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Pitout JDD, Church DL, Gregson DB, Chow BL, McCracken M, Mulvey M, Laupland KB (2007). Molecular epidemiology of CTXM-producing Escherichia coli in the Calgary Health Region: emergence of CTX-M-15-producing isolates. Antimicrob. Agents Chemother. 51: 1281-1286.

Pelczar JR, Harley JP, Klein DA (1993). Microbiology: Concepts and Applications. McGraw-Hill Inc., New York, pp. 591-603.

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Full Length Research Paper

Echinoderm diversity in Mudasal Odai and Nagapattinam coast of south east India

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Echinoderm diversity was studied from Mudasal Odai (Lat.11°29'N; Long. 79°46' E) and Nagapattinam (Lat. 10° 46' N; Long. 79° 59' E) coast of Tamil Nadu, south east India. We recorded 14 species, 11 genera, 8 families, 5 orders and 3 classes in Mudasal Odai and 11 species, 8 genera, 6 families, 5 orders and 3 classes in Nagapattinam coast. The most diverse families are Temnopleuridae (4 species in Mudasal Odai and Nagapattinam). Among the genera, *Salmacis*, *Astropecten* and *Echinodiscus* has two species each in both study areas. The Echinoderm species *Temnopleurus torumatics* is the dominant in both Mudasal Odai and Nagapattinam coasts. Three species (*Stellaster equestris, Ophiocnemis mamorata* and *Salmacis virgulata*) in Mudasal Odai and three species (*Salmacis bicolor*, *Echinodiscus auritus*, *Echinodiscus bisperforatus*) in Nagapattinam coast were recorded as abundant species. Three species (*Pentaceraster regulus*, *S. bicolor*, *E. auritus*) in Mudasal Odai and four species (*Stellaster equestris*, *O. mamorata*, *Salmaciella dussumieri*, *Salmacis virgulata*) in Nagapattinam were reported as co-abundant species. Three species are present in two coasts, four species are present in Mudasal Odai. All echinoderm species are present in Mudasal Odai coast; three species are absent in Nagapattinam coast.

Key words: Echinoderm, Mudasal Odai coast, Nagapattinam coast, Temnopleuridae, *Temnopleurus torumatics*, *Salmacis*.

INTRODUCTION

Echinoderms have calcium-rich skeleton, five-part body plan with arms, water-vascular system interconnected canals with thousands of tiny hollow tube feet, and skin gills that are used for respiration and waste removal. There are different classes which include starfish, brittle stars, sea urchins, sand dollars, sea lilies and sea cucumber. Echinoderms are marine and widely distributed in benthic habitats from the intertidal to deep sea zones. About 6000 living species of echinoderms have been described in the world, of which more than 1000 have been listed for the Indo-West Pacific (Guille et al., 1986). Indo-West Pacific shallow-water echinoderm fauna is considered as rich resources (Clark and Rowe, 1971). Sea stars (Echinodermata: Asteroidea) are of great importance in marine ecosystems because, among other organisms and factors, some act as key species due to their predatory activities (Menge, 1982). The diversity of echinoderms is reported from the near shore regions of the Colombian Pacific coast (Neira and Cantera, 2005), at the Mauritius in the Indian Ocean (Rowe and Richmond, 2004), the Galapagos Islands in the Pacific (Hickman, 2009), coasts along the tropical west Pacific (Pearse, 2009), near the shore region of the Alaska Pacific coast (Chenelot et al., 2007), and in the Atlantic shelf around the British Isles

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(Ellis and Rogers, 2000). Echinoderm species are listed in Singapore (Bedford, 1900), China (Liao and Clark, 1995), Taiwan (Chao and Chang, 1989), Vietnam (Dao, 1994), Australia (Rowe and Gates, 1995) and India (Sastry, 2007).

MATERIALS AND METHODS

Echinoderms were collected from Mudasal Odai (Lat.11°29'N; Long. 79°46' E) and Nagapattinam (Lat. 10°46' N; Long. 79°59' E) landing centers, south east coast of India. Mudasal Odai 150 trawlers and Nagapattinam 500 trawlers were operated during the day and night. Trawlers operated the trawl nets at the depth of 10 – 30 m depth at both study areas. Sampling was made randomly from 5 heaps in Mudasal Odai and 10 heaps in Nagapattinam contributing 100 kg. Samples of each species were collected from 4 to 5 heaps from single trawl. About 100 kg of heaps were randomly sampled every week and consolidated as weekly total. Monthly performance was calculated and repeated. The results are categorized as follows: dominant when above 200 individuals exist (++++), abundant when individuals are about 100 – 200 (+++), co-abundant when individuals are about 50 – 100, and present when individuals number was below 50 (+). The samples were brought to the laboratory, cleaned with brush and identified using appropriate reference (Clark and Rowe, 1971).

RESULTS

The diversity of the echinoderms from two landing centers was 8 families, 11 genera and 14 species (Table 1, Figures 1 and 2). The number of species per family varies considerably (1 to 4 species). The most diverse family is the Temnopleuridae (4 species in Mudasal Odai and Nagapattinam), followed by the Astropectinidae (2 species in Mudasal Odai and Nagaipattianm), the Oraesteridae (2 species in Mudasal Odai, 1 species in Nagapattinam), and the Astriclypeidae (2 species in Mudasal Odai and Nagapattinam). Among the 14 species only one species (*Temnopleurus toreumatics*) was dominant in both coastal areas. Three species (*Stellaster equestris*, *Ophiocnemis mamorata*, *Salmacis virgulata*) in Mudasal Odai and three species (*Salmacis bicolor*, *Echinodiscus auritus*, *Echinodiscus bisperforaturs*) in Nagapattinam were abundant. Three co-abundant species (*Pentaceraster regulus*, *Salmacis bicolor*, *Echinodiscus auritus*) in Mudasal Odai and four co-abundant species (*Stellaster equestris*, *O. mamorata*, *Salmacis virgulata, Salmaciella dussumieri*) in Nagapattinam coast were reported. Three species (*Astropecten bengalensis*, *Astropecten indicus*, *Pentaceraster affinis*) in both coasts, seven species (*Luidia maculate*, *A. bengalensis*, *A. indicus*, *Pentaceraster affinis*, *S. dussumieri*, *Clypeaster humilis*, *E. bisperforatus*) in Mudasal Odai coast, three species (*A. bengalensis*, *A. indicus*, *Pentaceraster affinis*) in Nagapattinam coast were recorded present. All the 14 species were present in Mudasal Odai coast and three species (*L. maculate*, *P. regulus*, *C. humilis*) were absent in Nagapattinam coast. The species *E. bisperforatus* was recorded as abundant in Nagapattinam coast, but was recorded as a present in Mudasal Odai coast. The *S. dussumieri* was recorded as co-abundant in Nagapattinam coast, but was recorded as present in Mudasal Odai coast (Table 1).

DISCUSSION

A total of 86 echinoderm species were found in different parts of world, Census of Marine Life NaGISA programme (Natural Geography in Shore Areas, www.coml.nagisa.org) during 2003-2009; among these were 32 asteroids, 18 echinoids, 21 ophiuroids and 15 holothuroids (Iken et al., 2010). Echinoderm survey was made through scuba diving in the reef areas around Taiping Island, 39 species of echinoderms were found belonging to 17 families including 5 Crinoidea, 8 Asteroidea, 7 Ophiuroidea, 6 Echinoidea and 13 Holothuroidea at 40 m depth (Jeng, 1998). In Xisha Islands (China) 125 species echinoderms (3 Crinoidea, 38 Ophiuroidea, 17 Asteroidea, 26 Echinoidea, 41 Holothuroidea) were reported (Liao and Clark, 1995). Lane et al. (2000) recorded 982 species of echinoderms (111 crinoids, 227 asteroids, 272 ophiuroids, 167 echinoids and 203 holothuroids) in South China Sea (SCS). Li (1991) listed 197 species of echinoderms in the Nansha Islands (South China Sea) and Clark (1982) observed 95 species of echinoderms in Hong Kong and southern China. India has 651 species (Crinoidea: 65 species, Astereroidea: 158 species; Ophiuroidea: 152 species; Echinoidea: 113 species; Holothuroidea: 163 species) including Andaman and Nicobar Islands: 424 species and Tamil Nadu: 193 species (Sastry 2007). A total of 53 species of echinoderms belonging to 30 genera and 19 families were observed through scuba diving (up to 15 m depth) in 6 different areas (Aves Island, Sound Island, Rail Island, Karlo Island, Interview Island, and North Reef Island) of North Andaman, India (Koushik and Raghunathan, 2012).

Echinoids are one of the more diverse and successful echinoderm groups today. Fourteen species and 11 families were recorded in Taiwan water by Chao (2000). In the present study, 7 species of 3 families in Mudasal Odai coast and 6 species of 2 families in Nagapattinam coast were reported (Table 1, Figures 1 and 2). Asteroids are known with about 1,800 known species. There were 47 shallow water asteroid species recorded in the Gulf of California by Cintra-Buenrostro et al. (2005). In the present study, 6 species are reported to be affiliated with 4 genera (4 families) in Mudasal Odai coast and 4 species are affiliated with 3 genera (3 families) in Nagapattinam coast (Table 1, Figures 1 and 2). Herrero-Perezrul (2008) reported 22 species of echinoderms.

Asteroids were the most abundant, followed by echinoids and holothurians in the southern Gulf of California,

Table 1. Echinoderms recorded in trash fish of Mudasal Odai and Nagapattinam landing Centre.

S/N	Species name	Mudasal Odai	Nagapattinam
Class: Asteroidea			
Order: Paxillosida			
Family: Luidiidae			
1	*Luidia maculate* Muller and Troschel, 1842	+	-
Family: Astropectinidae			
2	*Astropecten bengalensis* Doderlein, 1917	+	+
3	*Astropecten indicus* Doderlein, 1889	+	+
Order: Valvatida			
Family: Goniasteridae			
4	*Stellaster equestris* (Retzius, 1805)	+++	++
Family: Oraesteridae			
5	*Pentaceraster affinis* (Muller and Troschel, 1842)	+	+
6	*Pentaceraster regulus* (Muller and Troschel, 1842)	++	-
Class: Ophiuroidea			
Order: Ophiurida			
Family: Ophiotrichidae			
7	*Ophiocnemis mamorata* (Lamarck, 1816)	+++	++
Class: Echinoidea			
Order: Camarodonta			
Family: Temnopleuridae			
8	*Salmacis bicolor* (L. Agassiz and Desor, 1846)	++	+++
9	*Salmacis virgulata* (L. Agassiz and Desor, 1846)	+++	++
10	*Salmaciella dussumieri* (L. Agassiz and Desor, 1846)	+	++
11	*Temnopleurus toreumaticus* (Leske, 1778)	++++	++++
Order: Clypeasteroida			
Family: Clypeasteridae			
12	*Clypeaster humilis* (Leske, 1778)	+	-
Family: Astriclypeidae			
13	*Echinodiscus auritus* Leske, 1778	++	+++
14	*Echinodiscus bisperforatus* Leske, 1778	+	+++

++++: Dominant; +++: Abundant; ++ Co abundant: +: Present; -: Not recorded.

Mexico. It seems that the community structure of echinoderms in the Gulf is relatively homogeneous and is dominated by asteroids (Reyes Bonilla et al., 2005). Echinoids species are dominating in Caribbean regions and asteroids and holoturians, in Northeast Pacific region (Iken et al., 2010). Ophiuroids were reported as dominant in South China Sea (Lane et al., 2000). In the present study, echinoids are more numerous (7 species in Mudasal Odai, 6 species in Nagapattinam) than asteroids (6 species in Mudasal Odai, 4 species in Nagapattinam) and holothurians are not recorded (Table 1, Figures 1 and 2).

Sea urchin abundance and diversity were more in regional-scale investigation in Mediterranean Sea (Guidetti and Dulcic, 2007). The causes for this pattern are uncertain but may be related to prevalence of thermo-philic species in sea urchins (Francour et al., 1994), lati-tudinal differences in recruitment success (Ebert, 1983; Tsujino et al., 2010) and/or salinity tolerance (Vidolin et al., 2007), competitive and predatory interactions (McClanahan and Shafir, 1990; Guidetti and Mori, 2005), relief from predation due to overfishing (Sala et al., 1998), as well as high adaptability of sea urchins to environmental stress (Starr

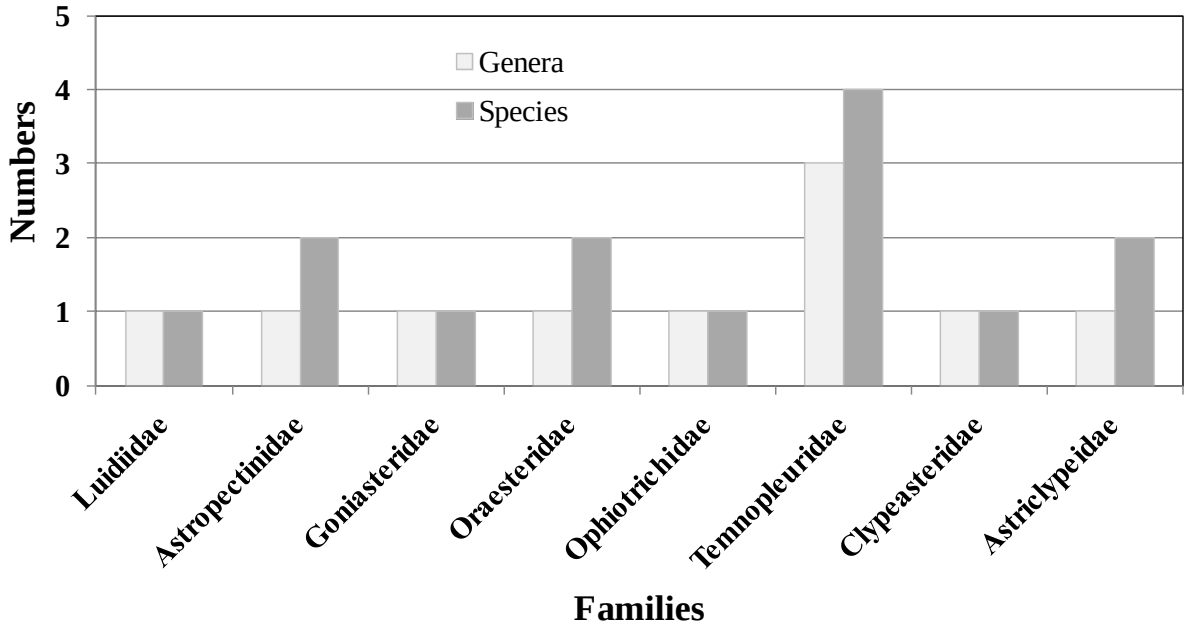

Figure 1. The number of families, genera and species of Echinoderms in Mudasal Odai coast.

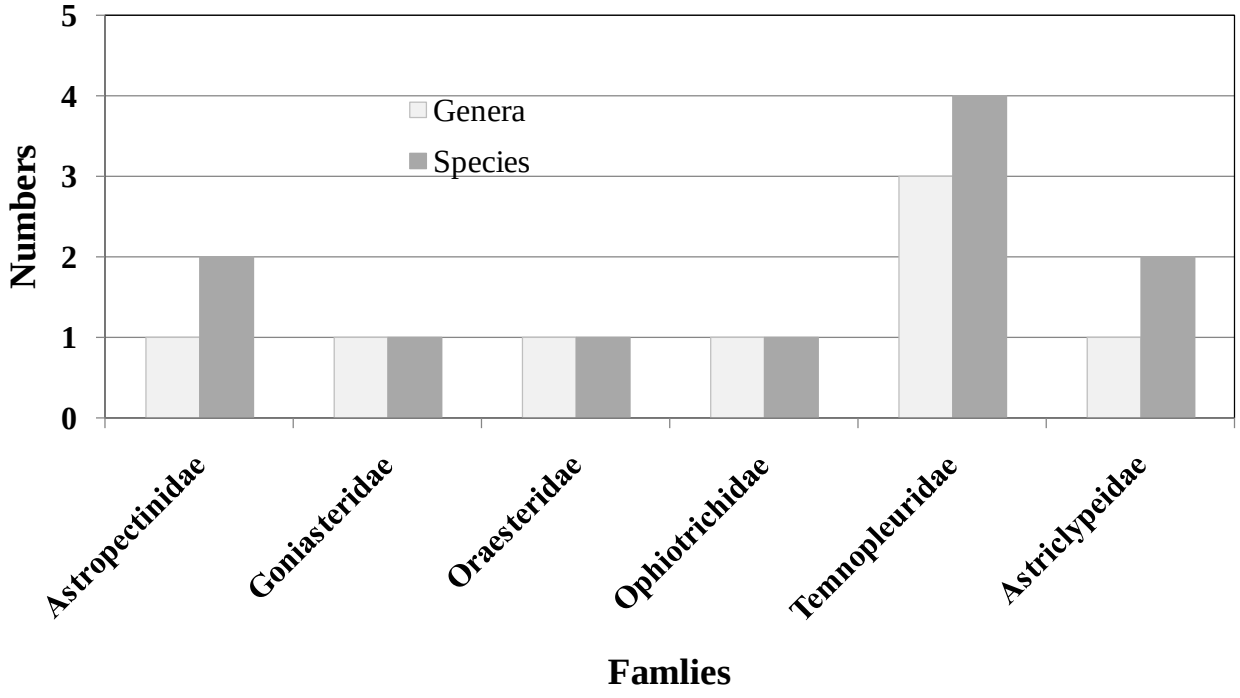

Figure 2. The numbers of families, genera and species of Echinoderms in Nagapattinam coast.

et al., 1993; Pancucci et al., 1993). In the present study, 3 genera and 4 species of echinoids are reported, among them 2 species of *Salmacis* (*S. bicolor*, *S. virgulata*), 1 species of *Salmaciella* (*S. dussumieri*) and one of *Temnopleurus* (*T. toreumaticus*) in both Mudasal Odai and Nagapattinam coast were recorded (Table 1). In the present study, *O. mamorata* was reported as abundant in Mudasal Odai coast and as co-abundant in Nagpattinam coast. Kanagaraj et al. (2008) reported *O. marmorata* associated with Rhizostome medusa *Rhopilema hispidum*

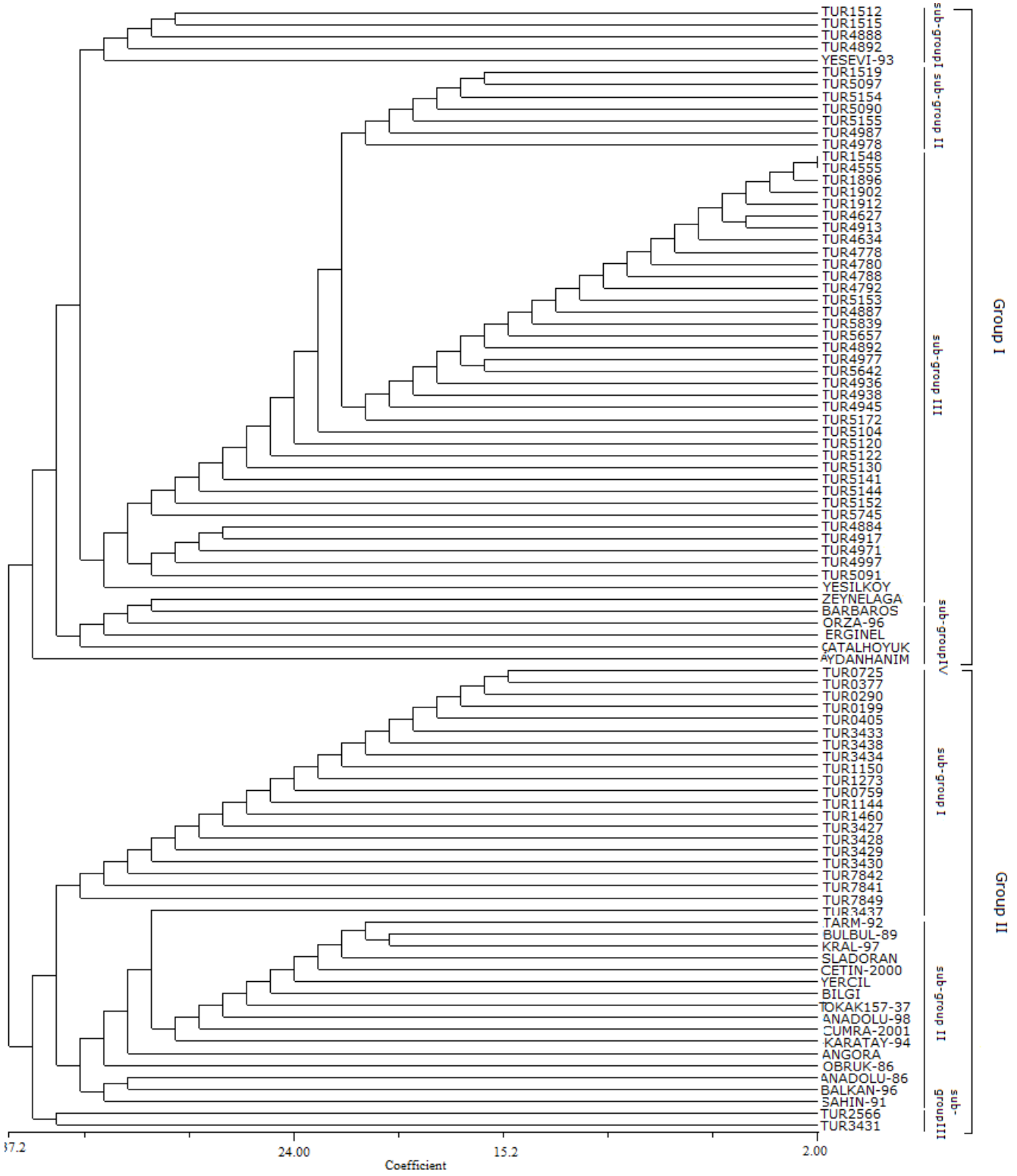

Figure 3. Dendrogram constructed by the UPGMA method.

from Vellar estuary, which is similar to one of our study areas. In Goniasteridea family, 40 species were reported from the sublittoral zone of the Straits of Florida (Halpern, 1970) and 26 species, in cold-water setting ranging from subtidal to abyssal depths of tropical Atlantic and North-east Pacific areas. During the present study, one species

(*S. equestris*) from the Goniasterideas family is recorded as abundant in Mudasal Odai coast and as co-abundant in Nagapattinam coast (Table 1). Sixteen ophiuroid species were reported from the Persian Gulf (Mortensen, 1940), 19 species, from Arabian coast of Persian Gulf (Price, 1981), 2 species, reported from Qeshm Island in the Persian Gulf (Reza Fatemi et al. 2010). The species *O. marmorata* is distributed in the Indian and west Pacific Oceans (Marsh, 1998). In the present study, the species (*O. mamorata*) in the family Ophiotrichidae is reported from the Ophiuroidea class as abundant in Mudasal Odai coast and as co-abundant in Nagapattinam coast (Table 1, Figures 1, 2 and 3).

Conclusion

In this study, 6 species of asteroids, 1 species of ophiuroids and 7 species of echinoids are reported. The family Temnopleuridae is dominant (4 species) followed by the families Astropectinidae and Astriclypeidae (2 species each). The *T. toreumaticus* is the dominant species in the present study. In Mudasal Odai coast, 14 species were present but in Nagapattinam coast 3 species were absent.

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REFERENCES

Bedford FP (1900). On the echinoderms from Singapore and Malacca. Proc. Zool. Soc. London 14: 271 – 299.

Chao S-M (2000). The irregular sea urchins (Echinodermata: Echinoidea) from Taiwan, with descriptions of six new records. Zool. Stud. 39: 250 – 265.

Chao S-M, K-H Chang (1989). Some shallow-water asteroids (Echinodermata: Asteroidea) from Taiwan. Bulletin of the Institute of Zoology, Academia Sinica 28: 215 – 223.

Chenelot HA, Iken K, Konar B, Edwards M (2007). Spatial and temporal distribution of echinoderms in rocky nearshore areas of Alaska. In: Selected papers of the NaGISA world congress 2006: Publications of the Seto Marine Biological Laboratory, eds. P.R. Rigby and Y. Shirayama, Special Publication Series. 8: 11 – 28.

Cintra-Buenrostro CE, Reyes-Bonilla H, Herreri-Perezrul MD (2005). Oceanographic conditions and diversity of sea stars (Echinodermata: Asteroidea) in the Gulf of California, Mexico. Revista de Biologia Tropical 53: 245 – 261.

Clark AM (1982). Echinoderms of Hong Kong. In: The marine flora and fauna of Hong Kong and Sourthern China eds. B.S. Morton and C.K. Tseng, Hong Kong: Hong Kong Univ. Press. pp. 485 – 501.

Clark AM, Rowe FWE (1971). Monograph of shallow water Indo-west Pacific Echinoderms. British Museum (Natural History), London. pp. 211 – 234.

Dao Tan Ho (1994). Check list of echinoderms in Vietnam 1: Crinoidea and Echinoidea. Science and Techniques publishing house, Vietnam: p. 111.

Ebert TA (1983). Recruitment in echinoderms. In *Echinoderm studies,* eds. M. Jangoux and J.M. Lawrence, I. Rotterdam: AA Balkema. 169 – 203.

Ellis JR, Rogers SI (2000). The distribution, relative abundance and diversity of echinoderms in the eastern English Channel, Bristol Channel, and Irish Sea. J. Mar. Biol. Assoc. UK. 80: 127 – 138.

Francour P, Boudouresque CF, Harmelin JG, Harmelin-Vivien ML, Quignard JP (1994). Are the Mediterranean waters becoming warmer? Information from biological indicators. Mar. Pollut. Bull. 28: 523 – 536.

Guidetti P, Dulcic J (2007). Relationships among predatory fish, sea urchins and barrens in Mediterranean rock reefs across a latitudinal gradient. Mar. Environ. Res. 63:168 – 184.

Guidetti P, Mori M (2005). Morpho-functional defenses of Mediterranean sea urchins, *Paracentrotus lividus* and *Arbacia lixula*, against fish predators. Mar. Biol. 147: 797 – 802.

Guille A, Laboute P, Menou JL (1986). Guide des étoiles de mer, oursins et autres échinoderms du lagon de Nouvelle-Calédonie. Paris: Edition de l'ORSTOM.

Halpern JA (1970). Goniasteridea (Echinodermata: Asteroidea) of the Straits of Florida. Bull. Mar. Sci. 20: 193 – 286.

Herrero-Perezrul MD (2008). Diversity and abundance of reef macro invertebrates (Mollusca; Echinodermata) in the southern Gulf of California, Mexico. Proceedings of the 11th International Coral Reef Symposium*,* Ft. Lauderdale, Florida. pp. 7 – 11.

Herrero-Perezrul MD, Reyes Bonilla H, Gonzalez Azcarraga A, Cintra Buenrostro CE, Rojas Sierra A (2008). Equinodermos. In: danemann GE, Ezcurra E (eds) Bahia de Los Angeles: recursos naturales y comunidad. Linea base 2007. *SEMARNAT-INE-PRONATURA NOROESTE-SDNHM*. Mexico pp.339 – 361.

Hickman CP (2009). Evolutionary responses of marine invertebrates to insular isolation in Galapagos. Galapagos Res. 66: 32 – 42.

Iken K, Konar B , Benedetti-Cecchi Lisandro, Cruz-Motta JJ, Knowlton A (2010). Large-Scale spatial distribution patterns of Echinoderms in nearshore rocky habitats. PLoS One 5: 1 – 14.

Jeng MS (1998). Shall-water Echinoderms of Taiping Island in the South China Sea. Zool. Stud. 37: 137 – 153.

Kanagaraj G, Sampath Kumar P, Morandini AC (2008). The occurrence of *Ophiocnemis marmorata* (Echinodermata: Ophiuroidea) Associated with the Rhizostome Medusa *Rhopilema hispidum* (Cnidaria: Scyphozoa). J. Ocean Univ. China 7: 421 – 424.

Koushik S, Raghunathan C (2012). A general account on community structure of echinoderms in north Andaman. Int. J. Biol. Pharm. Allied Sci. 1: 44 – 56.

Lane DJW, Marsh LM, VandenSpiegel D, Rowe FWE (2000). Echinoderm fauna of the South China Sea: An inventory and analysis of distribution patterns. Raffles Bull. Zool. 8: 459 – 493.

Li G (1991). Additional report on the echinoderms from the region of Nansha Islands. In Contribution on marine biological research of Nansha Islands and around the waters (I), eds. Q.C. Chen, Beijing: Ocean Press, (in Chinese) pp.189-197.

Liao Y, Clark AM (1995). The echinoderms of southern China. Science Press, Beijing New York. p. 614.

Marsh LM (1998). Hitch-hiking opiuroids. In *Echinoderms: San Francisco.* Proc. 9th Intl. Echinoderm Conf. eds. R.J. Mooi, and M.J. Telford, A.A. Bakelma, Rotterdam. pp. 393 - 396.

McClanahan TR, Shafir SH (1990). Causes and consequences of sea urchin abundance and diversity in Kenyan coral reef lagoons. Oecologia 83: 362 – 370.

Menge BA (1982). Effects of feeding on the environment: Asteroides. In: Echinoderm Nutrition, eds. M. Jangoux, and J.M. Lawrence, Balkema, Netherlands. pp. 521-551.

Neira R, Cantera JR (2005). Taxonomic composition and distribution of the echinoderm associations in the littoral ecosystems from the Colombian Pacific. Revista de Biologia Tropical 53: 195 – 206.

Pancucci P, Panayotidis P, Zenetos A (1993). Morphological changes in sea urchin populations as a response to environmental stress. In: Quantified phenotypic responses in morphology and physiology, ed. J.C. Aldrich, Ashford: JAPAGA. pp. 247 – 257.

Pearse JS (2009). Shallow-water asteroids, echinoids, and holothuroids at 6 sites across the tropical west Pacific, 1988-1989. Galaxea, J. Coral Reef Stud. 11: 1 – 9.

Price ARG (1981). Studies on the echinoderm fauna of the Western Arabian Gulf. J. Nat. Hist. 15: 1-15.

Reyes Bonilla H, González Azcárraga A, Rojas Sierra A (2005). Estructura de las asociaciones de las estrellas de mar (Asteroidea) en arrecifes rocosos del Golfo de California, Mexico. Revista de Biologia Tropical 53: 233 – 244.

Reza Fatemi SM, Jamili S, Valinassab T, Kuranlu N (2010). Diversity of Ophiuroidea from Lengeh Portand Qeshm Island in the Persian Gulf. J. Fish. Aquat. Sci. 5: 42 – 48.

Rowe FEW, Richmond MD (2004). A preliminary account of the shallow-water echinoderms of Rodrigues, Mauritius, western Indian Ocean. J. Nat. Hist. 38: 3273 – 3314.

Rowe FWE, Gates J (1995). Echinodermata. In: Zoological catalogue of Australia, ed. A. Wells, Melbourne: CSIRO Australia. pp. 510.

Sala E, Boudouresque CF, Harmelin-Vivien M (1998). Fishing, tropic cascades, and the structure of algal assemblages: evaluation of an old but untested paradigm. Oikos 82:425 – 239.

Sastry DRK (2007). Echinodermata of India an annotated list. Records of the Zoological Survey of India. Occasional Paper 271: 1 – 387.

Starr M, Himmelman J, Therriault JC (1993). Environmental control of green sea urchin, *Strongylocentrotus droebachiensis*, spawning in the St. Lawrence Estuary. Can. J. Fish. Aquac. Sci. 50: 894 – 901.Tsujino M et al. (2010). Distance decay of community dynamics in rocky intertidal sessile assemblages evaluated by transition matrix models. Popul. Ecol. 52: 171 – 180.

Vidolin D, Santos-Gouvea IA, Freire C (2007). Differences in ion regulation in the sea urchins *Lytechinus variegatus* and *Arbacia lixula* (Echinodermata: Echinoidea). J. Mar. Biol. Assoc. UK 87: 769 – 775.

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The role of homegardens for *in situ* conservation of plant biodiversity in Holeta Town, Oromia National Regional State, Ethiopia

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This study was conducted to assess the role of homegardens for *in situ* conservation of plant biodiversity in Holeta Town. In the garden data collection 75 homegardens were randomly selected. Ethnobotanical data were collected using homegarden observation, semi-structured interviews and market survey. Data were analyzed using preference ranking, direct matrix ranking, and descriptive statistics. A total of 112 plant species belonging to 93 genera and 43 families were identified which were classified to 14 functional groups. Out of which, 49 species (43%) were herbs, 32 species (29 %) were trees, 28 species (25 %) were shrubs, and (3%) species were climbers. Further analysis of the results showed that 70 species were cultivated, 35 were wild while 7 species were Ethiopia domesticated. Of the cultivated species, 41.07% were food crops and 58.93% were non-food crops. Family Fabaceae consisted of the highest number of species (11 species), whereas *Ensete ventricosum* was the most frequently occurring species (93.75%) in the homegardens of the area. Garden was managed by males (47.93%) and females (38.41%). Of the total plant species, 13% were medicinal plants, out of which 33.33% were nutraceutical plants. Direct matrix analysis showed that *Juniperus procera* was the most important versatile species followed by *Cordia africana.* These results indicate that homegardens studied play a crucial role in food security of the households and conservation *in situ* of these plant resources. However, insufficient agricultural support, small- sized gardens and the shifting of polycultural farming to few income generating food crops affect the diversity of species.

Key words: plant biodiversity, homegarden, hotspot, *In situ* conservation, indigenous knowledge.

INTRODUCTION

Biodiversity is crucial for survival, health and well-being of humans. It is giving greater resilience to ecosystems and organisms (Qualset et al., 1995). Complex, diversified and highly traditional rooted part of plant biodiversity conservation and utilization is found in homegardens (Kumar and Nair, 2006; Zemede, 2004).

Homegardens are variously named in English language as agroforestry homegardens, backyard gardens, farmyard, roof top garden, homestead farms, gardens (Kumar and Nair, 2004). In Ethiopia, a very common Amharic vernacular name equivalent for the term homegarden is "*Yeguaro-ersha*", in Oromo vernacular language is *"eddo*" means a land at a backyard of a house (Zemede, 2001).

Homegarden is commonly defined as land use systems involving deliberate management of multipurpose trees and shrubs in intimate association with annual and perennial agricultural crops and invariably, livestock within the compounds of individual houses, the whole tree-crop-animal unit being intensively managed by family labour (Christanty, 1990; Kumar and Nair, 2004). Such systems

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are essentially man-made and reflect the wisdom of the traditional culture and ecological knowledge that have evolved over the years (Kumar and Nair, 2004; Abebe et al., 2010).

The high diversity of species in home gardens plays wide socioeconomic and ecological roles. because it is related with the production of food and other products such as firewood, fodders, spices, medicinal plants and ornamentals (Christanty, 1985), prevention of environmental deterioration commonly associated with monocultural production systems, income generating sites (Hoogerbuugge and Fresco, 1993) and *in situ* conservation of agrobiodiversty (FAO 2001; Watson and Eyzaguirre, 2002). Generally, homegardens serve as refuges to a number of plant species, particularly those not widely grown in the larger agroecosystems. Moreover, they are the place of enormous indigenous knowledge (Eyzaguirre and Linares, 2004).

Ethiopia is one of the eight world's centers of origin and diversity of agricultural products. The tremendous variety and complexity of genetic resources results from *in situ* conservation of plants traditionally grown in homegardens (Zemede, 2001; Kumar and Nair, 2004). However, homegardens are currently under threat of genetic erosion such as, the displacement of great variety of landraces by few high-yielding varieties, loss of traditional knowledge of cropping patterns and management practices, socioeconomic factors and drought (Kumar and Nair, 2004; Zemede, 2004).

In Ethiopia, inventory and documentation of home gardens are very few. It has been concentrated in south and southwestern parts of Ethiopia (Zemede and Zerihun, 1997; Tesfaye, 2005; Talemos Seta, 2007; Abebe et al., 2010). Thus, the study was initiated to increase the knowledge of homegardens of northwestern Ethiopia, specifically in west part of Ethiopia, Holeta Town region. We provided analysis regarding plant species, management practices of local people and their contribution for agrobiodiversity conservation in this region.

MATERIALS AND METHODS

Description of the study area

Holeta Town is situated at a distance of 31 km West of Addis Ababa and located at 9°02' N latitude and 38°29' E longitude. The Town has an area of 5550 ha. Holeta Town is found in Oromia National Regional State (ONRS) of Ethiopia. Holeta Town is found at an average altitude of 2449 m a.s.l.

Selection of study sites and informants

During a reconnaissance survey (September, 2010) of the study area, overall information was obtained. Consequently, four study sites were identified and selected based on the presence of traditional homegarden practices and various ethnic communities (languages). They are described as Welayita community site (W.C.S), Gurage community site (G.C.S), Oromo community site (O.C.S) and Mixed community site (M.C.S).

A total of 400 houses (100 for each site) were randomly selected to determine the frequency of homegardens and to identify their local positions (front-yard, back-yard, side-yard or others). To undergo data collection and analysis, 75 homegardens were selected randomly from houses that practice homegardening. A total of 12 knowledgeable key informants were systematically selected from different sites with the assistance of community elders and local developmental agents for ethnobotanical data collection.

Data collection

Ethnobotanical data were collected by using semi structured interviews, field observation, market survey and ranking and scoring methods (Martin, 1995; Cotton, 1996). Interviews and discussions were conducted in Amharic (the local language) using a checklist of topics.

Direct matrix ranking was calculated for five multipurpose tree species in order to assess their relative importance to local people and to generate a matrix that represents the views of the entire community. Based on their relative uses, selected twelve key informants were asked to assign use values for each plant (using the following category 5 = best, 4 = very good, 3 = good, 2 = less used, 1 = least used and 0 = not used). In the end, the results of twelve respondents were summed up to generate a matrix that represents the views of the entire community (Martin, 1995; Cotton, 1996). Preference ranking was calculated for six food crops to determine the relative importance to local people. This technique was employed to rank some selected homegarden species according to their significances. Based on their personal preference of efficacy, selected informants were asked to assign use values for each plant (Highest score (10), while the one with the least effectiveness given the lowest score (1). The numbers are summed for all respondents, giving an overall ranking for the items by the selected group of respondents (Martin, 1995; Cotton, 1996).

Floristic composition data and plant identification

Floristic composition data collection was conducted on 75 sample plots of 10 m × 10 m (100 m^2) were delimited in 75 representative homegardens giving a total of 7500 m^2 or 0.75 ha. Then, counts of each species (presence or absence) were conducted on each plot. Specimens of plants found to be the homegardens were collected and local names and habits of each plant were recorded with the help of key informants and development agents. Botanical names were established by comparing specimens with those at the National Herbarium, Science Faculty of Addis Ababa University using available floras.

Data analysis

Ethnobotanical data were analyzed and summarized using descriptive statistical methods (percentages) and floristic composition data were analyzed for species diversity using appropriate equations of the following parameters: Frequency, Frequency classes A-E, Density, Shannon and Wiener index (H'), evenness and species richness, and Sorensen's Index of similarity (Kent and Coker, 1992; Shannon and Wiener, 1949; Whittaker, 1972)

RESULTS AND DISCUSION

Structure of homegardens in Holeta Town

The survey of 400 houses in Holeta Town indicated that 342 (85.50%) households were practicing homegardening.

The positions of homegardens are varying in type. The same case was reported by Zemede (2002), and Talemos Seta (2007).The size and diversity of species in the study area have positive correlations. With increase in holding size, more variations in species composition were encountered. Similarly, Tesfaye (2005) reported the same result in the study of diversity in homegarden agroforestry system of southern Ethiopia.

Homegardens in the study area are composed of trees, shrubs, herbs, climbing plants and food crops in different strata. They consist of trees approximately 10 to 15 m on the upper strata (*Eucalyptus camaldulensis, Erythrina brucei, Cupressus lusitanica*). Fruit crops *(Prunus persica)* and *Ensete ventricosum* encompassed the middle strata. Herbaceous plants up to 1 m from the ground strata *(Brassica carinata, Cymbopogon citrates*, *Beta vulgaris, Brassica carinata, Brassica oleracea, Daucus carota, Lycopersicon esculentum* and *Ocimum basilicum).* However, the horizontal structure of the species declines as one goes from homegarden to the out fields. This was also reported by Tesfaye (2005) in coffee-enset-based Sidama homegardens and Talemos (2007) enset-based homegardens in Welayita.

Plant diversity and composition of the homegardens of Holeta Town

A total of 112 plant species were identified and documented from the study area (Appendix I). These plant species were classified into 93 genera and 43 families. The commonly represented families were Fabaceae which contains 11 species, followed by Rutaceae and Poaceae in the second rank, which contain 8 species each, and Solanaceae in the third with 7 plant species.

The richest homegarden contained 47 species; whereas, the poorest garden contained 4 species and the mean was 22 species per homegarden. Among the recorded species, only 34 species (26.79%) were found in all study sites and 5 species in only two homegardens. From 112 plants species identified, 6.25% were indigenous plants such as *E. ventricosum*, *Juniperus procera* (Appendix I); 35 species were wild plants which grow, and 70 species were cultivated crops.

The growth form of the species were 49 (43%) herb species, 32 (29%) tree species, 28 (25%) shrub species, and 3% were climber plants. *E. camaldulensis*, *C. lusitanica*, and *Prunus persica* were the top tree species. *Rhamnus prinoides*, *Catha edulis*, and *Dovyalis caffra* were the most prominent shrub species in the study area.

The homegarden flora is composed of both food and non-food plants, accounting for 41.07% and 58.93% of the total of species respectively. Among the food crops, 19 species (17%) were fruit species, 15 species (13%) were vegetables and 6% pulses & cereals and ranked 1 to 3 in that order. On the other hand, from non-food components of the garden grown species, medicinal plants were 13% and construction & building plants were 12% and miscellaneous consisting of 5% ranked 1 to 3, respectively.

From the total number of species recorded in the study area, *E. ventricosum* (93.75%) was the most frequent species, followed by *E. camaldulensis* (90.63%).The species distributed in the frequency classes indicated 6.22% of high frequency values species occurred in higher frequency classes A and B. These classes include *E. ventricosum, E. camaldulensis*, *Justicia shimperiana, C. edulis, Solanum tuberosum* and *R. prinoides*. The remaining species were distributed in frequency classes C, D and E in ascending order containing 13.39%, 20.54% and 59.85% in that order a total of 93.78%, that indicated that more than half of species showed low frequencies. These results indicated that homegardens play a vital role in *in situ* conservation of agrobiodiversity (Lamprecht, 1989).

The value of Shannon-Wiener diversity index of sites ranges from 3.016 to 3.28 (Table 1). Naturally the Shannon's index value varies from 1.5 to 3.5 and rarely exceeds 4.5 (Kent and Coker, 1992).

Sorenson similarity index of the study area ranged from 0.206 - 0.346 or below 0.5 (Table 2), indicating the existence of low similarities/high species diversity among the recognized sites (Table 3). It may be related to the existence of diversified ethnic society in the study area, dissimilar habits for growing plants and preference of food crops as illustrated in (Table 4).

Factors that affect homegarden plant diversity

According to the results of semi-structured interviews, the diversity and productivity of homegardens in the study area were mainly affected by lack of agricultural support/ extension service (81.25%). Disease and pests are the main biological factors of the Welayita and Gurage community sites, which damaged market and non-market crops like *B. oleracea, Prunus persica,* and *S. tuberosum*.

Food plants in Holeta Town homegardens for nutrition and food security

Out of 112 plant species identified in the study area, 43 species distributed among 36 genera and 17 families were documented as food plants which accounted for 41.07% of the total. Among these, 45.50% were fruits, 30.23% vegetables, 13.95% pulses & cereals, 10.32% tubers and roots and 4% were spices. The fruits are the most usable parts (39.96%) and roots were least usable parts (4.35%) of the food plants. The diversity of food crops of the study area had significant role to increase nutritional and income status of the local people. Consequently, *P. persica* the most preferred and *Allium sativum* was the least preferred food crop (Table 4).

Table 1. Species numbers, Shannon Wiener diversity index and species evenness foreach study site.

Study site	Number of species (richness)	Shannon's index (H')	(H'/H'max)
Welayita C. D. S	81	3.260	0.74
Oromo C. D. S	57	3.016	0.76
Gurage C. D. S	65	3.283	0.79
Mixed C. S	87	3.161	0.72

Table 2. Sorenson similarity index of the homegardens of the study area.

Clustered HGs	Oromo C. D. S	Welayita C. D. S	Gurage C. D. S	Mixed C. S
Oromo C.D.S	1.00			
Welayita C.D.S	0.346	1.00		
Gurage C.D.S	0.212	0.217	1.00	
Mixed C. S	0.206	0.226	0.214	1.00

Table 3. Frequency of factors that affect diversity of homegardens.

Factor	Study site and frequency of factor					
	Welayita	Oromo	Gurage	Mixed	Total	percentage
Lack of agricultural support	7	3	8	8	26	81.25
Disease and pests	8	3	8	5	24	75.00
Garden size	5	1	7	6	19	59.38
Lack of water availability	2	8	-	7	17	53.13
Other			3	2	5	15.63
Market access	1	2	-	1	4	12.50

Table 4. Simple preferences ranking for widely used food crops in homegardens: 10- for most valuable, 1- for least valuable.

Scientific name	Key informant													
	1	2	3	4	5	6	7	8	9	10	11	12	Total score	Rank
Prunus persica	10	7	8	5	10	9	5	6	7	10	1	3	81	1
Malus sylvestris	1	6	10	2	4	5	10	10	5	8	9	9	79	2
Solanum tuberosum	7	10	1	4	8	6	9	5	8	6	9	5	78	3
Ensete ventricosum	2	9	8	8	9	8	4	3	9	8	4	3	75	4
Lycopersicon esculentum	6	2	7	10	6	10	3	4	8	5	2	6	69	5
Allium sativum	4	1	6	6	7	4	1	2	2	9	8	5	55	6

Important homegarden tree species with multiple uses

Homegarden owners and other people in Holeta Town have the tradition of using various tree species found in their homegardens for different purposes. The results of 12 key informants using direct matrix ranking in the four study sites showed that tree species have versatile uses (Table 5). The tree species were chosen according to the informant's consensus. Thus, *Juniperus procera* showed a total score of 239 (79.67%) and ranked first, *Cordia africana* and *Olea europaea* with a total of 227 (75.33%) and 219 (73%) second and third positions, respectively.

Homegarden plant species of HoletaTown with medicinal values

The traditions of planting nutraceutical plants and wild plant species in homegardens for medicinal purposes have a vital role to *in situ* conservation of agrobiodiversity. From a total of plant species (112) identified in the present study, 13% were used as traditional medicinal plants and distributed among 15 genera in 9 families (Appendix II). Among these, 33.33% were nutraceutical plants (Table 6) and 60% were wild plants. The findings obtained were similar to that of Belachew et al. (2003) that reported 133 plant species grown in the 'Gamo'

Table 5. Results of direct matrix ranking of five homegarden tree species and its six major uses. According to the 12 key informants.

Scientific name	Attributes and score								
	Construction and crafts	Fuel wood	Medicine	Live fence	Soil fertility	Shade	Total score	Rank	%
Cordia africana	47	34	-	44	57	45	227	2	75.33
Juniperus procera	55	32	-	54	54	44	239	1	79.67
Eucalyptus globulus	40	56	55	32	10	23	216	4	71.33
Olea europaea	44	28	23	31	44	49	219	3	73
Acacia Sesbania	43	55	-	33	42	22	195	5	65

Table 6. Medicinal and food (nutraceutical) plant species found in the study area.

Specie name	Part used as medicine	Health problems	Method of preparation and use
Allium sativum	Bulb	Headache, abdominal crump and flue	The bulb is eaten alone or with *Zingiber officinale*
Ensete ventricosum	Corm, leaf	Broken limbs	The underground corm is boiled and is eaten to recover from injured limbs
Punica granatum	Leaf	Expel tape worm	Decoction of the leaf is reported to be used as a tape worm remedy
Lepidium sativum	Seed	Constipation, evil eye diarrhea, skin rash	The seeds are ground, mixed with lemon & water & are taken orally to cure constipation & diarrhea / rubbed on the skin to treat skin rash

south Ethiopia homegardens of which 18 were medicinal plants.

Indigenous knowledge and homegarden management practices in Holeta Town

For maintenance, the diversity of homegarden species in Holeta Town depends on various indigenous management activities. Belachew et al. (2003) and Talemos (2007) confirmed the same results.

Homegarden owners of Welaiyta and Gurage communities sites developed indigenous knowledge about the preparation, classification and cultivating of *E. ventricosum. E. ventricosum* is a versatile crop that is used for food, fodder, medicinal and other uses (Table 7). In regions surrounding the study site, Zemede and Zerihun (1997) reported similar perception with regard to the functions of this valuable crop.

One of the best aspects of indigenous knowledge in the study area is work division in managing homegardens. Females managed (38.41%) vegetables, spices, and medicinal plants by planting, weeding, watering and selling (Christianity, 1990). Males participated (47.93%) cultivating cash crop plants and digging, designing, finding seed and seedling. Zemede (2002) remarked that the male family head is often accountable for designing homegarden structure, identifying suitable places for positioning the major crops, monitoring and strongly impacting the structure and direction of homegarden development. Our results confirmed homegardens are useful for the maintenance of good health in developing countries as also reported by UNICEF (1982). This indigenous know-

Table 7. Eight landraces of *Ensete ventricosum* recorded in Gurage community site.

Local variety name	Use
Kancho (G)	Food, Fodder, Fiber
Key enset (G)	Medicinal, Food, Fiber, Fodder
Guariye (G)	Medicinal, Food, Fiber, Fodder
K'ebbena (G)	Medicinal, Food, Fiber, Fodder
Deriye (G)	Food, Fiber, Fodder
Ankefe (G)	Food, Fiber, Fodder
Demret (G)	Medicinal, Food, Fiber, Fodder
Safar (G)	Medicinal, Food, Fiber, Fodder

G: Gurage language.

ledge is also important in the development of modern medicines as reported by Dawit et al. (2003) and Fisseha (2007).

CONCLUSION

The results of this study indicated that homegardens in Holeta Town had high species diversity and a rich floristic composition that is worthy of *in situ* conservation of plant biodiversity, trial sites of new variety of income source vegetables and other species. In addition, homegardens provide significant contributions for the gardener and the society as source of supplementary food, medicinal functions, and income. However, insufficient agricultural support, small sized garden and disease and pests affect the diversity of species. If these challenges receive attention by concerned institutions and researchers, the hotspot will maintain its existing biodiversity and traditional management systems on a sustainable basis in the future.

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REFERENCES

TesfayeAbebe, K.F Wiersum, F. Bonger F (2010). Spatial and temporal variation in crop diversity in agroforestry homegardens of southern Ethiopia

Belachew W, Zemede A, Sebsebe D (2003). Ethnobotanical Study of Useful Plants in Daniio Gade (Homegardens) In Southern Ethiopia. Ethiop. J. Biol. Sci., 2(2): 119-141.

Christanty L (1985). Homegardens in Tropical Asia: A special reference to Indonesia. Proceedings of the First International Workshop on Tropical Homegarden, 2-December, 1985, Bandung, Indonesia, pp.39-42.

Christanty L (1990). Homegardens in tropical Asia with special references to Indonesia .In: *tropical homegardens*, Pp .9-20 (Ladue, k. and Brazil, M. eds.). The United Nations University press, Tokyo, Japan.

Cotton CM (1996). Ethnobotany: Principle and Applications. John Wiley Sons Ltd Chichester, England.

Dawit A, Asfaw D, Kelbessa U (2003). Medicinal Plants and Other Useful Plants of Ethiopia. Ethiopian Health and Nutrition Research Institute, p.312.

Eyzaguirre P, Linares O eds (2004). Homegardens and agro biodiversity. Smithsonian Press. Washington, D.C. p. 254.

FAO (2001). Assessment of the World Food Security Situation. Committee on Food Security, Twenty-seventh Session, documents no CFS: 2001/2. FAO. Rome, Italy.

Fisseha M (2007). An Ethnobotanical study of Medicinal Plants in Wonago woreda , SNNPR, Ethiopia. M. Sc. Thesis, Addis Ababa University, p.72.

Hoogerbrugge I, Fresco LO (1993). Homegarden system: Agricultural characteristics and challenges. Intl. Inst. Environ. Devepment Gaxekeeper Series p.39.

Kent M, Coker P (1992). Vegetation Description and Analysis: A practical approach. Belhaven Press, London. p. 263.

Kumar BM, Nair PKR (2004). The enigma of tropical homegardens. Agroforestry Systems, Kluwer Academic Publisher.61:135-152.

Kumar BM, Nair PKR (2006). Tropical Homegardens: A time-tested Example of Sustainable Agroforestry. Environmental Experts S. L., p. 377.

Lamprecht H (1989). Siliculture in the tropics. Tropical forest ecosystems and their tree species possibilities and methods are the long-term utilization. T_2-verlagsgeslls chaft, RoBdort, Germany, p. 296.

Martin GJ (1995). Ethnobotany: A method Manual. Chapman and Hall, London. pp. 265-270.

Qualset CO, McGuire PE, Warburton ML (1995). Agrobiodiversity key to Agricultural productivity. Genetic Resource conservation program University of California, Davis, pp.35-41.

Shannon CE, Wiener W (1949). The mathematical theory of Communication. Unversity of Illions Press. Urbana III.

Talemos Seta (2007). Diversity in Ensete-Based Homegardens and Its Significance to Household Supply in Welayita (Southern Ethiopia): An Ethnobotanic Approach. M. Sc. Thesis, Addis Ababa University, p. 105.

Tesfaye Abebe (2005). Diversity in Homegarden Agroforestry Systems of Southern Ethiopia. Ph. D dissertation, Wageningen University, Netherlands.

UNICEF (1982). Homoegarden Handbook Biodiversity guide for Ethiopia. Word Conservation Monitering Center, Cambridge, Euphytica 96:1-2.

Watson JW, Eyzaguirre PB eds (2002). Homegardens and *in situ* conservation of plant genetic resources in farming systems. Proceedings of the Second International Home gardens Workshop, 17-19 July 2001, Witzenhausen, Federal Republic of Germany. Intl. Plant Genet. Resour Inst. (IPGRI), Rome, Italy pp.105-124.

Whittaker RH (1972). Evolution and measurement of species diversity. Taxon. 21:213-251.

Zemede Asfaw (2001). The role of homegardens in the production and conservation of medicinal plants. In: Conservation and Sustainable use of Medicinal plants in Ethiopia, (Medhin Zewdu and Abebe Demissie, eds.). Proceedings of the National Workshop on Biodiversity Conservation and Sustainable Use of Medicinal Plants in Ethiopia. 28 April - 1 May 1998. Institute of Biodiversity Conservation and Research, Addis Ababa, Ethiopia. pp. 76-91

Zemede Asfaw (2002). Homegardens in Ethiopia: Some observations and generalizations. In: Homegardens and *In situ* Conservation of Plant Genetic Resources in Farming Systems, (Watson J. W. and Eyzaguirre, P.B., eds.). Proceedings of the Second International Homegardens Workshop, July, 2001, Witzenhausen, Germany. Intl. Plant Genet. Resour. Inst. Rome, Italy. pp.125-139

Zemede Asfaw (2004). Homegarden and Agrobiodiversity. In: The enset based homegardens of Ethiopia, (Eyzaguirre and Linares eds.). Smithsonian Institution, Washington. pp. 123-147.

Zemede Asfaw, Zerihun Woldu (1997). Crop association of homegardens in Walayta and Gurage in Southern Ethiopia. SINET: Ethiop. J. Sci. 20(1):73-90.

Appendix I: List of plants found in Holeta homegardens.

Scientific name of plants	Local name (Amharic)	Family name	Habit	Collection number
Acacia abyssinica Hochst.ex Benth	Grar (A)	Fabaceae	tree	M035
Acacia melanoxylon R.Br	Omedla (A)	Fabaceae	tree	M064
Acacia Sesbania (vahl) Benth	Chaca (A)	Fabaceae	tree	M114
Ajuga integrifolia Buch-Ham ex-D.Don	Armagusa (A)	Lamiaceae	herb	M98
Allium cepa L.	Key shinkurt (A)	Alliaceae	herb	M033
Allium porrum L.	Baro shinkurt (A)	Alliaceae	herb	M023
Allium sativum L.	Netch shinkurt (A)	Alliaceae	herb	M040
Allophylus abyssinicus (Hochest) Radlkofer	Embuse (A)	Sapnidaceae	tree	M059
Anethum graveolens L.	Iensilal (A)	Apiaceae	herb	M053
Apium graveolens L.	Yeshorba kitel (A)	Apiaceae	herb	M014
Artemisia absinthium L.	Arrity (A)	Asteraceae	herb	M101
Arundo donax L.	Shenbeko (A)	Poaceae	herb	M083
Asparagus africanus L am	Serity (A)	Asparagaceae	climber	M021
Asplenium aethiopicum (Burm.f.)Bech	Fern (E)	Aspleniaceae	herb	M02
Beta vulgaris L.	Keyisir (A)	Chenopodiaceae	herb	M074
Beta vulgaris L.	Kosta (A)	Chenopodiaceae	herb	M056
Brassica carinata A.Br.	Yeguragie gomen (A)	Brassicaceae	herb	M088
Brassica integrifolia L.	Tikel gomen (A)	Brassicaceae	herb	M109
Brassica oleracea L. var. capitata	Yewer gomen (A)	Brassicaceae	herb	M093
Brassica oleracea L.	Gomen (A)	Brassicaceae	herb	M030
Buddleja davidii Franch.	Amfar (A)	Loganiaceae	shrub	
Callistemon citrinus (Curtis) Skeels	Bottle brush (E)	Myrtaceae	tree	M081
Canavalia africana L.	Adenguara (A)	Fabaceae	herb	M09
Citrus paradisi L.	Gripe fruit (A)	Rutaceae	shrub	M028
Canna indica L.	Setakuri (A)	Cannaceae	herb	M094
Capsicum annuum L.	Yeferenge karia (A)	Solanaceae	herb	M041
Carica papaya L.	Papay (A)	Caricaceae	herb	M115
Capsicum frutescens L.	Yabish karia (A)	Solanaceae	herb	M071
Carissa spinarum L.	Agam (A)	Apocynaceae	shrub	M025
Casimiroa edulis La Llave	Casimer (A)	Rutaceae	tree	M022
*Catha edulis (*Vahl.) Forssk.ex Endl	Chat (A) (E)	Celastraceae	shrub	M038
Citrus aurantium L.	Komtate (A)	Rutaceae	shrub	M090
Citrus aurantifolia (Christm.) Swingle	Lomi (A)	Rutaceae	shrub	M018
Citrus medica L.	Tirengo (A)	Rutaceae	shrub	M05
Citrus sinesis L. Osb	Birtukan (A)	Rutaceae	shrub	M010
Coccinia abyssinica (Lam) Cogn	Anchote (O)	Cucurbitaceae	herb	M103
Coffea arabica L.	Buna (A)	Rubiaceae	shrub	M034
Cordia africana Lam.	Wanza (A)	Boraginaceae	tree	M089
Croton macrostachyus Del.	Bisana (A)	Euphorbiaceae	tree	M024
Cucumis sativus L.	Kiar (A)	Cucurbitaceae	herb	M061
Cucurbita pepo L.	Duba (A)	Cucurbitaceae	herb	M043
Cupressus lusitanica Mill.	Yefireng tid (A)	Cupressaceae	tree	M090
Cymbopogon citralus (DC) Stapf	Tej-sar (A)	Poaceae	herb	M070
Daucus carota L.	Karot (A)	Apiaceae	herb	M112
Dovyalis caffra (Hook.f.Harv.)Hook.f.	Kosim (A)	Flacourtiaceae	shrub	M079
Ensete ventricosum (Welw) Cheesman	Enset (A)	Musaceae	herb	M087
Eragrostis tef (Zucc.)	Tef (A)	Poaceae	herb	M046
Erythrina brucei Schweinf	Korich (A)	Fabaceae	tree	M036
Eucalyptus camaldulensis Dehnh	Netch bahrzaf (A)	Myrtaceae	tree	M096
Eucalyptus globulus Labill	Key bahrzaf (A)	Myrtaceae	tree	M092

Appendix I. Contd.

Ficus elastica Roxb.	Yegoma zaf (A)	Moraceae	tree	M03
Ficus sur Forsk.	Sholla (A)	Moraceae	tree	M073
*Hagenia abyssinica (*Bruce) J. F. Gmel.	Koso (A)	Rosaceae	tree	M019
Hordeum vulgare L.	Gebs (A)	Poaceae	herb	M052
Juniperus procera Hochst,ex.Endl	Yabesha tid (A)	Cupresaceae	tree	M072
Justicia shimperiana L.	Sensel (A)	Acanthceae	shrub	M078
Lactuca sativa L.	Selata (A)	Asteraceae	herb	M060
Lepidium sativum L.	Fetto (A)	Brassicaceae	herb	M026
Ligustrum vulgare L.	Yeferenge mifakia (A)	Oleaceae	tree	M067
Lippia adoensis var adoensis	Kessie (A)	Verbenaceae	shrub	M051
Lippia adoensis var koseret Sebsebe	Koseret (A)	Verbenaceae	shrub	M068
Lycopersicon esculentum Mill	Timatim (A)	Solanaceae	herb	M084
Malus sylvestris Miller	Pom (apple) (A), (E)	Rosaceae	shrub	M065
Mentha spicata L.	Nana(A)	Lamiaceae	herb	M080
Millettia ferruginea (Hochst.) Bak	Birbira (A)	Fabaceae	tree	M099
Morus alba L.	Yeferenge injury (A)	Rosaceae	tree	M048
Musa X *paradisiaca* L.	Muse (A)	Musaceae	herb	M044
Myrtus communis L.	Ades (A)	Myrtaceae	shrub	M045
Nicotiana tobacum L.	Timbaho (A)	Solanaceae	herb	M016
Ocimum basilicum L.	Besobila (A)	Lamiaceae	herb	M031
Ocimum lamiifolium Hochst ex Benth	Demakese (A)	Lamiaceae	shrub	M017
Olea europaea L. sub sp cuspidata Wall ex G.Don.)Cif	Wyera (A)	Oleaceae	tree	M057
Osyris quadripartita Dec.	Kert (A)	Santslaceae	shrub	M076
Otostegia integrifolia Benth	Tinjuit (A)	Lamiaceae	shrub	M013
Pennisetum puprureum Schumach	Elphant grass (E)	Poaceae	herb	M100
Pentas schimperiana (A.Rich.)	Weynagifte (A)	Rubiaceae	herb	M066
Persea americana Mill	Abokado (A)	Lauraceae	tree	M058
Phoenix reclinata Jacq	Zenbaba (A)	Areaceae	tree	M020
Phaseolus vulgaris L.	Fossolia (A)	Fabaceae	herb	M011
Physalis peruviana L.	Yefirang awet (A)	Solanaceae	herb	M055
Phytolacca dodecandra L' Herit	Endod (A)	Phytolaccaceae	shrub/climber	M111
Pinus patulla Schiede ex Schltdl.&Cham	Arzelibanos (A)	Pinaceae	tree	M029
Pisum sativum L.	Ater (A)	Fabaceae	herb	M07
Plectranthus edulis L.	Yewelayta dinic (A)	Lamiaceae	herb	M010
Podocarpus falcatus (Thunbr.)R.B.ex.Mirb	Zigba (A)	Podocarpaceae	tree	M062
Prunus africana L.	Tikur enchet (A)	Rosaceae	tree	M063
Prunus x domestica L.	Prim (E)	Rosaceae	tree	M042
Prunus persica (L.) Batsch	KOk (A)	Rosaceae	tree	M027
Psidium guajava L.	Zitun I (A)	Myrtaceae	tree	M050
Punica granatum L.	Roman (A)	Punicaceae	shrub	M049
Rhamnus prinoides L' Herit.	Gasho (A)	Rhamanceae	shrub	M039
Ricinus communis L.	Golo (A)	Euphorbiaceae	shrub	M107
Rosa hybrida Hort.	Tigerda (A)	Rosaceae	shrub	M095
Rosmarinus officinalis L.	Sigametibesha (A)	Lamiaceae	shrub	M037
Ruta chalepensis L.	Tenadam (A)	Rutaceae	shrub	M032
Saccharum officinarum L.	Shenkorageda (A)	Poaceae	herb	M012
Salix subserrata Willd	Aleltu (A)	Salicaceae	tree	M113
Schinus molle L.	Kundoberberie (A)	Ancardiaceae	tree	M04
Sesbania sesban L. Merr	Sesbania (A)	Fabaceae	shrub	M104
Solanum nigrum L.	Yabish awit (A)	Solanaceae	herb	M001
Solanum tuberosum L.	Dinch (A)	Solanaceae	herb	M039
Sorghum bicolor L.	Tinquish (A)	Poaceae	herb	M054

Appendix I. Contd.

Trigonella foenum graecum	Abise (A)	Fabaceae	herb	M08
Verbena officinlis L.	Atuse (A)	Verbenaceae	shrub	M069
Vernonia amygdalina Del.	Grawa (A)	Asteraceae	tree	M108
Vica faba L.	Bakela (A)	Fabaceae	herb	M06
Vitis vinifera L.	Weyn (A)	Vitaceae	climber	M077
Washingtonia filifera L.	Zenbaba (A)	Areaceae	tree	M015
Zantedeschia aethiopica (L.) K.P.J Sprengel	Tirumbaabeba (A)	Areaceae	herb	M028
Zea mays L.	Bekolo (A)	Poaceae	herb	M047

** O: Oromo name, E: English name and A: Amharic name.

Appendix II: Species of medicinal plants widely used in the homegardens of Holeta Town.

Species name	Local name (Amharic)	Part used	Habit
Allium sativum	Nich senkurit	Bulb	herb
Artemisia absinthium	Ariti	Leaf	herb
Ajuga integrifolia	Armagusa	leaf	herb
Croton macrostachyus	Bisana	Leaf sap	tree
Cymbopogon citrates	Tej-sar	Root	herb
Verbena officinalis	Atuch	Leaf	shrub
Ensete ventricosum	Key enset	Corm, Leaf	herb
Eucalyptus globules	Nech bharzaf	Leaf	tree
Anethum graveolens	Insilal	Leaf	shrub
Hagenia abyssinica	Kosso	Flower	tree
Mentha spicata	Nana	Leaf	herb
Punica granatum	Roman	Leaf	shrub
Ruta chalepensis	Tena- adam	Leaf	shrub
Vernonia amygdalina	Grawa	Leaf	tree
Pentas schimperiana	Weynagift	leaf	herb
Lepidium sativum	Fetto	seed	herb

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Assessment of fuel resource diversity and utilization pattern in Nargu Wildlife Sanctuary of Himachal Pradesh, NW Himalaya

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Dearth in the studies related to the fuelwood collection trends, conservation and management has prompted the present work. Nargu Wildlife Sanctuary of Himachal Pradesh was assessed for the fuel resources because the region was not evaluated earlier and dependency of the stakeholders on the forest resources was soaring. In the twenty three villages studied, forty five species (33 trees and 12 shrubs) belonging to 23 families of fuel resource were recorded. In the three different altitudinal ranges of the area probability of use (PU) and resource use pattern (RUI) was studied and it was highest for *Quercus leucotrichophora* A. Camus (1879.30 kg household^{-1} year^{-1}), followed by *Rhododendron arboreum* Sm. (433.57 kg household^{-1} year^{-1}), *Cedrus deodara* (Roxb. ex D. Don) G. Don (425.22 kg household^{-1} year^{-1}), *Myrica esculenta* Buch.-Ham. ex Don (385.05 kg household^{-1} year^{-1}) and *Persea duthiei* (King. ex Hk.f.) Kostern. (370.96 kg household^{-1} year^{-1}). Among the surveyed villages, maximum total collection (7992 kg/hh/year) was done in Mandra followed by Seri (7524 kg/hh/year) and Drun (7476 kg/hh/year) villages. Of the total, 33 species were native to the Himalayan Region, 06 species native to the Himalayan region and neighboring countries and remaining species were non-natives. Major thrust of the study is to comprehensively manage the species highly-preferred for fuel, diversification of choice of species from natives to non-natives, and their large scale propagation.

Key words: Conservation, endemic, fuelwood, Indian Himalayan Region (IHR), native.

INTRODUCTION

Fuel resources in India continue to be the primary sources of domestic energy in the rural areas. In rural India, fuel wood is the major source of energy for the domestic use. Fuel wood demand in India ranged from 96 to 157 million tons annually including a rural demand of 80 to 128 million tones. This means annual consumption of 148 to 242 million tons per capita (Bhattacharaya and Nanda, 1992). In Himachal Pradesh, a Himalayan state, more than ninety percent of the population resides in rural areas. Here, alternative source of fuel are very limited in the villages so their dependence on the forests is inevitable. Unfortunately these resources are continuously being degraded (Shah, 1982; Khoshoo, 1987) with an alarming rate. However, extraction activities of the plant resources are limited in the protected areas but as far as fuel wood is concerned stakeholders have the rights to avail these resources to some limited extent. Continued unrecorded exploitation has been a threat to the sustenance of this resource even in the protected areas and study for such trends are urgently required. Few earlier studies have already recorded the fuel extraction trends in different parts of the Himalaya (Samant et al., 2000; Dhar et al.,

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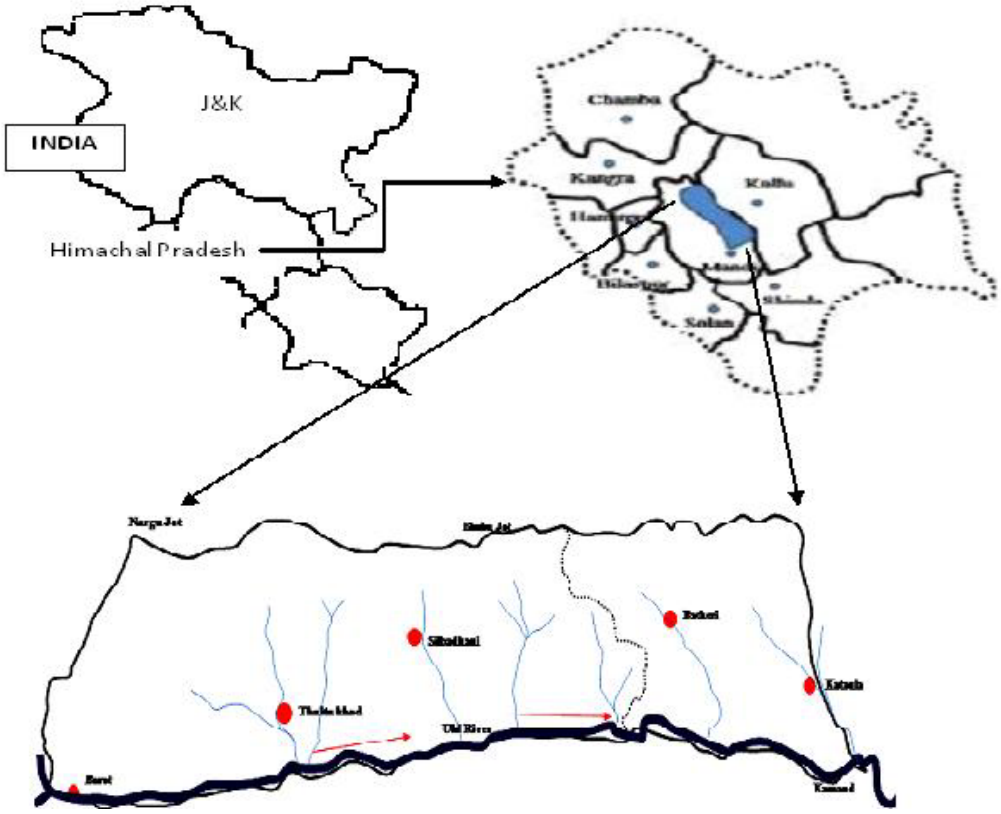

Figure 1. Map showing study area.

1998) and suggested the suitable conservation strategies. Nargu Wildlife Sanctuary (hereafter, NWLS) of Himachal Pradesh has large human population and is one of the biggest protected areas of the state, so dependence of the stakeholders upon forest resources is massive. Fuel resources in the region have not yet been assessed extensively. So the present work was done in the area with the following objectives. 1) diversity and extraction trend of the fuel resource, 2) annual quantity collected in the area, 3) species preference, 4) probability of use and resource use index, 5) nativity of the species, 6) dominant elements in the forest communities where fuel resource is present, 7) utilization pattern of the fuel resource and 8) to suggest a management strategy for conservation.

MATERIALS AND METHODS

Study area

The NWLS (31°046´N to 32°05´N Latitudes and 76°50´ to 77°04´ E Longitudes) is located in Mandi district of Himachal Pradesh (Figure 1). The Sanctuary was notified in 1972. It covers an area of over 278 Km^2 with an altitudinal range, 970 to 4000 m amsl. Temperature ranges between -10 to 35°C and mean annual rainfall is 1400 mm. It represents sub-tropical, temperate, sub-alpine and alpine vegetation. The Sanctuary is rich in biodiversity including a large number of mammals and birds. The livelihoods of the local villagers and graziers of 190 villages with 30,000 human population and 50,000 cattle population are dependent on the sanctuary. The inhabitants residing in the periphery are dependent on the Sanctuary for minor forest products (including medicinal and wild edible plants), fuel, fodder, timber, livestock grazing and various other purposes.

Trends of fuel collection

The sanctuary area is having diverse habitats and mostly the inhabitants of the sanctuary are dependent on forest produce for their sustenance. We surveyed 23 villages during 2008 to 2012 for extraction trend of fuel resource in three different altitudinal ranges of the sanctuary (that is, seven villages <1500 m, six villages 1500 to 1800 m and 10 villages >1800 m). In survey of the sanctuary, we found that the natives of the area start collecting fuel wood from end of November to end of February months. So we assume that the inhabitants collect fuel for about 90 days and considered these as total collection days (TCD). The dry fuel wood is stored in lots and used subsequently.

Data analysis

The information was gathered through semi structured questionnaires from the different surveyed villages and pooled together. For each species, mean collection collected (Kg $sample^{-1}$ day^{-1}; kg $household^{-1}$ $year^{-1}$), probability of use (PU) and resource use index (RUI) were calculated as follows:

Mean collection (Kg) of the species, A = T/N (1)

Where T = Total collection in all samples, and N= number of samples;

$$\text{Mean collection sample}^{-1}\,\text{day}^{-1},\ Cs = \frac{\sum_{i=1}^{n=6} A\,TPR_i}{\sum_{i=1}^{n=6} A\,TPR_i} \quad (2)$$

Where A = mean collection of the species, and TPR_i = Total population responsible for collection in the i^{th} village;

$$\text{Mean collection houseold}^{-1}\text{day}^{-1},\ Cd = 2Cs \quad (3)$$

$$\text{Mean collection houseold}^{-1}\text{year}^{-1},\ Cy = 90\ Cd \quad (4)$$

Where 90 was the total collection days per year;

$$\text{Probability of use, } PU = \sum F_i P_i / \sum P \quad (5)$$

Where F_i = frequency of collection of a species in the i^{th} village; P_i= population of the i^{th} village

$$\text{Resource Use Index, } RUI = CyPu \quad (6)$$

Where Cy= mean collection houseold^{-1} year $^{-1}$

RESULTS

Diversity and extraction trends of fuel resources

Among the 23 surveyed villages, total 45 species (33 trees and 12 shrubs) belonging to 23 families were used as fuel by the inhabitants. Rosaceae and Pinaceae were the dominant families (5 spp. each); followed by Moraceae (4 spp.); Fagaceae, Lauraceae and Meliaceae (3 spp. each). *Quercus leucotrichophora*, *Rhododendron arboreum*, *Neolitsea pallens*, *Pinus wallichiana*, *Berberis lycium*, *Sorbaria tomentosa*, *Alnus nitida* and *Desmodium elegans* were contributed most to collections as fuel (Table 1). Among the surveyed villages, maximum total collection (7992 kg/hh/year) was done in Mandra followed by Seri (7524 kg/hh/year) and Drun (7476 kg/hh/year) villages (Table 2 and Figure 2).

Mean collection was highest for *Q. leucotrichophora* (1879.30 kg household^{-1} year^{-1}), followed by *R. arboreum* (433.57 kg household^{-1} year^{-1}), *Cedrus deodara* (425.22 kg household^{-1} year^{-1}), *M. esculenta* (385.05 kg household^{-1} year^{-1}) and *Persea duthiei* (370.96 kg household^{-1} year^{-1}). The remaining species showed relatively low values (Table 1). Similar was the use of preference for the species in the entire area of the sanctuary. Species diversity, preference of use, their distribution in different communities, dominant elements of communities, altitude range, and utilization pattern of fuel resource for the entire area is shown in Table 3.

Village wise altitudinal mean fuel collection was more in villages which were below 1500 m and above 1800 m that is, 6672 and 7065 kg household^{-1} year^{-1} respectively. It was lesser in 1500 to 1800 m zone (6254 Kg household^{-1} year^{-1}). Same trend was shown for mean number of species collected in these altitudinal zones. It was 14, 12.7 and 10 in >1800 m, <1500 m and 1500 to 1800 m respectively (Figure 3).

Probability of use (PU) and resource use indices (RUI)

PU was highest for *Q. leucotrichophora* (0.95), followed by *R. arboreum* (0.55), *P. duthiei* (0.14), *C. deodara* and *M. esculenta* (0.12 each) indicating high pressure on these species. The remaining species showed < 0.1 PU and reflected their low preference or low availability in the wild. RUI ranged from 0.31 to 945.62. It was highest for *Q. leucotrichophora* (945.62), followed by *R. arboreum* (138.85), *C. deodara* (102.55) and *P. duthiei* (96.86) suggesting their great acceptability as fuel and high anthropogenic pressure on these species. The remaining species showed <96 RUI showing less use value (Table 1 and Figure 4).

Status and distribution of native and endemic species preferred

Of the total recorded (45 species), 33 species were native to the Himalayan Region, 06 species native to the Himalayan region and neighboring countries, and remaining species were non-natives. None of the species was found to be endemic to the Indian Himalayan Region (IHR) but there were 15 near endemic species few of these were *Abies pindrow, Cedrus deodara, Rhododendron campanulatum, Rhus wallichii, Indigofera heterantha* and *Aesculus indica* etc. (Table 1).

DISCUSSION

In the present study fuelwood resources and their consumption patterns have been studied in 23 villages of NWLS of Himachal Pradesh. The villages were located in three different altitudinal zones of the Sanctuary namely, <1500 m; 1500 to 1800 m and >1800 m. Number of species and mean collection (Kg household^{-1} year^{-1}) of the fuel wood species was more in the lower (<1500 m) and higher (>1800 m) altitude zones. This may be due to the abundance of forests and easily accessible resources in the vicinities of these zones.

The Sanctuary area is mostly dominated by evergreen broad leaved (*Quercus floribunda, Q. leucotrichophora, Quercus semecarpifolia* etc.) and evergreen coniferous (*Abies pindrow, C. deodara, P. wallichiana* etc.) communities. High probability of use (PU) and resource use index (RUI) of *Q. leucotrichophora, R. arboreum, P. duthiei, N. pallens, D. elegans* and *M. esculenta* etc. indicated

Table 1. Mean collection, probability of use (PU) and resource use index (RUI) of fuel resource in the NWLS.

Taxa	Family	Local name	Nativity	Mean collection (Kg/hh/year)	PU	RUI
Abies pindrow Royle*	Pinaceae	Tosh	Reg Himal	26.09	0.01	1.90
Aesculus indica Coleb. ex Wall.*	Hippocastanaceae	Khanor	Reg Himal	46.43	0.02	7.12
Albizzia lebbek Benth.	Mimosaceae	Sirish	As Trop et Subtrop	109.57	0.03	29.43
Alnusnitida (Spach) Endl.*	Betulaceae	Kolsh	Reg Himal	231.65	0.09	43.41
Thamnocalamus spathiflorus (Trin.) Munro*	Poaceae	Ringar	Reg Himal	22.43	0.01	1.54
Berberis lyceum Royle*	Berberidaceae	Kashmale	Reg Himal	64.70	0.03	10.80
Buddleja crispa Benth.	Loganiaceae	Sandhiyara	Reg Himal Burma	36	0.05	5.4
Cedrus deodara (Roxb. ex D. Don) G. Don*	Pinaceae	Dyar	Reg Himal	425.22	0.12	102.55
Celtis australis L.	Ulmaceae	Kharik	Europe Aust, Ind Or	64.17	0.02	5.74
Cinnamomum tamala Nees & Ebern*	Lauraceae	Tejpatta	Reg Himal	13.04	0.00	1.30
Debregeasia salicifolia (Don) Rendl.	Urticaceae	Saryahu	As et Afr Trop	284.35	0.07	51.73
Desmodium elegans DC.	Fabaceae	Safedkathi	China	297.39	0.08	51.76
Ficus palmate Forsk.	Moraceae	Fegra	Afr Trop, Arab, Ind Or	48.52	0.02	3.91
Ficus roxburghii Wall.	Moraceae	Triambal	Reg Himal, Burma	21.39	0.01	1.90
Ficus nemoralis Wall. ex Mir*	Moraceae	Dudhla	Reg Himal	18.26	0.01	1.64
Grewia oppositifolia Buch.-Ham. ex D. Don	Tiliaceae	Beul	Reg Himal	116.35	0.04	25.49
Indigofera heterantha Wall. ex Brand.	Fabaceae	Kali Kathi	Reg Hial	187.83	0.07	28.88
Jugulans regia L.*	Juglandaceae	Khor	As Occ, Reg Himal	6.78	0.00	0.34
Lyonia ovalifolia (Wall.) Drude	Ericaceae	Bheral	China	184.17	0.07	20.69
Melia azadiarach L.	Meliaceae	Drek	Reg Himal	37.57	0.01	3.76
Morus serrata Roxb.	Moraceae	Chimmu	Reg Himal	31.83	0.01	5.03
*Myrica esculenta*Buch. -Ham. ex Don	Myricaceae	Kafal	As Trop et Subtrop	385.05	0.12	72.42
Neolitsea pallens (D.Don) Momi. & Hara ex Hara	Lauraceae	Chhinchri	Reg Himal	163.30	0.06	30.29
Persea duthiei (King. ex Hk.f.) Kostern.*	Lauraceae	Dodru	Reg Himal	370.96	0.14	96.86
Picea smithiana (Wall.) Boiss.*	Pinaceae	Rai	Reg Himal	130.43	0.04	15.47
Pinus roxburghii Sarg.	Pinaceae	Chil	Reg Himal	221.74	0.06	50.37
Pinus wallichiana A.B. Jack.	Pinaceae	Kail	Reg Himal	110.09	0.03	10.64
Pistacia integerrima Stew.	Anacardiaceae	Kakare	Aegypt Persia, Reg Himal	9.39	0.00	0.47
Prinsepia utilis Royle	Rosaceae	Bhekhal	Reg Himal	25.04	0.02	5.74
Prunus cerasoides D. Don*	Rosaceae	Paja	Reg Himal	103.30	0.04	28.80
Prunus armeniaca L.	Rosaceae	Shara	Reg Caucas	24.00	0.01	2.19
Pyrus pashia Buch. -Ham. ex D. Don*	Rosaceae	Shegal	Reg Himal	188.87	0.07	31.25
Quercus floribunda Lindl.*	Fagaceae	Moharu	Reg Himal	107.7	0.05	9.7

Table 1 Contd.

Quercus leucotrichophora A.Camus	Fagaceae	Ban	Reg Himal	1879.30	0.95	945.62
Quercus semecarpifolia Sm.	Fagaceae	Kharshu	Reg Himal	39.6	0.01	2
Rhamnus purpureus Edgew	Rhamnaceae	Kubbal	Reg Himal	27.6	0.03	2.7
Rhododendron arboreum Sm.	Ericaceae	Burah	Ind Or Reg Himal Zeylan	433.57	0.55	138.85
Rhus javanica L.	Anacardiaceae	Titri	Reg Himal	79.30	0.08	12.05
Salix wallichiana Anders.	Salicaceae	Bashal	Reg Himal	30.6	0.03	1.8
Sorbaria tomentosa (Lindl.) Rehder	Rosaceae	Kushti	Reg Himal As Bor	84.00	0.02	11.92
Symplocos chinensis (Lour.) Decne.	Symplocaceae	Lojh	Japon	58.43	0.02	7.62
Toona ciliata Roem.	Meliaceae	Tuni	Malaya Austr	6.26	0.00	0.31
Toona serrata (Royle) Roem.	Meliaceae	Daral	Malaya Austr	6.26	0.00	0.31
Ulmus villosa Brand. ex Gamble*	Ulmaceae	Kshoh	Ind Or As	61.2	0.02	5.2
Viburnum mullah Buch. -Ham. ex D. Don	Caprifoliaceae	Talana	Am Bor	26.4	0.02	2.5

Kg/hh/yr = Kilogram/household/year; PU = Probability of use; RUI = Resource use index; Aegypt = Egypt; Am = America; As = Asia; Austr. = Australia; Bor = Borealis; et = And; Ind = India; Japon = Japan; LN = Local name; MC = Mean collection; Occ = Occidentalis; Or = Oriental; RegHimal = Himalayan region; Subtrop=Sub Tropical; Trop = Tropical;* = Near endemic.

Table 2. Village wise fuel collection in NWLS.

Village	Altitude (m)	Number of House holds	Population responsible for collection	Number of species collected	Total collection (Kg/h/year)
Rihagari	1140	33	66	8	6684
Malwara	1313	30	60	14	6804
Balh	1335	32	64	13	6972
Tikker	1370	45	90	18	7296
Kutahar	1394	37	74	9	5484
Arang	1437	34	68	14	6432
Ropa	1452	59	118	13	7032
Dharmed	1628	48	96	6	6120
Drun	1658	68	136	16	7476
Hurang	1693	66	132	7	6120
Kashala	1708	26	52	11	5124
Badaun	1728	30	60	12	7092
Swar	1738	28	56	6	5592
Mandra	1806	34	68	17	7992
Seri	1830	51	102	15	7524
Bulang	1837	64	128	14	6804
Dhar	1845	28	56	10	6348
Sudhar	1890	20	40	14	7092
Kampan	1894	31	62	14	6468
Jagtang	1900	30	60	12	7308
Graman	1909	68	136	15	7152
ShilhBadhani	2004	28	56	13	7188
Kungar	2066	29	58	14	6780

Figure 2. Fuel wood collection in NWLS; a) weighing up fuel wood, and b) Stakeholder carrying fuel wood resource.

Table 3. Preferences (1 indicates most preferred), altitudinal range and uses of the fuel species in NWLS.

Taxa	Preference	Altitudinal range	Communities	Utilization pattern	Dominant species
Quercus leucotrichophora	1	1000 - 2600	*Q. leucotrichophora, Q. leucotrichophora-C. deodara* mixed, *Q. l*eucotrichophora-*M. esculenta* mixed, *Q. leucotrichophora-N. pallens* mixed	M, Fd, At	*R. arboreum, Q. leucotrichophora, M. esculenta, Sarcococa saligna*
Rhododendron arboreum	2	1000 - 2300	*R. arboreum, R. arboreum-A. nitida* mixed, *R. arboreum-L. ovalifolia* mixed, *R. arboreum-Q. leucotrichophora* mixed	M, Ed	*R. arboreum, Q. leucotrichophora, Indigofera heterantha*
Cedrus deodara	3	1600 - 2500	*C. deodara, C. deodara-P. wallichiana* mixed, *C. deodara-Q. leucotrichophora* mixed	M, Ti, At, Misc	*C. deodara, S. saligna, Arundinaria spathiflora*
Persea duthiei	4	1000 - 2200	*R. arboreum-A. nitida* mixed, *Q. l*eucotrichophora-*M.esculenta* mixed, *A. indica-Persea duthiei* mixed	Fd, Misc	*R. arboreum, A. nitida*, *Q. leucotrichophora, S. saligna*
Myrica esculenta	5	1200 - 2000	*M. esculenta*, *M. esculenta-A. nitida* mixed	M, Ed	*M. esculenta, A. nitida, A.spathiflora*

Table 3. Contd.

Desmodium elegans	6	1500 - 2800	*C. deodara-P. wallichiana* mixed, *R. arboreum-L. ovalifolia* mixed	Fd	*Q.leucotrichophora, R. arboreum, S. saligna*
Debregeasia salicifolia	7	1000 - 1700	*R. arboreum-A.nitida* mixed, *Q. leucotrichophora*	M, Fd	*R. arboreum, Q. leucotrichophora, S. saligna*
Pinus roxburghii	8	1000 - 1600	*P. roxburghii, Q. l*eucotrichophora-*M.esculenta* mixed, *Q. leucotrichophora-N. pallens* mixed	Ti, At, Misc	*N. pallens, M.esculenta, A. spathiflora*
Alnus nitida	9	1300 - 2600	*A. nitida, A. nitida-Q. leucotrichophora* mixed, *M. esculenta-A. nitida* mixed*, Q. leucotrichophora*	M, Misc	*A. nitida, Q. leucotrichophora, S. saligna*
Pyrus pashia	10	1000 - 2600	*Q. l*eucotrichophora-*M.esculenta* mixed, *R. arboreum-Alnus nitida* mixed	Ed, Misc	*M. esculenta, Alnus nitida, Rhus javanica*
Neolitsea pallens	11	1500 - 2700	*Q. leucotrichophora-N. pallens* mixed, *A. indica-N. pallens* mixed	Fd, Misc	*N. pallens, Q. leucotrichophora, A. spathiflora*
Albizzia lebbek	12	1000 - 1500	*R. arboreum-A.nitida* mixed, *Q. leucotrichophora*	Misc	*P. roxburghii, Mallotus phillippensis-Sapindus mukorossi*
Indigofera heterantha	13	1500 - 3500	*Q. leucotrichophora, Q. leucotrichophora-C. deodara* mixed, *Q. leucotrichophora-M.esculenta* mixed	Fd	*Q.leucotrichophora, M.esculenta*
Prunus cerasoides	14	1200 - 1600	*R. arboreum-A.nitida* mixed, *Q. leucotrichophora, A. nitida-Q. leucotrichophora* mixed	Rel, Misc	*Q. leucotrichophora*
Grewia oppositifolia	15	1000 - 1400	*Q. leucotrichophora-M. esculenta* mixed, *Q. leucotrichophora*	Fi, Fd	*Q. leucotrichophora, Mallotus philipensis, M. esculenta, Sapindus mukrosii*
Lyonia ovalifolia	16	1200 - 2700	*M. esculenta-A.nitida* mixed, *R. arboreum-L. ovalifolia* mixed	M	*Q. leucotrichophora, R. arboreum, L. ovalifolia, Deutzia staminea*
Picea smithiana	17	2200 - 3300	*P. smithiana*, *P. smithiana-R. arboreum* mixed	Ti, At	*P. smithiana, R. arboreum, Wickstroemia canescens*
Rhus javanica	18	1200 - 2500	*Q. leucotrichophora, Q. leucotrichophora-C.deodara* mixed	M, Fd, Ed	*Q. leucotrichophora, C.deodara*

Table 3. Contd.

Sorbaria tomentosa	19	1700 - 2800	*Q. leucotrichophora-N. pallens* mixed, *A. indica-N. pallens* mixed	Misc	*Q. leucotrichophora, A. indica*
Berberis lycium	20	1000 - 2700	*Q. l*eucotrichophora-*M. esculenta* mixed, *R. arboreum-Alnus nitida* mixed	M, At	*Q. l*eucotrichophora, *M. esculenta, R. arboreum*
Pinus wallichiana	21	1600 - 2500	*P. wallichiana*, *A. nitida-Q. leucotrichophora* mixed,	Ti, At, Misc	*P. wallichiana, A. nitida, Berberis lyceum, S. saligna*
Quercus floribunda	22	2100 - 2700	*C. deodara-Q. leucotrichophora* mixed, *P. smithiana-R. arboreum* mixed	Fl, Fd	*C. deodara, Q. leucotrichophora, A. spathiflora*
Symplocos chinensis	23	1200 - 2600	*M. esculenta-A. nitida* mixed, *R. arboreum-L. ovalifolia* mixed	M, Fd, At	*M. esculenta, A. nitida*
Aesculus indica	24	1500 - 2800	*A. indica, A. indica-N. pallens mixed, A. indica-P. duthiei mixed, R. arboreum-A. nitida mixed, Q. leucotrichophora*	M, Fd, Ed, Misc	*A. indica, N. pallens, A. indica, P. duthiei*
Celtis australis	25	1500 - 2500	*Q. l*eucotrichophora-*M.esculenta* mixed, *Q. leucotrichophora*	Fd	*M. esculenta*, *Q. leucotrichophora*
Prinsepia utilis	26	1000 - 2900	*M. esculenta-A. nitida* mixed, *R. arboreum-L. ovalifolia* mixed	Rel, Misc	*M. esculenta, R. arboreum*
Buddleja crispa	27	1200 - 3200	*C. deodara-P. wallichiana*	Misc	*P. wallichiana, Q. leucotrichophora, A. spathiflora*
Ulmus villosa	28	1600 - 3500	*C. deodara-P. wallichiana, A. pindrow*	Fd, Rel, At	*C. deodara-P. wallichiana, A. pindrow*
Morus serrata	29	1500 - 2300	*Q. leucotrichophora-M. esculenta* mixed, *Q. leucotrichophora*	Fd, Ed	*Q. l*eucotrichophora-*M. esculenta*, *Q. leucotrichophora*
Ficus palmata	30	1000 - 1400	*M. esculenta-A. nitida* mixed, *R. arboreum-L. ovalifolia* mixed	Ed, M	*M. esculenta, A. nitida, J. regia*
Melia azadiarach	31	1000 - 1500	*M. esculenta-A. nitida* mixed, *J. regia, R. arboreum-L. ovalifolia* mixed	M, Misc	*M. esculenta, A. nitida, J. regia, R. arboreum, L. ovalifolia*
Rhamnus purpureus	32	1300 - 3000	*Q. l*eucotrichophora-*M. esculenta, C. deodara-P. wallichiana, A. pindrow*	Fd, Misc	*Q. l*eucotrichophora*, C. deodara, P. wallichiana*

Table 3. Contd.

Viburnum mullah	33	1800 - 3000	*Q. l*eucotrichophora-*M. esculenta, C. deodara-P. wallichiana*	Fd, Ed, Misc	*Q. l*eucotrichophora-*M. esculenta, C. deodara-P. wallichiana*
Prunus armeniaca	34	1000 - 2200	*M. esculenta-A. nitida* mixed, *R. arboreum-L. ovalifolia* mixed	M, Ed, Misc	*M. esculenta*, *R. arboreum, P. duthiei*
Quercus semecarpifolia	35	2400 - 3600	*P. wallichiana, A. pindrow*	Fd, Misc	*C. deodara, P. wallichiana, Betula utilis, A. spathiflora*
Abies pindrow	36	2600 - 3600	*A. pindrow, Q. semecarpifolia-A. pindrow* mixed	Ti, At	*A. pindrow, Q. semecarpifolia*
Ficus roxburghii	37	900 - 1400	*Q. leucotrichophora-M. esculenta* mixed, *Q. leucotrichophora*	Ed, Misc	*Q. leucotrichophora, M. esculenta, P. duthiei*
Salix wallichiana	38	1500 - 3600	*Q. leucotrichophora, P. wallichiana*	Fd, Fl, Misc	*Q. leucotrichophora, P. wallichiana*
Ficus nemoralis	39	1000 - 2000	*R. arboreum-A. nitida* mixed, *Q. leucotrichophora*	Fd, Ed	*R. arboreum, A. nitida*, *P. duthiei*
Thamnocalamus spathiflorus	40	1000 - 3300	*Q. leucotrichophora, Q. leucotrichophora-C. deodara* mixed	At, Misc	*Q. leucotrichophora, C. deodara*
Cinnamomum tamala	41	1000 - 1500	*Q. leucotrichophora, Q. l*eucotrichophora-*M.esculenta* mixed	M, Ed	*R. arboreum, A. nitida, Celtis australis*
Pistacia integerrima	42	1000 - 2200	*Q. leucotrichophora, Q. leucotrichophora-C. deodara* mixed	M, Fd	*Grewia oppositifolia, P. roxburghii*
Juglans regia	43	1700 - 3300	*J. regia, M. esculenta-A. nitida* mixed	M, Ed, Ti	*A. nitida, J. regia, R. arboreum*
Toona ciliata	44	1000 - 1500	*Q. leucotrichophora, R. arboreum-Q. leucotrichophora* mixed	Fd, Ti, Misc.	*Q. leucotrichophora, A. nitida, R. arboreum*
Toona serrata	45	1700 - 2400	*Q. leucotrichophora, R. arboreum-Q. leucotrichophora* mixed	Fd, Ti, Misc	*Q. leucotrichophora, R. arboreum*

At = Agricultural Tools; Ed = Edible; Fd = Fodder; Fi = Fiber; Fl = Fuel; M = Medicinal; Misc = Miscellaneous; Rel = Religious; Ti = Timber.

frequent use, high preference and high anthropogenic pressure on these species.

Degree of endemism for an area is important for prioritization of species for conservation (Myers et al., 2000). Endemic or native species may be competitively inferior to other widespread species (Kessler, 2001). Presence of 33 natives and 15 near endemic add to the significance of the area and also in compliance with the earlier works of the region.

Decrease in abundance of species used as sources of fuel suggests that more detailed information is urgently required on species-level trends and their conservation. A very few studies on the similar patterns and outcomes have been carried out so far in India (Samant et al., 2000; 2006; Singh and Sundriyal, 2009; Rawat et al., 2009; Bhattarai et al., 2009). Studies on development of conventional and *in-vitro* protocols for the mass scale propagation of these species and their establishment and maintenance in the *in-situ* and

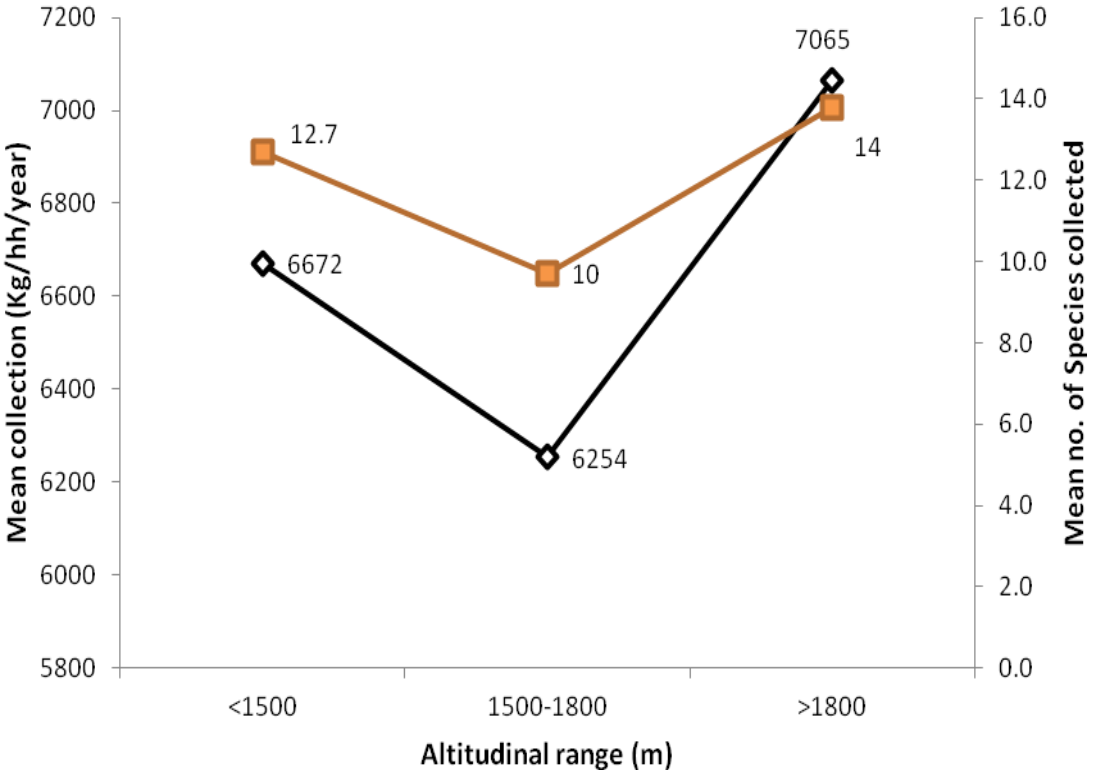

Figure 3. Village wise altitudinal mean fuel collection and number of species.

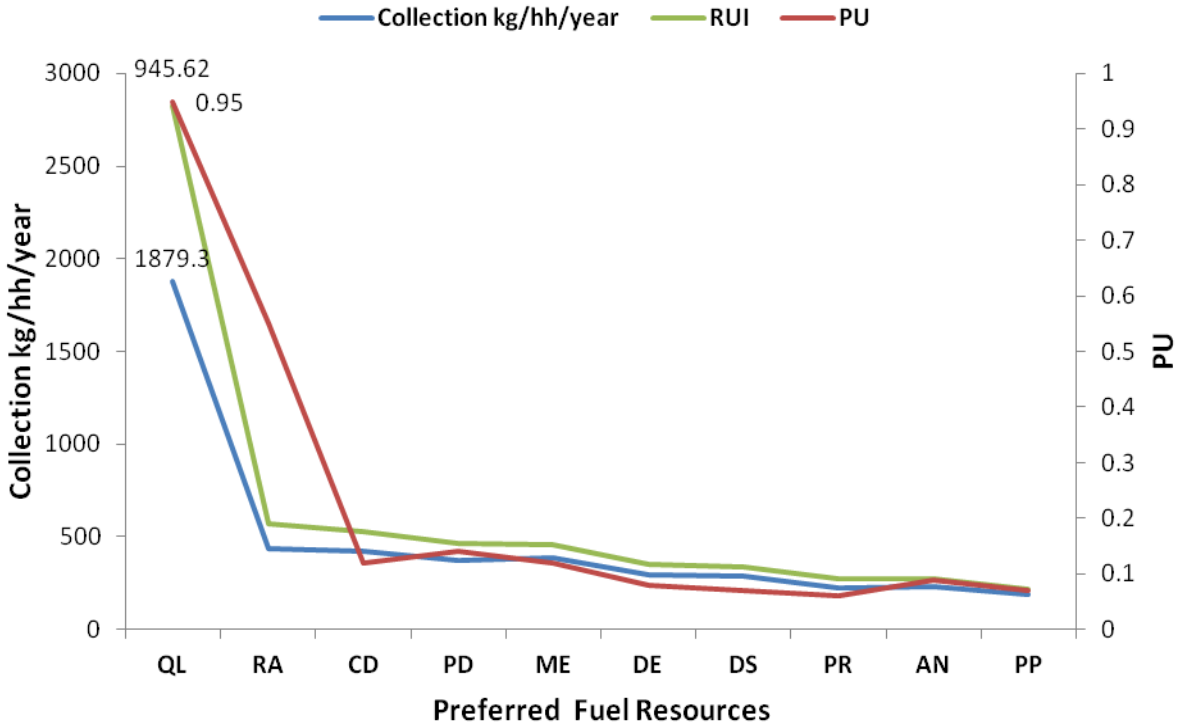

Figure 4. Total collections PU and RUI of the Preferred Fuel Species. QL = *Quercus leucotrichophora,* RA = *Rhododendron arboreum,* CD = *Cedrus deodara,* PD = *Persea duthiei*, ME = *Myrica esculenta*, DE = *Desmodium elegans*, DS = *Debregeasia salicifolia,* PR = *Pinus roxburghii*, AN = *Alnus nitida,* PP = *Pyrus pashia.*

ex-situ conditions are essentially required. Major thrust of the study is to comprehensively manage the species highly-preferred for fuel, diversification of choice of species from natives to non-natives, and their large scale propagation. Addition to this plantation of preferred species in the marginal and degraded lands through stakeholder's participation should promote conservation and management of fuel resources in the sanctuary.

Conservation perspectives

For the conservation and management of fuel resource of NWLS the following measures seem appropriate;

1. Annual extensive surveys to prepare a comprehensive database of fuel resources of NWLS for statistics on annual quantum of collection, species preference, probability of use, resource use index, multiple utility of fuel species.
2. Indigenous knowledge of fuel species of NWLS and their uses to improve planning and implementation of sustainable forest management in the sanctuary.
3. Promote highly preferred fuel species via means of *ex-situ* and *in-situ* conservation.
4. Awareness through training and extension programmes by means of various government and non-government agencies.

REFERENCES

Bhattacharaya B, Nanda SK (1992). Building Fuelwood demand-supply scenario. J. Rural Develop. 11(6):773-787.

Bhattarai S, Chaudhary RP, Taylor RSL (2009). The use of plants for fencing and fuelwood in Mustang District, Trans-Himalayas, Nepal. Scientific World 7 (7):59-63.

Dhar U, Rawal RS, Samant SS (1998). Wild plant resources and inhabitants in Askot Wildlife Sanctuary of Kumaun in Indian Himalaya: conservation issues. *In Biodiversity* Conservation in Managed and Protected Areas, ed. P.C. Kotwal and S. Banerjee, Bikaner: Agro Botanica, India. pp.128-142.

Kessler M (2001). Maximum plant community endemism at intermediate intensities of anthropogenic disturbance in Bolivian montane forest. Cons. Biol. 15:634-641.

Khoshoo TN (1987). Strategies for meeting the fire woods needs in the hills. In: Himalayan Energy Systems. Dhar TN and Sharma PN (ed.), Nainital, Gyanodya prakashan. pp.11-19.

Myers N, Mittermeir RA, Mittermeir CG, Fonseca GAB, Kent J (2000). Biodiversity hotspots for conservation priorities. Nature 403:853-858.

Rawat YS, Vishvakarma SCR, Todaria NP (2009). Fuel wood consumption pattern of tribal communities in cold desert of the Lahaul valley, North-Western Himalaya, India. Biomass Bioenerg. 33:1547–1557.

Samant SS, Dhar U, Rawal RS (2000). Assessment of Fuel resource diversity and Utilization Patterns in Askot Wildlife Sanctuary in Kumaon Himalaya, India, for conservation and management. Environ. Cons. 27(1):5-13.

Samant SS, Rawal RS, Dhar U (2006). Diversity, extraction, and status of fodder species in Askot Wildlife Sanctuary, West Himalaya, India. Int. J. Biod. Sci. Manag. 2:29-42.

Shah SL (1982). Ecological degradation and future of Agriculture in the Himalaya. Ind J. Agr. Econ. 37(1):1-22.

Singh N, Sundriyal RC (2009). Fuelwood, Fodder Consumption and Deficit Pattern in Central Himalayan Village, Nature and Science 7(4):85-88.

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Full Length Research Paper

A list of flowering wild plants in Tafila Province, Jordan

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Wild flowering plants in Tafila Province (South of Jordan) in terms of floristic features, with regards to its wild vascular plants were studied. A list of wild flowering plants was prepared. Field trips were made to the study area. A total number of 383 species belong to 198 genera and 48 families were recorded. Wild trees like *Cupressus sempervirens, Ceratonia siliqua, Quercus* sp. (Oak) and *Juniperus phoenica* were reported. Some recorded species such as *Anthemis maris- mortui,* or the medicinal rare species such as *Iris petrana* and *Iris nigricans*, *Salvadora persica*, *Osyris alba*, *Datura stramonium*, *Globularia Arabica* and *Amygdalus communis* are considered as endemic to the area. A number of historical economic trees have been recorded in the study area like *Pistacia atlantica;* some edible species are reported like *Malva* sp., *Allium* sp., *Gundelia tournefortii,* etc. Some exotic plant species were reported like *Iris* species and *Lupinus varius*. Some endemic species were reported, e.g *Iris petrana*, rare plant species were also recorded, e.g, *Globularia arabica, I. nigricans, Iris edomensis* and *Limonium* sp. Plant examples are listed and some selected photos for some plant species from the study area are included.

Key words: Plant diversity, Jordan, Tafila, conservation.

INTRODUCTION

Jordan is characterized by a wide range of physical, geographic and ecological conditions which have resulted in a wide variety of palnt biodiversity. Despite its small area (about 89.287 km^2), Jordan's location at the crossroads of climatic and botanic regions has endowed the country with a rich variety of plant life. Jordan belongs to four biogeographical regions called Saharo - Arabian (Badia), Irano - Turanian, Mediterranean and Sudanian (tropical). The vascular plants of Jordan have been surveyed to assess the plant biological diversity in the country. The total number of plant species recorded in Jordan exceeds 2500 species (Al-Eissawi, 1982, 1996). Tafila province is situated in the southern part of Jordan; it represents three out of four biogeographical regions in Jordan. These regions are Mediterranean, Irano-Terranian and Tropical or Sudanian Penetration (Al-Eissawi, 1996). The rainfall ranges from 50-400 mm/year). The temperature ranges from (-5 - 20°C) in winter and (20 - 33°C) in summer (Al-Eissawi, 1996).

The study area is characterized by its highly diversified plant species (Oran et al., 2002). The forest formation extends from Tafila to Ras- An-Naqab in the south. The whole forest ecosystem has suffered a great deal of human interaction. Therefore, vast areas were destroyed and almost have no forest vegetation except for randomly distributed remnants of degraded few wild trees. The best stand of this forest can be seen in the north of Tafila. The stand since 1992 has been announced as National Park and named Dana. The *Juniperus* forest formation is dominated by the leading species of *Juniperus phoenica* associated with *Cupressus sempervirens* on sand stone formation. In upper altitude, over 1300 m of the *Juniperus* vascular plants of Tafila province. The recorded species include herbs, shrubs and trees.

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forest is overtopped by a forest formation of evergreen Oak forest dominated by *Quercus coccifera.* *Ceratonia siliqua* (Karoob) was discovered within the Dana Reserve and on sand stone formation. Dana reserve has been established in Dana village as conservational mature (AL-Eisawi, 1996). This study provides a list of the flowering

Study aims

The study area was investigated for its plant diversity in an attempt to:

1. Survey, identify and conserve wild plant species in Tafila area.
2. Identify the wild natural resources in the study area.
3. Investigate the plant diversity potentials of the area.
4. Offer recommendations and mitigation measures to ecologically rehabilitate the study area in the future.

MATERIALS AND METHODS

Field trips and collection of plant specimens:

Plant material

In this inventory, botanical survey and extensive field trips were made in the study area for the period of 2008-2009. Collections of fresh plant specimens were made. The identification of plants was done based on

a) Flora Palaestina (parts 1, 2, 3 and 4) (Zohary, 1966; Feinbrun-Dothan, 1986).
b) Flora Orientalis. Boissier, P. E. (1867-1883).
c) List of Jordan Vascular Plants (Al- Eisawi, 1982, 1986).
d) Checklist of the Flora: Jordan Badia (Cope amd Al- Eisawi, 1998).
e) Checklist of wild edible plants in Jordan (AL- Eisawi and Takruri, 1989).
f) Comparison with similar herbarium specimens at the University of Jordan.

Illustrations

Photographs were taken on some leading herbs, shrubs and trees or the plant species that are dominating the overall total plants. All photographs were produced by the author.

Tables

A list of recorded species was provided.

Voucher specimens

Herbarium specimens (voucher specimen) were deposited at Amman Herbarium (AMM), Department of Biological Sciences, Faculty of Science, University of Jordan. Amman. Each of the collected specimens is given a serial number, properly identified and mounted on herbarium cabinets as a documented reference for further investigations.

RESULTS AND DISCUSSION

Tafila Province, Jordan is one of the most diverse regions in Jordan in terms of its phytogeographical variation and its high botanical diversity in terms of the number of plant species recorded Figure 1 to 3.

The majority of plant species recorded in the study area is facing the danger of loss and degradation, as the area is severely exposed to either man impact or environmental damaging factors. Some of these are the overgrazing; cutting of other old historical trees and collection of herbs for medicine and other irrational activities of the residents of the province populations of that area. Lot of the listed plant species are important genetic resources for their use as parents of cultivars, ornamental, medicinal plants, drought resistant, saline resistant, which can be used for the benefit of human kind. This study showed that this province has suffered severely from deforestation due to lack of any natural forest cover in spite of presence of natural environmental conditions needed for such ecosystem, and due to the irrational activities of the local community.

Recommendations

Plant biodiversity faces the danger of degradation and loss of many plant species as a result of both adverse human impact and environmental factors as it happens in Tafila province of Jordan. Changes in plant resources can directly reduce sources of food, fuel, structural materials and medicinal or genetic resources. Moreover, these changes are occurring at an unnaturally rapid rate as a consequence of human activities, such as land-use, climate change, nitrogen deposition, species introductions, increase in population, over exploitation of plant and animal species, pollution of soil, water and air. Biodiversity in Jordan was exposed to several threats leading to sharp decline in most of the Jordanian flora and the extinction of several species. Many species are at risk, or were classified as threatened or endangered or even extinct on the regional and global levels. This situation has resulted from various anthropogenic activities, as well as from a general lack of knowledge and awareness (Al-Eisawi et al., 2000). Yet serious attempts have been made to protect and conserve the plant genetic resources of the country. Many reserves have been established, but the laws and regulations governing them are not always enforced and dozens of species are facing dramatic pressure (EPA, 2001). As there is critical situation is Tafila province where hundreds of wild plant species are facing the threat of degradation, more attention from the authorities is needed.

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Table 1. List of plant species in the study area.

Family	Species recorded
Aizoaceae	*Aizoon canariense* L.
	Aizoon hispanicum L.
Apiaceae	*Ammi majus* L.
	Astoma seselifolium DC.
	Bifora testiculata (L.) Schultes
	Bupleurum lancifolium Hornem.
	Chaetosciadium trichospermum (L.) Boiss.
	Daucus subsessilis Boiss
	Deverra triradiata Hochst.
	Eryngium creticum Lam.
	Eryngium glomeratum Lam.
	Ferula blanchei Boiss.
	Ferula ovina (Boiss.) Boiss.
	Ferula tingitana L.
	Lagoecia cuminoides L.
	Malabaila secacul (Miller.) Boiss.
	Pimpinella corymbosa Boiss.
	Pimpinella olivieri Boiss.
	Pituranthos triradiatus (Hocht. ex Boiss.) Aschers& Schweinf.
	Scandix iberica M. Bieb.
	Scandix pecten-veneris L.
	Scandix stellata Banks & Sol.
	Torilis arvensis (Hudson) Link
	Torilis leptophylla (L.) Reichenb. fil.
	Torilis nodosa (L.) Gaertner.
	Turgenia latifolia (L.) Hoffm.
	Zosima absinthifolia (Vent.) Link
Boraginaceae	*Alkanna strigosa* Boiss. et Hohen.
	Alkanna tinctoria (L.) Tausch
	Anchusa aegyptiaca (L.) DC.
	Anchusa neglecta DC.-6075.
	Anchusa strigosa Banks& Sol.
	Arnebia linearifolia DC.
	Arnebia tinctoria Forskal.
	Asperugo procumbens L.
	Gastrocotyle hispida (Forskal) C.B. Clarke
	Heliotropium bacciferum Forskal
	Heliotropium europaeum L
	Heterocaryum szovitsianum (Fischer&C.A.Meyer) A.DC.
	Lappula barbata (Bieb.) Gürke
	Nonea philistaea Boiss.
Brassicaceae	*Alyssum damascenum* Boiss. et Gaill
	Alyssum iranicum Hausskn. et Baumg.
	Alyssum umbillatum Desv.
	Biscutella didyma L.
	Carrichtera annua (L.) DC.
	Erucaria boveana Cosson.
	Erucaria pinnata (Viv.) Tackholm & Boulos
	Farsetia aegyptiaca Turra

Table 1 Contd.

Caryophyllaceae	*Lepidium latifolium* L.
	Malcolmia africana (L.) R. Br
	Matthiola aspera Boiss.
	Matthiola parviflora (Schousb.) R. Br.-
	Notoceras bicorne (Solander) Caruel.
	Savignya parviflora (Delile) Webb.
	Sisymbrium bilobum (C.Koch) Grossh.
	Sisymbrium irio L
	Zilla spinosa (L.) Prantl
	Cerastium dichotomum L.
	Dianthus sinaicus Boiss.
	Gymnocarpos decandrum Forskal
	Gypsophila arabica Barkoudah
	Gypsophila pilosa Hudson.
	Holosteum umbellatum L.
	Minuartia formosa (Fenyl) Mattf.
	Paronychia argentea Lam.
	Paronychia palaestina Eig
	Paronychia sinaica Fresen
	Petrorhagia cretica (L.) P. W. Ball et Heywood
	*Polycarpon tetraphyllum (*L.) L
	Pteranthus dichotomus Forskal
	Robbairea delileana Milne-Redhead
	Silene aegyptiaca (L.) L. fil
	Silene conoidea L
	Silene linearis Decne.
	Silene longipetala Vent
	Silene palaestina Boiss
	Spergula fallax (Lowe) Krause
	Spergularia diandra (Guss.) Heldr. et Sart.
Chenopodiaceae	*Anabasis articulata* (Forskal) Moq.
	Anabasis syriaca Iljin.-
	Atriplex halimus L
	Atriplex rosea L.
	Bassia eriophora (Schrader*)* Ascherson
	Bassia muricata (L.) Ascherson
	Chenopodium album L
	Chenopodium vulvaria L
	Hammada scoparia (Pomel) Iljin
	Noaea mucronata (Forskal) Ascherson et Schweinf.
	Salsola baryosma (Schultes) Dandy.
Cistaceae	*Helianthemum aegyptiacum* (L.) Miller.
	Helianthemum ledifolium (L.) Miller
	Helianthemum lippii (L.) Dum. -Courset
	Helianthemum salicifolium (L.) Miller
	Helianthemum sancti-antonii Boiss
	Helianthemum vesicarium Boiss
	Umbilicus intermedius Boiss.
Cyperaceae	*Carex padystylis* J. Gay

Table 1 Contd.

	Pterocephalus brevis Coulter
	Pterocephalus plumsus (L.) Coult
	Pterocephalus sanctus Decne.
Dipsacaceae	*Scabiosa argentea* L
	Scabiosa palaestina L
	Scabiosa porphyroneura Blakelock
	Scabiosa prolifera L.
Ephedraceae	*Ephedra alte* C.A. Meyer
	Chrozophora tinctoria (L.) Ad. Juss.
Euphorbiaceae	*Euphorbia cheiradenia* Boiss. et Hohen.
	Euphorbia hierosolymitana Boiss
	Euphorpia petiolata Banks et Sol
	Acacia raddiana Savi
	Astragalus adpressiusculus Eig
	Astragalus cretaceus Boiss. et Kotschy
	Astragalus deinacanthus Boiss.
	Astragalus bethlehemiticus Boiss
	Astragalus macrocephalus Willd
	Astragalus sparsus Decne.
	Astragalus spinosus (Forskal) Muschler
	Astragalus tribuloides Delile
	Lathyrus cicera L.
	Lathyrus pseudocicera Pamp.
	Lathyrus setifolius L
	Lens orientalis (Boiss.) Schmalh.
	Lotus halophilus Boiss.et Spruner
Fabaceae	*Medicago laciniata* (L.) Miller
	Medicago lupulina L
	Medicago polymorpha L.
	Medicago radiata L.
	Onobrychis crista-galli (L.) Lam
	Onobrychis kotschyana Fenzl
	Onobrychis ptolemaica (Delile) Dc
	Onobrychis wettsteinii Nabelek
	Trifolium resupinatum L.
	Trigonella arabica Delile
	Trigonella astroites Fischer et C. A. Meyer
	Trigonella hamosa L.
	Trigonella schlumbergeri Boiss.
	Trigonella stellata Forskal.
	Vicia sericocarpa Fenzl
	Erodium arborescens (Desf.) Willd.
	Erodium glaucophyllum (L.) L'Hér
Geraniaceae	*Erodium gruinum* (L.) L'Hér-
	Erodium hirtum Willd.
	Erodium laciniatum (Cav.) Willd
	Erodium malacoides (L.) L' Hér.
	Erodium neuradifolium Delile
Globulariaceae	*Globularia arabica* Jaub.et Spach
Hypecoaceae	*Hypecoum imberbe* Sibth.& Sm
	Hypecoum pendulum L.
	Hypecoum procumbens L.

Table 1 Contd.

Iridaceae	*Crocus aleppicus* Baker
	Crocus cancellatus Herbert
	Crocus pallasii Goldb
	Iris edomensis Sealy.
	Iris nigricans Dinsm
	Iris petrana Dinsm
Lamiaceae	*Ballota saxatilis* Sieber ex C. Presl
	Ballota undulata (Sieber ex Fresen.) Bentham.
	Marrubium cuneatum Banks et. Sol.
	Phlomis brachyodon (Boiss.) Zohary
	Phlomis kurdia Rech. fill.
	Phlomis platystegia Post.
	Salvia ceratophylla L
	Salvia dominica L
	Salvia hierosolymitana Boiss.
	Salvia palaestina Bentham.
	Salvia syriaca L
	Satureja thymbra L
	Satureja thymbrifolia Hedge & Feinbr.
	Stachys aegyptiaca Person
	Ziziphora capitata L.
	Ziziphora tenuior L
Liliaceae	*Allium artemisietorum* Eig& Feinbr
	Allium neapolitanum Cyr.
	Allium sindjarensis Boiss.et Hausskn.
	Allium truncatum (Feinbr.) Kollmann& Zohary.
	Androcymbium palaestinum (Boiss.) Baker
	Asparagus aphyllus L.
	Asparagus stipularis Forskal
	Bellevalia ciliata (Cyr.) T.Nees.
	Bellevalia desertorum Eig& Feinbr.
	Colchicum ritchii R. Br.
	Colchicum tauri Siehe ex Stefanoff
	Colchicum tunicatum Feinbr
	Dipcadi erythraeum Webb et Berth.
	Fritillaria libanotica (Boiss.) Baker
	Gagea dayana Chodat & Beauvered.
	Gagea reticulata (Pallas) Schult. Fil.
	Leopoldia bicolor (Boiss.) Eig & Fienbr.
	Leopoldia comosa (L.) Parl.
	Leopoldia deserticola (Rech.fil.) Feinbr
	Ornithogalum montanum Cyr.
	Urginea maritima (L.) Baker.
Linaceae	*Linum mucronatum* Bertol
	Linum pubescens Banks & Sol
Loranthaceae	*Viscum cruciatum* Sieber ex Boiss.
Lythraceae	*Lythrum junceum* Banks et Sol.
Malvaceae	*Alcea rufescens* (Boiss.) Boiss
	Malva nicaeensis All.
	Malva parviflora L

Table 1 Contd.

	Malva sylvestris L.
	Aegilops biuncialis Vis
	Aegilops crassa Boiss. var.palaestina Eig-
	Aegilops ovata L
	Aven fatua L
	Boissiera squarrosa (Banks et Sol.) Nevski-
	Bromus danthoniae Trin.
	Bromus fasciculatus Presl var.alexandrinus Thell.
	Bromus lanceolatus Roth
	Bromus madritensis L.
	Bromus rubens L
	Bromus scoparius L.
	Bromus tectorum L.
	Bromus tomentellus Boiss.
	Dactylis glomerata L.
Poceae	*Eremopyrum bonaepartis* (Sprengel) Nevski.
	Hordeum glaucum Steudel
	Hordeum marinum Hudson
	Hordeum spontaneum C. Koch.
	Lolium rigidum Gaudin
	Lophochloa berythaea (Boiss.& Blanche) Bor
	Panicum repens L.
	Phalaris minor Retz.
	Poa annua L.
	Poa bulbosa L.
	Poa sinaica Steudel
	Schismus arabicus Nees var.minuts (Roemer &
	Schultes) Boiss.
	Stipa lagascae Roemer&Schultes
Orchidaceae	*Limodorum obortivum* (L.) Swartz
Orobanchaceae	*Cistanche tubulosa* (Schenk) wight.
	Orobanche ramosa L.
Papaveraceae	*Glaucium arabicum* Fresen.
	Roemeria hybrida (L.) DC.
	Plantago afra L.
	Plantago albicans L..
Plantaginaceae	*Plantago coronopus* L
	Plantago cylindrica Forskal.
	Plantago ovata Forskal.
	Plantago pumila L
	Limonium lobatum (L.fil.) O. Kuntze.
Plumbaginaceae	*Limonium meyeri* (Boiss.) O. Kuntze.
	Limonium pruinosum (L.) O. Kuntze.
	Limonium sinuatum (L.) Miller
Polygalaceae	*Polygala sinaica* Botsch
	Polygonum equisetiforme Sibth. Et Sm.
Polygonaceae	*Polygonum patulum* Bieb.
	Rumex cypirus Murb.

Table 1 Contd.

Primulaceae	*Anagallis arvensis* L
	Samolus valerandi L.
Ranunculaceae	*Adonis dentata* Delile.
	Anemone coronaria L.
	Ceratocephalas falcate (L.) Pers.
	Consolida sceroclada (Boiss.) Schrödinger
	Ranunculus arvensis L
	Ranunculus asiaticus L.
	Ranunculus damascenus Boiss.et Gaill
Resedaceae	*Ochradenus baccatus* Delile
	Reseda alba L.
	Reseda lutea L.
Rhamnaceae	*Rhamnus dispermus* Ehrenb .ex Boiss.
	Rhamnus palaestinus Boiss.
	Rhamnus punctatus Boiss
	Ziziphus lotus (L.) Lam.
Rosaceae	*Amygdalus communis* L.
	Amygdalus Korschinskyi (Hand -Mazz.) Bornm.
	Cerasus microcarpa (C.A.Meyer) C.Koch
	Rubus sanguineus Friv.
	Sarcopoterium spinosum (L.) Spach.
Rubiaceae	*Crucianella herbacea* Forskal
	Galium canum Req.
	Galium incanum Sm.
	Galium sinaicum (Delile ex Decne.) Boiss.
	Galium tricornutum Dandy.
	Rubia tenuifolia D'Urv.
	Rubia tinctorum L.
	Valantia hispida L
	Warburgina factorovskyi Eig.
Salicaceae	*Populus euphratica* Oliver
	Salix acmophylla Boiss.
Salvadoraceae	*Salvadora persica* L.
Santalaceae	*Osyris alba* L.
	Thesium humile Vahl
Scrophulariaceae	*Anarrhinum forskahlii* (J.F.Gmel.) Cuf.
	Kickxia aegyptiaca (L.) Nábelek
	Linaria haelava (Forskal.) Delile.
	Linaria simplex Desf.
	Parentucellia flaviflora (Boiss.) Nevski
	Scrophularia rubricaulis Boiss
	Scrophularia xanthoglossa Boiss.
	Scrophularia xylorrhiza Boiss. et Hausskn
	Verbascum fruticulosum Post.
	Veronica anagallis-aquatica L
	Veronica campylopoda Boiss.
	Veronica hederifolia L
Solanaceae	*Datura stramonium* L
	Hyoscyamus aureus L.
	Hyoscyamus reticulatus L.

Table 1 Contd.

Tamaricaceae	*Reaumuria hirtella* Jaub.et Spach
	Tamarix tetragyna Ehrenb.
Theligonaceae	*Theligonum cynocrambe* L.
Thymelaeaceae	*Daphne linearifolia* Hart
Urticaceae	*Parietaria officinalis* L.
	Parietaria punctata Willd.
Zygophyllaceae	*Fagonia bruguieri* DC
	Fagonia mollis Delile.
	Peganum harmala L.
	Zygophyllum dumosum Boiss.

Pistacia atlantica

Quercus coccifera

Juniperus phoenica

Cupressus sempervirens

Crataegus aronia

Figure 1. Some wild trees in Tafila Province.

Crocus hyemalis

Ononis natrix

Capparis spinosa

Senecio vernalis

Gundelia tournefortii

Sonchus oleraceus

Tragopogon buphthalmoides

Salvia hierosolymitana

Figure 2. Some plant species in Tafila Province.

Tulipa agenensis

Ornithogalum montanu

Lupinus varius

Ophrys lutea

Iris edomensis

Iris petrana

Iris nigricans

Amygdalus communis

Figure 2. Contd.

Eremostachys laciniata

Anchusa srtigosa

Pyrus syriaca

Calendula arvensis

Crataegus aronia

Ephedra alte

Hypoceum

Malva sylvestris

Figure 2. Contd.

Figure 3. Some medicinal plant species in Tafila Province.

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REFERENCES

AL- Eisawi DM (1982). List of Jordan vascular plants. Mitt. Bot. Mύnchen, 18:79-182.
AL- Eisawi DM (1986). Med- Checklist. OPTIMA, Geneve. Advisor of Jordanin OPTIMA. Vol.3.
AL- Eisawi DM, Takruri HR (1989). A checklist of wild edible plants in Jordan. Arab Gulf J. Res. Agric. Boil. Sci. B7(1):79-102.
AL- Eisawi DM (1996). Vegetation of Jordan. UNESCO-CAIRO OFFICE, Regional office for science and technology for the Arab States.
AL-Eisawi DM, EL-Oqlah A, Oran SA, Lahham J (2000). Jordan Country Study on Biological Diversity, Plant Biodiversity and Taxonomy. United Nations Environment Programme.
Boissier PE (1883). Flora Orientalis. Vol. I, II, III, IV, V, VI, Vols. and suppl., Lyon and Geneva.
Cope TA, Al-Eisawi D (1998). Checklist of the flora. In Dutton, R. W., Clarke, J.I. and Battikhi, A> M. Arid Land Resources and their management, Jordan's Desert Margin. 1st edition Kegan Paul International, London, pp. 183- 188.
EPA (Environmental Protection Agency) (2001). Agenda 21, Amman. Jordan.
Feinbrun- Dothan N (1986). Flora Palaestina. The Israel Academy of Sciences and Humanities: Jerusalem. 4: 39- 43.
Oran SA, AL- Eisawi DM, Belhaj O, Bu Zaid S, Raies A (2002). The plant biodiversity project in Jordan. Jordan Badia Research and Development Programme\HCST\Amman\Jordan. Final report.
WCMC (World Conservation Monitoring Center) (1992). Global Biodiversity: Status of the Earth's Living Resources, (1st edition). Capman and Hall. (Not cited in the work)
Zohary M (1966). Flora Palaestina, The Israel Academy of Sciences and Humanities, Part 1, 2, 3 and 4, Goldberg's Press. Jerusalem.

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Review

Gene duplication: A major force in evolution and bio-diversity

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Bridges reported one of the earliest observations of gene duplication from the doubling of a chromosomal band in a mutant of the fruit fly, *Drosophila melanogaster*, which exhibited extreme reduction in eye size. Based on whole-genome analysis of *Arabidopsis thaliana*, there is compelling evidence that angiosperms underwent two whole-genome duplication events early during their evolutionary history. Recent studies have shown that these events were crucial for the creation of many important developmental and regulatory genes found in extant angiosperm genomes. Recent studies provide strong indications that even yeast (*Saccharomyces cerevisiae*), with its compact genome, is in fact an ancient tetraploid. Gene duplication is providing new genetic material for mutation, drift and selection to act upon, the result of which is specialized or new gene functions. Without gene duplication, the plasticity of a genome or species in adapting to changing environments would be severely limited. The era of whole genome sequencing of model organisms suggests a number of duplication events take place while evolving modern species.

Key words: Evolution, genome duplication, diversity.

INTRODUCTION

An event in which one gene gives rise to two genes is generally known as duplication; in this, the two genes cannot be operationally distinguished from each other. Duplicated genes may remain in the same genome (known as paralogs) from where they arose and their presence may be in different genome (known as orthologs) after duplication. Gene duplication is believed to play an important role in evolutionary process by providing a chance to evolve new genes. Duplicated gene generates new opportunity for natural selection. At first Darwin published his idea about the “Origin of Species” but still it is a major issue. In 1900, when the rediscovery of Mendel’s law was proposed it gave us a better understanding of how genetic variations exist for traits. However, Bridges in 1936 first identified bar eye locus in drosophila and its effect on eye shape when duplicated. Besides, recombination duplication followed by diversification is one of the great paves for creation of variation. In 1970, Ohno, in his book, “Evolution by Gene Duplication”, had given a clear-cut idea about the origin of duplicated genes and the possible fate of gene duplication. He concluded that gene duplication is the only means by which a new gene can arise and argues that in the past whole genomes have been duplicated. Duplication may take place either in single genes, a segment of chromosome, whole chromosome or even the whole genome of a species. Transition from invertebrates to vertebrate could occur only if whole genomes were duplicated (Ohno, 1970). It has been found that all the present day angiosperm has undergone large scale gene duplication or whole genome

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duplication (Bodt et al., 2005). Ohno's representation of duplication as evolutionary force opened up a new window to find out evolutionary consequences through research. The idea that gene duplication has a fundamental role in the origin of diversity suggested numerous proposals for knowing how a new gene copy can emerge from its predecessor and evolve a novel function. The use of molecular markers technologies and the sequence information of the model organisms opened up new windows for carrying out research on duplication analysis, and determining the evolutionary pathways of organisms became interesting work.

MOLECULAR MECHANISMS OF GENE DUPLICATION

Duplicated gene may be produced by unequal crossing over, retro-transposition, duplicated DNA transposition and polyploidization.

Unequal crossing over

This produces tandem repeated sequences, that is, continuous repeats of DNA sequence. Depending on the position of crossing over, the duplicated regions can contain part of a gene, an entire gene, or several genes (Zhang, 2003). Unequal crossing over may lead to the evolvement of paraloguous gene through concerted evolution (Hurst and Smith, 1998; Li, 1997). Crossing over in a bivalent carrying duplication in one of the two chromosomes may lead to different consequences. If the duplicated segment pairs with its homologous segment in the other chromosome ignoring other homologous segments, then the unequal crossing over produces duplication of other segments Figure 1. If the duplicated segment is present in reverse orientation Figure 2 of the original segment or if duplication is present on the other arm, then the pairing followed by crossing over forms dicentric and acentric fragment. If there are duplicated segments on another non homologous chromosome Figure 3, crossing over with this duplicated region will produce two interchanged chromosomes (Gupta, 2007).

Retroposition

This is a process where messenger RNA (mRNA) of a gene is reverse transcribed to complementary DNA (cDNA) and then inserted into the genome. There are several molecular features of retroposition: lack of introns and regulatory sequences of gene, presence of poly- A sequence and presence of flanking short direct repeats. The major difference of this mechanism from unequal crossing over is the presence of introns. Introns are the short DNA sequence present in between the coding sequence of gene that splices out after transcription. If introns are present in the original genes, they will also be present in the duplicated genes through unequal crossing over, but absent in retrogenes. A duplicated gene generated by retroposition is usually unlinked to the original gene, because the insertion of cDNA into the genome is more or less random. Recent studies have found that retrogenes that land near other coding regions or even in the introns of expressed coding sequences are much more likely to be expressed than those that land far from coding sequences (Vinckenbosch et al., 2006). mi-RNAs are reported to be found in the intron, exons and intergeneric regions of human genome. Duplication of mi- RNAs is one of the mechanisms for their evolution into human genome. mi-RNAs are arranged mostly in 5000-nt clusters and their copies are scattered randomly throughout the genome at an average distance of 4.3×10^6 bp. Comparison of miRNAs copies with the transposable elements (TEs) revealed that most miRNAs homologues (96%) propagate by DNA transposons and retroelements (Titov and Vorozheykin, 2011).

Duplicative transposition

Duplicative transposition of DNA sequences can be accomplished by one of two main pathways: nonallelic homologous recombination (NAHR) or non- homologous end joining (NHEJ). The difference between two pathways is based on whether homologous sequences are used as a template during double-strand break repair, and this difference can also be used to infer the mechanism by which individual genes are duplicated. Recombination between these nonallelic homologous sequences can result in the duplication of the intervening sequences, which can then lead in turn to more duplications because of pairing between the new paralogs (Bailey et al., 2003). But other studies in human being have also found multiple cases with no repetitive DNA or long stretches of homologous sequence at duplication breakpoints, suggesting the action of NHEJ (Linardopoulou et al., 2005). Due to the relatively low proportion of duplicated sequences arranged in tandem in the human genome, it has been proposed that duplicative transposition is the major mode of duplication in humans (Samonte and Eichler, 2002). The number of retrogenes maintained in both mammals (Pan and Zhang, 2007) and Drosophila is lower than the number maintained by DNA-based intermediates (that is, unequal crossing-over and duplicative transposition), despite the fact that the mutation rate forming new retrocopies is higher (Pan and Zhang, 2007). The lack of functional regulatory DNA is likely to be the reason that very few of these paralogs are maintained for long; only 120 functional retrotransposed gene copies have been maintained in the human genome over the past 63 million years (Vinckenbosch et al., 2006).

Polyploidization

The fourth major mechanism of duplicate gene formation is

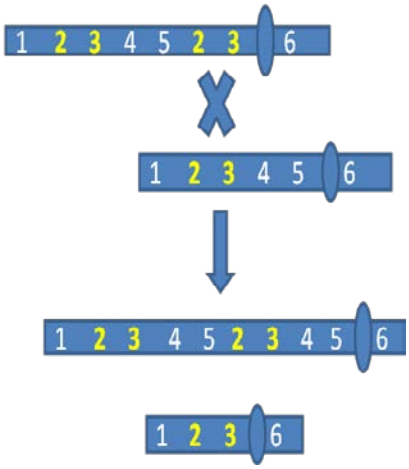

Figure 1. Duplication present on the same arm of chromosome.

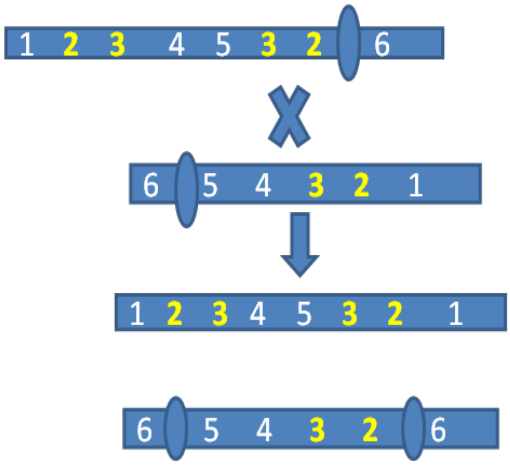

Figure 2. Duplication in reverse orientation.

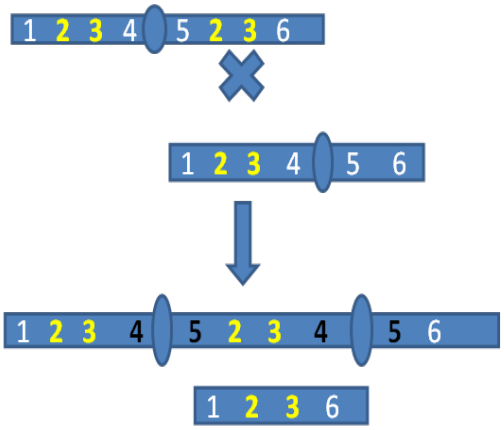

Figure 3. Duplication on another arm.

is polyploidization. Polyploidy is an evolutionary process whereby two or more genomes are brought together into the same nucleus, usually by hybridization followed by chromosome doubling. Ohno, in his book, pointed out that two rounds of genome duplication had taken place for the evolution of vertebrates. Recent studies provide strong indications about the importance of gene duplication in the origin of organisms. Even yeast (*Saccharomyces cerevisiae*), with its compact genome, is in fact an ancient tetraploid. A whole-genome duplication followed by massive gene loss and specialization has taken place during its evolutionary process (Kellis et al., 2004). In plants, polyploidy was proposed to have occurred in the lineage of at least 70% of angiosperms (Masterson, 1994) and in 95% of pteridophytes (Grant, 1981). Arabidopsis (Arabidopsis Genome Initiative, 2000) and rice (Goff et al., 2002) considered as classical diploids are apparently ancient polyploids (paleopolyploids). Many higher plant species considered as diploids because of their genetic and cytogenetic behavior are ancient polyploids that have undergone a process of extensive diploidization. Thus, polyploidy is one of the major processes that has driven and shaped the evolution of higher organisms.

DOES GENE DUPLICATION PROVIDE THE ENGINE FOR EVOLUTION?

How life evolved from a few primordial genes to the more than twenty thousands of genes in higher organisms was a major issue in Darwinism. The current primary hypothesis is that it occurred via gene duplication (Hurles, 2004). Shanks (2004) concluded that 'duplication is the way of acquiring new genes by organisms'. They appear as the result of duplication. Ohno concluded that "gene duplication is the only means by which a new gene can arise". Not only genes but whole genomes have been duplicated in the past, causing 'great leaps in evolution such as the transition from invertebrates to vertebrates, which could occur only if whole genomes were duplicated' (Ohno, 1970). Kellis et al. (2004) agree that 'whole-genome duplication followed by massive gene loss and specialization has long been postulated as a powerful mechanism of evolutionary innovation'. Genome duplication has been proved to be major events for angiosperm evolution (Bodt *et al*. 2005). The two major branches of the angiosperms (eudicots and monocots), estimated to have diverged 125–140 to 170–235 mya (Davies et al., 2004), show much more rapid structural evolution. This difference appears to be largely due to the tendency of angiosperms for chromosomal duplication and subsequent gene loss (Coghlan et al., 2005). Recent analyses of genome sequences suggest that genome duplication in angiosperms may be not merely episodic but truly cyclic, which causes various fitness advantages that erode over time, favoring new polyploidizations (Chapman et al., 2006).

THE FATES OF DUPLICATE GENES

Whole-genome duplications result in new gene copies of every gene in a genome and, obviously, all the flanking regulatory sequences. All the genes after duplication may not undergo fixation as most of the genes get lost from the genome. The birth and death of genes is a common theme in gene family and genome evolution with those genes involved in the physiologies that vary greatly among species (e.g. immunity, reproduction and sensory systems) probably having high rates of gene birth and death. After fixation, the fate of the gene (s) is determined by the function of that gene(s) in the genome (Zhang, 2003).

Pseudogenation

Generally, carrying out two identical genes in a particular genome is not advantageous, as duplicated genes produce functional redundancy (Zhang, 2003). Pseudogenization, the process by which a functional gene becomes a pseudogene Figure 4, usually occurs in the first few million years after duplication if the duplicated gene is not under any selection (Walsh, 1995; Lynch and Conery, 2000; Lynch et al., 2001; Harisson et al., 2002). There are two major forces through which duplicate genes undergo pseudogenation. These are mutation and deletion where changes in pseudogenes occur through promoter mutation, splicing junction lost, nonsense mutation or missense mutation (Harisson et al., 2002**)**. Mutation distracting the structure and function of one of the two genes is not removed by selection (Lynch and Conery, 2000; Lynch et al., 2001). Gradually, the mutation containing gene becomes a pseudogene, which is either not expressed or become non-functional. After a long time, pseudogenes will either get deleted from the genome or become more diverged from the parental genes that they are no longer identifiable with the original genes. In humans and mice, the size of the olfactory receptor gene family (~1000) is similar but the percentage of pseudogenes is >60% in humans and only 20% in mice (Rouquier et al., 2000; Mombaerts, 2001; Zhang and Firestein, 2002). This may be due to the lesser use of olfaction since the origin of hominoids, which can be compensated for by other sensory mechanisms such as better vision (Rouquier et al. 2000).

Occasionally, it has been observed that pseudegenes may also serve some functions. One functional gene (VH1) that encodes the heavy chain variable region of immunoglobulin in chicken. Immunoglobulin diversity is generated by gene conversion (Hurst and Smith, 1998) of the VH1 gene (Ota and Nei, 1995).

Conservation of gene function

There are several known proteins present in cell where large quantity is required by the cell for proper functioning. The first mechanism for maintaining a duplicate copy of gene proposed by Ohno (1970) was to simply increase the number of protein coding genes, where both loci maintain their original functions. Ohno (1970) proposed two possible models why these duplicates would maintain the original functions. The first model states that a second gene could provide functional redundancy if the original locus was disabled by mutation. The second possibility for why exact copies of duplicated genes are maintained is that there is an advantage of producing more of a gene to accomplish the increased levels of protein production in the cells. The most commonly cited examples are the highly duplicated ribosomal RNAs needed for development and histone proteins. Now the question arises: “how can two paralogous genes maintain the same function after duplication?’’ One of the possible mechanisms is concerted evolution (Li, 1997) and another is purifying selection (Nei et al., 2000). Concerted evolution: a mode of gene family evolution through which members of a family remain similar in sequence and function because of frequent gene conversion and/or unequal crossing over (Hurst and Smith, 1998; Li, 1997). Whereas strong purifying selection plays against mutations that modify gene function which can prevent duplicated genes from diverging. The difference between gene conversion and purifying selection can be described through synonymous or silent mutation; where, a synonymous nucleotide difference does not change the function of genes as the change in nucleotide in DNA sequence. Synonymous differences are more or less immune to selection and cannot be reduced by purifying selection whereas gene conversion homogenizes DNA sequences regardless of whether the differences are synonymous or non synonymous (Nei et al., 2000; Piontkivska et al., 2002; Hurst and Smith, 1998).

Sub-functionalization

In general, the duplicate gene is deleterious for the genome or species (some exceptions like histone protein coding genes). Two genes with identical functions are not maintained generally in the genome unless duplicated gene product is advantageous (Nowak et al., 1997; Lynch and Conery, 2000). After duplication, both the daughter genes are maintained in the genome for a period of time when they differ in some aspects of their functions. This can occur by subfunctionalization Figure 4, in which each daughter gene adopts part of the functions of their parental gene (Hughes, 1994; Force et al., 1999; Lynch and Force, 2000). For example, a pair of transcription factor genes in zebrafish is engrailed-1 and engrailed-1b generated by a chromosomal segmental duplication. Engrailed-1 is expressed in the pectoral appendage bud, whereas engrailed-1b is expressed in the neurons of hindbrain/spinal cord. Despite the sole engrailed-1 gene of mouse, orthologous to both genes (engrailed-1 and engrailed-1b) of the zebrafish is expressed in both pectoral appendage bud and hindbrain/spinal cord (Force

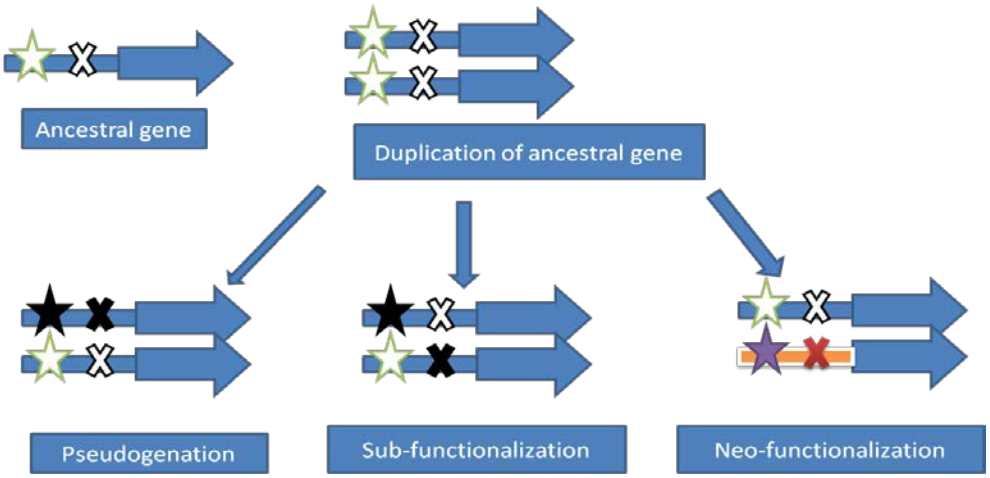

Figure 4. Diagrammatical representation of consequences of duplicated genes and the role of duplication evolving different gene function.

et al., 1999). Subfunctionalization of homeologous genes has great importance for speciation. If duplicated genes are subfunctionalized or reciprocally lost in geographically isolated populations and when such individuals from each population are united, it can lead to hybrids that lack both copies of a duplicated gene pair, resulting in hybrid inviability, reproductive isolation and speciation (Werth and Windham, 1991; Lynch and Force, 2000; Taylor et al., 2001).

Neo-functionalization

Origin of novel gene function is one of the most important outcomes of gene duplication. Gene duplication allows the evolution of genes with new functions Figure 4. Duplication followed by selection plays a major role in evolution as the selection maintains the initial amplification and beneficial mutant alleles where the less improved genes get lost from the genome (Nasvall, 2012). The evolution of a novel fruit shape in tomato (*Solanum lycopersicum*) *SUN* and its progenitor (*IQD12*) evolved by the chance of duplication. A plant specific protein (67 amino acid motif called *IQ67*) produced the gene (*SUN*) into a new regulatory context belonging to a gene family that is involved in calmodulin signaling. *SUN* is expressed at much higher levels during the early stages of fruit development, and up-regulation correlates with an elongated fruit shape instead of round type fruit produced by gene *IQD12* (Xiao et al., 2008). In contrast to that, the natural allopolyploid *Arabidopsis suecica* is readily resynthesized in the laboratory from its model progenitors, *A. thaliana* and *Arabidopsis arenosa*. An interesting feature of this allopolyploid was found; it grows to a larger stature and produces more biomass than either of its parents. Most of the genes up-regulated in allotetraploid were *CCA1* (*circadian clock associated 1*), which showed that *CCA1* and *LHY* were epigenetically suppressed in the allopolyploid and that this suppression strongly correlates with increased starch synthesis and chlorophyll content, ultimately leading to greater plant biomass (Ni et al., 2009).

DUPLICATION IN RELATION TO DIVERSITY AND SPECIATION

Duplication may take place in a part of gene, the whole gene, part of genome or the whole genome. Whole genome duplication leads to doubling of large quantity of genes at once and this provides large potential source of novelty. Selection pressure (neither completely randomly nor deterministically) would play out in different ways in different populations in different climatic situation Figure 5, potentially leading to increased rates of speciation (Christian et al., 2007). Genes that are duplicated by polyploidy could be expressed at equal levels, or there could be unequal expression or silencing of one copy. Most gene pairs formed by a WGD have only a brief lifespan before one copy becomes deleted, leaving the others to survive as a single-copy locus (Wang et al., 2004). Studies of newly created synthetic polyploids revealed that silencing of some duplicated genes often resulted in the onset of allopolyploidy (Wang et al., 2004, Kashkush et al., 2002; He et al., 2003), indicating that gene silencing is a common response to polyploidy. It is expected that the probability of retention is initially equal for both duplicates following WGD, but recent findings have suggested that one duplicate may be more susceptible to loss than others. It has been found that in *Arabidopsis thaliana*, one paralogon (duplicated genomic region) tends to contain significantly more genes than the others (Thomas et al., 2006). Silencing of genes can take place immediately at the first generation following polyploidy, although some genes are not silenced until later generations (Wang et al., 2004). Silencing and expression

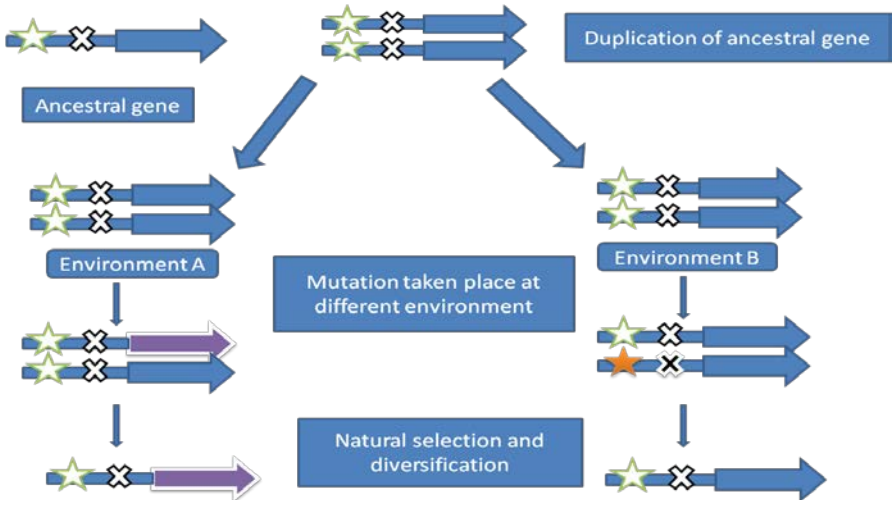

Figure 5. The process of gene diversification after duplication through natural selection.

of genes are many complex phenomenons as varying levels of gene expression are observed at organ level. Some duplicated genes are silenced immediately upon allopolyploidy in some organs of the plant but remain expressed in other organs (Adams et al., 2003). There is strong evidence for one round of genome doubling after the eudicot divergence and a second polyploidization event sometimes following the divergence of Arabidopsis and Brassica from their common ancestor with the Malvaceae, represented by cotton (Adams and Wendel, 2005).

It has been demonstrated recently that most eudicot plants are descendents of an ancient hexaploid ancestor (Jaillon et al., 2007), subsequently followed by lineage-specific tetraploidizations in some taxa: Populus (Tuskan et al., 2006; Jaillon et al., 2007), Arabidopsis (Bowers et al., 2003; Blanc et al., 2003 and Simillion et al. 2002), legumes (Cannon et al., 2006), but not recorded in Vitis (Jaillon et al. 2007). WGD has been proposed to be a lineage splitting force because of the subsequent occurrence of gene losses independently in different populations. In particular, reciprocal gene loss (RGL) occurs when two paralogs created by WGD are retained until speciation, after which each species loses a different copy (Scannell et al., 2006; Semon and Wolfe, 2007). After duplication, one of the two redundant copies of a gene should be free to accumulate mutation and become lost from the genome or gain some function without any consequence (Ohno, 1970). One analysis was performed just after artificial allopolyploidization in cotton where one paralog was silenced or down regulated in 5% of the gene pairs and that silencing was often organ-specific (Adams et al. 2004).

GENOME DUPLICATION AND THE ORIGIN OF ANGIOSPERM

It has been suggested that large-scale gene duplication or whole-genome duplication events can be associated with important evolutionary transitions and a major leaps in development of modern species. Angiosperms appear rather suddenly in the fossil record during the Jurassic (208–145 million years ago), with no obvious ancestors for a period of 80–90 million years before their appearance (Doyle and Donoghue, 1993). This ancestral lineage is coined ‘angiophytes’. It is presumed that angiophytes went through a period of little diversification during the late Triassic (220 Mya) and Jurassic, probaby because of the diversity-enhancing features, such as flowers (Wing and Boucher, 1998).

The recent transitional–combinational theory of the angiosperm origin suggests an evolution from Jurassic seed ferns through three fundamental transitions: (i) evolution of the carpel; (ii) emergence of double fertilization; and (iii) origin of the flower. The extant (or modern) angiosperms did not appear until the Early Cretaceous (145–125 Mya), when the final combination of these three angiosperm features occurred, as supported by evidence from micro- and macrofossils (Stuessy, 2004). The fossil record provides supporting evidence for this rapid diversification in floral form during the earliest phases of recorded flowering plant history. This diversification of angiosperms occurred during a period (the Aptian, 125-112 Mya) when their pollen and mega fossils were rare components of terrestrial floras and species diversity was low (Crane et al., 1995). Angiosperm fossils show a dramatic increase in diversity between the Albian (112–99.6 Mya) and the Cenomanian (99.6-93.5 Mya) at a global scale (Crane et al., 2004).

In 1996, when the sequencing of the flowering plant *A. thaliana* (Brassicaceae) genome began with its small genome, it was not expected to be an ancient polyploid. However, five years after the release of its genome sequence, there is compelling evidence that the Arabidopsis genome, or rather that of its ancestors, has been duplicated three times (events referred as 1R, 2R and 3R) during

the past 250 million years along with small scale continuous duplication (Sterck et al., 2007). Ancient polyploidy events might have directly influenced the increase in the number of plant species and plant complexity observed since the Early Cretaceous. Blanc and Wolfe (2004) studied the relationship between gene function and duplicate loss after the most recent polyploidy event (3R). Recently, Maere et al. (2005) developed an evolutionary model based on the KS distribution of the *Arabidopsis paranome* where they took into account the three major genome-wide duplication events (1R, 2R and 3R) and a continuous mode of small scale gene duplications (referred to as 0R). These studies all concluded that genes involved in transcriptional regulation and signal transduction have been preferentially retained following genome duplications. Similarly, developmental genes have been observed to be retained following genome duplications, particularly following the two oldest events, that is, 1R and 2R (Maere et al., 2005). Overall, the three polyploidy events in the ancestors of Arabidopsis might have been responsible for >90% of the transcription factors, signal transducers and developmental genes created during the past 250 million years.

S-adenosyl-l-methionine (SAM) dependent O-methyl transferases (OMTs) proteins are involved in the methylation of various secondary metabolites. Phylogeny across land plant lineages showed that OMT genes were distributed in two main classes, also suggesting that they have evolved by a gene duplication that had happened in the ancestor of land plants (Barakat et al., 2011). Soybean undergoes two separate polyploidy events resulting in 75% of genes present in multiple copies. Multiple events have taken place over the duplicated genes where sub functionalization, neo functionization, non functionalization or even the epigenetic or positional regulations play a role for gene regulation (Roulin et al., 2012).

DUPLICATION ANALYSIS IN MODEL ORGANISMS

Since 1990, the sequencing project has been launched in different organisms at different period of time; it revealed to us how to analyze the evolutionary pattern of different species by different chromosome rearrangements. The similarity and colinearity analysis of different species or within species among different chromosome has clearly shown the process of genome duplication over time and their role in species diversification. A cluster of resistance genes namely Tak703-1, Lrr703, Tak703, and Lrk703 have been identified in the D genome of wheat, where the structural cluster unit is conserved in nine grass genomes. Duplication has played major role in the *Tak*/*Lrk* evolution in oats, maize, barley, wheat, sorghum, and *Brachypodium*, while tandem duplication drove the expansion of this locus in *japonica* rice (Wang et al. 2013). Duplication analysis of some of the model organisms based on the genome sequencing data or comparing them with other species is described briefly as follows.

Duplication in arabidopsis genome (The Arabidopsis Genome Initiative, 2000)

The Arabidopsis Genome Initiative in 2000 published sequence analysis on model flowering plant, Arabidopsis. They used large-insert bacterial artificial chromosome (BAC), phage (P1) and transformation-competent artificial chromosome (TAC) libraries as the primary substrates for sequencing. The Arabidopsis genome sequence provides a complete view of chromosomal organization and clues to its evolutionary history. It revealed 1,528 tandem arrays containing 4,140 individual genes covering 17% of all genes of Arabidopsis. All the five chromosomes of Arabidopsis were aligned with each other in both orientations using MUMmer; and all segments were identified at least 1,000 bp in length; and 50% identity which revealed 24 large duplicated segments of 100 kb or larger, comprising 65.6Mb or 58% of the genome. But using TBLASTX to identify collinear clusters of genes in large duplicated chromosomal segments showed duplicated regions encompassing 67.9Mb, 60% of the genome. This study revealed a tetraploid ancestor was the progenitor of present day Arabidopsis as the majority of the Arabidopsis genome is represented in duplicated segments (Gaut and Doebley, 1997). A comparative sequence analysis of Arabidopsis and tomato estimated that duplication occurred in 112 Myr ago to form a tetraploid. The degrees of conservation of the duplicated segments might be due to divergence from an ancestral autotetraploid form, or might reflect differences present in an allotetraploid ancestor (Ku et al., 2000).

Duplication in *Saccharomyces cerevisiae*

Wolfe and Shields (1997) interpreted the presence and distribution of such regions in the *S. cerevisiae* genome as supporting a model of WGD. Kellis et al. (2004) showed that *S. cerevisiae* arose from complete duplication of eight ancestral chromosomes, and subsequently returned to functionally normal ploidy by massive loss of nearly 90% of duplicated genes in small deletions. They identified 145 paired regions in *S. cerevisiae*, tilling 88% of the genome and containing 457 duplicated gene pairs. The experiment was conducted by using *Kluyveromyces waltii*, closer to *S. cerevisiae* to identify orthologous regions. In contrast to the 1:1 mapping seen for close relatives19, most local regions in *K. waltii* are mapped to two regions in *S. cerevisiae*, with each containing matches to only a subset of the *K. waltii* genes. This clearly proved the evidence that ancient whole genome duplication would occur in the previous lineages of yeast.

Gene and chromosome duplication in rice (Report of IRGSP)

The International Rice Genome Sequencing Project was organized to achieve >99.99% accurate sequence using

Table 1. Duplication analysis in rice genome.

Chromosome number	Gene	Paralog
1	4,467	956 (21.4%)
2	3,011	616 (20.5%)
3	3197	493 (15.4%)
4	2,679	689 (25.7%)
5	2,426	472 (19.55)
6	2,342	484 (20.7%)
7	2,507	568 (22.7%)
8	2,286	489 (21.4%)
9	1,618	323 (20.4%)
10	1,724	433 (25.1%)
11	1,834	557 (30.4%)
12	1,870	497 (26.6%)
TOTAL	29,961	6577 (22.0%)

Table 2. Rice Arabidopsis synteny.

Chromosome number	Significant threshold (99.99%)
1	41
2	34
3	31
4	11
5	20
Total	137

a mapped based cloned sequencing strategies. More than 104,000 EST from a variety of rice tissue has been developed in EST database. Goff et al. (2002) describe a random shotgun sequencing of *Oryza sativa* L. ssp. *Japonica* (cv. Nipponbare) to discover rice genes, molecular markers for breeding and to mapped sequences for association of candidate genes. Using BLAST for comparing all H genes and M genes it was found that 77% were homologous to at least one other predicted genes. Chromosomal duplication was identified by comparing (BLASTN) more than 2000 mapped rice cDNA markers to the anchored portion of Syd. and it was observed that locally duplicated genes ranged from 15.4 to 30.4%, depending on the chromosome Table 1. The largest duplication is on the chromosomes 11 and 12. The amino acid substitution rate (d_A) was used to estimate the whole genome duplication that occurred in rice around 40 – 50 million years ago. Synteny analysis between rice and Arabidopsis chromosome showed 137 high confidence sytnenic groups at 99.9% threshold level (Table 2).

CONCLUSION

The most important contribution of gene duplication towards evolution is providing new genetic material for different mechanisms of evolutions, that is, mutation, drift and selection to act upon, the result of which is specialized or new gene functions. Duplication increases buffering activity of genome or species in adapting to changing environments where no more than two variants (alleles) exist at any locus within a (diploid) individual. Although, duplicated genes and genomes can provide the raw material for evolutionary diversification and the functional divergence of duplicated genes might offer a selective advantage to polyploids over a long time period, a beneficial effect of these duplications is assumed shortly after the duplication event. Lynch has suggested that differential gene duplication and pseudogenization in geographically isolated populations cause reproductive isolation and speciation, although this intriguing hypothesis awaits empirical evidence.

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REFERENCES

Adams KL, Cronn R, Percifield R, Wendel JF (2003). Genes duplicated by polyploidy show unequal contributions to the transcriptome and organ-specific reciprocal silencing. Proc. Natl. Acad. Sci. USA. 100:4649-4654.

Adams KL, Wendel JF (2005). Allele-specific, bi-directional silencing of an alcohol dehydrogenase gene in different organs of interspecific diploid cotton hybrids. Genetics 171:2139–2142.

Adams KL, Percifield R, Wendel JF (2004). Organ-specific silencing of duplicated genes in a newly synthesized cotton allotetraploid. Genetics 168: 2217-2226.

Arabidopsis Genome Initiative (2000). Analysis of the genome sequence of the flowering plant *Arabidopsis thaliana*. Nature 408:796–815.

Bailey JA, Liu G, Eichler EE (2003). An *Alu* transposition model for the origin and expansion of human segmental duplications. Am. J. Hum. Genet. 73:823–834.

Barakat A, Choi A, Yassin NB, Park JS, Sun Z, Carlson JE (2011). Comparative genomics and evolutionary analyses of the O-methyltransferase gene family in Populus. Gene 479 (1-2):37-46.

Blanc G, Hokamp K, Wolfe KH (2003). A recent polyploidy superimposed on older large-scale duplications in the Arabidopsis genome. Genome Res. 13:137-144.

Blanc G, Wolfe KH (2004). Functional divergence of duplicated genes formed by polyploidy during Arabidopsis evolution. Plant Cell. 16: 1679–1691.

Bowers JE, Chapman BA, Rong J, Paterson AH (2003). Unravelling angiosperm genome evolution by phylogenetic analysis of chromosomal duplication events. Nature 422:433-438.

Bridges CB (1936). The Bar 'gene' a duplication. Science 83:210–211.

Cannon SB, Sterck L, Rombauts S, Sato S, Cheung F, Gouzy J, Wang X, Mudge J, Vasdewani J, Schiex T et al. (2006). Legume genome evolution viewed through the *Medicago truncatula* and *Lotus japonicus* genomes. Proc. Natl Acad. Sci. 103:14959-14964.

Chapman BA, Bowers JE, Feltus FA, Paterson AH (2006). Buffering crucial functions by paleologous duplicated genes may impart cyclicality to angiosperm genome duplication. Proc. Natl. Acad. Sci. USA 103:2730–35.

Christian roth; Shruti Rastogi;, Lars Arvestad;, Katharina Dittmar;, Sara Light;, Diana Ekman;, And David A. Liberles (2007). Evolution After Gene Duplication: Models, Mechanisms, Sequences, Systems, and Organisms. J. Exp. Zool. B Mol. Dev. Evol. 308(1):58-73.

Coghlan A, Eichler EE, Oliver SG, Paterson AH, Stein L (2005). Chromosome evolution in eukaryotes: a multi-kingdom perspective.

Trends Genet. 21:673–82.
Crane PR, Friis EM, Pedersen KR (1995). The origin and early diversification of angiosperms. Nature 374: 27–33.
Crane PR, Herendeen P, Friis EM (2004). Fossils and plant phylogeny. Am. J. Bot. 91:1683–1699.
Davies TJ, Barraclough TG, Chase MW, Soltis PS, Soltis DE, Savolainen V (2004). Darwin's abominable mystery: Insights from a super tree of the angiosperms. Proc. Natl. Acad. Sci. USA 101:1904–09.
Doyle JA, Donoghue MJ (1993). Phylogenies and angiosperm diversification. Paleobiology 19: 141–167.
Force A, Cresko WA, Pickett FB, Proulx SR, Amemiya C, Lynch M (1999). The origin of subfunctions and modular gene regulation. Genetics 170:433–46.
Gaut BS, Doebley JF (1997). DNA sequence evidence for the segmental allotetraploid origin of maize. Proc. Natl Acad. Sci. 94: 6809-6814.
Goff SA, Ricke D, Lan TH, Presting G, Wang R, Dunn M, Glazebrook J, Sessions A, Oeller P, Varma H et al. (2002) A draft sequence of the rice genome (*Oryza sativa L. ssp. japonica*). Science 296: 92–100.
Grant V (1981). Plant Speciation. Columbia University Press, New York.
Gupta PK (2007). Duplication and Deficiencies. In: Cytogenetics (7th ed.). Rastogi Publication, Meerut. pp.19-43.
Harrison PM, Hegyi H, Balasubramanian S, Luscombe NM, Bertone P, Echols N, Johnson T, Gerstein M (2002). Molecular fossils in the human genome: identification and analysis of the pseudogenes in chromosomes 21 and 22. Genome Res. 12: 272–280.
He P, Friebe B, Gill B, Zhou J-M (2003). Allopolyploidy alters gene expression in the highly stable hexaploid wheat. Plant Mol Biol. 52:401-414.
Hughes AL (1994). The evolution of functionally novel proteins after gene duplication. Proc. Biol. Sci. 256:119–124.
Hurles M (2004). Gene duplication: the genomic trade in spare parts. PloS Biol. 2(7):900–904.
Hurst LD, Smith NGC (1998). The evolution of concerted evolution. Proc. R. Soc. Lond. Ser. B 265: 121–127.
Jaillon O, Aury JM, Noel B, Policriti A, Clepet C, Casagrande A, Choisne N, Aubourg S, Vitulo N, Jubin C et al.(2007). The grapevine genome sequence suggests ancestral hexaploidization in major angiosperm phyla. Nature 449:463-467.
Kashkush K, Feldman M, Levy AA (2002). Gene loss, silencing, and activation in a newly synthesized wheat allotetraploid. Genetics 160:1651-1659.
Kellis M, Birren BW, Lander ES (2004). Proof and evolutionary analysis of ancient genome duplication in the yeast *Saccharomyces cereviseae*. Nature 428:617-624.
Ku HM, Vision T, Liu J, Tanksley SD (2000). Comparing sequenced segments of the tomato and Arabidopsis genomes: Large-scale duplication followed by selective gene loss creates a network of synteny. Proc. Natl Acad. Sci. 97: 9121-9126.
Li WH (1997). Molecular Evolution, Sinauer.
Linardopoulou EV, Williams EM, Fan Y, Friedman C, Young JM, Trask BJ (2005). Human sub-telomeres are hot spots of inter chromosomal recombination and segmental duplication. Nature 437:94–100.
Lynch M, Force A (2000). The probability of duplicate gene preservation by subfunctionalization. Genetics 154: 459–473.
Lynch M, Conery JS (2000). The evolutionary fate and consequences of duplicate genes. Science 290: 1151–1155.
Lynch M, O'Hely M, Walsh B, Force A (2001). The probability of preservation of a newly arisen gene duplicate. Genetics 159: 1789–1804
Maere S, De Bodt S, Raes J, Casneuf T, Van Montagu M, Kuiper M, Van de Peer Y (2005). Modeling gene and genome duplications in eukaryotes. Proc. Natl. Acad. Sci. USA 102:5454-5459.
Masterson J (1994). Stomatal size in fossil plants: evidence for polyploidy in majority of angiosperms. Science 264: 421–423.
Mombaerts P (2001). The human repertoire of odorant receptor genes and pseudogenes. Annu. Rev. Genomics Hum. Genet. 2: 493–510.
Nei M (2009) Gene duplication and nucleotide substitution in evolution. Nature 221: 40–42.
Ni Z, Kim ED, Ha M, Lackey E, Liu J, Zhang Y, Sun Q, Chen ZJ (2009). Altered circadian rhythms regulate growth vigour in hybrids and allopolyploids. Nature 457: 327–331.
Nowak MA, Boerlijst MC, Smith JM (1997). Evolution of genetic redundancy. Nature 388:167–171.
Ohno S (1970). Evolution by Gene Duplication. Springer-Verlag.
Ota T, Nei M (1995). Evolution of immunoglobulin VH pseudogenes in chickens. Mol. Biol. Evol. 12: 94–102.
Pan D, Zhang L (2007). Quantifying the major mechanisms of recent gene duplications in the human and mouse genomes: a novel strategy to estimate gene duplication rates. Genome Biol. 8:R158.
Piontkivska H, Alejandro PR, Masatoshi N (2002). Purifying selection and birth-and-death evolution in the histone H4 gene family. Mol. Biol. Evol. 19: 689–697
Roulin A, Paul LA, Marc L, Jessica S, Andrew F, Greg M, Gary S, Rebecca WD, Scott AJ (2012). The fate of duplicated genes in a polyploid plant genome. Plant J. 73(1): 143-53.
Rouquier S, Blancher A, Giorgi D (2000). The olfactory receptor gene repertoire in primates and mouse: evidence for reduction of the functional fraction in primates. Proc. Natl. Acad. Sci. 97: 2870–2874.
Samonte RV, Eichler EE (2002). Segmental duplications and the evolutionof the primate genome. Nat Rev Genet. 3:65–72.
Scannell DR, Byrne KP, Gordon JL, Wong S, Wolfe KH (2006). Multiple rounds of speciation associated with reciprocal gene loss in polyploid yeasts. Nature 440:341-345.
Semon M, Wolfe KH (2007). Reciprocal gene loss between Tetraodon and zebrafish after whole genome duplication in their ancestor. Trends Genet. 23:108-112.
Shanks N (2004). *God, the Devil, and Darwin*, Oxford University Press, NY. p.74.
Simillion C, Vandepoele K, Van Montagu MC, Zabeau M, Van de Peer Y (2002). The hidden duplication past of Arabidopsis thaliana. Proc. Natl. Acad. Sci. USA 99:13627-13632.
Sterck L, Rombauts S, Vandepoele K, Rouze P, Peer YV (2007). How many genes are there in plants (. . . and why are they there)? Curr. Opin. Plant Biol. 10:199–203.
Stuessy TF (2004). A transitional–combinatorial theory for the origin of angiosperms. Taxon. 53:3–16.
Taylor JS, Peer VD, Meyer A (2001). Genome duplication, divergent resolution and speciation. Trends Genet. 17:299–301.
Thomas BC, Pedersen B, Freeling M (2006). Following tetraploidy in an Arabidopsis ancestor, genes were removed preferentially from one homologue leaving clusters enriched in the sensitive genes. Genome Res. 16:934-946.
Titov II, Vorozheykin PS (2011). Analysis of miRNA duplication in the human genome and the role of transposon evolution in this process. Russian J. Genet. 1(4): 308-314.
Tuskan GA, Difazio S, Jansson S, Bohlmann J, Grigoriev I, Hellsten U, Putnam N, Ralph S, Rombauts S, Salamov A et al. (2006). The genome of black cottonwood, Populus trichocarpa (Torr. & Gray). Science 313:1596-1604.
Vinckenbosch N, Dupanloup I, Kaessamann H (2006). Evolutionary fate of retroposed gene copies in the human genome. PNAS 103 (9): 3220-25.
Walsh JB (1995). How often do duplicated genes evolve new functions? Genetics 139: 421–428.
Wang J, Tian L, Madlung A, Lee HS, Chen M, Lee JJ, Watson B, Kagochi T, Comai L, Chen ZJ (2004). Stochastic and epigenetic changes of gene expression in Arabidopsis polyploids. Genetics 167:1961-1973.
Wang Z, Banik M, Cloutier S (2013). Divergent evolutionary mechanisms of co-located *Tak*/*Lrk* and *Glu-D3* loci revealed by comparative analysis of grass genomes. Genome 56(4):195-204.
Werth CR, Windham MD (1991). A model for divergent, allopatric speciation of polyploid pteridophytes resulting from silencing of duplicate-gene expression. Am. Nat. 137:515–526.
Wing SL, Boucher LD (1998). Ecological aspects of the cretaceous flowering plant radiation. Annu. Rev. Earth Planet Sci. 26: 379–421.
Wolfe KH, Shields DC (1997). Molecular evidence for an ancient duplication of the entire yeast genome. Nature 387:708–713.
Xiao H, Jiang N, Schaffner E, Stockinger EJ, van der Knaap E (2008). A retrotransposon-mediated gene duplication underlies morphological variation of tomato fruit. Science 319:1527–1530.
Zhang J (2003). Evolution by gene duplication: an update. Trends Ecol. Evol. 18:192-98.
Zhang X, Firestein S (2002). The olfactory receptor gene superfamily of the mouse. Nat. Neurosci. 5: 124–133.

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Role of sacred groves in ameliorating microclimate: A case study of Nagdev temple forest of Pauri Garhwal, Uttarakhand Himalaya, India

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To show the role of sacred grove in rejuvenating the microclimate, a study was conducted at the temple forest of Nagdev area (Latitude 30° 8' 30" N and Longitude 78° 46' 25" East) of Pauri Garhwal in Uttarakhand Himalaya, India. Nagdev temple forest area was compared with a nearby (control) site, having relatively more biotic disturbances. Weather parameters viz. temperatures- maximum and minimum, wind velocity, rainfall, sunshine hours, etc. have been collected from both study sites, compiled for monthly and annual values and compared. Daily climatic variables showed significant differences in some of the parameters. There are marked variations in the range of daily observations of all the microclimatic parameters of both sites. Relative humidity values both at morning and evening hours have clear differences, similarly, maximum and minimum temperatures have also shown remarkable differences, particularly lower range of minimum temperature at control site was -7.1°C, whereas it was -2.8°C in the temple forest. There were more days (12 days) with minus temperatures at control site as compared to temple forest (4 days). Snowfall was also high in the control site as compared to temple forest; bright sun shine hours and wind speed values are more at control site than temple forest site. Vegetation of both sites was studied following standard nested quadrat method for trees, shrubs and herbs. Phytosociological parameters of the study sites reveal that tree, shrub and herb species were more in number at temple forest site than the control site. All phytosociological parameters of tree, shrub and herb species common at both sites also showed differences in these parameters at both sites. Surface soil of both sites were also analysed for physicochemical attributes of their replicate samples and compared. Average values of soil samples for their different attributes have also shown clear variations in their ranges at both sites.

Key words: Nagdev temple forest, Pauri Garhwal Himalaya, Uttarakhand, vegetation, soil, microclimatic data.

INTRODUCTION

Sacred groves are important reservoirs of biodiversity, preserving indigenous plant species, particularly medicinal, aromatic and other ecologically and economically important plants. Joshi and Gadgil (1991) reported that sacred grove might serve important refugia for threatened and rare species. Besides, they preserve genetic diversity of even the common trees (Nair et al., 1997).

These groves have traditionally been conserved in the

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past, however, in the recent times, the scenario has changed due to decline in traditional value systems. Some authors have reported the depleting values of these groves, which is making them to perish (Chandran and Gadgil, 1993; Chandran, 1997; Singh et al., 1998). With improved accessibility and urbanization, sacred areas have turned into tourist places to serve economic interest (Saxena et al., 1998).

Sacred grove in hills of Garhwal and Kumaon (Uttarakhand) are mentioned in old Hindu scriptures like the *Puranas*. Believing trees to be abode of gods and ancestral spirits, patches of forests near villages are established, where deity/deities are worshipped. The trees/vegetation growing in these groves are not cut, as it is believed to belong to the deity. Only the dead/dried parts are sometimes used as has also been mentioned by Negi (2012). Even sometimes, sudden dying of trees of these forests are said to be indication of misha-ppenings/misfortune for the nearby villages. This type of restriction in these forests has helped conservation of native/indigenous species in these groves.

There are several studies on sacred groves in India, but only a few studies are from Uttarakhand. There are some well known sacred groves which truly represent the wealth of a religion based conservation traditions as reported by Bisht et al*. (*2007), Adhikari and Adhikari (2007), Angihotri et al*.* (2010 and 2012), Anthwal et al*.* (2010), Negi (2010), Gokhale et al. (2011), Pala et al. (2012) and Singh et al. (2010, 2011, 2012, 2013). Even though the biological diversity of Himalaya is very rich, there is little information available on the sacred groves and the conservation of biodiversity in Garhwal Himalaya (Sinha and Maikhuri, 1998).

It is very difficult to report the exact number of sacred groves in Uttarakhand, however, efforts made by some authors like 32 sacred groves by Sinha and Maikhuri (1998), Bisht et al. (2007) and 128 sacred groves by Negi (2010) are appreciable.

The present study was conducted at Nagdev temple forest in Nagdev Forest Range of Pauri Garhwal Forest Division of Uttarakhand Himalaya, India. The study reveals the status of plant diversity (in compartment 4 and 5), soil and meteorological variations inside the temple forest (a reserved forest) and nearby non-reserved forest area, which has comparatively more biotic interference Photos 1 and 2.

Study site

Nagdev Forest Range comes under Pauri Garhwal Forest Division of Uttarakhand Forest Department (Map 1). The altitudinal range is from 1805 to 2500 m msl and lies at Latitude 30° 8’ 30” N and Longitude 78° 46’ 25” East. The total forest area under Nagdev range is 6641.3 ha of which area of 336.7 ha comes under Nagdev Block.

The experimental area of present study lies under Nagdev Block and covers Compartment No. 4 covering an area of 11.5 ha and Compartment No. 5 with an area of 31.4 ha. Thus, the total area covered under Nagdev temple forest site is 42.9 ha. The nearby area is considered as control site covering an area of about 30 ha. Plants present in this area are being exploited by the nearby villagers to meet their requirement of fuelwood and fodder, thus biotic disturbance is high.

Map 1 shows location of Pauri Garhwal (Garhwal) in Uttarakhand. Map 2 shows Pauri Garhwal Forest Division and location of Nagdev Forest Range in Pauri Garhwal Forest Division. Map 3 shows location of compartments 4 and 5 in Nagdev Forest Range, which represents site II, alongwith nearby relatively disturbed area as control site or site I of the present study.

MATERIALS AND METHODS

Microclimatic studies

To study the microclimatic status of both sites, weather stations were installed inside Nagdev Temple Forest area (site II) and nearby control area (site I). Thermometers for maximum temperature, minimum temperature, wet bulb and dry bulb temperatures were installed inside Stevenson’s double screen for daily recording of maximum and minimum temperatures, wet bulb and dry bulb temperatures for calculation of relative humidity as per conversion tables of India Meteorological Department (IMD), Pune. Other instruments used were rainguage for daily rainfall recording, 3-cup Anemometer for recording of wind speed per hour and per 24 hours and sun shine recorder for recording sunshine hours (per 24 hour) from both sites.

Statistical analyses of these parameters were done by using GenStat Discovery Edition 3 by using general ANOVA.

Vegetational attributes

Tree, shrub and herb species were studied for their structural analysis by laying out nested quadrats as per Mishra (1968). The structural analysis, that is, frequency, density and abundance was studied as per Curtis and McIntosh (1950). The relative frequency, relative density and relative dominance and importance value index (IVI) were determined following Phillips (1959).

Soil samples were collected from 0-30, 30-60 and 60-90 cm depths. Mechanical and chemical analysis was done in the laboratory by following standard methods like pH by Richard's method (1954), organic carbon by Maynard (1991), nitrogen by ‘Macro Kjeldahl’ method (Loomis and Shull, 1937), phosphorus (P), potassium (K) and calcium (Ca) by Vogel's method (1961) and magnesium (Mg) by Young and Gill (1951) method.

RESULTS

Microclimatic studies

Daily data of wind speed (km hr^{-1}), maximum, minimum temperatures (°C), rainfall (mm), sun shine hours were collected from weather stations installed at both study sites (site I = control site, site II = Nagdev Temple Forest site). The daily data of 2008 and 2009 were compared at both sites.

Photo 1. Nagdev temple, Pauri, Garhwal Himalaya, India.

Photo 2. *Cedrus deodara* and C*upressus torulosa* trees at Nagdev temple forest area.

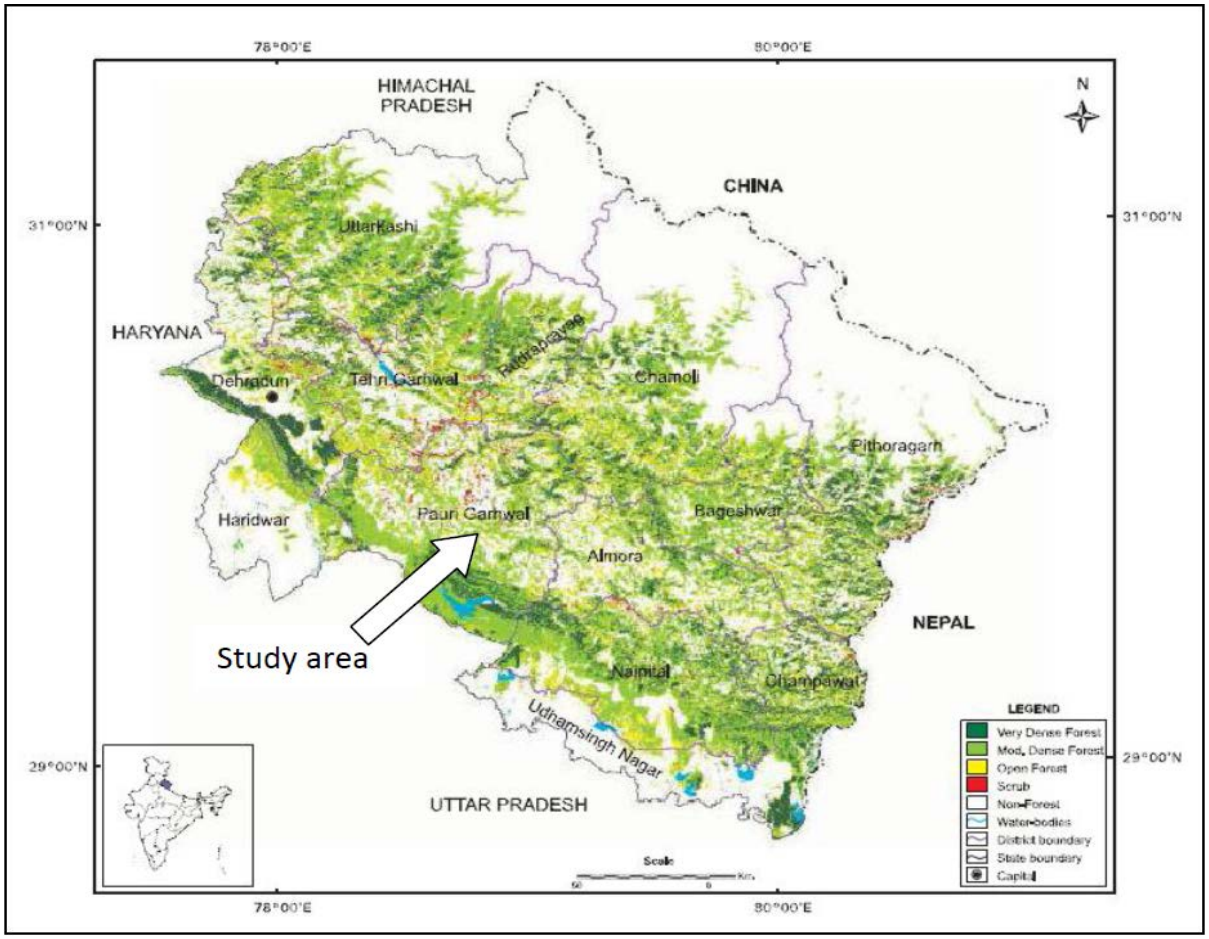
Average monthly and yearly values of both tsites were calculated from the daily data of all parameters. Average wind speed during 2009 was 1.4 km hr^{-1} more at site I as compared to site II, values of 2008 did not show much difference. Minimum temperature was higher during both years (2008 and 2009) at site II, maximum temperature was high (23.51°C) in temple forest than control site (21.66°C) during 2009, but during 2008 there was no much difference in maximum temperature.

Total rainfall was quite high at site II during 2008 (1158.9 mm), whereas at site I, it was 812.5 mm. Contrary to the total rainfall of 2008, the values of rainfall during 2009 were almost equal (577.2 and 577.7 mm, respectively) at site II and site I, as can be in Figure 1. It is noted that the difference in rainfall during the month of July of both years is higher at site II. It seems that the difference in April and July rainfall of 2008 has contributed to the difference of total rainfall (1158.9-812.5 = 346.4 mm) of this year.

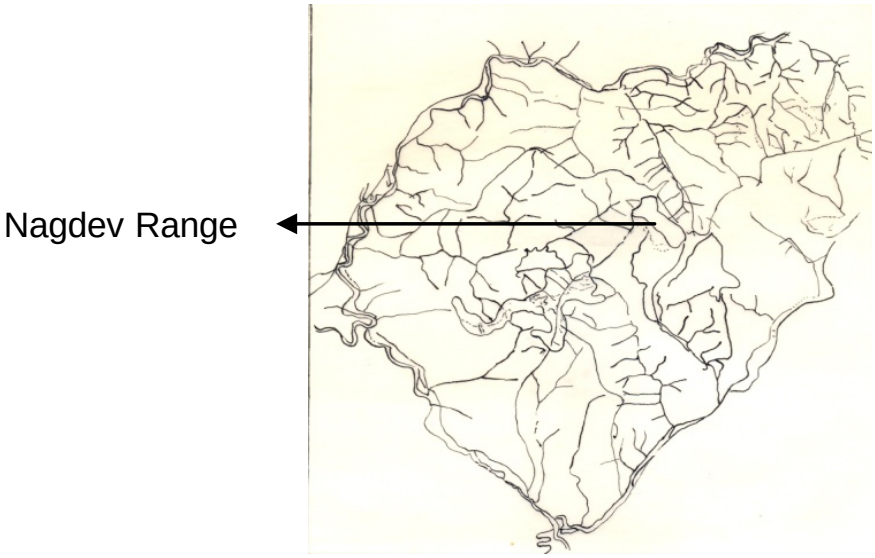
Average sunshine hours have shown difference of 1 h at control site as compared to temple forest (5.7 and 6.7, 6.2 and 7.3) during 2008 and 2009, respectively. Statistical analysis of these parameters using Microsoft Excel GenStat Discovery Edition 3 by using general ANOVA is depicted in Table 1. ANOVA among the months of two sites during 2008 and 2009 were analysed, which showed significant variation in the wind speed between the sites, as can be seen clearly in Table 2. Wind speed was higher at site I, that is, control site (3.32 Km hr^{-1}) than Temple forest area (2.33 Km hr^{-1}). The variation is significant at 5% level as revealed from the table (LSD, 0.44).

Variation in rainfall among months between the two sites is not significant (Table 2), although the total annual rainfall was quite comparable between the sites during 2008. This may be because of natural variability in rainfall during both study years, as is evidenced from the table also, which shows average rainfall of 58 and 72 mm at sites I and site II, respectively.

Variation in minimum temperature among months is not significant between the two sites as is clear from the table, but the annual average minimum temperature values are quite comparable as can be seen in the table. The minimum temperature at the control site was lower (9.68 and 9.06 during 2008 and 2009, respectively) than at the temple forest area site (11.21 and 11.01, during 2008 and 2009, respectively). Variation in maximum



Map 1. Location of Pauri Garhwal (Garhwal) in Uttarakhand, India.



Map not to scale

Map 2. Pauri Garhwal Forest Division.

Map 3. Location of study sites in Nagdev Range (Compartment 4 and 5). Map not to scale.

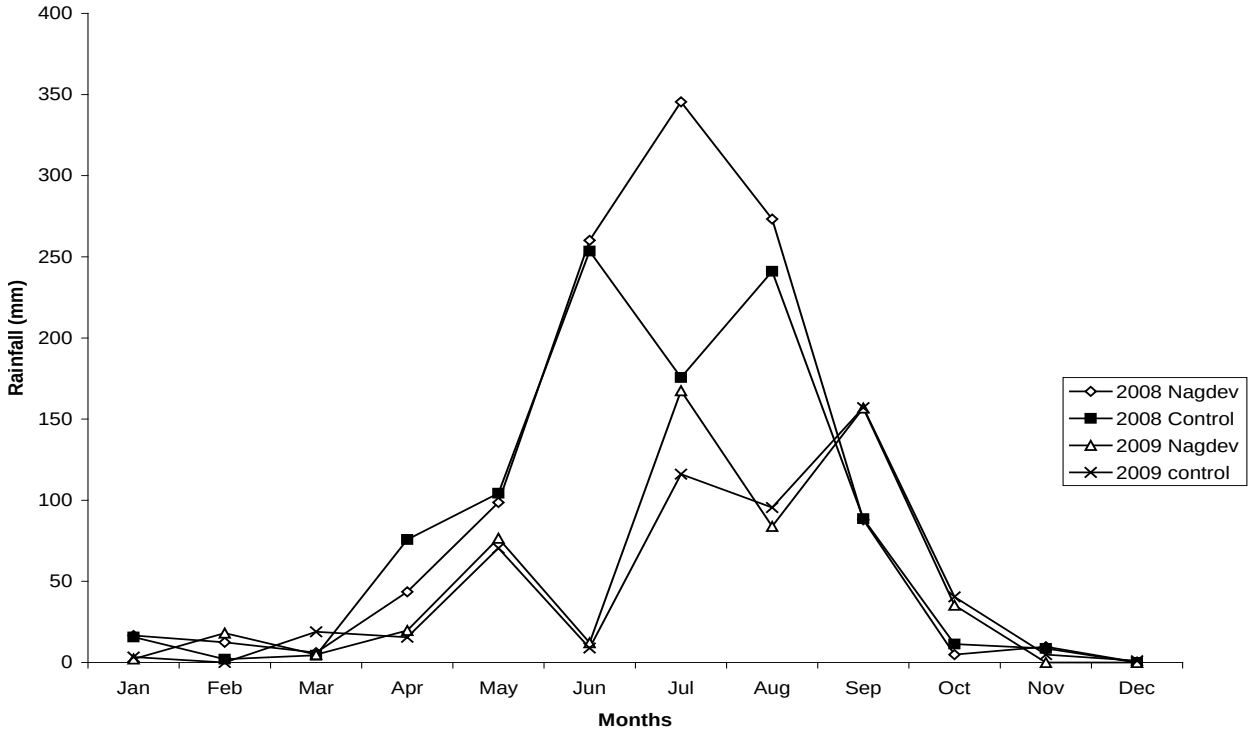


Figure 1. Monthly rainfall (mm) at Nagdev temple forest and the control site.

temperature among months is not significant between the two sites as is clear from Table 2. The maximum temperature at control site is 21.6°C, whereas it is 23.51°C in temple forest during 2009.

For sunshine hours, ANOVA among the months of two sites and between two years were analysed, which showed significant variation between the sites, as can be seen clearly from the Table 2. Sunshine hours are higher at site I (7.04) than Temple forest area (5.98). The variation is significant at 5% level as is revealed from the table (LSD, 1.015). Variability in meteorological data between two years is natural, as is clear from data of 2008 and 2009 at both study sites.

Phytosociological or vegetational studies

Seven tree species were recorded from control site,

Table 1. Statistical variation in different climatic parameters.

Parameter	Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Wind speed (km hr^{-1})	Site	1	11.7019	11.7019	20.05	<.001
	Residual	46	26.8433	0.5836		
	Total	47	38.5452			
Rainfall (mm)	Site	1	2493	2493	0.33	0.568NS
	Residual	46	347190	7548		
	Total	47	349683			
Minimum Temperature (°C)	Site	1	36.21	36.21	1.70	0.198NS
	Residual	46	976.94	21.24		
	Total	47	1013.15			
Maximum temperature (°C)	Site	1	12.0	12.0	0.73	0.398NS
	Residual	46	759.16	16.5		
	Total	47	771.16			
Sun shine hrs	Site	1	13.504	13.504	4.43	0.041
	Residual	46	140.249	3.049		
	Total	47	153.754			

Table 2. Variation in different climatic parameters at both sites.

Site	Wind speed (Km hr^{-1})	Rainfall (mm)	Minimum temperature (°C)	Maximum temperature (°C)	Sun shine hours
I	3.32	58	9.37	21.63	7.04
II	2.33	72	11.11	22.63	5.98
Mean	2.83	65	10.24	22.13	6.51
LSD	0.44	NS	NS	NS	1.015

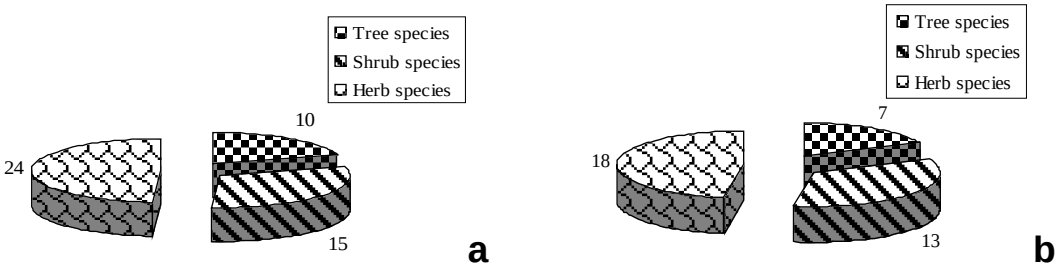


Figure 2. a and b shows number of tree, shrub and herb species at sites I and II.

whereas 10 were recorded from temple forest site (Figure 2a and b), out of which 6 tree species were common at both sites, these were *Cupressus torulosa* Don., *Myrica esculenta* Buch.-Ham. ex D. Don, *Cedrus deodara* Loud., *Quercus leucotrichophora* A. Camus ex Bahadur, *Rhododendron arboreum* Sm., *Pinus wallichiana* AB Jackson. Control site has *Pinus roxburghii* Sarg. trees in addition to these, which is indicator of disturbances at the site.

Shrub species recorded were more (15) at temple forest site than at the control site (13). Likewise herb species were more (24) at temple forest site as compared to control site (18). Some of shrub species are *Ilex dipyrena* Wall., *Rosa macrophylla* Lindl., *Strobilanthus wallichii* Nees., *Daphne papyracea* Wall., *Berberis aristata* DC., *Rubus ellipticus* Sm., *Lespedeza gerardiana* Grah., *Smilax parvifolia* Wall. etc. and herb species are *Achyranthes aspera* Linn., *Berberis aristata* DC., *Delphinium denudatum* Wall., *Oplismenus compositus* (Linn.) P. Beauv., *Oplismenus burmannii* (Retz.) Beauv., *Fragaria indica* Andrews, *Centella asiatica* (L.) Urb., *Ocimum basilicum* Linn., *Adiantum lunulatum* Burm.,

Table 3. Variations in the daily climatic data, soil and vegetational attributes at temple forest and control sites.

Parameters studied	Study site	
	Temple forest (Site II)	Control (Site I)
Microclimatic attributes		
Relative Humidity (%)		
Morning	61 to 100	28 to 100
Evening	50 to 100	5 to 99
Temperatures (°C)		
Maximum	7.7 to 31.5	5.7 to 29.1
Minimum	-2.8 to 15.0	-7.1 to 11.5
Bright Sun shine Hours	1 to 9.5	1 to 10.8
Wind speed (km hr^{-1})	0 to 4.69	0 to 14.28
Vegetational attributes*		
No. of tree species	10	7
No. of Shrub species	15	13
No. of herb species	24	18
Soil		
Texture	sandy- to loam	sandy- to sandy loam
Moisture	26.46%	10-35%
N	0.17-0.31	0.08-0.18
P	0.01-0.06	0.01-0.03
Ca	0.52-0.69	0.21-0.41
Mg	0.08-0.14	0.03-0.09
C	0.12-1.49	0.08-0.17

*Basal area, IVI, cd and species evenness values of 6 common tree species were more at temple forest site than control site.

Cyperus kyllinga Endi., *Clematis gouriana* Roxb. ex DC., *Rubus ellipticus* Sm., *Olea glandulifera* Wall., *Oxalis latifolia* Kunth, *Neyraudia arundinacea* Munro., *Ajuga parviflora* Benth., *Flueggea microcarpa* Bl. etc.

While calculating similarity index of herb species, dissimilarity index was more (0.6) at temple forest site as compared to the control site. This clearly indicates the role of temple forest in conservation of microclimate, which in turn has great influence on growth of herb species in any area.

While comparing basal area, IVI, diversity index, concentration of dominance (cd) and species evenness values of 6 common tree species at both sites, it was noted that basal area and species diversity index of *C. deodara, Q. leucotrichophora* and *R. arboreum* are more at temple site; IVI and cd of *Q. leucotrichophora* and *R. arboreum* are more at temple site; species richness of all 6 tree species is higher at temple forest site as compared to the control site.

Soil

Surface soil (0-30, 30-60 and 60-90 cm) were taken from both study sites and analysed for their attributes like texture, moisture, nutrients namely nitrogen, phosphorus (P), calcium (Ca), magnesium (Mg) and carbon (C). Both sites have shown remarkable differences in all these parameters. The range of all these parameters is given in Table 3, which clearly shows the ranges of nutrients alongwith moisture higher (26-46%) at temple forest site site II than site I (10-35%). The texture varied from sandy to loam at site II, where as it ranged from sandy to sandy loam at site I. N varied from 0.17 to 0.31%, P from 0.01 to 0.06%, Ca from 0.52 to 0.69%, Mg from 0.08 to 0.14% and C from 0.12 to 1.49% at site II. At site I N varied from 0.08 to 0.18%, P from 0.01 to 0.03%, Ca from 0.21 to 0.41%, Mg from 0.03 to 0.09% and C from 0.08 to 0.17, which are quite high at temple forest site i.e. site II.

DISCUSSION

Daily meteorological data have more importance than average values of months or years, as extreme climatic variables have great impact on local weather. Hence, it is worthwhile to compare daily data of both sites along with average values. Average monthly and yearly values of

both the sites have been given in Table 3 for the year 2008 and 2009. There are marked variations in the range of daily observations of all the microclimatic parameters of both sites. Relative humidity values at both morning hours and evening hours have clear differences, similarly maximum and minimum temperatures have also shown remarkable differences, particularly lower range of minimum temperature at control site is -7.1°C, where as it is -2.8°C in the temple forest. There were more days (12 days) with minus temperatures at control site as compared to temple forest (4 days). Snowfall was also high in the control site (there was snowfall of 16.1 mm on 11th and 29.3 mm on 12th February 2009) as compared to temple forest; Bright sun shine hours and wind speed values are more at control site than temple forest. Average values of soil attributes have also shown clear variations in the range.

Blanketing effect of temple forest is clearly depicted by the data of minimum temperature, as it is higher in temple forest (11.11°C) as compared to control site (9.37°C). Similarly, more wind speed and sunshine hours at the control site shows more openness and more desscation at control site, resulting to more evaporation and less soil moisture, which are very important microclimatic effects of this temple forest or sacred grove.

Conclusion

Although, there are many reports on general aspects of the sacred groves (Gadgil and Vartak, 1976; Boojh and Ramakrishnan, 1983; Khiewtan and Ramakrishnan, 1989; Ramakrishnan, 1996; Sinha and Maiklhuri, 1998; Basu, 2000, Murugan et al., 2008; Bhakat et al., 2003; Negi, 2010; Agnihotri et al., 2010; Gokhale, 2011), data based research results on different ecological/-microclimatic aspects of sacred groves are lacking. Hence, the data based research results of the present study can be of great importance for conserving the microclimate/modifying the microclimate of such sacred groves/temple forests or reserved forest areas.

There is an urgent need for recognizing these traditionally valued natural systems at various levels and planning for their better management, ultimately aiming to conserve biodiversity and microclimate. In this context, traditional values that help in conservation should be properly recognized and acknowledged.

Considering the present conditions of the groves, they can be used as repositories of endemic plants, soil seed bank, connective corridor for birds and animals in human dominated landscapes. Therefore, it requires combined and holistic approach to conserve the grove tradition in nearby villages.

Finally, the need of the hour is to make people aware of the importance of such sacred areas, involve people in their conservation and management, and explore their potential in improvement of livelihood of the nearby local inhabitants.

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REFERENCES

Adhikari SD, Adhikari BS (2007). Veneration of a Deity by Restoration of Sacred Grove in a Village Minar, Kumaun Region of Uttarakhand: A case study. J. Am. Sci. 3(2):45-49.

Agnihotri P, Sharma S, Dixit V, Singh H, Husain T (2010). Sacred groves from Kumaon Himalaya. Curr. Sci. 99(8):996-997.

Agnihotri P, Singh H, Husain T (2012). Patal Bhuvneshwar: a new sacred grove from Kumaon Himalaya. Curr. Sci. 102(5):830-831.

Anthwal A, Gupta N, Sharma A, Anthwal S, Kim KI-H (2010). Conserving biodiversity through traditional beliefs in sacred groves in Uttarakhand Himalaya, India. Resources, Conserv. Recycl. 54(11):962-971.

Basu R (2000). Studies on sacred groves and taboos in Purulia district of West Bengal. Indian Forester 126(12):1309-1318.

Bhakat RK, Pandit PK (2003). Role of sacred grove in conservation of medicinal plants. Indian Forester. 129(2):224-232.

Bisht S, Ghildiyal JC (2007). Sacred groves for biodiversity conservation in Uttarakhand Himalaya. Curr. Sci. 92(6):711-712.

Boojh R, Ramakrishnan PS (1983). Sacred groves and their role in environmental conservation. Strategies for Environmental Management, Souvenir Volume: 6-8. Department of Science and Environment of Uttar Pradesh, Lucknow.

Chandran MDS (1997). On the ecological history of the Western Ghats. Curr. Sci. 73:146-155.

Chandran MDS, Gadgil M (1993). Sacred groves and sacred trees of Uttara Kannada (a pilot study), Mimeograph. Centre for Ecological Sciences, IISc., Bangalore.

Curtis JJ, McIntosh RP (1950). The inter-relations of certain analytical and synthetic phytosociological character. Ecol. 31:4334-455.

Gadgil M, Vartak VD (1976). Sacred groves of Western Ghats of India. Ecol. Bot. 30:152-160.

Gokhale Y, Pala NA, Negi AK, Bhat JA, Todaria NP (2011). Sacred Landscapes as Repositories of Biodiversity: A Case study from the Hariyali Devi Sacred Landscape, Uttarakhand. Int. J. Conserv. Sci. 2(1):37-44.

Joshi NV, Gadgil M (1991). On the role of refugia in promoting prudent use of biological resources. Theor. Popul. Biol. 40:211-229.

Khiewtan RS, Ramakrishnan PS (1989). Socio-cultural studies of the sacred groves at Cherrapunji and adjoining areas in North-Eastern India. Man in India. 69(1):64-71.

Loomis WE, Shull AC (1973). Methods in Plant Physiology. McGraw Hill Book Co. Inc., New York.

Mishra R (1968). Ecology Workbook. Oxford and IBH Publication Co. Calcutta. 244.

Murugan, K, Ramachandran, VS, Swarupanandan, K, Ramesh, M (2008). Socio-cultural perspectives to sacred groves and serpentine worship in Palakkad district, Kerala. Ind. J. Traditional Knowledge. 7(3):463-465.

Nair HG, Gopikumar K, Pramod G, Krishnan K, Kumar KK (1997). Sacred groves in India - vanishing greenery. Curr. Sci. 72:697-698.

Negi CS (2010). The institution of taboo and the local resource management and conservation surrounding sacred natural sites in Uttarakhand, Central Himalaya. Int. J. Biodivers. Conserv. 2(8):186-195

Negi CS (2010). Traditional Culture and Biodiversity Conservation: Examples from Uttarakhand, Central Himalaya. Mt. Res. Dev. 30(3):259-265.

Negi CS (2012). Culture and Biodiversity Conservation: Case studies from Uttarakhand, Central Himalaya. J. Trad. Knowl.11(2):273-278
Pala NA, Gokhale Y, Negi AK, Razvi S, Todaria NP (2012). Local deities in conservation- A conservation practice in Banju Nami Tok sacred grove in Tehri Garhwal, Uttarakhand. Indian Forester 138(8):710-713.
Phillips EA (1959). Methods of vegetation study. Henry Holt and Co. Inc.
Richards LA (1954). Diagnosis and Improvement of Saline and Alkaline soils (ed.) USDA Hand book No. 60.
Saxena KG, Rao KS, Maikhuri RK (1998). Religious and cultural perspective of biodiversity conservation in India: A review. In: Conserving the Sacred for Biodiversity Management (eds. Ramakrishnan, PS, Saxena, KG, Chandrashekara, UM). Oxford and IBH Publishing Co., Ltd. New Delhi
Singh GS, Rao KS, Saxena KG (1998). Eco-cultural analysis of sacred species and ecosystems in Chhakinal Watershed, Himachal Pradesh. In: *Conserving the Sacred for Biodiversity Management* (eds. Ramakrishnan, PS, Saxena, KG, Chandrashekara, UM). Oxford and IBH Publishing Co., Ltd. New Delhi.
Singh H, Husain T, Agnihotri P (2010). Haat Kali sacred grove, Central Himalaya, Uttarakhand. Curr. Sci. 98(3):290.
Singh H, Husain T, Butt FA (2010). Ethno-Medicinal plants and their conservation through sacred groves in Pithoragarh district of central Himalaya, Uttarakhand. GEOBIOS. 37:53-56.
Singh H, Agnihotri P, Pande PC, Husain T (2011). Biodiversity conservation through a traditional beliefs system in Indian Himalaya: A case study from Nakuleshwar sacred grove. Environ. 31:246-253.
Singh H, Agnihotri P, Pande PC, Husain T (2013). Role of traditional knowledge in conserving biodiversity: a case study from Patal Bhuvneshwar sacred grove, Kumaon Himalaya, India. J. Biodivers. Manage. For. 2:1-5.
Singh H, Husain T, Pande PC, Iqbal M (2012). Biodiversity conservation through traditional beliefs system: a case study from Kumaon Himalayas, India. Int. J. Conserv. Sci. 3(1):21-28.
Singh, H, Agnihotri, P and Husain, T (2011). Medicinal plant diversity in newly reported sacred groves of Pithoragarh district, Uttarakhand. Indian Forester. 137(8): 1005-1008.
Sinha B, Maikhuri RK (1998). Conservation through 'Socio-cultural-religious Practice' in Garhwal Himalaya: A case study of Hariyali Sacred Site. In: Conserving the Sacred for Biodiversity Management (eds. Ramakrishnan, PS Saxena, KG, Chandrashekara, UM). Oxford and IBH Publishing Co., Ltd. New Delhi. pp.289-299.
Vogel AI (1961). Quantitative organic analysis including Elementary Instrumental Analysis. Longmans, Green & Co., Ltd., London.
Young HY, Gill RF (1951). Determination of Magnesium of plant tissue with thiozole yellow. Anal. Chem. 23:751-754.

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Conservation status of threatened medicinal plants of Mankial Valley Hindukush Range, Pakistan

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Conservation studies of 45 threatened medicinal plants were carried out for assessment of their conservation status, threats and recommendations growing in Mankial valley Hindukush Range Pakistan. Phytogeographically, the valley is present in the Sino Japanese floristic region and is a hot spot of endemism. A total of 45 taxa belonging to 35 families and 43 genera were collected and evaluated which include 13 (28.88%) vulnerable, 21 (46.66%) endangered and 11 (24.44%) critically endangered species. The number of plants scored with reference to its ecological amplitude and calculated historical distribution were compared with the IUCN criteria for threatened categories Version 3.1. The information regarding 'conservation status', threats and recommendations of the species were collected from the entire valley at different localities by filling questionnaire form 300 respondents including 260 male and 40 female. Mankial valley being naturally gifted with tremendous biodiversity, altitudinal and topographic variations is exposed to increasing human pressure, social injustice and low literacy rate that are destabilizing the biodiversity status especially species survival, habitat and ecosystem. According to the present studies, various parameters are contributing to make the important medicinal plants threatened including over exploitation (75.55%), fuel wood usage (35.55%), habitat loss (35.55%), over grazing (28.88%), deforestation (15.55%), use as timber (4.44%), bark usage (4.44%) and use as furniture (4.44%). Moreover, unsustainable utilization of plant natural resources and unscientific agricultural practices are the main threats to the 'plant biodiversity' growing in the valley. Therefore, studies regarding conservation status, threats and recommendations of threatened medicinal plants of Mankial Valley were proposed.

Key words: Conservation, deforestation, ecosystem, Hindukush Range, Mankial valley, over grazing.

INTRODUCTION

Biodiversity is the variability among living organisms from all sources including inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems (CBD, 2010). There are more than 270,000 vascular plant species supporting diverse kinds of ecosystem (Walter and Gillet, 1998). Due to severe anthropogenic activities, the natural flora is under stress and in many areas it is decreasing. Pakistan is presenting diverse climatic, topographic, altitudinal and phytogeographical variation supporting more than 6000 species with 428 endemics (Ali and Qaiser, 2010). There is a little work carried out on the conservation studies and the available data is deficient. More than 580 plants are reported by Nasir (1991) as threatened. In another study, it has been reported that 709 plants species are threatened and endangered in Pakistan (Chaudhri and Qureshi, 1991). While according to Walter and Gillet (1998), 14 flowering plants are threatened in Pakistan. It has been reported by IUCN (1994) that 20 species are considered to be target species in Pakistan (Shah

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and Baig, 1999). According to the IUCN Red list (2008), 19 plants are threatened in Pakistan. While according to Ali and Qaiser (2010), it has been reported that 21 species are threatened. Intensive studies for the determination of the conservation status, threats and recommendations for various species and fluctuation in its population has never been carried out.

The total flora of District Swat is consisting of 1550 species. It has been estimated that flora of Swat contains 87 threatened plants. According to previous studies, it has been reported that 6.3% taxa in Swat are threatened, in which 1.7% is endangered, 2.7% is vulnerable and 1.6% is rare (Shinwari et al., 2003). Pakistan has nine ecological and five phytogeographical zones and has diverse microhabitat presenting more than 428 endemics. Therefore, species with narrow area of distribution needs more attention. During studies of the tropical and sub tropical sub humid forests up to alpine pastures, 380 species are reported. The area under study is a hot spot in representing some highly medicinal and endemic species to Swat including *Indigofera heterantha* and *Ligesticum stewartii*. The inhabitants are totally dependent upon the plant natural resources growing in the valley for themselves and their cattles. They are interacting directly or indirectly with various plants for keeping their livelihood living. Therefore, studies regarding conservation status of important medicinal plants were carried out by considering various parameters including over exploitation, fuel wood, habitat loss, over grazing, fodder collection, deforestation, timber, bark use and furniture. The present studies show that the current situation in the valley regarding conservation status of some important medicinal plants is not encouraging. Among the total 45 taxa, 13 are vulnerable, 21 are endangered and 11 are critically endangered. Similarly, various parameters have adversely contributed to make certain species vulnerable, endangered and critically endangered. It is observed that over exploitation of medicinal plants is the contributing 75.55%, due to unavailability of alternative energy sources, fuel wood is contributing 35.55%, and thus due to deforestation the habitat loss is contributing 35.55%, while the over grazing is contributing 28.88%.

It is noted during the present study that anthropogenic activities are the main contributor in the unsustainable utilization of the plant natural resources growing in the area. Therefore, studies regarding the conservation status, threats and recommendations for some threatened medicinal plants were planned.

Study area

Mankial Valley is one of the deepest Valleys of the Hindukush Range lies on 35°, 12/ 24// North latitudes and 72°, 32/ 15// East longitudes. It occurs 17 km short of Kalam on east side of the Kalam-Bahrain road. On revenue index map, the area can be traced on Moza's (settlements units) bearing S. No. 18 and 19 (Badai and Mankial) with the land holdings of 20620 and 11658 acres. It is surrounded on the East by Kandya and Duber, on the West by Arayanai and Balakot, on the North by Boyoun and Shahoo and on the South by Ramet and Goornai. Altitude ranges from 1430 m at Mankial to 5726 m at Koohe Shaheen. The area is a mountainous terrain of high glaciated peaks, perennial snowfields, glaciers, falls, pastures, rivers, streams and intact forest. The percentage share by area of mountains, valleys/pastures and rivers is estimated to be 95, 45 and 0.5%, respectively. Pastures are at elevation of above 3000 m and come under alpine regions with severe long winters starting from September to end of March and a very mild summer from June till August. Floral diversity is very rich and economic potential are there. The area represents variety of micro habitats supporting a diversified biodiversity. The research area is present in northern Swat and the vegetation of Northern Swat is classified into cool temperate coniferous (1400 to 2000 m), cold temperate coniferous (2000 to 3000 m), sub alpine (3000 to 4000 m) and alpine zones (>4000 m). Mostly, these zones are away from the monsoon rains; therefore, usual rainfall is very low ranging from 160.6 to 660.4 mm and snowfall from 1.82 to 4.50 m. Sometimes more than 4.50 m snowfall has occasionally been reported.

Maximum temperature is about 10°C or less for 5 to 6 months. When the snow melts during June to August, ephemerals sprout. The temperature is below or 0°C during the period of December to March. Maximum temperature does not exceed beyond 15.9°C during winter recess. Due to short growing season, thick snow cover, intense solar radiation, high wind velocity and low temperature result in the prevalence of a xerophytic habitat for plants in the alpines, turning them dwarf, stunted, hairy and rosette leaves. The crooked and uneven appearance of the plants is resulted due to heavy snowfall in the area.

MATERIALS AND METHODS

Field study trips were arranged to the study area during 2010 to 2012. The information regarding 'conservation status', threats and recommendations was collected from 300 respondents including 260 male 40 female. Semi structured questionnaires and oral interviews methods were adopted after Croom (1983) and Lipp (1989). The informants were asked various questions for obtaining information regarding over exploitation, use as fuel wood, reasons for habitat loss, over grazing, fodder collection, deforestation, use as timber, use of specific bark and use as furniture species. Various areas of the Mankial valley including Mankial, Bhadai, Mianshkon, Ghund Patai, Baik, Jabba, Narra, Kamar Khwah, Chokial Banda, Kafar Banda, Kakora, Char Banda, Tapra, Serai and Mehnain. During the studies observation, GPS data, altitude, locality, and data regarding rate of consumption, uses, preference of use and major threats to the reduction in population size were obtained. The species were evaluated in the field for their distribution, historical background in the valley, use pattern, present frequency and they

were compared with the existing extent and its normal ecological habitat and nich. The information were collected from the local people regarding decline in the population size of these species, factors such as decline in the area of occupancy, extent of occurrence, loss of habitat, actual or potential level of exploitation, effects of introduced taxa and attack of pathogens. Each species was taxonomically described. The distribution and number of plants scored with reference to its ecological amplitude and calculated historical distribution were compared with the IUCN criteria for threatened categories Version 3.1 (IUCN, 2001) for evaluation of the conservation status of each species. The nine categories of IUCN (2001) were reduced to 3 categories. The plant species were then categorized into vulnerable, endangered and critically endangered species (IUCN, 2001).

The plant specimens were collected, documented, preserved and identified with the help of available literature (Nasir and Ali, 1970 to 1989; Ali and Nasir, 1989 to 1991; Ali and Qaiser, 1993 to 2012); and comparing with preserved herbarium specimens. The classification was carried out according to the most recent phylogenetic system of classification (APG) Angiosperm Phylogeny Group (Judd et al., 2002). The voucher specimens were deposited in the Herbarium Centre of Plant Biodiversity (CPB) University of Peshawar.

RESULTS

IUCN criteria for threatened categories Version 3.1 (IUCN, 2001) were used and category A of vulnerable, Categories A of endangered and Category A of critically endangered species was used for evaluation. A taxon is vulnerable when the best available evidence indicates that it meets any of criteria A, and it is therefore considered to be facing a high risk of extinction in the wild. Category-A reduction in population size based on, 1) An observed, estimated, inferred or suspected population size reduction of ≥50% over the last 10 years or three generations, whichever is the longer, where the causes of the reduction are: clearly reversible and understood and ceased, based on (and specifying) any of the following; (a) direct observation, (b) an index of abundance appropriate to the taxon, (c) a decline in area of occupancy, extent of occurrence and/or quality of habitat, (d) actual or potential levels of exploitation and (e) the effects of introduced taxa, hybridization, pathogens, pollutants, competitors or parasites. A taxon is endangered when the best available evidence indicates that it meets any of criteria A, and it is therefore considered to be facing a very high risk of extinction in the wild. Category-A reduction in population size based on, 1) An observed, estimated, inferred or suspected population size reduction of ≥70% over the last 10 years or three generations, whichever is the longer, where the causes of the reduction are clearly reversible and understood and ceased, based on (and specifying) any of the criteria a to e shown under vulnerable category.

A taxon is 'critically endangered' when the best available evidence indicates that it meets any of the criteria A, and it is therefore considered to be facing an extremely high risk of extinction in the wild. Category-A reduction in population size based on, 1) An observed, estimated, inferred or suspected population size reduction of ≥90% over the last 10 years or three generations, whichever is the longer, where the causes of the reduction are clearly reversible and understood and ceased, based on (and specifying) any of the criteria a to e shown under vulnerable category of IUCN (2001). A total of 45 taxa belonging to 35 families and 43 genera were collected and evaluated which include 13 vulnerable, 21 endangered and 11 critically endangered species. The gymnosperms were represented by 4 families, 4 genera and 4 species. The monocots were also represented by 4 families, 4 genera and 4 species. The dicots were represented by 27 families, 35 genera and 37 species. Family Plantaginaceae was the leading family among the dicot represented by 3 species each. While 8 families were presented by 2 species each and 18 families were presented by 1 species each. Based on the present studies and information given by the inhabitants of the area, the decline in population size and extent of occupancy of these species is a continuous practice. It is concluded that 34 (75.55%) species are suffering due to over exploitation, 16 (35.55%) species each are suffering due to fuel wood and habitat loss, 13 (28.88%) species are suffering from over grazing problems, 11 (24.44%) species are suffering due to fodder collection, 7 (15.55%) species are suffering from the deforestation and 2 (4.44%) species each are suffering due to their bark usage, furniture and timber species.

The detail of 'conservation status', threats and recommendations regarding each species has been given as follows:

Family: Cupressaceae
Scientific name: *Juniperus communis* L.
Vernacular name: Gugar
Voucher specimen: Mankial (Chokail Banda-I)
35° 21′ N and 72° 39′ E, 3088 m
Asad and Rashid 648 and 1574 (PUP and PMNH).

Conservation status, threats and recommendations

It is found at higher altitude after tree line in the valley distributed from 2100 to 3000 m. The main threats are its use as fuel wood and over grazing during the summer season by the pastoralists at higher altitude. The use as fuel wood and grazing may be controlled to insure the sustainable utilization and proper exploitation. The population is reduced by more than 30% over the last 10 years and it is falling under the category A (a and c) of vulnerable species.

Family: Ephedraceae
Scientific name: *Ephedra gerardiana* Wall. ex Stapf
Vernacular name: Asmania

Voucher specimen: Mankial (Gaider Jabba-I)
35° 18/ N and 72° 41/ E, 2810 m
Asad and Rashid 1842 (PUP and PMNH).

Conservation status, threats and recommendations

It is found in the valley at an altitude of 2810 m. The main threat is over exploitation due to its high medicinal value, also used as fuel wood. The over exploitation and use as fuel wood must be controlled to insure the sustainable utilization and proper exploitation. The population size is considerably reduced by more than 70% over the last 10 years/three generations. It is falling under the category A (a and c) of endangered species.

Family: Pinaceae
Scientific name: *Cedrus deodara* Roxb. ex Lamb.
Vernacular name: Diyar
Voucher specimen: Mankial (Bhadai Patti-III)
35° 20/ N and 72° 38/ E, 2058 m
Asad and Rashid 1880 (PUP and PMNH).

Conservation status, threats and recommendations

It is distributed in the valley from 1764 to 3000 m within the wild. The main threats are its use as a commercial timber, fuel wood and furniture. Its use as timber, fuel wood and furniture must be banned to insure the sustainable utilization and proper exploitation. The decline in area of occupancy has been occurred and ≥ 50% of the population has been reduced over the last 10 years/three generations. It is falling under category A (a and c) of vulnerable species.

Family: Taxaceae
Scientific name: *Taxus wallichiana* Zucc.
Vernacular name: Banya
Voucher specimen: Mankial (Takki Gaider-I)
35° 18/ N and 72° 39/ E, 2641 m
Asad and Rashid 1876 (PUP and PMNH).

Conservation status, threats and recommendations

It is found in the valley at an altitude of 2641 m. The main threats are its use for fuel wood, medicinal and timber purposes. Its use as fuel wood must be banned, while medicinal and timber use must be strictly checked. It has been observed by the local inhabitants that 80% of population has been reduced over the last 10 years and now it is very rarely distributed in the valley. It is falling under the category A (a and c) of critically endangered species.

Family: Colchicaceae
Scientific name: *Colchicum luteum* Baker
Vernacular name: Zairgulay
Voucher specimen: Mankial (Chokial Banda-II)
35° 22/ N and 72° 40/ E, 3275 m
Asad and Rashid 1891 (PUP and PMNH).

Conservation status, threats and recommendations

Important chemical colchicine is obtained from the underground corm of this species and it is also used as a medicinal plant. The main threat to this plant is over exploitation for medicinal purposes. Its' over exploitation as a high value medicinal plant must be stopped to insure its conservation. It is found in the valley at 3275 m. According to the local inhabitants, the population has decreased up to 75% due to its unique life form and unsustainable collection. It is falling under the category A (a, c and d) of the endangered species.

Family: Convallariaceae
Scientific name: *Polygonatum verticillatum* All.
Vernacular name: Nooryalam
Voucher specimen: Mankial (Gaider Jabba-III)
35° 18/ N and 72° 40/ E, 2820 m
Asad and Rashid 1720 (PUP and PMNH).

Conservation status, threats and recommendations

The underground rhizome of this species has been used for medicinal purposes. The main threat to this plant is its' over exploitation. Its' over exploitation as a high value medicinal plant must be stopped to insure its conservation. More than 70% of the population has been decreased due to its commercial utilization and market value therefore; it is falling under the category A (a, c and d) of the endangered species.

Family: Dioscoreaceae
Scientific name: *Dioscorea deltoidea* Wall. ex Kunth.
Vernacular name: Ratalu/kanees
Voucher specimen: Mankial (Bhadai-III)
35° 19/ N and 72° 38/ E, 1894 m
Asad and Rashid 526 and 1420 (PUP and PMNH).

Conservation status, threats and recommendations

This plant is an indicator of moist temperate forest collected at an altitude of 1894 m. The main threat is over exploitation due to its high medicinal value of tubers and deforestation. The over exploitation must be stopped and deforestation must be banned to control its further population loss. The population has been decreased up to 80%. It is falling under the category A (a, c and d) of the endangered species.

Family: Orchidaceae
Scientific name: *Dactylorhiza hatagirea* (D. Don) Soo.
Vernacular name: Sala
Voucher specimen: Mankial (Jabba-I)
35° 17/ N and 72° 40/ E, 2563 m
Asad and Rashid 446 (PUP and PMNH).

Conservation status, threats and recommendations

This species was collected from very few localities in the valley at an altitude of 3563 m. The main threats are over grazing and habitat loss. Over grazing must be banned to control habitat loss. The population has been decreased by more than 70% and decline in area of occupancy has also occurred. It is falling under the category A (a and c) of the endangered species.

Family: Adoxaceae
Scientific name: *Sambucus wightiana* Wall. ex Wight & Am.
Vernacular name: Mushkiara
Voucher specimen: Mankial (Bhadai-II)
35° 19/ N and 72° 38/ E, 1890 m
Asad and Rashid 6 (PUP and PMNH)

Conservation status, threats and recommendations

This species has been distributed in the valleys beds and collected at an altitude of 1890 m. The main threats are its use as over exploitation, fodder species, over grazing and gradual habitat loss. The over exploitation must be stopped, over grazing and use as a fodder must be banned and habitat loss must be controlled. The decline in area of occupancy has occurred and 50% of population loss has occurred. It is falling under the category A (a, c and d) of the vulnerable species.

Family: Adoxaceae
Scientific name: *Viburnum cotinifolium* D. Don
Vernacular name: Guch
Voucher specimen: Mankial (Mankial village)
35° 19/ N and 72° 37/ E, 1764 m
Asad and Rashid 340 (PUP and PMNH)

Conservation status, threats and recommendations

The fruits of this species are edible and it is also used as fodder and fuel wood. The main threats are its use as fodder and fuel wood. Its' use must be banned to reduce further decrease of its population. Distributed in the valley bottom and mountains slopes and collected from an altitude of 1764 m. The population has decreased by more than 75% and it is falling under the category A (a and c) of the endangered species.

Family: Amaranthaceae
Scientific name: *Chenopodium foliosum* Asch.
Vernacular name: Angooray
Voucher specimen: Mankial (Bhadai-III)
35° 19/ N and 72° 38/ E, 1894 m
Asad and Rashid 741 (PUP and PMNH).

Conservation status, threats and recommendations

This species has been collected at an altitude of 1894 m from very few localities and the decrease in population has been occurred. The main threats are deforestation, habitat loss and over grazing. The deforestation and over grazing must be banned to overcome the habitat loss. About 80% of the population has been decreased. It is falling under the category A (a and c) of the endangered species.

Family: Apiaceae
Scientific name: *Bupleurum nigrescens* E. Nasir
Vernacular name: Not known
Voucher specimen: Mankial (Ghund Patai)
35° 19/ N and 72° 37/ E, 1766 m
Asad and Rashid 559 (PUP and PMNH).

Conservation status, threats and recommendations

This species has been collected from an altitude of 1766 m and it has been observed that the population has been reduced by more than 60%. The main threats are over grazing, habitat loss and deforestation. The deforestation and over grazing must be banned. It is falling under the category A (a and c) of the vulnerable species.

Family: Apiaceae
Scientific name: *Ligusticum stewartii* (Hiroe) E. Nasir
Vernacular name: Not known
Voucher specimen: Mankial (Bhadai-II)
35° 19/ N and 72° 38/ E, 1890 m
Asad and Rashid 688 (PUP and PMNH).

Conservation status, threats and recommendations

This species is endemic to Swat and found in the valley from 1800 to 3000 m having a narrow geographic distribution due to its endemism. The main threats are over grazing, deforestation and habitat loss. The deforestation and over grazing must be banned to control the habitat loss. It is observed that about 85% of the population has been lost. It is falling under the category A (a, c and d) of the critically endangered species.

Family: Asteraceae
Scientific name: *Achillea millefolium* L.

Vernacular name: Jasifa/Jarai
Voucher specimen: Mankial (Serai-III)
35° 21′ N and 72° 40′ E, 2400 m
Asad and Rashid 661 (PUP and PMNH)

Conservation status, threats and recommendations

It is a very important medicinal and honey bee species. The main threat is its' over exploitation as a high value medicinal plant. Its collection and over exploitation must be banned. It has been observed that more than 60% of population has been reduced and decline in area of occupancy has been occurred. It is falling under the category A (a, c and d) of the vulnerable species.

Family: Asteraceae
Scientific name: *Saussurea albescens* (DC.) Sch.
Vernacular name: Azghakay
Voucher specimen: Mankial (Kafar Banda)
35° 18′ N and 72° 39′ E, 2835 m
Asad and Rashid 488 (PUP and PMNH).

Conservation status, threats and recommendations

It is distributed in the valley at higher altitudes and collected at an altitude of 2835 m. It has been observed that 75% of the population of this species has been decreased. The main threats are over grazing, deforestation and habitat loss. Deforestation and over grazing must be banned to control the habitat loss. It is falling under the category A (a, c and d) of the endangered species.

Family: Berberidaceae
Scientific name: *Berberis lycium* Royle
Vernacular name: Zairlargay/korai
Voucher specimen: Mankial (Bhadai Patti-II)
35° 20′ N and 72° 38′ E, 2054 m
Asad and Rashid 1825 (PUP and PMNH).

Conservation status, threats and recommendations

It is distributed scarcely in this Valley and the rhizome has a great medicinal value. It has been observed that more than 80% of the population has been decreased. The main threat is its' over exploitation as a medicinal plant, grazing, use as fuel wood, habitat loss and deforestation. Its' over exploitation must be controlled, its use as a fuel wood and grazing species must be banned. It is falling under the category A (a, c and d) of the endangered species.

Family: Berberidaceae
Scientific name: *Podophyllum hexandrum* Royle.

Vernacular name: Kakora
Voucher specimen: Mankial (Kafar Banda)
35° 18′ N and 72° 39′ E, 2835 m
Asad and Rashid 1873 (PUP and PMNH)

Conservation status, threats and recommendations

It is found in the Valley under the canopy of thick forest, collected at an altitude of 2835 m and the rhizome is highly medicinal. Due to its medicinal value, 85% of population has been decreased and now it is available from very few localities in the Valley. The main threat is over exploitation as a high value medicinal plant. Its' over exploitation must be banned. It is falling under the category A (a and c) of the endangered species.

Family: Betulaceae
Scientific name: *Betula utilis* D. Don
Vernacular name: Birich
Voucher specimen: Mankial (Char Banda)
35° 18′ N and 72° 41′ E, 3200 m
Asad and Rashid 1680 (PUP and PMNH)

Conservation status, threats and recommendations

It is found at the tree line in higher altitude and collected from 3200 m. The main threats are its usage as fuel wood at higher altitude and the bark is used as paper for spiritual curing. This plant is seen at very few places and the population size is reduced by 95%. Its use as fuel wood and paper bark species must be banned. It is falling under the category A (a, c and d) of the critically endangered species.

Family: Caprifoliaceae
Scientific name: *Valeriana jatamansi* Jones
Vernacular name: Mushke bala
Voucher specimen: Mankial (Serai-II)
35° 21′ N and 72° 41′ E, 2620 m
Asad and Rashid 1466 (PUP and PMNH).

Conservation status, threats and recommendations

It is distributed in the fertile beds of the forests and collected at an altitude of 2620 m in the Valley. The main threats are unsustainable collection and over exploitation as a medicinal species. The population has been reduced by 65% and decline in area of occupancy has occurred. Its collection and over exploitation must be banned. It is falling under the category A (a and c) of the vulnerable species.

Family: Elaeagnaceae
Scientific name: *Elaeagnus umbellate* Thunb.

Vernacular name: Ghanumranga
Voucher specimen: Mankial (Ghund Patti)
35° 19/ N and 72° 37/ E, 1766 m
Asad and Rashid 46 (PUP and PMNH).

Conservation status, threats and recommendations

It is found in the valley at lower altitude, found at only three localities in the valley and collected at an altitude of 1766 m. The main threats are its over exploitation as a medicinal species, fuel wood and fodder. The population has been reduced by 97% in the valley. Its' over exploitation as a medicinal species, fuel wood and fodder must be banned. It is falling under the category A (a, c and d) of the critically endangered species.

Family: Euphorbiaceae
Scientific name: *Euphorbia wallichii* Hook.
Vernacular name: Mandano
Voucher specimen: Mankial (Kamar Khwa Banda-I)
35° 22/ N and 72° 46/ E, 3088 m
Asad and Rashid 1038 (PUP and PMNH).

Conservation status, threats and recommendations

It is found sporadically in the Valley at higher altitude and collected from 3088 m. The main threats are its' over exploitation, habitat loss and deforestation. The deforestation and its over exploitation must be banned to control the habitat loss. The population size has been considerably reduced by more than 60%. It is falling under the category A (a and c) of the endangered species.

Family: Fabaceae
Scientific name: *Astragulus candolleanus* Royle ex Benth.
Vernacular name: Ghorjakay
Voucher specimen: Mankial (Bhadai-III)
35° 20/ N and 72° 38/ E, 2058 m
Asad and Rashid 1845 (PUP and PMNH).

Conservation status, threats and recommendations

It is found in the Valley at lower altitude, found at only four localities in the valley and collected at an altitude of 2058 m. The main threats are over exploitation, habitat loss and over grazing. Its collection must be banned, over grazing must be banned to control habitat loss. The population has been reduced by 90% and the area of occupancy is also reduced considerably. It is falling under the category A (a, c and d) of the critically endangered species locally in the valley.

Family: Fabaceae
Scientific name: *Indigofera heterantha* Wall. ex Brandis
Vernacular name: Ghoreja
Voucher specimen: Mankial (Mehnain-II)
35° 19/ N and 72° 38/ E, 1764 m
Asad and Rashid 874 (PUP and PMNH).

Conservation status, threats and recommendations

This species is endemic to Pakistan and distributed in the Valley at lower altitude and collected from 1764 m. The main threats are over exploitation, fodder value and extensive usage as fuel wood. Its collection and usage must be banned. The population size has been considerably reduced by more than 85%. It is falling under the category A (a, c and d) of the endangered species.

Family: Geraniceae
Scientific name: *Geranium wallichianum* D. Don ex Sweet
Vernacular name: Sra zeela
Voucher specimen: Mankial (Bhadai Patti-III)
35° 20/ N and 72° 38/ E, 2058 m
Asad and Rashid 766 (PUP and PMNH).

Conservation status, threats and recommendations

A high value medicinal plant distributed scarcely in the Valley and collected from an altitude of 2058 m. The population has been reduced by more than 75%. The main threats are its' over exploitation and unsustainable collection of the rhizome. Its' over exploitation and unsustainable collection must be banned. It is falling under the category A (a and c) of the endangered species.

Family: Hamamelidaceae
Scientific name: *Parrotiopsis jacquemontiana* (Dcne.) Rehder
Vernacular name: Pastaoonay
Voucher specimen: Mankial (Mehnain-I) 35° 19/ N and 72° 37/ E, 1764 m
Asad and Rashid 1874 (PUP and PMNH).

Conservation status, threats and recommendations

It is distributed at lower altitude along the river banks of north facing slope collected at an altitude of 1764 m. The main threats are its use as fodder and fuel wood species. Its use must be banned. The population has been reduced by more than 80% in the Valley due to over exploitation. It is falling under the category A (a and c) of the endangered species.

Family: Juglandaceae
Scientific name: *Juglans regia* L.

Vernacular name: Ghuzz
Voucher specimen: Mankial (Bhadai-I)
35° 19/ N and 72° 38/ E, 1886 m
Asad and Rashid 2270 (PUP and PMNH)

Conservation status, threats and recommendations

This is sporadically distributed in the Valley and collected at an altitude of 1886 m. The main threats are its use for making furniture and the bark is used locally used as *"Dandasa"*. Its use for making furniture must be banned. It has been observed that more than 60% population has been reduced. It is falling under the category A (a and c) of the vulnerable species.

Family: Lamiaceae
Scientific name: *Thymus linearis* Benth.
Vernacular name: Speerkay
Voucher specimen: Mankial (Serai-II)
35° 21/ N and 72° 41/ E, 2620 m
Asad and Rashid 810 (PUP and PMNH).

Conservation status, threats and recommendations

A high value medicinal and aromatic herb collected in the valley at 2620 m altitude. The main threat is its over exploitation as a high value medicinal herb. Its' over exploitation must be banned. The population has been decreased considerably up to more than 80%. It is falling under the category A (a and c) of the vulnerable species.

Family: Papaveraceae
Scientific name: *Corydalis diphylla* Wall.
Vernacular name: Bhutkis
Voucher specimen: Mankial (Mankial village)
35° 19/ N and 72° 36/ E, 1764 m
Asad and Rashid 353 (PUP and PMNH).

Conservation status, threats and recommendations

It is distributed at very few localities in the valley and collected at an altitude of 1764 m. The main threats are over exploitation as a medicinal plant, over grazing and habitat loss in the valley. Its' over exploitation must be banned and the over grazing must be banned to control the habitat loss. The population has been reduced up to more than 80%. It is falling under the category A (a and c) of the endangered species.

Family: Paeoniaceae
Scientific name: *Paeonia emodi* Wall. ex Royle
Vernacular name: Mamekh
Voucher specimen: Mankial (Kakora)
35° 17/ N and 72° 40/ E, 3035 m
Asad and Rashid 1072 (PUP and PMNH).

Conservation status, threats and recommendations

A high value medicinal plant present at only 8 localities in the valley collected at an altitude of 3035 m on north facing slope. The main threats are its unsustainable collection and over exploitation. Its unsustainable collection and over exploitation must be banned. More than 80% population and area of occupancy has been reduced. It is falling under the category A (a, c and d) of the critically endangered species.

Family: Plantaginaceae
Scientific name: *Plantago depressa* Willd.
Vernacular name: Isphaghol
Voucher specimen: Mankial (Jabba)
35° 17/ N and 72° 40/ E, 2563 m
Asad and Rashid 240 (PUP and PMNH).

Conservation status, threats and recommendations

This plant is distributed at the open places in the valley especially at south facing slope and collected from 2563 m altitude. The main threats are over grazing, over exploitation and habitat loss. Its' over exploitation must be banned and deforestation must be stopped to control the habitat loss. The population has been decreased by more than 60%. It is falling under the category A (a and c) of the vulnerable species.

Family: Plantaginaceae
Scientific name: *Plantago lanceolata* L.
Vernacular name: Warokay isphaghol
Voucher specimen: Mankial (Ghund Patai)
35° 19/ N and 72° 37/ E, 1766 m
Asad and Rashid 58 (PUP and PMNH).

Conservation status, threats and recommendations

It is found at lower altitude in the valley, collected at 1766 m. Found on south facing slopes at open places. The main threats are its' over exploitation, fodder value and habitat loss. Its' over exploitation and use must be banned; measures should be taken to minimize habitat loss. More than 55% of population has been decreased. It is falling under the category A (a and c) of the vulnerable species.

Family: Plantaginaceae
Scientific name: *Plantago major* Willd.
Vernacular name: Ghat isphaghol
Voucher specimen: Mankial (Mehnain-I)
35° 19/ N and 72° 37/ E, 1764 m

Asad and Rashid 175 (PUP and PMNH).

Conservation status, threats and recommendations

It is collected from lower altitude at 1764 m and found at open places on south facing slope. The main threat is its' over exploitation as high value medicinal and fodder value. Its' over exploitation must be banned. More than 70% of the population has been reduced. It is falling under the category A (a and c) of the vulnerable species.

Family: Polygonaceae
Scientific name: *Bistorta amplexicaulis* (D. Don) Green
Vernacular name: Masloon
Voucher specimen: Mankial (Baik-II)
35° 21/ N and 72° 39/ E, 2606 m
Asad and Rashid 787 (PUP and PMNH).

Conservation status, threats and recommendations

This plant is distributed in the valley at few localities and collected at an altitude of 2606 m. The main threats are its' over exploitation, over grazing and habitat loss. Its' over exploitation must be banned and the over grazing must be controlled to overcome the habitat loss. More than 60% population has been reduced. It is falling under the category A (a and c) of the endangered species.

Family: Ranunculaceae
Scientific name: *Aconitum heterophyllum* Wall. ex Royle
Vernacular name: Sarbawalay
Voucher specimen: Mankial (Chokial Banda-II)
35° 22/ N and 72° 40/ E, 3275 m
Asad and Rashid 189 (PUP and PMNH).

Conservation status, threats and recommendations

A very popular medicinal plant, collected at 3275 m, the rhizome is extensively collected for various medicinal purposes. The main threats are its unsustainable utilization and over exploitation. To conserve this species, the unsustainable utilization and over exploitation must be banned. The population has been reduced by more than 85% in the valley. It is falling under the category A (a, c and d) of the critically endangered species.

Family: Ranunculaceae
Scientific name: *Caltha alba* Camb.
Vernacular name: Baringu
Voucher specimen: Mankial (Gaider Jabba-III)
35° 18/ N and 72° 40/ E, 2820 m
Asad and Rashid 64 (PUP and PMNH).

Conservation status, threats and recommendations

Distributed at higher altitude and collected from 2820 m. The main threats are its over exploitation as a medicinal plant and habitat loss. The over exploitation must be banned and habitat loss must be controlled. The population is reduced by 65% in the valley. It is falling under the category A (a and c) of the vulnerable species.

Family: Rhamnaceae
Scientific name: *Ziziphus jujuba* Mill.
Vernacular name: Markhanaray
Voucher specimen: Mankial (Mankial bazar)
35° 19/ N and 72° 36/ E, 1764 m
Asad and Rashid 789 (PUP and PMNH).

Conservation status, threats and recommendations

This plant is collected from only form one locality Mankial Bazar at 1764 m. The main threats are over exploitation as a medicinal species and fuel wood. Its' over exploitation as medicinal and fuel wood species must be banned. About 98% population has been eliminated due to its medicinal, fodder and fuel wood use. It is falling under the category A (a, c and d) of the critically endangered species.

Family: Rosaceae
Scientific name: *Cotoneaster affinis* (Lindl) Schneider
Vernacular name: Mamanra
Voucher specimen: Mankial (Nara-II)
35° 22/ N and 72° 40/ E, 2768 m
Asad and Rashid 557 (PUP and PMNH).

Conservation status, threats and recommendations

It is collected from only 4 localities in the valley at 2768 m; it is observed that 90% population has been decreased and the area of occupancy has been shrinked. The main threats are its exploitation as a medicinal and fuel wood species. Its' over exploitation as medicinal and fuel wood species must be banned. It is falling under the category A (a, c and d) of the critically endangered species.

Family: Rosaceae
Scientific name: *Crataegus songarica* C. Koch
Vernacular name: Gony
Voucher specimen: Mankial (Tapra)
35° 20/ N and 72° 41/ E, 2060 m
Asad and Rashid 562 (PUP and PMNH).

Conservation status, threats and recommendations

It is collected from only two localities in the entire valley

at 2060 m; the main threats includes its over exploitation as a highly medicinal plant, fuel wood and fodder species. The over exploitation as a medicinal, fuel wood and fodder species must be banned. The population has been reduced by 98% and the area of occupancy has considerably decreased. It is falling under the category A (a, c and d) of the critically endangered species.

Family: Salicaceae
Scientific name: *Pouplus alba* L.
Vernacular name: Speerdad
Voucher specimen: Mankial (Bhadai-II)
35° 19′ N and 72° 38′ E, 1890 m
Asad and Rashid 1845 (PUP and PMNH).

Conservation status, threats and recommendations

It is collected from only one locality in Bhadai at 1890 m. The main threats are its over exploitation as medicinal, fuel wood and fodder value. Its' over exploitation must be banned. The area of occupancy has decreased and the population has been reduced by 98% in the valley. It is falling under the category A (a, c and d) of the critically endangered species.

Family: Sapindaceae
Scientific name: *Acer caesium* Wall. ex Brandis
Vernacular name: Chinaray
Voucher specimen: Mankial (Kafar Banda)
35° 18′ N and 72° 39′ E, 2835 m
Asad and Rashid 732 (PUP and PMNH)

Conservation status, threats and recommendations

It is only found at 2 localities on north facing slope and collected at an altitude of 2835 m. The main threats are its over exploitation as medicinal, fodder and fuel wood species. The over exploitation must be banned. The population has been decreased by 97% and the area of occupancy is considerably decreased. It is falling under the category A (a, c and d) of the critically endangered species.

Family: Sapindaceae
Scientific name: *Aesculus indica* (Wall. ex Camb.) Hook.
Vernacular name: Binkhor
Voucher specimen: Mankial (Jabba-I)
35° 17′ N and 72° 40′ E, 2563 m
Asad and Rashid 340 and 540 (PUP and PMNH).

Conservation status, threats and recommendations

The species has been reported from only six localities in the valley and collected from 2563 m. The main threats are over exploitation, fodder and fuel wood species. The over exploitation as a medicinal, fodder and fuel wood species must be banned. The area of occupancy is decreased and the population has been reduced up to 95% in the valley. It is falling under the category A (a, c and d) of the critically endangered species.

Family: Saxifragaceae
Scientific name: *Bergenia ciliata* (Haw.) Sternb.
Vernacular name: Zakhame Hayat
Voucher specimen: Mankial (Serai-II)
35° 21′ N and 72° 41′ E, 2620 m
Asad and Rashid 581 (PUP and PMNH).

Conservation status, threats and recommendations

It is collected at 2620 m from the valley and it is distributed on moist rocky habitat. The main threats are its over exploitation as a medicinal species and habitat loss. The over exploitation must be banned and habitat loss must be controlled. The population has been decreased by 60%. It is falling under the category A (a and c) of the vulnerable species.

Family: Solanaceae
Scientific name: *Solanum nigrum* L.
Vernacular name: Tambako
Voucher specimen: Mankial (Gaider Jabba-I)
35° 18′ N and 72° 41′ E, 2810 m
Asad and Rashid 299 (PUP and PMNH).

Conservation status, threats and recommendations

It is collected from the valley at 2810 m altitude. The main threats are over exploitation, unsustainable collection, habitat loss and over grazing. The over exploitation and unsustainable collection must be banned and habitat loss and over grazing must be controlled. The plant is highly medicinal and 80% population has been reduced. It is falling under the category A (a and c) of the endangered species.

Family: Thymeleaceae
Scientific name: *Daphne mucronata* Royle
Vernacular name: Leughonay
Voucher specimen: Mankial (Mehnain-I)
35° 19′ N and 72° 37′ E, 1764 m
Asad and Rashid 1350 (PUP and PMNH).

Conservation status, threats and recommendations

It is collected from 1764 m in the valley. The main threat is over exploitation as medicinal species. The over exploitation must be banned. About 80% of the

population has been decreased in the valley. It is falling under the category A (a and c) of the endangered species.

Family: Violaceae
Scientific name: *Viola biflora* L.
Vernacular name: Benausha
Voucher specimen: Mankial (Serai-IV)
35° 21/ N and 72° 40/ E, 2405 m
Asad and Rashid 400 (PUP and PMNH).

Conservation status, threats and recommendations

Found in the valley at 2405 m altitude. The main threat is over exploitation as a medicinal species. Its' over exploitation must be banned. About 75% population has been reduced and the area of occupancy is decreased. It is falling under the category A (a and c) of the endangered species.

DISCUSSION

The Mankial valley is naturally gifted with tremendous floral diversity and medicinal plants, therefore, conservation and sustainable utilization of the threatened medicinal flora is mandatory. Certain factors are severely affecting plant natural resources and traditional knowledge associated with them. Haq (2011) carried out conservation studies of 37 critically endangered and endangered species and concluded that 14 species were critically endangered and 23 species are endangered. He opined that over exploitation, loss of habitat, pathogens attack, invasive species and climate change are the main reasons of threatening these species. According to some other workers, extensive grazing, deforestation, forest fragmentation and habitat loss are causing species extinction in the wild. Conservation of threatened medicinal plants in the higher altitude is important because people living in isolated and far flung areas are mainly depended on plants and this may lead to extinction of many medicinally important species. Along with that timber use for mafia, fuel wood, fodder, medicinal uses, cutting, overgrazing, habitat loss and deforestation are the main reasons for elimination of important medicinal plants. The present study was designed to evaluate the threatened medicinal plants in the valley and among the total of 45 species evaluated against IUCN criteria Version 3.1 (2001). It is concluded that 13 (28.88%) species were vulnerable, 21 (46.66%) were endangered and 11 (24.44%) were critically endangered. These studies were based on category A (a to e) as mentioned in Version 3.1 for vulnerable (VU), endangered (EN) and critically threatened (CR) species.

It has been concluded that the main reasons for reduction of population of these important medicinal plants are over exploitation (75.55%), fuel wood (35.55%), habitat loss (35.55%), grazing (28.88%), fodder (24.44%), deforestation (15.55%), timber (4.44%), bark use (4.44%) and furniture (4.44%). Similarly, the unsustainable utilization of plant natural resources, unscientific agricultural practices and terrace farming; these medicinally important species are turning into threatened flora. The people in the valley are completely dependent upon plants and rely upon plants and plants products for their livelihood and curing different ailments. Conservation of these precious plants and the local knowledge associated with them are extremely important for the future planning, sustainable utilization and exploitation of these species. It is important to carry out concrete steps for the conservation of this natural wealth and to protect the genetic erosion of the threatened medicinal plants growing in the valley. Therefore, proper documentation, training of local inhabitants, controlling over exploitation, overgrazing, habitat loss and deforestation will be helping in conserving these resources. Further, *in-situ* conservation in the wild and *ex-situ* conservation in botanical gardens will help in conserving these threatened medicinal plants. For sustainability of such activities, legislation and monitoring will be of immense importance to conserve the threatened medicinal plants growing in the valley.

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REFERENCES

Ali H, Qaiser M (2010). Contribution to the Red List of Pakistan. A case study of *Astragalus gahiratensis* Ali (Fabaceae-Papilionoideae). Pak. J. Bot. 42(3):1523-1528.
Ali SI, Qaiser M (2012). Flora of Pak. Nos. 194-221. Department of Botany, Karachi University, Karachi.
Ali SI, Nasir YJ (1991). Flora of Pak. Nos. 191-193. Department of Botany, Karachi University, Karachi.
Chaudhri M, Qureshi RA (1991). Pakistan Endangered Flora II: A Checklist of Rare and Seriously Threatened Taxa of Pakistan. Pak. Syst. 5(1-2):1-84.
Croom EM (1983). Documenting and evaluating herbal remedies. Economic Botany 37:13-27.
Haq F (2011). Conservation status, threats and recommendations of the critically endangered and endangered species in Nandiar Khuwar catchment District Battagram, Pakistan. Int. J. Bio. Con. 3(2):27-35.
CBD (2010). Global Biodiversity Outlook 3, www.cbd.int/gbo3/?pub=6667&section=6729 cited on May 31, 2013.
IUCN (2008). IUCN Red List of Threatened species, www.iucnredlist.org cited on May 31, 2013.
IUCN Species Survival Commission (2001). IUCN Red List Categories, Version 3.1. Gland, Switzerland, Information Press, Oxford, UK. p.21.
Judd WS, Campbell CS, Kellog EA, Stevens PF, Donoghue MJ (2002). Plant Systematics: A Phylogenetic Approach, 2nd Edition. Sinauer Associates, Inc., Sunderland, MA, USA. pp.1-521.
Lipp FJ (1989). Methods for ethnopharmacological fieldwork. J. Ethnopharmacol. 25:1939-2150.

Nasir E, Ali SI (1989). Flora of Pak. Nos. 1-190. Botany Department, Karachi University, Karachi. Pakistan Agricultural Research Council, Islamabad.
Nasir YJ (1991). Threatened Plants of Pakistan. -In: Ali S. I and Ghaffar A. (eds.) Plant Life of South Asia. -Proceedings of the International Symposium Karachi. pp.229-234.
Shah M, Baig KJ (1999). Threatened Species Listing in PAKISTAN: Status, Issues and Prospects in using IUCN Red List Criteria at National Level: A Regional Consultative Workshop for South and Southeast Asia, IUCN Reg. Biodivers. Program, Asia. pp.70-81.
Shinwari ZK, Khan AA, Nakaike T (2003). Medicinal and other useful Plants of Swat Pakistan. Al-Aziz Communication Peshawar, Pakistan: pp.6-146.
Walter KS, Gillet HJ (1998). IUCN Red list of Threatened Plants. World Conservation Monitoring Center.-IUCN-The World Conservation Union, Gland, Switzerland and Cambridge UK

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Full Length Research Paper

Effect of physico-chemical conditions on the structure and composition of the phytoplankton community in Wular Lake at Lankrishipora, Kashmir

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The high altitude valley of Kashmir abounds in a vast array of freshwater bodies of lotic as well as lentic nature. Amongst these, lakes play an important role in biodiversity of this region. The present study on Wular Lake, Kashmir was undertaken from March, 2007 to February, 2008 to study abundance and distribution of phytoplankton and their correlation with physico-chemical conditions of water. A total of 64 phytoplankton belonging to bacillariophyceae, chlorophyceae, cyanophyceae and euglenophyceae were identified. Phytoplankton in general, showed two growth periods, one in spring and other in winter. A clear dominance of bacillariophyceae over chlorophyceae, cyanophyceae and euglenophyceae was observed throughout the study period. *Navicula* spp. with population density of 118 no./ml was recorded to be the most abundant species amongst bacillariophyceae at the selected site. Chlorophyceae formed the second most dominant group of phytoplankton with *Chlorella* spp. (112 no./ml) as the most abundant species. *Osillatoria* spp. with population density of 119 no./ml was found to be the most abundant amongst cyanophyceae. Euglenophyceae formed the least represented group of phytoplankton with peak population in spring. Statistically, bacillariophyceae and euglenophyceae showed significant negative correlation (r = -0.855 and r = -0.177) with water temperature, while cyanophyceae showed significant positive correlation (r = 0.745). Chlorophyceae showed non-significant positive correlation (r = 0.325) with water temperature at the selected site. Shannon-Wiener diversity index (H') value (1.672) was recorded for cyanophyceae, while the highest evenness (J') value (0.8872) was recorded for euglenophyceae. The value of Berger-Parker index of dominance (0.1859) was highest for bacillariophyceae. Canonical correspondance analysis (CCA) was also carried out to analyze the relationship between the physico-chemical parameters and the phytoplankton. It showed that the most important factors affecting phytoplankton distribution are water temperature, CO_2, chloride, transparency, TDS, alkalinity and dissolved oxygen.

Key words: Biodiversity, freshwater bodies, phytoplankton, Wular Lake.

INTRODUCTION

Lakes form a significant component of inland aquatic resources of India, especially because of their potential for fishery. These lakes also have high conservation values. Despite the ecosystem services they provide and their patrimonial value, their biological diversity has been seldom investigated. Biological diversity or biodiversity is the degree of variation of life forms within a given species, ecosystem, biome or planet. A diversity index

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is a quantitative measure that reflects how many different types (such as species) are there in a dataset, and simultaneously takes into account how evenly the basic entities (such as individuals) are distributed among those types. The value of a diversity index increases both when the number of types increases and when evenness increases. For a given number of types, the value of a diversity index is maximized when all types are equally abundant.

Neither ecological modeling nor effective protection/-management of these ecosystems will be possible without a comprehensive knowledge of the relationships between the biological diversity they host, and their environmental features. Phytoplankton is a key component of the lake biota in general, because it forms the base of the pyramid of productivity. Assuming that any increase in nutrient inputs leads to enhanced primary productivity, phytoplankton may serve as a relevant indicator of the trophic state in Indian lakes, as in other parts of the world (Szeląg-Wasielewska, 2006).

Phytoplankton is the chief primary producer of the aquatic environment which fixes solar energy by process of photosynthesis, assimilating carbon dioxide and water to produce carbohydrates. Phytoplanktonic species have different physiological requirements and thus show diverse responses to physical and chemical parameters such as light, temperature and nutrient regime. Their sensitivity and variations in species composition are often a reflection of significant alteration in ambient condition within an ecosystem (Devassy and Goes, 1988, 1989). Hence before any utilization of lake resources comes into consideration, plankton study is of primary interest. Earlier studies on lake phytoplankton diversity (Pieterse and Van, 1988; Vaulot, 2001; Pongswat et al., 2004; Kendirim, 2001; Millman et al., 2005; Tiwari and Chauhan, 2006; Sridhar et al., 2006; Tas and Gonulol, 2007; Senthilkumar and Sivakumar, 2008; Ganai et al., 2010) revealed the importance of this type of study. Studies showed that most of the phytoplankton was a great deal sensitive to the varying environment condition. That is to say, a negative change in phytoplankton composing the primary productivity affects all living creatures. Therefore, phytoplankton that is composed of the first ring of food chain should be examined taxo-nomically and ecologically.

Very few limnological investigations have been published on the plankton populations of freshwaters of Kashmir Himalaya (Kant and Kachroo, 1971; Kaul et al., 1978; Zutshi et al., 1980; Yousuf et al., 1986; Kaul and Pandit, 1998; Pandit, 1998; Sarwar, 1999; Zutshi and Gopal, 2000; Bhat and Pandit, 2003; Ganai et al., 2010).

In the present study, we focused on the abundance and distribution patterns of phytoplankton and its correlations with the physico-chemical properties of water in Wular Lake, Kashmir, which is the largest freshwater lake of India and Asia (A Ramsar site). The lake has now shrinked down from 20,000 to 2400 hectares due to continued silt deposition brought by its various tributaries, exceptionally high human interference in and around this lake in the form of agriculture, industrialization and urbanization. An area of 11, 853 kanal and 14 malras of land has been illegally encroached from Bandipora side alone. About 92 illegal construction shave been raised over the encroached land (Rashid, 2008). According to the renowned environ-mentalists, Wular has one of the most disturbed eco-system of India which needs attention of Indian government and from the local population being wetland of international importance (under the Ramsar con-vention, 1990). Reclamation of large areas for agricul-ture, large quantities of domestic sewage and agricultural run-off containing the plant nutrients have been the main factors responsible for accelerated aging or eutrophication of the lake. Thus, this situation provides compelling reasons to relate variations in physico-chemical characteristics to biological diversity (here phytoplankton), in order to assess the trophic status of this lake of prime importance. The data obtained would also help in antipollution conservation or con-servation strategies, in addition to formulating the diversity of the lake.

MATERIALS AND METHODS

The present study results from limnological investigation undertaken from March, 2007 to February, 2008 on Wular lake, Kashmir (34°15'-34°28' N Latitude and 74°30' - 74° 45' E longitude). The lake is chiefly fed by River Jhelum which flows in the lake on its South-eastern side near “Banyar”, leaving it at its south-western corner near Sopore.

Collection of samples

The sampling was carried out on a monthly basis from March, 2007 to February, 2008 at Lankrishipora (Map 1: sites I, II and III) between 9-10 a.m. The different physico-chemical parameters such as air and water temperature, dissolved oxygen, total alkalinity, pH, transparency, electrical conductivity, total dissolved solid, free carbon dioxide, chloride, total hardness, calcium, magnesium, nitrate-nitrogen (NO_3-N) and inorganic phosphorus were analyzed following the works of Theroux et al. (1943), Trivedy and Goel (1984) and APHA (1998).

Biological analysis

For phytoplankton analysis, monthly samples (500 ml) were collected from the site in wide mouth plastic bottle. 5 ml of Lugol’s iodine solution was added. After keeping it for 24 h, the supernatant was discarded and 20 ml concentrate was obtained. Quantitative analysis of phytoplankton was done by putting one drop of fixed sample (0.02 ml) on the glass slide and studying it under inverted microscope (Metzer). The results were obtained by recording the number of organisms per ml following Welch (1952). For qualitative analysis, the information given in Dippel (1904), Edmondson (1959) and Needham and Needham (1962) were used.

Three indices were used to obtain the estimation of species

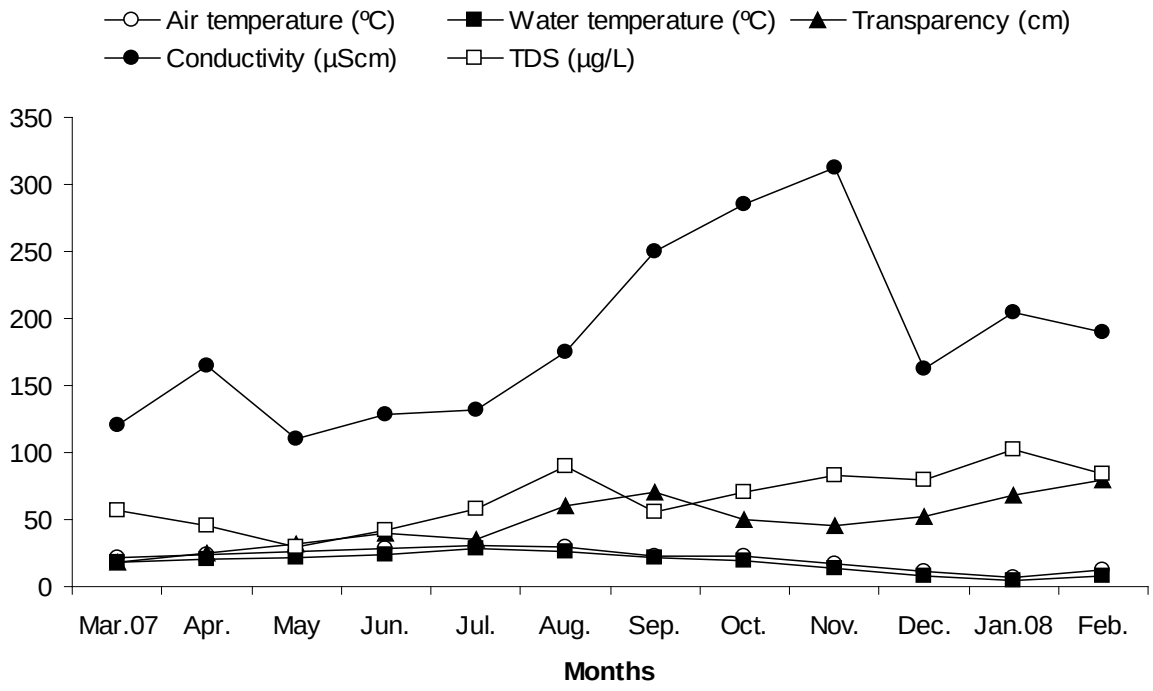


Figure 1. Monthly concentration of air, water, transparency, conductivity and TDS from March, 2007 to February 2008.

diversity, species richness and species evenness:

1. Species diversity was determined following Shannon-Wiener's Index (Ludwig and Reynolds, 1988) using the formula:

$H' = (\Sigma\ pi \ln pi)$

Where, Pi = n/N

N = No. of individual species, N = total density of all organisms.

2. Species dominance was calculated using Berger-Parker's Index (Berger and Parker, 1970) formula:

D= Nmax/ N

Where Nmax = density of most dominant species, N = density of all the species.

3. Evenness was calculated using the formula:

E1 = H1/ ln S (Pielou, 1975)

Where, H1 = species diversity; S = species richness.

Ordination analysis of phytoplanktonic community

The Version 2 of PAST Software Design was used (window Oyvind Hammer & D.A.T. Harper) for performing multivariate analysis of ecological data by canonical correspondence analysis (CCA) conducted to detect patterns of distribution of phytoplankton groups related to physical and chemical parameters. The results contain the environmental variables plotted as arrows emanating from the center of the graph along with points for the samples and phytoplankton groups. The arrows representing the environmental variables indicate the direction of maximum change of that variable across the diagram. The position of the species points indicates the environmental preference of the species.

RESULTS AND DISCUSSION

Abiotic parameters

Monthly variations in various physico-chemical parameters of the lake at the selected site are given in the Figures 1 to 4. The lake is influenced by a wide array of physico-chemical factors. Fluctuations of these factors affect the biota of the lake. Air temperature ranged from 7°C (January, 2008) to 31°C (July, 2007) whereas water temperature ranged between 5°C (January, 2008) and 28°C (July, 2007).

Lower water temperature was due to cold, low ambient temperature and shorter photoperiods. Water temperature influences aquatic life through metabolic rates and concentration of dissolved gases like carbon dioxide, oxygen and chemical solute. For transparency, values ranged between 0.45 (November, 2007) and 1.70 m (March, 2007).

Transparency remained high during winter which can be related to lower rate of decomposition and less human activities during winter. Transparency showed positive significant correlation with TDS (r = 0.656). Concentration of

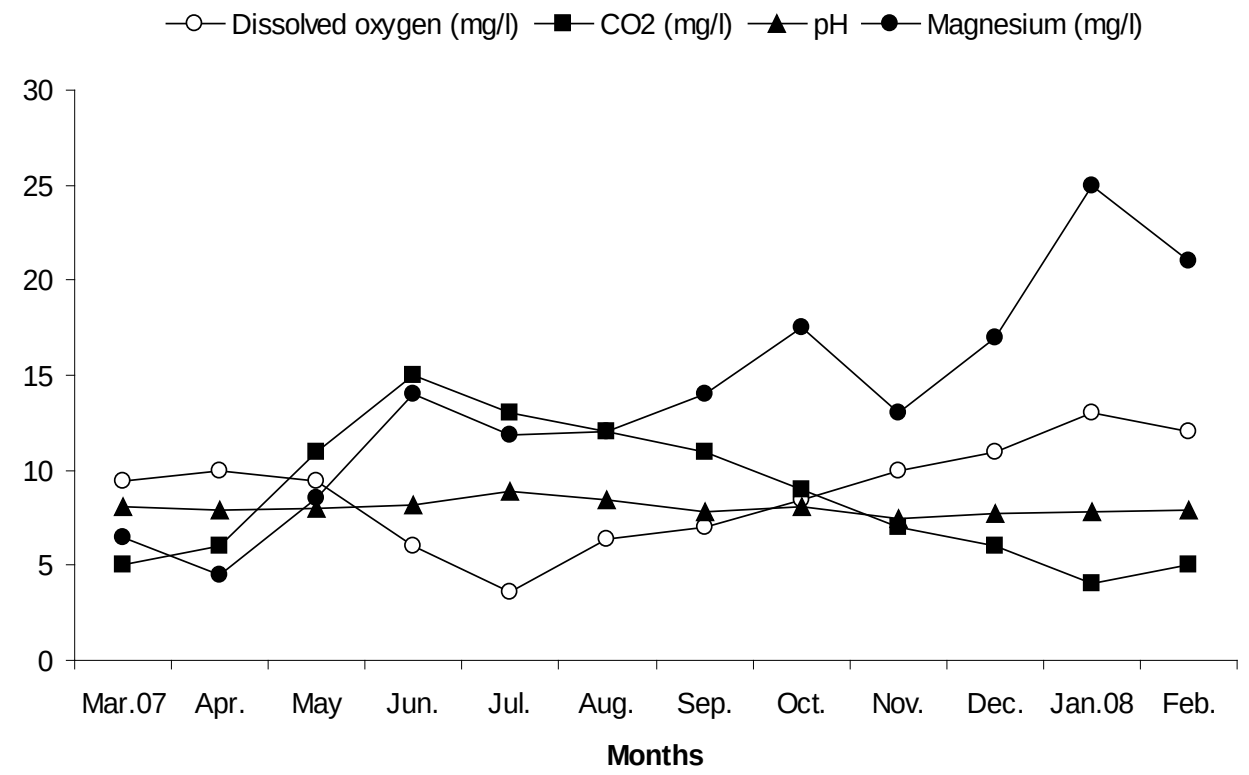


Figure 2. Monthly concentration of dissolved oxygen, CO_2, pH and magnesium from March, 2007 to February 2008.

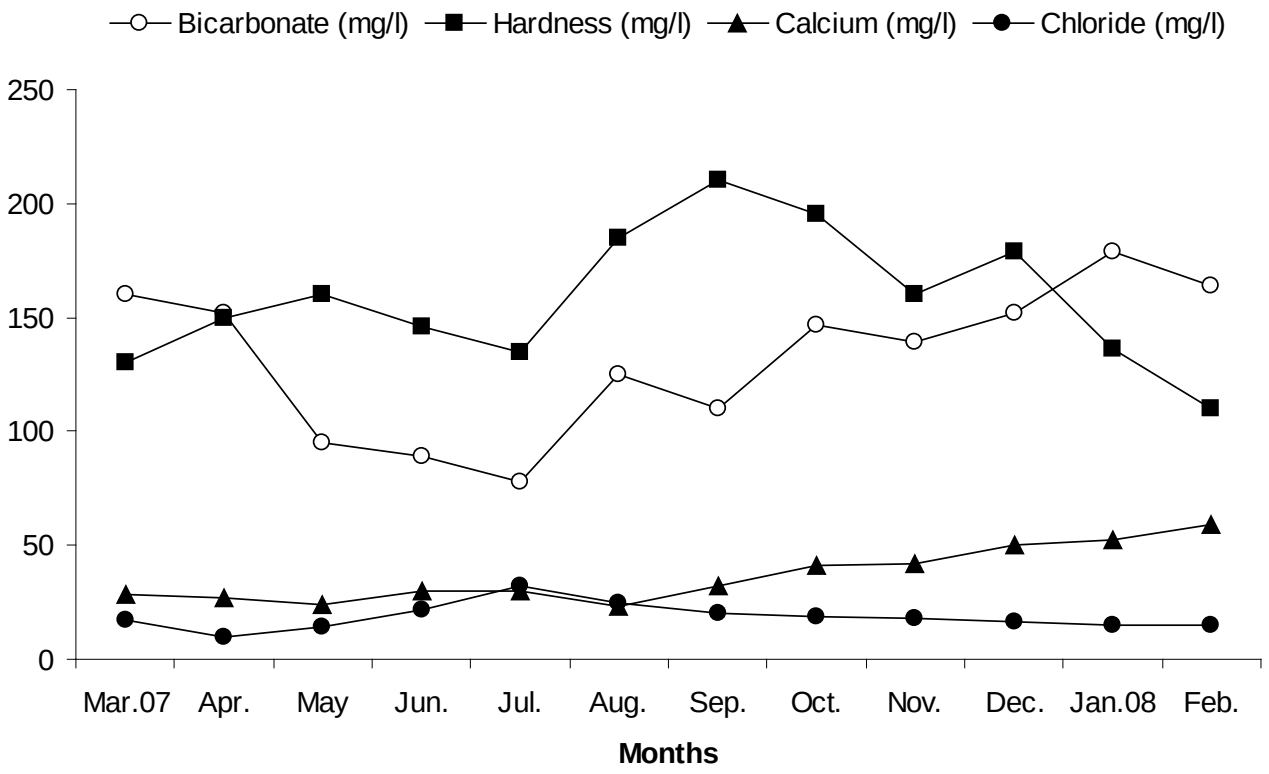


Figure 3. Monthly concentration of bicarbonate, hardness, calcium and chloride from March, 2007 to February 2008.

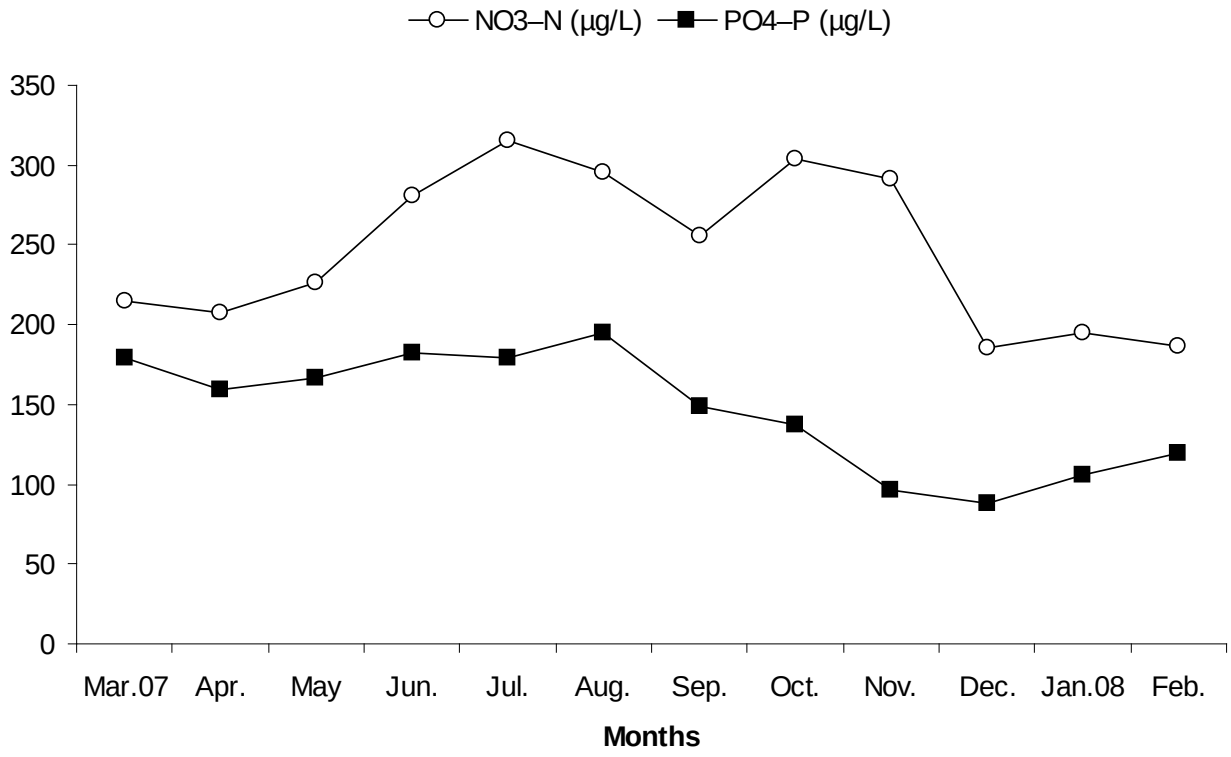


Figure 4. Monthly concentration of NO_3-N and PO_4-P from March, 2007 to February 2008.

conductivity varied from 110.0 (May, 2007) to 312.0 mg/l (October, 2007). Low values of electrical conductivity were recorded in spring and summer which could be related to locking of nutrients during seasons. Concentration of TDS varied from 42 (August, 2007) to 162.0 mg/l (February, 2008). Lower values of TDS were recorded during summer which is due to their utilization by plankton and other aquatic plants. Dissolved oxygen plays a crucial role in regulating the aquatic life. With regard to the dissolved oxygen variable, values fluctuated between 3.60 (July, 2007) and 13.0 mg/l (January, 2008). The higher values recorded for dissolved oxygen in solution in the winter period can be attributed to lower rate of decomposition, low respiratory demand and the capacity of water to hold high oxygen concentration at low temperature. Dissolved oxygen showed significant negative correlation with water temperature (r = -0.904) and significant positive cor-relation with pH (r = 0.811). For carbon dioxide, values fluctuated between 4.0 (January, 2008) and 15.0 mg/l (June, 2007). High values of free CO_2 were recorded during summer which can be attributed to higher decomposition rate and enhanced respiratory activities of plants and animals. pH remained on alkaline side throughout the period of investigation and ranged between 7.5 (November, 2007) and 8.9 (July, 2009). pH between 6.5 and 9.0 can support good fishery as such lake water is favorable from fisheries point of view. Statistically, pH showed positive significant correlation with alkalinity (r = 0.926). Alkalinity was of bicarbonate type only and varied from 78 (July, 2007) to 179 mg/l (January, 2008). Decline in conductivity values in spring and summer could be related to increase in phytoplankton and macrophyte population leading to increase in the uptake of nutrients. Hardness concentration in present study ranged between 110 (February, 2008) and 210 mg/l (September, 2007). High values of total hardness were recorded during autumn which can be related to inflowing sewage and high anthropogenic activities in and around the lake. Calcium values fluctuated between 23.0 (August, 2007) and 59.0 mg/l (February, 2008) whereas values of magnesium varied from minimum of 4.50 (April.2007) to maximum of 25.0 mg/l (January, 2008). Decline in values of calcium and magnesium were recorded in spring and summer which might be related to its active utilization by plankton and their uptake by aquatic vegetation and sedimentation. Values of chloride concentration ranged between 10 and 32.5 mg/l. The higher values of chloride were recorded in summer which is attributed to presence of large amount of organic matter of allocthonus and autochthonus origin and its concentration due to high ambient temperature.

According to Mc Caul and Crossland (1974), the most important factor responsible for eutrophication of fresh water lakes is PO_4-P and NO_3-N. In the present study, NO_3-N ranged between 186 (December, 2007) and 315

µg/l (July, 2007). High values were recorded during summer which could be attributed to decomposition of organic matter at higher temperature and entry of nitrogen fertilizers from catchment areas. Statistically, NO_3-N showed significant negative correlation with phytoplankton at the selected site. PO_4-P varied from 88 (December, 2007) to 195 µg/l (August, 2007). High values of PO_4-P were recorded in summer which can be related to decomposition of organic matter at high temperature, and decrease in water level leading to increase in concentration. Statistically, PO_4-P showed negative and non significant correlation with phytoplankton (r = -0.057).

Phytoplankton composition

Phytoplankton communities do not respond only to natural changes into the lakes, but may also present variations as a consequence of human interventions affecting the water body, either directly or through activities carried on in the basin as a whole. These influences affecting the lakes result in modifications to the structure and composition of the phytoplankton, which may take the form of changes in the taxa of which the algal associations are composed, in the abundance of each taxa, the richness and diversity of the associations, and other community parameters. Finally, due to the interdependence existing between the different organisms of which systems are composed, these variations in the phytoplankton communities translate to changes in the trophic chain and the productivity of the lakes. The biological spectrum of the lentic fresh water bodies are multidimensional where phytoplankton is useful in biomonitoring the ecological disturbance caused by a number of physico-chemical factors, sewage pollutants and other anthrogenic factors.

Limnological charac-teristics of Wular Lake in different seasons are related to the hydrological conditions of the River Jhelum and other inflowing streams also. This influence is reflected in the physico-chemical characteristics and the plankton communities of water in different seasons in present study. Seasonal variations in phytoplankton diversity were very pronounced.

This study however, documented very less number of phytoplankton when compared with the past studies as many of the species might have disappeared due to the heavy pollution. A total of 64 phytoplankton species (Table 1), belonging to four speciose groups, documented in this study indicate diverse nature of phytoplankton in general as well as that of Wular Lake in particular, of which 33 belong to bacillariophyceae, 21 to chlorophyceae, 8 to cyanophyceae and 2 to euglenaphyceae. The order of dominance was: Bacillariophyceae > Chlophyceae > Myxophyceae > Euglenophyceae.

The presence and absence of phytoplankton at the selected site is given in Table 1. Bacillariophyceae (33 species) constituted the most dominate speciose group of phytoplankton. The monthly percent contribution of bacillariophyceae in terms of population density at the selected site is given in Figure 5. Monthly percent contribution of bacillariophyceae varied from minimum of 7.1% (October, 2007) to a maximum of 82.9% (September, 2007). The population density of bacillariophyceae varied from a minimum of 16 no./ml in the month of July, 2007 to a maximum of 394 no./ml in the month of January, 2008 (Figure 7). The most abundant species in terms of population density were *Amphora* sp., *Cyclotella* spp., *Epithemia* spp., *Fragilaria* spp., *Longissima elongatum*, *Meriodion* spp. *Navicula* spp. and *Nitzchia* sp. *Navicula* spp. was recorded to be the most dominant species amongst the bacillariophyceae.

With respect to the phytoplankton communities, bacillariophyceae or diatom group remained dominant in the lake during winter in the present investigation which could be attributed to the fact that they are able to grow under the condition of weak light and low temperature which are less suitable for other algae and low concentration of nutrients (NO_3-N and PO_4-P) in the winter (December- January). The findings are in conformity with the findings of Munawar (1974) and Ganai et al. (2010). Statistically, bacillariophyceae showed negative correlation (r = -0.855) with water temperature at the selected site.

Chlorophyceae (21species) formed the second most speciose group at the selected site. The monthly percent contribution of chlorophyceae in terms of population density amongst different phytoplankton groups at the selected site is given in Figure 5. Monthly percent contribution of chlorophyceae varied from minimum of 7.4% (February, 2008) to a maximum of 64.8 (April, 2007). The number of chlorophyceae varied from a minimum of 21 no./ml in June, 2007 to a maximum of 326 no./ml in the month of May, 2007 at the selected site (Figure 7). The most abundant species in terms of population density were *Chlorella* spp., *Pediastrum* spp., *Spirogyra* spp. and *Volvox* spp.). Amongst chlorophyceae, *Chlorella* spp. was found to be the most dominant species at the selected site.

Chlorophyceae in present study depicted unimodal spring peak which could be related to increasing temperature in addition to increased phosphorus and nitrate concentration. Kant and Kachroo (1977) and Ganai et al. (2010) also reported a single chlorophycean peak in summer in Kashmir Himalayan lakes. Statistically, chlorophyceae depicted positive but non-significant correlation (r = 0.325) with water temperature at the selected site.

Cyanophyceae formed the third most speciose group of phytoplankton (8) at the selected site. Cyanophyceae are more efficient in utilizing CO_2 at high pH level and low light availability and thus, their abundance indicate the

Table 1. Monthly variations in population density (no./m)of phytoplankton in Wular Lake at Lankrishipora, Kashmir from March 2007 to February 2008 (+ = presence; - = absence).

Month / Genera	Mar07	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan08	Feb
Bacillariophyceae	-	-	-	-	-	-	-	-	-	-	-	-
Achananthes lanceolata	-	-	-	-	-	-	-	-	+	+	+	-
Amphora spp.	+	-	-	-	-	-	-	-	+	-	+	+
Amphora ovalis	-	-	-	-	-	-	-	-	-	-	-	-
Asterionella formosa	-	-	-	-	-	-	+	-	-	-	+	+
Ceratoneis arcus	-	-	-	-	-	-	-	-	-	-	+	+
Cyclotella spp.	+	+	-	-	-	-	-	-	+	+	+	+
Cymbella cistula	-	+	+	-	-	-	-	-	-	+	+	+
Closteriopsis longissima	+	+	-	-	-	-	+	-	-	+	+	+
Cocconeis placentula	-	-	-	-	-	-	-	-	-	-	+	+
Diatoma spp.	+	+	-	-	-	-	-	-	-	+	+	+
Diatoma vulgare	-	-	+	-	-	-	-	-	-	+	+	+
Epithemia spp.	+	+	-	-	+	+	-	-	-	+	+	+
Eunotia spp.	-	+	-	-	-	-	-	+	-	-	+	+
Frustulia spp.	-	+	+	-	-	-	-	-	-	+	+	+
Fragilaria spp.	-	-	+	-	-	-	-	-	-	+	+	+
Fragilaria capucina	-	-	-	-	-	-	-	-	-	-	-	-
Gomphonema spp.	+	-	-	-	+	+	-	-	-	+	+	+
Gomphonema gracile	-	-	-	-	-	-	-	-	-	-	+	+
Gomphonema germinatum	-	-	+	-	+	-	-	-	-	-	+	-
Longissima elongatum	-	+	+	-	-	-	-	-	-	+	+	+
Melosira spp.	-	-	-	-	-	-	-	+	-	-	+	+
Meridion circulare	-	+	+	-	-	-	-	-	-	-	-	-
Meridion spp.	+	-	-	-	-	-	-	-	+	+	+	+
Navicula spp.	+	+	+	-	-	+	+	+	-	+	+	+
Navicula americana	+	+	+	-	-	-	-	-	-	-	+	+
Nitzchia spp.	+	+	+	-	-	-	-	+	-	+	+	+
Nitzchia vermicularis	-	-	-	-	-	-	-	-	+	+	+	-
Stauroneis spp.	+	+	+	-	-	+	-	-	-	+	+	+
Surirella spp.	+	-	-	-	-	-	-	-	-	-	+	+
Synedra ascus	-	-	-	-	-	+	-	+	-	-	+	+
Synedra radiana	+	-	-	-	-	-	-	-	-	-	+	+
Synedra ulna	+	-	-	-	-	-	+	-	-	+	+	-
Tabellaria spp.	-	-	+	-	-	-	-	-	-	+	+	+
Chlorophyceae												
Actinastrum spp.	+	+	+	-	-	-	+	-	-	-	-	-
Ankistrodesmus spp.	+	+	+	-	-	-	+	-	+	+	-	-
Ankistrodesmus falcatus	-	+	+	-	-	-	-	+	-	-	-	-
Chlorella spp.	+	+	+	-	+	-	+	+	-	+	+	+
Coelastrium sphaericum	+	+	+	-	-	-	-	+	-	-	-	-
Chlamydomonas	-	+	+	-	-	+	-	-	+	+	-	-
Cosmarium spp.	+	+	+	-	+	+	+	-	-	-	-	-
Closterium spp.	+	+	+	-	-	-	+	-	+	+	-	-
Closterium leibleinii	+	+	+	-	-	-	-	-	-	-	+	-
Closterium setaceum	+	+	-	-	+	+	-	-	-	-	-	-
Eudorina spp.	+	+	+	-	-	+	-	-	-	-	-	-
Oedogonium spp.	-	+	+	-	+	+	-	-	-	-	-	-
Pediastrum spp.	+	+	+	-	-	+	+	+	+	-	-	-

Table 1 Contd.

Scenedesmus spp.	-	+	+	+	+	-	-	-	-	-	-	-
Selenastrum spp.	+	+	+	-	-	-	+	-	-	+	+	+
Selenastrum gracile	+	+	+	+	-	-	+	-	-	-	-	-
Spirogyra spp.	+	+	+	-	+	-	-	+	+	-	+	+
Tetraspora spp.	+	+	+	-	+	-	-	-	-	-	-	-
Ulothrix zonata	+	+	+	+	-	-	-	-	-	+	+	-
Volvox spp.	+	+	+	-	+	-	-	+	-	-	+	+
Zygnena spp.	+	+	-	-	+	+	+	-	-	+	-	-
Cyanophyceae												
Anabaena spp.	-	+	+	+	+	+	+	+	-	-	+	+
Lyngbya spp.	-	-	-		+	+	+	+	-	-	-	+
Microcystis spp.	+	-	-	+	+	+	-	-	-	-	+	+
Merismopedia spp.	-	+	-	+	+	+	-	-	+	-	-	-
Nostoc spp.	-	-	+	+	+	-	-	-	+	-	+	+
Oscillatoria spp.	-	+	+	+	+	+	+	+	+	-	-	+
Phormedium spp.	-	-	+	+	+	-	-	+	-	-	+	+
Rivularia spp.	+	+	-	-	+	+	-	+	+	-	+	+
Euglenophyceae												
Euglena ascus	+	+	+	-	-	-	-	-	-	+	+	+
Phacus spp.	+	+	+	-	-	-	-	-	-	-	+	+

eutrophic nature of water body (Lin, 1972).

The monthly percent contribution of cyanophyceae in terms of population density amongst different phyto-plankton groups is given in Figure 5. Monthly percent contribution of cyanophyceae varied from minimum of 0.0% (December, 2007) to a maximum of 82.5% (June, 2007). The population density of cyanophyceae varied from minimum of 6 no./ml in the month of march 2007 to a maximum of a 110 no./ml in July, 2007 (Figure 7). The most abundant species in terms of population densities were *Anabaena* spp., *Lyngbya* spp.) and *Oscillatoria* spp. The presence of *Merismopedia* and *Oscillatoria* spp. in the present study indicate the eutrophic nature of water body. Statistically, cyanophyceae showed positive correlation (r = 0.745) with water temperature at the selected site.

Blue-green algal (cyanophyceae) abundance was found to be the major portion in the phytoplankton community during autumn at the selected site. The reasons behind this result may be the moderate temperature, alkaline pH, low water volume and bright sunlight which created favourable condition for better propagation of this group of phytoplankton.

Euglenoid algae form a relatively large and diverse group but few species are truly planktonic (Wetzel, 1983). They are facultative heterotrophs and generally abundant in waters rich in organic matter. Euglenophyceae in the present study formed the least represented group of phytoplankton (2 species), which were represented by only two genera, *Euglena ascus* and *Phacus* spp. The monthly percent contribution of euglenophyceae in terms of population density amongst phytoplankton is given in Figure 5. Monthly percent contribution of euglenophyceae varied from minimum of 0.0% (June, July, August, September, October and November, 2007) to a maximum of 7.2 (April, 2007). *E. ascus* with population density of 72 no./ml was found to be the most abundant species amongst two genera. The number of euglenophyceae were found to vary from a minimum of 6 no./ml in December, 2007 to a maximum of 36 no./ml in May, 2007 (Figure 7). Statistically, euglenophyceae showed negative correlation (r = -0.535) with water temperature at the selected site of the lake.

With respect to the phytoplankton communities, euglenophyceae in the present study started emerging in winter and showed their higher proportion in the phytoplankton community in spring, 2007. Increasing temperature and accumulation of organic loads from surface run-off, autothonous and allocthonus organic load, sewage and clear sun-shine may be the reasons for the dominance of euglenophyceae in spring.

Unni (1993) who analyzed the data from a large number of studies, observed that the species diversity (50 to 100 species) of hypertrophic reservoirs is higher

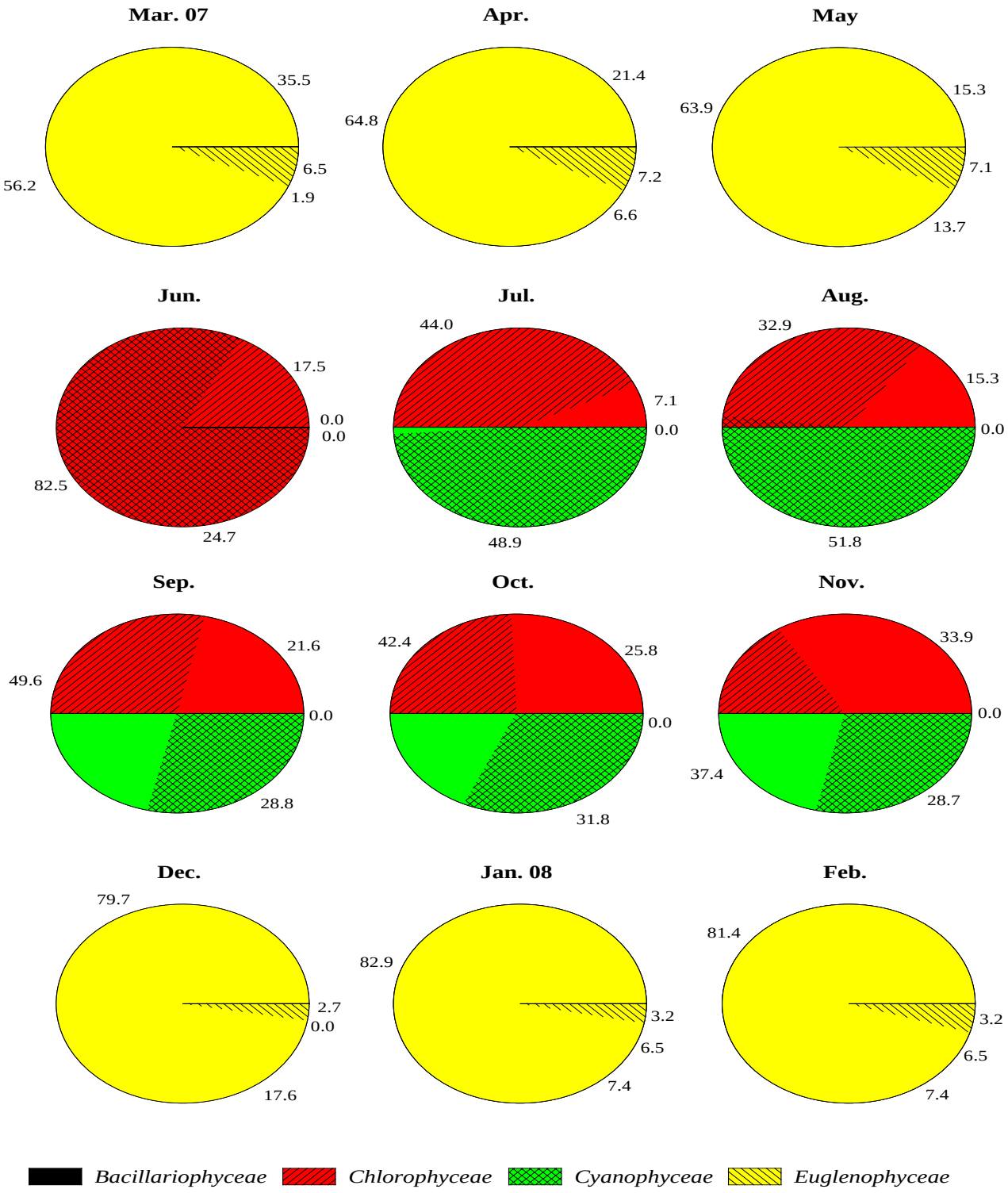


Figure 5. Monthly percent contribution of different phytoplankton groups in Wular Lake at Lankrishipora, Kashmir.

(and similar to that of tropical lakes in Southeast Asia) than that of the oligotrophic reservoirs (about 15 species). In a short term comparative study of nine south Indian reservoirs (between 9_270 and 11_480 N and 240 to 2300 maltitude), Uhlmann et al. (1982) also observed surprisingly large number of phytoplankton taxa (mostly

Table 2. Variation of diversity indices of different groups of phytoplankton in Wular lake, Kashmir during March, 2007 to February, 2008.

Group	Shannon_H	Evenness_e^H/S	Dominance_D
Bacillariophyceae	1.945	0.6355	0.1859
Chlorophyceae	2.094	0.6763	0.1616
Cyanophyceae	2.206	0.8251	0.1252
Euglenophyceae	1.672	0.8872	0.2032

green and blue-green algae) even in waters deficient in orthophosphates.

A number of workers have reported many algal species as indicators of water quality (Naik et al., 2005; Nandan and Aher, 2005; Zargar and Ghosh, 2006). Zargar and Ghosh (2006) in a study on Kadra reserviour of Karnataka listed several algal forms belonging to Chlorophyceae, Cyanophyceae, Euglenophyceae and Bacillariophyceae as indicators of water pollution. The Wular Lake is subjected to pollution due to addition of industrial effluents, fertilizers from agricultural lands and domestic sewage. Progressive enrichment of water with nutrients leads to mass production of algae, which in turn leads to the increased productivity and other undesirable biotic changes.

Nandan and Aher (2005) has shown the algal genera, Euglena, *Oscillatoria, Scenedesmus, Navicula, Nitzschia* and *Microcystis* which are the species found in organically polluted waters. Palmer (1969) has shown that genera like *Schenedesmus, Oscillatoria, Microcystis, Navicula, Nitzschia* and *Euglena* are the species found in organically polluted waters supported by More (1997). Similar genera were recorded in the present investigation thereby showing that lake is organically polluted. The epilethic and epiphytic algae are excellent indicators of water pollution (Round, 1965). In the present study, occurrence of *Oscillatoria, Phormidium, Lyngbya* and *Ulothrix* as epilethic algae and certain diatoms like *Gomphonema, Cymbella* and *Navicula* as epiphytic were recorded. Thus, algal communities can be used as indicators of pollution for assessing the water quality of this lake of international importance. The algae like *Microcystis aeruginosa* was used as the best single indicator of pollution and it was associated with the highest degree of civic pollution (Nandan and Aher, 2005). In the present study, *Microcystis* was also recorded in the selected site. The occurrence of *Oscillatoria* in the present study indicates pollutants of biological origin which agreed with the observations of Gadag et al. (2005).

It is reported that excessive growth of certain algal genera, viz., *Scenedesmus*, *Anabaena, Oscillatoria* and *Melosira* indicate nutrient enrichment of aquatic bodies (Kumar, 1990; Zargar and Ghosh, 2006).The present study on Wular Lake also support the findings. Studies show that the dominant phytoplankton and their seasonality are highly variable in different water bodies according to their nutrient status, age, morphometry and other locational factors (Gopal and Zutshi, 1998).

The study revealed that the water quality parameters such as temperature, pH, nitrate and phosphate play a very important role in altering the phytoplankton distribution. The human anthropogenic are the main causative agents in the increase of the nutrients in this lake of international importance.

Diversity indices

An important application of diversity indices in phytoplankton studies is their usage in the assessment of pollution. Species diversity is a function of species richness and evenness with which the individuals are distributed in these species (Margalef, 1958). Highest values of Shannon-Wiener Index were recorded for cyanophycece (2.206, Table2) and lowest for euglenophyceae (1.672, Table 2). For Indian lakes, the Shannon-Weiner diversity index proposed as diversity index greater than (> 4) is clean water; between 3-4 is mildly polluted water and less than 2 (< 2) is heavily polluted water (Shekhar et al., 2008). Since, the Shannon-Weiner diversity index in the present study ranged between 1.672 - 2.206 in the selected water body, therefore, this water body oscillates between moderately polluted to highly polluted. Maximum evenness values were recorded for euglenophyceae (0.8872, Table 2), being less speciose and evenly distributed and minimum for bacillariophyceae (0.6355). The present results indicate consistently higher phytoplankton even-ness with broadly identical values (Table 2).This reflects equitable abundance of various species throughout the study period. Highest values for species dominance were recorded for eulenophyceae (0.2032) and lowest for cyanophyceae (0.1252, Table 2). Phytoplankton groups indicate lower dominance with concurrent values.

Canonical correspondence analysis (CCA)

For CCA ordination, the group environmental bi-plot (Figure 6) shows the relations of the groups and

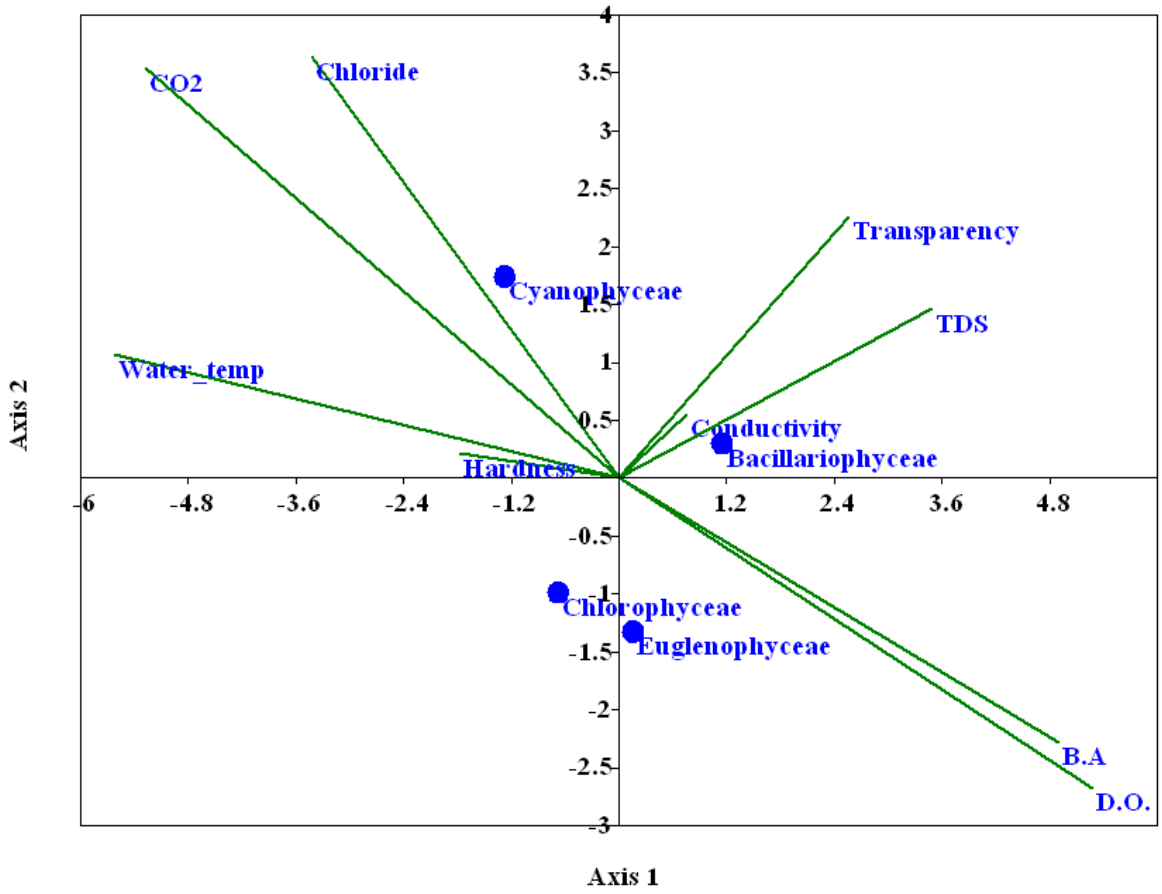


Figure 6. Canonical correspondence analysis (CCA) ordination diagram with 4 phytoplankton groups (Bacilariophycea, Chlorophycea, Euglenophyceas and Cyanophycea) and 9 quantitative environmental variables (lines). The environmental factors are: D.O, water temperaature, bicarbonate alkalinity, hardness, transparency, TDS, choloride, CO_2 and conductivity.

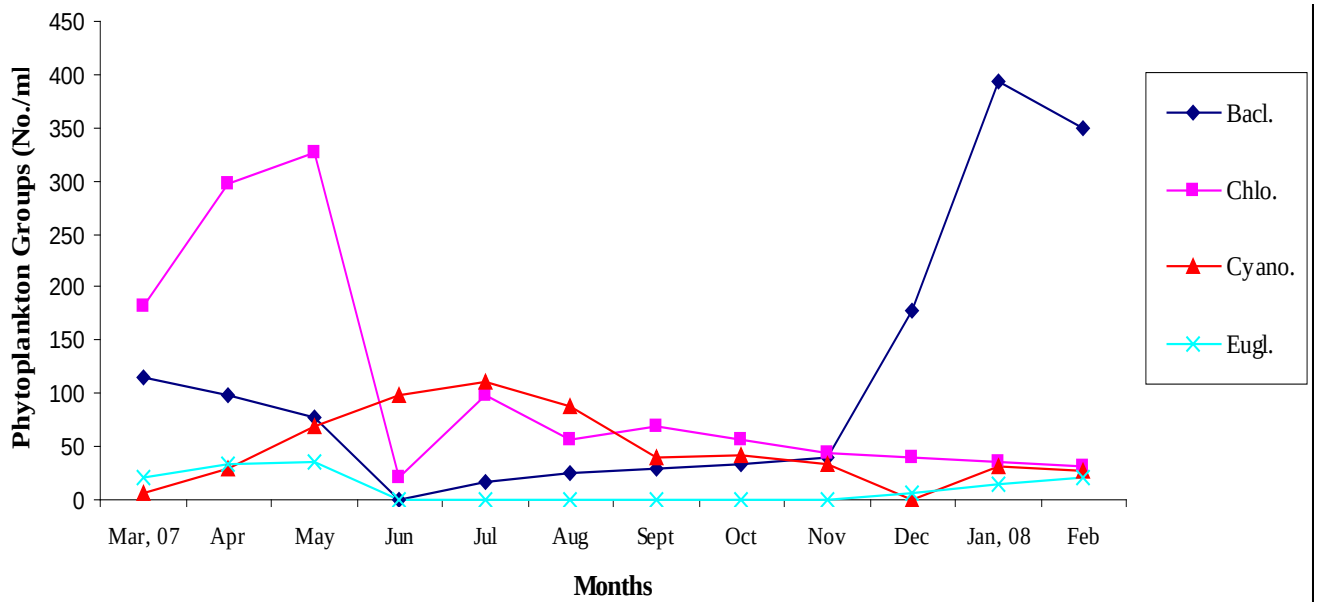
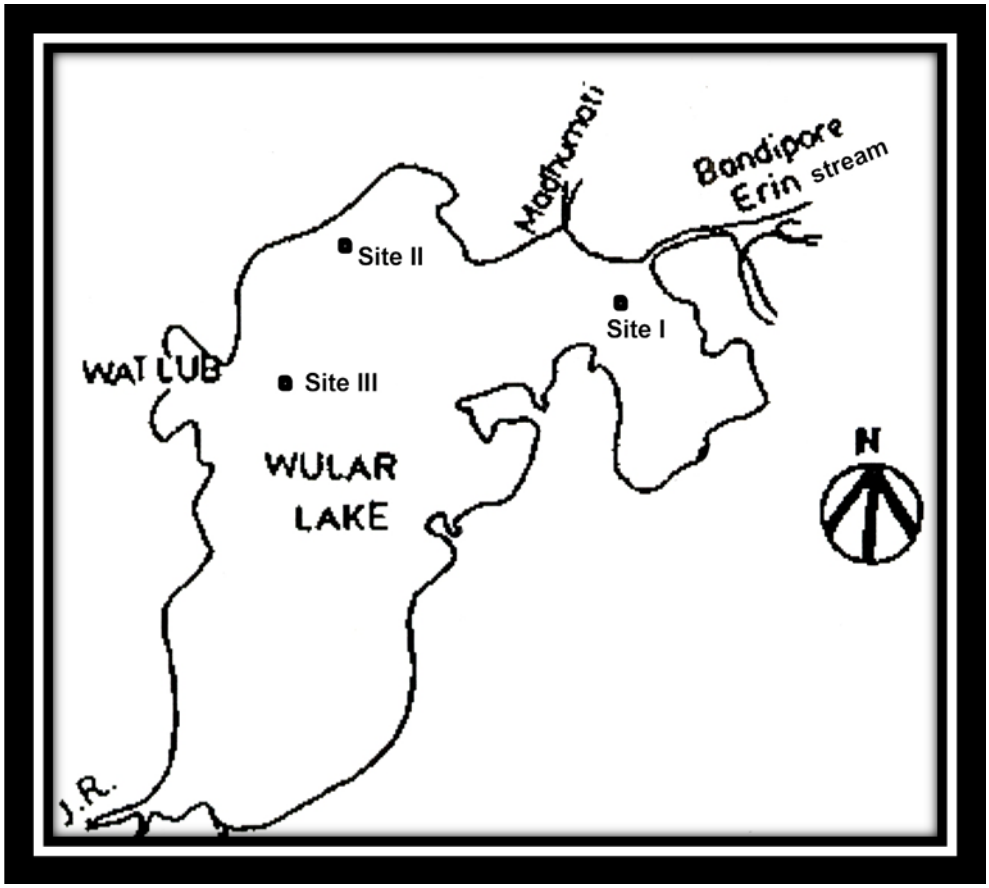


Figure 7. Monthly variations in phytoplankton groups during March, 2007 to February 2008.



Map 1. Wular Lake showing sampling stations. Site 1 (Lankrishipora).

environmental variables with the ordination axis. In the graph, environmental factors are indicated by the line, length of line represents the degree of relationship between sample plots, the distribution of phyto-plankton and environmental factors. The length of the arrow indicates the relative importance of the environmental variable in determining the axis. The positions of the group's centers (points) along the ordination axis represent their respective optima along the environmental gradient. The group-environmental correlation with axis 1 was 0.39. It correlated well with D.O, water temperature, bicarbonate alkalinity, transparency, TDS, chlorides and CO_2. The bacilariophyceae has the highest values on this axis. Group with lowest correlation with this axis was euglenaphyceae. In addition, the analysis make vertical lines connecting a particular group with the line of environmental factors closer to the connecting point near the line of environ-mental factor showing strong positive correlation.

Further, the most important factors affecting phyto-plankton distributions are water temperature, CO_2, chloride, transparency, TDS, alkalinity and dissolved oxygen (Figure 6). However, conductivity, hardness has lesser influence on the distribution of phytoplankton groups. Bacillariophyceae and cyanophyceae showed positive correla-tion with TDS and chloride, respectively.

Conclusions

Phytoplankton and its constituent group's speciose reflected the definite periodicity. Bacillariophyceae was the most dominant speciose and eulenophyceae was recorded to be the least speciose. In the current discussion on which index should be used, if any, it is shown that, the diversity index used here can give only a numerical value of the relation between species richness and species evenness. The ecological importance of each species is not included. Until the question is answered, if a high or low number of individuals, biomass, productivity, etc., make species more or less important in a community, diversity indices remain just mere numbers.

Further, from CCA, it was concluded that the most important factors affecting the phytoplankton distribution are water temperature, CO_2, chloride, transparency, TDS, alkalinity and dissolved oxygen. However, conductivity and hardness has lesser influence on the

distribution of phytoplankton groups.

Recommendation

Based on the seasonal variation of various physico-chemical properties of water and phytoplankton population, an integrated management approach combining capture and culture fishery (subject to provision of infrastructure by Government) during different seasons of the year in this lake of international importance could be taken up for augmenting fish production to a great extent. Further, the lake is facing extinction and as such international community should come to the rescue of this dying lake, before it is too late.

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REFERENCES

APHA (1998). Standard Methods for examination of water and wastewater. 20th Edition. American Public Health Association, Washington, D.C., USA. p.1193.

Berger WH, Parker FL (1970). Diversity of Planktonic foraminifera in deep sea sediments. Science, 168:1345-47.

Bhat SA, Pandit AK (2003). Phytoplankton dynamics in Anchar lake. J. Res. Dev. 3:71-969.

Devassy VP, Goes JI (1988). Phytoplankton community structure and succession in a tropical estuarine complex (central west coast of India). Estuarine, Coastal Shelf Sci. 27:671-685.

Devassy VP, Goes JI (1989). Seasonal patterns of phytoplankton biomass and productivity in a tropical estuarine complex (west coast of India). Proc. Ind. Acd. Sci. (Plant Sciences), 99:485-501.

Dippel L (1904). "Diatomeen Der Rhein - Mainebene Braunschweig". Druk und Verlag Friendrich Vieweg und Sohn. p. 170.

Edmondson WT (1959). Ward and Whipple's Freshwater Biology. 2nd Ed. Johan Wiley & Sons Inc., New York, pp.1-1248.

Gadag SS, Kodashetter MS, Birasal NR, Sambrani MI (2005). Of the microphytes and macrophytes in and around Heggeri lake (Haveri district). Proc. State level UGC sponsored seminar on biodiversity and its conservation held at KLE society's Gudleppa Hallikeri College, Haveri, 28-29th July 2005. p. 91.

Ganai AH, Parveen S, Khan AA, Maryam H (2010). Phytoplankton diversity at Watlab Ghat in Wular lake, Kashmir. Jour. Eco. Nat. Environ. 2(8):140-146.

Gopal B, Zutshi DP (1998). Fifty years of hydrobiological research in India. Hydrobiologia 384:267- 290.

Kamat SV (2000). Hydrobiological studies of two temple ponds in Ponda taluka Goa. Ecol. Environ. Cons. 6:361-362.

Kant S, Kachroo P (1971). Limnological Studies on Kashmir lakes. IV. Seasonal Distribution of phytoplankton in Dal and Nagin Lake. Proc. Ind. Natn. Sci. Acad. 40B:77-79.

Kant S, Kachroo P (1977). Limnological studies on Kashmir lakes I. Hydrological features, composition and periodicity of phytoplankton in Dal and Nagin lakes. Phykos. 16:77-79.

Kaul V, Pandit AK (1982). Biotic Factors and Food Chain Structure in some typical wetlands of Kashmir. J. Poll. Res. I(1-2):49-54.

Kaul V, Fotedar DN, Pandit AK, Trisal CL (1978). A Comparative Study of Plankton Population of some typical freshwater water bodies of Jammu and Kashmir State. In: Environmental Physiology and Ecology of Plants (D.N. Sen and R. P. Bansal, (eds), B. Singh, M. Pal Singh, Dehra Dun, India. pp. 249-269.

Kemdrim EC (2001). Check list of phytoplankton of Shedam reservoir in Plateau state. Nigerian .J. Aquatic Sci. 16:61-66.

Khan I, Nathar SA (1991). Effect of urban and industrial waste on species diversity of diatom community in a tropical river in Malaysia. Hydrobiologia, 224:175-184.

Kiran BR, Harish K, Babu Ravi Kumar M, Puttaiah ET, Devidas Kamath C (2006). Water quality assessment of Bhadra river with special reference to industrial pollution. Ind. J. Environ. Protect. 26:148-152.

Kumar HD (1990). Introductory Phycology. Pub. Affiliated East West Press Pvt.Ltd.

Lin CK (1972). Phytoplankton Succession in a eutrophic lake with special reference to blue-green algae blooms. Hydrobiologia, 39 (3):321-334.

Ludwig JA, Reynolds JF (1988). Statistical Ecology: A primer on methods and computing. John Wiley and Sons, New York.

Margalef R (1958). Information theory in ecology- Gen.Sys. 3: 36-71.Transl. R. Acad. Ciene.Artes. Barc. 32: 373-449.1957.

Mc Caul J, Crosland J (1974). Water Pollution. Harcourt Brace Jovanovick Inc., New York, p.206.

Millman M, Cherrier C, Ramastack J (2005). The seasonal succession of the phytoplankton community in Ada Hayden lake, North Basin, Ames, Lowa. Limnology laboratory, Lowa state university, Ames, Lowa.

Misra AP, Borugh BK, Sharma M (1999). Limnological investigation of a fresh water *tributary.* J. Freshwater Biol. 2:1-5.

More YS (1997). Limnological Study of Panzara dam & river. Ph.D thesis, North Maharashtra University, Jalgaon.

More YS, Nandan SN (2000). Hydrobiological study of algae of Panzara river (Maharashtra). Ecol. Environ. Cons. 6:99-103.

Munawar M (1974). Limnological studies on Freshwater ponds of Hyderabad, India. IV. The Biocene periodicity and species composition of unicellular and colonial plankton in polluted and unpolluted environments. Hydrobiologia 45:1-32.

Naik UG, Bhosale SH, Rathod JL, Bhat UG (2005). Diversity of phytoplanktonic groups in the river Kali, west coast of India. Proc.of the State Level UGC Sponsored Seminar on Biodiversity and its Conservation, Haveri, 28-29th July 2005. pp.192-196.

Nandan SN, Aher NH (2005). Algal community used for assessment of water quality of Haranbaree dam and Mosam river of Maharashtra. J. Environ.Biol. 26:223-227.

Needham JG, Needham PR (1962). A guide to study freshwater biology. Holden - De, Inc., Francisco

Pandit AK (1998). Plankton Dynamics in Freshwater wetlands of Kashmir. In: Ecology of polluted waters and toxicology, K.D. Mishra, (ed.). Technoscience publication, Jaipur, India Pielou, E.C.: Ecological Diversity. John Wiley and Sons, New York (1975).

Pillai NK (1986). Introduction to Planktonology. Ist Edn. Himalaya Publishing House, Bombay.

Pieterse AJH, Van Zyl JM (1988). Observation on the relation between phytoplankton diversity and environmental factors in the vaal river at balkfontien, South Africa. Hydrobiologia 169:199-207.

Pongswat S, Thammathaworn S, Peerapornipsal Y, Thanee N, Somsiri C (2004). Diversity of phytoplankton in the Rama IX lake, a man-made lake, Pethumthani Province, Thailand. Science Asia, 30:261-267.

Rashid I (2008). Daily greater Kashmir.

Round FE (1965). The biology of the algae. Edward Arnold Pub. London. p.269.

Sarwar SG (1999). Water quality and periphytic algal component of Archar lake, Kashmir. In: Inland water Resources, India, M.K.

Durga Prasad and P. Sankara Pitchaich (Eds). Discovery publishing house, New Delhi
Senthilkumar R, Sivakumar K (2008). Studies on phytoplankton diversity in response to abiotic factors in Veeranam lake in the Cuddalore district of Tamil Nadu. J. Environ. Biol. 29:747-752.
Shannon CE, Weaver W (1949). The Mathematical Theory of Communication. University of Illinois Press. Urbana, IL., USA.
Shapiro J (1990). Biomanipulation: The next phase making it stable. Hydrobiologia, 200/201:13-27.
Shekhar STR, Kiran BB, Puttaiah T, Shivraj Y, Mahadevan KM (2008). Phytoplankton as index of water quality with reference to industrial pollution. J. Environ. Biol. 29(2):233-236.
Singh SP, Pathak D, Singh R (2002). Hydrobiological studies of two ponds of Satna (M.P) India. Eco. Environ. Cons. 8: 289-292.
Singh SR, Srivastava VK (1988). Variation in water quality of Ganga River between Bauxar and Balia. Pollut. Res. 7:85-92.
Sridhar R, Thangaradjou T, Senthil Kumar S, Kannan L (2006). Water quality and phytoplankton characteristics in the Palk Bay, southeast coast of India. J. Environ. Biol. 27:561-566.
Szeląg - Wasielewska E (2006). Trophic Status of Lake Water Evaluated Using Phytoplankton Community Structure -Change after Two Decades. Polish J. Environ. Stud. 15(1):139-144.
Tas B, Arif Gonulo I (2007). An ecologic and taxonomic study on phytoplankton of a shallow lake, Turkey. J. Environ. Biol. 28:439-445.
Theroux FR, Eldrige EF, Mallmann WL (1943). Laboratory manual for Chemical and Bacterial Analysis of Water and Sewage. McGraw hill Book Co. Inc., New York
Tiwari A, Chauhan SVS (2006). Seasonal phytoplankton diversity of Kitham lake, Agra. J. Environ. Biol. 27:35-38
Trivedy RK, Goel PK (1984). Chemical and biological method for water pollution studies. Environmental Publications, Karad. India
Uhlmann D, Benndori J, Pankow I (1982). A note on the thermal and oxygen sratification and phytoplankton composition in some reservoirs in Tamilnadu and Kerala, India. Int. Revue ges. Hydrobiol. 67:63-84.
Unni KS (1993). Phytoplankton distribution in reservoirs and lakes of Indian subcontinent, a review. Verh. Int. Ver. Limnol. 25:1262-1265.
Vaulot D (2001). Phytoplankton.Centre Nationale de la Recherche Scientific et Universite Pierre et Marie Curie, Roscoff, France.
Wanganeo A, Gagroo S, Yousuf AR, Wanganeo R (2004). Latitudinal variation in phytoplankton assemblage. In: Biodiversity Scenario, (Khanna, D.R., Chopra A.R. and Prasad, G.) Discovery Publishing House, New Delhi
Wetzel RG (1983). Limnology. 2nd Ed. Sounders college publishing co., New York, pp.1-7679.
Yousuf R, Balki H, Qadri Y (1986). Limnological Features of a forest lake of Kashmir. J. Zool. Soc. India 38(1&2):29-42.
Zargar S, Ghosh TK (2006). Influence of cooling water discharges from Kaiga nuclear power plant on selected indices applied toplankton population of Kadra reservoir. J. Environ. Biol. 27:91-198.
Zutshi DP, Gopal B (2000). State of Biodiversity in Lakes and Wetlands of Kashmir Valley. In: Environment, biodiversity and conservation, (ed.) Khan, M.A. APH Publishing Corporation New Delhi
Zutshi DP, Subla BA, Khan MA, Wanganeo A (1980). Comparative Limnology of nine lakes of Jammu and Kashmir Himalayas. Hydrobiologia. 72:101-112.

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Full Length Research Paper

Ethnobotany, indigenous knowledge and unconscious preservation of the environment: An evaluation of indigenous knowledge in South and Southwest Regions of Cameroon

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A study was undertaken to understand the contributions of indigenous knowledge in environmental management and to evaluate some useful plants in selected tribal villages of South and Southwest Cameroon. Intensive field trips were carried out and interviews were conducted with the indigenous people using questionnaires that addressed the use of each plant species for various purposes, local/traditional name of species, plant parts used methods of preparation, prescription and administration for medicinal uses. The work resulted in the documentation of fifty two species of ethnomedicinal plants belonging to thirty families. Among the documented plants, Asteraceae, Fabaceae, Acanthaceae, Euphorbiaceae, Apocynaceae, were the five dominant families with three or more species followed by Rubiaceae, Piperaceae, Lamiaceae, Poaceae, and Apiaceae with two species each. Plants used in traditional medicine are used as decoctions, infusions, macerations, powders, mixtures, squeezing, boiling, and direct eating. Thirty seven species used for varied purposes ranging from cultural, culinary, ecological, and architectural, were identified spreading over 22 families. Some of the species had some interesting uses such as plants as indicator species for rich soils, plants believed to solve boundary conflicts and witch craft, wrapping and preserving food among others. Traditions, customs, beliefs and cultural rights play an important role in environmental conservation and biodiversity of the South and South west regions of Cameroon. Hence, there is a need to utilize and vulgarize the ethnobotanical information, encourage the indigenous people as they contribute immensely in preserving the biodiversity.

Key words: Cameroon, environmental management, ethnobotany, indigenous knowledge, traditions, unconscious preservation.

INTRODUCTION

The forest has been the main source of plant materials for used by various people in Africa and the World. About 300 million depend on forests directly for their subsistence, including about 60 million people of indigenous and ethnic groups, who are almost wholly dependent on forests. WHO (2010) reported that that about 80% of Africans depend on forest resources for shelter, medicine, rural architecture and engineering for their survival. Forests contribute tremendously to the economy of many countries (MEA, 2005; World Bank, 2003). Most urban areas often depend on forested areas for their water supply and benefit from the numerous, environmental services of forests and trees (FAO, 2007).

Indigenous knowledge has been defined as a body of

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knowledge built up by a group of people through generations living in close contact with nature or a systematic body of knowledge acquired by local people through the accumulation of experiences, informal experiments and an intimate understanding of the environment in a given culture. According to Rajasakeran and Arren (1992), Afolayan and Kambizi (2008), this knowledge has been the sole means of survival within many local communities for generations traditional knowledge greatly explains the intricate relationship between human and their natural environment and also contributes to improving forest science and forest management in many areas of the earth (Daou, 2000).

The contributions of the indigenous people to forest conservation have been ignored or belittled, even though they control most of the world's remaining natural forest areas either consciously or unconsciously through their traditional practices, with strong conservation ethics (Daou, 2000; Advice, 2009). Most of the useful tropical plants face extinction due to the extensive timber extraction, agricultural expansion and infrastructure development, all of which have increased dramatically in many parts within the tropics over the past two decades. The more recent attention given to tropical deforestation stems from concerns over various consequences, including the massive loss of biological diversity (Myers et al., 2000), loss of an important sink for atmospheric carbon dioxide, impacts on local and regional climate and negative effects on the livelihoods of people in tropical forests (Stone and D'Andrea, 2001).

Ethnobotany which is the scientific study of plant uses has led to new area of research and many drugs in use today have been discovered through ethno-botanical surveys. The classic example is the Quinine drug from the Quinine tree (*Cinchona calisaya, Cinchona ledgeriana, Cinchona succirubra*), shrub whose bark furnished quinine, one of the best anti-malaria medicine ever used. The use of plant-derived drugs for the treatment of malaria has a long and successful tradition. For example, quinine isolated from *Cinchona* and quinghaosu from *Artemisia annua* L. illustrates the potential value of investigating indigenous knowledge (traditionally used anti-malarial plants) for developing pharmaceutical anti-malarial drugs (Srisilam and Veersham, 2003).

Cameroon is one of the most diverse country in Africa in terms of plant biodiversity hosting over 7850 plant species (Onana, 2011) with 815 species being threatened (Onana et al., 2011) in different vegetation types including the Biafra forest with high rainfall, the Congolese forest, and the semi-deciduous forest with low rain fall (Letouzey, 1985). The vegetation of Cameroon ranges from lowland evergreen rainforest, semi-deciduous, deciduous, savanna woodland, and savanna grassland forest, at different altitudinal gradient of lowland, sub-montane, alpine and montane forest(Letouzey, 1985; Achoundong, 2007) and form part of the Guineo-Congolian region of endemism.

Forest management systems are primarily based on local experience of the specific society, have evolved over time and transmitted from generation to generation by word of mouth or by practice. Daou (2000) and Advice (2009), observed that this is the best way to manage our natural ecosystem since it is the same people using the resources from the environment.

This study sought to understand the contributions of indigenous knowledge, an appraisal of some useful plants species and their significance in biodiversity conservation in selected localities and villages in South and Southwest Regions of Cameroon.

MATERIALS AND METHODS

Study area

Cameroon lies on the west-central coast of Africa and occupies an area of 466.326 km^2 (de Wasseige, and Devers, 2009) between latitudes 2° and 13° N (about 1,200 km) and longitudes 8°30´and 16°10´ E, for the most part between 200 and 800 m above sea-level. Cameroon has been described as "All of Africa" in one triangle, since the country hosts a wide range of climates and ecosystems. In the north and extreme north extending up to Lake Chad, the country is covered by Sahelian Savannah, the center has the characteristics of high altitude moist savannah and the south is covered by dense tropical rainforest. The highest point is Mount Cameroon in the southwest, and the largest cities are Douala, Yaoundé and Garoua. Cameroon is home to over 200 different linguistic groups. This study was carried within some selected localities in the South and South West regions of Cameroon (Figures 1 and 2).

The Southwest Region is located at 5 25' 00''N 9 20' 00''E and covers an area of 24,571 km^2 (9,487 square miles) with a population of 1.21 million people, is divided into six divisions: Fako, Koupé-Manengouba, Lebialem, Manyu, Meme, and Ndian. These are in turn broken down into subdivisions. Important towns include the capital Buea, Limbe, Tiko, Kumba and Mamfe. Limbe in particular is a popular tourist resort notable for its fine beaches. Korup National Park is also a major attraction. Buea itself, meanwhile, sits at the foot of Mount Cameroon, and possesses an almost temperate climate markedly different from the rest of the province (Figure 3).

The South region is located at 2°30′N 11°45′E and covers an area 47,110 km^2 with a population of 520.000 people. It is bordered to the east by the East Region, to the north by the Centre Region, to the northwest by the Littoral Region, to the west by the Gulf of Guinea (part of the Atlantic Ocean), and to the south by the countries of Equatorial Guinea, Gabon, and Congo. The major ethnic groups in the South are the various Beti-Pahui peoples, specifically the Ewondos, Fangs and Bulus.

An ethnobotanical survey was undertaken during 2011 to 2012 for systematic documentation of traditional knowledge regarding traditional herbal remedies alongside other uses of plants. This work was done following field expeditions, to the South region of Cameroon around Kribi, working with the indigenes of the villages of Bisiang, Lokoundje, Pama and Elog-Batindi; -Tombel subdivision precisely in the villages around Mount Kupe, i.e. Mbule, Nyassoso, Kupe and Tombel, Korup forest area, villages around Korup National Park precisely, Ekondo-kondo, Fabe, Ikassa, Bulu, Mundemba, Meka and Dibonda). Field trips were conducted and from each locality, the indigenous people, herbal healers, men, women and children were interviewed to get information about the plants they use. Those who were knowledgeable were taken to the

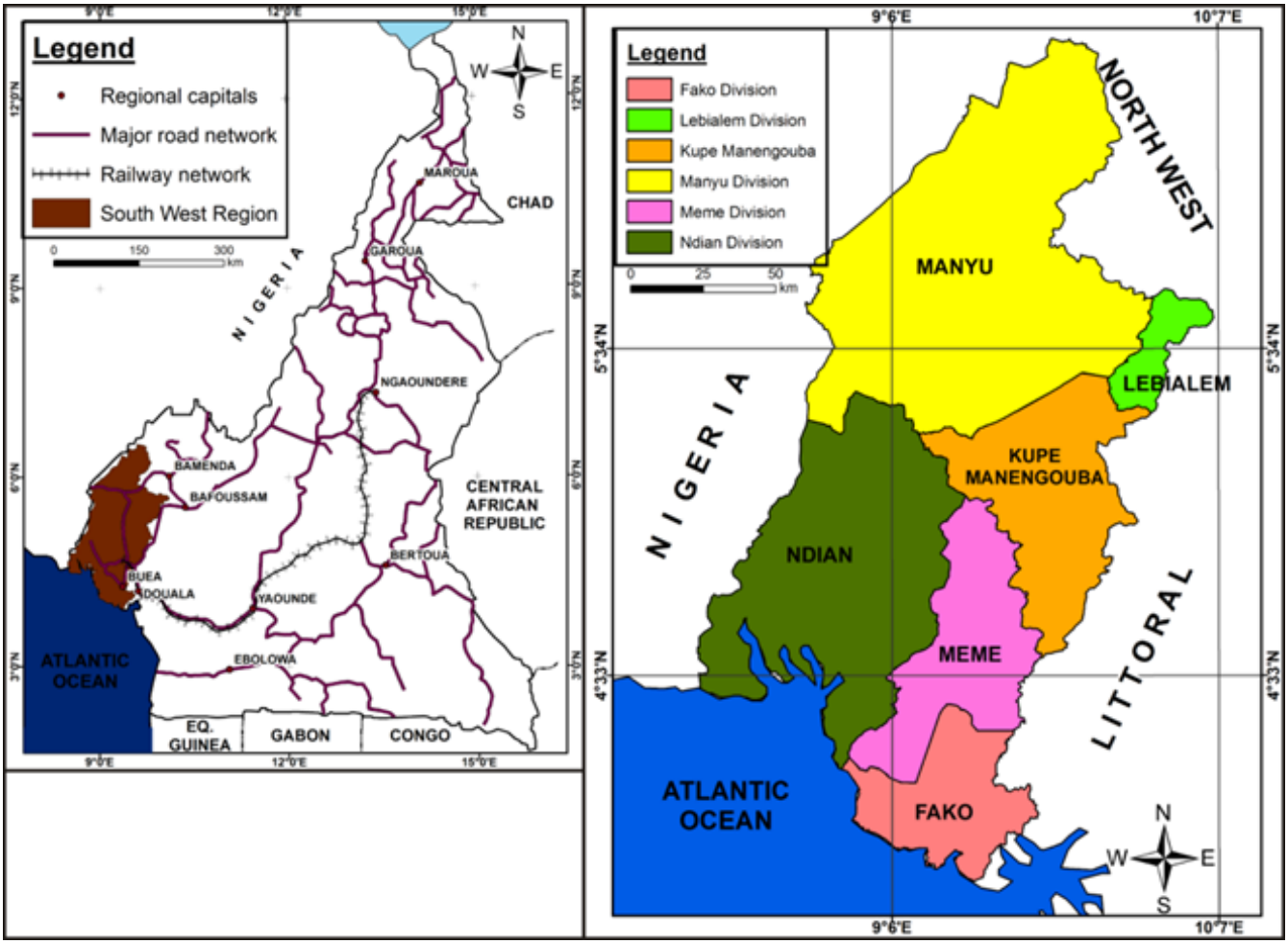

Figure 1. Map of Cameroon showing the South West Region.

field to help in the collection of specimens and care was taken to record vital information including common name, method of usage, if medicinal: method of preparation and administration. Specimens were identified using standard taxonomic methods and principles.

Ethno-botanical and indigenous knowledge survey

The following techniques were used to obtain information about the uses of plants among the indigenous people, The field method involved walking, talking and administering interviews to local people in the areas where they routinely collect and make use of plant materials. During interviews, the indigenous person picks up or shows a plant and explains its uses and in some cases gives a brief history of the plant together with its significance and impact to the community.

House-to-house interviews were done for localities where field-forest expeditions were not performed; people were interviewed with a questionnaire on the uses of plants used around their houses and the surrounding bushes. A local guide was selected in each area to explain the purpose of the study in the local language to simplify, translate and/or interpret in some cases. The questionnaire had open questions that addressed the use of the plant species, their local/traditional name of the species, parts used, and methods of preparation, prescription and administration. The focused data collection strategy was employed whereby similar information from many participants lends some credence. Vouchers specimens for all species encountered were collected identified using standard taxonomic methods and deposited at the Limbe Botanical Garden, Herbarium (SCA), Cameroon.

RESULTS

A total of 136 interviews were conducted and the men were more enthralled (72%) than the women (27%). A good number of the participants were older than 50 (35%) the other age ranges were 40 to 50years (24%) 30 to 39 years (18%) 20 to 29years (18%) and below 20 years (6%). Some children as young as 15 years old were able to give some very valuable information concerning some of the plants and their uses. The chief activity of most of the respondent's livelihood is farming and petty trading and majority of them had been based in their villages for more than 15 years. There is increase in the domestication of some of wild plants such as *Alstonia boonei, Baillonela toxisperma, Bidens pilosa, Cymbopgon*

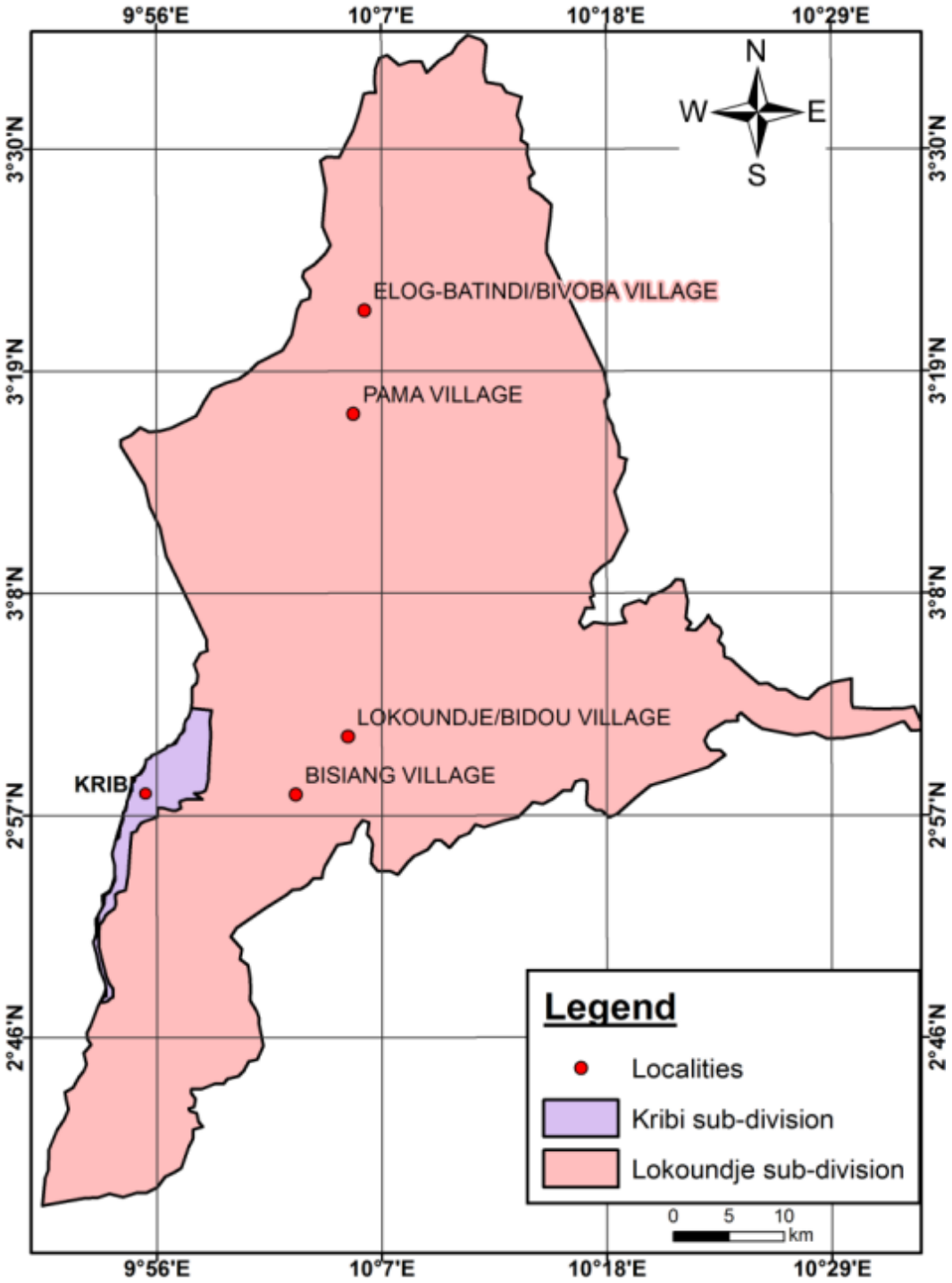

Figure 2. Map of Cameroon showing the selected localities.

citratus, Senna alata, Eremomastax speciosa, Centella asiatica, Morinda lucida, Ricinus communis by the indigenous people.

Table 1 enumerates the different medicinal plants identified during the study which led to the identification of 52 species of plants employed to treat various diseases, distributed over 30 families. A classification was done based on theplaceof interview, and the different parts of the plant utilized. The most dominant families were the Asteraceae (7) Fabaceae (5), Acanthaceae (3) Euphorbiaceous (3), Apocynaceae (3), two species each for Rubiaceae, Piperaceae, Lamiaceae, Poaceae, and Apiaceae, while the other families had a species each, indicating some diversity.

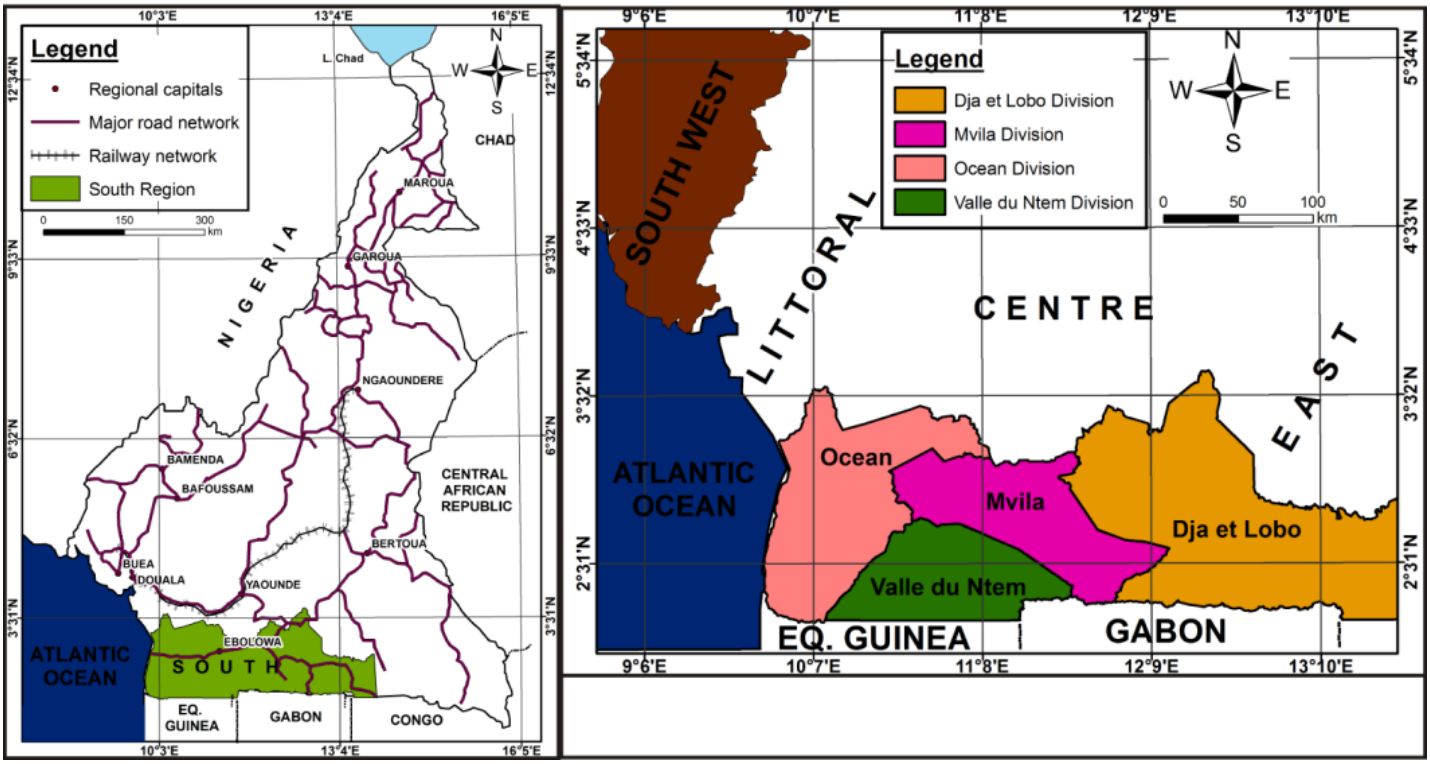

Figure 3. Map of Cameroon showing the different divisions.

Table 2 presents different methods of preparation and treatment of traditional remedies. Some twenty eight different diseases were being treated using the plants as decoctions, infusions, macerations, powders, mixtures, squeezing, boiling, and direct eating. In some cases the plants had to be mixed with oils or local gins before administration.

Different plant species are being used for varied purposes ranging from ecological, cultural, culinary/gastronomical and rural architectural/craft. 38 species were identified spread over 23 families as enumerated in Table 3.

Useful trees are usually planted around the farms include mango (*Mangifera indica*), coconut (*Cocos nucifera*) bush plum (*Dacryodes edulis*) avocado (*Persea americana*), papaya (*Carica papaya*) guava (*Psidium guajava*), cocoa (*Theobroma cacao*), and oil palm (*Elaeis guineensis*). Other species include tubers such as cocoyams (*Colocasia esculenta, Xanthosoma* sp) sweet potatoes (*Ipomoeabatatas)* cassava (*Manihot esculenta*), different species of yam,calabar yam (*Dioscorea rotundata,* Water yam *(D. alata), D. cayeneensis, D. dumentorum*).

Leafy vegetables commonly grown are bitterleaf (*Vernonia amygdalina*) 'green (*Amaranthuscreuntus*), fluted pumpkin (*Telferia occidentalis*) water leaf (*Talinum fructicosum*), Garden egg (*Solanum melongena*), 'anchia'(*Solanum macrocarpon*), 'krengkreng' (*Cochorus ollitorus*)'egusi'(*Citrullus colocynthis*) cereals and pulses such as cowpea(*Vigna unguiculata*), broad bean (*Phaseolus vulgaris*), maize (*Zea mays*) bananas and plantains (*Musa sapientum, Musa paradisiaca*).

Some ornamental plants which are cultivated to some extent include; *Clerodendron* spp, *Crinum natans, Catharanthus roseus, Dracaena* spp, *Mussaenda* spp. some Orchidaceaes, *Scadoxus*spp, *Spathodea* sp and *Lantana camara*

DISCUSSION

A wide variety of plants are being used by the locals or indigenous people for diverse purposes. Fifty two species of medicinal plants were identified during the study, employed to treat various diseases and conditions distributed over 30 families. Different methods were used for the interviews which revealed the exploitation of different parts of the plant for the treatment of diseases. The most dominant families were the Asteraceae (7), Fabaceae (5), Acanthaceae (3) and three each for Euphorbiaceae, Acanthaceae, Apocynaceae; two species each for Rubiaceae, Piperaceae, Lamiaceae, Poaceae, and Apiaceae, while the other families had a species each, indicating some diversity. Simbo (2010) in his findings also revealed the Asteraceae as the most dominant family and this group of plants have also been reported to possess a wide range of many biologically active compounds (Heinrich, 1998). Adjanochoun et al. (1996),

Table 1. Plants used by the indigenous people for treatment of diseases in the study areas.

Specie	Family	Place of interview		Plant organ utilized						
		Field	House	Root	Bark	Leaf	Stem	Fruit	Seed	Sap /Oil
Acanthus montanus	Acanthaceae	*				*				
Anchomanes difformis	Araceae	*	*			*				
Aframomum melegueta	Zingerberaceae	*							*	
Ageratum conyzoides	Asteraceae		*			*				
Alchornea cordifolia	Euphorbiaceae	*				*				
Aloe vera	Asphodelaceae		*							*
Alstonia boonei	Apocynaceae	*	*		*					
Angylocalyx talbotti	Fabaceae	*		*		*				
Annickia chlorantha	Annonaceae	*			*					
Aspilia africana	Asteraceae		*			*	*			
Asystasia gangetica	Acanthaceae	*	*			*				
Baillonela toxisperma	Sapotaceae	*			*					*
Barteria fistulosa	Passifloraceae	*			*					
Bidens pilosa	Asteraceae		*			*	*			
Carica papaya	Caricaceae		*	*		*			*	
Carpolobia lutea	Polygalaceae	*		*						
Ceiba pentandra	Bombacaceae	*			*					
Centella asiatica	Apiaceae	*				*	*			
Chromolaena odorata	Asteraceae		*			*				
Commelina beghalensis	Commelinaceae		*							*
Cyathula prostrata	Amaranthaceae		*			*				
Cylicodiscos gabonensis	Fabaceae	*			*					
Cyngopogon citratus	Poaceae		*			*				
Emilia coccinea	Asteraceae	*				*				
Entandrophragma utile	Meliaceae	*						*		
Eremomastax specioa	Acanthaceae		*			*				
Eryngium foetidum	Apiaceae	*				*	*			
Euphorbia hirta	Euphorbiaceae		*			*				
Garcinia kola	Clusiaceae	*	*						*	
Harungana madagascariensis	Hypericaceae	*			*					
Kalanchoe pinnata	Crassulaceae	*				*				
Lantana camara	Verbenaceae	*				*				
Lapotea ovalifolia	Urticaceae		*			*				
Lasianthera africana,	Icacinaceae	*				*				
Masularia accuminata	Rubiaceae	*		*						
Melanthera scandens	Asteraceae		*			*	*			
Mimosa pudica	Fabaceae		*			*				
Morinda lucinda	Rubiaceae	*		*						
Musanga cecropiodes	Moraceae	*								*
Ocimum bacilicum	Lamiaceae		*			*				
Panda oleosa	Pandaceae	*							*	
Piper guineensis	Piperaceae	*	*			*			*	
Piper umbellatum	Piperaceae	*				*				
Pterocarpus soyauxia	Fabaceae	*			*					*
Rauvolfia vomitoria	Apocynaceae	*	*							*
Ricinus communis	Euphorbiaceae		*			*				
Senna alata	Fabaceae	*				*				
Solenostemon monostacyus	Lamiaceae	*				*				
Spilanthes filicaulis	Asteraceae	*							*	

Table 1 Contd.

Tabernaemontana crassia	Apocynaceae	*			*	*
Zea mays	Poaceae	*		*		
Zingiber officinale	Zingiberaceae	*	*			

Table 2. Plants used by indigenous people in traditional remedies.

Specie	Method of preparation	Administration	Treatment
Acanthus montanus (Nees) T.Anderson Acanthaceae	Leaves are squeezed and water added.	Oral	Remedy for fever.
Ageratum conyzoides Linn. Asteraceae	Leaves and stems crushed and resulting liquid used for different ailments.	Oral/ External	Night poison, asthma gastritis, migraine, wounds to stop bleeding.
Anchomanes difformis Schott. Araceae	Leaves are crushed and liquid used as eye drops.	Oral	Eliminates worms from the eyes
Aframomum melegueta (Roscoe) K.Schum Zingiberaceae	A certain odd number of the seed "eye" is chewed by the nursing mother and spat on the baby and on the four corner of the room	External	Used for the protection against witchcraft especially in children crying at night as it is believed they are being frightened by evil spirits. It is also mixed with other leaves against snake bites and poison.
Baillonela toxisperma Pierre. Sapotaceae	Oil is extracted from the seed of this species known as "Njabe oil" and it helps to compliment medications that are difficult to take orally making them palatable.	Oral	Used to administer many plant extracts and mixtures. Used to improve the quality of the hair .
*Alstoniaboone i*R.Br. Apocynaceae	The thick bark is extracted from the tree and boil to extract white latex	Oral	Malaria related illnesses or complications and also to induce breast milk in breast feeding mothers
Angylocalyx oligophyllus (Bak) Bak.f Fabaceae	The leaves of this species is mixed with extract from *Ageratum conyzoides* (King grass) and enema is prepared for children.	Anal	Redness of the skin especially around the reproductive areas known as thrush orCandidiasis("jetty-jetty") in children
Annickia chlorantha (Oliv.) Setten& Maas Annonaceae	The bark is either put in alcohol or local gin (Afou-fou) and then consumed or sometimes boiled in a decoction with other plants e.g. bark of *Cylicodicos gabonensis*	Oral	Malaria related complications and body pains
*Aspilia africana,*Thouars. Asteraceae	Leaf extract/exudates are applied to wounds		Wounds especially fresh wounds. Exudate helps in coagulation of the blood
Asystasia gangetica (L.) T. Anderson Acanthaceae	A mixture is prepared from the leaves together with other plant species and the paste is licked.	Oral	Prevention against witch craft and evil spirits. Used for vomiting.

Table 2 Contd.

Barteria fistulosa Mast. Passifloraceae	The bark and leaves are used to prepare a concoction and sometimes the ant that is associated with the plant is used to force thieves to speak the truth.	External	It is used for the treatment of rheumatism that is a common illness of elderly people and also to get the truth from thieves.
Bidens pilosa L. Asteraceae	Leaves and stems are infused and taken as tea.	Oral	For cough and fever
Carpolobia lutea G. Don Polygalaceae	Root is dug and chewed, liquid extract is swallowed for few minutes.	Oral	Stimulate and enhance erection of the penis in male
Centella asiatica (L.) Urb Apiaceae	Whole plant is macerated and resulting solution used. The leaves and stems eaten	Oral	Loss of memory, skin problems
Commelina benghalensis L. Commelinaceae	The stem of plant is harvested and mucilage squeezed out and applied on the affected portions.	External	Ringworm and skin diseases
Cymbopogon citratus(DC.) Stapf. Poaceae	The leaves are boiled sometimes together with, other species like *Carica papaya* and *Eremomastax speciosa* Hochst.	Oral	Prevention against malaria and upgrading blood level
Drymaria cordata (L.) Schultes. Caryophyllaceae	Whole plant is macerated and paste obtained.	External	For wounds and insect bites.
Elaeis guineensis Jacq. Arecaceae	Kernel oil (Manyanga) is prepared from the nut and used as a compliment to other medicinal plant extract by making it palatable.	Oral	Skin diseases, stomach disorder and convulsion in children
Emilia coccinea (Sims.) G.Don Asteraceae	Leaves are infused	Oral	Fever and gastric pains. Extract used for wounds.
Entandrophragma utile (Dawe & Sprague) Sprague Meliaceae	The fruits are used to prepare hot pepper soup with spices like *Piper guineensis.*	Oral/ External	Prevent internal blood clotting and abscesses from a tree fallen victim. Woody pericarp used for couch mixtures.
Eremomastax specioca Hochst Acanthaceae	Leaves are macerated. Leaves are boiled and the resulting solution used.	Oral	Improvement and recuperation of blood in anemic patients.
Eryngium foetidum L. Apiaceae	Leaves are squeezed or ground with some water and resulting solution used.	External	Used for abscesses and boils
Euphorbia hirta L. Euphorbiaceae	Latex and water used as eye drops, helps to eliminate foreign objects.		Eye drops, cleaning of the eyes stops redness. Used for fungal infections. Stomach disorder.

Table 2 Contd.

Garcinia kola Heckel. Clusiaceae	The fruit is harvested, seed peeled, and eaten by many old and middle age people	Oral	Delay ejaculation during sexual intercourse in male and also serve as a stimulant. Used for bad breath.
Harungana madagascariensis Lam ex Poir Hypericaceae	Decoction is prepared from the bark.	Oral	Back complication in children
Kalanchoe pinnata (Lam) Pers. Crassulaceae	Leaves are macerated withvery little water and extract used.	External	Ear problems
Lantana camara L. Verbenaceae	Decoction of leaves Maceration of leaves		Diarrheoa Fresh wounds
Lapotea ovalifolia Gaudich. Urticaceae	Enema is prepared from leaves.	Anal	Treatment of children's illness and initiate movement of the baby.
Lasianthera africana, P.Beauv. Icacinaceae	The leaves are squeezed, boiled and the resulting concoction taken.	Oral	Diarrhea and stomach related complications
Melanthera scandens J.P.Rohr Asteraceae	Leaves and stems are infused	Oral	Constipation
Mimosa pudica L. Fabaceae	The leaves are ground to form a paste and then applied to the painful portion and the fresh creeping stem is used to beat up young babies for the initiation of movement.	External	Speed up the process or hasten the maturity and softness of boils and abscesses. It also initiates movement in babies
Morinda lucida Benth. Rubiaceae	The roots are prepared with extracts from other plants by boiling for few hours	Oral	Erection problems in male and high blood patients
Masularia acuminata (G Don)Hoyle Rubiaceae	The roots are chewed together with the fruit of oil palm.	Oral	Enhances male erection for preparedness for sexual action.
Musanga cecrpioides R.Br. Urticaceae	The liquid from the root of this plant is collected with a container and taken.	Oral	Induces breast milk in breast feeding mothers.
Piper umbellatum L. Piperaceae	The young leaves, roots or the entire plant are ground together with *Aframomum melegueta* (Mbungu or Alagata pepper) and rubbed on abscesses and swollen parts,	External	Hasten the maturity and softness of boils and abscesses

Table 2 Contd.

Pterocarpus soyauxia Taubert Fabaceae	The bark is ground and mixed with "calabar chalk",(calcium carbonate) and rubbed on the body for decoration	External	Used for side pains. Serve as decoration powder during traditional marriage or ceremony
Rauvolfia vomitoria Afzel. Apocynaceae	The latex of this species is extracted and put in water.	Oral	Highly active against malaria parasite. Patients with high blood pressure.
Ricinus communis Linn. Euphorbiaceae	Leaves are boiled and a bath taken using the water.	External	Muscle weakness
Senna alata(l.) Roxb. Fabaceae	The leaf extract is squeezed and applied to the affected portion, or in case of yellow fever, the leaves are boiled and the extract drunk. For stomach complications leaves are crushed and extract drunk.	External or Oral	Used for skin/dermatological problems especially fungal, yellow fever and stomach complications.
Solenostemon monostacyus Thonn. Lamiaceae	Leaves and flowers are crushed and rubbed on the forehead.	External	Severe headache.
Spilanthes filicaulisJacq. Asteraceae	Decoction of leaves and inflorescence mixed with *Aframomum melegueta*. The heads (capitulum) are chewed.	Oral/External	Cough and chest pain. Also used for toothache.
Tabernaemontana crassia Benth. Apocynaceae	The wounded individual cuts the bark of this species and applies to the wounded area to stop blood flow.	External	Wounds and fresh cuts.
Zea mays Linn. Poaceae	Silk is infused and drunk as tea	Oral	Diuretic especially for women suffering from edema.
Zingiber officinale Rosc. Zingiberaceae	Rhizome is ground and mixed with honey and lime		Used for very serious cough

Jiofack et al. (2010), documented traditional uses of plant species that treat some important diseases and some of the plants recorded in this study have also been described in earlier literature (Focho et al., 2009a; Idu et al., 2009). The study has revealed some new and interesting uses of plants.

A number of methods were identified for the preparation of traditional remedies. These included squeezing, grinding/crushing, boiling (hot infusion), decoction and paste and these were administered internally or externally. Squeezing and decoction were the most common methods of preparation within the study area, especially in cases where plant leaves were the main parts to be used. These findings are consistent with those of Jiofack et al. (2010), where they observed the use of plants in traditional medicine as decoctions, infusions, macerations, powders, mixtures, squeezing in water, boiling, and direct eating. Inhalation of vapour through breathing from boiled or warmed plant parts was one of the methods of administration of the herbal remedies. Most solutions or concoctions were either taken orally or as enema, other methods included, use of steam baths of hot infusions, application of crushed plant part directly to the skin, rubbing (plant parts are crushed and mixed with water or oil and rubbed on the body), powders, chewing and spitting. A few remedies were given with oils, mostly by use of palm and kernel oils from (*Elaeis guinensis* Jacq.) 'njabe' oil from (*Baillonela toxisperma* (Hook. f.) Benth. which is added in preparations to make them palatable to be taken orally or to increase their consistency and quality for application on the affected parts.

Preparation of the medicinal mixtures depended on the

Table 3. Species of plants used for ecological, cultural and rural architectural and other purposes by the indigenous people.

Species	Family	Common/Local name	Uses
Afrostyrax lepidophyllus Perkins &Gilg.	Huaceae	Country onion	Spice/Preservation of food
Alchornea cordiflolia (Schum&Thonn.) Muell.Arg	Euphorbiaceae		Rural architecture. Used to construct life fence
Alchornea laxiflora.(Benth.) Pax&K Hoffm.	Euphorbiaceae		Rural architecture. Used to construct life fence
Bridelia micranta (Hochst) Baill.	Phyllanthaceae		Rural architecture. Used to construct life fence
Antiaris toxisperma L.	Moraceae	Wodombo	Ecological, for trapping of animals
Bambusa vulgaris Schrad.ex Wendl.	Poaceae	Konga, Indian bamboo	Building and construction, furniture, baskets,
Bixa orellana L.	Bixaceae	Lipstick plant	Seeds used as dye and as lipstick
Ceiba pentandra (L.) Gaertn.	Malvaceae	Boma tree. Silk cotton tree	Ecological in farmland. Cotton from fruits is used for stuffing pillows and mattresses and cleaning purposes.
Citrus aurantifolia (Christm.)Swingle.	Rutaceae	Lime	Used to clean rusty iron, particularly files and farm tools. Fruits are also eaten.
Cola lepidota Schott and Endl.	Malvaceae	Monkey cola	Ecological in farmland, rural architecture, bark is used as fiber to make straps for baskets and bags.
Cola nitida (Vent) Schott&Endl.	Malvaceae	Country cola	Seeds used culturally for entertainment and for ceremonies.
Crescentiacujete L.	Bignoniaceae	Calabash tree	Appreciated for the large, round fruits, used to make containers for palm wine.
Cylicodiscus gabonensis (Taubert.) Harms.	Fabaceae	Denya	Ecological/indicator species to show the soil is rich for agriculture. Timber species.
Dracaena sanderiana Hort.Sander	Asparagaceae (Dracaenaceae)		Culture/boundary plant
Dracaena talbotii	Asparagaceae (Dracaenaceae)	Boundary plant Peace plant	Peaceful settlement of boundary conflict, demarcation of land
Elaeis guineensis Jacq.	Arecaceae	Oil palm tree	Very useful. Almost every part of the plant is utilized. Seeds for oil, leaves for thatching, brooms, thorns for removal of jiggers and foreign particles in foot and hands, maggotsfrom the tree are eaten, Kernel oil used medicinally and as body lotion,

Table 3. Contd.

Ficus exasperata Vahl.	Moraceae	Sand paper plant	Coarse leaf surfaces used for polishing furniture and craft.
Garcinia mannii Oliv.	Clusiaceae		Used as chewing sticks in place of toothbrush. Dental hygiene.
Gnetum buchholzianum Engl.	Gnetaceae	Eru	Leaves are eaten when mixed with *Talinumfructicosum.* Very popular vegetable.
Irvingia gabonensis & I. wombolu	Irvinginaceae	Bush mango	Sees are used as condiment, soup thickener
Maesobotrya dusenii Benth.	Phyllanthaceae		Rural architecture/ Building poles and trap poles
Megaphrynium Macrostachyum (Benth.)Milne-Redh	Maranthaceae		Food wrapping/Roofing huts.Stems used for making mats.
Mitragyna ciliata Korth.	Rubiaceae		Leaves are large and round and used traditionally to wrap fruits and seeds especially kolanuts.
Musanga cecropioides R.Br	Urticaceae	Ikombokom Umbrella tree	Rural architecture : in farm tool
Pandanus candellabrum, Parckinson.	Pandanaceae		Mats are plaited from leaves. Thatching.
Phyllobotryon spathulatum. Muell.Arg	Salicaceae		Large leathery leaves are used for temporary roofing.
*Pterocarpus soyauxii*Taubert. .	Fabaceae	Cam wood	Cultural for child birth and marriages red wood has many local uses and a red dye is extracted from it. Young leaves are used as a green vegetable. Also used for making mortars/pestles
Pycnanthus angolensis Welw.)Warb	Myristicaceae	Nasamba	Ecological, improves soil fertility. The seeds have a very high fat content, and will sometimes burn like candies.
Raphia hookeri G.Mann & H.Wendl.	Arecaceae	Mat	Rural architecture/Building construction, thatching /craft, basketry
Ricinodendron heudelotii (Baill.)Heckel.	Euphorbiaceae	Njangsang	The wood is used for planks and making mortars. Seeds used as spice.
Ricinus communis	Euphorbiaceae	Castor oil plant	(groundseed used for food storage against insects. Ash from burned wood is usedinsecticide.
Scyphocephalium mannii Warb.	Myristicaceae	Bofi	Ecological, improve soil fertility.
Spathodea campanulata P.Beauv.	Bignoniaceae		Ecological, life fence and ornamental tree.
Staudtia kamerunensis Warb.	Myristicaceae	Matanda	Rural architecture, ecological in farmland

Table 3. Contd.

Terminalia catappa L.	Combretaceae	Banga school	Ecological used as shade tree, kernels are edible and used by children for games.
Tetrapleura tetraptera (Schum.) Taubert.	Fabaceae	Four corner	Rural architecture. The flesh from two of the four wings on the large fruits is used as a spice. The fruits are edible
Thaumatococcus danielii (Benneth.)Benth.	Marantaceae	Ngongo leaf,	Cultural, preparation of delicacies' Food wrapping which leaves a good flavour. Used for making mats.
Trichoscypha acuminata Hook.f.	Anacardiaceae	Mandodo	Ecological in farmland/ fruits which have a sweet sour taste are edible.
Xylopia ethiopica (Dunal) A.Rich.	Annonaceae		Cultural, preparation of delicacies'. Used as a spice/flavouring
Truimfetta cordlfolia Guilleman & al.	Malvaceae		Leaf used as toilet paper. Used also for making ropes.

needs of the people as the herbalist avoided preparations in advance, undoubtedly being conscious of preservation concerns, an observation made by Omwuliri et al. (2005). However in some instances, different methods were employed for preservation of the plants or plant parts which include drying in sun or in a barn ('banda') in the traditional kitchen where wood is being used for fire, wrapping in fresh leaves such as banana leaves or Maranthaceae leaves, burying in a cool area beside settlement and in some cases the preparations are mixed with oil for long lasting use. Some of these observations corroborate findings of Focho et al. (2009a), Ngono et al. (2011). Most of the remedies were prepared from a single plant source, for example, *Alstonia boonei* (for treating malaria and body pain, *Eremomastax speciosa* as blood tonic, an observation also made by Idu et al. (2010), where they found the roots of *Ancomanes difformis* being used for anti hypertamia. Some preparations required a mixture of two or more plants, such as was the case of redness of the skin, treated by administering a mixture of *Angylocalyx oligophyllus* and *Ageratum conyzoides, Cymbopogon citratus, Carica papaya and Eremomastax speciosa* for malaria and improvement of the blood, *Entandrophragma utile* and *Piper guineensis* for the treatment of blood clotting and abscesses, *Massularia acuminata* roots and fruits of *Elaeis guineensis to* accelerate maturity and softness of abscesses and boils. Mixing different plants in the preparation of remedies was also reported by Sombo (2010), where he proposed that there may be increase effectiveness when combined.

Many of the species encountered have been cited by other authors for same and different illnesses such as *Eremomastax specioca* used as blood tonic (Fongod et al., 2013); *Alstonia boonei*, as anti-malarial (Adjanohoun et al., 1996) and Focho et al. (2009b) reported the plant in the treatment of epilepsy, hernia and snake bites. *Annickia chlorantha* is confirmed by Adjanohoun et al. (1996) in treating malaria. *Aspilia africana*, in this study is known as a very good coagulant, but Waako et al., 2005 reported it as anti-malarial. *Elaeis guineensis*, was also recorded in Focho et al. 2009b for the treatment of convulsions. *Garcinia kola,* is also confirmed by Egbe et al. (2012); Focho et al. (2009b) as an aphrodisiac.

A good majority of the common and most frequently used plants such as *Chromoelaena odorata*, *Commelina benghalensis, Ageratum conyzoides*, popularly known as the 'king plant', *Emilia coccinea, Aloe vera* and *Eremomastax speciosa* were found around homes and farms. Domestication of some wild plant species is being done by herbalists where they confirmed being unsuccessful in some instances, probably due to habitat change or differences. Domestication of some of these plants is for ease of access whenever needed, a view perceived by (Tongo and Ekwalla, 2003). Most of the interviewees interestingly knew the importance of plants around them and everything is thought out for a more unswerving supply thus contributing in their conservation, a view held by Cheek et al. (2004). Traditional knowledge of medicinal plants and their use by indigenous culture are not only useful for conservation of cultural traditions and biodiversity but also for community healthcare and drug development now and in the future (Hanazki, 2000; Pei, 2001). There is therefore, the need to encourage domestication and cultivation of medicinal plants as well as put in place conservation measures to ensure sustainable source of plant materials. The use of plants for medicinal purposes has been reported in other continents of the world, (Rajendran et al., 2012; Shailendra and Chauhan,

2012; Pandy, 2003).

Thirty eight species used for varied purposes ranging from ecological, cultural, culinary/gastronomical and rural engineering, were identified distributed over 23 families (Table 3). Some of the species had some interesting uses such as plants as indicator species for rich soils (*Cylicodiscus gabonensis* and *Pycnanthus angolensis*), plants believed to solve boundary conflicts and witch craft (*Dracaena talbothi* and *Aframomum melegueta*) wrapping and preserving food (species of Maranthaceae) among others. The indigenes showed a lot of mastery of the plants and their different parts which they exploit for diverse uses.

The indigenous people allow cherished plant species that provide services to the crops such as shade and protection of the soil from erosion and degradation. In certain areas, farmers were found working or farming around a tree because they believe it fertilizes the crop thereby leading to improved production. The indigenous people eat a variety of fruits which they cultivate around their homes such as mangoes, avocado, guavas, coconut and others as well as vegetables, cereals and pulses, roots and stems of plants. This also helps in conserving the biodiversity. The people make use of intrinsic knowledge in addressing some of their snags, for example in situations where they are lost in the forest during hunting expeditions or in their search for plants, they survive by eating food and fruits that animals such as monkeys or apes feed on as they believe these animals look much like them. Consequently, eating foods such as “monkey cola” - *Cola lepidota* or sucking fruits of “Mandodo” - *Trichocypha acuminata* will help them during their stay in the forest as they find their way.

A number of interesting observations were made where farmers were found bending some of the leaves of *Colocasia esculenta* (L.) Schott.(“Makabo coco”- cocoyam) for the crop to increase the size and number of tubers. To them reducing the vegetative parts of the crop causes it to develop more tubers the part most consumed. They were also found taking off the reproductive parts of vegetables as was the case of *Talinum fructicosum* (L.) Juss.to increase the production of vegetative parts especially the leaves as this is what is typically consumed. Also another astonishing observation was with a species of *Xanthosoma* (cocoyam ‘Egg coco’ or “Akpana coco”). It was noticed that in majority of the communities where this crop was being grown for human consumption, the indigenes believe that when grown in an area where there are dry sticks, that would hit the crop from time to time in the field especially during heavy winds or storms, consumption will not cause itching of the cocoyam. On the other hand, if it is grown on any farmland without dry sticks from trees dropping on them, the cocoyam would only be best for pigs because of the itchy nature.

Traditions, customs, beliefs and cultural rights play an important role in environmental conservation and biodiversity. Many of the communities in the African countries maintain shrines and protected forests which are being used as places of worship and for other ritual. Secret parts in the forest of most these indigenous people in the study areas are considered as a place of worship and ritual grounds, so villagers are not allowed to move freely in such places to either pick up fruits such as “Bush mango’ or “Country onions” or harvest vegetables such as “Eru”. Such acts are only possible with permission that must be given to individuals who intend to carry out any adventures within these secret parts. Some sites were encountered with such restrictions, for instance in the Rumpi Hills where the ethnic groups of Lepenja, Mbu-Bakundu, Upper Ballong and others share a forest that people or villagers cannot access without some cultural rites. We observed that some of these practices and beliefs about certain species contribute towards their conservation as these species are perceived to have powers to cause certain horrendous consequences for humans if destroyed. Some species improve on the soils for agriculture and others are believed to have abilities to communicate some messages to humans (Tzepo and Chaba, 2004). Eyong (2007) holds that a strong sustainability connection should exist between indigenous and modern knowledge and time-tested ancient wisdoms which when combined with modern technologies can create solid foundations for sustainable development in different regions.

Conclusion

The study revealed that over many years, the local communities have acquired valuable practical knowledge about the local natural resources and therefore to some unknown extent actively manage and conserve their resources guided by indigenous knowledge. A comprehensive proactive policy framework is the best way to conserve indigenous knowledge that can help produce, use and maintain diversity. There is a need to build on the existing resources of indigenous species by improving on their management to sustain the resources as well as further domestication of highly valued species.

Living conditions of the indigenes can be improved somehow, may be by introducing other species to complement the existing vegetation which they are so tightly attached to, improved methods of fabrication, construction or generation of some of the products from the plants could be initiated to make them highly competitive in the market.

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REFERENCES

Achoundong G (2007). “Vegetation,” In: N. Houstin and C. Seignobos, Ed., Atlas of Cameroon’Les editions Jeune Afrique, Paris, pp.64-65.

Adjanohoun JE, Aboubakar N, Dramane K, Ebot ME, Ekpere JA, Enow-Orock EJ, Focho DA, Gibilele ZO, Kamanyi A, Kamsu-Kom J, Keita A, Mbenkum T, Mbi CN, Mbome LL, Mubiru NK, Nancy WL, Nkongmeneck B, Satabie B, Tame V, Wirmim CK (1996). Traditional Medicine and Pharmacopoeia.Contribution to ethnobotanical and floristic studies in Cameroon OAU/STRC Lagos. p.570.

Advice V (2009). The Paradox of Africa’s Poverty: the Role of Indigenous Knowledge in Zimbabwe’s Environmental Management Issues J. Sustainable Development in Africa. 10(4):1520-5509.

Afolayan AJ, Kambizi L (2008). The Impact of the Indigenous Knowledge System on theConservation of Forest Medicinal Plants in Guruve, Zimbabwe, Department of Botany, University of Fort Hare, Alice 5700, South Africa

Cheek M, Pollard BJ, Darbyshire I, Onana JM, Wild C (2004). The Plants of the Kupe_Mwanenguba and the Bakossi Mountains, Cameroon: A conservation checklist. p.258.

Daou J (2000). Indigenous Knowledge and Anthropological Constraints in the Context of Conservation Programs in Central Africa. In: Sangha River Region. Yale F&ES Bulletin.pp.130-140.

deWasseige C, Devers D, de Marcken P, Eba'aAtyi R, Nasi R, Mayaux (2009). "Les Forêts du Bassin du Congo – Etat des Forêts 2008."Office des publications de l'Unioneuropéenne, 2009. : 426.

Egbe EA, Tabot PT, Fonge BA (2012). Ethnobotany and Prioritization of Some Selected Tree Species in South-western Cameroon. Ethnobot. Res. App. 10:235-246.

Eyong CT (2007). Indigenous peoples of Central Africa’s biodiversity regions hold important knowledge for sustainable livelihoods and biodiversity conservation. Tribes and Tribals, Special, 1:121-139.

FAO (2007).State of the world’s forests: 2007. FAO: Rome.

Focho DA, Nkeng APE, Fonge BA, Fongod AN, Muh CN, Ndam TW, Afegenui T (2009a). Diversity of plants used to treat respiratory diseases in Tubah, Northwest region, Cameroon. Afr. J. Pharm. Pharmacol. 3(11):573-580.

Focho DA, Newu MC, Anjah MG, Nwana FA, Fonge BA (2009b). Ethnobotanical survey of trees in Fundong, Northwest Region, Cameroon. J. Ethnobiol. Ethnomed. 5:17.

Fongod AGN, Modjenpa NB, Veranso MC (2013). Ethnobotany of Acanthaceae in the Mount Cameroon region. J. Med. Plt. Res. 7(38):2859-2866.

Hanazki N, Tamishoro JY, Leitao-Filho H, Gegossi A (2000). Diversity of Plant Uses in Caicaras Communities from the Atlantic forest coast, Brazil. Biodiver. Conserv. 9:597-615.

Heinrich M, Robles M, West JE, Ortiz de Montellano BR, Rodriguez E (1998). Ethnopharmacology of Mexican Asteraceae (Compositae) Ann. Rev. Pharmacol. Toxicol. 38:539–565. doi: 10.1146/annurev.pharmtox.38.1.539.

Idu McD, Erhabor JO, Efijuemue HM (2010). Documentation on Medicinal Plants Sold in Markets in Abeokuta, Nigeria. Trop. J. Pharmaceut. Res. 9(2):110-118.

Letouzey R (1985). Notice de la carte phytogéographique du Cameroun au 1/50000. Institut de la carte internationale de la végétation. Toulouse-France et IRA de Yaoundé- Cameroun.

MEA (Millennium Ecosystem Assessment) (2005). Ecosystems and Human Well-Being: Policy Responses. Volume 3, Ch. 8.Island Press, Washington, DC.

Mokuku T, Mokuku C (2004). The Role of Indigenous Knowledge in Biodiversity Conservation in the Lesotho Highlands: Exploring indigenous epistemology. Southern Afr. J. Environ. Edu. 21:38-49.

Ngono NRA, Koanga MML, Tchinda TA, Magnifouet NH, Motso CPR, Mballa BZ, Ebelle ERM, Ndifor F, Biyiti L, Amvam ZPH (2011). Ethnobotanical survey of some Cameroonian plants used for treatment of viral diseases. Afr. J. Plt. Sci. 5(1):15-21.

Onana JM (2011). The vascular plants of Cameroon, a Taxonomic checklist with IUCN Assessments, IRAD-National Herbarium of Cameroon, Yaounde. p.195.

Onana JM, Cheek M (2011). The Red Data Book of the Flowering Plants of Cameroon. RBG, Kew. p.578.

Omwuliri FC, Wonang DL (2005). Studies on the combined antibacterial action of ginger (*Zingiber officinale* L.) and garlic (*Allium sativum* L.) on some bacteria. Nig. J. Bot. 18:224-228.

Pandy IB (2003). Some traditional home remedies used in and around Kampur city (Uttar Pradesh) India. Ethnobot.15 : 129-131

Pei SJ (2001).Ethnobotanical approaches of Traditional medicine studies: Some experiences from Asia. Pharmaceut. Biol. 39:74-79.

Rajendran SM, Shekar KC, Sundaresan V (2002). Ethnomedicinal core of Valaya of Seithur Hill of Virudnagar district.Indian J. Trad. Med. 1:59-64.

Rajasekan B, Arren M (1992). A framework for incorporating IKSs into agricultural extension organization for sustainable agricultural development in India. Paper presented at the Ninth Annual Conference of the Association for International Agricultural and Extension Education, Arlington, VA, United States.

Shailendra K, Chauhan AKS (2012). Ethnomedicinal plants used by Gujjars in Bharatpur, Rajasthan. Ethnobot. 24:119-122

Simbo DJ (2010). An ethnobotanical survey of medicinal plants in Babungo, Northwest Region, Cameroon. J. Ethnobiol. Ethnomed**.** 6:8.

Srisilam K, Veersham C (2003). Antimalarials of plant origin. In: Nishan, I., Khanu, A. (Eds.), Role of Biotechnology in Medicinal and Aromatic Plants, 7:17–47.

Stone RD, D’Andrea C (2001). Tropical Forest and the Human Spirit. Journey to the Brink of Hope, Berkerley, CA: University of California Press.

Waako PJ, Smith P, Folb PI (2005). *In vitro* interaction of *Aspilia africana* (Pers) CD Adams, a traditional antimalarialmedicinal plant with artemisinin against *Plasmodium falciparum*. J. Ethnopharmacol. 102(2):262–268.

World Bank (2003). Cornerstones for Conservation. World Bank Assistance for Protected Areas 1988-2003. World Bank, Washington, D.C.

WHO (2010). The World Health Report 2010, Berlin, Germany.

Zapfack LJ, Ayeni SO, Besong S, Mdaihli M (2001). Ethnobotanical Survey of the Takamanda Forest Reserve. Department of Plant Biology, University of Yaounde, Cameroon Project for Protection of Forest around Akwaya (PROFA), MINEF-GTZ, Mamfe, Cameroon.

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'Population status, nesting sites and seasonal fluctuation of Egyptian vultures (*Neophron percnopterus*): Dynamics and implications for the species conservation in and around Jodhpur

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Nine species of vulture were reported in India. Out of them, four species *Gyps indicus*, *Gyps bengalensis*, *Sacrogyps calvus* and *Neophron percnopterus* are permanent residents and remain in and around Jodhpur. The remaining three species *Gyps fulvus*, *Gyps himalayensis* and *Aegypus monachus* are migratory species and come to site from October to February in winter season. Resident species reproduce here due to availability of food through out the year. Egyptian vulture is a smaller bird with naked head and without long scrawny neck and is permanent resident of Thar Desert. It is has maximum population as compared to other species of vultures observed in the area investigated in the present study.

Key words: Breeding, migratory, population, resident, vulture, Thar Desert.

INTRODUCTION

Vultures are most important scavenger and play an important role in clearing animal carcasses and municipal dumps. Vultures are large birds carrion eaters and are divi-ded into two groups: The New World Vultures and Old World Vultures. New World vultures are under the order Falconiformes of family Cathartidae and Old World vultures belong to the family Accipitridae. The New World vultures are distributed from Southern Canada to the Falkland Islands and the Old World vultures are widely distributed in Asia, Africa and Europe. The subfamily *Aegypinae* of *Accipitridae* contains 15 species of Old World vultures. Due to a lot of variations in geographical and environmental gradient nine species are reported to be present in India (Ali and Ripley, 1987), out of which, seven species have been reported and observed in and around Jodhpur on the tassel of the Great Indian Thar Desert. These include King vulture (*Sarcogyps calvus*), Cinereous vulture (*Aegypius monachus*), Egyptian vulture (*Neophron percnopterus*), Eurasian griffon (*Gyps fulvus*), Himalayan griffon (*Gyps himalayensis*), Long-billed vulture (*Gype indicus*) and White-rumped vulture (*Gyps bengalensis*) (Chhangani and Mohnot, 2002).

Thar Desert of India lies between 25° and 30° N latitude and 69.5° to 76° Longitude (Rahmani, 1997). Jodhpur, the part of Thar Desert situated at 26° 19 N' latitude and 73° 8' S longitude is rich in vulture species. Dry and hot climate conditions favour xerophytes vegetation which is a favorable site for nest building for residual species of Vulture. Migratory species come to Jodhpur to avoid adverse conditions at their native places. King vulture, long-billed vultures, white-backed vulture and Egyptian vulture are residents of Jodhpur whereas Eurasian griffon,

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Himalayan griffon and Cinereous vultures are migratory and observed in Thar Desert during winter season (October to March). The population explosion in this region has generated several new challenges to-wards the habitats and food availability for vulture therein and thus has affected the eco-status of vultures in this region.

Vultures are large gregarious species that breed colonially in cliffs, forming large nesting groups (Cramp and Simmons, 1980; Mundy et al., 1992). Vulture nests are usually located on the trees or in the ridges of rocks. The nests may be built by a pair of bird; they are usually large and durable and used year after year; most of the nests are built by branches, twigs and sticks of local plants.

Vultures are nature's most successful scavengers and they provide an array of ecological, economic and cultural services. As the only known obligate scavengers, vultures are uniquely adapted to a scavenging lifestyle. Vultures' unique adaptations include soaring flight, keen eyesight and extremely low pH levels in their stomachs (Balmford, 2013). Presently, 14 of 23 (61%) vulture species worldwide are threatened with extinction and the most rapid declines have occurred in the vulture-rich regions of Asia and Africa (Ogada et al., 2012). The reasons for the population decline vary: poisoning or human persecution or both features in the list of nearly every declining species. Deliberate poisoning of carnivores is likely the most widespread cause of vulture poisoning.

Monitoring the population size of vulture is often a difficult task as most species are territorial and widely distributed over a sizable area. Different species of vulture show local seasonal fluctuation and their number and activity may vary throughout a day or a season (Newton, 1979). As a result improved monitoring techniques consist of counting birds at their breeding or roosting sites early in the morning or late in the evening before or after their daily foraging trips (Robertson and Boshoff, 1986; Mundy et al., 1992; Marincovie and Orladie 1994; Borello and Borello, 2002).

There has been drastic decline in the vulture population in Indian sub-continent over last two decades (Rahmani, 1998; Prakash, 1999; Prakash and Rahmani, 1999; Virani et al., 2001; Prakash et al., 2003; Chhangani, 2005; Gilbert et al., 2006). Since 1996, the breeding ecology and population of vulture study in and around Jodhpur and in the Thar desert have been examined by monitoring the nesting site, making censuses, recording predation, observing inter-species interaction and locating seasonal migration (Chhangani and Mohnot, 2004; Chhangani, 2002a, b, c, 2005; Chhangani et al., 2002).

Egyptian vulture is resident species of Jodhpur and has maximum population compared to other vultures observed in the same area. It is playing a major ecological role in removing municipal waste and animal carcasses. It is a smaller bird, rather kite like vulture with naked head and without long scrawny neck. Its body size is 66 cm or 26 inch in length. Adult bird has overall dirty white color with nacked yellow head, face and fore neck. Young one has blackish or chocolate brown mottled with whitish blotches on back, breast and greater wing coverts. Many other intermediate colors phase out during its gradual transition from young to adult white pulmage. In overhead aspect, it looks like some eagle, but its longer, narrower, wings and wedge shaped tail differentiate it from eagles. Its scarf is not completely developed and its legs are dirty white color in adult birds.

The aim of the present study was to examine population status, fluctuation and breeding of vultures in and around Jodhpur with special reference to Egyptian vulture (*N. percnopterus*).

MATERIALS AND METHODS

Study area

The study site, Jodhpur (26° 17"59 N and 73° 02"02E) is situated in the Western part of Rajasthan and is a prominent part of great Indian Thar Desert. Topographically, it is by and large, plain and openly interrupted by hillocks. During summer, the temperature ranges between 6° C to 45°C while in May and June it rises up to 49°C. The annual average rainfall is 300 mm, distributed over 20 rainy days. This wide range of climatic condition has led to the formation of different habitat types of vulture in and around the city of Jodhpur.

Survey technique

The methodological approaches used in this investigation are as follows:

Exploration of vultures' nest site

The intensive survey of the study area was undertaken from September 2006 to December 2008 to locate vultures' nest and feeding sites in and around Jodhpur within a radius of 50 Km. Information about various nest and feeding site was collected from literature available, local people information, presence of water bodies, safe and large trees, large rock and cliffs, wild life, livestock population, high tension electricity line and carcasses dumping ground. The following is the list of various nesting sites of vultures studied during this investigation period (Figure 1).

1. Mehrangarh Fort (Jodhpur Fort)
2. Arna Jarna hillock
3. CAZRI Campus
4. Barli Village
5. Machia Safari Park
6. Nagana Hill Barmer
7. Guda Vishnoian (Protected area)
8. Ratkuriya
9. Sathin (Protected area)
10. Bheembhadak Kayalana
11. Machia Fort

After initial surveys of different sites, intensive study was carried out at Keru Barli dumpling site of Jodhpur till the end of December 2008 to know the ecological specificities of the vulture species' inhabit therein. The reason for selecting this site was the maximum availability of vulture population because daily 15 to 20 dead cattle are carried in this area and vultures spend their maximum time in searching for food materials. Moreover, there are three small water bodies present and at 2-3 km distance, there is the presence of Kailana canal which provides drinking water throughout the year. Extensive survey for daily and seasonal fluctuations and their moni-

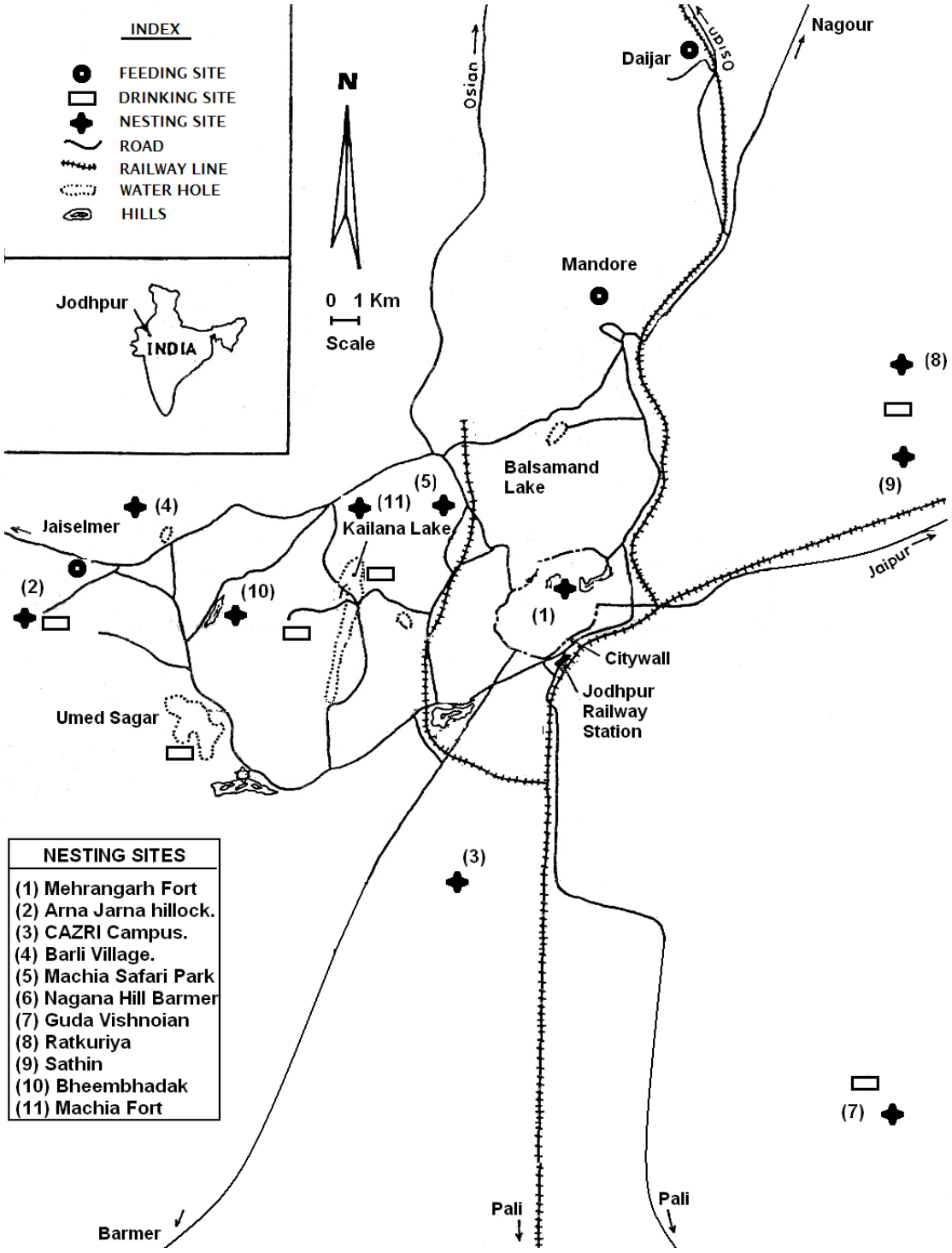

Figure 1. Location of nesting, feeding and drinking sites for Egyptian Vulture in and around Jodhpur, India

monitoring was undertaken in the study area by daily visits, using a motorbike.

Identification

Identification of different species of vulture is carried out on the basis of color pattern of body, upper and under wing color pattern, length of bill, plumage orientation and shape, rump, head and neck regions colors. Identification of juvenile and adult birds is carried on the basis of feathers patterns such as juvenile birds have smaller and more pointed wing and tail feather than adult. Feathers of scarf are longer, more lanceolate or spiky and less fluffy than that of adult; while adult birds have large, more rounded flight and tail feather than juveniles and the feathers of the scarf are mostly whi-

tish and fluffy in appearance.

Field measures

To estimate accurate population of vultures a regular monitoring was done for counting of birds which started from early morning to late afternoon from October 2006 to December 2008. All visits are spaced out by 2-3 days so as to cover all fluctuations homogenously. Data collected on their population, daily activity, local and seasonal migration in relation to temperature, predation by cats, jackals, foxes and dogs on vulture eggs, chicks and on adults have also been recorded besides their intra species competition. Nest counts were made once in a month in the study area. The total count of the active nests was carried out during December and March, when maximum breeding pairs were found. More attention was given on feeding site counting because of all species availability for longer time at feeding station. The seasonal and daily fluctuation status of different species of Vulture was studied by means of head counting method, supported by photography and videography. Observations were made from a safe distance ranging 300-600 m from the cliffs or behind the walls with the aid of 10 x 50 binoculars and a spotting scope with 30x and 70x eyepieces.

Microclimatic statistics

The Digital Minimum-Maximum Hygro Thermometer and a Digital Lux meter (LX-101A, LT Lutron) were used to record microclimatic parameters viz. temperature, relative humidity and light intensity at dumping ground. Relative humidity was assessed as, dry (0-44%), normal (45-74%) and wet (75% and onwards). All these microclimatic parameters were recorded in every week of a month of the study period.

RESULTS AND DISCUSSION

Nine species of vulture have been reported by Ali and Ripley (1987) in India. Out of them seven species were reported in Thar Desert, Rajasthan by Chhangani (2002). Extensive surveys were conducted between October 2006 and December 2008 in Keru dumping site, Jodhpur to assess the vulture population. During present investigation, six species of vulture were observed in selected area during different phases of the year and one previously reported species *Sacrogyps calvus* was not observed. Out of the six species, three are migratory viz. *Gyps fulvus, G. Himalyensis* and *Aegypus monacus* and they are observed only in the months of breeding season (November-February). The remaining three species viz. *G. indicus, G. bengalensis* and *N. percnopterus* are resident species and are observed throughout the year.

Population

The population status of Egyptian vulture (*N. percnopterus*) was counted at different nesting sites from month of October 2006 to December 2008. The maximum population of Egyptian vulture (815 individuals) was observed in 2006. In 2006 onwards the population of Egyptian vulture showed negative trend and was foundto be 618 individuals in 2007 and 326 individuals in 2008. Population of Egyptian vulture gradually built up from October and reached its peak during January and February due to food and water availability. While from March onwards their numbersstarteddecreasingandtheentirevulturepopulation thinned down from May to August, with the increase in temperature and unfriendly environment.

Seasonal fluctuation among Egyptian Vulture

The temporal variation in population of vultures is produced by different ecological pressures such as levels of human disturbance, climatic conditions and food availability (Thomson et al, 1990, Donazar and Feijoo, 2002). The number of vultures largely depends on regular food supplies (Donazar et al., 1996; Margalida and Boudet, 2003), although an element of social organization might also be involved (Rabenold, 1986; Parker et al., 1995).

The data obtained regarding the seasonal fluctuation of different species of vultures in the study area is of great significance. Egyptian vulture is present throughout the year and breeds in this region. Except from March-July, their number remained constant during most of the investigated phase (Table 1, Figure 2). The fluctuation in Egyptian vulture in this area during summer season is primarily due to scarcity of water, food and other unfriendly ecological parameter such as high temperature and very low humidity.

Daily variation among Egyptian Vulture

Generally, vultures feed on dead carcasses and play an important role in environment clearing. Among different species of vultures particular species individuals play an important role during eating and different individual species' number fluctuate in a day during eating. It was observed that resident species *N. percnopterus* shows its presence around carcasses due to its nesting site close to dump area; *Gyps* species shows its presence at dump area between 9.00-10.00 AM and its number continuously increases till late afternoon. Vultures like to feed upon 2-3 days old carcasses which are easy to open. The opening of carcasses is a difficult task and it is mostly performed by *Aegypus monachus* because of its strong pointed and slightly tilted bills and generally this activity occurs between 10.00-12.00 AM with this species *N. percnopterus* (Table 2).

Communal feeding

Different species of vultures feed along with others birds and mammals at the same feeding site. Common birds observed feeding at the dumping site along with vultures of different species were Cattle egret (*Bubulcus ibis*), common raven *(Corvus corax)*, Drongo (*Dicrurus macrocercus*), Green bee-eaters (*Merops philippinus*), House crow (*Carvus splendens*) and Rosy pastar (*Strunus roseus*). Mammals incorporate feral dog (*Canis familiaris*) and Jackal (*Canis aureas*).

Table 1. Seasonal variation among the population of Egyptian vulture's species in 2006-08.

Year and Month	*Neophron percnopterus*
October 2006	635 ± 4.16*
November 2006	815 ± 9.46
December 2006	471 ± 1214
January 2007	618 ± 10.34
February 2007	480 ± 2.95
March 2007	383 ± 4.63
April 2007	223 ± 4.58
May 2007	166 ± 3.83
June 2007	106 ± 4.80
July 2007	68 ± 2.58
August 2007	135 ± 3.51
September 2007	237 ± 2.53
October 2007	243 ± 3.75
November 2007	184 ± 1.33
December 2007	254 ± 2.52
January 2008	259 ± 2.23
February 2008	285 ± 5.23
March 2008	289 ± 5.32
April 2008	239 ± 4.23
May 2008	215 ± 4.32
June 2008	154 ± 1.43
July 2008	63 ± 1.21
August 2008	76 ± 2.32
September 2008	88 ± 4.32
October 2008	211 ± 3.32
November 2008	264 ± 3.858
December 2008	326 ± 2.331

*± = Standard error.

Table 2. Presence of Egyptian Vulture in feeding places during different time period of the day.

Time*	*Neophron percnopterus*
9.30 am	122 ± 2.22#
10.30 am	132 ± 1.21
11.30 am	24 ± 0.23
12.30 pm	13 ± 0.24
1.30 pm	9 ± 0.21
2.30 pm	53 ± 0.97
3.30 pm	112 ± 1.23
4.30 pm	187 ± 1.12

*± = Standard error; # = International Standard Time GMT +5.30 h.

Complete opening of carcasses takes approximately half an hour; during that time the remaining species of *Gyps* continuously produce heat in and around dumping area. When carcasses are completely opened, then *Gyps fulvus* and *Gyups himalyeiness* come and dominate over *Aegypus monachus* and *Neophron percnopterus* during eating. It was observed that a large number of individual population of *Gyps fulvus* mainly dominate over all species of vulture to eat soft tissue like liver, kidney, heart and stomach part of carcasses. During this investigation, it was observed that if there is no type of disturbance in dump area, then opened carcasses are completely eaten by vultures in half an hour. After feeding on the carcasses, *G. fulvus* and *G. himalyensis* go to field area; during that time *A. monachus*, *G. indicus* and *N. perchnopterus* (Figure 3) will get the opportunity to eat the remaining carcasses with feral dogs (Table 2).

During eating of soft tissue of carcasses, there were a lot of inter and intra specific competitions observed. In intra-specific competition, *G. fulvus* and *G. himalyensis* dominate over other species of vultures and even dogs. Many times, it was observed that feral dogs bark and follow the vultures to get opportunity to feed upon carcasses. Mainly, Gyps species leave the carcasses area in late afternoon and show their presence near water bodies like Kailana Canal in Machia Safari Park and Barli pond in Barli village for drinking water. During that time, the remaining carcasses would be eaten by *A. monachus, N. percnopterus, G. indivus* and *G. bengalensis* as well as feral dogs, hawk and common crows.

Breeding of Egyptian Vulture

Seven species of vultures have been observed in and around Jodhpur on the tassel of the Great Indian Thar Desert. Of them, King Vulture (*S. calvus*), long-billed vultures (*G. indicus*), white-backed vulture (*G. bengalensis*) and Egyptian vulture (*N. percnopterus*) are residents and breed in Jodhpur (Chhangani and Mohnot, 2002). As far as the habitat use of nest is concerned, *Neophron percnopterus* is observed on high tension electricity poles, *Prosophis cineraria* and *Tecomela undulata* in old heritage building. A total of 67 nests of Egyptian vultures were found during October 2006 to December 2008 at 11 different nesting sites as shown in Table 3.

Mortality

At Jodhpur site from 2006 to 2008, 21 dead Egyptian Vultures were observed at various location in and around Jodhpur and when average total population of Egyptian vulture was recorded, it was more than 400; total death rate of 5.25% was observed in total population. Forty percent (eight) of them were due to electrocution and the remaining was due to natural death or another reason. Most deaths due to electrocution were observed at Keru dumping site. Two sides of this area are road track and parallel to this high voltage electricity line passes. Maximum death observed in *N. percnopterus* is due to electrocution and road accidents (Figure 4).

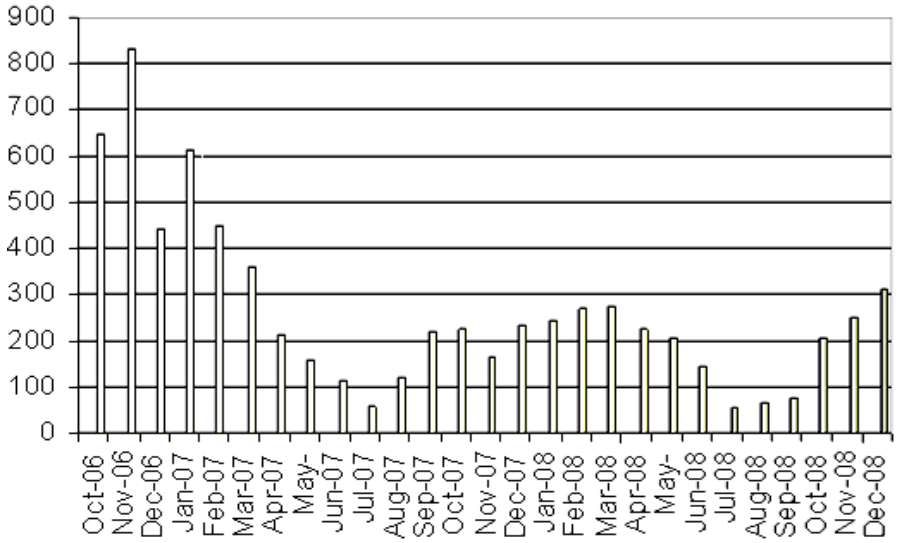

Figure 2. Seasonal variation among Egyptian Vulture in and around Jodhpur from October 2006 to December 2008.

Figure 3. *Nephron perchnopterus* feeding on remaining carcasses.

Conservation status and recommendations

The findings of this investigation suggest that the human population explosion had insisted various kinds of new building network of electricity lines, increase in mining and use of explosive matter in mining activity, renovation of forts and cutting of large trees and as well as other graphical changes in this region. Simultaneously, such kinds of eco-transformations have occurred either due to introduction of IGNP (Indra Gandhi Nahar Pariyojna) in the Thar Desert or some other kind of ecological parameters including drought, in this region. All these changes

Figure 4. Death of *N. percnopterus* owing to road accident near nesting site.

Table 3. Nesting sites and number of nest of Egyptian Vulture in and around Jodhpur.

Nesting site	Total number of nests
Mehrangarh Fort (Jodhpur Fort)	3
Arna Jarna hillock	7
CAZRI Campus	2
Barli Village	2
Machia Safari Park	8
Nagana Hill Barmer	2
Guda Vishnoian (Protected area)	11
Ratkuriya	12
Sathin (Protected area)	14
Bheembhadak Kayalana	4
Machia Fort	2
Total	**67**

ges have adversely affected the eco-status and demography of vultures in and around Jodhpur.

This study shows clearly that vulture diversity in this region declines day by day rather than increasing. The main reason behind this declination is loss of habitat, electrocution, unavailability of food and feral dog com-petition. Safe nesting and roosting sites are declining for the vulture in and around Jodhpur City. The insufficiency of good and safe nesting sites reduces their breeding success and increases chick mortality of the Egyptian vulture as found in the present study. Deforestation for agricultural interests, urbanization and firewood are also serious threat to nesting sites. Uncontrolled mining activity has vanished many of the cliffs and rocks, which were safe for nesting and roosting. These conditions have forced vultures to nest in risky cliffs, trees like *P. cinerara*, *T. undulata* and high tension electricity poles. Such cliffs are accessible by jackals, foxes and jungle cats, which are potential predators of the vulture eggs and chicks. Nesting on electricity poles is very risky and maximum death observed among Egyptian vulture is due to electrocution. Scarcity of nesting sites also increases intra and inter species competition for food and to occupy nests. During this interaction, many a time chicks and juveniles fall from the nests and are killed or injured and often become victim of dogs and other animals. It is high time to pro-

pose a remedial measure for increasing the vulture population in this area which is important for eco balance point of view. It is suggested that exhaustive study is required to know about the vulture eco status in the remaining districts of the Thar Desert. It will help to prepare the vulture conservation policy in the Thar Desert.

Conclusion

Monitoring of Egyptian Vulture during the winter season, that is, November-February would produce the most reliable population estimate. Surveys later than February should be avoided as non-breeding individuals of migratory species abandon the colonies. Colonies void of birds during May-October every year do not reflect a decline in population size and should not be regarded as deserted. Serious efforts must be taken to conserve and protect the breeding and feeding habitats of all species of vultures in the area investigated.

REFERENCES

Ali S, Ripley R (1987). Compact handbook of the birds of India and Pakistan. Oxford University press, Delhi. pp. 296-314.

Balmford A (2013) Pollution, Politics, and Vultures. Science 339:653-654.

Borello WD, Borello RM (2002). The breedings status and colony dynamics of Cape Vulture *Gyps coprotheres* in Botswana. Bird Conserv. Int. 12: 79-97.

Chhangani AK (2002a). Vultures the most eco-friendly birds. Sci. Rep. 39: 56-59.

Chhangani AK (2002). Avifavna in and around Jodhpur city, Rajasthan, India. Newsletter for Birdwatchers 42: 24-26.

Chhangani AK (2002b). Successful rescue and rearing of India long billed Vulture at Jodhpur zoo. India. Zoos Prints 17:20-22.

Chhangani AK (2002c). Ecology of Vulture of different species and an around Jodhpur (Rajasthan), India. Tiger Paper 29: 28-32.

Chhangani AK (2005). Population ecology of Vultures in the western Rajasthan, India. Indian Forester 131: 1373-1382.

Chhangani AK, Mohnot SM (2004). Is diclophenac the only cause of Vultures decline? Curr. Sci. 87: 1496-1497.

Chhangani AK, Mohnot SM, Purohit AK (2002). Population status of vultures in and around Jodhpur with special reference to long billed vulture (*Gyps Indicus*). J. Natcon. 14: 121-130.

Cramp S, Simmon KEL (1980). The birds of Western palearctic. Oxford University Press, Vol. II. Oxford.

Donazar JA, Ceballos O, Tella JL (1996). Communal roosts of Egyptian Vultures (*Neophron percnopterus*): dynamics and implications for the species conservation In Biologiay Conservacion delas Rapaces Mediterráneas, Monografias; Edn: Muntaner J, Mayol J. 4:189–201.

Donazar JA, Feijoo JE (2002). Social structure of Andean Condor roosts: influence of sex, age and season. Condor 104: 832–837.

Gilbert M, Watson RT, Virani MZ, Oaks JL, Ahmad S, Jamshed M, Choudhary I, Arshad M, Mahmood S, Ali A, Khan AA (2006). Rapid population declines and mortality clusters in three Oriental White Backed Vulture *Gyps bengalensis* colonies in Pakistan due to diclophenac poisoning. Oryx 40: 388-399.

Margalida A, Boudet J (2003). Dynamics and temporal variation in age structure at a communal roost of Egyptian Vultures (*Neophron percnopterus*) in north- eastern Spain. J. Raptor Res. 37: 252–256.

Marincovie S, Orladie L (1994). Status of the Griffon Vulture *Gyps fulvus* in Serbia. In Rapton Conservation Today; Ed. Meyburg BU, Chancellor RD: The Pica Press, Berlin. pp. 163-172.

Mundy PJ, Butchart d, Ledger J, Piper S (1992). The Vultures of Africa. Acorn Books and Russel Friedman Books, Randburg.

Newton I (1979). Population Ecology of Raptors. Buteo Books, Vermillion.

Ogada DL, Keesing F, Virani MZ (2012). Dropping dead: causes and consequences of vulture population declines worldwide. Ann. N. Y. Acad. Sci. 1249: 57-71.

Parker PG, Waite TA, Decker MD (1995). Kinship and association in communally roosting black Vultures. Anim. Behav. 49: 395–401.

Prakash V (1999). Status of Vulture in Keoladeo National Park, Bharatpur, Rajasthan, with special reference to population crash in Gyps species. J. Bombay Nat. Hist. Soc. 96: 365-368.

Prakash V, Rahmani AR (1999). Notes about the decline of Indian Vultures, with particular reference to Keoladeo National Park. Vulture's News 41:6-13.

Prakash VD, Pain J, Chunningham AA, Donald PF, Prakash N, Verma A, Gargi R, Kumar SS, Rahmani AR (2003). Catastrophic collapse of Indian white backed Gyps bengalensis and long billed Gyps indicus Vulture population. Biol. Conserv. 109:381-390.

Rabenold P (1986). Family associations in communally roosting black Vultures. Auk 103: 32–41.

Rahmani AR (1997). The effect of Indra Gandhi Nahar Project on the avifauna of the Thar Desert. J. Bombay Nat. Hist. Soc. 94: 233-236.

Rahmani AR (1998). Decline of Vultures in India newsletter. Bird watchers 38(5):80-81.

Robertson AS, Boshoff AF (1986). The Feeding Ecology of Cape Vultures *Gyps coprotheres* in a Stock Farming Area. Biol. Conserv. 35: 63–86.

Thomson WL, Yahner RH, Storm GL (1990). Winter use and habitat characteristics of Vulture communal roosts. J. Wildl. Manage. 54: 77–83.

Virani M, Gilbert M, Watson R, Oaks L, Benson P, Khan AA, Baral HS, Giri JB (2001). Asian Vulture crisis project: field results from Pakistan and Nepal for the 2000–2001 field season; Edn. Katzner T, J. Parry Jones Eds. Reports from the workshop on Indian Gyps Vultures, 4th Eurasian congress on raptors, Sevilla, Spain, September 2001. Seville, Spain: Estacion Biologica Donana Raptor Research Foundation. pp. 7–9.

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Full Length Research Paper

Pattern of litter fall and litter decomposition in a *Quercus leucotrichophora* A. Camus forest in Kumaun Himalaya

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The present paper reports on the leaf litter, wood litter, miscellaneous litter and total litter fall in *Quercus leucotrichophora* forests of the Kumaun Himalaya. Peak values of leaf, wood and miscellaneous litter fall occurred in May, June and November and December respectively. The total annual litter fall was 538.85 g m^{-2}, of which leaf, wood and miscellaneous litters accounted for 72.35, 23.04 and 4.53% respectively. Monthly leaf litter fall, wood litter fall and total litter fall was positively related to the monthly temperature of the site.

Key words: Kumaun Himalaya, leaf Litter fall, wood litter fall, miscellaneous litter fall, total litter fall, seasonal variation.

INTRODUCTION

Litter fall because of its intrinsic nature to all vegetation represents an innate part in the organic continuity and the self perpetuating nature of forests, being the major pathway of nutrients return to the soil. The cycling of materials is inherent in the functioning of ecosystems and is integral to their structure and functioning. The importance of litter production has been recognised for a long period of time and consequently many studies have been carried out. Litter fall has an important influence on soil formation because it is a major component in the circulation of mineral elements and contains many complex organic compounds, which vary in biological degradability (Spain, 1973).

Mathur et al. (1982) observed that the thick layer of humus beneath the forest floor improves the infiltration rates of the forest soils. Verma et al. (1982) reported a great heterogeneity in the chemical contents of forest soil under heterogenous forest composition. Dwyer and Merriam (1981) observed that greater litter weight and depth reduced moisture loss and supported a larger bacterial population. Thus litter on the forest floor plays a significant role in determining the moisture status, runoff pattern and liberation of mineral elements accumulated in the aerial parts of the vegetation. Litter fall represents an essential link in organic production – decomposition cycle and is thus a fundamental ecosystem process (Meentemeyer et al., 1982). Proctor (1983) has argued that litter fall is relatively easy to measure and has been investigated at least for one of the following reasons: to provide an index of production; to give information (when combined with measurements of floor litter standing-crop) on decomposition rates; to give information on tree phenology, and to quantify an important pathway in mineral nutrient cycles.

Decomposition process play important role in soil fertility, in terms of nutrient regeneration and maintenance of organic matter level. The release of nutrients from decomposing leaf litter is a basic process

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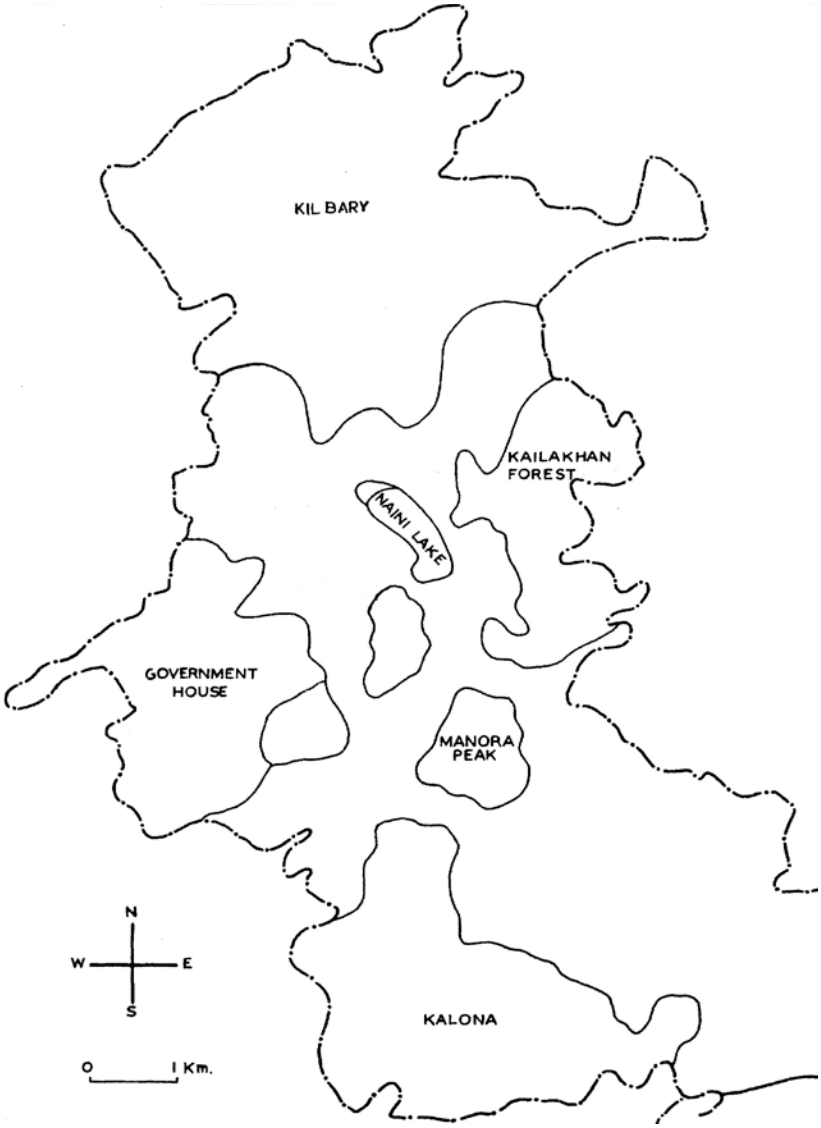

Figure 1. Location of oak forest in Kumaun study area.

in nutrient cycling within forest. Decomposition of litter is regulated by a host of variables including the litter's physical and chemical properties, habitat and macro and microfaunal responses. From 10,000 to 4,000 years B. P., *Quercus leucotrichophora* was dominant at elevation from 1,000 to 2,000 m throughout the Central and Western Himalaya. *Q. leucotrichophora* are intricately associated not only with agro-ecosystems but also with the life-support systems of the inhabitants of the hills in this area. This species is heavily used for fuel and fodder, and can be correlated with natural springs and wildlife (Singh, 1981). With increasing biotic stress, this species depleted rapidly in recent years.

The paper describes: (1) to quantify the annual litter fall and litter decomposition in *Q. leucotrichophora* forest and (2) to compare the results with those of other deciduous forests in the Mediterranean and temperate regions.

METHODOLOGY

Location

The study was conducted in Kuamun Himalaya, India (29°18'N, 79°28'E, and elevation 2200 m above mean sea level) (Figure 1). Principal site characteristics are given in Table 1. Detailed descriptions of the vegetation of this region are available in Saxena and Singh (1982), Singh and Singh (1986) and Tiwari et al. (1986).

Climate

The climate is characterized by a summer monsoon and the year has four distinct seasons namely, monsoon (July to September), post-monsoon (October to November), winter (December to

Table 1. Predominant species, mean annual rainfall, mean annual temperature, altitude and certain soil characteristics of the study site in Kumaun Himalayan forest.

Forest site/ dominant species	Total annual rainfall (mm)	Mean annual Temp. (°C)	Altitude (m)	Organic matter	Soil characteristics (0 - 30 cm depth) available				
					C (%)	Sand (%)	Silt (%)	Clay (%)	pH
Quercus leucotrichophora, Myrica esculenta, Rhododendron arboretum, Acer oblongum	2195	28	2000-2200	13.18	7.65	78.12	16.56	6.89	5.3

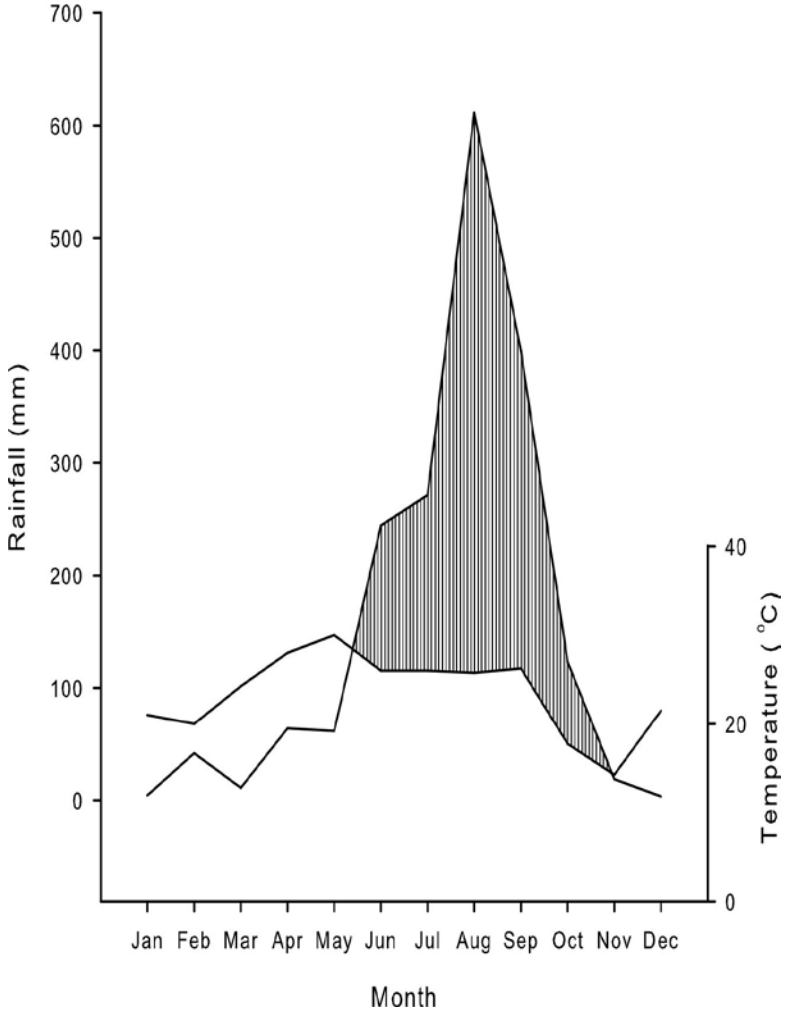

Figure 2. Rainfall and mean monthly temperature for the experimental site.

January) and summer (April to mid-June). Climatic data for 2008 to 2009 were obtained from the State Observatory at Nainital (Figure 2). The average annual rainfall is 195.87 mm of, 60% of which was occurs in the rainy season and the mean daily temperature ranges from 3.5 to 28°C.

Soils

The soils are residual, originating from slates, phyllites, sandstone, and limestone of the Krol series. Typical features of the soils of oak-dominated forests, as described by Saxena (1979), Tewari (1982), and Upreti (1982) are: (1) soils are generally brown in colour, sandy loam in texture, and slightly acidic; (2) the percentage of sand in the soil tends to decrease with increasing elevation, but is greater at disturbed than undisturbed sites; (3) soils are generally nitrogen-rich; within the same forest the nitrogen content is invariably higher on mesic hill slopes than on drier slopes. Sand predominates in the soil (60 to 80%), while the silt and clay contents are 10 to 20 and 5 to 10%, respectively. Organic matter ranges between 10.0 and 18.5% and available C between 3.2 and 8.1%, the soil pH ranges between 5 and 6 (Table 1).

For studying litter production in banj oak forest three plots of 31.5 ×

Table 2. Coefficients of correlation, slope and intercepts of the relationships between litter fall per month (Y, gm^{-2}) and mean monthly temperature (X, °C) of *Quercus leucotrichophora* forest.

Litter type	Intercept	Slope	r
Leaf	-79.30	3.776	0.873**
Wood	-11.611	0.737	0.737**
Miscellaneous	-1.01	0.107	0.803**

** Significant at P < 0.01.

Table 3 Coefficients of correlation, slope and intercepts of the relationships between litter fall per month (Y, gm^{-2}) and mean monthly rainfall (X, mm) of *Quercus leucotrichophora* forest.

Litter type	Intercept	Slope	r
Leaf	43.676	-0.241	-0.628*
Wood	13.718	- 0.076	-0.858**
Miscellaneous	1.699	0.007	0.554*

*Significant at P < 0.05, ** Significant at P < 0.01.

Table 4 Seasonal pattern of litter fall estimated through litter traps (g m^{-2} ± SE).

Season	Litter fall pattern			
	Leaf	Wood	Miscellaneous	Total
Winter	74.60 ± 2.5	29.85 ± 4.2	9.00 ± 3.2	113.45 ± 7.5
Summer	184.35 ± 12.5	45.15 ± 6.4	4.05 ± 2.1	233.55 ± 9.3
Monsoon	75.35 ± 4.7	35.30 ± 8.2	5.60 ± 1.8	116.65 ± 3.7
post monsoon	55.60 ± 3.6	13.85 ± 2.4	5.75 ± 1.3	75.2 ± 5.3

31.5 m^2 were selected on site. The litter was measured by placing five litter traps (1 × 1 m^2) on the forest floor randomly at each site. Each trap was 2 mm mesh nylon, supported by wooden sides with 25 cm height. Litter from these traps was collected separately in paper bags and brought in to laboratory where the sample was sorted out in to three main categories namely (i) leaf litter (ii) woo-den litter (<2 cm Diameter) and (iii) miscellaneous litter and dried in shade. Litter sampling study was done during May 2008 to April 2010.

The air-dried leaves were thoroughly mixed and 10 g samples were enclosed in 20 × 20 cm nylon bags (Crossley and Hoglund, 1962). Mesh size was 10 mm. Thirty six litter bags were placed on the forest floor in the beginning of the rainy season of 2008. No spatial displacement of bags due to wind action, etc. was noticed during the study. These bags were removed at monthly intervals. At each sampling time, retrieved bags were brought back to the laboratory, extra material was removed and the wet weight of the material measured. The material was reweighed after oven drying at 60°C.

RESULTS AND DISCUSSION

Litter fall

The leaf fall is greatest in the summer season (47.29%), followed by the monsoon (19.33%), winter (19.13%) and post monsoon seasons (14.26%). The contribution of leaf litter to total annual litter production was highest during summer months; the leaf litter accounted for 18.47% (May) to 12.53% (June) of the respective total monthly fall (Figure 3).

The contribution of wood litter to total annual litter production was highest during summer seasons; the wood litter accounted for 13.74% (June) to 10.14% (May) of the respective total monthly fall. The wood fall was greatest in the summer season (36.92%), followed by the monsoon (28.86%), winter (24.4%) and post monsoon seasons (9.81%).

The contribution of miscellaneous litter to total annual litter production was highest during winter seasons; the miscellaneous litter accounted for 12.3% (January) to 6.15% (December) of the respective total monthly fall. The miscellaneous fall was greatest in the winter season (36.69%), followed by the post monsoon (23.57%), monsoon (22.96%) and summer season (16.6%).

The relationship between the litter fall to mean monthly temperature and mean monthly rainfall was found significant (Tables 2 and 3). The contribution of leaf fall to total annual litter in respective month was highest during summer months; the leaf litter accounted for 78.7% (April) to 84.0% (May). The wood fall contribution was highest during monsoon months; the wood litter accounted for 31.7% (August) to 27.1% (September) and highest during winter by Miscellaneous litter. The miscellaneous litter accounted for 6.7% (December) to 19.2% (January) (Table 4).

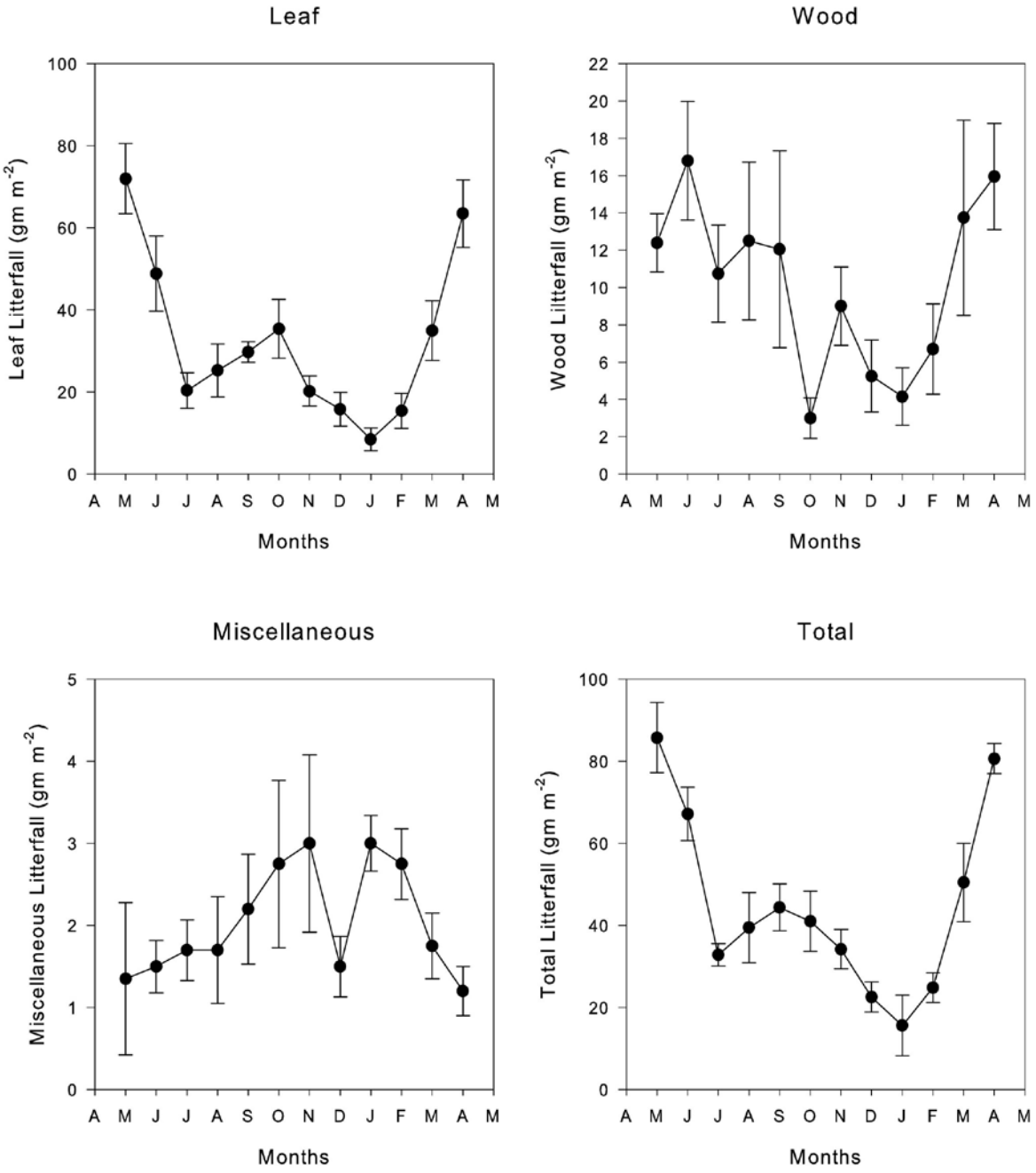

Figure 3. Monthly leaf, wood, miscellaneous and total litter fall (g m^{-2}) in banj oak forest.

Litter decomposition

Moderate temperate and abundant moisture in rainy season and higher temperature of summer season are congenial for decomposition. The loss in dry weight of oak litter during the first one year of decomposition was 67.55%, the faster decomposition rate was calculated in the month of August (10.22%) and September (9.45%). While lowest rate of decomposition was in noted in the month of May (2.11%). Singh and Singh (1984) have reported 80.45% decomposition for oak litter in 365 days. The present finding is in contradictory to the observation of Singh and Singh (1984).

The weight loss rate on each site was markedly affected by rainfall; the weight loss per month and the rainfall per month were positively related according to the following formula:

$Y = 2.048 + 0.114\ X$ (r = 0. 0.803, d.f. = 11, P < 0.01)

Where, Y = percentage weight loss per month (%) and X = rainfall per month (mm).

Table 5. Annual litter fall values (t ha^{-1}) of some temperate and Mediterranean forests (all fractions).

Forest type	Location	Litter fall	Reference
Temperate			
Quercus petraea	England	3.86	Carlisle et al., (1966)
Q. petraea	Netherlands	6.31	van der Drift (1981)
Q. robur	Sweden	5.28	Anderson (1970)
Q. floribunda Q. lanuginosa, Q. leucotrichophora	India	4.7 - 7.8	Rawat and Singh (1989)
Q. leucotrichophora	Kailakhan	5.39	Present study
Q. cerris var. *cerris*	Northern Turkey	6.81	Kutbay and Horuz (2001)
Q. pyrenaica	Salamanca, Spain	5.62	Gallardo et al. (1989)
North American oak forests	Minnesota, USA	4.57	Reiners and Reiners (1970)
Quercus-Acer	USA	4.89	Vitousek (1982)
Quercus-Betula	USA	3.70	Witkamp and van der Drift (1971)
Acer-Fagus-Quercus	Indiana, USA	5.23	Vitousek et al.,(1982)
Alnus rubra	Oregon, USA	4.49 - 9.90	Zavitkovski and Newton (1971)
A. rubra	USA	7.80	Turner et al. (1976)
Castanea sativa	Salamanca, Spain	6.18	Gallardo et al., (1989)
Fagus sylvatica	Southern Sweden	5.70	Nihlgard (1972)
Mediterranean			
Quercus coccifera	Southern France	2.30 - 2.60	Rapp (1969)
Q. ilex	Southern France	3.80 - 7.00	Rapp (1969)
Q. ilex	France	4.22	Lossaint and Rapp (1978)
Q. ilex	Etna, Italy	3.57	Leonardi and Rapp (1981)
Q ilex	Spain	2.28	Bellot et al., (1992)
Q. ilex	Northern Spain	3.1	Mayor and Roda (1992)
Q. suber	Iberian Peninsula	2.88 - 4.33	Robert et al.,(1996)

The moisture content of decomposing leaf litter was positively related, according to the following regression:

$Y = 3.810 + 0.017\ X$ (r = 0.744, d.f. = 11, P < 0.01)

Where, Y = % weight loss per 60 days and X = % moisture content on each 60th day.

The production of litter depends primarily on the site productivity, but other properties of the environment, as well as chance, may introduce important variation. Litter alters the physical and chemical environment directly and indirectly. The physical changes produced by litter also alter the activity of decomposers, resulting in an indirect effect on the chemical environment.

Williams and Gray (1974) and Sain and Broadbent (1975) have stressed the positive effect of the moisture content on decomposition rate. The moisture content of decomposing leaf litter varied markedly on site as did the periodic weight loss. The annual litter fall value of the studied *Q. leucotrichophora* forest was 5.39 t ha^{-1}. This value is somewhat similar to the values reported from India (Table 5). With 72% percentage contribution of leaf fall to the total annual litter fall was comparable to the values reported by Singh (1992) for dry deciduous forests of India. This value is also similiar to global averages (70% for leaf litter) reported by Meentemeyer et al. (1982) and it is within the range of 40 to 85% given for temperate forests around the world by Rodin and Bazilevich (1967). A review of litter fall data for a number of temperate and Mediterranean forests is given in. In an earlier review Madge (1965) found annual litter mass values between 3.6 and 39.9 t ha^{-1} in the temperate region. Annual litter fall values of evergreen Mediterranean-type *Quercus* forests were lower than those of temperate deciduous *Quercus* forests including the studied Turkey oak forest.

REFERENCES

Anderson F (1970). Ecological studies in a Scanian woodland and meadow area, southern Sweden. II. Plant biomass, primary production and turnover of organic matter. Bot. Not. 123:8-51.

Bellot J, Sanchez JR, Lledo MJ, Martinez P, Escarre A (1992). Litterfall as a measure of primary production in Mediterranean holm-oak forest. Vegetatio. 99-100:69-76.

Carlisle A, Brown AHF, White EJ (1966). Litterfall, leaf production and effects of defoliation by *Tortrix viridiana* in a sessile oak *(Quercus petraea)* woodland. J. Ecol. 54:65-85.

Dwyer LM, Merriam G (1981). Influence of topographic heterogeneity on deciduous litter decomposition. Oikos. 37:228-237.

Gallardo JF, Santa Regina I, San Miguel C (1989). Ciclos bioegeoquimicos en bosques de la Sierra de Bejur (Salamanca, Espana). 1. Production de hojarasca. Rev. Ecol. Bioi. Sol. 26:35-46.

Kutbay HG, Hourz A (2001). Litter fall and nutrient return in *Quercus cerris* L. var. *Cerris* forests in the central black sea region of turkey. Pak. J. Bot. 33(3):293-303.

Kutbay HG, Kilinç M (1994). Sclerophylly in *Quercus cerris* L. var. *cerris* and *Phillyrea latifolia* L. and edaphic relations of these species. Vegetatio. 113:93-97. Leonardi S, Rapp M (1981). Retour au sol d' éléments mineraux et d' azote par 1' intermediaire des litières dans un ecosystème à *Quercus ilex* L. du Monte Minardo (Etna). Flora. 171:329-337.

Lossaint P, Rapp M (1978). La fôret méditerranéenne des chénes verts. In: (Eds.): M. Lamotte, F. Bourliére. Problèmes d' Écologie, Ecosystèmes Terrestres. Ed. Masson, Paris. pp. 129-185.

Madge DS (1965). Leaf fall and litter disappearance in tropical forests. Pedobiologia. 5:273-288.

Mathur HN, Singh RP, Gupta MK (1982). Comparative study of infiltration in soil under forest cover and agriculture in temperate climate. Indian Forester. 108:648-652.

Mayor X, Rodá F (1992). Is primary production in holm oak forests nutrient limited? Vegetation. 100:209-217.

Meentemeyer V, Box EO, Thompson R (1982). World patterns and amounts of terrestrial plant litter production. Bioscience. 32:125-128.

Nihlgard B (1972). Plant biomass, primary production and distribution of chemical elements in a beech and a planted spruce forest in southern Sweden. Oikos. 23:69-81.

Proctor J (1983). Tropical forest litter fall. I. - Problems of data comparison. In: Sutton, S L., Whitmore, T. C. & Chadwick, A. C. (eds.), Tropical rain forest: ecology and management, Blackwell Scientific Publications, Oxford. pp. 267-273.

Rapp M (1969). Production de litière et apport au sol d' éléments minéraux dans deux Écosystemes méditerranéenne de la fôret de *Quercus ilex* et la garrigue de *Q. coccifera*. Oecol. Plant. 4:377-410.

Rawat YS, Singh JS (1989). Forest floor biomass, litter fall and nutrient return in Central Himalayan oak forests. Vegetatio. 82:113-125.

Reiners WA, Reiners NM (1970). Energy and nutrient dynamics of forest floors in three Minnesota forests. J. Ecol. 58:497-519.

Robert B, Caritat A, Bertoni G, Vilar L, Molinas M (1996). Nutrient content and seasonal fluctuations in the leaf component of cork oak: (*Quercus suber* L.) litter fall. Vegetatio. 122:29-35.

Rodin LE, Bazilevicb NL (1967). Production and mineral cycling in terrestrial vegetation, Oliver and Boyd Ltd., Edinburgh, London.

Sain P, Broadbent FE (1975). Moisture absorption, mold growth and decomposition of rice straw at different relative humidities. Agron. J. 67:759-762.

Saxena AK (1979). Ecology of vegetation complex of northwestern catchment of river Gola. Ph.D. Thesis, Kumaun University, Nainital. p. 484.

Saxena AK, Singh JS (1982). A phytosociological analysis of woody species in forest communities of a part of Kumaun Himalaya. Vegetatio. 50:3-22.

Singh JS, Singh SP (1984). An Integrated Ecological study of Eastern Kumaun Himalaya with Emphasis on Natural Resources. Final report (HCS/DST/76) Kumaun University, Nainital. pp. 1-3.

Singh L (1992). Dry matter and nutrient inputs through litter fall in dry tropical forest of India. Vegetatio. 98:129-140.

Singh SP (1981). Rural ecosystems and development in the Himalaya. In Singh, J. S., Singh, S. P., and Shashtri, C. (eds.), Science and Rural Development in Mountains. Gyanodaya Prakashan, Nainital, India, pp. 74-87.

Singh SP, Singh JS (1986). Structure and function of the Central Himalayan oak forests. Proc. Indian Acad. Sci. (Plant Sci.). 96:159-189.

Spain AV (1973). Litter fall in a New South Wales conifer forest: A multivariate comparison of plant nutrient element status and return in four species. J. Appl. Ecol. 10:527-556.

Tewari JC (1982). Vegetation analysis along altitudinal gradients around Naini Tal. Ph.D. Thesis, Kumaun University, Nainital, India. pp.570.

Tiwari AK, Mehta JS, Goel OP, Singh JS (1986). Geoforestry of landslide affected areas in a part of Central Himalaya. Environ. Conser. 13:299-309.

Turner J, Cole DW, Gessel SP (1976). Mineral nutrient accumulation and cycling in a stand of red alder (Alnus rubra). J. Ecol. 64:965-974.

Upreti N (1982). A study on phytosociology and state of regeneration of oak forests at Nainital. Ph.D. Thesis, Kumaun University, Nainital. p. 481.

Van der Drift J (1981). In: Dynamic Properties of Forest Ecosystems (Ed): D.E. Reichle. Cambridge University Press, Cambridge. p. 607.

Verma SC, Jain RK, Rao MV, Misra PN, Murty AS (1982). Influence of canopy and soil composition of man made forest in alkali soil of Bhanthra (Lucknow). Indian Forester. 108:431-437.

Vitousek P (1982). Nutrient cycling and nutrient use efficiency. Amer. Not. 119:553-572.

Vitousek P, Gosz JR, Grier CC, Melillo JM, Reiners WA (1982). A comparative analysis of potential nitrification and nitrate mobility in forest ecosystems. Ecol. Manogr. 52:155-177.

Williams ST, Gray TRG (1974). Decomposition of litter on the soil surface. In: Dickinson CH, Pugh GJF (Eds) Biology of plant litter decomposition, Academic, London. 2:611-632.

Witkamp M, van der Drift J (1971). Breakdown of forests litter in relation to environmental factors. Plant Soil. 15:293-311.

Zavitkovski J, Newton M (1971). Litter fall and litter accumulation in red alder stands in Western Oregon. Plant Soil. 35:257-268.

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Full Length Research Paper

Correlation and path coefficient analysis of yield and yield components in lentil (*Lens culinaris* Medik.) germplasm in the highlands of Bale, Ethiopia

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Genetic diversity is essential for genetic improvement of given crops. If the information on genetic diversity is not enough to utilize, the available variability genetic diversity study should be crucial. Accordingly, twelve lentil germplasms were evaluated at two locations, Sinana and Agarfa, South eastern Ethiopia in the 2012/13 cropping season to obtain information on genetic diversity and variability in the Ethiopian lentil germplasm. At Sinana, the genotypic correlation revealed that number of pod per plant had positive and highly significant association with seed yield, whereas hundred seed weight, days to maturity, number of seeds/plant and plant height had positive but non-significant association with seed yield per plot. However, negative association was observed for stand percentage. At Agarfa, positive and highly significant association was observed between number of pods/plant and seed yield, whereas plant height and number of seeds/pod had negative and highly significant association with seed yield at the genotypic level. The genotypic path analysis at Sinana showed that number of pods/plant and seeds/pod had very high and positive direct effect on seed yield, whereas days to maturity and plant height had negative direct effect on seed yield. At Agarfa, positive direct effect on seed yield was observed in days to maturity and stand percentage; whereas negative direct effect on seed yield was observed in plant height and hundred seed weight at genotypic level.

Key words: Genetic diversity, correlation, direct and indirect effect.

INTRODUCTION

Lentil (*Lens culinaris* Medik.) was one of the first domesticated plant species; its remains are as old as those of einkorn, emmer, barley and pea (Harlan, 1992). It has been cultivated for 10,000 years in the most difficult agricultural environments; is is perhaps second only to barley in this sense. It is an old world legume grown mainly in Central and South west Asia, Southern Europe, North Africa and Ethiopia. Ethiopia ranks first in its production and acreage in Africa followed by Eritrea, morocco, Egypt and Tunisia.

In world's lentil production, Ethiopia is 10th, India is leading followed by Canada, Turkey and Bangladesh (FAO, 2001). In Ethiopia, 1 616809.37 hectares of land are allocated for pulse crops; out of which 109895.27 is cultivated with lentil, which accounts for 6.79% of the total land allotted for pulse crops. In the study sites, Bale Zone, Ethiopia ester lentil accounts for 4.99% of the total pulse crops (CSA, 2011). The average lentil seed yield obtained in the study area ranged from 15-22qt./ha.

The lentil (*L. culinaris* Medikus subsp. *culinaris*) is a lens-shaped grain legume well known as a nutritious food. It grows as an annual bushy leguminous plant;

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Table 1. Lists of lentil genotypes tested in the study.

SRRL-27-6
FLIP-86-16L
SRRL-36-5
FLIP-86-38L
SRRL-20-5
ILL-590
SRRL-17-5
Acc. No. 36152
Acc. No. 36103
ILL-1861
Asano
Local cultivar

typically 20-45 cm tall; it produces many small purse shaped pods containing one to two seeds each. Lentil seed is a rich source of protein, minerals (K, P, Fe and Zn) and vitamins for human nutrition (Bhatty, 1988). Furthermore, because of its high lysine and tryptophane content, its consumption with wheat or rice provides a balance in essential amino acids for human nutrition. Lentil straw is also a valued animal feed (Erskine et al., 1990).

Lentil seeds are consumed as whole grains and as dehulled *dhal*. There are two types of lentil: the large seeded (*macrosperma*) and the small to medium sized seeded (*microsperma*) lentil. The color of seeds also varies with lines being brown, red, green or white. Lentil seeds are relatively higher in protein content (25 percen-tage), carbohydrates and calories than other legumes (Muehlbauer et al. 1985).

Plant breeders are seldom interested in one character, and therefore, there is the need to examine the relationship among various characters, especially between yield and other characters. Selection is an integral part of a breeding program by which genotypes with high productivity in a given environment could be developed. However, selection for high yield is made difficult because of its complex nature. This selection criterion takes into account the information on interrelationship among agronomic characters, their relationship with grain yield as well as their direct influence on grain yield. Nevertheless, selection for yield *via* highly correlated characters becomes easy if the contribution of different characters to yield is quantified using path coefficient analysis (Dewey and Lu, 1959). According to Hawatin (1978), when there is little or no work done on determining associations of characters, selection may be based on little more than an intelligent guess and it may lead to the practice of unilateral selection of characters.

Generally, information and knowledge of the extent and pattern of variability, particularly of genetic variability present in a population of a given crop is absolutely essential for further improvement of the crop. In Ethiopia, since the information on genetic diversity and correlation among different growth parameters on lentil is limited, this study was mainly emphasized to generate informa-tion on the genetic variability and association among yield components in lentil. Based on this, the aim of this present work is study the associations among yields and yield related traits in lentil.

MATERIALS AND METHODS

The experiment was carried out at two locations. One of the experimental sites was at the research farm of Sinana Agricultural Research Center, Oromia Agriculture Research Institute, and the other was at Agarfa sub-site in Southeastern Ethiopia. The experiment was conducted at each location on vertisol clay loam soil under rain fed conditions during the Meher season (August-January) of 2012/13 cropping season. Meher season is characterized by annual rain fall of 850 mm, and with minimum and maximum temperature of 9 and 22°C, respectively.

Twelve lentil genotypes were used for this study (Table 1). The genotypes were arranged in randomized complete block design with four replications. Each experimental plot consisted of 4m long rows with inter-row spacing of 20-cm. Seeding rate was applied at the rate of 65 kg/ha .Weeds were controlled by hand. Data were collected on both plot and plant basis.

Phenotypic (r_p) and genotypic (r_g) correlation coefficient

Correlation coefficient (r)

Phenotypic correlation, the observable correlation between two variables, which includes both genotypic and environmental effects, and genotypic correlation, the inherent association between two variables were estimated using the standard procedure suggested by Miller et al. (1958). Covariance analysis between all pairs of the variables followed the same form as the variance. Thus, estimates of genetic covariance component between two traits (σg_{xy}) and the phenotypic covariance component (σp_{xy}) were derived in the same fashion as for the corresponding variance components:

$$r_{gxy} = \frac{\sigma g_{xy}}{\left[\sqrt{\sigma^2 g_x \mathrm{X} \sigma^2 g_y}\right]}$$

$$r_{pxy} = \frac{\sigma p_{xy}}{\left[\sqrt{\sigma^2 p_x \mathrm{X} \sigma^2 p_y}\right]}$$

where, σg_{xy} = genotypic covariance of two variables x and y; σp_{xy} = phenotypic covariance of two variables x and y.

Path coefficient analysis

Path coefficient analysis was carried out using the phenotypic correlation coefficients as well as genotypic correlation coefficients to determine the direct and indirect effects of the yield components and other morphological characters on seed yield. Path coefficient analysis was also conducted to determine the direct and indirect effect of various traits on seed yield using the general formula of Dewey and Lu (1959).

Table 2. Genotypic correlation coefficient (above diagonal) and phenotypic correlation coefficient (below diagonal) for 7 traits of lentil genotypes tested at Sinana in 2012.

	Days to mature	Plant ht. (cm)	Stand percentage	Number of pod/plant	Number of seed/pod	100 seed wt. (g)	Seed yield (kg/ha)
Days to mature		0.47	-0.07	0.71**	0.39	0.21	0.44
Plant height (cm)	0.17		-0.20	-0.33	0.92**	0.20	0.09
Stand percentage	-0.06	0.03		-0.94**	0.73**	0.24	-0.04
No. pod/plant	0.04	0.17	0.12		-0.18	-0.06	0.97**
No. seed/pod	0.05	0.04	0.01	-0.05		0.35	0.23
100 seed wt	0.20	0.11	0.10	0.01	0.10		0.52
Seed yield	0.30	0.16	0.08	0.04	-0.03	0.36	

** Significant at n-2 degree freedom, where n is the number of genotypes.

Table 3. Genotypic correlation coefficient (above diagonal) and phenotypic correlation coefficient (below diagonal) for 7 traits of lentil genotypes tested at Agarfa in 2012.

	Days to Mature	Plant ht. (cm)	Stand percentage	Number of pod/plant	Number of seed/pod	100 seed wt. (g)	Seed yield (kg/ha)
Days to Mature		0.26	0.08	0.76**	-0.04	0.21	0.03
Plant ht. (cm)	0.006		0.01	-0.12	0.02	-0.40	-0.73**
Stand percentage	0.21	-0.02		0.09	-0.47	0.20	0.12
No. pod/plant	0.15	0.05	-0.02		0.82**	-0.93**	0.92**
No. seed/pod	0.05	0.09	-0.11	-0.03		-0.08	-0.89**
100 seed wt	0.14	-0.10	0.11	-0.15	0.03		0.23
Seed yield	0.04	0.03	0.28	0.02	0.03	0.17	

Path coefficient

$$r_{ij} = p_{ij} + \sum r_{ik} p_{kj}$$

where, r_{ij} = mutual association between the independent character (i) and dependent character (j) as measured by the correlation coefficients; p_{ij} = components of direct effects of the independent character (i) on the dependent variable (j) as measured by the path coefficients and $\sum r_{ik} p_{kj}$ = summation of components of indirect effects of a given independent character (i) on a given dependent character (j) *via* all other independent characters (k).

RESULTS AND DISCUSSION

Correlation studies

Estimates of correlation coefficient at genotypic and phenotypic level for individual locations are given in Tables 2 and 3.

At Sinana (Table 2), number of pods/plant (0.92) had positive and highly significant association with seed yield. Similar positive association between number of pods/plant and seed yield was reported by different investigators (Seifu, 1988; Ramigry et al., 1989; Zaman et al., 1989; Bakhsh et al., 1991; Esmail et al., 1994; Khattab, 1995; Kumar et al., 1995; Singh et al., 1995; Abo-Shetaia et al., 1997; Chakraborty and Haque, 2000).

Though the association was non-significant, hundred seed weight (0.52), days to maturity (0.44), number of seeds/pod (0.23) also showed positive association with seed yield. However, stand percentage had very low and negative association with seed yield at genotypic level. Though the correlation value of seed yield with other parameters at phenotypic level was low, it showed the same trend with the corresponding genotypic correlation. The association among other parameters indicates plant height and stand percentage had positive and highly significant association with number of seeds/pod; whereas, stand percentage had negative and highly significant association with number of pods/plant. In the same manner, days to maturity also had positive and highly significant association with number of pods/plant. Positive and non-significant association was also observed among days to maturity, plant height, stand percentage and number of seeds/pod with hundred seed weight. Days to maturity also had positive association with plant height; whereas the other parameters had negative association with one another at genotypic level.

At Agarfa (Table 3) similar to Sinana, the correlation between numbers of pods/plant with seed yield was positive and highly significant. This indicates that plants with more number of pods per plant provide more seed yield than those of less number of pods. Thus selection for pods per plant will bring about a significant seed yield

Table 4. Estimate of direct (bold) and indirect effect at genotypic levels for 6 traits on seed yield at Sinana.

Variables	Days to mature	Plant ht. (cm)	Stand percentage	Number of pod/plant	Number of seed/pod	100 seed wt. (g)
Days to mature	-0.82	-0.38	0.03	0.88	0.64	0.09
Plant ht. (cm)	-0.39	-0.80	0.08	-0.41	1.52	0.09
Stand percentage	0.06	0.16	-0.40	-1.15	1.20	0.10
No. pod/plant	-0.59	0.27	0.37	1.23	-0.29	-0.02
No. seed/pod	-0.32	-0.74	-0.29	-0.22	1.64	0.15
100 seed wt	-0.17	-0.16	-0.09	-0.07	0.58	0.44

Table 5. Estimate of direct (bold) and indirect effect at phenotypic levels for 6 traits on seed yield at Sinana.

Traits	Days to Mature	Plant ht. (cm)	Stand percentage	Number of pod/plant	Number of seed/pod	100 seed wt. (g)
Days to Mature	0.23	0.016	-0.003	-0.00002	-0.004	0.059
Plant ht. (cm)	0.04	0.094	0.002	-0.0001	-0.003	0.033
Stand percentage	-0.01	0.003	0.06	-0.00005	-0.001	0.031
No. pod/plant	0.01	0.016	0.01	-0.0004	0.004	0.002
No. seed/pod	0.01	0.004	0.0004	0.00002	-0.1	0.031
100 seed wt	0.05	0.010	0.01	-0.000003	-0.01	0.304

improvement. This finding was in agreement with the result reported by Khattab (1995), Kumar et al. (1995), Singh et al. (1995), Abo-Shetaia et al. (1997) and Chakraborty and Haque (2000). Plant height (-0.73) and number of seeds/pod (-0.89) had negative and highly significant association with seed yield. The association among other parameters indicated as number of pod per plant showed positive and highly significant association with number of seeds/pod (0.82); and negative but highly significant association with hundred seed weight (-0.93). Days to maturity (0.76) had also positive and highly significant association with number of pods/plant.

Path analysis

Genotypic and phenotypic direct and indirect effect of six traits on seed yield at Sinana is presented in Tables 4 and 5, respectively. Accordingly, high level of direct effect was observed by number of seed/pod (1.64) followed by number of pods/plant (1.23) and hundred seed weight (0.44). On the contrary, days to maturity, plant height and stand percentage had negative direct effect on seed yield. Days to maturity and plant height though had positive association with seed yield, their direct effect was negative. This was due to the counter balancing of the negative indirect effect of other parameters. Days to maturity had positive indirect effect on seed yield *via* number of pods/plant (0.88) and seeds/pod (0.64), hundred seed weight (0.09) and stand percentage (0.03). And it also had negative indirect effect on seed yield *via* plant height. Number of pods/plant not only had positive and high direct effect on seed yield, it also had negative indirect effect on seed yield *via* days to maturity, number of seeds/pod and hundred seed weight. Therefore, one has to take this into consideration if seed yield improvement is to be achieved *via* number of pods/plant. Similar trend was observed among the parameters on seed yield at the phenotypic level, though the values are too low.

In Agarfa, at genotypic level (Table 6), positive direct effect on seed yield was observed in days to maturity (0.92) and stand percentage (0.05). Negative direct effect on seed yield was observed in plant height (-1.41), hundred seed weight (-0.98), number of seeds/pod (-0.53) and number of pods/plant (-0.44). At this location, though number of pods/plant and hundred seed weight had negative direct effect on seed yield, they had positive association with seed yield. This is due to the counter balancing of the positive indirect effect of other parameters. Number of pods per plant had positive indirect effect on seed yield *via* all parameters except number of seeds/plant. On the other hand, number of seeds per pod had negative indirect effect on seed yield *via* all parameters except hundred seed weight. Hundred seed weight had positive indirect effect on seed yield *via* all parameters. Similar trend again was observed in the variables for the phenotypic path too. At phenotypic level (Table 7), only stand % showed positive direct effect on seed yield but the other parameters showed negative direct effect on seed.

Conclusion

Understanding of the magnitude of variability present in crop plants and the degree of association between the

Table 6. Estimate of direct (bold) and indirect effect at genotypic levels for 6 traits on seed yield at Agarfa.

Trait	Days to Mature	Plant ht. (cm)	Stand percentage	Number of pod/plant	Number of seed/pod	100 seed wt. (g)
Days to mature	0.92	-0.37	0.001	-0.33	0.02	-0.21
Plant ht. (cm)	0.24	-1.41	0.00	0.05	-0.01	0.39
Stand percentage	0.07	-0.01	0.05	-0.04	0.25	-0.20
No. pod/plant	0.70	0.17	0.001	-0.44	-0.43	0.91
No. seed/pod	-0.04	-0.02	-0.02	-0.36	-0.53	0.08
100 seed wt	0.20	0.56	0.01	0.40	0.04	-0.98

Table 7. Estimate of direct (bold) and indirect effect at phenotypic levels for 6 traits on seed yield at Agarfa.

Traits	Days to Mature	Plant ht. (cm)	Stand percentage	Number of pod/plant	Number of seed/pod	100 seed wt. (g)
Days to Mature	-0.05	0.0003	0.06	0.008	0.003	0.02
Plant ht. (cm)	0.00	0.05	-0.01	0.003	0.01	-0.02
Stand percentage	-0.01	-0.0010	0.28	-0.001	-0.01	0.02
No. pod/plant	-0.01	0.0022	-0.01	0.054	-0.002	-0.02
No. seed/pod	0.00	0.004	-0.03	-0.002	0.06	0.01
100 seed wt	-0.01	-0.005	0.03	-0.008	0.002	0.16

different agronomic characters is of utmost importance as it provides the base for effective selection. The study of correlation indicates that for most of the parameters the genotypic and phenotypic correlation showed the same trend, though genotypic correlation was higher than the corresponding phenotypic correlation coefficient. From the result, it was observed that number of pods/plant had positive and significant association with seed yield at both locations. Significant negative association was also observed at Agarfa in number of seeds/pod and plant height with seed yield.

Path coefficient analysis showed number of pods/plant, seeds/pod and hundred seed weight had positive direct effect on seed yield at Sinana, whereas the same parameters had negative direct effect on seed yield at Agarfa. Therefore, for these two locations our selection criteria should be considered very seriously or different selection criteria should be developed.

In conclusion, the present investigation indicated that there is wide range of genetic variability for the character studied. From the study, number of pods/plant and hundred seed weight were found to be positively correlated with seed yield and among other parameters. However, it would be advantageous to study more number of genotypes over locations and years to confirm the importance of these traits as direct contributor for seed yield. Furthermore, analysis on both correlation and path coefficient analysis was made on individual location, though the soil type for the two locations is the same. This is due to the variation in the result for the correlation and path. Therefore, to have separate selection strategies for the two sites, the combined analysis was not that important in order to conclude which selection criteria can fit the two sites.

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REFERENCES

Abo-Shetaia AM, El-gawad AAA, Khttab AM, Mokhtar SA (1997). Physiological parameters and yield attributes as selection criteria in lentil crop. Ann. Agric. Sci. 42(2): 323-336.

Bakhsh A, Zubair M, Ghafoor A (1991). Character correlation and path analysis in linetil. Pak. J. Agric. Res. 12(4): 246-251

Bhatty RS (1988). Composition and quality of lentil (*Lens culinaris* Medik.): a review. Can. Inst. Food Sci. Technol. 21:144–160.

Chakraborty M, Haque MF (2000). Genetic variability and component analysis in lentil (*Lens culinaris* Medik.). J. Res. Birsa Agric. Univ. 12(2): 199-204.

CSA (Central Statistics Authority). 2011. Central Statistics Authority Report on Area and Production of Crops. Stat. Bull. Agric. Sample Survey, Volume I, Addis Ababa, Ethiopia.

Dewey DR, Lu KH (1959). A correlation and path coefficient analysis of components of crescent Wheat grass seed production. Agron. J. 51: 515-518.
Erskine W, Rihawe S, Capper BS (1990). Variation in lentil straw quality. Anim. Feed Sci. Technol. 28:61–69.
Esmail AM, Mohamed AA, Hamid A, Rabie EM (1994). Analysis of yield variation in lentil (*ens culinaris* Medik.). Ann. Agric. Sci. 32(3): 1073-1087.
Food and Agricultural Organization (FAO) (2001). Statistical bulletin 1(2): 17-38
Harlan J (1992). Crops and Man. Am. Soc. Agron., Madison, Wisconsin, USA.
Hawatin GC (1978). Selection criteria in chickpeas, broad beans and lentils. Introduction to breeding food legumes. ICARDA, Aleppo. Syria. pp. 1-7.
Khattab SAM (1995). Association and path analysis in lentil under different irrigation regimes. Egypt. J. Agric. Res. 29(1/2): 13-25.
Kumar ADP, Singh, Singh BB (1995). Association analysis in lentil. Indian J. Pulses Res. 8(1): 20-24.
Miller PA, Williams JC, Robinsin HF, Comstock RF (1958). Estimation of genotypic and environmental variances and covariance's in upland cotton and their implication in selection. Agron. J. 50: 126-131.
Muehlbauer FJ, Cubero JI, Summerfield RJ (1985). Lentil (*Lens culinaris Medik*.). In: R J Summerfield and E I I Roberts (eds) Grain Legume Crops. Collins, 8 Grafton Street, London, UK. pp. 266–311.
Ramigry SR, Paliwal KK, Tomar SK (1989). Variability and correlation of seed yield and other quantitative characters in lentil. Lens Newsletter 16 (1):19-23.
Seifu Tsegaye (1988). Correlation and path coefficient analysis in lentil (*Lens culinaris* Medik.) and their implication for selection. M.Sc. thesis, Heremaya University of Agriculture, Haremaya, Ethiopia.
Singh SP, Lal KB, Krishna.1995. Physiological parameters for selection in lentil (*Lens esculenta* L.). Legumes Res. 18(2): 129-132.
Zaman MW, Mian MAK, Rahman MM (1989). Variability and correlation studies in local germplasm of lentil in Bangladesh. Lens Newsletter 16 (1): 17-20.

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