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Tarsar Lake
Courtesy Dr. Arshid Jehangir & Dr Sami Ullah

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Scavenging Effect of Rainfall on Black Carbon Aerosols Over the Parbati Glacier (4321 m amsl) in the Northwestern Himalaya, India

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ABSTRACT

Black carbon aerosol (BCA) is the part of carbonaceous aerosols having high tendency to absorb the solar radiation, which strongly contributes to warming of the atmosphere. The present study addresses the status of scavenging of black carbon aerosol due to rainfall over the Parbati Glacier in the northwestern Himalaya in Himachal Pradesh. The measurements of the black carbon aerosols and rainfall have been carried out during August - September, 2016 over the Parbati Glacier (4321 m amsl). The diurnal variation of the mass concentration of the black carbon showed 0.47 $\mu g\ m^{-3}$ on 19th August, 2016 with higher concentration during the dry day (no rainfall) and lower concentration with 0.05 $\mu g\ m^{-3}$ during the rainy day (16.5 mm) on 15th August, 2016. The diurnal variation of the black carbon also showed bi-modal peak, high concentration during morning and evening hours as compared to noon and afternoon hours. The regression analysis in statistical fit between black carbon and rainfall shows that there is a reduction of about 0.12 $\mu g\ m^{-3}$ of black carbon aerosols loading at every 1-mm increase in the rainfall intensity over the Parbati Glacier during observation days. This study shows that the drastic decrease in the loading of the black carbon aerosol is due to scavenging effect of rainfall. There was found a strong correlation of BC with rainfall -0.61. Looking at BC relationship with other meteorological parameters like temperature and relative humidity, their correlation with them was positive + 0.56 and + 0.10 respectively; while with wind speed, it was negative -0.10. However, the long-term measurements are required to estimate scavenging effect of rainfall and other related parameters over the black carbon aerosol deposition.

Keywords: *Scavenging efficiency, Black carbon, Rainfall, Parbati Glacier, Northwestern Himalaya*

INTRODUCTION

Ambient aerosols over the Himalayan region are usually composed of mineral dust and carbonaceous species due to a widespread arid and semi-arid areas in the Western India and highly polluted areas in the south Asia, which together account for 50−80% of the total suspended particle mass (Adhikari *et al.,* 2007; Carrico *et al.,* 2003; Rangarajan *et* *al.,* 2007). Black carbon is the collective carbon-rich aromatic residues and condensates from the incomplete combustion of fossil fuels and biomass (Hammes *et al.,* 2007). In the last decade, the black carbon aerosol has become the most interesting scientific concern due to its special characteristics of interaction with solar radiation, an important role as cloud condensation nuclei, effect on snow albedo, and consequences for climate modification (Hansen and Nazareenko, 2004; Ramanathan and Carmichael, 2008). The transport of BC from lower latitude regions to the Himalayan atmosphere and subsequently its deposition on glaciers, snow and ice has also been a centre of attraction to the world wide scientific community (Gogoi *et al.,* 2015). In the atmosphere, BC contributes to global warming and alters cloud formation processes (McConell *et al.,* 2007). BC has a spherical shape of about 500 nm in diameter with homogenous surface (Fu *et al.,* 2004). Due to its small size, these particles can remain airborne in the atmosphere for about one week, which has enough time to undergo long distance transport and may reach even up to the most remote sites (Masiello and Druffel, 1998). After traveling to some distance, due to the dry and wet deposition; they get scavenged and settle down on the surface (Samara and Tsitouridou, 2000). The scavenging and depositional processes control the concentrations of the aerosols and lemmatizes their life time in the atmosphere (Latha *et al.,* 2005). In comparison to many other inorganic aerosols like sulfates and nitrates, black carbon is more hydrophilic. Due to its more hydrophilic characteristics, it has a tendency to exist longer lifetime in the atmosphere (Andronache, 2004). During dry seasons, it has 7 to 10 days average residence time in the atmosphere, while in the rainy season it is about 5 days or less than this (Reddy and Venkataraman, 2000). Due to these special characteristics of the BC, it requires longer studies to observe it's eco-environmental impacts. As the atmosphere is a dynamic one, so is the bahaviour of the black carbon concentration. Local meteorology plays an important role in determining concentration level of pollutants. During dry, slow and calm wind conditions, concentration of pollutants may remain high and less dispersion would take place. On the other hand, during precipitation its concentration goes down due to washout effect. The aim of the present study therefore is to know the overall concentration of black carbon throughout the season and during rainy days it is going to be affected due to scavenging effect.

MATERIAL AND METHODS

The observation of black carbon aerosol (BCA) during August-September was carried out at the Parbati Glacier (31^0 45' - $31^0$55' N; 77^0 45' – 77^0 51' E) during 2016 in the north-western Indian Himalaya (Fig.1). BCA was measured using Aethalometer (AE-33, Magee Scientific, USA). This is the first time observation of the BC over the Parbati Glacier. The sampling site was at the snout of the glacier (4321 m amsl) which falls in the Western Himalaya and is located at 31^{0} 49'44.50" N latitude and 77^{0}47'36.54" E longitudes.

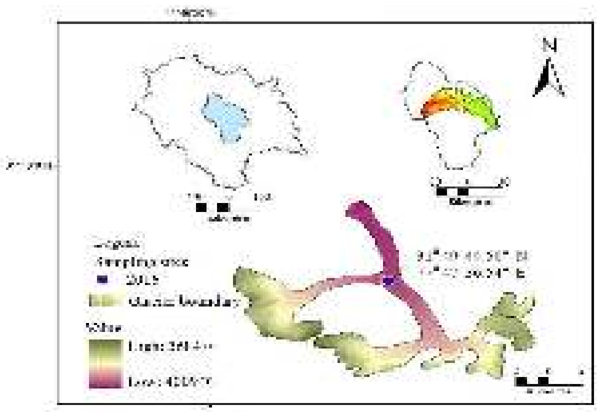


Fig.1. Map showing the study area and sampling site at the Parbati Glacier

A 7-channel Aethalometer (Model AE-33, Magee Scientific, USA) was used to suck ambient air at a flow rate of 5 LPM from a height of 3m above ground during each 1 min of set time for measurement. However, BC measured at 880 nm wavelength was used in this study since this wavelength absorbs maximum BC as compared to other wavelengths. The BC is the sole absorbent of light at 880 nm, as a result; this channel is used to study BCA. Aethalometer measures the attenuation of a beam of light transmitted through a filter, while the filter continuously load the samples. The rainfall measurement is carried out through Tipping Bucket Rain Gauge (Young, Model 52202/52/203, Campbell Scientific) which collects and gives data at 1-minute interval. The scavenging efficiency was analysed by regression analysis and statistical fit between rainfall intensity and black carbon concentration was done using in a following way:

$$\text{Slope} = (y_1 - y_2) / (x_1 - x_2) \text{ ---- (i)}$$

Where; x_1 and y_1 are the x and y coordinates for the first point and x_2 and y_2 are the x and y coordinates for the second point.

$$y = mx + b \text{ ----------------------- (ii)}$$

Where; m is the slope of the line, b is the y intercept of the line, x is the independent variable and y is the dependent variable.

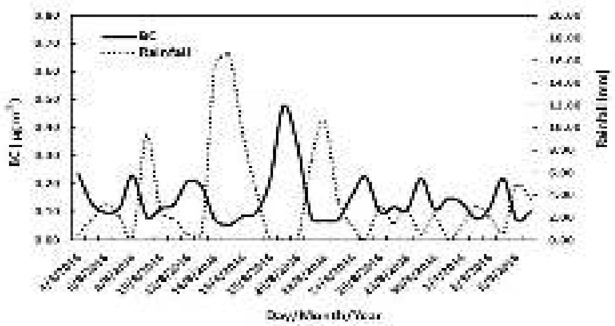
To understand the BC source, whether it is local or transported from some other regions, air mass backward trajectories were drawn and analyzed using Hybrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) Model of the National Oceanic and Atmospheric Administration (NOAA).

RESULTS AND DISCUSSION

i. Scavenging effect of rainfall on BCA

Figure 2 shows the daily variation of the black carbon aerosol and rainfall during the observation days. Variation shows that there was a drastic reduction in the mass concentration of the black carbon during rainfall in the region and the concentration was higher when there was no rainfall. Average BCA concentration was observed low in the Parbati Glacier region as compared to other sub-urban sites according to the past studies (Allen *et al.,* 1999; Babu *et al.,* 2002).

On 19th August 2016, it was a dry day (no rainfall) when the highest mass concentration (0.47 μ gm^{-3}) of BCA was measured. This dry day was followed by 25th August, 2016 with 0.22 μg m^{-3}. Whereas during high rainfall days mainly on 15th August, 2016 and 22nd August, 2018, rainfall was measured highest with 16.5 mm and 10.5 mm respectively. During these two high rainfall days, BCA was found to be lowest 0.05 μ gm^{-3} followed by 0.08 μ gm^{-3}



in the Parbati Glacier (Fig.2).

Fig.2. Daily variation of black carbon concentration and rainfall amount at the Parbati Glacier

It therefore makes clear that there is reasonable washout effect of the rainfall on the BCA concentration. During dry season, a phenomenal high differential heating of the land surface takes place with the air masses. This atmospheric phenomenon enhances the BCA loading in these locations through transportation from the continental region (Chen *et al.,* 2001; Latha and Badrinath, 2003; Latha *et al.,* 2004).

Hourly variation of the BCA concentration shows bimodal peaks during both rainy and dry days. Its highest concentration was found to be in the morning hours (between 7:00 to 11:00 IST) and in the evening hours (between 18:00 to 21:00 IST) as compared to the afternoon hours (Fig. 3).

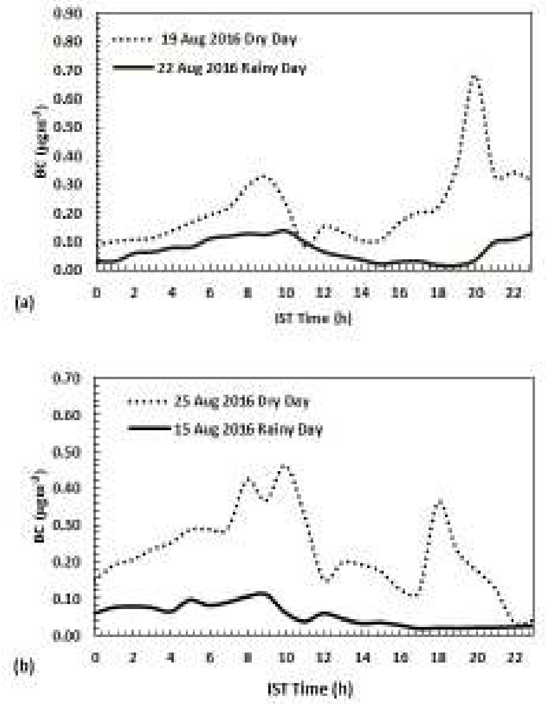


Fig.3. Washout effect of rainfall on BCA: (a & b) Dry (19 Aug 2016 & 25 Aug 2016) and Wet Day (22 Aug 2016 &15 Aug 2016)

On account of a turbulence caused due to solar heating during the morning hours, it results in the breakdown of the nighttime stability of the boundary layer. This causes mixing up of the nocturnal aerosols close to the earth's surface. During afternoon hours due to the surface heating, it starts again an increase in the boundary layer, which causes the dispersion of the aerosols (Latha *et al.*, 2005; Latha and Badrinath, 2003).

With the help of a regression analysis, a statistical fit or correlation between black carbon concentration and rainfall intensity indicates (-0.61) the strong negative correlation. The estimated slope is observed - 0.012 with the help of regression analysis. It represents that in every 1- mm increase in the rainfall, there was about 0.12 µg m^{-3} reduction in the mass concentration of the black carbon in the region. On average, it is a decrease in the concentration of the BCA mainly because of the scavenging effect of rainfall in the study area (Fig. 4).

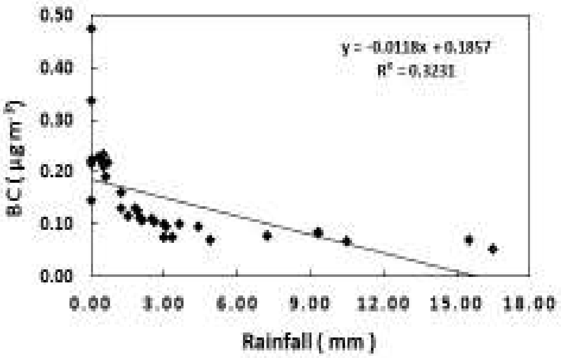


Fig. 4. Correlation of black carbon with rainfall

ii. Other local meteorological parameters and their correlation with BCA

Meteorological conditions play an important role in a transfer and dispersion of the concentration of BCA. Figure 5 shows the daily variations in temperature, wind speed and relative humidity during the observation period in 2016.

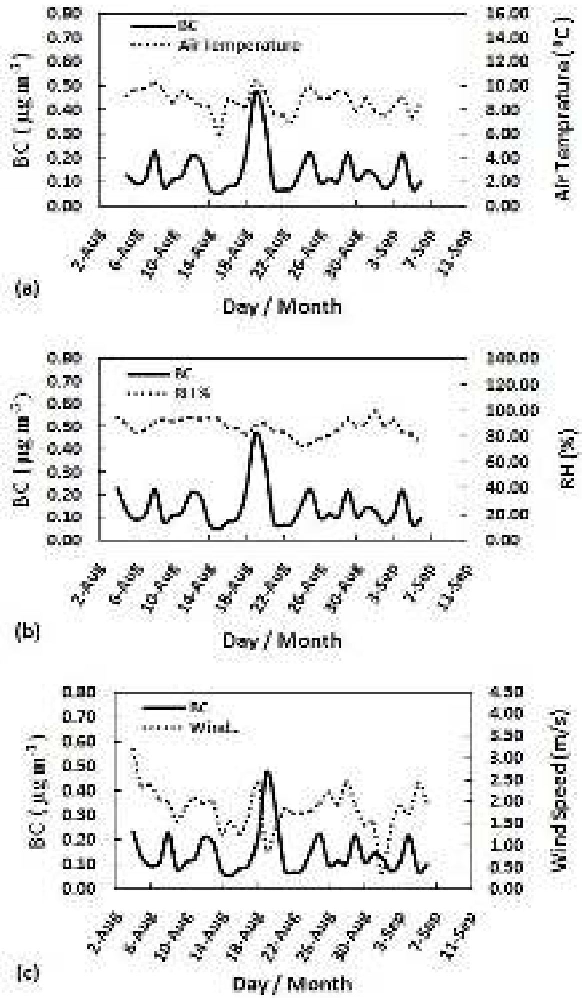


Fig.5. Local meteorology at the Parbati Glacier: (a) temperature, (b) relative humidity and (c) wind speed

Table 1. Local meteorology and their correlation with black carbon over the Parbati Glacier, 2016

Parameters	Avg	Max	Min	SD	Correla-tion with BC
BC ($\mu g\ m^{-3}$) n= 816	0.14 ± 0.02	0.45	0.05	0.09	-
Rainfall* (mm) n= 816	114.5 ± 0.72	16.5	0.00	4.23	- 0.61
Temp (^{0}C) n= 816	8.75 ± 0.17	10.45	6.06	0.98	+ 0.56
RH (%) n= 816	87.29 ± 1.13	100	72.73	6.62	+ 0.10
Wind Speed (m/s) n= 816	1.84 ± 0.09	3.19	0.36	0.51	- 0.10

**Total Rainfall,*
n-indicates 1 sample representing 24 hours duration

The prevailing local meteorological parameters showed that the average air temperature during 2016 was 8.75 ^{0}C indicating 6.06 ^{0}C on 15th August, 2016 as minimum and 10.45^{0}C as maximum on 19thAugust, 2016. The average wind speed was 1.84 m/s at the observation site during sampling days. The maximum wind speed was observed as 3.19 m/s on 4th August 2016, while the minimum was observed to be 0.36 m/s on 1st September 2016. The average relative humidity was observed 87.29 % in 2016 (Table .1).

Correlation of black carbon aerosol with different meteorological parameters shows the negative correlation with rainfall (-0.61) and wind speed (-0.10). Whereas, the temperature and the relative humidity show the positive correlation + 0.56 and + 0.10 with the black carbon aerosol respectively (see Table 1 & Fig.6).

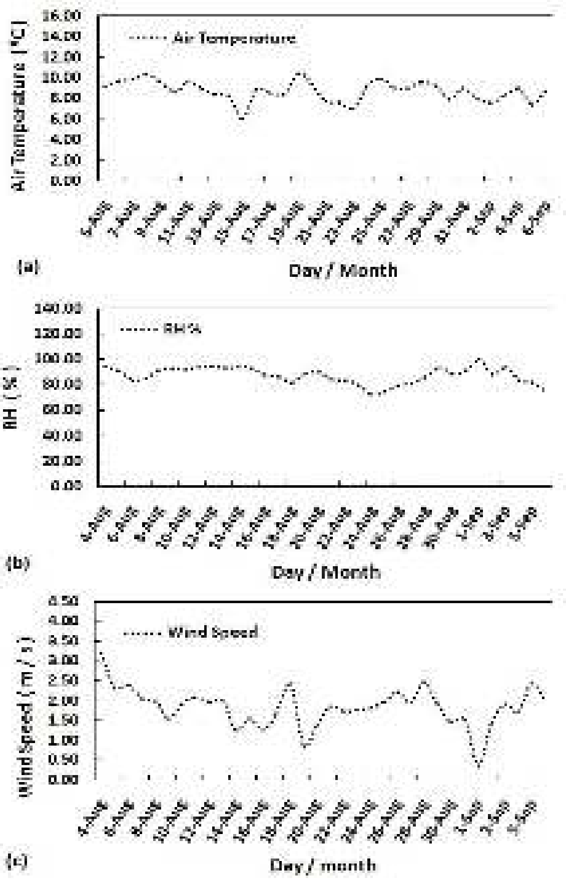


Fig.6. Correlation of BCA with: (a) air temperature, (b) relative humidity and (c) wind speed

In the sub-mountain alpine and sub-alpine region of the Parbati Glacier, there remain a number of the shepherd groups with their transhumance practice at the observation site towards the South and South-East direction and stayed there for about 3 months from mid-June to mid-September. Villagers of

Nakthan, Barshaini, Tosh, Pulga, Tulga, etc. also live in the South and South-East direction in the low lying valley. They use wood (biomass burning) and kerosene/diesel (fossil fuel burning) for cooking and heating purposes, which also contribute to BCA concentration at the observation site. In addition, in the low lying valley sites of the glacier, vehicular emissions in summer and forest fires in winter and open burning of waste irrespective to any season have been the other regional sources of black carbon aerosols. The wind direction at the observation site during 2016 was from the South and South-East direction at maximum times, which shows that the aerosols with the help of air masses are transported from the low lying regions up to the glacier sites (Fig.7a).

iii. External sources of BCA- HYSPLIT backward trajectory

7-days HYSPLIT back trajectories (<u>http://www.arl.noaa.gov/ready.html</u>) have been computed to identify the air masses reaching the Parbati Glacier to distinguish the potential outside sources contributing to aerosol burden over the sampling location. The time period of 7 days was chosen based on the longer life time of BCA aerosol in a free troposphere (Ramanathan *et al.,* 2001; Andronache*,* 2004). Based on trajectories analysis, the maximum air masses were coming from the Bay of Bengal which reached at the observation site from the South and the South-East direction. These back trajectories showed that the air masses reached at the observation site were supposed to carry some concentration of black carbon from outside sources (Fig.7b).

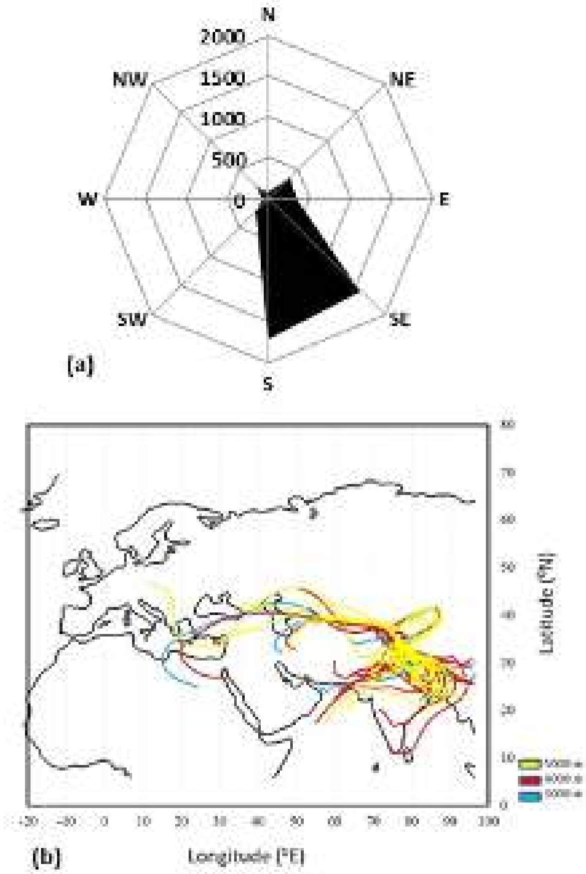


Fig.7. Local and external sources: (a) Wind rose and (b) HYSPLIT backward trajectories showing transportation of pollution episodes from the outside region

These evidences therefore show clearly that there are also external sources contributing to existing BCA concentration in the present study region along with the local sources.

CONCLUSION

The observation of black carbon over the Parbati Glacier indicates that during rainy days mass concentration of the BCA was lower as compared to the dry days which vividly indicate the scavenging effect of rainfall over BCA concentration. Correlation between BCA and rainfall data shows the ~ 0.12 μg m^{-3} reduction in the mass BCA concentration upon an increase of 1mm in the rainfall intensity. The average BCA concentration shows similar pattern of bi-modal peak, high during morning and evening hours at 7:00 to 11:00 and 18:00 to 21:00, respectively.

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Diversity and Density Patterns of Macroinvertebrates on Different Macrophytes in Dal Lake, Kashmir

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ABSTRACT

The present study was carried out during June - October, 2013 to see how differently macroinvererterbrates colonise macrophytes in Dal Lake. For the purpose seven macrophytic species namely *Ceratophyllum demersum, Chara* sp., *Hydrilla vercillata, Myriophyllum spicatum***,** *Potomogeton lucens, Potomogeton natans* and *Utricularia* sp. were investigated for the associated macroinvertebrates. The study revealed a total of 14 macroinvertebrate taxa belonging to three phyla Arthropoda, Annelida and Mollusca. Arthropoda being the most prominent phyla was represented by class Insecta and Arachinida. Class Insecta represented by 10 taxa contributing majority, whereas Class Arachnida was represented by only one taxa. Mollusca was the second dominant phyla represented by two families: Physidae and Planorbidae. The least prominent phyla Annelida was represented by just 1 order (Rhynenobdella) of class Hirudinia. The detritus feeding Annelida showed their presence on *Potamogeton natans*. Among the insects, Chironomidae larvae were much more diverse showing higher density on *Ceratophyllum demersum* followed by *Potamogeton lucens, Potamogeton natans* and then *Hydrilla verticellata.* The highest number of taxa was observed on *Potomogeton natans* (11) and highest mean number of individuals was observed on *Ceratophyllum demersum* (92.60). Biodiversity index result showed Shannon wiener diversity index and Simpson index was highest for *Potamogeton natans* and lowest for *Chara* sp. Principal component analysis of the data resulted in two PCs with eigen values greater than 1, which explained 83 percent of the variance in the data. The first two PCs explained 56.7 and 24.9 percent of the variance, respectively.

Key words: *Arthropoda, Annelida, Density, Macroinvertebrates, Macrophytes, Mollusca*

INTRODUCTION

Macrophytes constitute an important component of aquatic ecosystems. They play important role in maintaining the functioning and biodiversity, besides providing habitat to a large number of invertebrate fauna associated with them. (Scheffer, 1998). Aquatic vegetation provides habitat to several species belonging to various taxa like Arthopoda, Annelida and

Mollusca (Habib and Yousuf, 2014). Floating and submerged macrophytes are especially important with regards to the energy dynamics of aquatic ecosystem besides providing shelter to a number of macroinvertebrates. Many species of macroinvertebrate which are of special concern are also being harbored by macrophytes. Macroinvertebrates consume macrophytes directly as food (Gregg and Ross, 1985). They also use the periphyton attached on the surface of these plants as a source of food (James *et al*., 2000; Hillebrand, 2002).

Some of the characteristics of macrophytes like architecture of leaves and growth habit of plant affect diversity, abundance and community composition of macro-invertebrates (Sharma *et al.,* 2015). Many macroinvertebrates show some sort of "preference" or substrate association for some specific macrophytes depending on the pants architecture, density (Dvorak and Best, 1982; Cyr and Downing, 1988), composition and abundance (Rooke 1986; Dudley 1988; Cattaneo *et al.,* 1998). From the ecological point of view, the littoral zone of a lake is of great ecological importance (Brinkhurst, 1974; Vadeboncoeur *et al.,* 2002). These vegetation sites have more diversity as well as richness in macoinvetebrates than those in open water (Olson *et al*., 1994; Savage and Beaumont, 1997).

Macrophytes also have some importance with regards to the habitat structure of an aquatic ecosystem (Danielle and Barmuta, 2004; McAbendroth *et al.,* 2005). They have been increasingly used to bio-monitor aquatic systems as they are immobile and cannot leave the substrate on which they are attached. This gives them the ability to tolerate unfavorable environmental conditions and indicate both short as well as long term hydrological stresses (Moore *et al.,* 2012). Macroinvetebrates in turn have also their importance with regards to food web interactions, comprising fish and birds (McQueen *et al.,* 1986; Cyr and Downing, 1988; Batzer *et al.,* 1993). Aquatic invertebrates have served as an effective biological indicator for decades but amongst these entomofauna has been found to be a much more stable and reliable indicator of pollution. The present work is an attempt to see the effect of the architecture of macrophytes on diversity and density pattern of macroinvetebrates. The Dal Lake is for most part infested with macrophytes of the four recognized categories, viz., submerged, rooted free floating leaf, emergent and free floating types. A total of 31 species of macrophytes have been reported from the lake (Qadri and Yousuf, 2008). The macrophytes like *Ceratophylum demersum, Potamogeton lucens, Potamogeton natans, Myriophyllum spicatum, Hydrilla verticillata, Utricularia* sp.and *Chara* sp. are the most prominent ones that are found in the lake. These submerged macrophytes with their characteristic finely dissected and densely packed leaves provide an adequate shelter and food source for macro-invetebrates (Lillie and Budd, 1992; Thorp *et al.,* 1997; Balci and Kennedy, 2003). Although, each macrophyte does not appear to have a characteristic fauna associated with it, different submerged plants do provide a specific substratum that can be utilized by different types of invertebrates (Krecker, 1939).

MATERIAL AND METHODS

Study area and study site

Dal lake of Kashmir is situated in the north–east of Srinagar at a latitude of 34^o 07' N latitude and longitude of 74^{o}52' E at an altitude of 1584 m above mean sea level. For the present study, four sampling sites of Dal Lake were selected. These sites are:

I) Hazratbal basin

This site is located within the Hazratbal Basin of Dal Lake (34^0 07′ 59.4″ N and 74^0 51′ 27.6″ E). It is severely infested with *Nymphoides peltata, Ceratophyllum demersum*, *Myriophyllum spicatum, Hydrilla verticillata* and *Potamogeton crispus. Ceratophyllum demersum* and *Potamogeton natans* which were collected from this site.

II) Nishat basin

This site is located within the Nishat Basin of Dal Lake close to the aeration pumps installed in the Lake just in front of the famous Nishat Garden (34^0 08' 30.5" N and 74^{0}51′ 42.0" E). The area supports thick macrophyte growth of both submerged and floating macrophytes dominated by *Myriophyllum spicatum, Ceratophyllum demersum* and *Salvinia* sp. *Hydrilla verticillata* and *Potamogeton lucens* which were collected from this site.

III) Gagribal basin

This site lies within the Gagribal basin of Dal Lake between geographical coordinates of 34^0 05′25.5″N latitude and 75^0 51′05″E longitude. It is located in the centre of the basin. This site is quite open and is visited by tourists in Shikaras. *Myriophyllum spicatum* and *Utricularia* sp. were collected from this site.

IV) Gagribal basin

This site also lies within the Gagribal basin of Dal Lake between geographical coordinates of 34^0 55.1′N latitude and 74^0 51′E longitude. The site is surrounded by a number of houseboats. *Chara* sp. was collected from this site.

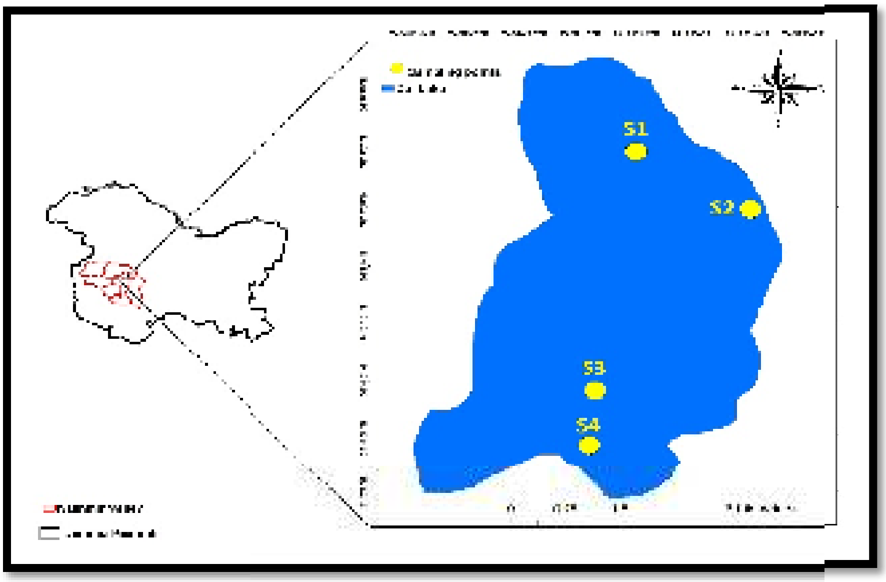


Fig.1. Satellite image of study area and study sites.

Methodology

The first and foremost aim of the present study was to obtain the baseline data on the diversity and density of the macroinvetebrates associated with different species of macrophytes i.e., *Hydrilla vercillata, Ceratophyllum demersum, Potomogeton natans, Potomogeton lucens, Myriophyllum spicatum***,** *Chara* sp. *and Utricularia* sp. This necessitated the macrophytes to be brought to the laboratory from the sampling station. This was done by collecting the macrophytes in properly labelled transparent polythene bags which are light in weight and easy to transport. Macrophytes were collected by using a long club (wooden rod) fitted with an iron hook at one end. It was lowered into water in the region of macrophytes strands and within the macrophytes strand, the club was rotated so that the macrophytes get twirled or inter-wined with the hook of the club (modified after Beckett *et al.,* 1991). Only two to three rotations of the club were sufficient to cut out quantum of macrophytes more than that required for the analysis. The club was immediately taken out of the water and the macrophytes attached with it were transferred into the polythene bags. Quadrats of size 1m^2 were used to collect the macrophytes of a fixed area for the proper analysis of the macro invertebrates. In the laboratory, 100 g of each kind of macrophyte were taken one by one in a big flask of 1000 ml capacity. About 200 ml of water was added to the flask and was vigorously shaken to dislodge the invertebrates associated with it. This process dislodged most of the macroinvetebrates associated with macrophytes. The macrophytes were then placed in dissection trays or petridishes to scratch those macroinvetebrates which were not dislodged due to the process of shaking in the flask. The water from the flask was passed through a sieve (0.5mm mesh size) into a beaker so that any macroinvetebrates which may occasionally squeeze out through the sieve could be collected from the collected water. Macroinvetebrates were picked up from the sieve and the dissection tray with a fine camel hair brush and were preserved in 10% formalin in properly labeled photographic film vials. The macroinvetebrates of each kind associated with a particular type of macrophytes were counted and preserved in the same vial. The identification of the macroinvetebrates was done by the help of standard taxonomic keys (Pennak, 1978; Mc Cafferty and Provonsha, 1981; Edmondson, 1992; Ward, 1992).

RESULTS AND DISCUSSION

A total number of 14 taxa of macroinvetebrates level were recorded from 7 macrophytic species of Dal Lake. The macroinvetebrate taxa belonged to 3 phyla were spread over 6 orders and 10 families. Annelida was represented by 1 order (Rhynenobdella) of class Hirudinia. Mollusca represented by 2 taxa (*Physella* sp. and *Gyraulus* sp.). Phylum Arthropoda was represented by 11 taxa, 10 taxa represented by only class Insecta. Class Arachnida was represented by 1 taxa (*Dolomedes* sp.) from the order Arenae. Class Insecta contributed majority of class forms with 10 taxa belonging to 3 different orders i.e., Diptera (8 species), Odonata (1 species) and Lepidoptera (1 species). Among 14 taxa of macro-inverebrates, Insecta was the most abundant group, dominated by species *Chironomidae, Diamesinae* sp. followed by *Bezzia* sp. and *Enallgma* sp. The highest number of taxa was observed on *Potomogeton natans* (11) followed by *Ceratophyllum demersum* (10), *Hydrilla verticella* (7), *Potomogeton lucens* (5), *Myriophyllum spicatum* and *Utricularia* sp. share same number of taxa (2) whereas, lowest number of taxa was found on *Chara* sp.(1)(Fig.1). During the study highest mean number of individuals was observed on *Ceratophyllum demersum* (92.60) followed by *Potomogeton natans* (63.20), *Potomogeton lucens* (57.30), *Hydrilla verticella* (43.40), *Myriophyllum spicatum* (8.00), *Chara* sp.(7.50) and lowest mean individuals was found on *Utricularia* sp. (4.50)(Fig.2).

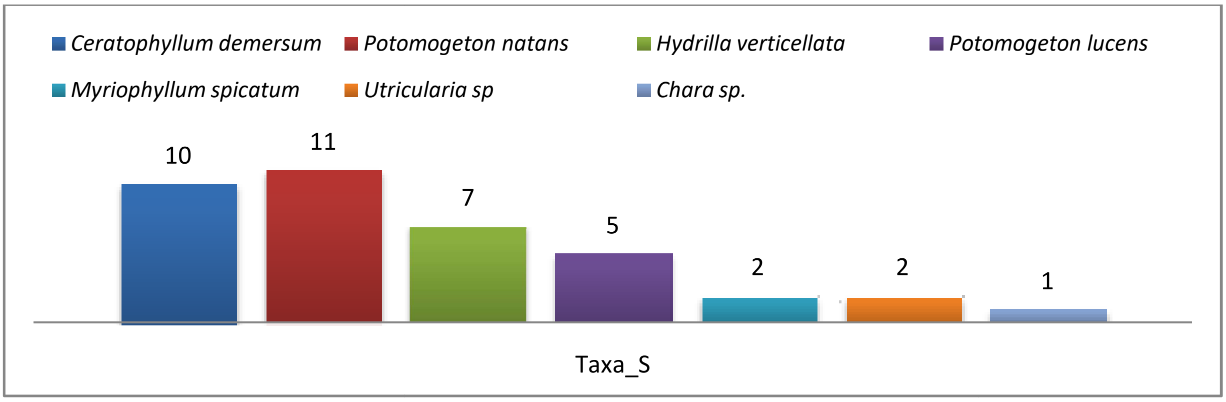


Fig. 1. Total number of taxa present during the study

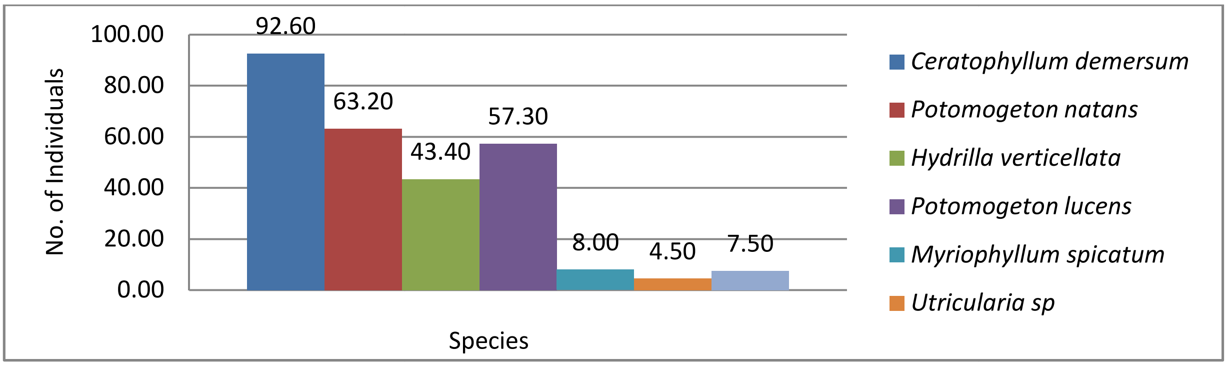


Fig. 2. Total number of mean individuals present during the study.

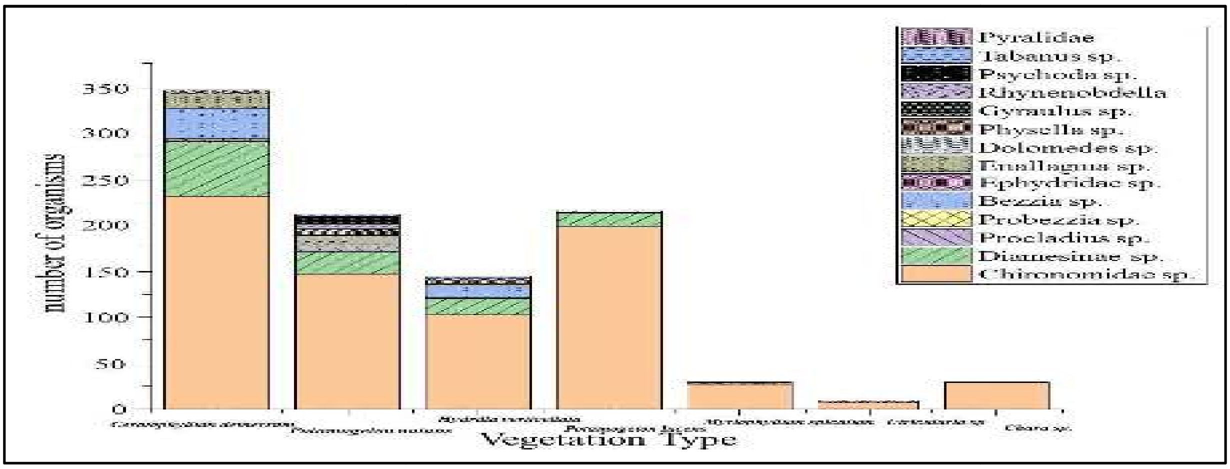
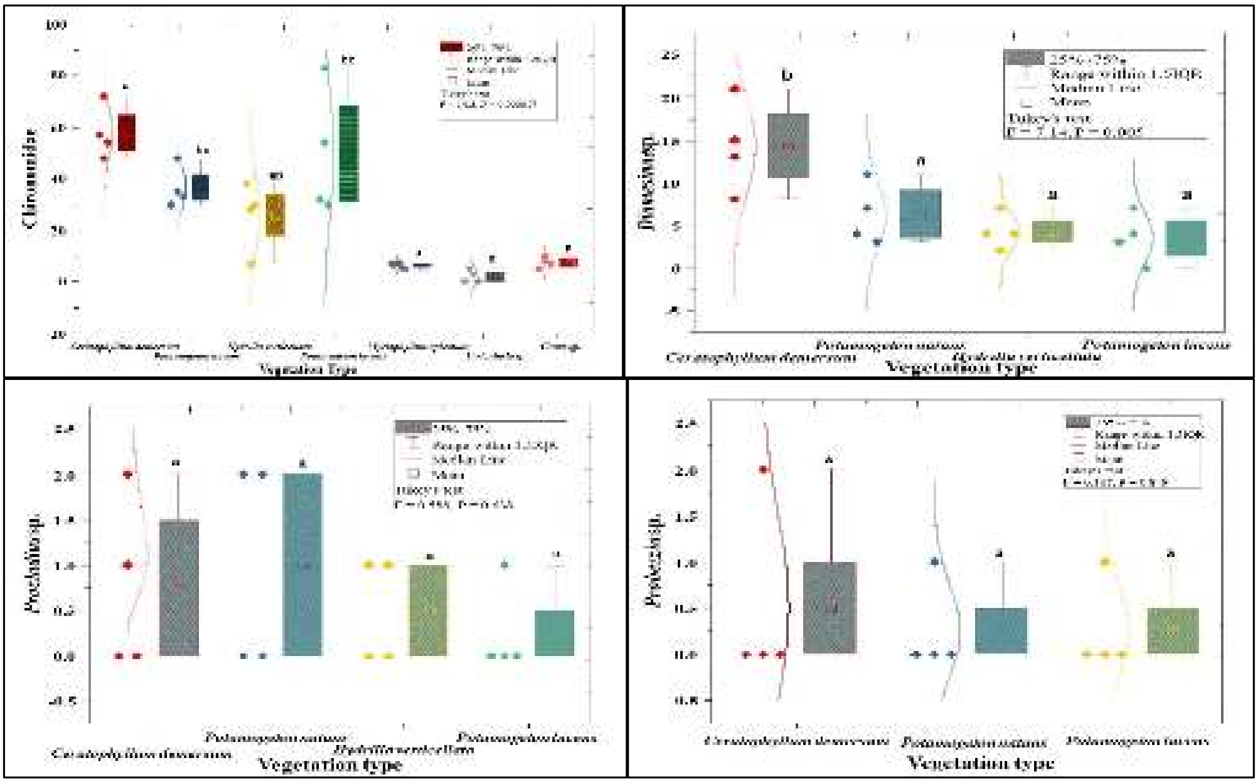


Fig. 3. Number of macroinvertebrates associated with vegetation type

During the study it was observed that *Chironomidae* sp. was the most abundant specie associated with all the seven macrophytes followed by *Diamesinae* sp. and *Procladius* sp. which was harbored by four macrophytes (*Ceratophyllum deme-rsum, Potamogetan natans, Hydrilla verticellata* and *Potamogeton lucens*). Taxa *Physella* sp. was allied with four macrophytes namely (*Ceratophyllum demersum*, *Potam-ogeton natans, Hydrella verticellaria* and *Myriophyllum spicatum*). Whereas, taxa *Tabanus* sp. was found to be associated with three macrophytes only (*Potamogeton lucens, Hydrilla verticellata and Potamogeton natans*). Similarly taxa *Enallagma* sp. was associated with three macrophytes (*Ceratophyllum demersum, Potam-ogeton natans*, *Hydrilla verticellata*). Whereas, *Bezzia* sp. was associated with two macrophytes (*Hydrilla verticellata* and *Ceratophyllum demersum*). Probezzia sp. was also associated with two macrophytes only (*Ceratopyllum demersum* and *Potamogeton lucens*). Some of the macroinvertebrate taxa were harboured by only single macrophytic species such as *Psychoda* sp., *Gyraulus* sp., *Rhynenobdella* sp. and *Dolomedes* sp. were allied with only one macrophyte (*Potamogeton natans*). Similarly *Pyralidae* sp. was associated with (*Urticularia* sp.) and *Ephydridae* sp. was associated with (*Ceratophyllum demersum*) only (Fig.3 & 4).



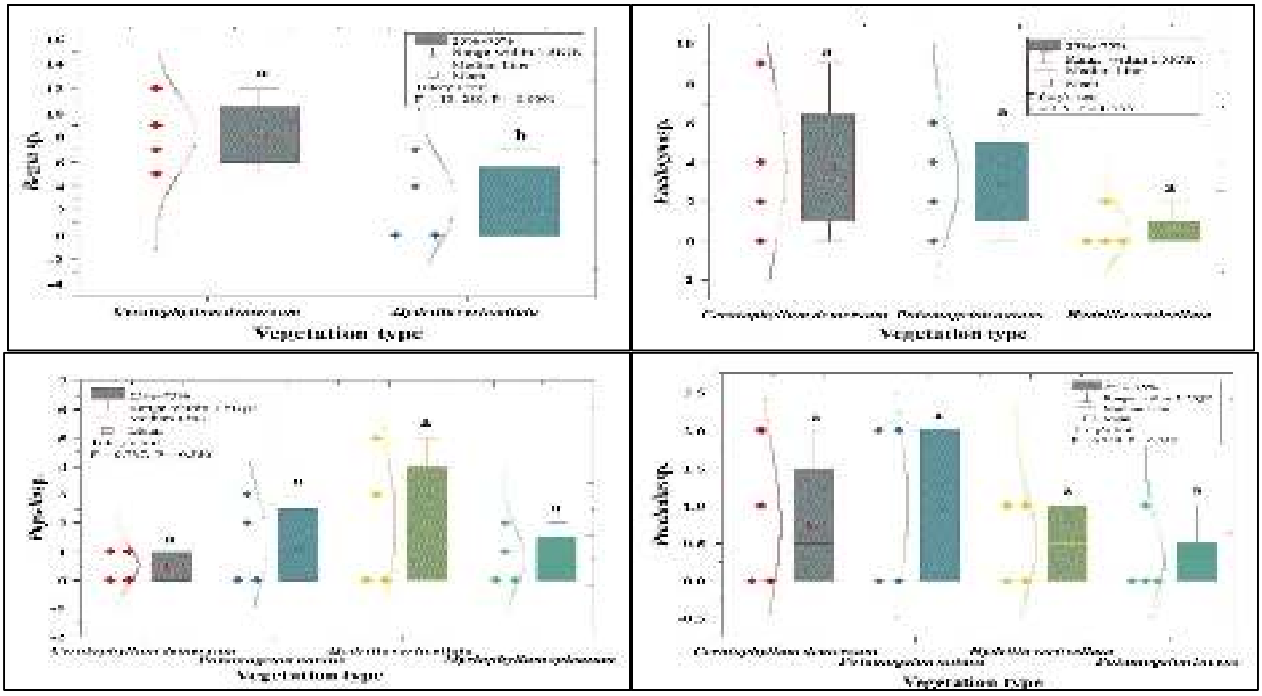


Fig.4. Box plot showing range, mean and ANOVA (Tukey's test) of macroinvertebrates across different vegetation type (dissimilar letters show significant variation).

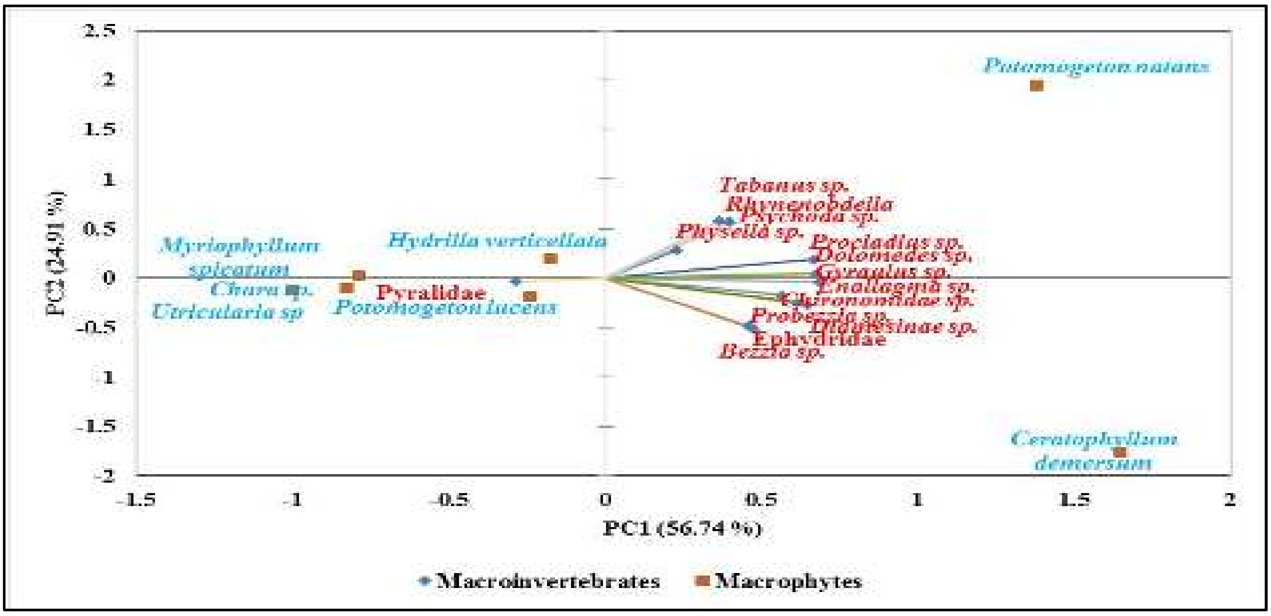


Fig. 5. Biplot of macroinvertebrate and macrophyte data from all samples

Table 1. Loadings of environmental variables on the first two principal components (PC) derived from principal components analyses of macroinvertebrate and macrophyte data from all samples (Boldfaced values, absolute value of loading were considered high).

Eigenvalue/Variability	PC1	PC2
Eigenvalue	7.943	3.488
Variability (%)	56.738	24.914
Cumulative %	56.738	81.652
Macroinvertebrates	PC1	PC2
Chironomidae sp.	**0.801**	0.244
Diamesinae sp.	**0.916**	0.380
Procladius sp.	**0.941**	-0.261
Probezzia sp.	**0.869**	0.343
Bezzia sp.	0.648	**0.691**
Ephydridae sp.	0.672	**0.718**
Enallagma sp.	**0.972**	0.061
Dolomedes sp.	**0.957**	-0.061
Physella sp.	0.325	-0.398
Gyraulus sp.	**0.957**	-0.061
Rhynenobdella sp.	0.563	**-0.797**
Psychoda sp.	0.563	**-0.797**
Tabanus sp.	0.516	**-0.814**
Pyralidae sp.	-0.408	0.051
Vegetation type		
Ceratophyllum demersum	**4.642**	3.283
Potamogeton natans	**3.889**	-3.646
Hydrilla verticellata	-0.498	-0.363
Potamogeton lucens	-0.679	0.344
Myriophyllum spicatum	**-2.215**	-0.043
Utricularia sp.	**-2.813**	0.234
Chara sp.	**-2.324**	0.191

Investigation of the factor loadings of the macroinvertebrates and macrophytes on the first two PCs of the data sets revealed that relationship existing between habitat gradients potentially affected epiphytic macro-invertebrates. Principal components analysis of the data resulted in two PCs with eigen values greater than 1, which explained 83 percent of the variance in the data. The first two PCs explained 56.7 and 24.9 percent of the variance, respectively. The first principal component represents a gradient in *Ceratophyllum demersum, Potamogeton natans* and correlated macro-invertebrates. No macrophyte loaded highly on PC2, but the moderate loadings of five macroinvertebrates indicate that this component represents a certain moderate relation (Table 5; Fig.1).

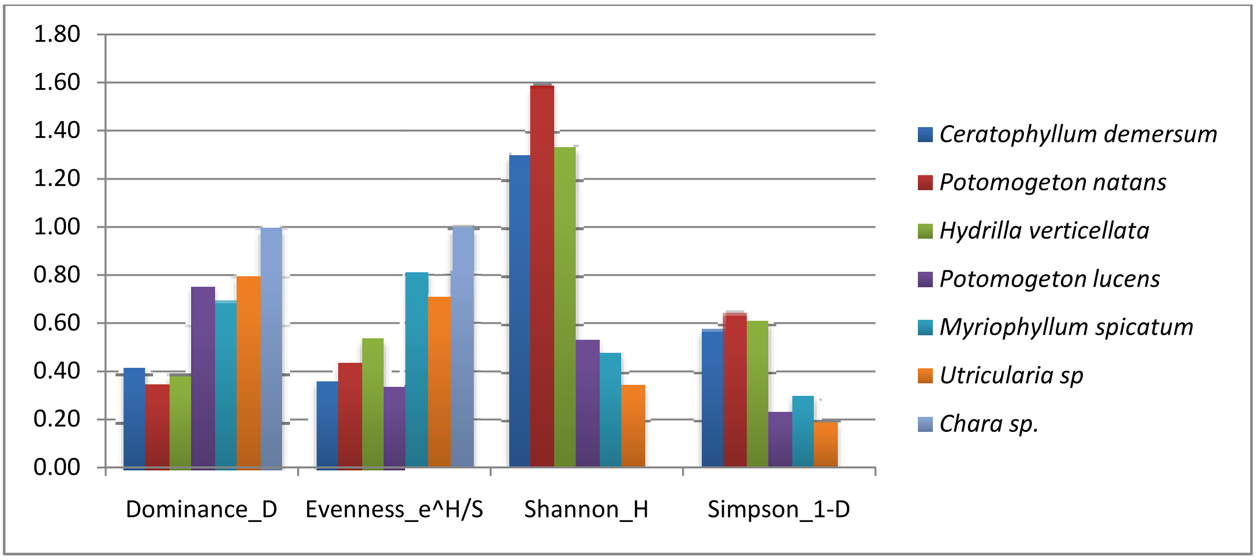


Fig.6. Various biodiversity indices for macroinvertebrates

While assessing the various biodiversity score, it was found that highest dominance and evenness score was shown by *Chara* sp. and lowest dominance score by *Potamogeton natans* and evenness score by *Potamogeton lucens*. Whereas, Shannon wiener diversity index and Simpson index was highest for *Potamogeton natans* and lowest for *Chara* sp. (Fig. 6).

Generally high numbers of macro-invetebrates were found attached to *C. demersum* followed by *P. natans, P.lucens* and *H. verticillata* and least for *Myriophyllum spicatum, Utricularia* sp. and *Chara* sp. *Ceratophyllum demersum* formbowl shaped whorls together, near the tip of the stem. The abundance of epiphytic invertebrates on aquatic macrophytes can be influenced by different plant architecture types (Cheruvelil *et al.,* 2006). Contrary to other studies (Chilton, 1990) a drastic decline in number of invertebrates associated with *M. spicatum* was observed despite of it having elaborate surface area for colonization. It may be as a result of increased release of all elopathically active compounds that might have hampered the growth of periphyton which in turn limited the invertebrate diversity (Sand-Jensen and Sondergaard, 1981; Leu *et al.,* 2002).

The Chironomidae larvae were much more diverse showing higher density on *Ceratophyllum demersum* followed by *Potamogeton lucens, Potamogeton natans*, and then *Hydrilla verticellata. Chironomidae* sp. was the dominant group and recorded its highest number in the highly polluted sections. It is well documented that the family Chironomidae is considered to be a pollution tolerant family of Order Diptera which may be due to the presence of haemoglobin pigment that helps them to collect oxygen directly from the atmosphere (Chowdhary *et al.,* 2013). *Psychoda* sp. was found only at Hazratbal site. Among insects worth-mentioning was *Enallgma* sp. (Odonata-Coenagrionidae) commonly called dragon fly. Among the non-insect arthropoda, Arachnida represented by 1 taxa (*Dolomedes* sp.) from the order Areneae, collected from *Ceratophyllum demersum* and *Potamogeton natans* does not show any significant diversity on any other macrophyte. Plant architecture is having effect on density and development of epiphytic organisms (Bhat *et al*., 2012).

Phylum Mollusca shows their presence on *Hydrilla verticillata* followed by *Potamogeton natans, Myriophyllum spicatum* and *Ceratophyllum demersum* to be as a result of the greater surface area provided by the vegetation types (Krull, 1970; Downing, 1981; Harrod, 1964). Generally *Physella* sp feed on periphyton but they can also consume living plant material and detritus. This species has a wide distribution and tolerance of a broad range of habitats, and tolerance to habitat modification (Burch, 1989). Phylum Annelida shows their presence on *Potamogeton natans* as they feed on detritus. Thus Aquatic macrophytes have been shown to be significant habitat structurers, are very much influential on the composition of the associated fauna. Increase in macroinvertebrate abundance, richness and diversity due to macrophyte habitat complexity may be explained by simple mechanisms that involve the availability of habitat, which increases the possibility of available food and consequently attracts other organisms, which then relate to each other while utilizing this complexity as shelter (Sidine and Eduardo, 2010).

CONCLUSION

In conclusion, this study demonstrates that macrophytes like *Ceratophyllum demersum, Potomogeton lucens, Potomogeton natans* and *Hydrilla verticellata* offer a conducive substrate for growth and development of macroinvetebrates as compared to others like (*Myriophyllum spicatum, Utricularia* sp. and *Chara* sp.). *Ceratophyllum demersum* having dissected leaves and bowl shaped whorl set harboured higher macroinvetebrate density. Among the insects *Chironmidae* sp was dominant taxa due to its wide ecological amplitude. From the present study it is thus safe to conclude that there is a significant role of macrophytic architecture on diversity and density pattern of macro-invertebrates.

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An Overview of Transition in Traditional Agriculture of Ladakh

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ABSTRACT

In recent times, one of the significant features of the unique, mountainous region of Ladakh, lying on the high altitude has been the transformation in the traditional subsistence economy and trends towards livelihood diversification. This will have a direct impact on the dominant economic activities of the region, i.e., agriculture and pastoralism. Ladakh consists of two districts i.e. Leh and Kargil. Pastoral and agriculture activities have been entirely dependent on each other. Agriculture in the region primarily is of subsistence type and only a few crops have been traditionally grown, because of cold arid climate, high altitude, extremely rugged and isolated terrain, absence of market etc. The major crops cultivated included Grim (Naked Barley), wheat, peas and alfa-alfa for fodder. Agriculture occupied all the workforce and social institutions and practices were all built around agrarian lifestyle. The agricultural areas are confined to the relatively lower areas which correspond with the river valleys particularly in the central and western Ladakh.

The isolated, ecologically sensitive, region of Ladakh has been exposed to major changes during the last fifty years due to political factors as well as increased development activities and interaction with the outside world. Present study was carried out in two villages of Leh district i.e. Skuru and Saboo. Secondary data has also been used along with primary data. The study shows transition in the economy which resulted in changes in the traditional agricultural practices, crop diversification, mechanisation, fertilizers intake etc. Traditionally, large share of the total cropped area was under barley and wheat. Households have increased vegetable production for domestic use as well as cash crop mainly to meet demand of army and tourism industry. Introduction of public distribution system in the region resulted in increase in dependency and decline of cultivation of traditional crops like wheat and barley. Traditional practices started declining in recent times and use of chemical fertilizers and mechanisation has increased. There has been increase in total area under fodder crops and alfalfa is one of the main fodder crops of the region.

Key words: *Himalaya, Agriculture, LCH, Kargil*

INTRODUCTION

The unique ecosystem of Ladakh, nestling between the lofty Himalayas and the mighty Karakoram, has resulted in the evolution of a traditional triad of people, cattle and fields forming the major components of the farming system. The economy of this region has primarily been based on subsistence agriculture along with livestock rearing. People here have adapted themselves to harsh environment of cold-arid climate and rugged terrain through locally developed institutional setup and customs. As cultivable land and water are limited, cultivated land cannot be extended easily to meet the needs of households. Traditionally in Ladakh, rule of primogeniture was such that entire land and other property passed from father to eldest son in a family. Along with that, polyandry maintains household unity and it inhibited population growth, which reduced fragmentation of land and lowered pressure of population on resource-poor environment (Demenge, 2007). Polyandry was abolished through state legislation in early 1940s, leading to fragmentation of land and large estates owned by the monasteries were dismantled (Mankelow, 2003). Other customs had also started undergoing changes with transitions in social values and various other aspects.

The whole region is characterised by high altitude rugged topography. Patches confined mostly to lower portions of valleys along river courses have been developed for cultivation. Land has been made suitable for farming by levelling and terracing it. Landholdings are generally small in size and there is absence of a large continuous patches of cultivable land. The farming system that has developed is based upon indigenous methods of construction of kuhls (man-made narrow irrigation channels) for irrigation and using manure consisting of animal dung and human waste. Kuhls, based on the principle of gravity, bring water to agricultural fields located at lower elevations than the source of water and the point of diversion. Kuhls in this region have been constructed through collective effort of community under the leadership of religious monasteries, locally called Gompas (Singh, 1995).

Traditionally, agricultural system was basically meant for self-consumption or subsistence, with limited agricultural surplus. Surplus produced by farmers was exchanged in an age-old barter system with traders and nomads (Singh, 1997). Farmers of the region traditionally exchanged grain with nomads for products like salt, wool, butter and other animal products and traces of the practice still continue in some remote pockets of the region.

Factors like absence of soil cover, scarcity of water (as precipitation is low) and low temperature affect agriculture of cold arid region of Ladakh (Singh, 1992). Despite environmental constraints, agriculture of this region had been sustaining the local population (Osmaston, 1989), as well as livestock, along with population and livestock of caravans that passed through or came to Ladakh for trade. Pastoral and agriculture activities have been entirely dependent on each other. Manure was constantly needed to maintain soil fertility and fodder was needed for cattle during the extremely cold winters when natural pastures were not available for grazing due to snow and ice cover. Cultivation in Ladakh is entirely dependent on irrigation due to arid conditions. Irrigation is possible only in summer months from melt water.

Economy of Ladakh has historically evolved around barter system of exchange, with minimal presence of cash. The introduction of tourism industry, permanent stationing of military troops after the 1962 Sino-Indian skirmishes and Indo-Pak border disputes as well as wars of 1965 and 1971, and consequent construction of National Highways linking Ladakh with Kashmir and Manali, have led to integration of Ladakh with the world system (Michaud, 1991; Goodall, 2004), transition and monetization of economy of the region.

These post 1960's changes in the economy had significant impact on the dominant economic activities of Ladakh, i.e., agriculture and pastoralism. A rapid growth of tourism industry after 1974 along with the presence of defence forces induced many farmers to adopt new crops and diversify their production. Thus, it becomes imperative to look at crop diversification and cropping patterns as these are relatively recent influences.

One of important parameters of economic structure is the total number of workers engaged in various economic activities. As stated earlier, majority of people were traditionally engaged in agriculture excluding nomads and lamas who are forbidden by rules from engaging in economic activities. There was dominance of primary sector in Ladakh. In 1971, primary sector employed 84.69 per cent of total workers as against 3.55 per cent and 11.76 per cent in secondary and tertiary sector respectively. There has been a significant shift from primary to tertiary sector over a period of four decades from 1971-2011, with a marginal change in secondary sector. Primary sector constituted 27.21 per cent workers in 2011, while their share in tertiary sector rose to 71.02 per cent. Increase in the tertiary sector was at the expense of primary sector. One of the most important reasons for transition of economy from primary sector to tertiary sector was opening up of Ladakh for tourism in 1974. Tourism industry generated a variety of jobs. It engaged a large number of workers, predominantly males. In addition to tourism industry, the stationing of defence forces also created employment opportunities. These mainly related to defence needs, infrastructure development, transport, communication and logistics, which further enhance tourist arrivals. Improvement in education facilities and increase in literacy rate led to increase in preference for engagement in non primary activities. Increase in off- farm employment opportunities and labour shortages resulted in adoption of mechanisation and hiring of labour from outside the region for agriculture. Local people find non-farm activities lucrative and relatively less strenuous. Young people are moving out from the confined world of their villages to seek education and employment outside agriculture and pastoralism activities.

There was a complete absence of mech-anisation in the region and use of chemical fertilisers was very limited till the recent past. Local manure derived from animal dung and human waste has been used in the field since early times. Till recent times, manure was applied to agricultural fields by teams of men and women, who would load donkeys which they would collectively pool. This practice is fading gradually as quantity of organic farm manure used as a proportion of fertilisers is declining, whereas use of chemical fertilisers has been rising over time. Additionally, tractors and other vehicles are increasingly being used in place of draught animals to carry manure to the field. An attempt has also been made to find out changes in traditional practices, usage of different chemical fertilisers and technical inputs that have come up over time.

MATERIAL AND METHODS

The data has been collected from both primary and secondary sources. Secondary sources include Directorate of Economics and Statistics, Ministry of Agriculture (1999-00 to 2012-13), Census of India and Statistical handbooks of Leh and Kargil districts

Detailed field survey was undertaken in October 2016 in two villages of Leh district, i.e. Skuru and Saboo, with the help of a questionnaire at household level to achieve objectives of the study properly. Information of individuals within household was also collected.

The economic transition that has taken place in Ladakh has led to changes in economic activities such as agriculture and pasto-ralism, though the changes are not uniform.These vary across the region. In addition, physiographic and climatic variations also play a significant role in determining livelihood activities and aspects related to population, etc.

Purposive method of sampling has been used for this study. The criteria for selection of villages included nearness to urban centre and connectivity, etc. It is assumed that villages situated in proximity to main town of Leh will have maximum impact of internal and external forces of change on agricultural and pastoralism activities. On the contrary, remote villages shall have lesser impact. In light of this, two villages from Leh district were selected. These included Saboo village near Leh town and Skuru in Nubra.

Skuru village chosen from Nubra is situated on the bank of River Shyok and is around six hours drive from Leh town. It is situated across Khardungla pass which has the highest motorable road in the world. The entire Nubra valley gets disconnected from rest of Ladakh, when Khardungla pass gets blocked due to heavy snowfall in winter months. Saboo village located, within the Indus valley, at a distance of 6 km from Leh town. The village extends from 3500m to 3745m altitude (Tiwari *et al.,* 2015). It has better connectivity for the movement of people, goods and agricultural inputs and outputs.

A total of 80 randomly selected households were surveyed. Skuru village had 55 households in 2011. Out of these, 30 households, accounting for slightly more than 50 per cent, were selected for the survey. Saboo is a big village and it had 261 households in 2011, out of which, 50 (about 19 per cent of the total households) were randomly selected for the survey. There are five wards in the village namely Saboo, Phoo, Mayak, Yoknos and Ayu.

RESULTS AND DISCUSSION

Historically, only a few crops were grown in Ladakh. This was mainly due to harsh natural conditions as well as lack of access to a wider variety of crops and seeds due to relative isolation of the region and absence of market. Agriculture land was used mainly to grow food crops such as Grim (Naked Barley), wheat and peas etc. for which the environment is conducive in terms of major requirements including short growing season. Grim, which is locally known as 'ne' or 'nes', is one of the most important staple crops of Ladakh. It is grown in almost all villages of the Ladakh up to an altitude of 4400m (Osmaston, 1994). Traditional food such a 'paba' and 'ngamphe' are prepared from the flour of roasted grim. Besides, a local popular drink called 'chang' (local beer) is brewed with it. Other varieties of barley were also grown such as Yangmar, Sermo, Tugzur, etc. Wheat crop (locally called 'to' or 'dho') requires longer time to mature in comparison to Grim. It is cultivated in and around hamlets situated at lower altitudes. This crop is considered superior by locals (Singh, 1997).

Peas known as sran-ma form an important source of nutrition for people and it helps in regaining fertility due to its quality of helping to fix nitrogen in the soil. It is also grown in most of the villages. After harvesting, most of the crops are partly or fully roasted and milled together with barley to make flour (Osmaston, 1994). Some proportion of peas grown has begun to be eaten green and raw during summer in recent years. Mustard has been grown widely in this region, and it's oil is used for lighting, cooking and as hair and body oil. Lucerne or alfalfa is an important fodder crop which is grown on less fertile land by most farmers for use as winter forage when pastures are not available.

Traditional Buddhist institutions in Ladakh evolved in conformity with limited production possibilities and were characterised by socio-cultural practices such as polyandry, inheritance through primogeniture and monastic way of life to ensure that balance remains between population and carrying capacity of land. Process of crop cultivation evolved around the family unit as traditional system. Family provided most of inputs as well as consumed bulk of the output. Labour required for agricultural activities was provided by the members of the household. Livestocks owned by family were used for ploughing fields, threshing, transporting manure and grain etc. Seeds used in the field are obtained from previous harvest (Gokhale, 1986). Historically there was a system of community sharing of labour and resources like farm tools and animals. But with more people getting engaged in non-farm activities and almost every family sending children for education, there has been a decline in all such traditions.

Traditionally, in most areas of Ladakh except Changthang, subsistence agriculture along with livestock rearing was practised. Once the sowing season starts and seeds are sown, cattle are taken to high altitude pastures known as Doksa. This, in a way, kept livestock away from cultivated fields and provided fresh grazing areas. Doksa usually acts as a collective diary where cheese and butter are made in large quantities. One member from each family lives there in rotation to tend to animals. When threshing is completed, livestock are brought back to villages (Chatterji, 1992).

Cropping pattern

The main crops grown in the region in past were barley, wheat, other grains and non-food crops, which mainly consist of fodder crops, especially alfalfa. The other grains largely included Grim (Naked Barley), Garas and Bakla (Broad Beans) and Trumba (Buckwheat) (Singh, 1978).

Table 1 shows that there is a predominance of food crops in the region. These covered around 78 per cent of the total cropped area. Grim is the principal crop followed by wheat. Fodder crops accounted for 18.21 per cent of the total cropped area in 1950-51, and it’s share increased in later period.

As it has been discussed earlier, agriculture and livestock rearing are almost dependent on each other. Livestock forms one of the important components of the economy of Ladakh. Fodder crop is essential in order to forage-livestock during winter months in the absence of pasture availability.

Table 1. Area under principal crops in Ladakh, 1950-1970 (Area in terms of percentage to total cropped area)

Year	Wheat	Barley	Other food grains [1]	Fruits & Vegetables	Oilseeds	Non-Food Crop	TCA (hectare)[2]
1950-51	16.93	5.84	54.94	0.72	1.45	18.21	16238
1955-56	17.80	7.94	51.53	2.60	1.26	18.82	16858
1959-60	17.27	5.94	54.79	3.03	1.23	17.68	17012
1967-68	18.86	4.86	53.34	2.92	0.54	19.51	17460
1969-70	18.24	4.52	55.20	2.19	0.33	19.51	17807

Source – Retrieved from H. Singh, 1978

[1] Other food grains mainly include Grim (Naked Barley) and it covers the largest area. Other crop in this category are Peas, Grim (Naked Barley), Garas and Bakla (Broad Beans) and Trumba (Buckwheat). [2] TCA is Total Cropped Area and is given in hectare

There has been a minimal increase in area under wheat, other food grains and fruits and vegetables with a slight decline in share of area under Barley and oilseeds between 1950 and 1970. The increase in area under these can relate to increase in the total cropped area. It has been mentioned in some of the studies that with the opening of Leh-Srinagar road in 1966, important commodities like oil and spices etc became available to a number of villages in the region which are situated on the main road. It led to a decline in the cultivation of oilseeds.

Over this period of twenty years from 1950-70, cropping pattern of the region remains same with very little change. There was slight increase in total cropped area. There was a low level of diversification in agriculture of the region and agriculture was primarily of subsistence nature. Environmental constraints on agriculture in terms of harsh terrain, cold-arid climate, dearth of cultivable land, paucity of water for irrigation led to just a small share of total geographical area being cropped.

Major changes took place in the economy of Ladakh post-1960s because of various factors as mentioned earlier. Table 2 shows area under major crops in Ladakh post-2000. These include other food grains (mainly Grim), fodder crops, wheat, fruits and vegetables. There was predominance of Grim in the region followed by non-food crops and wheat before 1970. With the shift in traditional barter economy to cash and commercialization of economy, there was slight change in cropping pattern with Grim remaining the dominant crop. Area under other food grains constituted 53 per cent of the total cropped area in 1999-2000. It mainly included Grim (Naked Barley), which represents around 46 per cent of cultivated land.

Table 2. Area under principal crops in Ladakh, 1999-2013 (Area in terms of percentage to total cropped area)

Year	Wheat	Barley	Other food grains	Fruits & Vegetables	Oilseeds	Fodder Crop	Total Cropped Area (hectares)
1999-00	22.02	0.82	53.38	3.28	0.12	20.33	19015
2004-05	21.42	0.37	47.85	2.76	0.31	27.28	20422
2009-10	20.87	0.19	46.97	3.94	0.42	27.61	21361
2012-13	13.22	0.02	50.47	4.34	0.47	31.48	18281

Source- Directorate of Economics and Statistics and Statistical Handbook of Leh and Kargil Districts.

Share of wheat in total cropped area started decreasing along with area under barley after 1999-2000. This decline was because of introduction of Public Distribution System in the region during post-1970s phase. Ladakh literally gets isolated from rest of the country due to mountain passes getting blocked because of heavy snow during winter months. Essential commodities like rice, sugar, wheat flour and kerosene are mostly stocked in government warehouses according to requirements of the region and available at subsidised price under PDS. Ladakh has become largely dependent on rice and wheat imported from outside areas in recent years. There is less need to farm because people get grains at subsidized and cheap price. Hence the local cultivation of wheat and barley decreased.

Nearly 80676 and 79586 quintals of rice were distributed in Leh and Kargil districts respectively in 2014-15. Quantity of wheat flour (Atta) distributed was 75738 and 58269 quintals in Kargil and Leh districts in that year. Price of rice was Rs. 10 per kg for people having Above Poverty Line (APL) card and at Rs 6.40 for Below Poverty Line (BPL) card holders. Wheat flour was provided at Rs. 8.00 per kg and Rs. 5.35 per kg for APL and BPL card holders respectively.

Every household in the surveyed villages is availing PDS facility and PDS ration store is available in both. Subsidised rice supplied through the PDS is increasingly replacing locally grown barley as the main staple diet. Rice, previously was symbol of social prestige and considered a luxury in the Ladakhi diet, has now become a cheap staple, subsidised by the government (Pelliciardi, 2013). Many people in the region feel that the government should encourage local farmers to increase traditional grain production and procure barley and wheat from local people rather than importing it from Punjab and other areas. This in a way would promote traditional agriculture of Ladakh. Tsering, a resident of Saboo village, stated, “Our food comes from PDS ration depot and, ironically, our own grain (barley) is stored in sacks and is eaten by rats". The combination of improved infrastructure, job availability and subsidized food has resulted in migration of people especially males from villages to Leh town to work in non-farm activities like tourism industry and others (Kingsnorth, 2000). Supply of subsidised rice and wheat through PDS in the region directly as well as indirectly also discourage farmers to intensify their local food grain production and resulting in diversification of cropping pattern toward cash crops.

Nearly 2.19 per cent of the total cultivated area was under fruits and vegetables in 1970. It increased by more than 50 per cent in 2012-13, though it still represents a small proportion of total cropped area. The increase in area under fruits and vegetables is to meet the demand generated by armed forces and tourists in the region (Bisht, 2008). Other factors like increase in population, urbanisation and growth in income also led to increase in demand for local vegetable production (Stobdan *et al.,* 2018). People of the region started consuming wide varieties of vegetables and fruits in the last few years. Farmers of the villages which are located near urban centres and army settlements earn good income by selling vegetables. This has persuaded many farmers to cultivate vegetables and market-oriented crops as a sort of market gardening form of agriculture. Wide varieties of vegetables like potatoes, cabbage, carrots, turnips, tomatoes, onions, cauliflower and lettuce etc. are grown in many parts of the region for both self-consumption and sale. Potatoes are the foremost vegetable supplied to the defence forces.

Ladakh being strategically located a large number of army troops are stationed in the region. Essential nutritional support to the army operating in high altitude is provided from resources available locally, as timely supply of fresh vegetables from far off plain areas is not always possible due to logistic constraints (Stobdan *et al.,* 2018). So, vegetables, especially during summer season, are being supplied directly from farmers' field to the army through cooperative marketing societies. Cooperative societies were established in most of the blocks to regularise sale and purchase of vegetables to the defence forces. Days are fixed for different villages and vehicles owned by the army come to villages to collect vegetables and take these to army supply department (Mann, 2002). Receipts are issued to each producer against the quantity he/she supplies. Farmers have to collect the amount for sale from cooperative banks. Therefore supply of vegetables to army emerged as a major market for local farmers in this remote mountainous region.

Defence Institute of High Altitude Research (DIHAR), formerly known as Field Research Laboratory (FRL), plays a significant role in improving the diversity and quantity of various vegetables in Ladakh region. It was established in 1962. Farmers training and activities are being conducted extensively by agencies such as DIHAR, State Agriculture Department etc to promote vegetable cultivation in the region. These agencies also provide seeds and seedlings, farm implements, technical inputs etc.

Traditionally, one of the important factors restricting the number of livestock has been shortage of fodder in winter. Consequently, the number of animals kept in each household depended on the fodder storage capacity for winter months. Natural pastureland is important source of fodder in Changthang plateau, whereas, alfalfa and crop residue comprise major part of fodder in valleys of central and western parts of Ladakh. There has been significant increase in area under fodder crop from 18 per cent in 1950-51 to 31 per cent in 2012-13. Important factors influencing fodder production are cropping pattern, climate, socio-economic conditions, type of livestock etc (Kumar *et al.,* 2016). This increase in area under fodder crops can be explained by the increase in the number of livestock, change in livestock composition etc and changes in cropping pattern. Animals are fed on fallow land, hay, willow leaves, residue of crops, alfalfa and other stored fodder during entire winter. Considering the compulsion of stall-feeding of cattle during winters, farmers devote significant portion of agricultural land for growing fodder crops. Orchards are also inter-cropped with alfalfa in many villages. Sheep Husbandry Department also buys fodder crop from locals, and it fetches around Rs. 1500-Rs. 1700 per quintal (as informed during field survey). Fodder crops like alfalfa grow with less water and on land which are not very suitable for cultivation of food crops. It takes less time and labour in growing fodder crops. Traditionally, there was dominance of cereal crops like wheat, barley, buckwheat and mustard etc. Residue and straw of these crops supplied good amount of fodder for livestock. Now, there is more cultivation of vegetables, which provide lesser residue for fodder, thus adversely impacting availability of fodder, and is resulting in expansion in fodder production.

There has been an increase in total cropped area from around 16,238 hectares in 1950 to around 21,361 hectares in 2009-10. This shows that some additional land has been brought under plough over the years. Expansion of irrigation projects initiated by the government in the region may also have played a role for this increase. There has been slight diversification in agriculture post-1999-2000, with increase in share of area under fruits and vegetables, albeit at low rate. It shows that commercial crops have taken important place in the agriculture economy of Ladakh, which earlier was primarily of subsistence kind.

There are a few variations in cropping pattern of the two districts of Leh and Kargil in Ladakh region. There was predominance of food crops in both the districts during 1999-00 to 2012-13. Leh district had the highest proportion of area under Grim in all the years followed by wheat, fodder crop, other millets and pulses and fruits and vegetables.

Over the period of one decade, there has been a decline in the area under Grim, Wheat and Barley, while there has been a significant increase in land under fodder crop, fruits and vegetables and other millets and pulses in Leh district. Acreage under wheat decreased from 16.27 per cent in 1999-2000 to 12.13 percent in 2012-13 in Kargil district.

Table 3. District-wise area under principal crops in Ladakh, 1999-2013 (Area in terms of percentage to total cropped area)

Year and District	**Wheat**	**Barley**	**Grim**	**Other Millets and Pulses**	**Fruits and Vegetables**	**Oilseeds**	**Fodder Crop**	**TCA (hectares)**
Leh								
1999-00	28.23	1.69	52.69	5.56	3.14	0.24	8.45	9152
2004-05	28.36	0.72	42.15	5.22	3.04	0.61	19.91	10499
2009-10	25.37	0.38	43.81	5.65	4.22	0.81	19.76	10604
2012-13	14.83	0.05	38.97	11.00	5.55	1.17	28.43	7363
Kargil								
1999-00	16.27		39.68	9.24	3.42		31.39	9852
2004-05	14.08		37.29	11.08	2.47		35.09	9923
2009-10	15.99		32.14	11.95	3.62	0.52	35.79	10010
2012-13	12.13		39.80	11.00	3.53		33.54	10914

Source: Directorate of Economics and Statistics and Statistical Handbooks of Leh and Kargil Districts.

Kargil district has low level of diversification in agriculture compared to Leh district. Another important outcome from Table III is that there has been decline in the total cropped area in Leh district, while the same is increasing in Kargil district. This could be because of a lot of land in Leh district has been diverted to other uses related to tourism. Another reason may also be the high birth rate in Kargil district, leading to increased pressure on land. In general, there have been slight changes in cropping pattern of both districts.

Transitions in the traditional economic activities of the region have not been uniform throughout Ladakh. Villages situated in proximity of main town of Leh have maximum impact of internal and external forces of change on agriculture activity. Table 4 shows that the main crops grown in Saboo and Skuru villages include Grim, wheat and vegetables. In Skuru village, Grim crop covered a larger share of total cropped area, whereas dominance of potato and Grimwere seen in Saboo.

Respondents in Skuru village reported that quantity of wheat grown is very less in their village as it's yield is very low. It might be due to climatic and soil factors. Traditionally they exchanged grim with wheat from neighbouring villages. They also get wheat flour from PDS at a low price. Less area is devoted to vegetables and potato in Skuru village in comparison to Saboo village. They cultivate these crops primarily for self-consumption. There is absence of cooperative society in their village. Nearest market for vegetables is at Disket village which is located at a distance of about one hour by road. Travelling cost and expenditure comes out to be higher than income procured from selling vegetables. Some of the farmers sell their vegetables at nearby army camp. Farmers of the village aspire to devote major proportion of their land for vegetable cultivation if demand rises and they get good price.

Saboo village is known for potato cultivation in the region and they devote large share of total cropped area for potato (Tewari *et al.,* 2015). It is one of the major sources of income of farmers. Potato is also cultivated together with pea. They sell their potato either at Leh market or supply it to army. Cooperative society is effectively functioning in the village. Vehicles of cooperative society come to Saboo during agriculture season and take vegetables of all kind on rotational basis. Farmers of Saboo, on an average, earn Rs 12,000 to Rs 20,000 annually by selling potatoes. Other vegetables like cabbage, onion, tomato, cauliflower, carrot, leafy vegetables etc are also supplied to the army and sold at Leh market.

Technological inputs in agriculture

Technological development is essential to overcome natural constraints on economic activities of the region. It acts as one of the major components in overall development of the region. Agriculture has been practised in a very traditional manner in Ladakh till recent years. Agricultural implements were quite primitive, and level of technology was very low in raditional system. It used to be based on local knowledge and made up of local resources. Ploughing was done with the help of dzo or yak. Plough, locally known as ‘shoel’, was commonly made of wood with a small iron blade. Ploughing was done solely by men, while both men and women worked to level the surface with ‘T’ shaped tool called ‘baath’. Threshing of harvested crop was done with the help of combination of animals like dzo, horse, cow etc on a flat, circular shaped piece of land known as ‘chokra’. Fields were ploughed once before the onset of winter.

All this work used to be traditionally done through community gathering, cooperative basis and mutual exchange of labour between community groups called Phaspun. This process of sharing the work force and animals is known as *bes* (in local language) in the Indus valley and *pay* in Zanskar (Dame and Mankelow 2010). There is a shift in usage of agricultural implements from traditional primitive to modern technology and decline in such system across Ladakh in recent years.

Mechanisation such as use of tractor and power tiller is a very recent phenomenon in Ladakh. A plot of land which usually takes one whole day to plough using dzo or yak, can now be ploughed with a tractor in one hour on an average, reducing and saving labour and time.

Most households in Saboo village, in the absence of family labour, prefer to hire agricultural labour during peak time in agricultural season, mostly during ploughing, sowing and harvesting time, while in Skuru village, majority of the households still follow community sharing of labour and resources. A unique feature of Ladakh agriculture and landscape is a cattle type, locally called ‘dzo’. ‘Dzo’ is a hybrid between yak and cow that is extensively used for ploughing fields due to its hardy nature. In Skuru almost all the households who don’t own dzo responded that they help with work particularly at ploughing and sowing time in the fields of dzo owning households. In return, they get dzo for ploughing for their own fields. This is mutually a beneficial sharing system involving more optimal labour or human work and use of dzo. Ploughing in Skuru is entirely done by using animal power, whereas some of the households in Saboo use tractor and power tillers to plough their fields.

One of the respondents suggested that “Ploughing by tractors destroys fields by reducing its fertility and makes it hard, but it saves time in the absence of family labour.” Some respondents also lamented regretfully that in years to come traditional methods of ploughing and tools related to it will disappear.

It has been mentioned in the Economic Review, 2014-15 of Leh district that one of the objectives of Agriculture Department is to improve yield per hectare of vegetables, cereals, fodder, pulses etc. There has been significant increase in production of cash crops, mainly vegetables. With the introduction of poly/green-houses, people have started cultivating green leafy vegetables during early or late winter months of October-November and February-March.

Greenhouses are also used to grow vegetable saplings before agriculture season starts for transplantation later. Incentives are given by agencies like DIHAR, State Agriculture Department etc to farmers for construction of greenhouses, vegetable storage structure and compost pits. There has been increase in use of greenhouses, which not only improved dietary intake of vegetables during winter months but also offered an economic opportunity for farmers of the region to sell early season vegetables (Angmo *et al.,*

Fig. a. Ploughing field with Dzo in Nubra in 2016.

Fig. b. Tractor being used for ploughing field in Nubra in 2016

Fig. c. Power tiller being used for ploughing field in Nubra in 2016.

Irrigation

Water is one of the pre-requisites for cultivation in the cold arid region of Ladakh. Traditional irrigation system in the region has been managed by local institution, and includes the maintenance and construction of physical infrastructure and proper distribution of water among villagers. Water for irrigation was diverted from stream through channels. Usually, in the evening, water is stored in small reservoir called 'Zing' in local language. Stored glacier water is then used the following day in the fields. Each village has large networks of canals and zings (storage tanks). Locally, irrigation channels are called 'Yura' or 'Yurba'. Water is considered to be a common resource; farmers don't have to pay any amount for irrigation, as is also the practice in the similar, adjoining cold desert of Lahaul Valley in Himachal Pradesh (Kuniyal *et al.*, 2004). Both men and women do watering of fields. In every village, a person called Churpon or Chunpa is appointed who regulates and ensures proper and equal distribution of scarce water in village on rotational basis. The turn of watering the crop fields is known as 'Chures'. Water is distributed according to order, which had been listed in red book of village, which is with revenue department of the village (Hill *et al.,* 2007). In return, Churpon is given grain by every household in the village. Presently, churpon is elected on a rotational basis from each household for some period and it has been made mandatory for every family to provide churpon. Payment to the Churpon, which traditionally made in kind, has now been replaced by money. Even fines levied for breaking rules are paid in cash, which earlier used to be in kind. In Saboo village a penalty of Rs 400- Rs 500 is being charged, if rule is broken.

About 15033 hectares of land was under irrigation in 1950, which constitutes 92 per cent of the total gross cropped area and 100 per cent of the cultivated area was under irrigation (Singh 1978). Agriculture season lasts for about six months and in the remaining months farming is not possible due to severe cold. Because of short growing season, only one crop is grown in a year except in some villages situated in the lower valleys.

There has been a slight increase in total irrigated area in the region in the last five decades. Table IV reveals that 95 per cent of total gross cropped area is under irrigation in 1999-2000 and 100 per cent of net sown area is under irrigation. It also shows that total irrigated area has remained same with minimal change since 1999 till 2010-11. It, however, registered a decline in 2012-13. This may be because some land was diverted from agriculture for infrastructure and tourism related activities. It is supported by the fact that similar decline was seen both in Net Sown Area and Gross Cropped Area. It becomes clear from the table that irrigation is a prerequisite for agricultural activities in Ladakh. As water for irrigation is diverted from streams, rivers,etc, to the field through nallahs or channels, it is influenced by snowfall during winter months. Some irrigation projects funded by the government are already taking place in the region to bring more land under cultivation.

Table 4. Total irrigated area in Ladakh, 1999-2013 (Area in terms of hectare)

YEARS	Total Area Irrigated	Total Net Sown Area	Total Gross Cropped Area
1999-00	18094	18094	19015
2001-02	19763	19763	20928
2003-04	19712	19712	20948
2005-06	19949	19949	21171
2008-09	19967	19967	21248
2010-11	19694	19694	20948
2012-13	16741	16741	18281

Source: Directorate of Economics and Statistics, Ministry of Agriculture.

Almost all the households surveyed in villages of Skuru and Saboo responded that Kuhls are the only source of irrigation. It was reported in both the villages that before the start of agricultural season, villagers gather to clean Kuhls and do maintenance work of all the major kuhls in the village. It is an age-old tradition in villages. Newly constructed kuhls under government project have been made of cement; whereas rocks, soil and sand formed the main material for their construction in the past. Some channels for irrigation are under construction in Skuru village. These channels bring water to ‘Thang’ area of the village, where villagers have planted trees and grow fodder crop alfalfa.

Some of the major irrigation projects channels for irrigation are under constructed in Ladakh in last few decades include Khurbathang irrigation project, Igoo-Phey Irrigation Project, Nuruchan Irrigation Project and Hanley Irrigation Project etc. In last few years, artificial glaciers have been built in some villages in order to conserve winter water and to overcome an acute water shortage, particularly during early summer months of April and May, when there is little water in the streams and there is intense competition amongst farmers for watering their newly planted crops. Traditionally water from kuhls was also used to grind flour with the help of water mill. It used to be very common in almost every village. There used to be two–three water mills in larger villages. Local system was such that some

Fig. d. Modern cemented irrigation canals (Kuhls)

share of flour was given to mill owner as rent. Presently, mills running on diesel powered generating sets are used in almost every part of the region. People prefer diesel powered generating sets because these take less time and are much faster, and they do not have to put their own manual labour.

Fertilizers intake

Apart from irrigation and technological inputs, other inputs like fertilisers also play major role in agricultural development. Traditionally, chemical fertilisers were used on a very small scale because of their non-availability due to lack of accessibility. More water for irrigation is needed for using chemical fertilisers, which the region was lacking. Crop rotation has been practised in Ladakh to retain fertility. Manure composed of animal dung and human excreta has been used in the fields since early times. Majority of households still use local manure prepared at home in the surveyed village of Skuru, and they practice traditional system of manuring the field by loading it on donkey. Some households in both Saboo and Skuru have experimented with urea and NPK and most of them narrated as to how it makes soil hard. Saboo village which is located near urban centre of Leh has experienced more changes in these practices in comparison to Skuru.

Local government had started distributing chemical fertilisers like ammonium Sulphate, urea, DAP, phosphate and potash etc. since late 1960s. The consumption of chemical fertilisers was very low. It was mostly used on agricultural department farms for experimenting purpose (Singh, 1978). These fertiliseris are distributed from agriculture department stores located at headquarters of every block. Most of the households in the region except nomads of Changthang have been selling livestock like goats, sheep, dzos, and horses, etc. in the last few years. This might be due to shortage of labour in a family, with children attending schools and other members getting engaged in non-agricultural activities. One of the respondents informed that livestock rearing has become very difficult. In the absence of livestock in households, they have to either buy manure or use chemical fertiliser. It was informed by some respondents that "when most family members are engaged in non-agricultural activities, it becomes easier and takes less time in using chemical fertiliser, though it has a negative impact on land".

Table 5. District-wise fertilizers intake in Ladakh (Quantity in 000 quintals)

Year/District	Nitrogen	Phosphorous	District	Nitrogen	Phosphorous
Leh			**Kargil**		
2011-12	3.98	4	2008-09	5.08	1.76
2012-13	3.85	3.78	2010-11	5.87	2.05
2013-14	3.9	3.26	2011-12	5.64	1.96
2014-15	3.72	2.81			

Source- Statistical Handbooks of Leh and Kargil Districts, 2014-15

Table 5 reveals that total quantity of fertilizers has remained almost same over the years. Around 3980 quintals of nitrogen were used in Leh district against 5080 quintals in Kargil in 2011-12, while it was 4000 and 1760 quintals of phosphorous in Leh and Kargil districts respectively. There has been a decline in the intake of both nitrogen and phosphorous over the years in Leh district while their use has increased in Kargil district.

Farmers have traditionally used seed from previous year's harvest and to a large extent they continue to do so. During the field survey, majority of people stated that they use traditional and stored seeds. There has been a tradition of exchange of seed between one household and another within the same village or of different villages. The government, since 1967,is distributing high yielding improved varieties of seed in order to improve productivity of food grain in the region. Seed amounting to 49.26 quintals, 1.68 quintals and 39.94 quintals of cereals, vegetables and potatoes were distributed in 1967-68 (Singh, 1978).

Table 6. District-wise distribution of improved seeds (in tonnes)

Year and District	**Wheat**	**Pulses**	**Oilseed**	**Vegetable**	**Fodder**
Leh					
2011-12	82.05	22.1	10.06	619.74	1010.59
2012-13	146.25	14.92	3.84	896.7	1075.2
2013-14	606.5	324	409.3	1028.18	732.16
Kargil	**Wheat**	**Grim**	**Vegetable**	**Fodder/Pulses**	
2010-11	28	110	146.1	24.86	
2011-12	30	140	150	72.1	
2012-13	33	77	118.4	65.92	
2013-14	35	76.55	144	13.1	

Source- Statistical Handbooks of Leh and Kargil Districts, 2014-15

Table 6 shows that distribution of improved varieties of seed is the highest in Leh district in comparison to Kargil district. Among all the crops, improved seeds of fodder and vegetables were distributed in larger quantity in Leh district, whereas Grim and vegetable were important in Kargil. This also reflects the shift in cropping pattern from subsistence to commercial based crops. Amongst vegetables, improved seed of potatoes werelargely distributed.

CONCLUSION

It can be summarised from above discussion that with the transition of economy from primary to tertiary activities, shifts are also taking place in traditional subsistence agriculture of the region. Consequently, there is a change in the economy from subsistence farming and barter trade to commercial and cash-driven economy. Recent development of the region, post 1960s border skirmishes, and it's opening for tourism in 1974, development of irrigation, technological inputs along with other factors have led to diversification of cropping pattern, shifts in traditional agricultural practices etc. One of the important features of the present agricultural system of the region is the increasing cultivation of vegetables and decline in production of traditional crops. Though the total area under vegetable farming is low, yet it shows influence of modernisation in agriculture. It is becoming an important source of income for many farmers in Ladakh. There is a need to educate farmers regarding various techniques and methods of vegetable cultivation. Local Government needs to conserve and promote traditional cultivation practices and seeds rather than relying on imported foodgrains from outside the region. Long term impact of some aspects of modern agriculture This would also have an impact on changing food habits and health in the region, and would, in a way, promote traditional agricultural practices to blend harmoniously, and in ecologically sustainable way, with modern agricultural techniques in Ladakh.

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Present Status of *Platanus orientalis* L. in District Pulwama of Jammu and Kashmir

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ABSTRACT

With the elevated echelon of urban augmentation in Kashmir and the associated developmental pressure, a critical point has been reached to safeguard the chinar heritage. Since chinar is the natural treasure it symbolize for the long-term future and the indifference and apathy that exists cannot be afforded which may result extinction of chinar tree. The present study has been carried out in district Pulwama to find out the magnitude of degradation and reduction spectrum of chinar tree botanically identified as *Platanus orientalis* L. and commonly known as "Bouin" in Kashmiri. The study encompassed all the four tehsils of district namely Awantipora, Pulwama, Pampore and Tral. The total number of chinar trees that presently subsist in the district is 4358, out of which 2406 are healthy and 1952 have turned old and senile. The study shows that there were 2829 chinar trees in Pulwama tehsil, 507 in Awantipora tehsil , 437 in Pampore tehsil and 585 in Tral tehsil. The overall degradation of Chinar tree in the district is 44.79%. As per the existing tree cover of district Pulwama the highest degradation (non-healthy condition) was seen in Pampore tehsil (48.51%), followed by Awantipora tehsil(45.36%), Pulwama tehsil (45.35%) and lowest was seen in Tral tehsil (38.8%).The study revealed that reduction rate of *Platanus orientalis* increased since 1990. From 1990-2000 the reduction rate increased from 7.8% to 12.3% from 2000-2014. During this time only 159 new trees have been planted. Among them mostly are in the tehsil Pulwama. The degradation and reduction (natural and anthropogenic) spectrum as analysed for the chinar trees encountered. During the survey it was revealed that the process of degradation and reduction of chinar tree is going on an alarming rate which is a serious matter of concern. Furthermore, the tree has been found exterminated in almost all high altitude villages and habitations (above 1750 m amsl) of the district.

Key words: *Platanus orientalis L, Kashmir, Pulwama*, *Anthropogenic, Degradation*

INTRODUCTION

The plant *Platanus orientalis* L. called as Plane or Chinar,is a decidious tree, naturally found in south-eastern Europe, Middle East and India (Kavadas, 1956.; Saima, 2018). Chinar is found naturally in riverine soil; however, it is quite capable of thriving in dry soils as well, once it is established. The tree known for its elegance and exuberance has remained an attraction for artists and litterateurs. Kashmir Valley is the home of world's oldest chinar tree (627 years old) which is located in village Chattergam of district Budgam, believed to be planted in 1374 A.D by an Islamic mystic Syed Abul Qaim Hamdani (RA) who accompanied Mir Syed Ali Hamdani (RA) from Iran to Kashmir, which has a girth of 31.85 m atground level and 14.78 m at breast height (Wadoo, 2002). In the Kashmir valley almost every village has at least one tree (Lawrence, 1895). The tree is basically planted for ornamental purposes, especially by roadsides and parks (Mozaffarian, 1994 and 1996; Abdullah, 2017) and is one of the main features of gardens in Kashmir (Rix and Fay, 2017). It is widely planted to improve the microclimate (Pourkhabbaz *et al*., 2010), and also utilized for medicinal values (Ganaie and Nawachoo, 2003). During 1990's due to turmoil in the valley, destruction of chinar trees took place at large scale and the trend has not stopped yet. The tree is feeling the brunt of ongoing widening of the national highway (NH I) in Kashmir valley, other roads, railway track construction and increase in other commercial constructional activities. In spite of enjoying status of state tree and having legal protection, the tree is facing a huge risk for its existence within the valley. Active participation of local communities is a critical component towards the conservation of chinar tree in Kashmir valley. Framing of laws is not sufficient to preserve the tree but at the same time awareness must be raised among the masses for its preservation. Serious steps must be taken to expedite social forestry to improve the diminishing condition which in turn can prove more beneficial. Social inclusion is the core element of conservation of chinar tree, local participation should be made a major tool for protection and management and in return they must be given right to harness the tree for their domestic benefits (fuel, timber etc.) in judicious way. Further government and concerned authorities should start awareness programmes regarding importance and protection of heritage tree and should encourage plantation drives in education institutions, idle lands and forest areas. The species is also considered threatened within some countries and has been classed as Data Deficient due to insufficient population studies (Baristow and Rivers, 2017). No systematic scientific study related to *Platanus orientalis* has been carried out so far in the world and particularly in Kashmir. Pulwama is typical district of Kashmir valley with all the general features of the valley. The present study has been carried out keeping the objective of enumerating the number of the trees and to assess their environmental status. The results can be extrapolated for the whole valley to provide a general picture for time being.

MATERIAL AND METHODS

Study area

District Pulwama (area 1086sq. Km), a district of south Kashmir is one of the most affected area with respect to the obliteration of the chinar trees (Saima, 2018). The district is located at 33°37’-34°06’ N latitude and 74°33’- 75°14’ E longitude with an average altitude of 1630m amsl (Singh and Andrabi, 2014).

The district is flanked by two high mountain ranges namely Zanskar range in north-east and Pir Panjal range in south-west side. It is bounded by Srinagar in the north, in the west by Shopian and Budgam and in the east and south by Anantnag and Kulgam. Pulwama district comprised of 550 villages, which until 2007 were grouped in 5 tehsils including Awantipora, Pampore, Pulwama, Shopian and Tral. District Pulwama was bifurcated in to 2 districts in 2007 viz. District Pulwama and District Shopian. District Pulwama now has 4 tehsils viz. Awantipora, Pampore, Pulwama (Kakapora, Pulwama, Rajporaand Shahoora) and Tral (Tral and Aripal). The total number of villages came down to 331 and 4 Community Blocks. The total area of the district is 951Km^2 (Mir and Saleem, 2016).

Table. 1. Showing approximate geographical area of different tehsils of district Pulwama

Tehsil-wise total geographical area of district Pulwama		
Name of the Tehsil	**Area (Km^2)**	**Constituencies and villages**
Pulwama	356	206 villages, 4 constituencies Shahooora, Kakapora, Pulwama and Rajpora
Tral	365	88 villages
Pampore	215	30 villages
Awantipora	151	49 villages
Total	1086	373 Villages

Source: State Revenue Department J&K 2016.

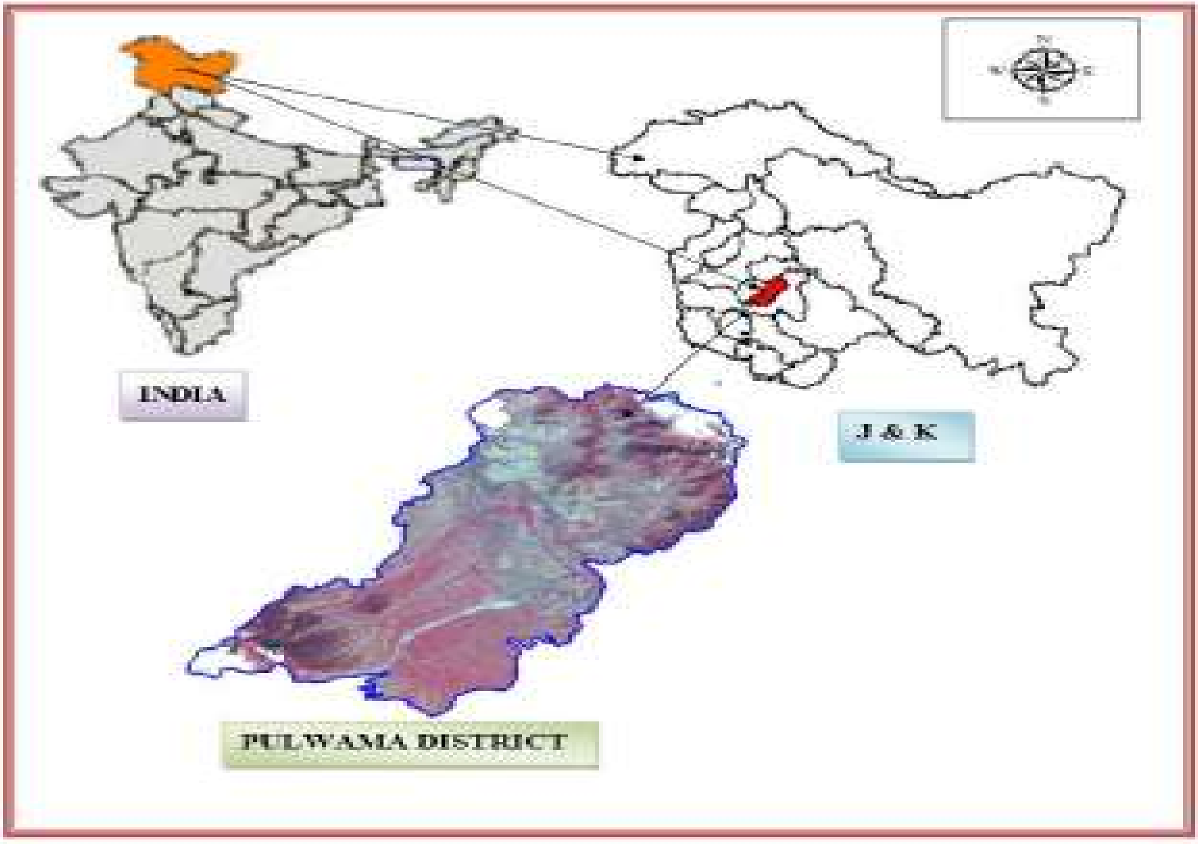

Fig. 1. Showing district Pulwama map

Field survey and methodology

The study was carried out in 2014-2015 wherein every village and habitation of all the four erstwhile tehsils (Pulwama, Pampore, Awantipora and Tral) were visited. All the villages were surveyed regularly and besides self-study, investigations were made from local dwellers, numberdars, chowkidars, patwaris and revenue department as well. The biomass was estimated roughly, Partially degraded trees (with dead biomass less than 20%), Significantly degraded trees (with dead biomass more than 20%) and Healthy trees (with no or less than 5 % dead biomass). Trees lost since 1990 were calculated as naturally dead trees (trees dead without human intervention or with certain type of diseases) and anthropogenically dead trees (trees dead due to direct human intervention). Further newly planted trees since 1990 were also calculated (all those trees planted in open areas or in protected areas as colleges, parks and hospitals for decorative purposes).

RESULTS AND DISCUSSION

The number of existing chinar trees at present in Tehsil Pulwama were found to be about 2829. More than 20 chinar trees were found in villages like Achan, Arihal, Chandgam, Bundzoo, Bellow, Bonoora, Chandpora, Deer, Drusoo, Gabarpora, Gooso, Haal, Kakapora, Khedarmooh, Koil, Mitrigama, Newa, Payer, Pirtaki, Rahmoo, Tomlahal and Vasoora. Out of the 2829 chinars, number of degraded trees constitutes 1283 accounting for 45.35% of the total tree cover of tehsil Pulwama (Table 1). The total number of trees lost since 1990 in the tehsil account for 776. A general degradation spectrum was seen almost in all villages of tehsil Pulwama, however most affected villages were Sirnoo, Monghama, Drussu, Washbugh, Bellow and Rajpora villages. Correspondingly the number of trees in tehsil Awantipora were 507, out of which 230 trees are degraded which is about 45.36% of the total tree cover of the tehsil. In tehsil Awantipora, 20 or more chinar trees were found in Awantipora town and villages of Panzgam and Malangpora only. It was also found that about 100 chinar trees were hacked along the national highway (NH-1A) during its various construction phases. Likewise in tehsil Pampore more than twenty chinar trees were found in Shaar Shali (61), Pampore town (53), Khrew (51), Lethpora (29) and Wuyan (23) villages. Out of the total 437 trees about 212 (48.51%) were found degraded. Highest degradation in the tehsil was seen in the villages of Androosa, Khrew, Dusoo and Lethpora. The total number of dead trees in the tehsil since 1990 is 142. In tehsil Tral, most of the villages have very few number of chinar trees. The total number of chinar trees existing at present in Tral Tehsil is 576. Highest number of chinar trees were found in Gang (96) being a small habitation, followed by Tral town (80) and Monghama (24).

Total number of trees in tehsil Pulwama in 1990 was 3440, which was reduced to 3164 in year 2000 and 2829 in 2014. Since 1990 number of dead trees accounts to 742 (137 naturally and 605 anthropogenically), a reduction of 17.76% to the original number was found. During this time only 131 new trees have established that too in colleges, schools and few in public parks. In tehsil Pulwama human activity was found responsible for 81.5% of the total reduction whereas apparent natural causes were found responsible for 19.5% of the reduction. Similarly the total number of trees in tehsil Awantipora in 1990 was 632, since 1990 one hundred and sixty (160) chinar trees have been lost but only four new trees have been established, resulting overall reduction of 23. 52%. It has been found that 71.2% of the chinar trees were damaged anthropogenically and about 28.8% were affected naturally in the tehsil Awantipora. The number of trees in tehsil Pampore dwindled from 542 in 1990 to 526 in 2000 and437 in 2014, which is a reduction of 19.37% of the original number. The total number of trees in tehsil Tral was 732 in 1990, which was dwindled to 576, which implies that Tral witnessed the reduction of 20.73%.

Humans have always been ignorant about the benefits of nature and the pit they put themselves in is depressing. Owing to turmoil and increase in habitational areas, population and various constructional works (houses, schools, hospitals, government departments etc.) are main reasons behind the degradation and reduction of *Platanus orientalis* tree cover. The dwindling numbers of *Platanus orientalis* is one of the sad and symptomatic stories of the environmental and cultural heritage threats that exist in Kashmir, and illustrate the present state-wide ignorance and apathy towards the values of centuries of traditions and harmonic coexistence with nature and place. The present study seems that the plantation of the chinar tree has remained a conscious and deliberate social cause as otherwise the tree has no such a big economic importance, neither its wood has remained any product of demand. The tree has got acclimatized very well with the environmental conditions of valley; the favourable altitude within the study site is up to 2000 meters above sea level. The present study also reveals a pathetic situation of trees, except in few places; however at places like Khangund (Tral), Tengpona, Tiken and Kakapora, the chinar trees are fenced and protected partially from direct anthropogenic effects. The study also revealed that most of the tree number decline is due to the direct anthropogenic factors rather than natural causes. River Jehlum passes through tehsil Awantipora and a large part of it are swampy areas not fit for growth and survival of chinar. The tehsils of Pampore and Tral have a large kerawa (plateau) area which usually remains dry and therefore resulted in reduction in the establishment of the chinar trees. Further a large part of these tehsils is mountainous and therefore unsuitable for chinar tree growth. A sharp decline of trees since 1990 can be attributed to lawlessness which prevailed in the state and also to the rapid growth of population and unscientific urbanization which is still rampant in the State (Saima, 2018; Gozkar and Samiullah, 2010; Raina, 2010). Even though the chinar tree enjoys a status of ‘heritage tree’ but its wanton cutting is still prevalent in the region purely because of poor implementation of the concerned laws.

Table 2. Tehsil-wise present status of chinar tree in district Pulwama

S. No.	Name of tehsil	Total number of existing tress	Partially degraded trees	Fully degraded trees	Number of healthy trees	Naturally dead trees	Anthropo-genically dead trees
1.	Pulwama	2829	854	429	1546	137	605
2.	Awantipora	507	176	54	277	15	145
3.	Pampore	437	151	61	225	29	112
4.	Tral	585	160	67	358	30	131
Total		4358	1341	611	2406	211	993

Table 3. Tehsil-wise reduction of chinar trees since 1990

Name of tehsil	No. of trees in 1990	No. of trees in 2000	Total number of trees in 2014	Total number of trees lost since 1990	No. of newly established tree since 1990
Pulwama	3440	3164	2829	742	131
Awantipora	663	603	507	160	04
Pampore	542	526	437	141	16
Tral	738	673	585	161	08
Total	5383	4966	4358	1204	159

Source: Revenue department Pulwama

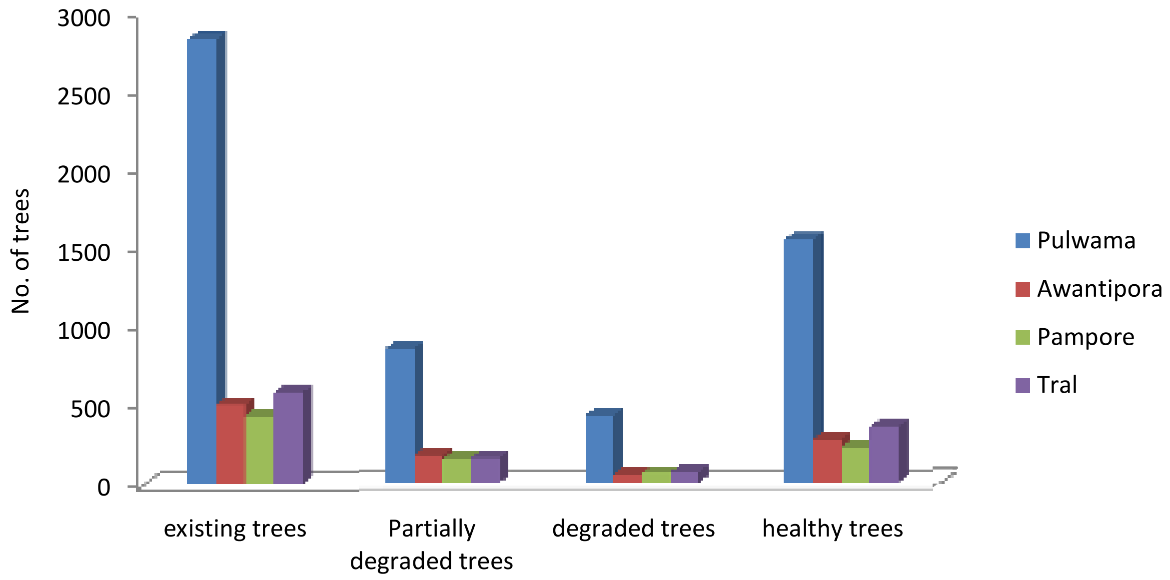

Fig. 2. Environmental status of chinar tree in district Pulwama

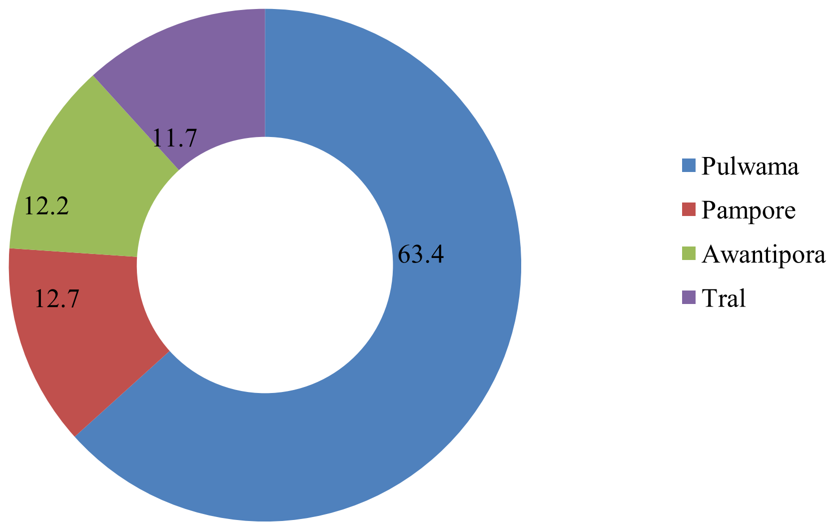

Fig. 3. Graph showing %age wise degradation in various tehsils of district Pulwama

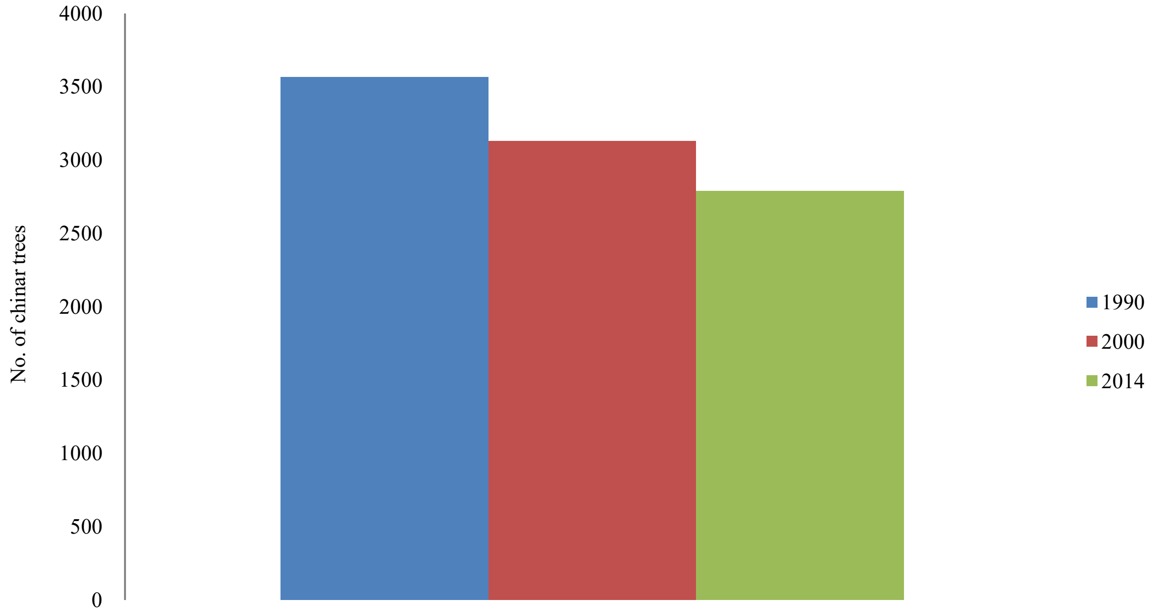

Fig. 4. Graph showing reduction of chinar tree in tehsil Pulwama since 1990

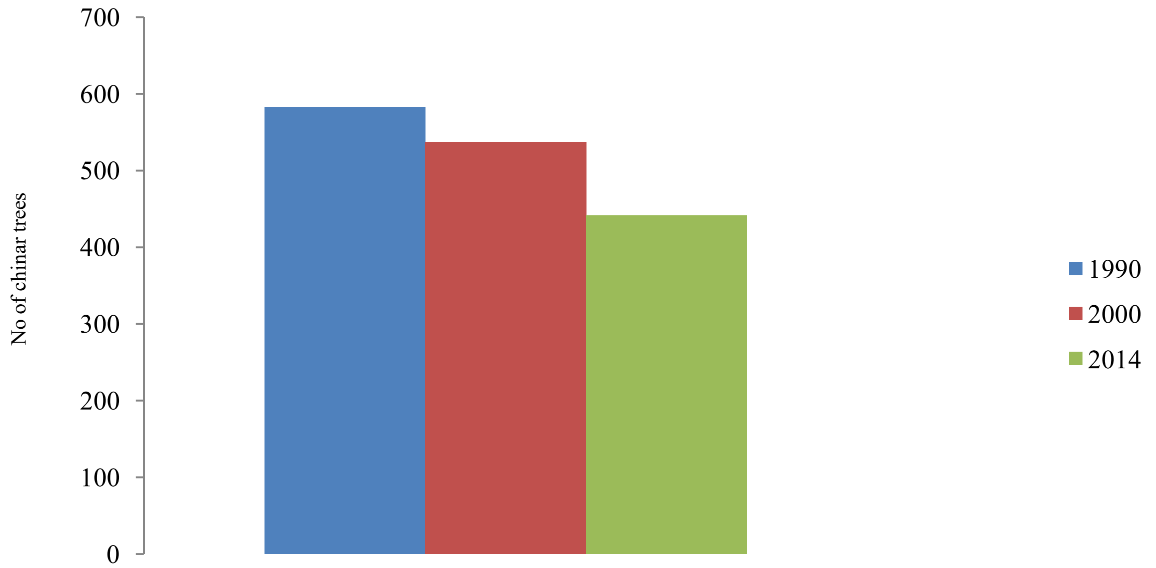

Fig. 5. Graph showing reduction of chinar tree in tehsil Pampore since 1990

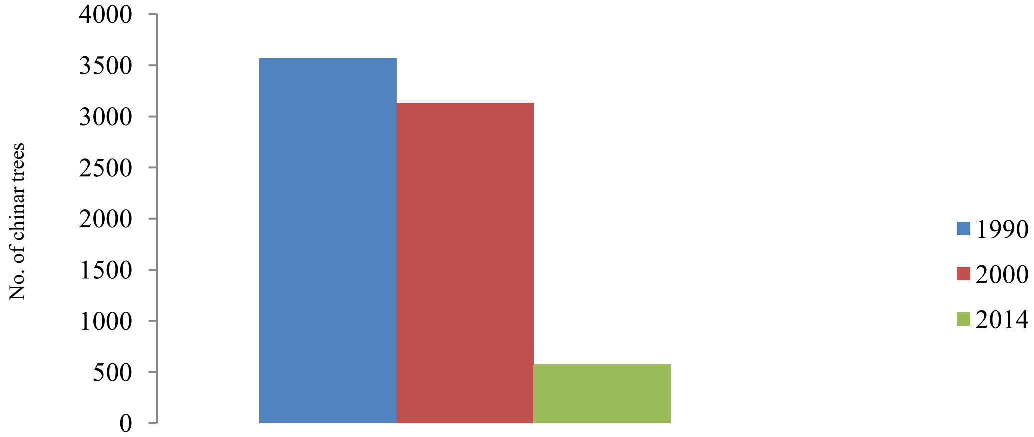

Fig. 6. Graph showing reduction of chinar tree in tehsil Awantipora since 1990

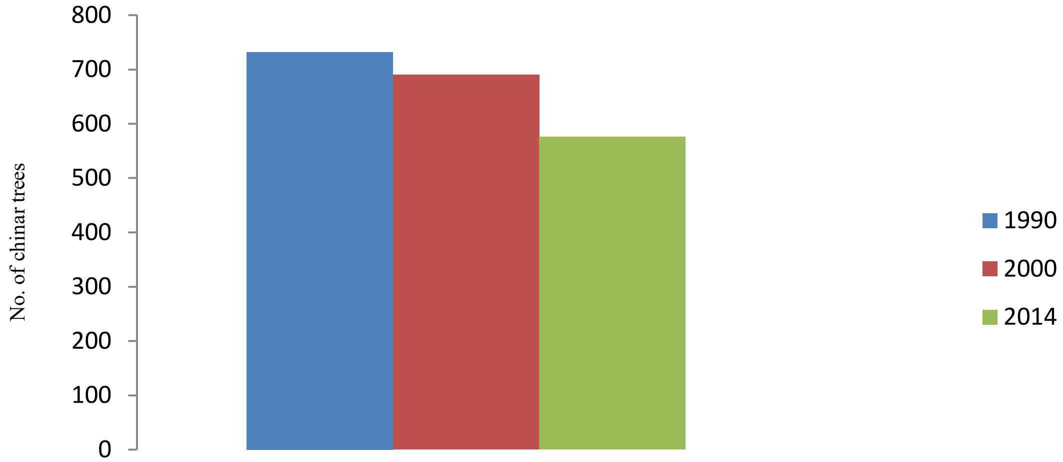

Fig. 7. Graph showing reduction of chinar tree in tehsil Pampore since 1990

CONCLUSION

The current study clearly evaluates the environmental status of chinar tree in district Pulwama. From the study it is evident that the chinar tree is facing the axe ruthlessly at an alarming rate. The degradation in Pulwama district is 45% of the total trees cover and almost 23% of the tree is reduced since 1990. Hence it is important that the steps must be taken to drastically reduce the rate of degradation. A conscious effort at civil society level as well as at the government level must be taken to protect this precious heritage of Kashmir. Laws are to be modified and government agencies which are responsible for their protection are to make responsible for their census, management and protection. Chinar tree should be given real status of heritage tree by implementation of legal protection, halting the corrupt tolerance of illegal felling, high penalties for damaging and felling chinars. A 'Chipkoo' type movement should be launched to spread the awareness about the importance of the Chinar trees.

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Water Quality Monitoring of Some Freshwater Springs in Hazratbal Tehsil, Srinagar, Kashmir Himalaya

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ABSTRACT

Some springs in Hazratbal Tehsil were assessed to determine their quality for consumption and usage. As the springs present in that area are most important source of drinking water and is used for agricultural practices and the water is consumed in its natural state without any treatment. Thirty water samples were collected from thirty different springs and physico chemical parameters were analyzed using standard methods. The overall status of spring waters was found to be acidic to highly alkaline and hard water. The ionic composition of spring waters revealed predominance of bicarbonate and calcium over other ions and, consequently, the usual ionic progression was HCO_3^- > Ca^{2+} >Mg^{2+}. Cluster analysis categorized study areas into two main clusters (Cluster 1 and Cluster 2). From cluster analysis it was found that nitrate values was relatively similar between the two clusters, with slight variations within sub-clusters. While calculating the correlation ($p<0.05$) it was found that various parameters like water temperature, pH, DO, nitrate, ortho phosphorous, silicate and total phosphorus was negatively correlated with most of the water parameters. Box plot comparison test of different physico-chemical parameters along different sites was done. Results reveal the springs have good water quality conditions, which fall within the permissible limit prescribed by WHO and BIS. Water quality index results based on various physiochemical parameters showed almost all values were found within permissible and desirable water quality standards.

Key words: *Kashmir, Water chemistry, Cluster analysis, Correlation.*

INTRODUCTION

Springs are a rich source of freshwater for people all over the globe. Importance of these upwelling aquifers is understood in the fact that rural and urban populations depend on their water for a variety of purposes, making them indispensable to communities. Springs have been associated with mineral-rich water, low frequency of pathogenic organisms, less incidence of pollution, while in the same rhythm acting as a valuable reservoir for irrigation, drinking, aquaculture, and even religious purposes. USA has average water footprint per year per capita of 2842 cubic metres, which is enough to fill an Olympic swimming pool, i.e. an average of 7786 litres of water per person per day. Per person per day use is 2934 litres in China. However in India, the water availability per capita is 1720.29 cubic meter per year (Hameed, 2018). Springs are refuge for pollution-sensitive organisms thriving at locations where anthropogenic activities have debarred all other resources of their sheen because these constitute the last polluted natural resource in densely populated areas. In India, Himalayan communities are hugely dependent on spring water, securing water issues at '*groundwater*' level. As spring sustainable development has not given due importance so far. At the same time protective legislation of springs is insufficient leading to water abuse in their natural habitat (Cantonati *et al.*, 2012). The largest user of groundwater in the world is India. The nation uses an estimated 251 cubic kilometres of groundwater per year i.e. over a quarter of the global total. Dependency on groundwater is more than 85% of drinking water supplies and 60% of agriculture. This showcases the importance of groundwater resource in the country. However, the number of aquifers reaching unsustainable levels of exploitation is accelerating. If such a trend continues, in 20 years 60% of all aquifers in India will approach critical status (Engineer, 2018).

Since the early 1980s, people of Kashmir have started to face increasing shortages of water which was unheard of earlier due to modest requirements. The population, like other parts of India, is witnessing an enormous growth which in turn pressurizes the water resources they are hugely dependent upon. The population of Kashmir Valley, as per 2011 census, is 1,25,41,302 which represents 1.04% of the total population of the country. The population of Srinagar district is 12,36,829 (Census of India, 2011). The water requirements for the population of Srinagar city are directly drawn from surface water resources, such as river Jhelum and water bodies like Dal, Nigeen, etc. Hazratbal tehsil, being the area at the urban fringe is experiencing rapid urban growth and form potential area for future expansion of the city. And thus water shortages stem from unproductive use of freshwater, degradation of the available surface water resource by pollution and by non-utilization or under-utilization of groundwater from aquifers. This has resulted in less flow rate of springs; permanent springs turning seasonal, and seasonal springs drying up completely. Springs are disappearing at an alarming rate globally, and most of that loss goes unrecognized. Our valley is no exception, and the situation is more alarming than ever in light of climate change predictions for Himalayas (IPCC, 2007). While studying some ground-water resources it was shown that intense chemical weathering processes and ground-water flow pattern in the valley follows the local surface topography which not only modifies the hydrogeochemical facies but also controls distribution of spring waters (Jeelani *et al.*, 2014). To provide a better view of importance of springs in Kashmir Valley, a section of Srinagar district was undertaken for study. This section included Hazratbal Tehsil, and about 30 different springs of varying nature and types were taken into consideration for this study. To assess drinking water quality of represent-tative freshwater springs of Hazratbal Tehsil of Srinagar District.

Study area

The study area selected for this research work was Hazratbal tehsil. It is one of the 8 tehsils in district Srinagar. Streams, springs, lakes, and wetlands neighboring the world-famous Dal Lake are a part of its water resource. Thirty spring samples were collected from the Hazratbal area. Elevations varied between 1592m to 1935 m above sea level. A plethora of vegetation cover could be found varying in size, proportion and quantity from one spring site to another. Two of the spring samples were collected from Dachigam National Park with due permission from the park authorities. Some important characteristics including geographical co-ordinates and elevation of selected water springs are given in (Table 1; Fig.1).

Table 1. Hydrogeochemical characteristics of 30 freshwater springs of Hazratbal tehsil of district Srinagar

Site No.	Site Name	Latitude	Longitude	Elevation (m asl)	Mean Discharge (L/s)	Magni-tude	Dominant Vegetation
1	Kral Nag	34°09'54.8"	74°51'02.6"	1595	Stagnant	8	*Populus* sp., *Acacia* sp., *Salix alba*.
2	Wanihama Payeen	34°09'58.5"	74°51'07.6"	1597	Stagnant	8	*Populus* sp., *Malus pumila*
3	Palbagh Nag (Batpora)	34°09'36.1"	74°50'55.3"	1598	0.5	6	*Platanus orientalis*, *Populus* sp., *Acacia* sp.
4	Batpora High School	34°09'32.3"	74°50'42.0"	1603	Stagnant	8	*Platanus orientalis*, *Populus* sp., *Acacia* sp.
5	Azad Colony	34°09'42.1"	74°50'40.6"	1594	0.057	7	*Populus* sp., vegetable garden
6	Batpora Ballah	34°10'10.0"	74°50'33.6"	1612	1.25	5	*Platanus orientalis*, *Populus* sp., *Acacia* sp., and *Juglans regia*
7	Noubough	34°10'38.7"	74°49'58.4"	1625	Stagnant	8	*Populus* sp., *Acacia* sp., *Juglans regia*
8	Wanihama Ballah Masjid	34°10'52.4"	74°50'55.9"	1622	0.75	6	*Populus* sp., *Acacia* sp., *Platanus orientalis*, *Juglans regia*
9	Wanihama Ballah	34°10'57.2"	74°50'54.7"	1935	1.875	5	*Populus* sp., *Acacia* sp., *Juglans regia*
10	Vijnag	34°11'07.9"	74°51'04.8"	1654	0.35	6	*Populus sp.*, *Acacia* sp
11	Batpora Nag	34°11'11.4"	74°50'56.2"	1636	0.166	6	*Populus* sp., *Acacia* sp., *Juglans regia*
12	Chuientwean Nag	34°11'15.6"	74°51'05.9"	1658	0.833	6	*Populus* sp., *Acacia* sp., *Salix alba, Malus pumila*.

13	Gadbal (Bakura)	34°11'42.9"	74°50'29.6"	1723	0.765	6	*Platanus orientalis*, *Populus* sp., *Salix alba*, *Prosopis glandulosa*
14	Virwar Nag	34°11'11.1"	74°51'30.1"	1659	232.26	3	*Acacia* sp., *Salix alba*, *Prosopis glandulosa*
15	Reshipora Nag	34°11'21.5"	74°51'31.6"	1672	0.493	6	*Salix alba*, *Populus* sp., *Acacia sp.*, *Juglans regia*, *Platanus orientalis*
16	Kral Kund Nag	34°11'05.1"	74°51'04.96"	1654	3.5	5	*Pyrus pashia*, *Salix alba*, *Acacia* sp., *Prosopis glandulosa*
17	Chattarhama	34°10'59.4"	74°52'04.5"	1647	Stagnant	8	*Populus* sp., *Acacia* sp., *Platanus orientalis*
18	Bijirteng Nag (Danihama)	34°10'24.2"	74°56'07.0"	1664	1	5	*Populus* sp., *Acacia* sp., *Salix alba*
19	Boninar Nag (Danihama)	34°10'15.8"	74°53'15.5"	1656	0.333	6	*Acacia* sp., *Populus* sp., *Platanus orientalis*
20	Astan Nag (Mulfaq)	34°10'07.8"	74°52'48.4"	1626	0.1	6	*Acacia* sp., *Prosopis glandulosa*, *Morus serrata*
21	Draphama Nag (DNP)	34°10'07.7"	74°52'43.2"	1628	0.338	6	*Populus* sp., *Juglans regia*, *Aesculus indica*
22	Oak Patch Spring (DNP)	34°08'27.7"	74°55'57.5"	1753	Stagnant	8	*Morus serrata*, *Prunus armeniaca*, Ferns, *Rubus ellipticus*
23	Kaunsar Nag (DAULM)	34°09'36.8"	74°54'36.8"	1763	Stagnant	8	*Populus* sp., *Ulmus wallichiana*
24	Mal Nag (Harwan)	34°09'25.6"	74°53'47.8"	1650	Stagnant	8	*Juglans regia*, *Platanus orientalis*, *Salix alba*
25	Astan Nag (Harwan)	34°09'09.7"	74°53'26.4"	1634	0.214	6	Ferns, *Urtica dioica*, *Salix alba*, *Populus* sp., Thorns
26	Mustafa Colony (Chandpora)	34°09'29.3"	74°53'26.3"	1634	Stagnant	8	*Populus* sp. and *Salix alba*.
27	Meerakshah Nag (Shalimar)	34°08'44.2"	74°52'21.0"	1613	Stagnant	8	*Platanus orientalis*, *Populus* sp., *Salix alba*
28	Chakora Nag (Ishber)	34°08'05.2"	74°52'36.9"	1615	Stagnant	8	*Morus serrata*, and *Salix alba*
29	Deoun Nag	34°08'01.8"	74°52'53.2"	1614	0.652	6	*Juglnas regia*, and *Salix alba*
30	Meayt Nag	34°07'43.4"	74°52'51"	1592	Stagnant	8	*Pinus wallichiana, Malus pumila,Prunus armeniaca*

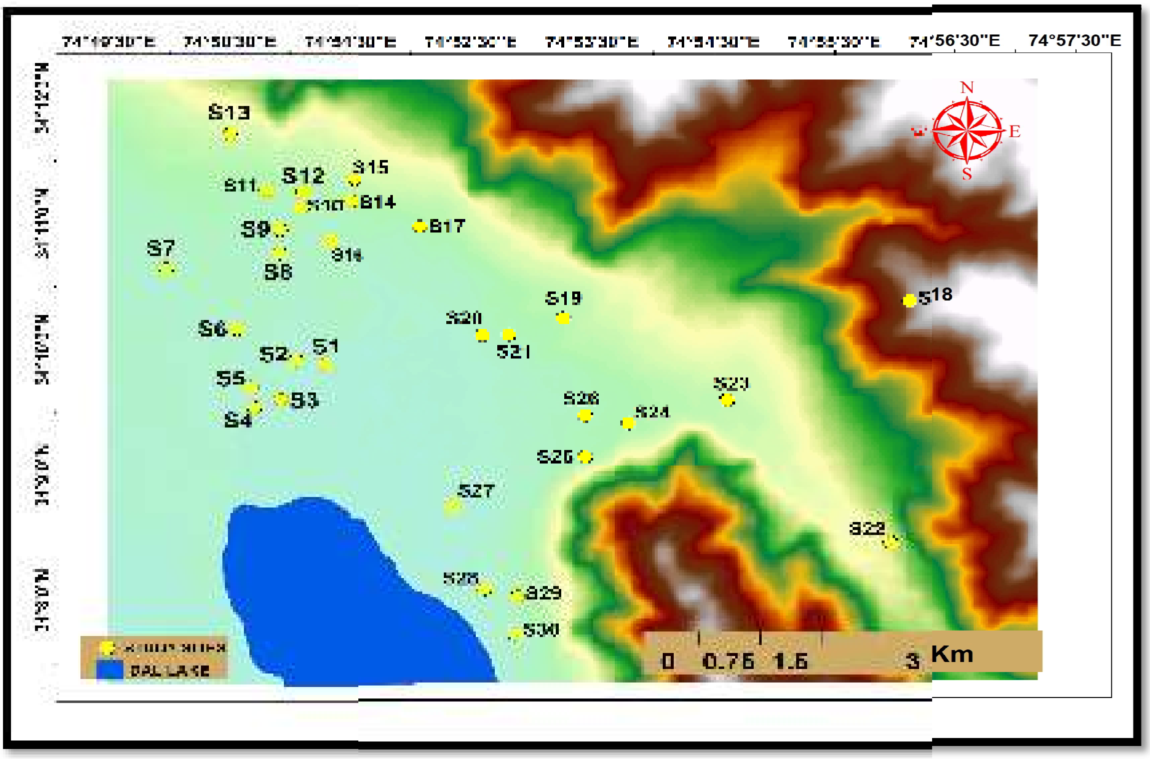


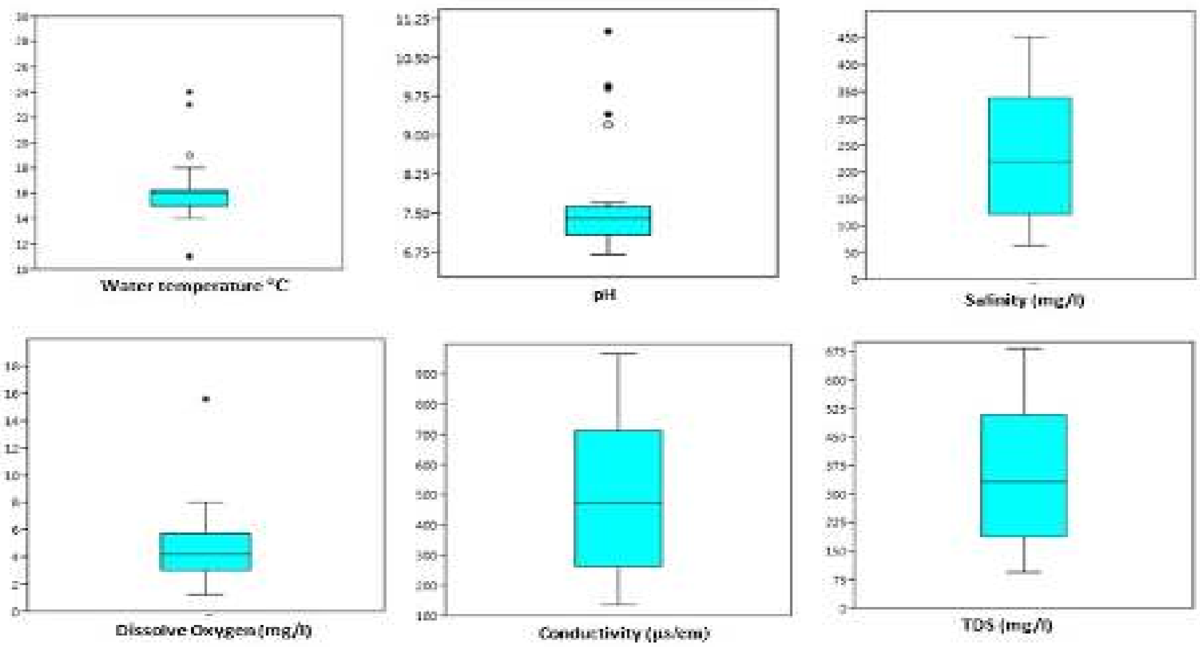
Fig. 1. Map showing location of study area and study sites across Hazratbal tehsil

MATERIAL AND METHODS

The main aim of study was to collect a portion of material (water) small enough in volume to be transported handily and handled in the laboratory while still accurately representing the material that is being sampled (APHA, 2005). Samples have to be taken care of in such a way that no significant change in composition occurs before the analysis is carried out. For the present study, thirty sites were selected and water samples were collected and stored in 1 litre capacity unsoiled plastic bottles. Before the collection of samples, the bottles were carefully washed with distilled water. Each sample was analyzed for different physico-chemical parameters such as temperature, pH, conductivity, chloride, alkalinity, total hardness, calcium hardness, total dissolved solids, ammonia, nitrite, nitrate, ortho-phosphorous, total phosphorus, iron and sulphate. Results obtained were verified by careful calibration and blank measurements (APHA, 2005; Wetzel and Likens, 2000). All statistical calculation was done through Microsoft office EXCEL 2007 and PAST (v.1.93) software applications were also employed for statistical analysis.

RESULTS AND DISCUSSION

To locate the significant differences between various water parameters, they were subjected to tukeys box plot analysis. The results showed that some parameters have significant as well as non-significant variation. The parameters such as water temperature, pH, DO, conductivity, silicate, iron, ammonical-nitrogen, alkalinity, ortho phosphorous and total phosphorous showed significant differences as the values vary at certain sites. The outliers present in the graphs showed the extreme values at certain during the study period among various study sites (Fig.2). Majority of springs recorded temperature in the range of 15–20°C. Some of the springs recorded temperature of <15°C whereas some springs recorded temperature above 20°C, qualifying as warm springs. This indicates that water has been somehow stagnant for longer period of time or hydrothermal activity has been ongoing beneath the surface. The water was found to have slightly acidic to highly alkaline pH (6.7-11). The highly alkaline character of springs may be due to limestone rich lithology of the valley, liberating Ca^{2+} and Mg^{2+} ions into the water. Electrical conductivity was found in the range 136-968 µS/cm, indicating high mineral content. Significant variations and relatively higher values of conductivity in some springs are likely attributed to contamination from fertilizer inputs from the catchment area (Kumar *et al*., 1996). All values of TDS were found to be in proportion with electrical conductivity. Salinity at the study sites ranged from 62 mg/L – 452 mg/L. Groundwater salinity depends on aquifer geology and its chemical characteristics (Al-Naeem, 2015). Thus, variations in these features, in and around the study areas, affected the spring salinity. The values of DO ranged from 1.2 mg/L – 9 mg/L. The fluctuation in DO values may be due to difference in water temperature and algal growth (Singh *et al*., 2014). The presence of relatively high oxygen at some sites seems to be a function of good periphytic algal populations liberating oxygen. As hardness is measured in terms of Ca^{2+} and Mg^{2+} ions, concentration of these indicates water quality. Total hardness values ranged from 48 mg/L – 274 mg/L, thereby indicating hard water character of the springs. The major source of Ca^{2+} and Mg^{2+} ions may be attributed to limestone, gypsum and dolomite rocks in the valley. Majority of springs fall in hard and very hard water category. The difference in alkalinity values may be due to the prevailing land use type and recharge zones and also due to the presence of bicarbonates released from rocks. In general, ionic composition of spring waters revealed predominance of bicarbonate and calcium over other ions and, therefore, the usual ionic progression was $HCO_3^- > Ca^{2+} > Mg^{2+}$same trend was seen in springs from Pulwama district of Kashmir valley (Bhat *et al*., 2010). The quantity of nitrate and ammonia present in water in the form of nitrogen are of great interest because of their nutrient values. Nitrate concentration varied from 214 µg/L – 3844 µg/L. Higher concentration of nitrate at some sites could be contributed by nitrogenous fertilizers, human and animal wastes, and even decomposition of living matter. Presence of ammonia in water indicates ammonification. Ammonia values ranged from 5µg/L – 302 µg/L. The main source of ammonical-nitrogen in these springs could be due to decomposition of organic matter and of sewage near springs. The concentration of ortho and total phosphorous fluctuated between 16µg/L –188 µg/L and 57µg/L –769µg/L respectively. The possible source of phosphates can be artificial or anthropogenic which depends on activities that occur in the area under study. The presence of phosphates in higher concentrations is directly influenced by agriculture and horticulture activities undertaken in the catchment of these springs (Kipngetich *et al*., 2013). Phosphates, as nutrients, have the potential for growth of macrophytes and other algal masses. The concentration of sulphate varied from 6 mg/L – 53 mg/L. High concentration of sulphate at some sites is linked to dissolution of gypsum, which underlies the springs (Obiefuna and Sheriff, 2011). Values of specific parameters were compared with permissible and desired limit standards provided by WHO and BIS. All values were found within permissible and desirable water quality standards (Table 2).



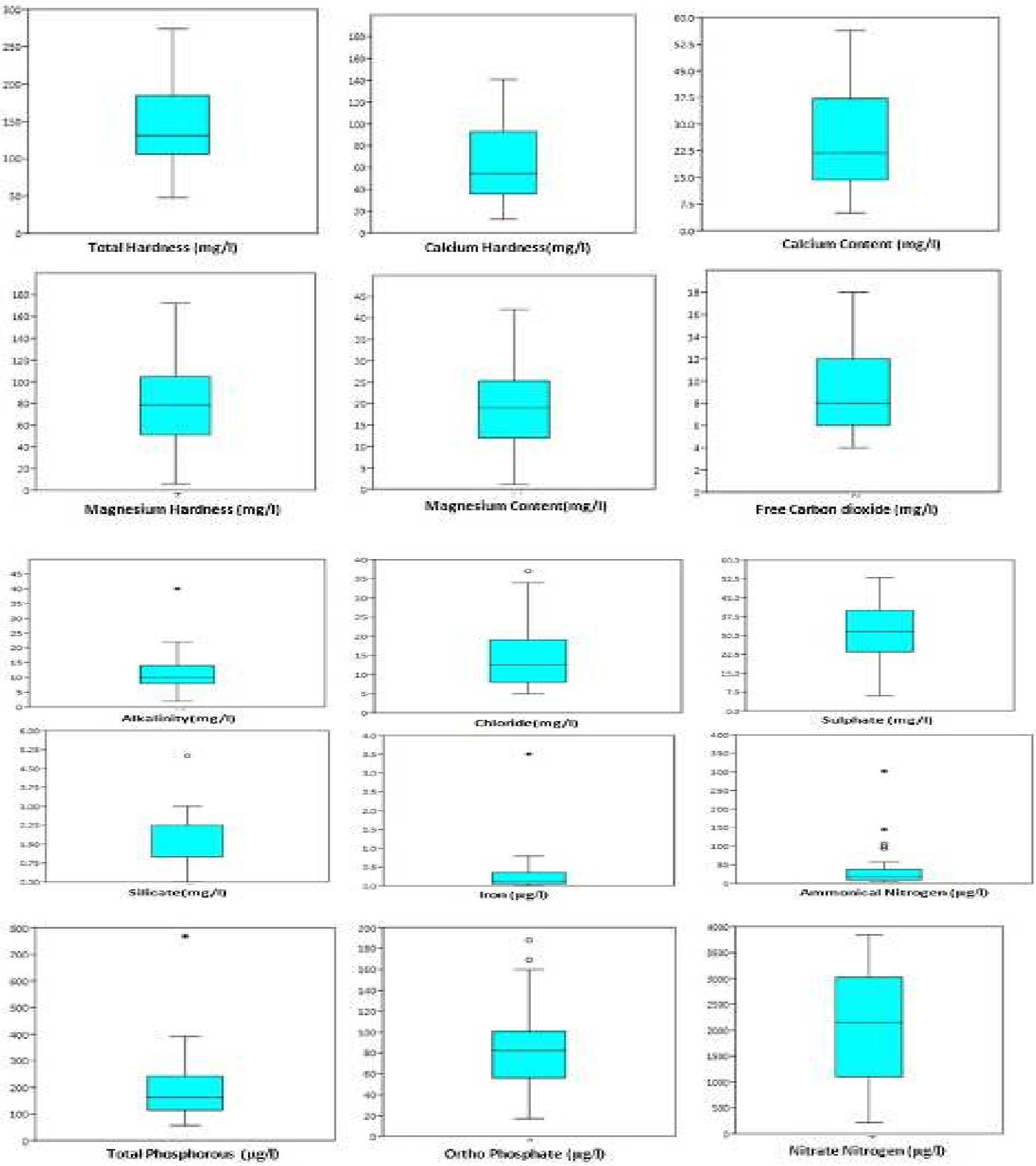


Fig. 2. Box plot comparison test of different physico-chemical parameters

Table 2. Range in values of various physico-chemical parameters of spring waters

Parameters	Observed range of samples	WHO & Indian Standards	
		Desirable	**Permissible**
pH	6.7 – 11	6.5-8.5	6.0-9.0
Conductivity (µS/cm)	136 – 968	750	1400
Salinity (mg/L)	62 – 452	--	--
Total dissolved solids (mg/L)	94 – 682	600	600
Total alkalinity (mg/L)	39 – 156	300	600
Chloride (mg/L)	5 – 37	250	1000
Total hardness (mg/L)	48 – 274	300	600
Calcium (mg/L)	5 – 56	75	200
Magnesium (mg/L)	1 – 42	30	100
Sulphate (mg/L)	6 – 53	200	400
Iron (µg/L)	0.008 – 3.503	300	1000
Nitrate (µg/L)	214 – 3844	45000	100000
Nitrite (µg/L)	9 – 337	--	--
Ammonia (µg/L)	5 – 302	--	--
Ortho-phosphorous (µg/L)	16 – 188	--	--
Total phosphorous (µg/L)	57 – 769	--	--

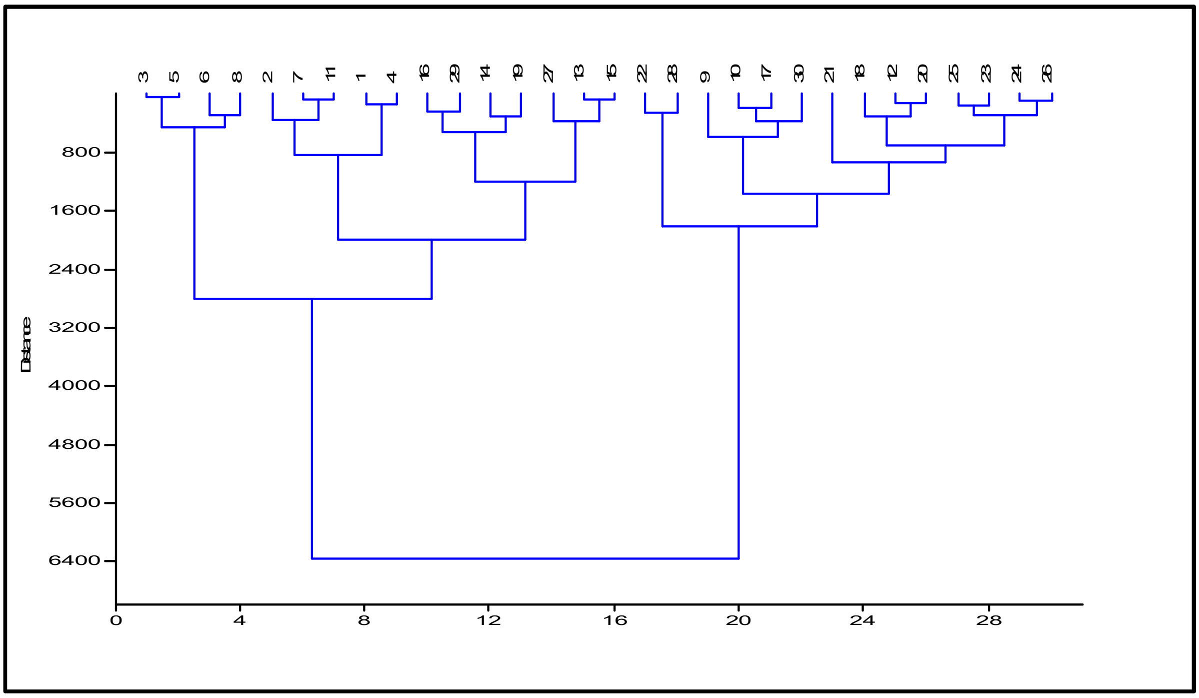


Fig. 3. Dendrogram showing clustering of respective sites

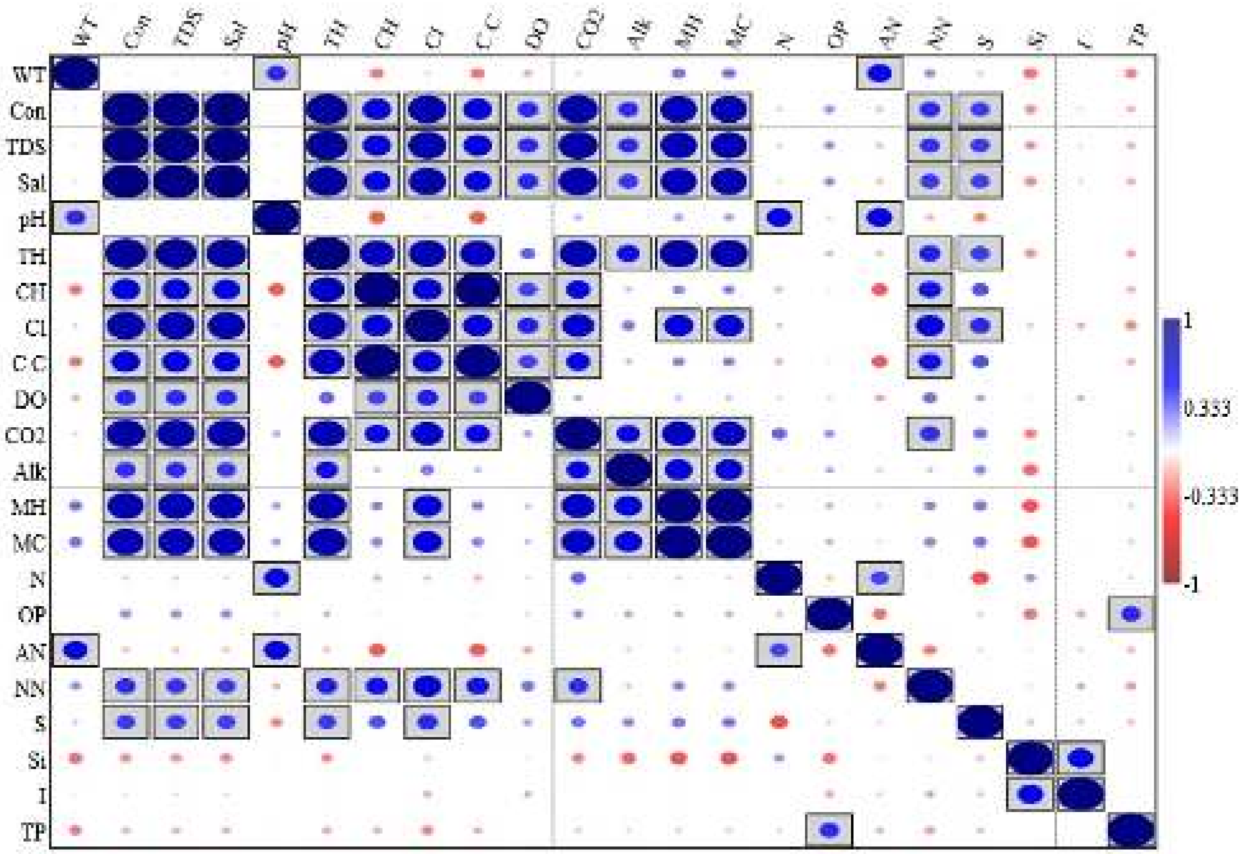


Fig. 4. Correlation of various physico chemical parameters (boxed p<0.05)

In our study, cluster analysis categorized study areas into two main clusters. The first two clusters comprised of sites in the following order: Cluster 1 contained sites 3, 5, 6, 8, 2, 7, 11, 1, 4, 6, 29, 14, 19, 27, 13, and 15, whereas Cluster 2 contained sites 22, 28, 9, 10, 17, 30, 21, 18, 12, 20, 25, 23, 24, and 26. This reveals that Cluster 1 sites have similar hydro-chemical characteristics, which are different from Cluster 2 sites. Cluster 1 is sub-divided into two sub-clusters while Cluster 2 sub-divides into two as well, showing further classification of sites as being similar in water quality parameters Talking about major parameters affecting the physico-chemical nature of drinking water, it was found that Cluster 2 sites were more alkaline than Cluster 1 sites. Cluster 2 sites had lesser conductivity, chloride content, total hardness, calcium content, and magnesium content than Cluster 1. Nitrate values were relatively similar between the two clusters, with slight variations within sub-clusters (Fig. 3).

Correlation matrix of different water parameters was calculated at $p<0.05$ significance level, some important correlations has been observed which revealed parameters like water temperature, pH, DO, nitrate, ortho phosphorous, silicate and total phosphorus was negatively correlated with most of the water parameters. Temperature being important parameter causing many direct and indirect effects, here directly affecting the solubility of gases which clearly depicts that increase in temperature can lead to decrease in DO. Whereas total phosphorous was found to be in strong positive correlation with ortho phosphorus which showed increase in concentration of total phosphorous could lead to increase in concentration of ortho phosphorous. Similarly conductivity, TDS, salinity, hardness, alkalinity was found to be in strong positive correlation with other water parameters. Alkalinity helps in regulating pH of water thus was found to be significant (Fig.4).

Table 3. Water quality index of various sites as per WHO standards

WQI	0-50	50-100	100-200	200-300	>300
Water quality	**Excellent**	**Very good**	**Poor**	**Very Poor**	**Unsuitable for drinking**
1	-	62.09	-	-	-
2	-	53.47	-	-	-
3	-	63.24	-	-	-
4	-	57.96	-	-	-
5	-	64.65	-	-	-
6	-	65.16	-	-	-
7	-	51.61	-	-	-
8	-	54.91	-	-	-
9	47.43	-	-	-	-
10	43.82	-	-	-	-
11	-	52.22	-	-	-
12	40.87	-	-	-	-
13	37.86	-	-	-	-
14	42.83	-	-	-	-
15	36.84	-	-	-	-
16	40.95	-	-	-	-
17	-	50.21	-	-	-
18	-	52.11	-	-	-
19	47.23	-	-	-	-
20	39.06	-	-	-	-

21	33.93	-	-	-	-
22	36.57	-	-	-	-
23	36.16	-	-	-	-
24	31.66	-	-	-	-
25	37.22	-	-	-	-
26	30.11	-	-	-	-
27	-	50.87	-	-	-
28	45.95	-	-	-	-
29	34.68	-	-	-	-
30	-	50.76	-	-	-

Mathematical calculations determined WQI for thirty sampled sites which helped assemble these into groups demarcated by the WHO. Out of 30 sites, 17 sites qualified as being in the excellent water quality while 13 sites were eligible for very good water quality. Thus, from the following observations it was found that the sites present in Cluster 2 presented excellent water quality than Cluster 1. No study site was grouped under poor or very poor WQI category (Table 3). This signifies that water, from the springs under study, is safe for consumption. Hence, the local population can safely utilize water from these springs for carrying out daily life activities, such as drinking, irrigation, and cattle rearing. During the course of sampling, it was also observed that the neighbouring population was dependent on freshwater springs in their area. The dependence was particularly evident in regions where the springs fell within residential environs or near agricultural fields. Such springs were properly maintained as well, such as springs present at site 24, 26 and 29. But springs that were located near roadsides were neglected and poorly managed, resulting in massive formations of algae, and eutrophication. This deteriorates the spring water quality which in turn affects water usage requirements of the surrounding populace.

CONCLUSION

The findings revealed that the studied springs have excellent to very good water quality conditions, which fall within the permissible limit prescribed by WHO and BIS. Thus population can safely utilize water from these springs but should implement some hygienic and proper management practices for carrying out daily life activities, such as drinking, irrigation, and cattle rearing. This conclusion is supplemented by results obtained from WQI. But many of these springs aren't handled well and need attention as they have the potential to fulfill water demands of the nearby population. These need to be taken care of with proper management techniques, and by prompting stakeholders to share the responsibility of spring water protection.

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Biodiversity Assessment of Butterflies in Kumaun Lesser Himalayan Oak Forest for Promoting Ecotourism at City Nainital

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ABSTRACT

Butterflies have long fascinated humans and portrayed as an important element from ecotourism point of view. In the present study, a foot trail lying in an unprotected temperate forest was assessed based on seasonal data on distribution of butterfly fauna to generate impetus for 'Butterfly Ecotourism' in the city Nainital located in Kumaun Himalaya of Uttarakhand. Field surveys conducted from June, 2017 to April, 2018 downhill up to 5 km in the forest along the walking trail revealed the presence of 42 species of butterflies under six families and six species of the total recorded species protected legally under Indian Wildlife (Protection) Act, 1972. Family Nymphalidae with 17 species of the total recorded species was found dominating in the study area, followed by Pieridae (ten species), Lycaenidae (six species), Papilionidae (four species), Riodinidae (three species) and Hesperidae (two species), respectively. Database relating to seasonal pattern in abundance of butterflies indicates that there was no significant difference of species count in during three periods of observations: spring, rainy and autumn seasons; however abundance of butterflies varied across different seasons. Based on evaluation of diversity indices for different seasons, spring season exhibited maximum butterfly diversity which also coincides with peak tourist influx season in the region. Moreover, 45.23% of the total species were found active in variable abundance throughout the seasons that include species like *Danaus chrysippus* (Linnaeus), *Euploea core* (Cramer), *Junonia iphita* (Cramer), *Vanessa indica* (Herbst), *Catopsilia pomona* (Fabricius), *Heliophorus sena* (Kollar), *Papilio polytes* Linnaeus, *Dodona durga* (Kollar) and others. The overall findings are important providing baseline data for studying temporal changes in butterfly community over time, besides can also be used for drawing immediate attention of managers and planners towards promoting education, research, conservation and ecotourism at the Nainital city.

Key words: *Butterfly trail, Lake City, Rare species, Seasonality, Sustainable development*

INTRODUCTION

Posed by global environmental challenges such as climate change, pollution, natural resource depletion, deforestation, ocean acidification and others, modern nature conservationists especially in developing countries acknowledge the concept of 'Ecotourism' as a potential and effective means of balancing conservation objectives with human development in a sustainable manner (Shoo and Songorwa, 2013). Ecotourism as a form of participatory conservation strategy serves environmental friendly tourism with socio-economic benefits to the local community while conserving natural resources (Cheung, 2015; Eshun *et al*., 2016). Amongst all insects, butterflies are considered as planet's most majestic creature with brilliantly colored and exquisitely patterned wings, and have always been most fascinating to human kind from the time memorial (Singh, 2017). With relatively well known ecology, butterflies form a crucial aspect of the ecosystems, acting as a strong pollinator, a food source for predators at various levels (Tiple *et al*., 2006) and indicative of general environmental attributes such as conservation value (Ehrlich and Murphy, 1987; Brown *et al*., 2000); disturbances (Kocher and Williams, 2000), environmental health and quality (Kunte, 2000; Sawchik *et al*., 2005); climate change (Hellmann, 2002; Hill *et al*., 2002) and as surrogate taxa for assessing conservation threats to other biodiversity groups (Thomas, 2005; Hayes *et al*., 2009). Butterflies play critical roles at the nexus between environmental science and environmental action (Fleishman and Murphy, 2009) and are often used as flagship species in conservation programs (New, 2011). In more recent, they are rendered as an efficient tourism product in nature based tourism as well as for destination development (Kurnianto *et al*., 2016; Ismail *et al*., 2018). Butterflies, because of their great diversity and aesthetic beauty, represent a natural resource that can be managed in different ways (Lopez-Collado *et al*., 2016). The development of butterfly zones for *in situ* conservation protect not only the butterfly diversity and entire habitat for wide range of native plants and insects but also serve to promote environmental education, research, restoration goals and butterfly ecotourism (Mathew and Anto, 2007; Cutting, 2012, Revathy and Mathew, 2014, Hamdin *et al*., 2015; Sanwal *et al*., 2017).

The state of Uttarakhand located in Lesser Himalayan Domain of Indian Himalayan region is endowed with magnificently diverse landscapes, marvelous range of biodiversity, enough religious and cultural tourist potential (Ahmed, 2013; Choudhuri, 2016; Monga *et al*., 2016). The state presents a large variety of habitats for several charismatic vertebrate fauna and is home to at least 500 species of butterflies (Sondhi and Kunte, 2018). In addition, butterflies of the Kumaun region have been studied systematically, since 1880's. In the most pioneering studies by Doherty (1886), a total of 271 species of butterflies have been recorded from the Kumaun region. Hannyngton (1910-11) made a detailed survey of butterflies and recorded about 378 species including many endemic ones from the Kumaun region. Subsequently, several studies have been conducted by various workers to explore the butterfly diversity at different locations in the Kumaun Himalaya (Smetacek, 2002, 2004; Joshi and Arya, 2007; Tyagi *et al*., 2011; Smetacek, 2011, 2012; Arya *et al*., 2014, 2016a, 2016b; Sondhi, 2017; Farooq and Arya, 2018; Verma and Arya, 2018). The Himalayan state of Uttarakhand promotes ecotourism in protected areas, apart from eco-parks created for ecotourism in Kumaun and Garhwal regions (Kala, 2013), however such integrated planning of conservation is most awaited in regions other than protected areas, important from the standpoints of sustainable tourism development. Furthermore, policies and strategies adopted for *ex situ* and *in situ* conservation of butterflies in form of gardens and parks are presently being practiced and much encouraged in Dehradun and Nainital districts of state Uttarakhand (Meena and Dayakrishna, 2017; Sanwal *et al*., 2017; Sondhi and Kunte, 2018). Nainital located in Kumaun Himalaya is a prime example of Lake Township that has been severely impacted by human activities like increased urbanization and logarithmic tourist influx into the watershed has affected the ecology of fragile areas to a great extent (Shah *et al*., 2009). Ensued from this scenario, areas rich for butterfly diversity should be identified and can be prioritized for *in situ* conservation through setting up butterfly parks or trails in the catchment area of city Nainital which will also aid in developing sustainable form of ecotourism in areas other than wildlife parks. In context of this, a foot trail located in the temperate forest adjacent to city Nainital has been evaluated for its potency to prioritize it for development of 'Butterfly Trail' as a part of promoting conservation and ecotourism in the region. Ideally, the value of a tourist brochure of wilderness area would be greatly enhanced if the best season for sighting a particular faunal group is recommended (Borkar and Komarpant, 2004). Keeping this in view, a preliminary checklist on butterfly diversity available in the forest trail with their seasonal patterns was prepared during the present study.

MATERIAL AND METHODS

Study site

Deriving its name from goddess Naina Devi, Nainital (also known as Lake City) is one of the most pristine hill stations set up in early 19^{th} century during British Era and is renowned worldwide for its picturesque natural lake flanked by steep hills covered with mixed oak-conifer forests. The salubrious climate and rich cultural heritage attracts thousands of tourists throughout the year in Lake City (Tamta, 2016). The city is located at an altitude of 1938 m a. s. l. at the level of lake, stretched between 29°21' to 29°24' N latitudes and 79°25' to 79°29' E longitudes in Kumaun Lesser Himalayan domain of state Uttarakhand, India (Fig. 1). The region experiences temperate and wet monsoon type of climate (Singh and Singh, 1992) with average monthly temperature varying from 15°C to 30°C during hot summer and from 2°C to 16°C in cold winter. The average annual rainfall around the catchment area is about 1200 mm. The whole year could be divisible into three major seasons- warm and dry summer season, warm and moist rainy season and cold and snowy winter season. Present study was undertaken during June, 2017 to April, 2018 in forest surrounding the foot trail that starts from 'Birla Chungi' nearby Birla Vidyamandir School located on the ridge named Sher-ka-Danda and ends with a low lying valley of the village Ratighat. The present forest trail located at an elevation of about 400 meters above from lake in the city is covered with temperate type of vegetation which gradually merges into subtropical pine forest with decreasing altitude towards the village. A perennial stream on the verge of drying flows adjacent to the forest trail which has its own recreational use, and architecture like small bridges built on the stream from British Era are structural elements in the study area. In the present study, the foot trail which was traversed up to 5 km downhill from 'Birla Chungi' is dominated with oak mixed forest. The floral diversity along the walking trail includes various species of trees, shrubs, herbs, grasses, ferns and others which are congenial for butterflies (Table 1). The present study site is characterized as unprotected and moderately disturbed forest and activities like collection of minor and major forest products by local villagers, dumping of trash and litter along the walking trail, grazing by animals, visitations by local people and tourists for amusement and observing nature are frequent in the study area (Fig. 2).

Fig. 1. Map showing the location of present study site at city Nainital

Butterfly census and data analysis: Sampling of butterflies in forest along the walking trail was conducted bi-weekly following Pollard Walk Technique (Pollard, 1979 and Pollard and Yates, 1993). The butterflies were counted around a radius of 5 m while traversing the trail slowly at a uniform pace mainly during 7.00 to 15.00 hours of a day. Using direct sightings or photographic evidences, butterflies were identified in the field with reference to butterfly identification literature (Haribal, 1992; Kumar, 2008; Kehimkar, 2014; Singh, 2017; Sondhi and Kunte, 2018). None of the butterfly was either caught or killed in the field. Status of butterflies was evaluated as per the number of sightings in the study area and were categorized as very common (more than 100 sightings), common (41-100 sightings), uncommon (11-40 sightings) and rare (1-10 sightings). Seasonal fluctuation in community assemblage of butterflies was studied quantitatively in three different seasons *viz.* rainy (June to August), autumn (September to November) and spring (February to April) and using the software program PAST (2005), various measures of diversity indices (dominance, Shannon diversity and evenness) were worked out in order to understand seasonal diversity of butterflies.

RESULTS AND DISCUSSION

Studies related to abundance and diversity of insects and other invertebrates add key building blocks to the wildlife value of a site (Hopwood, 2013). A total count of 1669 individuals of butterflies belonging to 42 species and 30 genera under six families was made in the present study (Table 2 and Fig. 3). Among recorded butterfly families, Nymphalidae was the most species rich consisting 17 species followed by Pieridae (10 species), Lycaenidae (six species), Papilionidae (four species), Riodinidae (three species) and Hesperidae (two species), respectively. Abundance of butterflies varied significantly among different families. Family Nymphalidae was dominant again with 45.29% of total individuals, followed by Pieridae (31.04%), Lycaenidae (11.20%), Papilionidae (8.33%), Hesperidae (2.09%) and Riodinidae (2.04%), respectively (Fig. 4). The polyphagous feeding behavior exhibited by larvae of species belonging to family Nymphalidae and Pieridae might be responsible for such abundance of butterflies in the study area. The members of Asteraceae were mostly found to be used by butterflies as nectar food plants along the foot trail. Moreover, predominance of butterflies of family Nymphalidae in the study area is in line with the findings that have also been reported earlier at different locations in city Nainital (Arya *et al*., 2014, 2016a; Garia *et al*., 2016; Meena and Dayakrishna, 2017). In comparison, Arya *et al.* (2014) documented 27 species of butterflies majority of which belonged to family Nymphalidae and Pieridae from academic institutions like D.S.B. Campus and Administrative Block of Kumaun University, Nainital. Arya *et al.* (2016a) recorded 37 species of butterflies from temperate forests located in the city Nainital with majority of species belonged to family Nymphalidae (20 species) and Pieridae (nine species). Garia *et al.* (2016) reported 37 species of butterflies from Naina Devi Himalayan Bird Conservation Reserve located at Kilbury forest which is 13 km north of Nainital. More recently, Meena and Dayakrishna (2017) prepared a list of 29 species of butterflies from the campus of Bharat Ratna Pt. Govind Ballabh Pant High

Altitude Zoo, Nainital established for *ex situ* conservation of endemic wildlife to Himalayan region. Nymphalidae was again most species rich family with 14 species, followed by Pieridae (seven species), Lycaenidae and Papilionidae (four species each), respectively. Overall, these findings indicate that species richness of butterflies was high in the present study site as compared to areas explored for butterfly diversity in and around Lake City. Based on number of sightings, four species of butterflies namely, *Pieris brassicae* (Linneaus), *Junonia iphita* (Cramer), *Aglais cashmiriensis* (Kollar) and *Papilio polytes* (Linneaus) were recorded as fairly common which accounted 30.85% of total individuals recorded in the present study. Similarly, 17 species (40.47% of the total species) were recorded as common, most of which belonged to family Nymphalidae and Pieridae, while 15 species of butterflies such as *Symbrenthia lilaea* (Hewitson), *Vanessa cardui* (Linnaeus), *Libythea lepita* Moore, *Ypthima nikea* Moore, *Lethe insana* (Kollar), *Danaus genutia* (Cramer), *Argyreus hyperbius* (Linnaeus) of family Nymphalidae and *Colias erate* (Esper), *Eurema brigitta* (Stoll) of family Pieridae and rest belonging to the other families were recorded as uncommon during study period. On the other hand, species of butterflies like *Abisara fylla* (Westwood), *Heliophorus oda* (Hewitson), *Graphium agamemnon* (Linneaus), *Lethe verma* (Kollar) and *Melanitis leda* (Linnaeus) were recorded as least abundant and rare in terms of their local status. Apart from this, six species having protected status under the Indian Wildlife Act namely *Euploea core* (Cramer), *Libythea lepita* Moore, *Melanitis leda* (Linnaeus), *Heliophorus oda* (Hewitson), *Lampides boeticus* (Linnaeus) and *Everes argiades diporides* Chapman were also recorded.

Seasonal conditions are considered to be the major factor in determining spatial and temporal distribution of butterflies and other insects (Kunte, 1999; Ramya *et al*., 2017). Fig. 5 shows the number of species with individuals of butterflies arranged family wise across spring, rainy and autumn seasons of the study period. The figure indicates that there was no significant difference in species count however, abundance of butterflies belonging to different families was found to be varied across different seasons. The individual abundance of families Pieridae, Lycaenidae and Riodinidae was reported maximum for the spring season, followed by rainy and autumn seasons, whereas members of families Nymphalidae and Hesperidae were found abundant during rainy season, followed by spring and autumn seasons. On the other hand, abundance of butterflies belonging to family Papilionidae was recorded maximum during autumn season and least in rainy season. Of the total butterfly species, eight species were seasonal (based on flight periods) i.e. they were recorded in specific seasons. The butterfly species such as *Libythea lepita* Moore, *Melanitis leda* (Linnaeus) belonging to family Nymphalidae, *Heliophorus oda* (Hewitson) of family Lycaenidae, *Graphium agamemnon* (Linnaeus) of family Papilionidae and *Dodona dipoea* Hewitson, *Abisara fylla* (Westwood) of family Riodinidae were recorded during spring season in the present study. Species of family Nymphalidae *Lethe verma* (Kollar) was recorded during rainy season, whereas *Lampides boeticus* (Linnaeus) of family Lycaenidae was found with flight period during the autumn season. The species such as *Callerebia scanda* (Kollar), *Symbrenthia lilaea* (Hewitson), *Vanessa cardui* (Linnaeus), *Eurema brigitta* (Stoll), *Aporia agathon* (Gray), *Notocrypta curvifascia* and *Tagiades cohaerens cynthia* Evans were found during rainy and spring seasons. On the other hand, species of butterflies such as *Danaus genutia* (Cramer), *Colias erate* (Esper), *Byasa polyeuctes* (Doubleday) and *Papilio protenor* Cramer were recorded during autumn and spring seasons, whereas species such as *Argyreus hyperbius* (Linnaeus), *Lethe insana* (Kollar), *Ypthima nikea* Moore and *Lycaena pavana* (Westwood) were found with flight periods during rainy and autumn seasons. Apart from this, 19 species of butterflies remained active in variable abundance throughout the seasons that include species like *Aglais cashmiriensis* (Kollar), *Danaus chrysippus* (Linnaeus), *Euploea core* (Cramer), *Junonia iphita* (Cramer), *Vanessa indica* (Herbst), *Pieris canidia* (Linnaeus), *Colias fieldii* Menetries, *Catopsilia pomona* (Fabricius), *Heliophorus sena* (Kollar), *Papilio polytes* Linnaeus, *Dodona durga* (Kollar) and few others.

It is thus, evident from these results that different seasons crucially influence the population structure of many species of butterflies. Moreover, seasonal fluctuations faced by different generations may include changes in ambient temperature and light levels, rainfall, differential availability of resting places, periodic supply of nectar and larval host plants, vegetation cover, and a differential set of predators and predation risk (Shobana *et al*., 2012 and Sajjad *et al*., 2012). Phenology of insects, especially life span and the number of generations per year besides their fecundity and host plant range also determine their population fluctuations across the seasons (Sajjad *et al*., 2012). The diversity indices that were calculated have been given in Table 3 depicting information about distribution of butterfly community across different seasons during the study period. Shannon Wiener Diversity index (H') was calculated as 3.486 for overall samplings indicating rich diversity for the sampled area. During the study period, maximum species diversity was recorded during spring season (3.397), followed by rainy (3.387) and autumn (3.258). Such species diversity of butterflies across the seasons were found to be slight contradictory with observations that have also been recorded earlier in Kumaun Himalaya (Joshi and Arya, 2007; Tyagi *et al*., 2011; Arya *et al*., 2016b; Verma and Arya, 2018). Simpson's Dominance Index ranged from 0.9492 to 0.9599 which is nearer to 1, indicating the dominance of certain species of butterflies as *Aglais cashmiriensis* (Kollar), *Junonia iphita* (Cramer), *Pieris brassicae* (Linnaeus), *Papilio polytes* (Linnaeus), etc. in the forest trail. Moreover, Pielou's Evenness Index (J′) for the butterfly communities is 0.9326 which expresses that species were evenly distributed across the seasons during the study period.

From the past many years due to rapid expansion and increased urbanization augmented by unplanned and non regulated tourism management, several threats like frequent landslides, diminished spring water, forest fires, depleted forest cover and vegetation are disturbing fragile ecological processes in Nainital. These drastic alterations are leading to a decline in the vegetation primarily and ultimately in all forms of fauna through a number of eco-biological components of the complex food web. This necessitates immediate and proper conservation of natural resources while developing sustained and eco-friendly form of tourism. Besides the conservation of biological diversity, the establishment of Butterfly trail would encourage a number of nature lover tourists which in turn would generate economic incentives to local stakeholders. Several native plant species serving as host plants should be afforested to develop better survival and breeding grounds for butterflies in the study area. Such active measures would be helpful in building complementary inventory of insects and other fauna essential for providing ecosystem services in the urban region of Nainital.

Table 1. List of plant species with their families available in the study area

S. No.	Species name	Botanical Family
	Trees	
1.	*Quercus leucotrichophora* A.	Fagaceae
2.	*Quercus floribunda* Lindl. ex A. Camus	Fagaceae
3.	*Cornus macrophylla* Wall.	Cornaceae
4.	*Rhododendron arboreum* Sm.	Ericaceae
5.	*Acer oblongum* Wall. ex DC.	Sapindaceae
6.	*Acer pictum* Thunb.	Sapindaceae
7.	*Acer caesium* Wall. ex Brandis	Sapindaceae
8.	*Betula utilis* D.Don	Betulaceae

9.	*Aesculus indica* (Wall. ex Camb) Hook. F	Hippocastanaceae
10.	*Fraxinus micrantha* L.	Oleaceae
11.	*Litsea umbrosa* Nees.	Lauraceae
12.	*Machilus duthiei* King ex Hook. F.	Lauraceae
13.	*Carpinus viminea* Wall. ex Lindl.	Betulaceae
14.	*Ficus nemoralis* Wall.	Moraceae
15.	*Magnolia grandiflora* L.	Magnoliaceae
	Shrubs	
16.	*Berberis asiatica* Roxb. ex. Dc.	Berberidaceae
17.	*Coriaria nepalensis* Wall.	Coriariaceae
18.	*Pyracantha crenulata* (Don) Roem.	Rosaceae
19.	*Rubus ellipticus* Sm.	Rosaceae
20.	*Virburnum cotinifolium* Don	Caprifoliaceae
21.	*Sarcococca saligana* (D. Don.) Muell.	Buxaceae
22.	*Daphne papyracea* Wall. ex Steud.	Thymelaeaceae
23.	*Rosa macrophylla* Lindl.	Rosaceae
24.	*Urtica dioca* Linn.	Urticaceae
25.	*Reinwardtia indica* Dum.	Linaceae
26.	*Myrsine africana* L.	Myrsinaceae
27.	*Indigofera pulchella* Roxb.	Fabaceae
28.	*Debregeasia longifolia* (Burm. f.) Wedd.	Urticaceae
	Herbs	
29.	*Ainsliaea aptera* DC.	Asteraceae
30.	*Oxalis corniculata* L.	Oxalidaceae
31.	*Euphorbia hirta* L.	Euphorbiaceae
32.	*Bidens pillosa* L.	Asteraceae
33.	*Galium rotundifolium* Linn.	Rubiaceae
34.	*Pilea scripta* (Buch.-Ham. ex D. Don)	Urticaceae
35.	*Geranium wallichianum* D. Don ex Sweet	Geraniaceae
36.	*Artemisia nilagirica* (Clarke) Pamp.	Asteraceae
37.	*Trifolium repens* L.	Fabaceae
38.	*Viola canescens* Wall.	Violaceae
39.	*Erigeron annuus* (L.) Pers.	Asteraceae
40.	*Galium asperifolium* Wall. ex Roxb.	Rubiaceae
41.	*Achyranthes bidentata* Blume	Amaranthaceae
42.	*Anaphalis busua* (Buch.-Ham. ex. D. Don) DC.	Asteraceae
43.	*Bistorta amplexicaulis* (D. Don) Greene	Polygonaceae
44.	*Fragaria indica* Andr.	Rosaceae
45.	*Hedychium spicatum* Buch.-Ham. ex Sm.	Zingiberaceae
46.	*Microstylis wallichii* Lindl.	Orchideaceae

Table 2. Species composition and status of butterflies recorded in and around the forest trail located in city Nainital during June, 2017 to April, 2018

S.No.	Scientific name	Common name	Status	Relative Abundance
		Family: Nymphalidae		
1.	*Aglais cashmiriensis* (Kollar)	Indian Tortoiseshell	FC	6.17
2.	*Argyreus hyperbius* (Linnaeus)	Indian Fritillary	UC	2.09
3.	*Callerebia scanda* (Kollar)	Pallid Argus	C	4.13
4.	*Danaus chrysippus* (Linnaeus)	Plain Tiger	C	2.93
5.	*Danaus genutia* (Cramer)	Striped Tiger	UC	1.49
6.	*Euploea core* (Cramer)	Common Indian Crow	C	2.93
7.	*Junonia iphita* (Cramer)	Chocolate Pansy	FC	6.77
8.	*Junonia orithiya* (Linnaeus)	Blue Pansy	C	5.03
9.	*Lethe insana* (Kollar)	Common Forester	UC	1.44
10.	*Lethe verma* (Kollar)	Straight-Banded Treebrown	R	0.42
11.	*Libythea lepita* Moore	Common Beak	UC	1.19
12.	*Melanitis leda* (Linneaus)	Common Evening Brown	R	0.48
13.	*Neptis yerburyi yerburyi* (Butler)	Yerbury's Sailar	C	2.52
14.	*Symbrenthia lilaea* (Hewitson)	Common Jester	UC	1.61
15.	*Vanessa cardui* (Linnaeus)	Painted Lady	UC	2.04
16.	*Vanessa indica* (Herbst)	Indian Red Admiral	C	3.29
17.	*Ypthima nikea* Moore	Moore's Five-Ring	UC	0.72
		Family: Pieridae		
18.	*Aporia agathon* (Gray)	Great Blackvein	C	2.87
19.	*Catopsilia pomona* (Fabricius)	Common Emigrant	C	3.17
20.	*Colias erate* (Esper)	Pale Clouded Yellow	UC	1.38
21.	*Colias fieldii* Menetries	Dark Clouded Yellow	C	2.93
22.	*Eurema brigitta* (Stoll)	Small Grass Yellow	UC	1.68
23.	*Eurema hecabe* (Linneaus)	Common Grass Yellow	C	3.53
24.	*Eurema laeta* (Boisduval)	Spotless Grass Yellow	C	3.11
25.	*Gonepteryx rhamni nepalensis* Doubleday	Common Brimstone	C	2.52

26.	*Pieris brassicae* (Linnaeus)	Large Cabbage White	FC	6.83
27.	*Pieris canidia* (Linnaeus)	Indian Cabbage White	C	2.99
Family: Lycaenidae				
28.	*Celastrina huegelii* (Moore)	Large Hedge Blue	C	2.52
29.	*Everes argiades diporides* Chapman	Tailed Cupid	C	2.52
30.	*Heliophorus oda* (Hewitson)	Eastern Blue Sapphire	R	0.29
31.	*Heliophorus sena* (Kollar)	Sorrel Sapphire	C	2.93
32.	*Lampides boeticus* (Linneaus)	Pea Blue	UC	1.44
33.	*Lycaena pavana* (Westwood)	White-Bordered Copper	UC	1.49
Family: Papilionidae				
34.	*Byasa polyeuctes* (Doubleday)	Common Windmill	C	0.78
35.	*Graphium agamemnon* (Linneaus)	Tailed Jay	R	0.42
36.	*Papilio polytes* Linneaus	Common Mormon	FC	6.05
37.	*Papilio protenor* Cramer	Spangle	UC	1.08
Family: Riodinidae				
38.	*Abisara fylla* (Westwood)	Dark Judy	R	0.29
39.	*Dodona dipoea* Hewitson	Lesser Punch	R	0.24
40.	*Dodona durga* (Kollar)	Common Punch	UC	1.49
Family: Hesperidae				
41.	*Notocrypta curvifascia* (Felder &Felder)	Restricted Demon	UC	1.38
42.	*Tagiades cohaerens cynthia* Evans	Evan's Snow Flat	UC	0.72

(Abbreviations used: C= common; FC= fairly common; UC= uncommon; R= rare)

Table 3. Seasonal variation in diversity indices of butterflies observed during the study period

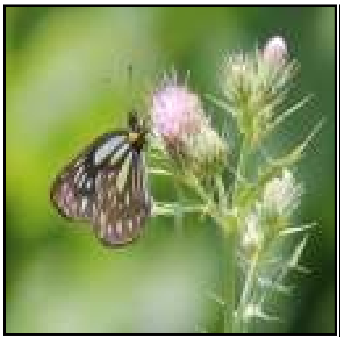
Indices	**Rainy**	**Autumn**	**Spring**	**Total**
Simpson	0.9595	0.9492	0.9599	0.9636
Shannon	3.387	3.258	3.397	3.486
Equitability/Pielou (J')	0.9312	0.9091	0.9339	0.9326

Fig. 2. Images showing observed level of disturbances along foot trail in the study area

Vanessa indica

Lethe verma

Lethe insana



Aporia agathon

Neptis yerburyi yerburyi

Vanessa cardui

Callerebia scanda

Ypthima nikea

Libythea lepita

Junonia iphita

Melanitis leda

Symbrenthia lilea

Fig. 3. Some of the observed species of butterflies during the study period

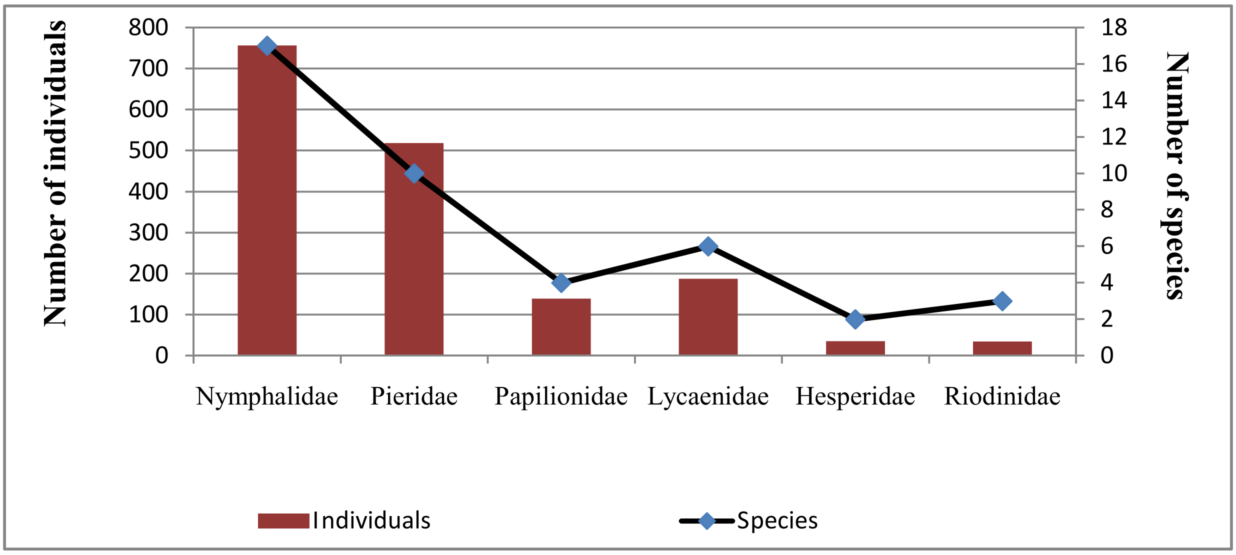


Fig. 4. Variation in total number of species and individuals of different families of butterflies recorded from the forest trail

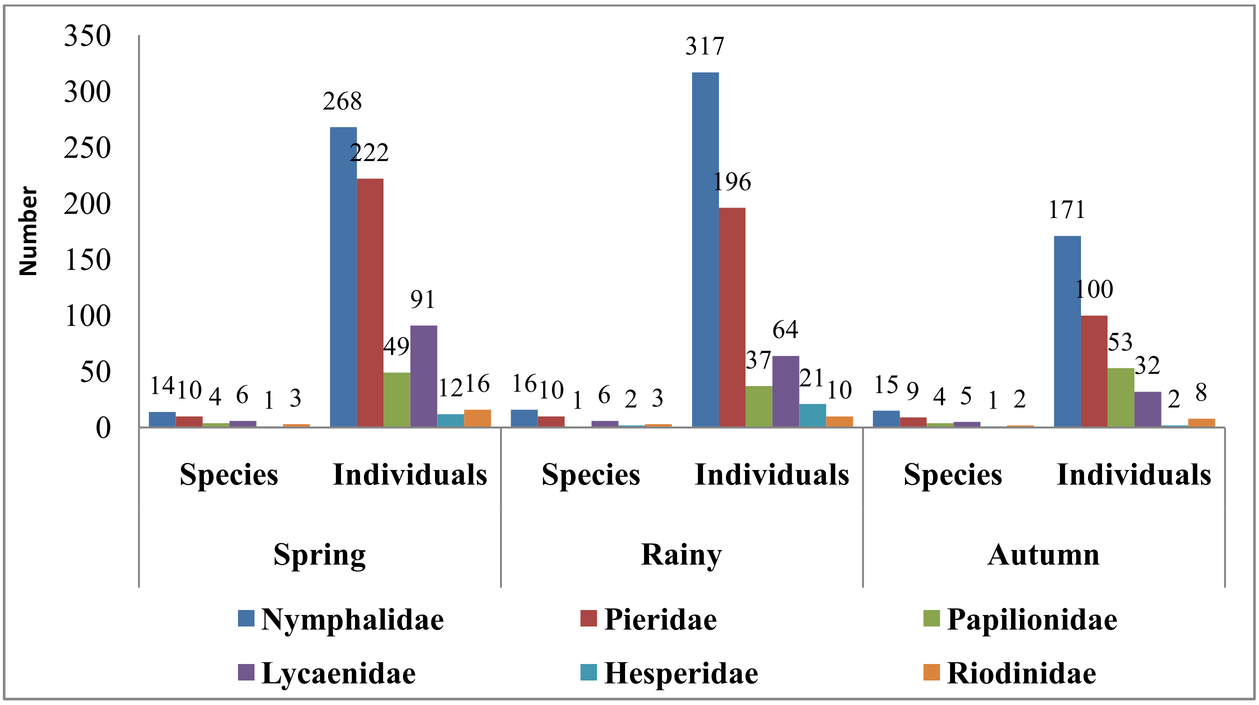


Fig. 5. Family wise seasonal variation of butterflies in terms of number of species and individuals recorded from the forest trail

CONCLUSION

Based on observations of the present study, it is suggested that temperate forest around the foot trail linking urban city Nainital to rural Ratighat is rich for butterfly community when compared to the various areas assessed earlier at times for butterfly diversity at city Nainital, thus establishment of biodiversity offsets such as Butterfly 'Trail' or 'Park' within a timeframe would be the most significant way forward to promote *in situ* conservation of butterflies. High species richness throughout the seasons, with peak abundance of butterflies during spring that also coincides with tourism season of the region is a good indicator for potential of this forest trail for promoting butterfly ecotourism in city Nainital. The creation of butterfly offsets will further help to create awareness in masses about the conservation of biodiversity and natural resources by synchronizing these valuable assets with the livelihood of local community.

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Petrography and Primary Volcanic Features of the Panjal Traps of Lidderwat Section in Pahalgam, Kashmir (NW- Himalaya)

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ABSTRACT

The early Permian Panjal traps of Kashmir were formed during the opening of the Neo-tethys Ocean. These traps are composed of mafic and silicic volcanic rocks. This work presents field and petrographic characteristics of the Panjal traps from Lidderwat section of Pahalgam, Kashmir valley. The study has been carried out on a succession of seven flows. The samples under thin section analysis exhibit pyroxene and plagioclase as primary minerals whereas biotite, chlorite and sometimes hornblende occur as secondary phases. The textural relationship reveals that the crystallization of pyroxene appears as first mineral phase and was superseded by the precipitation of plagioclase thus causing pyroxene to occur as inclusions in the plagioclase phenocrysts. Plagioclase dominates throughout the whole lava flow sequence. Pyroxene, tending towards the iron-rich variants, shows a slight increase in proportion in the upper flows. Opaques range in size from small microscopic dust in lower beds to microphenocrystic size fractions in the upper flows. Their mineralogical composition resembles to tholeiitic basalts. The presence of both elongated and rounded vesicles indicates that the Panjal traps had experienced stress conditions during the Himalayan orogeny. In addition, presence of columnar joint patterns and vesicles suggest that the eruption of Panjal traps was under sub-areal conditions in this part of igneous province.

Key words: *Panjal traps, Basalts, Himalaya, Columnar joints.*

INTRODUCTION

Basaltic volcanism indicates thermal and chemical evolution of all the terrestrial planets of the Solar System (Embey-Isztin, 2007). These magmatic activities are probes of chemical compositions and physical conditions in planetary mantles that are hidden from direct observation by depth and time. Basaltic magmas are generated in all tectonic settings such as convergent, divergent plate margins and intraplate areas. Terrestrial volcanism of the 'flood basalt' type comprises voluminous outpourings of dominantly tholeiitic basalts in intraplate settings, which constitute the so-called 'Large Igneous Provinces' (LIPs). The Panjal volcanics are the oldest, and also the most deformed, of known Phanerozoic Continental Flood Basalt Provinces (Vanny, 1993). They cover approximately 12000 km^2 of NW India and their total thickness is ~3000 m in the Pir Panjal Range (south-western Kashmir) to ≤300 m in the Zanskar Range (north-eastern Kashmir) with individual flows around 30m (Middlemiss, 1910; Wadia, 1934; Fuchs, 1987; Chauvet *et al.,* 2008). The Panjal traps are formed by a succession of bedded basaltic flows. Different flows of the Panjal traps are well developed at Lidderwat in Lidder valley (Pahalgam, East Kashmir). Their precise age data is missing, except recently given, 289 ± 3 Ma age for these volcanics by Shellnutt *et al.*, 2011. In the present work samples have been collected from Lidderwat area of Lidder valley, Pahalgam which lies in district Anantnag of J&K State, between the lat-long of 34^0 10′ N and 75^0 17′ E. The aim of present work is to decipher the nature of magma based on the field and petrographic characteristics.

Geology of study area

The lithological description of different stratigraphic horizons present in the study area (Fig. 1) is described in following paragraph.

Muth Quartzite of Devonian age is a thick 650 meters succession of snow white to greenish grey quartzite present in the study area. It is generally massive having granular texture. The Syringothyris limestone of Early Carboniferous age conformably overlies the Muth Quartzite Formation in the Lidder valley and is composed of Shale, limestone and Quartzite. The thickness of this formation is 300 meters. The most characteristic fossil found in this stratigraphic unit is "Syringothyris Caspidate". Syringothyris limestone is conformably overlain by Fenestella shale of Middle Carboniferous age. Fenestella Series is a thick sequence of quartzite and shale of about 600m thickness. Agglomeratic slate, a mixture of siliciclastic and volcaniclastic rocks, overlies the Fenestella shale. Agglomeratic slate underlies the main eruptive sequence of the Panjal Traps. The Panjal Traps, which are chiefly basalt and basaltic andisite in composition covers large portion of the study area (Fig. 1). Panjal Traps are followed by sandstones and carbonates of the Zewan Formation and the shales of the Uppermost Permian-Lower Triassic Khunamuh Formation.

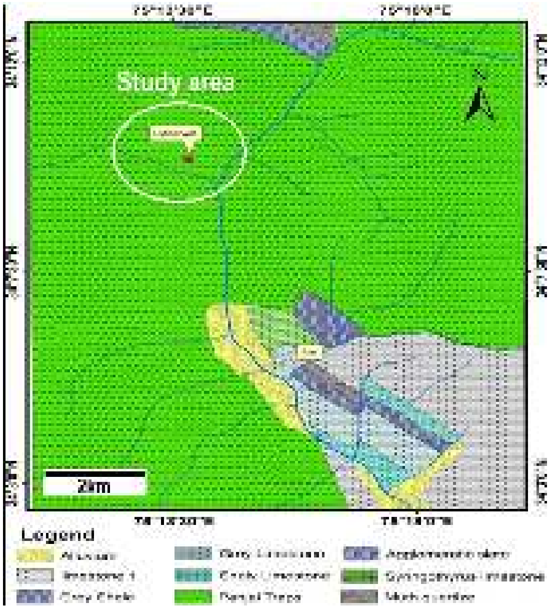

Fig. 1. General geological map of study area (Lidderwat, Pahalgam) (after Bhat and Zainudin, 1979).

MATERIAL AND METHODS

Fresh twenty samples were collected from different flows of the Panjal traps in the study area. Both the ordinary and electronic binocular microscopes (LEICA-EC3, 1.6.0 version) were used for petrographic studies. Micropho-tographs were documented showing mineralogical and textural characteristics or samples.

RESULTS AND DISCUSSION

Primary volcanic features

The Panjal trap is a greenish to grey colored rock with some dark varieties. They are very hard, compact, massive, and generally fine grained. Samples were collected from seven flows at Lidderwat in Pahalgam area (Fig. 2a). The height of the cliff is approximately 50 feet and thicknesses of flows varied from 2 to 4 meters.

Fig.2a. Sample site at Lidderwat, Pahalgam

Flows were differentiated in the field on the basis of column joint shape & size and presence of vesicles. Top flows were inaccessible due to steepness of the cliff. Primary volcanic features are discussed in following headings:

Columnar joints

Columnar jointing has been found in variety of rocks (Spry, 1962; Spry and Solomon, 1964; Sengupta and Ray, 2006). However, it is frequently allied with igneous bodies that are divided into columns along a network of polygonal fractures. Columnar jointing is always associated with decrease in volume, creating tensional stresses within the body (Hetényi *et al*., 2012). This volume decrease can be due to thermal contraction (cooling lava body; e.g. Mallett, 1875; Hetényi *et al*., 2012). Columnar joint formation involves the processes such as crystallization around nucleation centers, convection cells, contractional cooling and large-scale constitutional super-cooling (Spry, 1962; Guy, 2010). The commonly acknowledged view for columnar jointing is contraction cooling which was first proposed by Raspe (1776); it states that the network of fractures forming the column boundaries develops due to mechanical stress buildup while the lava cools and contracts. Columnar joints are very prominent in the Panjal traps; they constitute an important primary volcanic feature of the flows. The variation in the pattern of columnar joints between the flows is helpful in delineating the individual flows. Three faces of hexagonal column, perpendicular to bedding, were observed in each flow. The size of the column and the direction of joints, however, differed from one flow to another. Most studies agree that the length of a polygon-bounding fracture segment is a function of the cooling rate $\partial T/\partial t$ (Lore *et al*., 2001). Slower cooling creates wider (stouter) columns; faster cooling creates narrower (slenderer) columns. Finally, since for a given magma composition glass content is usually proportional to the cooling rate (slower cooling results in higher crystallinity; faster cooling results in increased glass content of the rock), lavas solidifying into glassier rocks are expected to have slender columns than more crystalline lavas. Very less glass content as observed in Lidderwat samples supports slow cooling of flows, hence, these flows show stouter columns (Fig. 2b).

Fig. 2b. Columnar joint patterns at Lidderwat section.

Vesicles

The Panjal volcanics are generally vesicular and the size of the vesicles generally ranges from <1 cm to >8 cm (longest-axis) with most of the vesicles have elongated shape. Rounded vesicles generally occur in the upper part of flows where as elongated ones are confined to the basal parts. The infillings of vesicles is more or less selective; the elongated vesicles are mostly filled with chlorite (Fig. 3a) whereas rounded vesicles are filled with quartz (Fig. 3b).

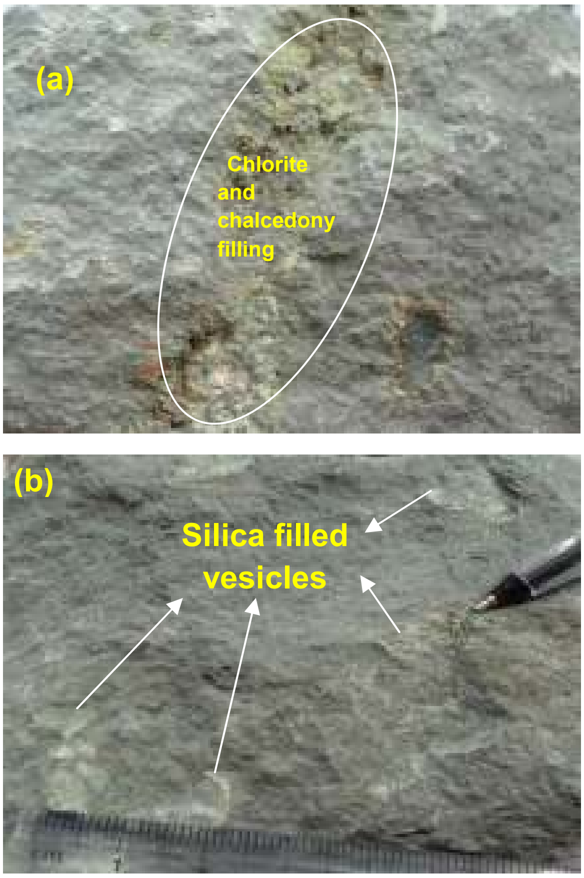

Fig. 3. (a) Elongated vesicle filled with chlorite; (b) rounded vesicles filled with quartz.

Petrography

Seven lava flows were sampled in the Lidderwat section. The variation in mineralogy of the studied samples is not quite regular. Microscopic features of each studied flow are given in Table 1. Under microscope, samples show hemicrystalline assemblage of plagioclase feldspar and pyroxenes (Fig. 4a). Groundmass is represented by microliths of these minerals and their alteration products. Opaque minerals vary in size from microscopic dust to small microphenocrysts. Ophitic to sub-ophitic textures are widespread in these flows (Fig. 4b). Small pyroxene inclusions in the phenocrysts observed in a few lower flows may indicate an earlier crystallization of pyroxene from the magma. Plagioclase shows participation in three phases like megaphenocrysts, microphenocrysts, and minute microliths. Megaphenocrysts are confined to lower flows whereas the microphenocrysts and microliths of plagioclase do exist in all studied flows. The megaphenocrysts and microphenocrysts are generally fractured. In these fractures chlorite and epidote has grown up. The well twinned plagioclase crystals show carlsbad twinning (Fig. 4c). At places complete alteration of pyroxenes, saussuritization and sericitization is observed. Colourless to nearly non-pleochroic pyroxenes (augite) occur as short prisms. The composition of the pyroxene in the lower flows is represented by Ca-rich clinopyroxene. Fe-rich augites are found in upper flows as demarcated by their higher relief and extinction angle as compared to ca-rich augites. In groundmass pyroxene follows a similar trend in composition from Ca-rich clinopyroxene in the lower porphyritic flows to iron-rich variants in the upper flows. Opaques are common in all the flows. However, they form an insignificant amount in the lower flows and are confined to the microcrystalline groundmass. Magnetite and ilmenite has been identified in the middle and upper flows. Magnetite occurs as separate equant grains and also forms inclusions in both the plagioclase and pyroxenes (Fig. 4a). Ilmenite usually forms patches and skeletal crystals (Fig. 4d). The concentration of both ilmenite and magenite gradually increases in the upper flows. Biotite and albite are observed along cleavage traces and fractures which indicates their secondary origin (Fig. 4e). Biotite occurs as tiny flakes to 0.12 mm in size. It is found in a few samples as brown to greenish brown coloured, tiny flakes associated with epidote, chlorite and plagioclase. Important alteration products of plagioclase and pyroxene are epidote, chlorite, hornblende tremolite and actinolite. Epidote occurs as subhedral to anhedral grains ranging in size from 0.1 mm to 0.46 mm in general (Fig. 4f).

Table 1. Microscopic features of different flows from Lidderwat, Pahalgam

S. No	Sample number	Flow number	Location	Latitudes-longitudes	Microscopic features
01	1-L	I	Lidderwat	34° 9′31″N-75° 14′31″E	Medium to coarse grained. Plagioclase and Ca-rich pyroxenes. Chlorite along cleavage planes.
02	2-L	II	Lidderwat	34° 9′32″N-75° 14′31″E	Altered plagioclase laths. Development of Amphiboles.
03	3-L	III	Lidderwat	34° 9′31″N-75° 14′31″E	Microcrysts of plagioclase embedded in pyroxenes, showing ophitic to sub-ophitic textures.
04	4-L	IV	Lidderwat	34° 9′35″N-75° 14′33″E	Phenocrysts of plagioclase and pyroxenes embedded in fine ground mass, showing porphyritic texture.
05	5-L	V	Lidderwat	34°9′35″N-75° 14′35″E	Rounded vesicles of 1 cm in diameter, filled with quartz and epidote. Plagioclase and pyroxenes as phenocrysts.
06	6-L	VI	Lidderwat	34°9′35″N-75°14′35″E	Plagioclase, Fe-rich pyroxenes, Biotite along cracks.
07	7-L	VII	Lidderwat	34°9′35″N-75°14′35″E	Fine grained texture. Altered plagioclase and pyroxenes. Elongated vesicles filled with chlorite.

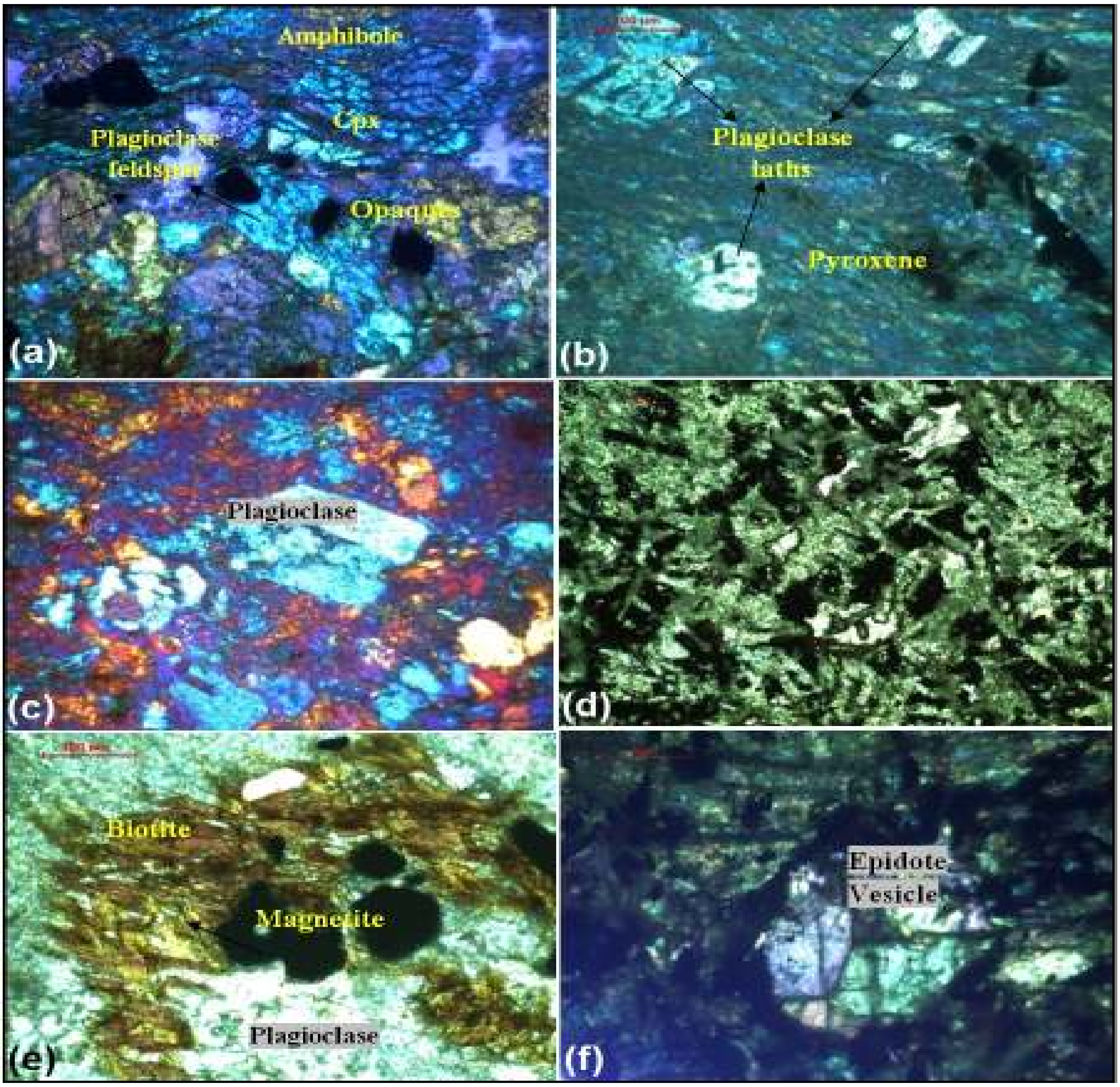

Fig. 4. Microphotographs of Panjal traps of Lidderwat, Pahalgam (a) showing plagioclase, clinopyroxene and development of amphibole (under cross polars), (b) showing ophitic texture under cross polars, (c) showing carlsbad twinned plagioclase under cross polars, (d) showing quartz (white patches), opaques (black patches) and chlorite (green patches) under plane polarized light, (e) showing biotite, plagioclase and magnetite under plane polarized light and (f) showing epidote within vesicle.

It is characterized by various intensities of pleochroism from yellow to yellowish green and greenish. It also occurs commonly as aggregates and discrete grains and sometimes appears to be zoisite. Epidote occurs within the centre and margins of plagioclase. Chlorite is generally very fine to fine grained mineral. It occurs characteristically as flakes, scales, fibers and sheave like aggregates. Chlorite shows yellowish green to grass green pleochroism and exhibits grey and bluish anomalous interference colour.

Petrogenesis

The generation of basaltic magma from the mantle is a critical first step in developing a comprehensive understanding of magma genesis. Following three magma series like calc-alkaline series, tholeiite series and alkaline series are most common basaltic magma series. Calc-alkaline series is limited mostly to convergent plate boundaries. Alkaline series is formed in intra-plate settings whereas tholeiite series is mostly formed in divergent plate boundaries. The main petrographic characteristics of each are given by Winter, 2001. Petrographic characteristics like presence of plagioclase and pyroxenes as phenocrysts and in groundmass, presence of sub-ophitic texture and rarity of olivine indicates tholeiite nature of studied samples. Iron enrichment of pyroxences from bottom to top flows also indicates tholeiitic nature of studied samples. Absence of primary hydrous minerals implies absence of original water content in the magma also supports that the studied samples are of tholeiitic descent.

Intra-plate magmatic activities have occurred throughout the geological history of the earth (Winter, 2000). Panjal traps are one of the most important outpouring of magma that had occurred during the Carboniferous to Permian times. Some debatable issues having international importance are related to Panjal traps such as their eruption age, involvement in mass extinction, origin and environmental conditions during eruption. It is known that intra-plate magmatic activities can happen either in continental or oceanic or under both conditions. With the help of primary volcanic features (columnar joints and vesicles), geochemical and isotopic data it is possible to determine the eruption environmental conditions of volcanic rocks. Thus, the presence of primary volcanic features such as columnar joint patterns and vesicles indicate that the Panjal volcanic eruption in this part of large igneous province had happened under aerial/ continental conditions. Lidderwat flows show stouter columns, which indicate slow cooling of lava. This implication is also supported by low content of glass in Lidderwat flows. The presence of elongated vesicles in the direction of NE-SW implies that the Panjal volcanics had been subjected to stress conditions mainly in the SW-NE directions. The deformation of these volcanics due to Himalayan orogeny is also noted by previous workers such as Chauvet *et al.,* (2008). Absence of olivine as groundmass and/or phenocryst, presence of clinopyroxene (augite) in groundmass and phenocryst and presence of early plagioclase as phenocryst indicates tholeiitic basalt nature of the studied Panjal volcanics (Winter, 2000). In addition, the presence of iron oxides supports the tholeiitic nature of studied lava flows.

CONCLUSION

The studied Panjal traps are basalt to andesite in composition. They are composed of plagioclase feldspar and pyroxenes. Microliths of these minerals and their alteration products represent the groundmass. The heavy minerals are mostly in higher concentration in the lower parts of flows than in the upper parts of flows. This indicates that the settling of the heavy minerals during eruption. The base of every flow is marked by the presence of heavy minerals including magnetite etc. They have tholeiitic characteristics as supported by their mineralogy. Presence of columnar joint patterns and vesicles suggests that the studied flows were erupted under aerial conditions. Presence of elongated vesicles (in NW-SE direction) infers that these flows were subjected to compressional stresses due to Himalayan orogeny.

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Agrobiodiversity in Gewarh Valley: A Case Study from Almora District, Uttarakhand

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ABSTRACT

Kumaun Himalayas has been always known for its rich agro-biodiversity due to diverse agro-climatic conditions given a broad altitudinal regime in the region. While exploring agro-biodiversity in two villages of 'Gewarh valley' in Almora district of Uttarakhand, 78 species (both food crops and trees) were documented out of which 11 plants belonged to Fabaceae. The study villages have greater diversity of tree species as well. The number of food crops per unit area was generally higher in the kitchen garden. Plantation of trees on the bunds of the fields is common for bund stabilization and reducing soil erosion. It was also observed that the crops and the cropping pattern have changed over a period of time owing to diversion from mixed cropping to cash crops or monocropping, crop-raiding by wild animals, labour scarcity due to migration, water scarcity, *etc*. Crop-raiding has been emerged out as a major threat to the existing agro-biodiversity in the villages which needs to be dealt immediately. In order to continue harnessing the tangible and intangible benefits, plausible interventions are needed by involving local communities in order to enrich the agro-biodiversity in the hill farming systems thereof for the overall eco-development of the mountain region.

Key words: *Agro-biodiversity, Communities, Conservation, Himalaya*

INTRODUCTION

Himalayan region provides shelter to more than 10,000 plant species, out of which around 3160 species belonging to 71 genera are endemic (Sathyakumar and Bashir, 2010). Topography and soil conditions together with diverse climatic conditions manifest species richness in agro-biodiversity (Pande *et al.,* 2016). For the people of the region, agro-biodiversity has always been an integral part of the livelihood. In the Uttarakhand hills, around 40 crop species, 16 types of pulses, 6 types of millets, 8 types of vegetables, 5 types of condiments, 5 types of pseudocereals and 6 types of cereals landraces have been reported (Maikhuri *et al.,* 2001). The local communities also preserve the different landraces of the crops which are suitable to those micro-climatic conditions (Bungla *et al.,* 2014). In a case study of Jardhar village of Garhwal Himalaya in Uttarakhand, the local people revealed that in earlier time period, their brides used to bring seeds with them from their parental home and when they used to go back home on visits, they took with them seeds from their marital home. In this way, seeds were exchanged without trading (Gupta, 2008). However, such cultural heritage is in transition (Maikhuri *et al.,* 2001), as a major portion of the Himalayan population has migrated from the hills towards the plains and metro-cities in search of better job opportunities and lifestyle, because of which many villages have turned into ghost villages. If we analyse the scenario of Uttarakhand, the total number of uninhabited villages have increased from 1034 (in the 2011 Census) to 1768 (in 2018), registering a rise of 734 villages in these seven years, which indicates the clear-cut threat to the existing agro-biodiversity of the region. Apart from this, ineffective tools and technologies, land tenure policies, over-exploitation of natural resources (Khumbongmayum *et al.,* 2004), inappropriate socio-economic and environmental conservation policies, increased weed infestation (Saxena and Ramakrishnan, 1984; Kohli *et al.,* 2004 and Murali and Setty, 2001), depleting carrying capacity of the rangelands (Negi, 1990; Rao, 1997), loss of genetic diversity (Maikhuri, 1993; Singh, 1997), hydrological change (Valdiya and Bartarya, 1991), soil erosion (Jain *et al.,* 2001), natural calamities and crop raiding by wild animals (Chauhan *et al.,* 2009) are also threatening the existing agro-ecosystems of the region.

Despite these, there are a few remote villages that still bear rich agro-biodiversity and play a significant role in the agro-biodiversity conservation in the region. Hence, the present study documents the richness of agro-biodiversity in two remote villages of hill district Almora in Uttarakhand.

MATERIAL AND METHODS

The present study was conducted in two adjacent villages namely, Dantola (29^{o}51.266’ N and 79^{o}22.962’ E) and Mahatgaon (29^{o}51.608’N and 79^{o}22.507’E) of the district Almora in the Gewarh valley of Uttarakhand, where the altitude varies from 1010 m asl to 1106 m asl (Fig.1 and 2).

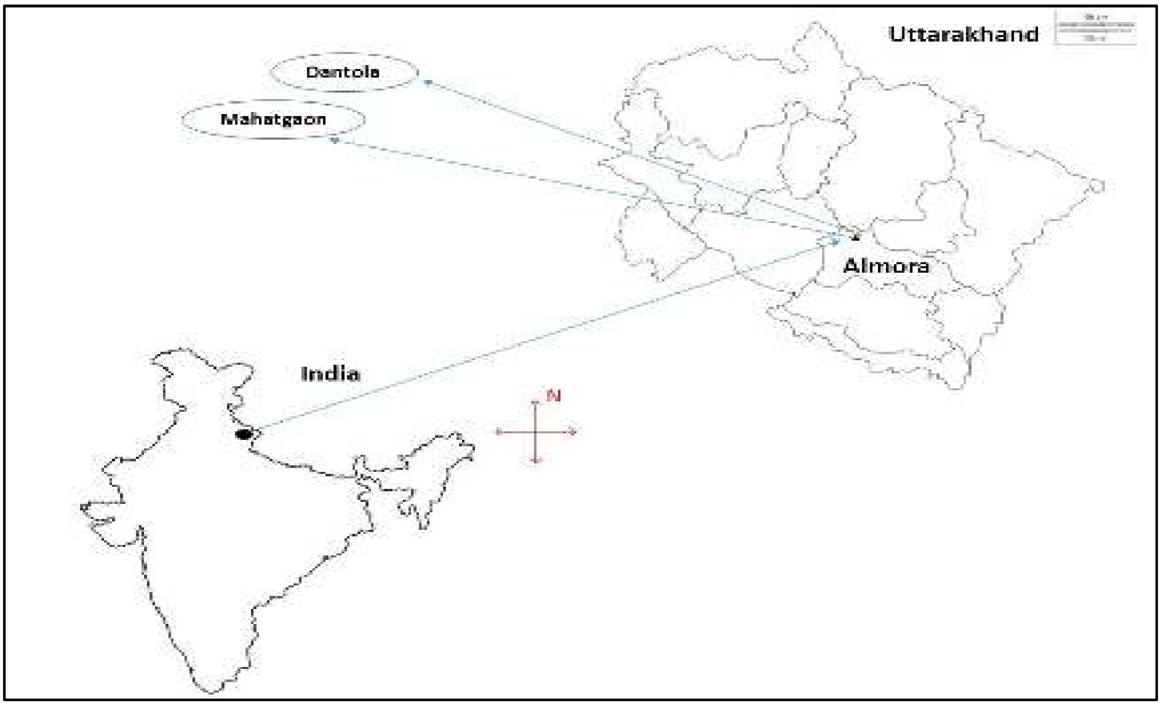

Fig. 1. Location map of the study area

The district Almora covers an area of 3144 km^2 and shares its boundary with Pithoragarh district in the East, Pauri Garhwal district in the west, Bageshwar and Chamoli district in the north and Nainital and Champawat district in the south. The district receives an actual annual rainfall of 862.8 mm (Uttarakhand District Factbook, Almora District, 2017). Agriculture is the source of livelihood for more than fifty percent people of the district. The main agricultural crops grown in the district are rice, wheat, millet, tea, apples, peaches, apricots, plums, etc. Total forest cover of the district is 1583 km^2 (around 50% of the total area) that signify its crucial role in livelihood of the people of the hill district (Uttarakhand District Factbook, Almora District, 2017).

The study villages are situated in 'Gewarh valley' which is well known for its scenic beauty, biodiversity and rich cultural heritages, because of which many tourists visit the region every year. The total area of the village Dantola is 100.228 ha, out of which 56.993 ha comes under village forest, 35.283 ha area is under agriculture (both irrigated and non-irrigated), and 0.711 ha culturable wasteland. Likewise, the total area of the village Mahatgaon is 79.426 ha, out of which 41.6 ha is village forest, 31.54 ha is agriculture area (both irrigated and non-irrigated), 1.136 ha is culturable wasteland and 3.656 ha is unculturable wasteland (Uttarakhand Revenue Department). The total number of households in Dantola and Mahatgaon are 44 and 72, respectively. More than 70% of the households were of traditional type, made of slate (locally called pathar/pathal), mud, cow dung, big stones and wood. The villagers use both traditional 'chullah' (stove, made of mud) and LPG gas for cooking, although the 'chullah' is preferred during winter.

The residents are mainly involved in agriculture for their livelihood. In the summers (May to June), the villagers experience water scarcity. Nonetheless, the area gets a good sunshine along with sufficient amount of rainfall all through the year. Major portion (74%) of the rainfall is received from south-west monsoon (Bhunya *et al.,* 2010). The agricultural crops are eventually grown without keeping the land fallow for a long time. Nevertheless, the land remains barren for 15-20 days after every cropping season. Most of the agricultural activities are done by the women making them the backbone of the agro-ecosystem conservation. A door-to-door survey was conducted in the village with the help of a structured and pre-tested questionnaire during the year 2017 and the information regarding the agro-biodiversity was gathered by covering 68% households from Dantola and 53% households from Mahatgaon village along with the regular field visits. During the survey, one person from each of these household was chosen who gave his/her family views to answer the questions.

Fig. 2. A panoramic view of the study area

RESULTS AND DISCUSSION

Earlier, the cropping pattern in the villages was fully traditional as the farmers were using their own seeds along with farmyard manure and wood ash as the source of fertilizers. But, during the recent years, the farmers have also started buying seeds from agriculture department and chemical fertilizers like urea and NPK. Earlier, the crop cultivation involved manual operations and usage of oxen. Now-a-days, with the advent of road access, the farmers have started using tractors and threshers for ploughing and harvesting respectively. The traditional mixed cropping system has also been replaced by monocropping system due to labour scarcity.

The vegetation in the study villages includes forest, agriculture and wasteland/fallowland (both culturable and non-culturable). The same arable land is cultivated twice a year, both in *rabi* (October/ November-April/May) and *kharif* (May/June-September/October) season (Table 1). The land is kept fallow for around 15-20 days at the end of every cropping season. All crops are irrigated in the *rabi* season, as the rainfall is not sufficient for the crops. In *kharif* season, only paddy (transplanted) is irrigated. Due to the increased scarcity of water, the area under paddy is decreasing year by year. The major *rabi* crops are wheat, barley, lentil, gram, brown mustard, mustard and flax seed. Likewise, major *kharif* season crops are paddy, sorghum, black soybean or *bhat,* soybean, finger millet, urdbean or mash and horsegram.

Different agro-forestry trees like *Pyrus pashia* (Mehal), *Bombax ceiba* (Semal), *Grewia optiva* (Bhimal), *Ficus racemosa* (Timil), *etc.* are found scattered on the bunds of agricultural fields. Out of these trees, *Pyrus pashia* (Mehal) is very much preferred by the villagers for planting on the bunds as it is a thorny tree because of which they are not approached by monkeys and apes. It is also a source of fuelwood and used to make agricultural tools. Apart from crops, fruit trees are also grown scattered in the village and in kitchen gardens. The villagers fulfill their requirement of vegetables and spices from the kitchen garden as every household has a kitchen garden. Overall, 78 major species were documented in both the villages including cereals, pulses, millets, vegetables, fruits, agro-forestry trees and shrubs (Table 2).

Table 1. Major crops grown in *rabi* and *kharif* season

***Rabi* crops**	***Kharif* crops**
Triticum aestivum (L.), *Hordeum vulgare* (L.), *Lens culinaris* Medik., *Linum usitatissimum* (L.), *Brassica juncea* **(L.)** Czern and Cross**.**, *Brassica campestris* L., *Trifolium alexandrinum* L.	*Oryza sativa* (L), *Eleusine coracana* (L.), *Sorghum vulgare* (L.) Pers., *Glycine max* (L.) Merr., *Glycine max, Vigna mungo* (L.), *Macrotyloma uniflorum* (Lam.) verdc.
Monocropping and Intercropping of major agricultural crops	
Monocropping 1. *Glycine max* (Soybean) 2. *Glycine max* (L.) Merr. (Bhat, also known as Black Soybean) 3. *Oryza sativa* (transplanted paddy) 4. *Triticum aestivum* (Wheat) 5. *Hordeum vulgare* L. (Barley) 6. *Cicer arientinum* L (Gram (few farmers)) 7. *Eleusine coracana* (L.) (Madua) 8. *Macrotyloma uniflorum* (Lam.) verdc. (Gahat, grown only in Dantola) 9. *Vigna mungo* (L.) (black gram/urd) **Intercropping** 1. *Oryza sativa* (rained) + *Sorghum vulgare* (Paddy+Jowar) 2. *Triticum aestivum* + *Brassica campestris* (Wheat+Mustard) 3. *Glycine max* + *Sorghum vulgare*+ *Zea mays* (Bhat/soyabean+jowar+ maize) 4. *Lens culinaris* + *Brassica juncea* (Masoor+Rye) 5. *Triticum aestivum/Lens culinaris* + *Linum usitatissimum* (Alsi is grown on side of the field) 6. *Macrotyloma uniflorum* (Lam.) Verdc. + *Sorghum vulgare* (L.) Pers. (Gahat +Jowar)	

Table 2. Species richness in the agro-ecosystems of the study villages

S. No.	**Botanical Name**	**Vernacular name**	**Family**	**Habit**	**Part used**	**Uses**
Cereals						
1	*Oryza sativa* L.	Dhan	Poaceae	Herb	Seed, whole plant	Food, fodder, sacred
2	*Triticum aestivum* L.	Gehun	Poaceae	Herb	Seed, whole plant	Food, fodder, sacred
3	*Zea mays* L.#	Makka	Poaceae	Herb	Seed, whole plant	Food, fodder, sacred
Millets						
4	*Eleusine coracana* (L.)	Madua	Poaceae	Herb	Seed, whole plant	Food, fodder, sacred
5	*Hordeum vulgare* L.	Jau	Poaceae	Herb	Seed, whole plant	Fodder, sacred
6	*Sorghum vulgare* (L.) Pers.	Jowar	Poaceae	Herb	Seed, whole plant	Fodder, broom, sacred
Pulses						
7	*Glycine max* (L.) Merr.	Bhat	Fabaceae	Herb	Seed, whole plant	Food, fodder

8	*Glycine max* (L.) Merr.	Soyabean	Fabaceae	Herb	Seed, whole plant	Food, fodder
9	*Lens culinaris* Medik.	Masoor	Fabaceae	Herb	Seed, whole plant	Food, fodder
10	*Cicer arientinum* L.*	Channa	Fabaceae	Herb	Seed, whole plant	Food, fodder
11	*Vigna mungo* (L.)	Urd/mash	Fabaceae	Herb	Seed, whole plant	Food, fodder
12	*Macrotyloma Uniflorum* (Lam.) verdc.	Gahat	Fabaceae	Herb	Seed, whole plant	Food, medicinal, fodder
13	*Pisum sativum* L.#	Matar	Fabaceae	Herb	Seeds	Food
14	*Phaseolus vulgaris* L. #	Beans	Fabaceae	Herb	Seeds, Pods	Food
Oilseeds						
15	*Linum usitatissimum* L.*	Alsi	Linaceae	Herb	Seed	Food, Oil, medicinal
16	*Brassica juncea* **(**L.**)** Czern**.** and Coss**.**	Rye	Brassicaceae	Herb	Seed, whole plant	Food, Oil, spices, fodder, sacred
17	*Brassica campestris* L.	Sarson	Brassicaceae	Herb	Seed, whole plant	Food, Oil, fodder, oil is applied on pulses before storage, medicinal, sacred
Fodder crop						
18	*Trifolium alexandrinum* L.+	Barseem	Fabaceae	Herb	Whole plant	Fodder
Vegetable crops						
19	*Solanum tuberosum* L. #	Aalu	Solanaceae	Herb	Tuber, whole plant	Food, fodder
20	*Colocasia esculenta* (L.) Schott. #	Gaderi	Araceae	Herb	Leaves, tuber	Food
21	*Raphanus sativus* L. #	Muli	Brassicaceae	Herb	Roots, leaves	Food, fodder, medicinal
22	*Lagenaria siceraria* (Mol.) Standl. #	Lauki	Cucurbitaceae	Climber	Fruit	Food
23	*Luffa cylindrical* (L.) M. Roem. #	Torai	Cucurbitaceae	Climber	Fruit	Food
24	*Trichosanthes cucumerina var. anguina* (L.) #	Chichan Snake gourd	Cucurbitaceae	Climber	Fruit	Food
25	*Benincasa hispida* (Thunb.) Cong. #	Bhuj	Cucurbitaceae	Climber	Fruit	Food
26	*Cucurbita maxima* Duch.#	Kaddu	Cucurbitaceae	Climber	Fruit	Food
27	*Solanum melongena*L. #	Baigan	Solanaceae	Herb	Fruit	Food
28	*Spinacea oleracea*L. #	Palak	Chenopodiaceae	Herb	Leaves	Food

29	*Abelmoschus esculentus* (L.) Moench.#	Bhindi	Malvaceae	Herb	Fruit	Food
30	*Brassica nigra* Koch.#	Lai	Brassicaceae	Herb	Leaves	Food
31	*Dioscorea bulbifera* L.#	Gethi	Dioscoreaceae	Climber	Tuber	Food, medicinal
32	*Momardica charantia* L.#	Karela	Cucurbitaceae	Climber	Fruit	Food
33	*Cucumis sativus* L.#	Kakdi/ Kheera	Cucurbitaceae	Climber	Fruit	Food
34	*Brassica oleracea* L.#	Phoolgobhi	Brassicaceae	Herb	Inflorescence	Food
Spices						
35	*Zingiber officinale* Roscoe.#	Adrak	Zingiberaceae	Herb	Rhizome	Spices, medicinal, food
36	*Allium sativum* L.#	Lehsun	Liliaceae	Herb	Bulb	Food, Spices, medicinal
37	*Allium cepa* L.#	Pyaj	Liliaceae	Herb	Bulb	Spices, food
38	*Capsicum frutescens* L.#	Mirch	Solanaceae	Herb	Fruit	Spices, food
39	*Capsicum annum* L.#	Shimla mirch	Solanaceae	Herb	Fruit	Food, spices
40	*Mentha arvensis* L.#	Pudina	Lamiaceae	Herb	Leaves	Food, Spices, medicinal
41	*Curcuma domestica* Valet#	Haldi	Zingiberaceae	Herb	Rhizome	Food, spices, sacred, medicinal
42	*Coriandrum sativum* L.#	Dhaniya	Apiaceae	Herb	Leaves, seeds	Spices, Food
43	*Trigonella foenum-graecum* L.#	Methi	Fabaceae	Herb	Seed, leaves	Food, spices, medicinal
Dominant Trees (both fruiting and agro-forestry trees, scattered in kitchen garden, fields and fallow land)						
44	*Mangifera indica* L.	Aam	Anacardiaceae	Tree	Fruit, wood	Food, pickle, sacred, fuelwood
45	*Psidium guajava* L.	Amrud	Myrtaceae	Tree	Fruit, leaves	Food, medicinal
46	*Prunus domestica* L.	Pulum	Rosaceae	Tree	Fruit	Food
47	*Prunus persica* (L.) Batsch.	Aadu	Rosaceae	Tree	Fruit	Food
48	*Juglans regia* L.	Akhrot	Juglandaceae	Tree	Fruit	Food, leaves insect repellent in grainages, medicinal
49	*Punica granatum* L.	Dadhim	Punicaceae	Tree	Fruit	Food
50	*Morus alba* L.	Toot	Moraceae	Tree	Fruit	Food, fodder

51	*Pyrus communis* L.*	Nashpati	Rosaceae	Tree	Fruit	Food, fodder
52	*Musa paradisiacal* L.	Kela	Musaceae	Herb	Fruit	Food, sacred
53	*Litchi chinensis* Sonn.*	Litchi	Sapindaceae	Tree	Fruit	Food
54	*Syzigium cuminii* (L.)	Jamun	Myrtaceae	Tree	Fruit	Food
55	*Emblica officinalis* Gaertn.	Amla	Phyllanthaceae	Tree	Fruit	Food, sacred
56	*Melia azadirach* L.	Bakain	Meliaceae	Tree	Leaves	Fodder
57	*Bombax ceiba* L.	Semal	Bombacaceae	Tree	flower	Food
58	*Ficus relegiosa* L.	Peepal	Moraceae	Tree	Whole tree	Sacred
59	*Grevia optiva* Dumm. Ex Burret.	Bhimal	Tiliaceae	Tree	Leaves, branches	Fibre, fodder, fuel
60	*Ficus auriculata* Lour	Timil	Moraceae	Tree	Leaves, wood, fruit	Food, sacred, fodder
61	*Ficus palmata* Forsk.	Bedu	Moraceae	Tree	Leaves, fruit	Food, medicinal, fodder
62	*Pyrus pashia* Buch.-Ham. Ex.D. Don	Mehal	Rosaceae	Tree	Whole tree	Sacred, storing dried grass and paddy straw, food, agricultural implements
63	*Toona serrata* (Royle) M. Roemer	Tun	Meliaceae	Tree	Wood	Construction
64	*Celtis australis* Linn.	Kharig	Ulmaceae	Tree	Leaves	Fodder
65	*Ficus subincisa* Buch. – Ham.	Chachari	Moraceae	Tree	Leaves	Fodder
66	*Populous deltoides* W.Bartram ex Marshall *	Poplar	Salicaceae	Tree	Wood	Plantation
67	*Dalbergia sissoo* Roxb. Ex DC.*	Shisham	Fabaceae	Tree	Wood	Plantation
68	*Pinus roxbhurghii* Sarg.	Chir	Pinaceae	Tree	Wood, seed	Food, Construction, fuelwood
69	*Prunus cerasoides* Don.	Painya	Rosaceae	Tree	Wood, leaves	Agriculture implement, fodder, sacred
70	*Citrus pseudolimon* Tan.#	Hill lemon	Rutaceae	Tree	Fruit	Food, medicinal
71	*Phoenix dactylifera* L.	Khajur	Arecaceae	Tree	Fruit	Soil binder
Major shrubs						
72	*Barberis aristata* DC.	Kilmora	Berberidaceae	Shrub	Fruit, roots, bark	Food, medicinal
73	*Rubus ellipticus* Smith in Rees	Hisalu	Rosaceae	Shrub	Fruit,	Food, medicinal

74	*Ziziphus spp.*	Ber	Rhamnaceae	Shrub	Fruit	Food
75	*Ricinus communis* L.	Arand	Euphorbiaceae	Under shrub	Leaves, fruit	Medicinal
76	*Urtica dioica* Linn.	Bichu-ghas	Urticaceae	Herb	leaves	Food, medicinal
77	*Pyracantha crenulata* Roxb.	Ghingaru	Rosaceae	Shrub /tree	Wood	Small tools
78	*Citrus aurantifolia* (Christm.) Swing.#	Kagjinimboo	Rutaceae	Shrub	Fruit	Food, medicinal

* Crops, only grown in village Dantola
#Crops grown in kitchen garden
+Crop grown in village Mahatgaon

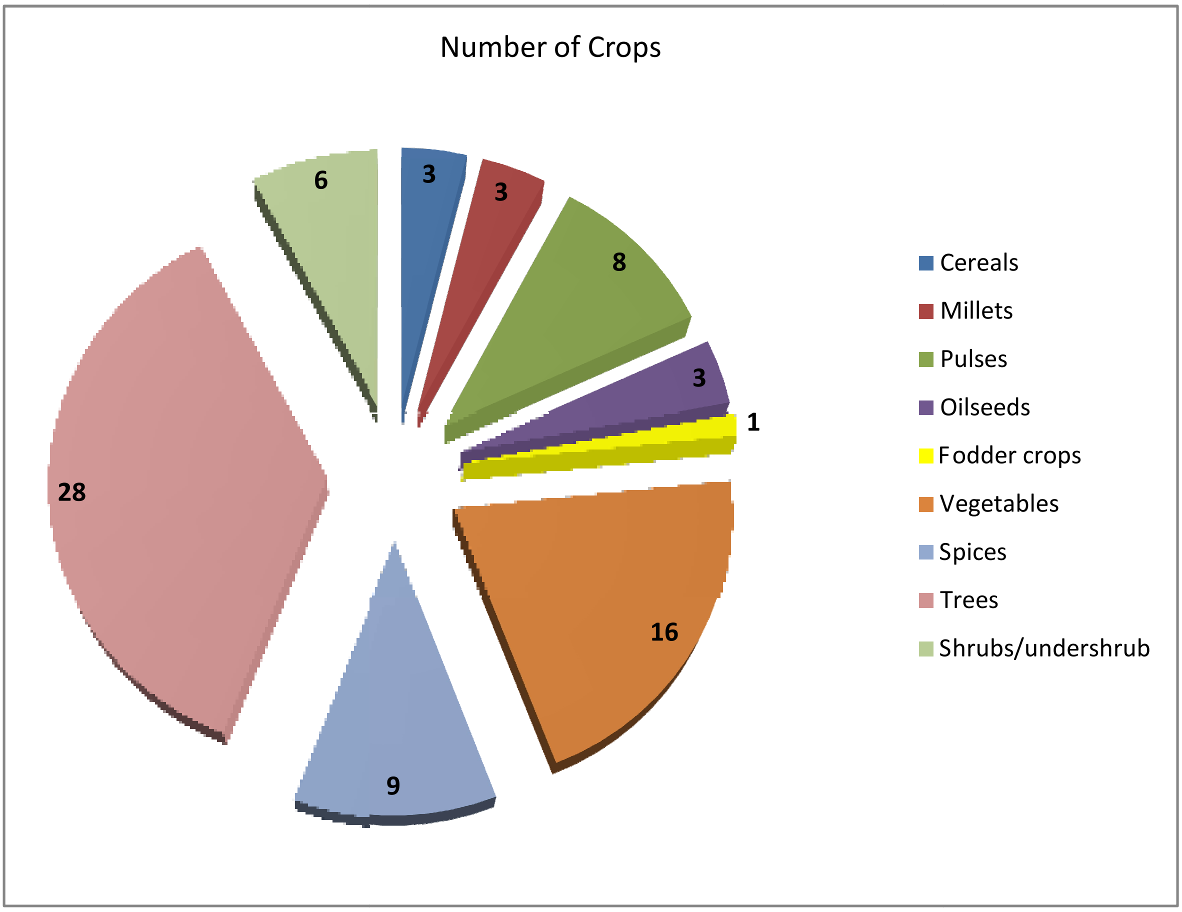

Fig. 3. Distribution of agro-biodiversity in the study villages

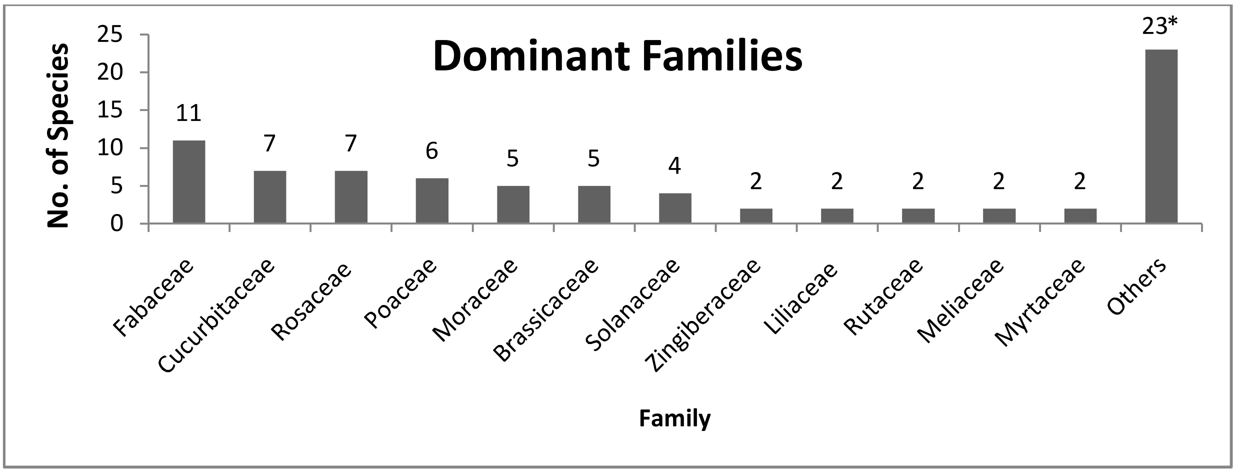

Fig. 4. Taxonomic distribution of food crops in the study villages, (* 1 species, each representing 23 different families)

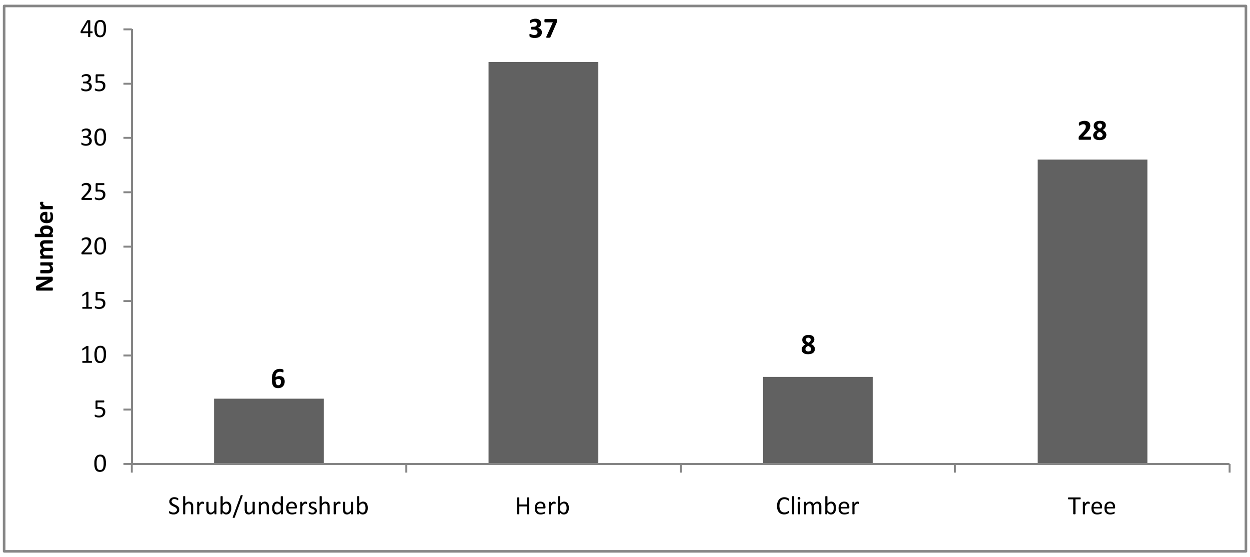

Fig. 5. Distribution of agro-biodiversity based on plant habit

Overall, 78 major species were documented in both the villages including cereals, pulses, millets, vegetables, fruits, agro-forestry trees and shrubs (Fig. 3). Among crops, almost all of the farmers use their local land races for all the crops, only a few by seeds of paddy and wheat provided by the State Agriculture Department. In the study villages, kitchen garden constituted a major farm activity that had around 30 crops, mostly the vegetables. A greater diversity was also exhibited by woody perennials in the agro-forestry system that included fruit trees, fodder trees, fuelwood trees, etc. (Table 2). Fig. 4 indicates that Fabaceae (11 species) is the dominant family, followed by Cucurbitaceae (8 species), Rosaceae (7 species), Poaceae (6 species), Moraceae and Brassicaceae (5 species) and Solanaceae (4 species). Around 47% of plants recorded in the village agro-ecosystem were herbs that included cereals, vegetables, millets, oilseeds and pulses (Fig. 5). There were 19 plants which are used for medicinal purposes. The thorny shrubs of *Berberis aristata* and *Rubus ellipticus*, besides acting as fence, provide edible fruits to the workers in the field. Among woody perennials, the fruiting trees are generally planted within the residential area, while other agro-forestry trees are found in the fields and fallow land. Our study recorded 14 plants having sacred values in the region which justifies the protection of these species because of their use in rituals and festivals of local people. As a proposition towards conservation of agro-biodiversity, the people of the study area celebrates several festivals like 'Harela', 'Phooldehi', *etc.* (Rautela and Karki, 2015). Thus, agro-biodiversity is an irreplaceable form of ecosystem service to these Himalayan communities.

Despite being contiguous, the villages had differences in the distribution and/or cultivation of crops including multipurpose trees. For example, village Dantola has the system of plantation of Shisham (*Dalbergia sissoo*) and Poplar (*Populous deltoides*) and also cultivation of flax (*Linum usitatissimum*) and fruit crops such as litchi (*Litchi chinensis*) and plum (*Prunus domestica* L.), which were not observed in the other study village. Further, the traditional crops such as Foxtail millets, pearl millets that were earlier grown have been given-up due to labour scarcity due to migration and crop raiding by wild animals like wild pig, fox, monkeys and apes. Wild pig (locally known as '*Barha*') is a major crop raider in the villages, because of which there is a substantial loss in crop production every year, thus diverting the interest of villagers from agriculture. Such phenomena have led to a gradual loss of biodiversity that were abundant as local landraces before. Notwithstanding, many crop varieties and landraces are still conserved because of their religious and socio-cultural values, despite several ecological and socio-economic challenges.

In the state of Uttarakhand, the communities have always been passionate about nature. One of the great examples of traditional communities protecting their ecosystem is

'Chipko Andolan' or 'Hug the Trees Movement' (1973) of Chamoli region of Uttarakhand in which the local people hugged the trees of their forest to protect them from cutting (Bhatt, 1990). Another great example is 'Beej Bachao Andolan' (BBA) or 'Save-the-Seeds Movement' (late 1980s) of Tehri Garhwal (Gupta, 2008) in view of saving traditional seeds of the hills along with promoting traditional farming practices. The indigenous people have had mutual relationship with their ecosystem as they utilize the natural resource like food, fodder, timber, fuel wood, fiber, flosses, edible wild products, ivory, etc., in a sustainable manner and in return, they protect their ecosystem by following certain rules and regulation or associating the ecosystem to their deities, taboos, rituals, festivals and customs (Negi, 2010). Thus, their involvement becomes important while formulating the conservation policies (Pant and Ramisch, 2010). Agrawal and Gibson (1999) have also emphasized on community-based conservation on which the failure or success of any conservation efforts depend *viz*., (i) the multiple actors with multiple interests that make up communities, (ii) the processes through which these actors interrelate, and, (iii) the institutional arrangements that structure their inter-actions.

CONCLUSION

The study leads to the conclusion that the selected villages are rich in agro-biodiversity, because of its immense contribution to their livelihood. Kitchen garden is the most diverse system where the number of crops per unit area is maximum. The study found that the threats to the existing agro-biodiversity (*i.e.* crop raiding, migration, *etc.*) are increasing which require immediate attention of the policy makers in order to prevent its further degradation and maintain sustainability in the region. Given the present day requirements of the local people and international commitments, it is important to balance our conservation efforts between conservation of traditional crops/ cultivars and food security and achieve socio-economic development to retain the hill farmers in village and sustain Himalayan agriculture linking ecology with economics and ethics.

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Hydrochemical Characteristics of Groundwater in Mahua Block, Dausa District, Rajasthan with a Special Reference to Fluoride Concentration

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ABSTRACT

Hydrochemical characteristics of groundwater in Mahua block provides an important information about the sources of dissolved ions, and hydro-geochemical processes, involved. Groundwater samples were collected from 20 different locations of Mahua block and analysed for 14 different physio-chemical parameters for understanding the geochemistry of the study area. The results show that the average value of pH measured are about 8.28 showing alkaline nature. The chloride (Cl^-) is the most dominant anion and sodium (Na+) is the major cation in groundwater. Dissolution of rocks and soil structure are responsible for increasing the concentration of dissolved ions. On the basis of total hardness (TH) values, all the samples fall in very hard category. Fluoride concentration varies from 0.72 to 3.88 mg/l with an average of 2.14 mg/l. Moreover, according to the BIS and WHO, 85% and 60% of the ground water samples, respectively exceed the maximum desirable limit of fluoride. Hydrogeochemical facies of the samples suggest that 95% of the samples concentrated Na^+ HCO_3, Ca^{+2} Na^+ HCO_3 and Ca^{+2} HCO_3- salts. The correlation analysis indicates that groundwater chemistry in Mahua block is mainly controlled by geology and oxidation of pyrite along with minimum contribution from anthropogenic activities.

Key words: *Hydrochemistry, Fluoride, Mahua block, Dausa, Rajasthan.*

INTRODUCTION

Groundwater is one of the most important resource, and essential for sustenance of living beings and other activities. Fluoride is a major element present in the groundwater. It helps for development of bones and enamel formation. A daily dose of 0.5 ppm is required for proper formation of enamel and bone, which otherwise cause dental caries, lack of enamel formation and bone fragility (Alhava *et al.,* 1980; Akpata *et al.,* 1997; Cao *et al.,* 2000; Ayenew, 2008). Fluoride is present in the form of naturally occurring minerals as fluorite (CaF_2), cryolite (Na_3AlF_6), muscovite, biotite, topaz, tourmalite, hornblende and villianmite

(Handa, 1975; Msonda *et al.,* 2007). The fluoride concentrations are generally found to be higher in water with high alkalinity. Fluoride (~21.0 mg/l) was found in groundwater at Madanapur village, Kurmapalli watershed, Nalgonda district, Andhra Pradesh, which is one of the highest fluoride values in groundwater of granite terrain in India (Mondal *et al.,* 2009). The rock sample analysis revealed that the rock water interaction has enriched the fluoride values in this area. Muralidharan *et al.* (2002) reported that Rajasthan has maximum number of people affected by high fluoride concentration in groundwater. High fluoride concentration and fluorosis in the country are commonly generated in arid and semi-arid climate, with granite and gneisses being the dominant rock types. (Handa, 1988; Teotia *et al.,* 2004; Subba Rao, 2009). Fluoride pollution of groundwater remains a widespread problem, throughout the world. It has been observed that groundwater is the major drinking water source in the villages of Mahua block, Dausa, Rajasthan state, India (Fig.1). Endemic fluorosis as well as its prevalence and severity are poorly known in the study area. Thus, the main objectives of the present study are to (1) assess the groundwater quality for drinking purpose, and (2) evaluate the fluoride content and identifying the sources of fluoride (F^-) in the ground water wells.

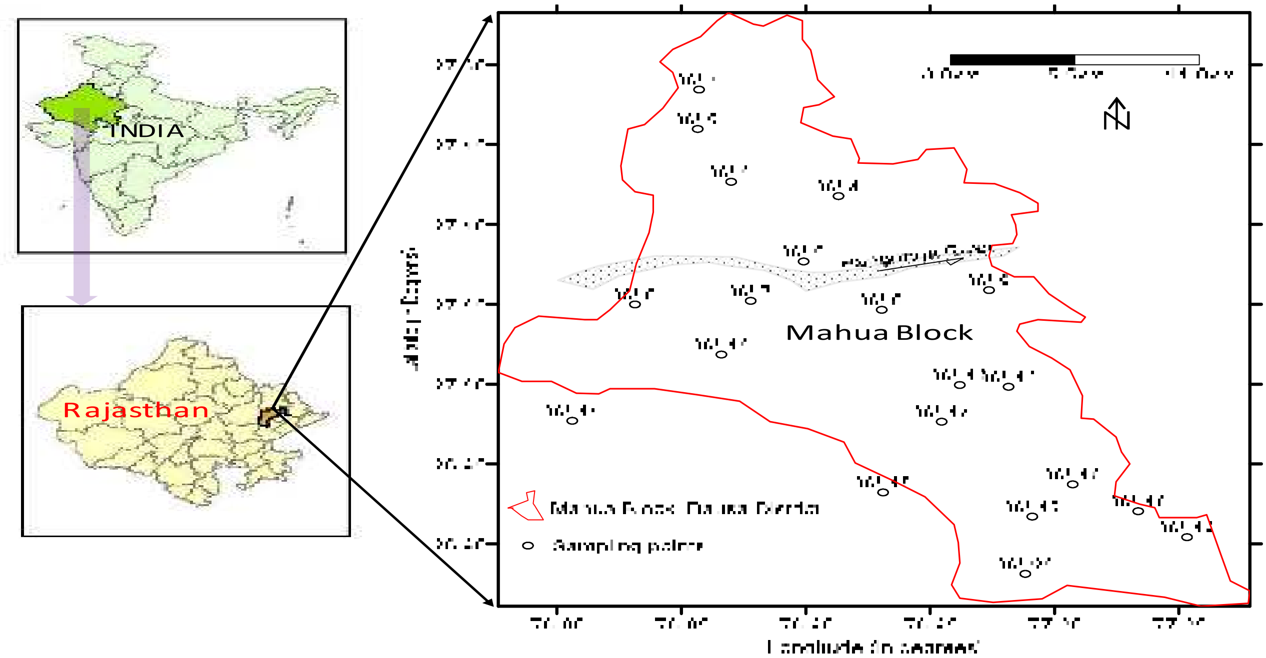

Fig.1. Location map of the study area and distribution of the sampling points in Mahua block, Dausa District, Rajasthan

Study area

The study area is located in between 76° 48′ 14″ – 77° 03′ 00″ E longitude and 26° 52′ 45″- 27° 11′ 00″ N latitudes covering an area of approximately 505 sq.km (Fig.1) with semi-arid climate. The Banganga river flows from the east to west and the block is broadly divided into two parts. The mean maximum temperature ranges between 40°C and 45°C in the summers during months of May-June, and the minimum temperature fluctuates between 3°C and 10°C in the winters during months of January-February. The maximum rainfall (about 94.5%) occurs mainly due to SW monsoon and the mean annual rainfall is about 562 mm. The predominant geological formations of the study area are Alluvium, Delhi Super Group and Bhilwara Super Group. Alluvium (composed of sand, clay, kankar and gravel) forms the principal and potential aquifer in this area. Quaternary alluvium is the principal water bearing formation occupying 84.65% of the study area (CGWB, 2008). Talus and scree deposits and hard rocks of Bhilwara and Delhi Super Group rest in a small part forming 15.35% of the minor aquifers. Groundwater occurs in the unconfined to confined conditions in the primary porosity (i.e., pore spaces).

MATERIAL AND METHODS

About 20 groundwater samples were collected from the study area in the month of May, 2015 (in pre-monsoon season). These samples were collected in plastic containers previously thoroughly cleaned with distilled water and subsequently with sampled groundwater before filling. The pH, total dissolved solids (TDS) and electrical conductivity (EC) of the collected water samples were measured on spot using the portable pH-meter, TDS meter and electrical conductivity meter respectively. The samples were acidified using HNO_3 for cation analysis. The samples were stored in ice box and were carried to the laboratory and kept at 4^0C for further chemical analysis. Other major parameters F^-, NO^{3-}, Ca^{+2}, Mg^{+2}, Na^+, K^+, Cl^-, HCO_3- and SO_4^{-2} were analysed according to the standard procedures (APHA, 2005). Fluoride concentration was measured by ion-selective electrode method. Magnesium and calcium were estimated by volumetric titration using Ethylene Diammine Tetra Acetic Acid (EDTA). Chloride ion concentration was determined by volumetric titration using $AgNO_3$. Sodium and potassium were determined by flame photometer. Sulphate was measured using turbidity meter. The analytical precision for the measurements of cations and anions, indicated by the ionic balance error (IBE), was computed on the basis of ion expressed in meq/l. The value of IBE was observed to be within a limit of ±5 (Mandel and Shiftan, 1980). Correlation co-efficient (r) between each of the parameters were also estimated using the regression analysis.

RESULTS AND DISCUSSION

General hydrochemistry

The general composition of the groundwater samples from the Mahua block, Dausa are summarized in Table 1. Statistical measures such as minimum, maximum and average are also presented in Table 2. The pH of groundwater samples ranged from 8.00 to 8.50 with an average of 8.28 (±0.1), indicating that the groundwater is alkaline in nature. As per the Bureau of Indian standards (BIS, 2012) and World Health Organization (WHO, 2011) standards, all the samples are within permissible limit (6.50-8.50) meant for human consumption. The TDS of groundwater samples ranging between 523 and 3626 mg/l with an average value of 1543 mg/l, suggest that TDS exceeds the permissible limit (2000 mg/l, IS10500:2004). Five groundwater samples from the Mahua block had TDS values in excess of the permissible limit (>2000mg/l). The TDS contour map had been prepared and shown in Fig. 2a. It indicates that the groundwater quality in the western and south-eastern parts of the study area is not in good condition. Generally, the higher TDS values cause gastro-intestinal irritation to human beings (Sarala *et al.,* 2012).

The total hardness (TH) levels in groundwater samples varied from 180 to 1500 mg/l. According to Durfor and Becker (1964), all the groundwater samples fall in very hard category, which can cause scaling problem to air-conditioning plants (Hem, 1991). The chloride concentration ranged from 43 to 1617 mg/l with an average of 494 mg/l. It was more than the permissible limit for drinking water (>200mg/l) in the entire study area except in the northern part (Fig. 2b).

The nitrate (NO_3^-) concentration in groundwater varied from 01 to 159 mg/l with an average of 28 mg/l (Table 2), indicating high concentration of nitrate (NO_3^-) in drinking water. The contour map of nitrate shows that its concentration is more than 45 mg/l in the extreme south-eastern and eastern parts (Fig. 3a). Hence, this is mostly responsible for methemo-globinemia (Blue baby syndrome) to infants and is assumed to be a result of agricultural activities, which is practiced largely in this area. Most of the rural habitations, where groundwater sampling was done, fall under intensive cultivation areas, and farmers have been using nitrogen rich fertilizers since last few decades. Moreover, animal waste disposal might be responsible for NO_3^- enrichments in local aquifers (Suthar *et al.,* 2009).

Table 1. Hydrogeochemical parameters of the groundwater of the Mahua block, Dausa district, Rajasthan

Well ID	pH	EC	TDS	TH	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	HCO_3^-	CO_3^{-2}	Cl^-	NO_3^-	F^-	SO_4^{-2}
W-1	8.40	1010	602	470	24	100	77	5	366	36	113	13	3.52	439
W-2	8.50	970	523	335	40	57	74	5	305	48	135	12	3.88	ND
W-3	8.40	1180	667	180	12	36	200	4	354	24	170	5	3.06	108
W-4	8.40	2280	1243	325	40	55	384	2	744	60	213	9	3.28	646
W-5	8.20	2100	1123	205	12	43	395	2	842	ND	248	2	3.28	ND
W-6	8.40	6040	3382	1395	136	257	770	10	195	24	1617	31	0.96	ND
W-7	8.40	1050	585	325	34	58	110	2	378	60	71	15	2.66	341
W-8	8.30	1220	693	315	30	58	145	1	610	36	43	24	3.64	490
W-9	8.40	2500	1440	425	42	78	395	5	525	36	418	47	1.70	38
W-10	8.50	3420	1889	700	52	139	480	5	366	60	837	11	1.58	98
W-11	8.00	6320	3626	1500	144	277	784	10	244	ND	1609	33	1.34	367
W-12	8.10	2680	1512	400	36	75	435	5	574	ND	440	7	1.46	228
W-13	8.10	3000	1762	685	54	134	354	78	561	ND	425	95	0.84	146
W-14	8.40	2420	1374	450	52	78	345	9	500	36	447	11	1.70	156
W-15	8.00	4680	2676	645	32	137	784	7	549	ND	1064	9	0.72	348
W-16	8.30	4000	2310	375	38	68	770	3	830	36	617	14	2.06	127
W-17	8.30	1780	996	520	40	102	170	7	488	36	213	57	1.22	50
W-18	8.10	4200	2460	645	56	123	681	7	549	ND	815	14	1.22	122
W-19	8.30	2290	1394	345	48	55	384	2	586	36	319	159	1.34	46
W-20	8.00	1080	616	295	24	57	120	2	683	ND	71	1	3.24	50

All values, except pH and EC 25^{o}C, are in mg/l, ND: Not detected.

Table 2. Statistics of physical and chemical variables of groundwater samples (N=20)

Variable	Minimum	Maximum	Average
pH	8.00	8.50	8.28
EC	970	6320	2711
TDS	523	3626	1543
TH	180	1500	527
Ca^{2+}	12	144	47
Mg^{2+}	36	277	99
Na^{+}	74	784	393
K^{+}	1	78	9
HCO_3^-	195	842	512
CO_3^{-2}	ND	60	26
Cl^-	43	1617	494
NO_3^-	1	159	28
F-	0.72	3.88	2.14
SO_4^{-2}	ND	646	190

Except pH and EC values, the limit of all variables are in mg/l; ND: Not detected

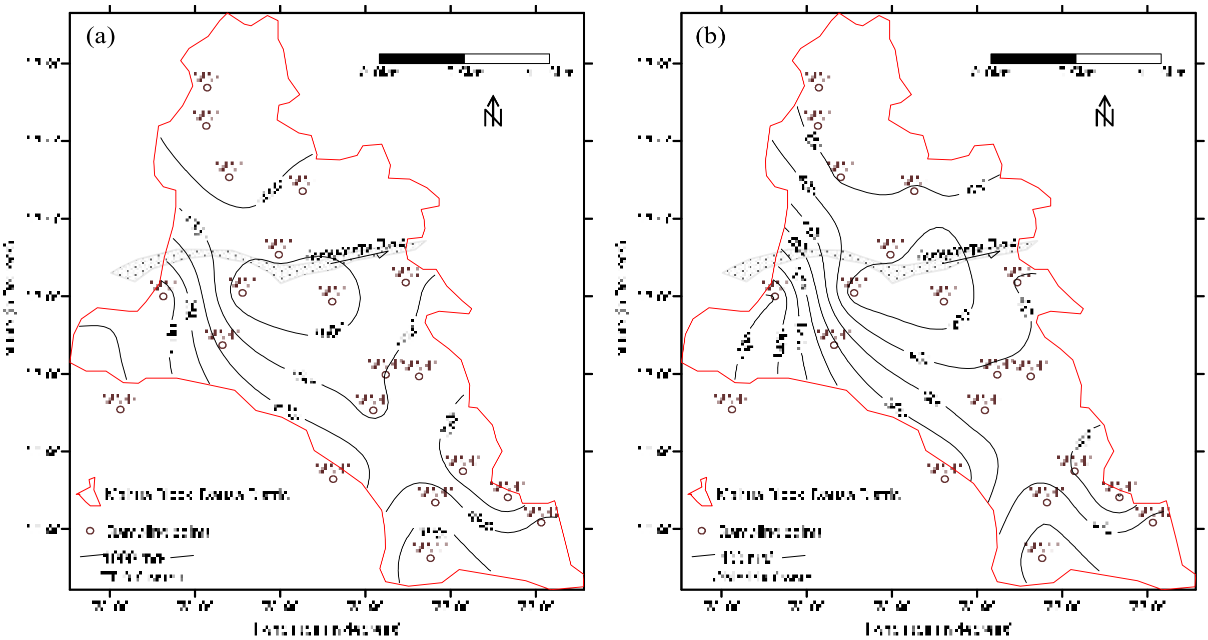

Fig. 2. Showing contour map of (a) TDS (in mg/l), and (b) Cl^- (in mg/l) in Mahua block, Dausa District, Rajasthan

The fluoride concentration in water samples varied between 0.72 to 3.88 mg/l with an average value of 2.14 mg/l. According to Bureau of Indian Standards (BIS, 2012), 85% of the samples exceeded the maximum desirable limit and 60% of samples exceeded the maximum desirable limit as per the World Health Organization (WHO, 2011) standards. The contour map of fluoride concentration has been shown in Fig. 3b. It indicates that fluoride concentration is within the permissible limit (<1.5mg/l) in the western part and in small patches in southern part of the study area. Fluoride is electro negative element hence quickly reacts to form fluoride compounds. Therefore, presence of free fluorine molecule is an obsolete possibility but under favourable physico-chemical conditions, it may occur in dissolved form in groundwater (Handa, 1975; Salve *et al.,* 2008). A higher value of pH in study area favours the enrichment of fluoride in groundwater. Thus biotite/muscovite can increase the concentration of fluoride in groundwater. The alkaline nature of groundwater favours the solubility of fluoride bearing minerals. The cations are mainly dominated in groundwater such as Na^{+}> Mg^{+2}> Ca^{+2}> K^{+} whereas anions, Cl^{-}> HCO_3^{-}> SO_4^{-2}> NO_3^{-} >CO_3^{2-}> F^{-}. Based on significant major ionic concentrations in the groundwater, the quality of it has been deteriorated significantly in the study area.

Correlation between different hydro-chemical constituents

Correlation is a statistical method, which shows the dependency of one variable to the other variables (Mondal *et al.,* 2005; Sarwade *et al.,* 2007; Srinivasamoorthy *et al.,* 2013). Hence, it is used to compute the degree of interrelationship between the two chemical variables (Edet *et al.,* 2003).

Table 3 shows the result of correlation coefficients of various analysed physico-chemical parameters in the groundwater samples of Mahua block. The correlation co-efficient between Ca^{+2} and Mg^{+2} is 0.91. This strong positive correlation between chemical variables are showing common origin of these ions. The SO_4^{-2} shows very low correlation with Ca^{+2} (-0.03), Mg^{+2} (0.01) and Na^{+} (-0.04), but it does also not show significant correlation with NO_3^{-} concentration (Table 3). Dissolution of sulphate minerals ($CaSO_4$, $MgSO_4$) and oxidation of pyrite were less important in the groundwater chemistry of Mahua block, Rajasthan. Good correlation is observed between Na^{+} and Cl^{-} (r^2 =0.87), Mg^{+2} and Cl^{-} (r^2 =0.91), and Ca^{+2} and Cl^{-} (r^2 =0.85) indicating common source viz., calcium, magnesium and sodium rich ($CaCl_2$, $MgCl_2$ and NaCl) minerals in the study area. A positive correlation between Cl^{-} and Na^{+} with EC values shows that dissolution of ions from rocks is a major controlling factor of EC. Negative correlation was observed among the fluoride concentration with EC (-0.71), Cl_2 (-0.67) and NO_3 (-0.42), but positive one with the pH.

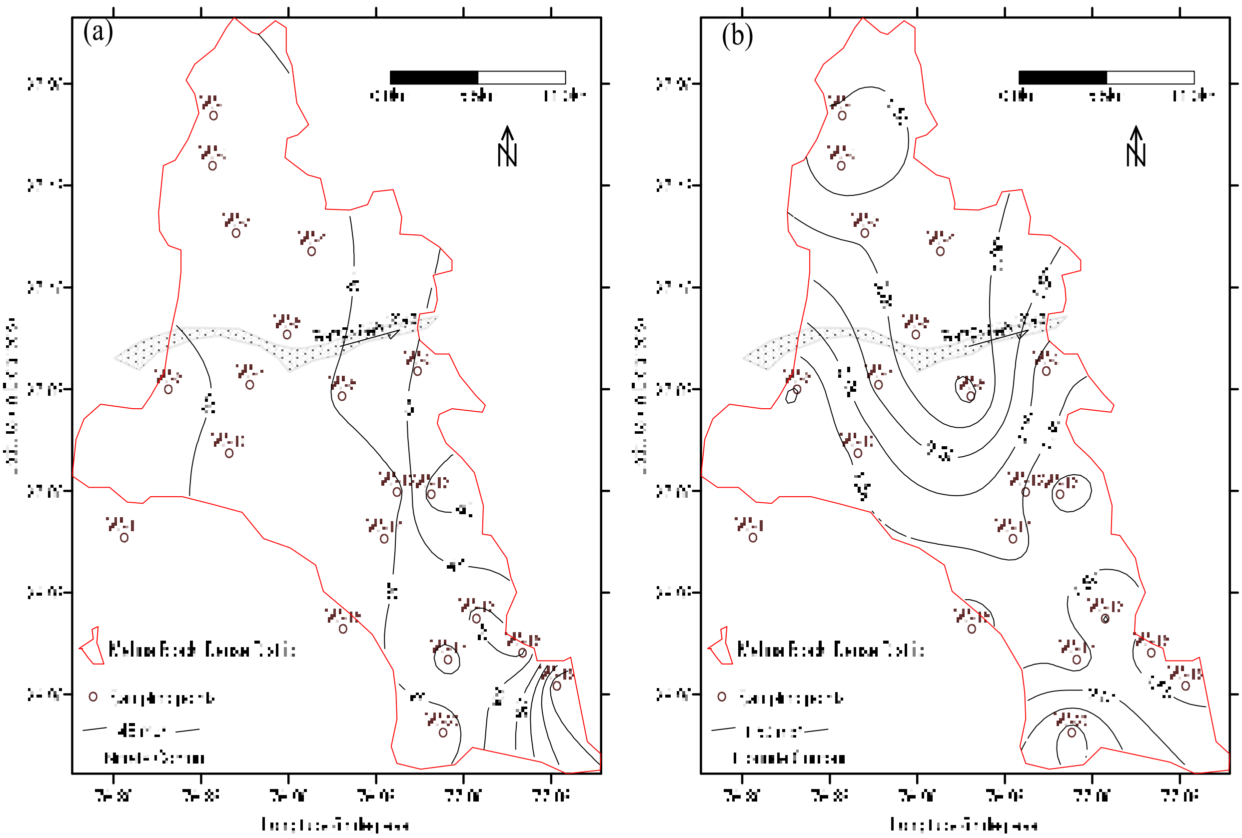

Fig. 3. Showing contour map of (a) NO_3^- (in mg/l), and (b) F^- (in mg/l) in Mahua block, Dausa District, Rajasthan

Table 3. Correlation matrix of physico-chemical variables of groundwater samples in the study area (the values in bold indicate significant correlation)

	pH	EC	TDS	TH	Ca^{2+}	Mg^{2+}	Na^+	K^+	HCO_3^-	CO_3^{-2}	Cl^-	NO_3^-	F^-	SO_4^{-2}
pH	1.00													
EC	-0.37	1.00												
TDS	-0.38	**0.99**	1.00											
TH	-0.24	**0.85**	**0.84**	1.00										
Ca^{2+}	-0.13	**0.80**	**0.80**	**0.94**	1.00									
Mg^{2+}	-0.27	**0.85**	**0.84**	**0.99**	**0.91**	1.00								
Na^+	-0.38	**0.94**	**0.95**	0.63	0.59	0.64	1.00							
K^+	-0.26	0.15	0.17	0.23	0.16	0.25	0.05	1.00						
HCO_3^-	-0.28	-0.22	-0.21	-0.58	-0.56	-0.58	0.03	-0.03	1.00					
CO_3^{-2}	**0.88**	-0.37	-0.39	-0.26	-0.14	-0.29	-0.37	-0.32	-0.17	1.00				
Cl^-	-0.29	**0.97**	**0.96**	**0.91**	**0.85**	**0.91**	**0.87**	0.09	-0.41	-0.33	1.00			
NO_3^-	-0.03	0.05	0.08	0.09	0.18	0.07	0.01	0.39	-0.01	0.01	0.01	1.00		
F^-	0.36	-0.71	-0.72	-0.57	-0.51	-0.58	-0.67	-0.38	0.17	0.34	-0.67	-0.42	1.00	
SO_4^{-2}	-0.07	-0.04	-0.04	0.01	-0.03	0.01	-0.04	-0.08	0.07	0.20	-0.08	-0.22	0.25	1.00

Hydrogeochemical facies

Groundwater can be accessed on the basis of geochemical components present in natural solution (Xiano *et al.,* 2012). In order to provide precise distribution of chemistry of groundwater, Piper trilinear chart/ diagram is mostly used (Piper, 1944; Kumar *et al.,* 2015). The Piper trilinear diagram (Fig. 4) shows that Na^{+}- HCO_3^{-}, Ca^{+2}- Na^{+}- HCO_3^{-} and Ca^{+2} - HCO_3^{-} are the major hydrogeochemical facies in the groundwater of the study area with minor contribution of Na^{+} - HCO_3^{-} type of hydrogeochemical facies. The composition of major ions indicates the dominancy of alkalis (Na^{+} and K^{+}) and strong acids (Cl^{-} and SO_4^{-2}) over alkaline earths (Ca^{+2} and Mg^{+2}) and weak acids (HCO_3^{-}), respectively. Approximately, 8 ground water samples fall in no carbonate alkali and 6 samples fall no cation-anion pair; however, ~5 samples fall in carbonate hardness (secondary alkalinity) and only 1 sample falls in carbonate alkali.

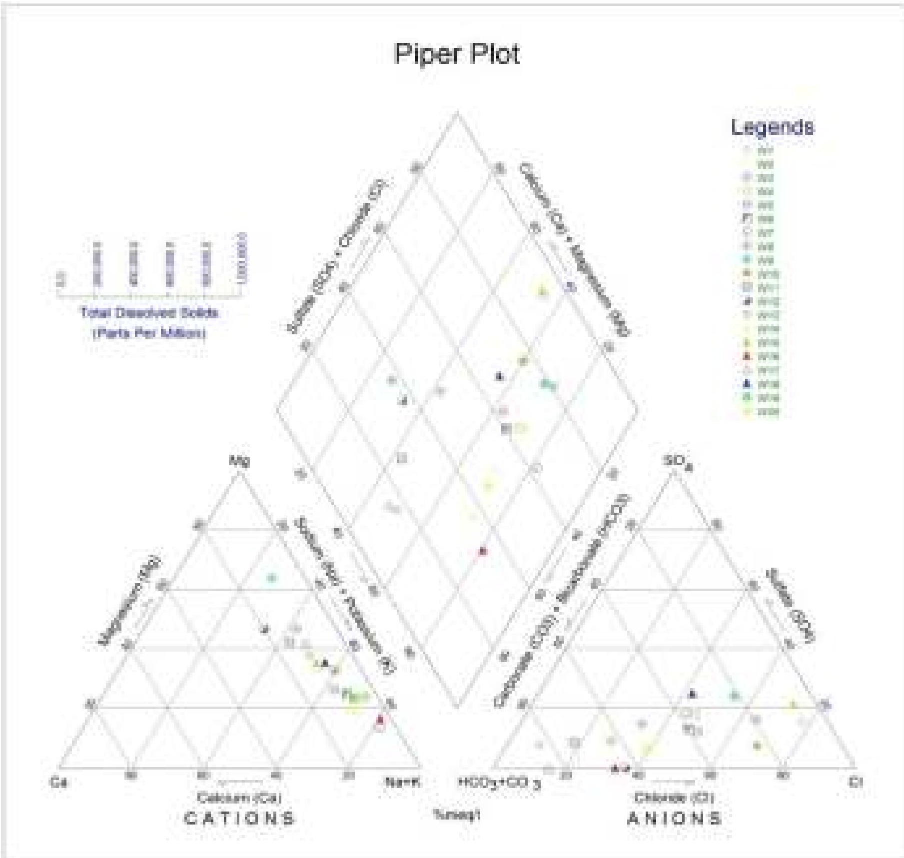

Fig. 4. Distribution of the groundwater samples from Mahua block on Piper diagram

CONCLUSION

Hydrochemical characteristics of ground water is carried out in Mahua block, Dausa district, Rajasthan with a systematic groundwater sampling. The analysis shows that majority of samples (about 85%) contain excess fluoride than desirable limit. Based on total hardness (TH), all the groundwater samples fall in very hard category. According to TDS classification, about 25% of groundwater samples fall in above permissible limit. The dominancy of the major cations and anions in groundwater is observed as Na^{+}> Mg^{+2}> Ca^{+2}> K^{+} (cations) and Cl^{-}> HCO_3^{-}> SO_4^{-2}> NO_3^{-} >CO_3^{2-}>F^{-}(anions). The high concentration of fluoride is depending on composition of rock and water rock interaction in the area. Since, the study area lies in arid to semi-arid environment, the temperature in summer is very high and precipitation is very less; hence the maximum concentration of fluoride in Mahua block is due to dissolution of fluoride bearing minerals and fluorite dissolution. The statistical analysis shows that there is a positive correlation (r^2 =0.91) between $Ca^{+2}$and Mg^{+2}. The SO_4^{-2} shows a very low correlation with Ca^{+2}, Mg^{+2}, and Na^{+}. On the basis of Piper Trilinear Diagram, Na^{+}- HCO_3^{-}, Ca^{+2}- Na^{+}- HCO_3^{-} and Ca^{+2}- HCO_3^{-} are the most dominant water type in this block. This indicates that the quality of groundwater is mostly controlled by the oxidation of pyrite. The information providing in the article can be useful for both government as well as private agencies for the sustainable management of groundwater resource.

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Aspects of Breeding of Tickell's Thrush (*Turdus unicolor* Tickell, 1833) in Kupwara, Jammu and Kashmir, India

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ABSTRACT

Tickell's thrush (*Turdus unicolor* Tickell, 1833), a lesser studied bird species is endemic to the Indian sub-continent. Locally known as Kastur, the bird is very famous for its melody songs. It is a summer visitor to Kashmir and begins to arrive here in early April, breeds here, and stays until August when the outward migration begins which is complete by mid-September. Though the bird is common in Himalayas and is evaluated as Least Concern by International Union for Conservation of Nature (IUCN), the information on its various ecological aspects is not available. The present study has been carried out to provide a better understanding of some aspects of breeding biology of the Tickell's thrush in Kupwara District of Kashmir for two breeding seasons (April to August) of 2015 and 2016. Peak nesting was in May and peak laying in June. Average clutch size was 3.84 (±0.59 SD) and average incubation period 18.5 (±0.69 SD) days. Hatching and fledging success was 77% and 71% respectively.

Key words: *Tickell's Thrush, Breeding, Hatching, Fledging, Kupwara, Kashmir*

INTRODUCTION

Tickell's thrush (Passeriformes: Turdidae) is endemic to the Indian sub-continent and has a discontinuous breeding range from Pakistan through Kashmir to Nepal and western Bhutan (Grimmett *et al*., 1998). The global population size has not been quantified, but the species is described as common in the western Himalayas and uncommon in Nepal (Del Hoyo *et al*., 2005). Evaluated as Least Concern (IUCN, 2016), the species has a large range and is not believed to be decreasing rapidly (Birdlife International, 2019). The population trend is difficult to determine because of uncertainty over the impacts of habitat modification on population sizes (Birdlife International, 2019).

It is a common summer visitor to Himalayas found from Chitral, east through Kashmir to Nepal and Sikkim (Ali and Ripley, 1987). It is a summer visitor to Kashmir and begins to arrive here in early April, breeds here, and stays until August when the outward migration begins which is complete by mid-September. Locally called as "Kastur", the bird is very famous for its melody songs. It is an ashy grey bird, paler below. At close quarters it may be noticed that in the female chin and throat is almost white, bordered by black stripes. The bird feeds on ground mainly on worms and insects. It is not a shy bird and does not hesitate to appear in well-populated areas. The data on distribution, conservation status, breeding biology and ecological requirements of species is lacking from Kashmir Himalaya which invites a detailed study on these aspects.

Breeding is a key aspect of the life history of any animal species. In birds, studies on reproductive biology vary from simple records of breeding in general avifaunal inventories to detailed studies based on monitoring of nests and young throughout the breeding cycle. Information derived from these studies is essential for the improvement of avian life history theory and the implementation of sound management and conservation actions for these organisms and their habitats (Mauricio *et al*., 2013). The present study on breeding aspects of the Tickell's thrush at Kupwara is therefore, a step aimed at to generate the data on timing of breeding, breeding habitat, nest location, clutch size, incubation, nesting and hatching success which are necessary for improving our understanding of life history strategy of the bird species. Further, the baseline data on these aspects may help in better management planning to save the breeding grounds of this bird species in the Kashmir Himalayan region.

MATERIAL AND METHODS

The present study was carried out during two breeding seasons (April to August) of 2015 and 2016 at Kandi Khas village (34°38.490'N, 074° 29.540'E and elevation, 5254 ft.) in Kupwara district of Jammu and Kashmir (Fig. 1A). The nests were located by generally following the birds during breeding season usually with the nesting material or food or other cues (Balakrishnan, 2010). A nest was defined as any depression in which the bird laid one or more eggs (Miller and Jhonson, 1978). Once found, the nest was visited every alternate day. Studies on egg laying, clutch size, incubation behavior and incubation period were conducted. Clutch initiation dates were determined either by direct observation or by back dating (hatching dates minus mean incubation period). Care was taken to avoid the disturbance of the bird or nest during monitoring and to expose the nests to predation (Martin and Geupel, 1993). Nests that produced at least one young were considered successful. Hatching and nestling success were respectively defined as the probability that eggs laid would hatch and the probability that hatchlings would fledge. These calculations were done as per the method provided by Mayfield (1961). Analysis of digital images was done by using Image J analysis software (Version 2.01).

RESULTS AND DISCUSSION

Nest building

Nest building started from mid-April and continued throughout June. May was peak nesting month with 60% nests built in this month (Table 1). Nests were built on various plants and also under the roof of buildings and in walls. Out of 67 nests, 54 were built on plants (Table 1) and only 13 were found under roof tops or in walls. Bates and Lowther (1952) observed the nests in mulberry trees, willows and poplars within village limits and in gardens and groves. Base of the nest is made by mosses mixed with wet clay so that it remains fixed with support. Soft twigs, leaves, grass, root hair, animal hair, pieces of cotton and cloth were used in nest building. Bates and Lowther (1952) found that the nest is neither huge nor neat but compact and cup deep, built chiefly of dry grass with a lining of fine roots and usually contains a quantity of moss, a few leaves and other material.

Egg laying

Egg laying started after completion of nest building. June was the peak laying month with 50% eggs laid in this month (Table 1). An egg (Fig, 1B) was laid daily or alternately usually in the morning. Out of 40 nests, laying occurred alternately in nine (22.5%) while in the remaining 31 nests laying occurred daily. Alternate laying was observed in late nests (late July and August). Brackbill (1958) observed daily laying in wood thrush (*Hylocichla mustelina*). The egg has greenish background with more or less thickly speckled or blotched dull reddish brown spots. Eggs were variable in shape, but round, elongated or pyriform ovals were common. The clutch size ranged from 3 to 5 with an average of 3.84 (± 0.59 SD, n=67). Kelleher and Halloran (2006) reported a clutch size of 4.1 for song thrush (*Turdus philomelas*). A total of 257 eggs were laid in 67 nests. Clutch size of 3 was found in 18 nests, 4 in 42 nests and 5 in the remaining 7 nests (Table 1). Brackbill (1958) also observed a common clutch size of 3–4 in wood thrush while Davanco *et al*. (2013) reported a clutch size of 2.52 (±0.72 SD) in pale breasted thrush (*Turdus leucomelas*).

Incubation

Incubation commenced after the completion of clutch. The females incubated eggs while the males stood guard around the nest area and kept keen vigil on enemies. Similar behavior has been reported by Brackbill (1958) in wood thrush. During incubation the nest was left by female usually in the morning and before evening for 17 to 24 minutes for feeding and defecation. The average incubation period of the thrush was 18.5 days (±0.69 SD, n=20) (range 18–20 days) (Table 1).

Hatching

Hatchlings (Fig. 1C) were altricial and completely dependent upon parents (Fig. 1D). The average nestling period was 21.24 days (19 to 22). On the basis of exposure hatching success was 77% and fledging success 71% (Table 1). Hatching success of 89.6% for song thrush was reported by Kelleher and Halloran (2006). Natural enemies that destroyed eggs as well as hatchlings were common starling (*Sternus vulgaris*), yellow-billed blue magpie (*Urocissa flavirostis*), blue whistling thrush (*Myophonus caeruleus*) and large-billed crow (*Corvus macrorhynchos*)

Table 1. Different breeding aspects of Tickell's thrush (*T. unicolor*)

Timing of nest building					
Month	**Number of nests built**				**Percentage (%)**
	2015	**2016**	**Total**	**n**	
April	02	01	03	40	7.5
May	14	10	24		60
June	04	05	09		22.5
July	02	02	04		10
Nesting site locations on different plant species					
Plant species	**Number of nests located**		**n**	**Percentage (%)**	
Morus alba	12		54	22.22	
Ulmus villosa	07			12.96	
Salix sp.	07			12.96	
Malus domestica	06			11.11	
Celtis australis	06			11.11	
Prunus amygdalus	05			9.26	
Rosa sp.	04			7.41	
Pyrus communis	03			5.55	
Rubina pseudoacacia	03			5.55	
Populous sp.	01			1.85	
Timing of egg-laying					
Month	**Number of eggs laid (n=40)**			**Percentage (%)**	
	2015	**2016**	**Total**		
May	11	16	27	16.77	
June	43	38	81	50.31	
July	21	16	37	22.98	

August	09	07	16	9.93	
Clutch size					
Clutch size	**Number of nests (± SD)**	**n=N**			
3	18	67			
4	42				
5	07				
Average	3.84 ± 0.59				
Incubation period					
Number of nests	**Incubation period (± SD)**	**n**			
12	18	20			
06	19				
02	20				
Average	18.5 ± 0.69				
Mayfield Hatching success					
Variable	**Exposure days**	**Number of eggs**	**Number of eggs failed**	**Daily survival**	**Success rate**
Incubation	2820	257	40	0.986	0.77
Nestling	2870	217	44	0.985	0.71

N= Total number of nests, **n**= Number of nests

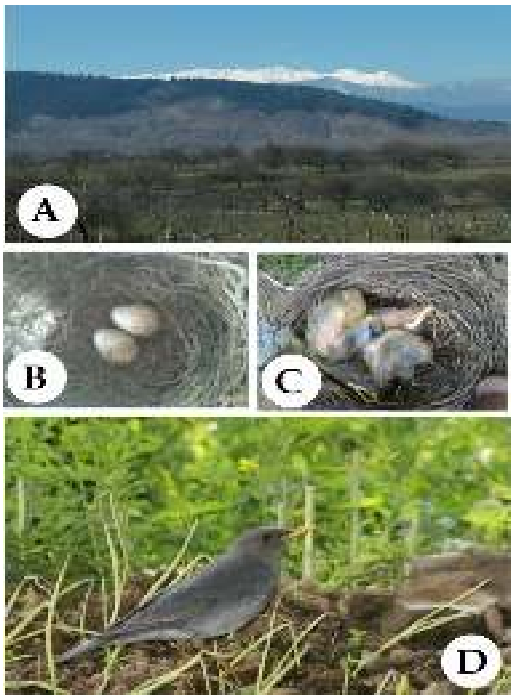

Fig. 1. Breeding aspects of Tickell's thrush (*Turdus unicolor*). A. A landscape view of the Kandi Khas village (Jammu & Kashmir), B. Eggs laid in nest, C. Hatchlings, D. Adult

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