Journal of Medicinal Plants Research Vol. 4(20), pp. 2080-2091, 18 October, 2010
Available online at http://www.academicjournals.org/JMPR
ISSN 1996-0875 ©2010 Academic Journals

Full Length Research Paper

Impact of human pressure on the population structure of *Persicaria amplexicaule*, *Valeriana jatamansi* and *Viola serpens* the naturally growing medicinal plants in Malam Jaba, Swat, Pakistan

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Accepted 26 July, 2010

A study on the population structure of *Persicaria amplexicaule*, *Valeriana jatamansi* and *Viola serpens* was conducted during 2002 – 2004 in different ecologically important sites of Malam Jabba, Swat, Pakistan. The results revealed that overall population density of each plant showed a significant decrease after the collection period. However, all the investigated parameters generally showed two to four-fold increase in protected sites as compared to the unprotected areas. The growth performance of the tested species increased with rise in elevation. The abundance/distribution and overall population of each targeted plant was generally high in North facing slopes as compared to South facing features. The air and soil temperatures were slightly higher in open areas as compared to the protected sites and showed a decline with increasing elevation. Both air and soil temperatures were relatively higher in Southern slopes as compared to North-eastern slopes in Malam Jabba. By using cluster analysis, dynamic, normal and regressive populations were distinguished in the population of selected plants. The three population types differed with respect to their population size and total plant density. The differences were maximum in dynamic, intermediate in normal, and lowest in regressive populations. The study concluded that the conservation of the remaining populations of targeted plants would best be achieved by proper time of sustainable harvesting.

Key words: Medicinal plants population, management practices, local people, collection period.

INTRODUCTION

Malam Jabba valley is situated in the North eastern part of Swat in Pakistan. The altitude of the valley varies from 1200 m at the valley entrance to 3200 m. The terrace is mountainous, occupying the floristically rich Southern extension of Hindu Kush Raj of Hindu Kush mountain range. Wood, tourism, animal rearing, farming, fruits, and medicinal plants are among the major sources of income for the inhabitants (Sher and Hussain, 2009; Sher et al., 2010).

Conserving medicinal plants and forest biodiversity are part of poverty reduction and local public health prevention efforts (Bodeker, 2005). Current trends in commercial exploitation of wood and medicinal plants severely damaged the natural forests and pastures in Swat and a number of wildly growing healing plants became rare and sparse (Olsen and Larsen, 2003; Sher et al., 2010). The non-existence of any cultivation/*ex-situ* management programs, no nurseries, or protected areas for commercially exploited medicinal plants are among the additional factors, which endangered the wild life in Swat (Sher and Hussain, 2009). The evaluations of changes occurring in ecological conditions are often based on vegetation monitoring. Usually changes in densities, frequencies, and abundances of targeted plants with a narrow ecological tolerance are frequently used as indicators for local ecological change or habitat quality (Akerele et al., 1991). Nevertheless, the observed

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changes in abundance are linked to demographic data and plant conservation is frequently assumed to be benefited from management measures. Thus, it was considered necessary to scrutinize the effects on habitat loss due to over harvesting and altitude on the population status of medicinal plants in Malam Jabba (Swat).

A relatively simple approach to describe a species population structures, is by determining its relative densities at different stages of growth. Additionally, a population ecological approach to investigate the demography of certain targeted plants might be adopted (Palmer, 198; Hutchings, 1991). In some cases, where the state or changes of population of certain plants can be targeted; such a situation can represent the composition of the whole plant community, and the targeted species can be used as indicators in ‘monitoring programs’. However, the limitation is to select an abundant species instead of rare or endangered one, so that the basic monitoring and conservation design requirement is satisfied (Fiedler, 1987; Hutchings, 1991).

In general, population ecology of the targeted plants might be used as a tool in vegetation monitoring. Any difference in population structures of selected plants at a phenological stage might be correlated to differences among their environment including: surrounding vegetation composition, climate, structure, soil conditions, altitude and management of grazing, and harvesting, etc. (Malik et al., 2007). Imminent changes in any stage structure of plant community are indicative of degradation and warrant suitable management strategies (Buhler and Schmed, 2001; Hou et al., 2009). In designing the present investigation, the population dynamics and density of targeted plants (*Persicaria amplexicaule* D. Don., *Valeriana jatamansi* Jones, and *Viola serpens* Wall ex Roxb.) were expected to be higher before the collection period. Therefore, regimes positively affecting the demographic viability of targeted plants were examined for possible short-term conservation. In addition, there is a dearth of scientific reports on the trade value of selected plants for the long run, their population size, their harvest, habitat, distribution, availability, phenology, and natural regeneration rate in Malam Jabba. There is an urgent need for a scientific probe to understand the gravity of the problem, loss of medicinally important plants, awareness of local people about management practices, and to propose possible solutions. In the present study, populations of targeted plants were studied at five life stages related to harvesting, habitat loss, altitude, and vegetation structure and the results are presented in the present communication.

MATERIALS AND METHODS

Rational for selecting species

The rational behind the selection of three plants was the danger of over collection due to high demand. The study was aimed to find and introduce suitable measures, which could make a way for sustainable supply of those plants contributing to increase the income of inhabitants of the local inhabitants.

Field procedures

The current study was carried out, at six locations in Malam Jabba area with altitudes ranging between 1500 to 3200 m during 2002 - 2004. The targeted plants were as follows: *P. amplexicaule.* D. Don. (Polygonaceae), *V. jatamansi* Jones (Valerianaceae)*,* and *V. serpens* Wall ex Roxb (Violaceae). All the three plants were selected on the basis of their commercial and medicinal importance (Sher and Hussain, 2009). A general outlook of the targeted medicinal plants was prepared which included their history of collection, and human influences. Since the study is based on many objectives, therefore, the methodology adopted for each of the objective is given as follows:

Abundance and distribution

To assess the abundance, distribution and population of each targeted species in each site of the valley, transect walks were made along the important routes, throughout the targeted area. This has covered all slopes, aspects and altitudes according to Global Positioning System (Dominy and Duncan, 2001). For each plant species found, the local people were asked to tell its abundance and distribution in the past. This was judged by comparing the present data with 20 years old records. This abundance scale combines, local precise knowledge of the inhabitants and personal observations made in the field to notice any pertinent events giving an average percentage of abundance for a plant species. And under some circumstances, it may not be practicable to make actual counts, but profusion may be rapidly estimated according to the scale of abundance similar to the above mentioned categories (Wikum and Shanhotzer, 1978; Damgaard, 2009).

Sampling procedures

After a preliminary survey of the study area, 10 representative sites were selected on the basis of physiognomic contrast, altitude, habitat, species composition and stages of degradation (deforestation, grazing, over harvesting and erosion). There were distinct South and North-east facing slopes in the Malam Jabba hills. The general vegetation data in these two aspects was collected at five altitudinal zone viz: 1500 m (foot hill), 1900 - 2300 m (mid hills) and 2700 - 3200 m (top hill). The data of each targeted species was collected by using 10 x 10 m quadrate in each site of the study. In each site ten square, each of 10 x 10 m were fixed with 4 wooden pegs at 4 corners following the methods described by Shreshta et al. (1998) and marked for later re-identification. The quadrates were laid randomly in a nested manner.

In-situ management study

A 6 x 6 hectare forestland in Malam Jabba site was protected for the last three years with the participation of the local community. The impact of protection on the regeneration and overall population size of targeted plants was recorded in 20, 10 x 10 m quadrates. There were criteria for inclusion and exclusion of individual plants occurring on the margins of the 10 x 10 m quadrates. This was decided well before starting the counting and practiced throughout. All those plants whose roots lied inside or beneath the quadrate line, irrespective of their shoot, were counted. In case of compact patch, the patch was counted as one individual. All species were recorded and clipped separately. The fresh weight of each was determined.

Soil analysis

Duplicate soil samples were collected from each site upto a depth of 5 cm. The air-dried samples were analyzed for physical and chemical characteristics. Air and soil temperature were also determined by using air and soil thermometers.

Statistical data analysis

Differences in the population density and dynamics of targeted plants before and after collection periods at different altitudes were tested with a two sample *t*-tests followed by student-Newman-Keuls multiple comparison by applying MINITAB statistical software, (versin-0.2 minitab Inc.). By using MINITAB package, two hypotheses were tested:

(i) That the density of targeted plants was greater before than the density after collection and
(ii) For some plants it was greater while for others lesser as per altitude and harvesting intensity at the specified level of significance Alpa is equal to 0.05 (Hartigan, 1975). The relationships between the relative proportion (%) of each life stage and the structure of the surrounding vegetation were investigated using multiple regression analysis (Sokal and Rohlf, 1981; Henry et al., 1999; Hegland et al., 2001). Residuals were checked for normality using the Kolmogorow-Smirnow one-sample test with the Lilliefors option (Wilkinson, 1989). The vegetation data were subjected to ordination with a detrained correspondence analysis (DCA) (Hill, 1979) with computer package CANOCO (Ter-Break, 1992). This analysis aims at finding ordination axes along with species scores show maximum dispersion. The dispersion is a measure of the amount of variance accounted for by the axes. The population types of each targeted plant on the DCA axes were plotted, to investigate the differences in vegetation types that were positively or negatively correlated with the different population types (Ratliff and Westfall, 1992; Hegland et al., 2001).

Classification of life stages

Life stages for each targeted plant were distinguished on the basis of field observations and the data obtained (Ouborg, 1993; Hegland et al., 2001) as follows:

1. Seedling (S): With cotyledons and mostly one leaf pair.
2. Juveniles (J): With one to two leaves and a rosette with a diameter of approximately 2 -5 cm.
3. Vegetative adults (V): A large plant, with at least four pairs of leaves, leaves considerably thicker than those of the juveniles stage and having diameter 3 - 7 cm depending upon species, sometimes bearing flowers.
4. Reproductive adults (R): The plants normally having one to five seeds and fruits and one to five flowering stalks in addition to the rosette of matured leaves.
5. Mature adults (M): The plants having ripened seeds and fruits and in a position to shed both the seeds and fruits to generate new individuals.

RESULTS

Edaphology

The colour of soils at different altitudes and aspects varied from grey-brownish to grey-blackish and grey in both the North eastern and Southern aspects. Similarly, the texture of soil varied from loamy sand or sandy clay and loamy silt to sandy clay loam. The percentage of litter contents, pH, and electrical conductivity, water holding capacity, and organic matter in both the Southern and Northern aspects were studied. Similarly, water holding capacity, organic matter, N, P, and K, Ca, Mg and chloride contents exhibited significant differences in both the Southern and Northern aspects. The air and soil temperatures were slightly higher on the South facing slopes as compared to the North East facing slopes. In both the cases, there was a gradual decrease in temperature with rising altitude.

Abundance and distribution

The targeted medicinal plants were found and widely distributed from lower temperate forests of lower altitude (1500 m) to the high altitude (3200 m) temperate, sub-alpine and alpine forests of the investigated area (Table 1). However, their distribution and abundance range was influenced by altitude, aspect and slope of the slope.

P. amplexicaule

The results presented in Table 1 demonstrated that *P. amplexicaule* was found in all the study sites of the investigated area except telegram. It was frequently existing in Malam, Kuh, Spinay Uba, Upper Jabba and Lower Jabba. However, it was occasional in Kishawara site, and rarely found in Gat Sar, Shaltalu and Ilanai. The results showed that the over all population size and abundance of this species was slightly decreased with increasing elevation within the study areas. It appeared with a high distribution frequency in Malam (65%) and Spinay Uba (60%), where with as 50% distribution frequency in each Kuh, Lower Jabba, and Upper Jabba. It had low distribution frequency in Gat Sar, Shaltalu and Kishawara (30% in each site) and having 10% distribution frequency in Ilanai. On the other hand its distribution frequency was 95% in protected area. *P. amplexicaule* was common in moist areas growing under coniferous shade. It was rarely found in highly grazed and disturbed sites.

V. jatamansi

The results revealed that the relative abundance of *V. jatamansi* was low in Kishawara and occasional in Spinay Uba. It was frequently available in Kuh, Malam, Lower Jabba and Upper Jabba, while in all other sites it was absent (Table 2). The overall population size and abundance of this species increased with rise in elevation in the sites under study. It had high distribution frequency in Upper and Lower Jabba (90% in each site), Kuh

Table 1. Relative abundance of targeted species in various sites of the study.

Sites	Plant species											
	P. amplexicaule				*V. jatamansi*				*V. serpens*			
	Altitude (m)	Aspect	Slope	Abundance	Altitude (m)	Aspect	Slope	Abundance	Altitude (m)	Aspect	Slope	Abundance
Telegram	1200	South	Plain	0	1200	South	Plain	0	1200	South	Plain	1
Ilanai	1300	South East	Plain	1	1300	South East	Plain	0	1300	South East	Plain	2
Shaltalu	1600	South West	Moderate	2	1600	South West	Moderate	0	1600	South West	Moderate	2
Gat Sar	1500	South	Moderate	2	1450	South	Moderate	0	1450	South	Moderate	3
Kishawara	1700	North West	Moderate	3	1700	North West	Moderate	2	1700	North West	Moderate	4
Kuh	2300	North	Moderate to high	4	2300	North	Moderate to high	4	2300	North	Moderate to high	5
Spinay Uba	1800	North East	Moderate to high	4	1800	North East	Moderate to high	3	1800	North East	Moderate to high	4
Malam	1900	North	Moderate to high	4	1900	North	Moderate to high	4	1900	North	Moderate to high	5
Upper Jabba	3200	North West	Moderate to high	4	3200	North West	Moderate to high	4	3200	North West	Moderate to high	4
Lower Jabba	2700	North East	Moderate to high	4	2700	North East	Moderate to high	4	2700	North East	Moderate to high	5
Protected Area	1900	North	Moderate to high	5	1900	North	Moderate to high	5	1900	North	Moderate to high	5

0 = Absent, 1 = Very Rare, 2 = Rare, 3 = Occasional, 4 = Frequent, 5 = Abundant.

(70%), Malam and Spinay Uba (65% in each site). It had 85% distribution frequency in protected area, and was absent in telegram, Ilanai, Shaltalu and Gat Sar, while having 15% distribution frequencies in Kishawara. *V. Jatamansi* was found mostly growing on relatively open North east and west facing slopes and preferred moist habitat. *V. Jatamansi* was mostly associated with Geranium spp., Primula spp. and Potentilla spp. in coniferous forest. It was found in more grazed and disturbed areas near the temporary shepherd's hut, and on areas with cattle dung manure.

V. serpens

It was distributed in all the study sites of the investigated area. However, it was occasionally found in Gat Sar and frequently available in Kishawara, Spinay Uba and Upper Jabba while dominant in Kuh, Malam and Lower Jabba. *V. serpens* was rarely found in Ilanai and Shaltalu and very rare in telegram (Table 2). It was noticed that the population and abundance of this species was slightly decreased with the rising elevation in the study areas. It appeared with a high distribution frequency in Malam, Spinay Uba, Kuh, Lower Jabba and Upper Jabba while the species appeared with low distribution frequency in the remaining sites. *V. serpens* had 100% distribution frequency in the protected area preferring North, North east and west facing slopes. It was either occasional or rarely available in Southern or South east and west facing slopes. *V. serpens* was found mostly associated with coniferous shade. It was found very rare in the highly grazed and disturbed sites near the villages.

Table 2. Density, Frequency and Herbage cover of targeted plants before and after collection period at various locations of the study.

Sites/ altitude (meters)	Plant species																							
	P. amplexicaule								*V. jatamansi*								*V. serpens*							
	Before collection April–May 2002–2004				After collection August–September 2002–2004				Before collection April–May 2002–2004				After collection August–September 2002–2004				Before collection April–May 2002–2004				After collection August–September 2002–2004			
	D	F	H	L	D	F	H	L	D	F	H	L	D	F	H	L	D	F	H	L	D	F	H	L
Talegram (1200)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	10	11	R	4	8	7	M
Ilanai (1300)	12	10	5	J	7	90	2	M	0	0	0	0	0	0	0	0	17	20	10	R	6	15	4	M
Gat Sar (1500)	13	30	7	J	9	20	3	M	0	0	0	0	0	0	0	0	14	30	10	R	5	15	5	M
Shaltalu (1600)	21	30	9	V	7	20	4	M	0	0	0	0	0	0	0	0	17	30	11	R	6	10	6	M
Kishawara (1700)	32	30	12	V	12	15	5	M	18	15	10	V	6	5	5	M	19	45	15	R	8	20	6	M
Spinay Uba (1800)	44	60	19	J	19	35	7	M	25	65	15	V	14	30	6	M	47	60	20	R	19	25	8	M
Malam (1900)	70	65	32	V	31	25	13	M	54	65	20	V	17	20	9	M	71	80	31	R	24	35	11	M
Kuh (2300)	52	50	40	V	17	20	15	M	61	70	20	V	23	35	8	M	19	60	29	R	27	25	10	M
L. Jabba (2700)	48	50	40	V	13	20	19	M	59	90	22	V	21	40	11	M	80	95	35	R	36	30	10	M
U. Jabba (3200)	47	50	27	J	12	25	16	M	71	90	35	V	27	50	13	M	42	45	30	R	19	30	10	M
Protected area(1900)	87	95	55	V	95	10	60	M	79	85	40	V	88	90	60	M	91	10	45	R	99	90	52	M

D = Density, F = Frequency, H = Herbage cover, J = Juvenile, L = Life stage, M = Mature, R = Reproductive, V = Vegetative adult.

Population density

The study revealed that the overall population density of targeted plant varied due to differences in sites of the investigated area as shown in Table 2.

P. amplexicaule

P. amplexicaule was found in very low density in Gat Sar (13), Shaltalu (21) and Ilanai (12) before collection period, while available in high density in the protected site (87) and Malam (70) and closely followed by Kuh (52), Lower Jabba (48), Upper Jabba (47), Spinay Uba (44) and Kishawara (32). *P. amplexicaule* was absent in telegram. A decreasing trend in population density was obvious after collection period as compared to the growth in protected sites. The population density before collection showed dependence on elevation and was found highest at 2700 m height (Table 2).

V. jatamansi

V. jatamansi had low population density in Kishawara (18) and Spinay Uba (25) as compared to higher density in the protected area (79) before collection period. All over, the population size and abundance of this species increased with the rising of elevation. However, density decreased many fold after collection period in the study areas (Table 2).

V. serpens

V. sepens was found to have lowest density in telegram (10) as compared to: Gat Sar (14), Ilanai and Shaltalu (17), and Kishawara (19). The density in protected area was (91) followed by: Lower Jabba (80), Kuh (79), Malam (71), Spinay Uba (47), and Upper Jabba (42). In addition, *V. serpens* had lowest density at lower altitude which increased with the increasing of elevation before collection period. After the collection period *V. serpens* showed 2 to 3 fold decline in population

Table 3. Analysis of variance statistics of the K-means clustering of population stage structures (proportions of each life stage) of each targeted plants into three groups at the sample level and the population level.

Variable		SS-between	d.f.	SS-within	d.f.	F-ratio	P-value	F-corrections	P-corrections
Sample level	Seedlings	0.022	2	0.024	48	2.40	0.098	5.41	0.004
	Juveniles	1.630	2	0.426	48	92.08	<0.002	50.01	<0.002
	Vegetative adult	0.258	2	0.641	48	9.61	<0.002	10.02	<0.002
	Reproductive adult	0.435	2	0.631	48	16.16	<0.002	5.00	0.012
	Matures	2.367	2	0.762	48	74.42	<0.002	33.44	<0.002
Population level	Seedlings	0.044	2	0.006	20	7.20	0.005	7.11	0.005
	Juveniles	0.422	2	0.240	20	17.60	<0.002	17.53	<0.002
	Vegetative adults	0.026	2	0.231	20	1.06	0.355	6.78	0.066
	Reproductive adults	0.162	2	0.231	20	7.10	0.005	1.38	0.298
	Matures	0.481	2	0.211	20	24.00	<0.002	19.01	<0.002

The last two columns give the F-ratio and the P-value for corrections. For clusters analysis, the small and large generation plants were pooled.

density. Furthermore, the density was generally higher in North, North east and west facing aspects in contrast to South, South-east and west facing aspects (Table 2).

Herbage cover

P. amplexicaule

A high herbage cover of *P. amplexicaule* was recorded in Kuh and Lower Jabba (40% each); while lower in Spinay Uba (19%) and Kishawara (12%) and lowest in Ilanai (5%), Gat Sar (7%) and Shaltalu (9%) before the collection period. This species was absent in telegram, while its herbage cover was highest in the protected area (55%) as compared to open sites (Table 2).

V. jatamansi

V. jatamansi appeared with a minimum herbage cover in Kishawara (10%) and Spinay Uba (15%) while maximum herbage covers in protected area (40%). It was closely followed by Upper Jabba (35%), Lower Jabba (22%), Kuh and Malam (20% each) before collection period. It was absent in all other sites of the study area (Table 2).

V. serpens

The results (Table 2) showed that the herbage cover of *V. serpens* was more in the protected site (45%) as compared to unprotected area. Whilst in Lower Jabba its herbage cover was 35% followed by Malam (31%), Upper Jabba (30%) and Kuh (29%) before the collection period. It produced minimum herbage cover in the remaining sites of the study area and varied from 10 to 20% before the collection period. It was interesting to notice that the cover of targeted species increased with the increase of altitude within the study area (Table 2). Moreover, it was observed that all the investigated plants appeared with a very good herbage cover in North, North east and west facing aspects (Table 2).

Population types

The results showed that three groups of population types emerged viz: dynamic, normal and regressive for each targeted plant from the K-means clustering (Tables 3 and 4). Pre-selection of two, four or five groups for the clustering led to small groups, with only a few samples, combined with very large groups of each targeted species after the collection period. The pre-selection of three groups was based upon the number of samples in each group large enough for a meaningful interpretation, and a subjective correction was performed on a few samples/square. At the population level, there were no significant differences existing between the types of population of each plant with regard to the relative proportions of vegetative adult individuals. After corrections, this changed to the reproductively adult stage (Table 3). The classification of the three population types could be interpreted as follows:

Dynamic population group appeared to have high proportion of young life stages, primarily seedlings, and juveniles. Consequently, the proportions of adult plants were low and most of the mature plants were small. This type was characterized by relatively high S+J/M-ratio, with a mean value of 2.4 and a range of 0.69 to 24.0. On the average the proportion of young life stages was 0.80. The present study revealed that there was no clear vegetation succession involved in the habitat of each

Table 4. Summary of the sampled plots and clustering of targeted plants into three structure types after collection period.

Sites	S+J/M-ratio	Population type	Overall population type	Population size	Management procedure for collection
Telegram	0.00	R	R	32	Early and then year round collection
Ilanai	0.20	R(N)	R	198	Early and then year round collection
Gat Sar	0.33	R	R	240	Early and then year round collection
Shaltalu	0.31	R(N)	R	200	Early and then year round collection
Kishawara	0.86	R(N)	R	340	Early and then year round collection
Spinay Uba	0.87	N	N	1560	Late collection
Malam	0.12	N(D)	N	1955	Late collection
Kuh	0.87	N	D	1820	Late collection
Lower Jabba	1.56	D	D	2280	Late collection
Upper Jabba	24.0	N(D)	D	220	Late collection
Protected sites	0.69	D	D	26330	Protected

S+J/M-ratio = Ratio of seedling + Juveniles to mature, D = Dynamic population, N = Normal population, R = Regressive population, Population size was determined after defer treatment (1999).

targeted plant. This cluster was denoted as “dynamic”.

Normal cluster

It comprised of populations with lower proportions of seedlings and juveniles than dynamic populations and relatively high proportions of vegetative adults, reproductive adults and mature plants. Mature plants were scarce in this type. The S+J/M-ratio had a mean value of 0.24 and ranged from 0.12 to 0.87 and the average proportions of young life stages were 0.41. This cluster was denoted as normal or stable population. The present study also revealed that the population of regressive type consisted primarily of vegetative adult, reproductive adults, and particularly mature plants. Only few young life stages seedlings and juveniles were found, therefore, the S+J/M-ratio was zero and the mean proportion of young life stages was only 0.1. This type was therefore, named ‘regressive type population’.

The three population types had significantly different (S+J/M-ratio, K-W test, X^2=38.0, d.f=2, P=0.002) proportions of young life stages (K-W test, X^2=37.2, d.f=2, P=0.002). Total plant density per population of each species was also distinctly different. Median ranged from 20.3 plants (each targeted species) per quadrate in the dynamic population, through 12.5 plants in the normal, to 6.5 plants per quadrate in the regressive population (K-W test, X=12.9, d.f=2, P=0.002). The same tendency was recorded for the population size where the medians were 500 individuals for both the dynamic and stable populations and 300 for regressive type (K-W test, X=5.9, d.f=2, P=0.05). None of the populations of the later clusters consisted of more than 250 individuals. Additionally, there was a significant positive correlation between population size and the proportion of young plants (r_s=0.322, n=24, P=0.05), suggesting that larger populations were in general more dynamic. The present study also revealed that there was no significant difference existing between the medians of vegetation structure parameters and between the population types. However, the multiple regression analysis with the vegetation structure parameters as independent variables and the proportions of the life stages as dependent variables yielded some significant correlations (Table 4). At both the quadrate and population levels, there was a significant negative correlation between the soil cover by litter and the percentage of mature plants. At the population level, a positive correlation existed between the percentages of juveniles and matures the (S+J)/M ratio and the percentage of soil cover by litter. Moreover, there were no significant differences in any of the soil parameters between the population types (K-W tests, P=0.978), none of the variables showed any significant correlation with other parameters, including population size or the (S+J)/M ratio.

Population types in relation to the vegetation structure

The DCA ordination revealed a significant proportion of variation in the species composition of vegetation, consisting of variances, co-variances, correlation and two axes. The axis corresponds to an eigen value, where eigen value in the variance accounted for the axis. The ordination information showed the ecological association and resemblance between targeted species and plant communities. The DCA ordination verified the presence of significant differences in vegetation structure/composition between the plant population types (viz: normal, dynamic and regressive) of targeted plants (Monte Carlo test; P=0.02). However, these differences could not be explained by any significant correlation

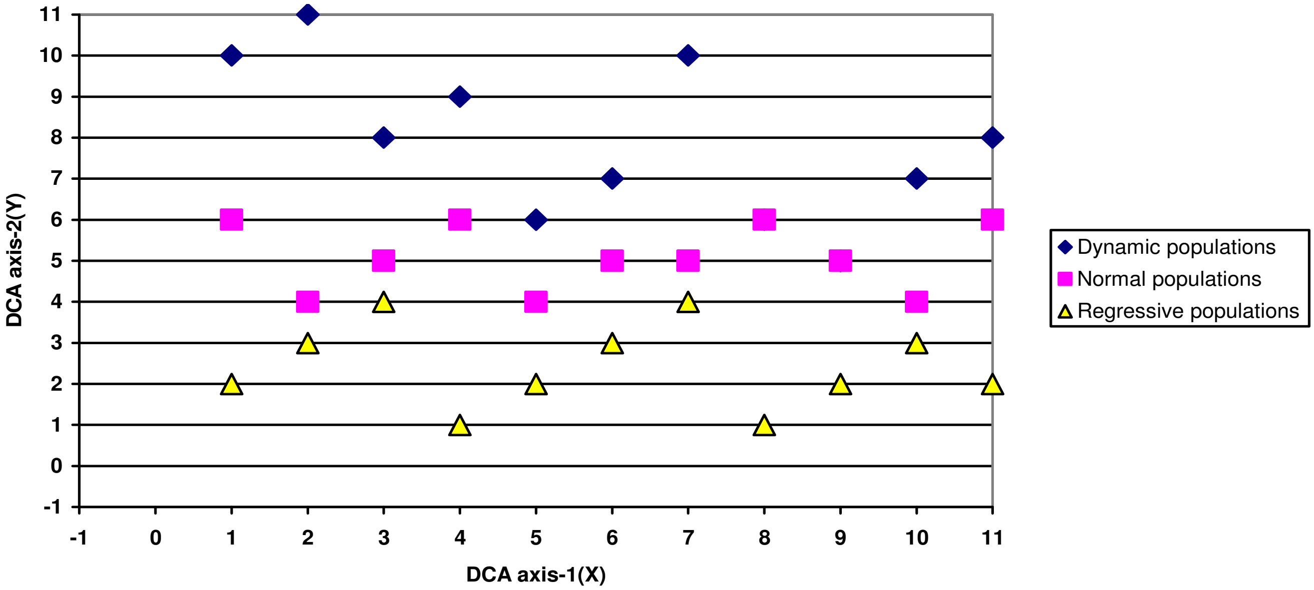

Figure 1. Ordination diagram (DCA axis 1 and 2) showing the distribution of individual samples (square) labelled according to the population types of targeted plants, and the position of a selection of the most informative co-occurring plant species.
Species found on the top of the ordination diagram had normal and dynamic populations, while species occurring on the bottom had regressive populations of targeted plants.

◆ *Paeonia emodi, Pinus wallichiana, Abies pindrows, etc.*
■ *Adiantum capillus-veneris, Bergenia ciliata, Pteris* spp.*, Picea smithiana, Persicaria amplexicaule, etc*
△ *Artemisia* spp.*, Viburnum nervosum, Indigofera heterantha, Themeda* spp.*, Sibaldia cuneata, Senecio* spp.*, etc.*

coefficient of the environmental variables with the DCA axis. The (S+J)/M ratio and population size of targeted plants were significantly negatively correlated with DCA axis (r_s= -1.465) and -1.466, respectively n=53, P=0.002. The study assessed and evaluated the occurrence and associations of species composition and vegetation structure around targeted plants. *Pinus wallichinana, Abies pindrow, Picea smithiana, Viburnum nervosum, Sibaldia cuneata* and *Adiantum capillus - veneris* were the typical species occurring only at sites where targeted plants had normal and dynamic populations. In the regressive population of targeted plants there were several species of nutrient rich conditions, such as *Indigofera heterantha, Urtica dioca, Medicago polymorpha* and *Cynodon dactylon* (Figure 1). There was a marginally significant difference in the number of species (per population) between the population types of targeted plants (K.W test, X^2=5.01, d.f=2, P=0.096). It was concluded that the number of species was high in dynamic and normal populations in contrast to low numbers of species in regressive populations of targeted plants. DCA was the most widely used ordination procedure in ecology and available in computer statistical packages (multivariate statistical package). The use of this technique reflected population types of targeted plants on the DCA axes with respect to differences which existed in vegetation structure and composition between the types.

DISCUSSION

Soil analysis

The results of the present investigation demonstrated a clear-cut decline in contents of soil nutrients, in the study areas. Our findings are in agreement with the earlier reports where erosion and deforestation were held responsible for the loss of organic matter, nitrogen, and phosphorus from the top fertile soil layer (Vladychensky, 1992; Lal, 1998; Zheng, 2005). However, during current study, water-holding capacity was relatively high at certain places, and it was associated with high organic matter contents. Those sites were rich in trees and shrub layer. At the top high elevation a decreased water holding capacity resulted which was ascribed to erosion and compaction of the soil as a result of trampling of grazing animals. Such nutrient deficient habitats with poor water holding and nutrient retention capacity are generally unfavorable for the growth of seedlings of plants under study, which were adapted to shady and organically rich soil conditions (Teunissen et al., 1995). The air and soil temperature was slightly higher on south facing slopes compared to the north-east facing slopes (Ozenda, 1954; Oosting, 1956). The air and soil temperature was slightly higher in unprotected sites as compared to protected sites. Moreover, in all the cases, there was a gradual decrease in temperature with rising altitude; both aspects had the same air and soil temperature. Our finding are in conformity with earlier reports that south facing slopes of Docut Hills had higher temperature and lower humidity as compared to North facing slopes (Sher et al., 2010). Likewise, it was observed that the North and South facing slopes of Karamar Hills had different micro climatic condition and vegetation (Sher et al., 2005).

Abundance and distribution

As regards abundance and distribution of the targeted medicinal plants (*P. amplexicaule, V. jatamansi and V. serpens*) is concerned, all were found throughout the study area representing: temperate forests to sub-alpine, and alpine pastures and meadows. There was clear evidence that the targeted plants particularly liked to grow at high altitudes in coniferous vegetation. However, the distribution was dependent on altitude aspect and inclination of the slope. These findings were in full agreement with the results of earlier studies showing that the population of *P. amplexicaule, V. jatamansi, V. serpens,* and *Dioscorea deltoidea*, was higher in sub-alpine and alpine pastures (Shrestha et al., 1998). Some variation observed in the pattern of distribution might be attributed to the differences in harvesting intensity, grazing, habitat loss, and coniferous vegetation stand.

These factors adversely affected the natural regeneration and seriously reduced the availability of targeted plant species in particular sites of the study area. All these results complied with our earlier observations (Sher et al., 2004), where livestock population increase, grazing and human pressures, tremendously affected the forest products; and several indigenous plant species were becoming rare and sparse in the area (Sher et al., 2004). In addition, due to environmental degradation, and indiscriminate collection of medicinal plants, the numbers of endangered species were increasing every day. Our findings were substantiated by earlier observations where topographic, edaphic, and biotic factors were described to determine the shape, distribution, and availability of plant community and association setup within the major climatic zones (Sher et al., 2010; Rawat and Sathyakumar, 2010).

The present study found that the targeted plants mostly grow and occur on relatively open North east facing slopes, and prefer moist habitat. *P. amplexicaule* and *V. serpens* were found mostly associated with each other under the coniferous shade. Both were found very rarely in highly grazed and disturbed sites near the villages. *V. jatamansi* was found mostly associated with Geranium spp., Primula spp. and Potentilla spp., etc. in coniferous forests. The species was available on more intensely grazed and disturbed areas near the temporary shepherd's huts and on areas with cattle dung manure. In present study, it was also established that the existence and distribution of targeted plants were the result of interactions of physical and biotic factors within different habitats. This may give valuable indications to the characteristics of the site/habitats for other associated important plant species. Our findings are supported by earlier investigations showing that plant community association and structure might support population of one another (Sikarwar, 1996; Kala et al., 2006; Sher and Hussain, 2009). The population status of targeted species at lower altitude (that is, 1900 and 2300 m) was highly threatened by intensive agriculture and expansion of settlements in the study area. Such observations were coupled with other factors, such as over harvesting and over grazing to promote sustainable use and homogenous distribution of targeted species. As a result, the whole plant climate reduced from phanerophytic to therophytic and geophytic, and on the basis of leaf spectra where the area was dominated by microphyllous and nannophyllous. It reflected that the environmental conditions were severely disturbed and unfavorable for existing vegetation.

In general, it was noticed that both *P. amplexicaule* and *V. serpens* were palatable but non-preferred species for cattle, goats, and sheep and for other wild animals. *V. jatamansi* on the other side, was neither palatable nor a preferred species for all domestic as well as wild animals. Therefore, it did not suffer much by usual normal grazing. Nevertheless, the habitat and species composition, both were adversely affected by over-grazing while trampling damaged the young seedlings.

Population types

The observed categorization of targeted plant populations into three types viz: dynamic, normal and regressive was based on the relative proportions of the different life stages. However, besides the stage structure, there were certain other features that also contributed in distinguishing the population types. These included differences in population size, density of targeted plants, vegetation structure and composition. The results of our findings were supported by earlier studies where *Salvia pratensis* was categorized in three types of populations based on the phenological behaviour of the plant (Hegland et al., 2001). The findings of present study supported the hypothesis that different types of population structure of targeted plants could be identified. Hence, the terms population clusters were symbolized as: dynamic, normal, and regressive, after comparison with the findings of the earlier researchers (Hegland et al. 1994;

Hegland, et al., 2001). However, with the long-term demographic studies and matrix projection models, could identify all the three population types (Hegland et al., 2001) found in *Gentiana pneumononthe* to the actual population growth rates (measured as the finite rate of increase, λ). The present study also revealed that the three population types of targeted plants viz: Dynamic population increased ($\lambda>1$); normal population was stable ($\lambda=1$); and regressive population declined ($\lambda<1$). It is, therefore, possible that the three population types in targeted plants might show similar growth rates; however, it still needed to be confirmed.

The present endeavour also explained that viable population of targeted plants would be found in vegetation with a higher conservation value (in protected site) which would be reflected in higher species diversity or the occurrence of other rare and sparse species. It was observed that to some extent, the species composition of the surrounding vegetation was associated with the viability of targeted plants-population. However, dynamic and normal populations had rich species diversity and the differences were small and only marginally significant. The findings are in line with the study of Hegland et al. (2001) who reported that dynamic and normal population of *S. pratensis* showed higher species diversity with insignificant differences in contrast to the regressive population. However, other species (*Plectranthus – Sibbaldia – Themeda*) such as characteristic plant community of coniferous forest were indeed restricted to sites with dynamic and normal populations of targeted plants. Whereas species in nutrient rich conditions were associated with regressive populations of *P. amplexicaule, V. jatamansi* and *V. serpens*. In the current study, it was also noticed that the intensity rather than the type of management, significantly enhanced the mortality of the younger phenological stages due to destruction of flowering stalks by grazing cattle reducing seed-set (Bissels et al., 2004). In the end, the non-availability of seedling and juvenile individuals lead to disturbance and instability in their population. The results of our study were in accordance with another investigation where due to such reasons a decrease in population structure in size of *Succisa pratensis* and *Swertia perennis* was established (Buhler and Schmid, 200; Lenert et al., 2002).

In our present study, interestingly the fractions of individuals in the juvenile were not affected at all by both grazing and collection intensities. These findings indicated the destruction of adult plants which were finished before the completion maturity cycle under high biotic pressure. A similar negative relationship between management intensity and the proportion of seedlings and juveniles in targeted plant populations may apply to the other type of management and the wrong time of collection. As a result, the plant fails to complete their biological life cycle, and set fruits and seeds, which have adversely affected the population structure and types of targeted plants.

Population density

The natural regeneration of targeted medicinal plants (*P. amplexicaule, V. jatamansi,* and *V. serpens*) was severely affected by indiscriminate cutting of forests, heavy grazing and over harvesting in particular areas of the study. Therefore, their overall population density, coverage varied considerably in different sites of the investigated area. The overall population density and coverage of targeted species generally showed 40 to 50% decrease after collection. The signs of habitat loss were mostly observed at lower altitude. The sign of over harvesting and over grazing was observed throughout the investigated area. The current market information also supported our results, where due to high demand; a large amounts of the desired plants were over harvested (Sher et al., 2004) Our findings are in line with earlier reports on forest degradation by deforestation and overgrazing leading to severe reduction in population size and density of non timber forest products in Dolpa forest of Nepal (Belal and Springuel, 1996). These three types of disturbances adversely affected the population size and density of medicinal plants (*P. amplexicaule, V. jatamansi* and *V. serpens*) in different sites under current study.

The population density and coverage of targeted medicinal plants were increasing in protected areas (Malam, 1900 m), confirming that the targeted pharmacopeial plants grow in bulk quantities (40% more) in the reserved/protected areas of the present study. These findings supplemented the earlier proposed suggestion that protection might help in favor of revival of the original vegetation and recovery of natural habitats where degradation resulted due to heavy biotic interference (Sher et al., 2010). The results of the present study revealed that in unprotected sites of the study area, targeted plants were declining rapidly. As a result, these species occur rare in some of the sites of the present study area. This effect might be attributed to over extraction, grazing, and deforestation.

Effect of altitude and aspect

The physical and chemical analysis of habitat features revealed that the vegetation composition, structure and over all population size and abundance of targeted plants was mainly governed by altitude and aspect. Plants occurring at higher elevation acquired perennial nature due to short growing season of 4 to 6 months. They, therefore, required a prolonged growth periods of 6 to 10 years depending upon the plant species concerned (Sher et al., 2005). During the present study, it was observed that the density and coverage of targeted plants generally showed an increase of 3 to 5 times with rise in altitude.

Furthermore, it was also observed that parameters determined for each targeted plants appeared with promising results in the North, North-east and west facing aspects in contrast to South, South-east and west facing aspects. The study generally observed that key stone/umbrella species of targeted plants were mostly present on Northeast and west facing slopes in the study area. Therefore, targeted plants have significant population size and density in the North, North-east and west facing slopes. Secondly, it might be due to their close association with some plants such as *Cedrus deodara, Pinus wallachiana* and *Abies pindrow.* This agrees with the finding of Tuxil and Nabhan (1998) who reported that key stone species and other association of plants of the same habitat/nature are needed for ecological communities, which provide favourable micro-habitats such as shady cover from intense sun and buffering from cold winter night air. Targeted plants are shade and moist loving plants. Altitude and slope aspect modify temperature, light and moisture condition of an area. The air and soil temperature of southern aspect were higher than those of North-east and west slopes at all altitudes. In earlier study, we reported that North facing slope were relatively cooler than South facing slopes in Karmar Hills (Sher et al., 2005). In the present study area, the South facing slopes in early May felt spring while those of North-east and west facing slopes were still dormant and snow covered. The South facing slopes were relatively unfavourable in comparision to the North facing slopes, therefore, the production of targeted plants declined on these slopes. The effects of altitude on densities and phenological stage structure of targeted plants might also be explained by the confounding effect of management intensity. The low altitude was often closer to the residential areas of the farmers and collectors in contrast to medium and high altitude. Therefore, it was highly facilitated for intense harvesting, grazing, and other disturbances in contrast to medium and high altitude. As a result, the population densities of targeted plants had lost or on the verge of their extinction.

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