. Chaudhary, S.A., 1999. Flora of the Kingdsom of Saudi Arabia. Ministry of agriculture and water, National Herbarium, Riyadh, pp: 691.
19. Hussain, F., 1989. Field and Laboratory Manual of Plant Ecology. National Academy of Higher Education, University Grants Commission, Islamabad, Pakistan.
20. Curtis, J.T. and R.P. Mclntosh, 1951. An upland forests continues in the prairie forest border region of Wisconsin. Ecology, 32: 476-449.
21. Muller-Dombois, D. and H. Ellenberg, 1974. Aims and methods of vegetation ecology. John Willey and Sons. Inc., New York.
22. Klinka, K., H.Y.H. Chen, Q. Wang and L. de Montigny, 1996. Forest canopies and their influence on understory vegetation in early seral stands on West Vancouver Island. Northwest Sci., 70: 193-200.
23. Missin, L., G. Du Bus de Warnaffe and M. Jonard, 2001. Effects of fertilization on the vascular ground vegetation of European beech (*Fagus sylvatica* L.) and sessile oak (*Quercus petraea* (Matt.) Lieb.) stands. Ann. For. Sci., 58: 829-842.
24. Hutchinson, T.F., E.J. Boerner, L.R. Iverson, S. Sutherland and E.K. Sutherland, 1999. Landscape patterns of understory composition and richness across a moisture and nitrogen mineralization gradient in Ohio (USA) Quercus forests. Plant Ecol., 144: 177-189.
25. Gower, S.T. and Y. Son, 1992. Differences in soil and leaf litterfall nitrogen dynamics for five forest plantations. Soil Sci. Soc. Am. J., 56: 1959-1966.
26. Naz, N., M. Hameed, M. Ashraf, M. Arshad and M.S.A. Ahmad, 2010. Impact of salinity on species association and phytosociology of halophytic plant communities in the Cholistan desert, Pakistan. Pak. J. Bot., 42(4): 2359-2367.
27. Callaway, R.M., D. Cipollini, K. Barto, G.C. Thelen, S.G. Hallett, D. Prati, K. Stinson and J. Klironomos, 1991. Novel Weapons: Invasive plant suppresses fungal mutualists in America but not in its native Europe. Ecology, 89(4): 1043-1055.
28. Hong, Q., K. Klinka and B. Sivak, 1997. Diversity of the understory vascular vegetation in 40 year old and old growth forest stands on Vancouver Island, British Columbia. J. Veg. Sci., 8: 778-780.
29. Whitney, G.G. and D.R. Foster, 1988. Overstory composition and age as determinants of the understory flora of woods of central New England. J. Ecol., 76: 867-876.

30. Holderegger, R., 1996. Effects of litter removal on the germination of *Anemone nemorosa* L. Flora, 191: 175-178.
31. Sydes, C. and J.P. Grime, 1981a. Effects of tree leaf litter on herbaceous vegetation in deciduous woodland. I - Field Investigation. J. Ecol., 69: 237-248.
32. Sydes, C. and J.P. Grime, 1981b. Effects of tree leaf litter on herbaceous vegetation in deciduous woodland. II - An experimental investigation. J. Ecol., 69: 249-262.