Research Article

Floristic composition, biological spectrum and phenological pattern of vegetation in the subtropical forest of Kotli District, AJK, Pakistan

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Abstract

A comprehensive floristic survey of Kotli District, Azad Jammu and Kashmir was conducted during 2014-2016 to analyse phytodiversity and ecological characteristics of plant resources. The flora comprised of 202 plant species distributed among 71 families and 176 genera. Of these, 6 species were pteridophytes, 1 species was a gymnosperm, 159 species were dicotyledons and 36 species were monocotyledons. Based on species numbers, Asteraceae (23 Spp), Poaceae (20 Spp), Fabaceae (15 Spp), Labiatae (11 Spp), and Euphorbiaceae (07 Spp) were the leading families. Based on biological spectrum, therophytes (73 Spp., 36.14 %) were dominant followed by hemicryptophytes (19.31%), nanophanerophytes (13.37%), geophytes (10.40%), lianas (7.92%), chamaephytes (7.43%) and megaphanerophytes (5.45%). Nanophylls (36.14%), leptophylls (26.73%) and microphylls (26.24%) were the major leaf size classes. Phenological study revealed four different flowering seasons, with April the peak flowering month during which 122 species blossomed. This current study will provide essential baseline information for ecologists, taxonomists and conservationists to carry out more detailed ecological investigations and conservation management planning for the plant resources of this area.

Keywords: Floristic list; Life form; Leaf spectra; Phenology; Kotli

Introduction

The diversity and ecological characteristics of the plants of a particular area depend upon environmental conditions, including altitude and climate. Thus ecological characteristics, such as life form, leaf spectra

and phenological pattern, can be used as indicators of prevailing environmental conditions [1]. Flora refers to all plant life occurring in any particular geographic region at a specific geological period and includes the number of species. In contrast

vegetation refers to the number and distribution of individuals of different plant species in a particular ecosystem [2]. The study of floristic composition is a common taxonomic practice as it provides the baseline information for subsequent, more detailed ecological investigation as well as planning for conservation and sustainable management of the resources of the area [1, 3]. The concept of life form was first introduced by Humboldt with the term Vegetative Form. It ranked next to floristic composition in ecological studies [4] and is the outcome of the adaptation of plants to certain climatic conditions [5]. The life form of a plant reflects the climate of the area and is also useful in comparing the geographical distribution of plant communities. Traditionally it was used in the description of vegetation structure at the community level [6]. The most compact and consistent classification of life form is that of Raunkiaer, which is based on the degree of presence and protection of perennating buds. On the basis of life form, he recognized three different phytoclimates on earth including the therophytic climate in deserts, hemicryptophytic in the temperate zone and phanerophytic in the tropics. Mueller-Dumbois and Ellenberg [7] divided plant species in to five main life form categories based on similarity in their structure and function. Similarly leaf size classes have been used in vegetation description and in order to understand the physiological processes of plants and plant communities [8]. Phenology refers to the study of the timing and causes of repeated biological phenomena with respect to the non-living and living factors and the relationship between the phases of different or the same species [9, 10]. Small variations in climate can have a great effect on the vegetation [11]. For example, vegetation can be characterized by different patterns of climate-induced phenological events [12],

with flowering induced by significant rain in the months of winter and summer, temperature differences, changes in photoperiodism, and drought [13]. In addition to characterizing the vegetation, such studies can also be useful in developing effective management strategies as well as better understanding community level interactions and the vegetation regeneration potential [14].

Some previous evaluation studies have been carried out on the floristic composition and ecological characteristics and phenological patterns of the vegetation of the more remote regions of Pakistan, including Azad Kashmir [1, 3, 15-23]. However, the inaccessibility of the Kotli District means that this area has received very little exploration by plant taxonomists and ecologists, with only a very few published studies [23-28]. Therefore, the present work was conducted in order to report on this areas floristic diversity and its ecological characteristics in order to provide the baseline information for subsequent more detailed ecological investigations and to provide the basis for conservation management of the natural resources of the area.

Materials and methods

Study area, vegetation and climate

Kotli is one of the biodiversity rich areas of Azad Jammu and Kashmir. The district is located 130 km north of Islamabad, the capital of Pakistan ($73^{\circ}47.180' E$ to $74^{\circ}04.613' E$ longitude; $33^{\circ}23.069' N$ to $33^{\circ}29.344' N$ latitude; altitudinal range 450 m to 1900 m). Figure 1 shows the location of the various sampling sites used in this study. The region is mountainous and covers an area of 1860 km². Climatically the area is dry subtropical at the lower altitudes and subtropical humid in the upper reaches with a mean annual precipitation of 1250 mm. Three different forest types have been recognized in the area, namely subtropical

scrub forest, subtropical chir pine forest and subtropical broad leaf humid forest. The highest average monthly precipitation is recorded during the month of July (291 mm), while the lowest average monthly precipitation of 19 mm occurs during the month of November. Temperatures reach a peak during June and July, with average daily minimum temperatures of 23.5°C and 23.7°C respectively and maximum temperatures of 37.1°C and 33.9°C

respectively, while the coldest months are December and January with mean minimum temperatures of 4.8 °C and 3.9 °C respectively and mean maximum temperatures of 20.8°C and 18.6°C respectively. The mean maximum relative humidity of 68.2 % occurs during August and the minimum relative humidity of 33.2% occurs during March (Source: Pakistan Meteorological Department, Lahore).

Figure 1. Shows the location of the various sampling sites used in this study

Field surveys and plant collection

Field surveys were conducted throughout the district during 2014-2016. Plants were collected in triplicate, dried and mounted on herbarium sheets. The plants were identified by using flora of Pakistan [29, 30]. The correct names were obtained from tropicos (www.tropicos.org) and the international

plant name index (www.ipni.org). The identifications were further confirmed at the National Herbarium at the Pakistan Museum of Natural History, Islamabad and the ISI indexed Herbarium of the Department of Botany, QAU. The voucher specimens were deposited in the herbarium of the Department of Botany, PMAS- Arid

Agriculture University Rawalpindi, Pakistan.

Floristic list, life form and leaf spectra

A complete list of plant species was prepared by alphabetical arrangement of the plant families and then in each plant family different plant species were arranged alphabetically. Plants were classified in to different life form and leaf size classes following Raunkiaer (1934), Hussain (1989), Badsha *et al* (2013) and Ali *et al.* (2016) [3, 6, 16, 31]. For quick estimation of leaf size in the field, the diagram of Raunkiaer (1934) was used.

Phenology

The phenological observations of plants were recorded monthly from August 2014 to July 2016. Starting month and duration of strobili development, sporogenesis and flowering was recorded for each plant species. A Microsoft excel sheet was prepared by giving value 1 when the species was found in a flowering or reproductive stage in a particular month and 0 other wise. The sheet was then exported into PC ORD version 5 [32, 33]. Cluster analysis was performed to merge the months in to four different flowering seasons. The percentage of flowering within each month was calculated by applying the formula

$$\text{Flowering \%} = \frac{\text{Number of species found flowering within a particular month}}{\text{Total number of Species}} \times 100$$

Results

The detailed floristic checklist is given in Appendix I which includes family, botanical

name, life form, leaf spectra, seasonality and phenology of plant species.

Appendix I. Floristic composition, Biological Spectrum and phenology of plant species recorded from District Kotli, Azad Jammu & Kashmir

Division/Family	S. No	Species	Seasonality		Life Form	Leaf Spectra	Phenology
			Monsoon	Spring			
A. Pteridophytes							
Dryopteridaceae	1.	<i>Dryopteris stewartii</i> Fraser-Jenk.	+	+	G	Me	May- Sep
Pteridaceae	2.	<i>Adiantum incisum</i> Forssk.	+	+	G	N	Jun-Oct
	3.	<i>Adiantum venustum</i> D. Don	+	-	G	N	Jun-Aug
	4.	<i>Onychium japonicum</i> (Thunb.) Kunze	+	-	G	L	Jun-Sep
	5.	<i>Pteris cretica</i> L.	+	+	G	Mi	Jun-Aug
Selaginellaceae	6.	<i>Selaginella chrysocaulos</i> (Hook. & Grev.) Spring	+	-	G	L	May-Aug
B. Gymnosperms							
Pinaceae	7.	<i>Pinus roxburghii</i> Sargent	+	+	MP	L	Mar-Apr
C. Angiosperms							
a. Monocotyledons							
Araceae	8.	<i>Sauromatum venosum</i> (Aiton) Kunth	+	-	G	Me	Apr-May
Asparagaceae	9.	<i>Asparagus capitatus subsp. gracilis</i> (Royle ex Baker) Browicz	+	-	NP	L	Mar-Sep
	10.	<i>Drimia indica</i> (Roxb.) Jessop	+	-	G	L	Apr-May
Colchicaceae	11.	<i>Gloriosa superba</i> L.	-	+	L	Mi	Jul-Sep
Commelinaceae	12.	<i>Commelina benghalensis</i> L.	+	+	Th	Mi	Aug-Nov
Cyperaceae	13.	<i>Carex sempervirens</i> Vill.	+	+	H	L	Apr-Jul
	14.	<i>Cyperus difformis</i> L.	+	-	G	N	Jul-Sep
	15.	<i>Cyperus niveus</i> Retz.	+	+	G	L	Apr-Aug
	16.	<i>Cyperus rotundus</i> L.	+	-	G	N	Apr-Oct

	17.	<i>Erioscirpus comosus</i> (Nees) Palla	+	+	G	L	Mar-Apr
Dioscoreaceae	18.	<i>Dioscorea bulbifera</i> L.	+	-	L	Me	Jul-Sep
	19.	<i>Dioscorea melanophyma</i> Prain & Burkill	+	-	L	Me	Aug-Oct
Juncaceae	20.	<i>Juncus articulatus</i> L.	+	-	G	L	Apr-May
Liliaceae	21.	<i>Gagea pakistanica</i> Levichev & Ali	-	+	G	L	Mar-Apr
Orchidaceae	22.	<i>Zeuxine strateumatica</i> (L.) Schltr.	+	-	Th	Mi	Mar-Apr
Poaceae	23.	<i>Aristida adscensionis</i> L.	+	-	Th	Mi	Jul-Oct
	24.	<i>Brachiaria eruciformis</i> (Sm.) Griseb.	-	+	Th	L	Jul-Sep
	25.	<i>Brachiaria reptans</i> (L.) C.A. Gardner & C.E. Hubb.	+	+	Th	L	Jun-Nov
	26.	<i>Cenchrus ciliaris</i> L.	-	+	H	L	Feb-Mar
	27.	<i>Chrysopogon aucheri</i> (Boiss.) Stapf	+	+	H	L	Mar-May
	28.	<i>Cynodon dactylon</i> (L.) Pers.	+	+	H	L	Round the year
	29.	<i>Dactyloctenium aegyptium</i> (L.) Willd.		+	Th	Mi	Jul-Oct
	30.	<i>Dichanthium annulatum</i> (Forssk.) Stapf	+	+	H	N	Mar-Oct
	31.	<i>Digitaria setigera</i> Roth	-	+	Th	L	Sep-Oct
	32.	<i>Eleusine indica</i> (L.) Gaertn.	-	+	Th	L	Jun-Aug
	33.	<i>Eragrostis japonica</i> (Thunb.) Trin.	+	-	Th	N	Aug-Oct
	34.	<i>Heteropogon contortus</i> (L.) P. Beauv. ex Roem. & Schult.	+	+	H	N	Sep-Nov
	35.	<i>Imperata cylindrica</i> (L.) P. Beauv.	+	+	G	L	Apr-Aug
	36.	<i>Oplismenus undulatifolius</i> (Ard.) P. Beauv.	-	+	H	L	Aug-Sep
	37.	<i>Poa annua</i> L.	-	+	Th	L	Apr-Sep
	38.	<i>Saccharum spontaneum</i> L.	+	+	Ch	L	Jul-Sep
	39.	<i>Setaria pumila</i> (Poir.) Roem. & Schult.	+	+	Th	N	Jun-Oct
	40.	<i>Setaria viridis</i> (L.) P. Beauv.	+	+	Th	N	Jun-Sep
	41.	<i>Sorghum halepense</i> (L.) Pers.	+	+	G	N	May-Oct
	42.	<i>Themeda anathera</i> (Nees ex Steud.) Hack.	+	+	H	L	Jun-Oct
Smilacaceae	43.	<i>Smilax glaucophylla</i> Klotzsch	+	+	L	Mi	Apr-May
b. Dicotyledons							
Acanthaceae	44.	<i>Barleria cristata</i> L.	+	-	Ch	Mi	Nov-Feb
	45.	<i>Dicliptera bupleuroides</i> Nees	+	+	Th	L	Jun-Oct
	46.	<i>Justicia adhatoda</i> L.	+	+	NP	Me	Jul-Oct
	47.	<i>Justicia peploides</i> (Nees) T. Anderson	+	-	Th	N	Jul-Sep
	48.	<i>Pteracanthus alatus</i> (Wall. ex Nees) Bremek.	+	-	Th	Mi	Jul-Sep
Adoxaceae	49.	<i>Viburnum grandiflorum</i> Wallich ex DC	+	+	NP	Me	Nov-Jun
Aizoaceae	50.	<i>Zaleya pentandra</i> (L.) C. Jeffrey	+	-	Ch	N	Apr-Jul
Amaranthaceae	51.	<i>Achyranthes aspera</i> L.	+	+	Th	N	Mar-Aug
	52.	<i>Alternanthera pungens</i> Kunth	+	-	Th	N	Jun-Oct
	53.	<i>Amaranthus viridis</i> L.	+	+	Th	N	Round the year
	54.	<i>Chenopodium album</i> L.	+	-	Th	N	Jan-Sep
	55.	<i>Pupalia lappacea</i> (L.) Juss.	-	+	Ch	N	Apr-Nov

Anacardiaceae	56.	<i>Cotinus coggygria</i> Scop.	+	+	NP	Mi	Apr-May
Apiaceae	57.	<i>Aegopodium podagrari</i> L.	+	-	Th	Mi	Feb-May
	58.	<i>Bupleurum falcatum</i> L.	+	-	Th	L	Jun-Oct
	59.	<i>Heracleum candicans</i> Wall. ex DC.	+		Ch	Me	Jun-Sep
	60.	<i>Scandix pecten-veneris</i> L.	-	+	Th	L	Mar-May
	61.	<i>Torilis nodosa</i> (L.) Gaertn.	-	+	Th	L	Mar-May
Apocynaceae	62.	<i>Carissa opaca</i> Stapf ex Haines	+	+	NP	Mi	Apr-Jun
	63.	<i>Nerium oleander</i> L.	+	+	NP	Mi	Apr-Sep
	64.	<i>Tylophora hirsuta</i> (Wall.) Wight	+	-	L	Me	Jul-Sep
Araliaceae	65.	<i>Hedera nepalensis</i> K. Koch.	+	+	L	Mi	Jul-Sep
Asteraceae	66.	<i>Achillea millefolium</i> L.	+	+	H	L	Jun-Sep
	67.	<i>Adenostemma lavenia</i> (L.) Kuntze	+	-	Th	Mi	Apr-May
	68.	<i>Anaphalis margaritacea</i> (L.) Benth. and Hook.f.	+	-	G	N	Jul-Sep
	69.	<i>Artemisia scoparia</i> Waldst. & Kit.	+	+	Ch	L	Jul-Nov
	70.	<i>Bidens bipinnata</i> L.	-	+	H	Mi	Dec-Mar
	71.	<i>Bidens biternata</i> (Lour.) Merr. & Sherff	+	+	Th	N	Dec-Mar
	72.	<i>Carpesium cernuum</i> L.	+	+	Th	Mi	Jul-Sep
	73.	<i>Cirsium wallichii</i> DC.	+	+	H	N	Apr-Jun
	74.	<i>Conyza bonariensis</i> (L.) Cronq.	+	+	Th	N	Mar-Jun
	75.	<i>Gerbera gossypina</i> (Royle) Beauv.	+	+	Th	Mi	May-Jul
	76.	<i>Lactuca dissecta</i> D. Don	-	+	H	N	Mar-May
	77.	<i>Launaea procumbens</i> (Roxb.) Ramayya & Rajagopal	+	-	Ch	Me	Mar-Apr
	78.	<i>Myriactis nepalensis</i> Less.	+	-	Th	N	Sep-Oct
	79.	<i>Parthenium hysterophorus</i> L.	+	+	Th	N	Apr-Oct
	80.	<i>Saussurea heteromalla</i> (D. Don) Handel-Mazzetti	+	-	H	Mi	Mar-Aug
	81.	<i>Senecio nudicaulis</i> Buchanan-Hamilton ex D. Don	-	+	G	Mi	Apr-May
	82.	<i>Serratula praealta</i> L.	-	+	H	N	Jul-Sep
	83.	<i>Sonchus arvensis</i> L.	-	+	Th	N	Feb-May
	84.	<i>Sonchus asper</i> (L.) Hill	+	+	Th	Me	Mar-Jun
	85.	<i>Taraxacum officinale</i> F.H. Wigg.	+	+	G	Mi	Feb-Apr
	86.	<i>Tridax procumbens</i> L.	+	+	H	Mi	Sep-Jan
	87.	<i>Vernonia cinerea</i> (L.) Less.	+	+	Th	L	Mar-Jun
	88.	<i>Youngia japonica</i> (L.) DC.	-	+	Th	N	Mar-May
Balsaminaceae	89.	<i>Impatiens edgeworthii</i> Hook. f.	-	+	Th	Mi	Jul-Sep
Berberidaceae	90.	<i>Berberis lycium</i> Royle	+	+	NP	N	Apr-Jun
Boraginaceae	91.	<i>Buglossoides arvensis</i> (L.) I.M. Johnst.	+	+	Th	L	Jan-Apr
	92.	<i>Cynoglossum lanceolatum</i> Forssk.	+	+	H	N	Jun-Sep
	93.	<i>Onosma thomsonii</i> Clarke	+	-	H	Mi	Apr-May
	94.	<i>Trichodesma indicum</i> (L.) Lehm.	+	+	Th	N	Mar-Aug
Brassicaceae	95.	<i>Capsella bursa-pastoris</i> (L.) Medik	-	+	Th	L	Feb-Jun
	96.	<i>Lepidium sativum</i> L.	-	+	H	N	Apr-Jun
	97.	<i>Neslia apiculata</i> Fisch., C.A. Mey. & Ave'-Lall.	-	+	Th	L	Mar-Apr
Campanulaceae	98.	<i>Campanula pallida</i> Wall.	+	-	Th	N	Apr-Jul
Caprifoliaceae	99.	<i>Lonicera quinquelocularis</i> Hardwicke	+	+	NP	Me	Mar-Jul
Caryophyllaceae	100.	<i>Arenaria neelgherrensis</i> Wight & Arn.	+	-	Th	L	Mar-Aug

	101.	<i>Silene conoidea</i> L.	-	+	Th	N	Mar-May
	102.	<i>Stellaria media</i> (L.) Vill.	-	+	Th	L	Jan-Apr
Celastraceae	103.	<i>Maytenus royleana</i> (Wall. ex M.A. Lawson) Cufod.	+	+	NP	N	Feb-Apr
Convolvulaceae	104.	<i>Evolvulus alsinoides</i> (L.) L.	+	-	Ch	N	Feb-Oct
	105.	<i>Ipomoea eriocarpa</i> R.Br.	+	-	L	Mi	Jul-Oct
	106.	<i>Ipomoea hederacea</i> Jacq.	+	-	L	Mi	Sep-Oct
	107.	<i>Ipomoea pestigridis</i> L.	+	-	L	Mi	Aug-Oct
Elaeagnaceae	108.	<i>Elaeagnus parvifolia</i> Wall. ex Royle	+	+	NP	Mi	May-Jun
Euphorbiaceae	109.	<i>Mallotus philippensis</i> (Lamk.) Mull. Arg.	+	+	MP	Me	Mar-May
	110.	<i>Euphorbia esula</i> L.	+	+	H	N	May-Aug
	111.	<i>Euphorbia helioscopia</i> L.	-	+	Th	N	Jan-Apr
	112.	<i>Euphorbia hirta</i> L.	+	+	Th	N	Jun-Dec
	113.	<i>Euphorbia indica</i> Lam.	+	+	Th	N	Jun-Sep
	114.	<i>Euphorbia prolifera</i> Buch.-Ham. ex D. Don	+	-	H	L	Mar-Jun
	115.	<i>Euphorbia prostrata</i> Ait.	+	-	H	L	Mar-Dec
Fabaceae	116.	<i>Acacia modesta</i> Wall.	+	+	MP	L	Mar-May
	117.	<i>Alysicarpus bupleurifolius</i> (L.) DC.	+	-	Th	N	Sep-Oct
	118.	<i>Argyrolobium roseum</i> Jaub.	+	+	Th	N	Apr-Aug
	119.	<i>Astragalus psilocentros</i> Fisch.	+	+	NP	L	Mar-May
	120.	<i>Astragalus leucocephalus</i> Grah. ex Benth.	-	+	Ch	L	Mar-Jul
	121.	<i>Butea monosperma</i> (Lam.) Taubert	+	+	MP	Me	Mar-May
	122.	<i>Indigofera heterantha</i> Wall. ex Brandis	+	+	NP	L	Apr-May
	123.	<i>Indigofera linifolia</i> (L.f.) Retz.	+	-	Ch	L	May-Aug
	124.	<i>Lespedeza juncea</i> var. <i>sericea</i> F.B. Forbes & Hemsl.	+	+	Th	L	Jun-Oct
	125.	<i>Rhynchosia pseudo-cajan</i> Camb.	+	+	NP	N	May-Jun
	126.	<i>Lotus corniculatus</i> L.	+	-	H	L	Mar-Apr
	127.	<i>Medicago polymorpha</i> L.	+	+	Th	N	Round the year
	128.	<i>Melilotus indica</i> (L.) All.	+	+	Th	L	Mar-May
	129.	<i>Trifolium repens</i> L.	+	-	H	N	Mar-Apr
	130.	<i>Vicia sativa</i> L.	-	+	L	L	May-Aug
Fagaceae	131.	<i>Quercus incana</i> W. Bartram	+	+	MP	Me	Apr-May
Flacourtiaceae	132.	<i>Flacourtia indica</i> (Burm. f.) Merrill.	+	+	MP	Mi	Mar-Apr
Gentianaceae	133.	<i>Gentianodes decemfida</i> (Ham.) Omer, Ali & Qaiser	-	+	H	N	Feb-Mar
	134.	<i>Swertia petiolata</i> D. Don	+	-	Th	Mi	Jul-Nov
Geraniaceae	135.	<i>Erodium cicutarium</i> (L.) L'Hér. ex Aiton	-	+	Th	L	Mar-Apr
	136.	<i>Geranium nepalense</i> Sweet	+	+	H	Mi	Apr-Sep
	137.	<i>Geranium ocellatum</i> Camb.	-	+	Th	Mi	Mar-Apr
	138.	<i>Geranium rotundifolium</i> L.	+	+	Th	N	Mar-Apr
Hypericaceae	139.	<i>Hypericum oblongifolium</i> Choisy	+	+	NP	Mi	Mar-Aug
	140.	<i>Hypericum perforatum</i> L.	+	-	Ch	N	Jun-Sep
Lamiaceae	141.	<i>Ajuga bracteosa</i> Wallich ex Benth.	+	+	Th	Mi	Mar-Dec
	142.	<i>Ajuga parviflora</i> Benth.	+	+	Th	Mi	Mar-Jun
	143.	<i>Anisomeles indica</i> (L.) Kuntze	+	-	H	Mi	Apr-Sep
	144.	<i>Calamintha umbrosa</i> (M. Bieb.)	+	-	H	N	Apr-Jul

	145.	Fisch. & C.A. Mey.					
	146.	<i>Colebrookea oppositifolia</i> Smith.	+	+	NP	Me	Jan-Apr
	147.	<i>Isodon rugosus</i> (Wall. ex Benth.) Codd	+	+	NP	L	Mar-Oct
	148.	<i>Micromeria biflora</i> (Buch.-Ham. ex D. Don) Benth.	+	+	Th	L	Apr-Oct
	149.	<i>Otostegia limbata</i> (Bth.) Bioss.	+	+	NP	L	Apr-Aug
	150.	<i>Origanum vulgare</i> L.	+	+	H	N	Jul-Oct
	151.	<i>Salvia mocroftiana</i> Wall. ex Benth.	-	+	Ch	Me	Apr-Jun
	152.	<i>Salvia plebeia</i> R.Br.	+	-	Ch	Mi	Mar-Jun
Loranthaceae	153.	<i>Loranthus pulverulentus</i> Wall.	+	+	NP	Me	Dec-Apr
Lythraceae	154.	<i>Punica granatum</i> L.	+	+	NP	N	Apr-Jul
	155.	<i>Woodfordia fruticosa</i> (L.) Kurz	+	+	NP	N	Mar-May
Malvaceae	156.	<i>Malva parviflora</i> L.	+	-	Th	Mi	Dec-Mar
	157.	<i>Malvastrum coromandelianum</i> (L.) Garcke	+	+	Th	N	Mar-Sep
	158.	<i>Sida cordata</i> (Burm.f.) Borss. var. <i>cordata</i>	-	+	Th	L	Round the year
	159.	<i>Sida cordifolia</i> L.	+	+	Th	N	Apr-Aug
	160.	<i>Triumfetta pentandra</i> A.Rich.	+	-	Th	Mi	Jul-Sep
Menispermaceae	161.	<i>Cissampelos pareira</i> var. <i>hirsuta</i> (Buch.-Ham. ex DC.) Forman	+	-	L	Mi	Jun-Sep
Nyctaginaceae	162.	<i>Boerhavia procumbens</i> Banks ex Roxb.	+	+	H	N	Round the year
Oleaceae	163.	<i>Olea ferruginea</i> Royle	+	+	MP	N	Apr-May
	164.	<i>Jasminum officinale</i> L.	+	+	L	N	May-Jul
Onagraceae	165.	<i>Oenothera rosea</i> L. Herit. ex Ait.	+	+	H	N	Apr-Sep
Oxalidaceae	166.	<i>Oxalis corniculata</i> L.	+	+	H	N	Mar-Dec
Papaveraceae	167.	<i>Fumaria indica</i> Pugsley	-	+	Th	N	Feb-Jun
Phyllanthaceae	168.	<i>Phyllanthus urinaria</i> L.	+	-	Th	L	Aug-Sep
Plantaginaceae	169.	<i>Plantago lanceolata</i> L.	+	+	H	N	Mar-Aug
Polygalaceae	170.	<i>Polygala abyssinica</i> R. Br. ex Fresen.	+	-	Th	Mi	Apr-Sep
Polygonaceae	171.	<i>Polygonum aviculare</i> L.	+	+	H	L	Mar-Sep
	172.	<i>Polygonum plebeium</i> R. Br.	-	+	Th	L	Feb-Sep
	173.	<i>Rumex dentatus</i> L.	-	+	G	Me	Mar-Apr
	174.	<i>Rumex hastatus</i> D. Don	-	+	Ch	N	Mar-Aug
Primulaceae	175.	<i>Anagallis arvensis</i> L.	-	+	Th	N	Feb-Mar
	176.	<i>Androsace umbellata</i> (Lour.) Merrill	+	+	H	N	Mar-Apr
	177.	<i>Myrsine africana</i> L.	+	+	NP	N	Mar-May
Ranunculaceae	178.	<i>Clematis grata</i> Wall.	+	+	L	N	Apr-Aug
	179.	<i>Ranunculus laetus</i> Wall. ex Royle	+	+	H	Mi	Apr-Aug
	180.	<i>Ranunculus muricatus</i> L.	-	+	Th	Mi	Mar-May
	181.	<i>Thalictrum foliolosum</i> DC.	+	-	Ch	N	Jul-Sep
Rhamnaceae	182.	<i>Ziziphus mauritiana</i> var. <i>spontanea</i> (Edgew.) R.R. Stewart ex Qaiser & Nazim.	+	+	MP	N	Jun-Sep
Rosaceae	183.	<i>Duchesnea indica</i> (Andrews) Teschem.	+	+	H	N	Mar-May
	184.	<i>Geum canadense</i> Jacq.	+	+	H	Mi	Jun-Sep
	185.	<i>Prunus persica</i> (L.) Batsch	+	+	MP	Mi	Feb-Apr
	186.	<i>Rosa brunonii</i> Lindl.	+	+	L	N	Apr-Jun
	187.	<i>Rubus fruticosus</i> L.	+	+	NP	Mi	Apr-Oct
Rubiaceae	188.	<i>Galium aparine</i> L.	+	+	Th	L	Mar-May

	189.	<i>Rubia cordifolia</i> L.	+	+	L	N	Jun-Nov
Rutaceae	190.	<i>Zanthoxylum armatum</i> DC.	+	+	NP	N	Mar-Apr
Salicaceae	191.	<i>Casearia tomentosa</i> Roxb.	+	+	MP	Me	Mar-Jun
	192.	<i>Salix acomophylla</i> Boiss.	+	+	MP	Mi	Oct-Mar
Sapindaceae	193.	<i>Dodonaea viscosa</i> (L.)	+	+	NP	N	Jan-Mar
Saxifragaceae	194.	<i>Bergenia ciliata</i> Sternb.	+	+	H	Me	Mar-Jul
Scrophulariaceae	195.	<i>Verbascum thapsus</i> L.	-	+	Th	Me	Mar-Sep
Simaroubaceae	196.	<i>Ailanthus altissima</i> (Mill.) Swingle	+	+	NP	Mi	Jul-Aug
Solanaceae	197.	<i>Physalis divaricata</i> D. Don	+	-	Th	Mi	Aug-Oct
	198.	<i>Solanum nigrum</i> L.	+	+	Th	Mi	Round the year
	199.	<i>Solanum surattense</i> Burm. f.	-	+	H	Me	Mar-Sep
Urticaceae	200.	<i>Debregeasia salicifolia</i> (D. Don) Rendle	+	+	NP	Mi	Mar-Jun
Verbenaceae	201.	<i>Lantana camara</i> L.	+	+	NP	Mi	Mar-Oct
Violaceae	202.	<i>Viola canescens</i> Wall.ex Roxb.	+	+	G	N	Mar-Aug
Vitaceae	203.	<i>Cissus carnosa</i> Lam.	+	-	L	Mi	Jul-Sep

Floristic composition

Floristic composition

The flora of District Kotli consisted of 202 species of 71 families and 176 genera (Table 1). Of these, there were 159 species of dicotyledons, 36 species of monocotyledons, one species of gymnosperm and six species of pteridophytes. *Pinus roxburghii* was the only gymnosperm present in the investigated area. On the basis of growth form, 11 trees, 28 shrubs and 163 herbs comprised the 5.45%, 13.86% and 80.69% of the floral diversity of the investigated area (Table 2, Figure 2).

Asteraceae (23 Spp.) and Poaceae (20 Spp.) were the dominant families followed by Fabaceae (15 Spp.), Labiatae (11 Spp.), and Euphorbiaceae (7 Spp.). Acanthaceae, Amaranthaceae, Apiaceae, Cyperaceae, Malvaceae and Rosaceae had 5 species each. Boraginaceae, Convolvulaceae, Geraniaceae, Polygonaceae, Pteridaceae and Ranunculaceae had 4 species each (Table 3, Figure 3). Each of the Apocynaceae, Brassicaceae, Caryophyllaceae, Primulaceae and Solanaceae had 3 species. The remaining 49 families had two or fewer species (Table 3).

Table 1. Taxonomic distribution of recorded plant species from District Kotli

Taxa	Taxonomic distribution				Total
	Pteridophytes	Gymnosperms	Angiosperms		
			Monocotyledons		
Families	3 (4.23%)	1(1.41%)	11 (15.49%)	56 (78.87%)	71
Genera	5 (2.84%)	1 (0.57%)	31 (17.61%)	139 (78.98%)	176
Species	6 (2.97%)	1 (0.50%)	36 (17.82%)	159 (78.71%)	202

Table 2. Summary of ecological characteristics of the flora of District Kotli

S. No	Ecological Characteristics	No	Percentage
Flora			
I.	Total Species	202	-
II.	Family	71	-
III.	Genera	176	-
Habit			
I.	Tree	11	5.45
II.	Shrub	28	13.86
III.	Herb	163	80.69
Seasonality/Aspect			
IV.	Monsoon	162	52.43
V.	Spring	147	47.57
Life Form Spectra			
I.	Megaphanerophyte	11	5.45
II.	Nanophanerophyte	27	13.37
III.	Therophyte	73	36.14
IV.	Hemicryptophyte	39	19.31
V.	Geophyte	21	10.40
VI.	Chamaephyte	15	7.43
VII.	Lianas	16	7.92
Leaf Spectra			
I.	Leptophyll	54	26.73
II.	Nanophyll	73	36.14
III.	Microphyll	53	26.24
IV.	Mesophyll	22	10.89

Table 3. Number of species in recorded plant families from District Kotli

S.No	Family	No. of Species	S.No	Family	No. of Species
1.	Asteraceae	23	37.	Berberidaceae	01
2.	Poaceae	20	38.	Campanulaceae	01
3.	Fabaceae	15	39.	Caprifoliaceae	01
4.	Labiatae	11	40.	Celastraceae	01
5.	Euphorbiaceae	07	41.	Colchicaceae	01
6.	Acanthaceae	05	42.	Commelinaceae	01
7.	Amaranthaceae	05	43.	Dryopteridaceae	01
8.	Apiaceae	05	44.	Elaeagnaceae	01
9.	Cyperaceae	05	45.	Fagaceae	01
10.	Malvaceae	05	46.	Flacourtiaceae	01
11.	Rosaceae	05	47.	Juncaceae	01
12.	Boraginaceae	04	48.	Liliaceae	01
13.	Convolvulaceae	04	49.	Loranthaceae	01
14.	Geraniaceae	04	50.	Menispermaceae	01
15.	Polygonaceae	04	51.	Nyctaginaceae	01

16.	Pteridaceae	04	52.	Onagraceae	01
17.	Ranunculaceae	04	53.	Orchidaceae	01
18.	Apocynaceae	03	54.	Oxalidaceae	01
19.	Brassicaceae	03	55.	Papaveraceae	01
20.	Caryophyllaceae	03	56.	Phyllanthaceae	01
21.	Primulaceae	03	57.	Pinaceae	01
22.	Solanaceae	03	58.	Plantaginaceae	01
23.	Asparagaceae	02	59.	Polygalaceae	01
24.	Dioscoreaceae	02	60.	Rhamnaceae	01
25.	Gentianaceae	02	61.	Rutaceae	01
26.	Hypericaceae	02	62.	Sapindaceae	01
27.	Lythraceae	02	63.	Saxifragaceae	01
28.	Oleaceae	02	64.	Scrophulariaceae	01
29.	Rubiaceae	02	65.	Selaginellaceae	01
30.	Salicaceae	02	66.	Simaroubaceae	01
31.	Adoxaceae	01	67.	Smilacaceae	01
32.	Aizoaceae	01	68.	Urticaceae	01
33.	Anacardiaceae	01	69.	Verbenaceae	01
34.	Araceae	01	70.	Violaceae	01
35.	Araliaceae	01	71.	Vitaceae	01
36.	Balsaminaceae	01

Figure 2. Percent share of various habit forms of vegetation of the District Kotli

Life form and its seasonal variation

The flora of the study area was overall dominated by therophytes (73 Spp., 36.14 %), followed by hemicryptophytes (39 Spp., 19.31%), nanophanerophytes (27 Spp., 13.37%), geophytes (21 Spp., 10.40%),

lianas (16 Spp., 7.92%), chamaephytes (15 Spp., 7.43%), and megaphanerophytes (11 Spp., 5.45%) (Table 2).

Seasonal variation in life form was also reflected in the data. In spring there were 36.05% (53 Spp) therophytes, 21.09% (31

Spp.) hemicryptophytes, 17.69% (26 Spp.) nanophanerophytes, 8.16% (12 Spp.) geophytes, 7.48% (11 Spp.) megaphanerophytes, 5.44% (8 Spp.) lianas, and 4.08% (6 Spp.) chamaephytes recorded. While in the monsoon season, there were 30.86% (50 Spp) therophytes, 19.14% (31 Spp.) hemicryptophytes, 16.67% (27 Spp.)

nanophanerophytes, 11.11% (18 Spp.) geophytes, 8.64% (14 Spp.) lianas, 6.79% (11 Spp.) megaphanerophytes, and 6.79% (11 Spp.) chamaephytes recorded (Table 4 Figure 4). The percentage of therophytes was high during spring as compared to monsoon season.

Table 4. Seasonal variation in life form and leaf size spectra of plants of District Kotli

Parameters	Season/Aspect			
	Monsoon		Spring	
	No	%	No	%
A. Life Form				
Megaphanerophyte	11	6.79	11	7.48
Nanophanerophyte	27	16.67	26	17.69
Therophyte	50	30.86	53	36.05
Hemicryptophyte	31	19.14	31	21.09
Geophyte	18	11.11	12	8.16
Chamaephyte	11	6.79	06	4.08
Lianas	14	8.64	08	5.44
Total	162		147	
B. Leaf Spectra				
Leptophyll	37	22.84	42	28.57
Nanophyll	61	37.65	56	38.10
Microphyll	46	28.40	33	22.45
Mesophyll	18	11.11	16	10.88
Total	162		147

Figure 3. Top 17 plant families represented by highest number of species in the study area which share 64.36% of the total species

Figure 4. Graphical representation of seasonal variation in life form of District Kotli

Leaf spectra and its seasonal variation

The flora of study area was overall dominated by nanophylls (73 Spp; 36.14%) followed by leptophylls (54 Spp.; 26.73%) and microphylls (53 Spp.; 26.24%). While mesophylls (22 Spp.; 10.89%) were much lower in number (Table 2). Seasonal variation in leaf spectra shows that during the spring season there were 38.10% (56

Spp.) nanophylls, 28.57% (42 Spp.) leptophylls, 22.45% (33 Spp.) microphylls and 10.88% (16 Spp.) mesophylls. While in the monsoon season there were 37.65% (61 Spp.) nanophylls, 28.40% (46 Spp.) microphylls, 22.84% (37 Spp.) leptophylls and 11.11% (18 Spp.) mesophylls recorded (Table 4, Figure 5).

Figure 5. Graphical representation of seasonal variation in leaf spectra

Phenological behaviour

Four different flowering seasons could be observed in the investigated region (Figure 6). The first flowering season stretches from March to May (spring) during which 52.81 % of species were found in flowering. The second season (summer) stretches from June to August during which 53.80 % of species were found in bloom. The third season (autumn) occurs from September to October during which 34.40% plants were in flower. The fourth season (winter) occurs from November to February during which only 10.40% species were found in flower.

The flowering trend decreased from spring into the winter season. It was observed that the majority of plant species (122 Spp.;

60.40%) were found in flower during April followed by May (111 Spp.; 54.95%) and July (111 Spp.; 54.95%), and then August (108 Spp.; 53.47%). Whereas the least number of species were found in flower during the months of December (17 Spp. 8.42%) and January (18 Spp.; 8.91%). The maximum number of plant species initiated flowering during the month of March (60 spp. 29.70%) followed by April (43 Spp.: 21.29%), June (25 Spp. 12.38%) and July (23 Spp.; 11.39%). (Table 5, Figure 7). Peak flowering in trees, shrubs and herbs occurred during April, while among the grasses flowering was at a peak during August. Ferns for the most part reproduced during June-August.

Table 5. Average monthly phenological findings for the flora of Kotli, AJK

Months	Species found in flowering		Species started flowering	
	No	%	No	%
January	18	8.91	12	5.94
February	28	13.86	11	5.45
March	87	43.07	60	29.70
April	122	60.40	43	21.29
May	111	54.95	10	4.95
June	107	52.97	25	12.38
July	111	54.95	23	11.39
August	108	53.47	07	3.47
September	89	44.06	06	2.97
October	50	24.75	01	0.50
November	21	10.40	01	0.50
December	17	8.42	03	1.49

Figure 6. Wards cluster analysis dendrogram based on the phenological pattern of the vascular flora of Kotli District, AJ&K

Figure 7. Seasonal variation in phenological pattern of vascular flora of Kotli District, AJ&K

Discussion

Floristic composition

Floristic diversity is the total number of plant species of an area and can be affected by anthropogenic interactions, grazing, soil erosion and natural disasters such as earthquakes that may cause landslides. The floristic check list of District Kotli is composed of 202 species that were distributed into 71 families and 176 genera. Asteraceae, Poaceae, Fabaceae, Labiatae are

the leading families in the area on the basis of the number of species, but on the basis of importance value, Poaceae and Pinaceae are the dominant families both during surveys during the monsoon and the spring seasons. Stewart also reported these families to be well represented in Pakistan and Azad Kashmir [34], as did Ilyas and his co-workers from Kablul valley of Swat [35], Tanvir and his coworkers from Bagh district of Azad Kashmir [36] and Amjad and his co-

workers from Nikyal valley of Azad Kashmir [28]. Some other works also report similar findings in other regions of Pakistan [1, 15, 27, 37] and abroad [38, 39]. Our results are consistently supported by them as Poaceae and Asteraceae have emerged as the common families in the investigated area. Both these two families have also been reported to contain more species as compared to other families by Ali and his co-workers from the Chilas valley, Swat [16] and Hussain and Chaudhary from the Samhani valley, Azad Kashmir [40]. The members of the Poaceae and Asteraceae are found in a diverse range of habitats due to their broad ecological amplitude.

Many species have been floristically listed from District Kolti, however most of them have a limited distribution on a quantitative basis due to their restricted life cycle. High species number is the indication of high species diversity and richness in the area. Qualitative features like floristic composition alone cannot provide the true picture of subtropical zone of Kotli district therefore the quantitative parameters and ecological behavior of vegetation resources like habit, phenology, life form and leaf spectra and ethno ecological potential should also be studied for a full description of the plant resources of this area.

Life form

The biological spectrum of the vegetation can be developed by classifying all the species of higher plants in to life form classes and expressing their ratio both in numbers as well as percentages. The biological spectrum provides an indication of the existing climatic condition and can be helpful in comparing widely separated geographical communities. However the proportion of various life forms within the biological spectrum may be changed due to biotic influences such as deforestation, overgrazing, agricultural practices and trampling etc [3, 23, 41].

The life form of the flora and different plant communities in the study area indicates that therophytes are dominant followed by hemicryptophytes both in the spring and monsoon seasons.

Geophytes, nanophanerophyte, lianas, chamaephytes and megaphanerophytes are the next most important on the basis of the number of species. Therophytes are indicators of subtropical and desert climates while hemicryptophytes are more characteristic of cool and humid conditions [18, 23, 28, 42, 43]. The reported life forms reflects the climatic conditions in the study area with changes occurring from the dry subtropical zone to the humid zone with increasing altitude. These results are in line with Sher and his co-worker who reported the dominance of therophytes in subtropical forest in Chagharzai Bunir [44]. Similarly Ali and his coworker reported the dominance of therophytes from the Chail valley in Swat which is also consistent with our findings [16].

The dominance of therophytes over other life forms in the study area can be interpreted as not only a response to the harsh climate but also to anthropogenic pressures on the flora. The other possible reason could be the availability of moisture in the form of rain. Qureshi and his coworker also reported similar findings from Koont [45, 46]. Our results are also consistent with Costa and his coworkers who reported the dominance of therophytes in south eastern Brazil [47]. Our findings are also supported by Kar and his coworkers who reported the dominance of therophytes from grassland in Odisha, India [48]. However, the dominance of therophytes in almost all zones might also be due to habitat disturbance, deforestation, overgrazing and trampling [44, 49-51].

The percentage of therophytes was high in spring as compared to the monsoon season because in spring season there is always a

flush of annual plants [18]. Hussain and his co-workers reported that in Girbanr and Dabargai Hills therophytes were dominant due to unfavorable habitat conditions [52]. Most researchers reported similar conclusions [48, 53, 28] from certain other parts of world and our findings in this regard are supported by them.

Kotli is warm at lower altitudes and climatically cool at higher altitudes; this was reflected in the number of hemicryptophytes which increased in the sub-tropical broad leaf humid forest association (1550m-1897m). Saxena and his coworkers considered hemicryptophytes as the dominant life form in temperate or humid conditions and support our results [54].

The final life form class, the phanerophytes, decreased with altitude in the study area. Phanerophytes are best represented as a class in open physiognomies [55]. The climate of the Kotli District is suitable to support the growth of phanerophytes but severe anthropogenic pressures have greatly decreased their dominance in the study area.

Leaf spectra

The leaf size spectrum is helpful in understanding the physiological processes of plant species. The current study reveals the dominance of nanophylls followed by leptophylls in the study area. Badshah and his coworkers reported nanophylly as the dominant leaf size in Waziristan [21]. Similarly Sher & Khan reported high percentages of leptophylls and nanophylls from the Chagarzai area [44]. Our findings are thus in line with these previous studies. Malik and his co-workers reported the dominance of microphylls in other areas of Azad Jammu and Kashmir [18, 23]. The disagreement with their results is due to differences in climatic conditions and altitude. The leaf size along with the habit and root system can be helpful in determining the climatic zone of a study area. Small sized leaves are an indicator of

dry and xeric conditions [18, 23, 25, 28]. This is because in dry areas and particularly in mountains, the soil has a low nutrient and water content making it difficult for plant roots to absorb moisture and nutrient and thus encouraging the dominance of nanophyllous and leptophyllous vegetation, as was observed in our study area. The ratio of different leaf size classes changes during different seasons in the study area due to the presence of annuals and rhizomatous geophytes. Malik and his coworkers and Batalha and Martins also reported that leaf size is directly related to the soil conditions and the availability of moisture [18, 23, 55]. Leaf size alone could not be used to identify the climate or specific zone of the investigated area; root system and the habit of plants might play an equal role.

Phenology

According to the International Biological Program (IBP), phenology refers to “the study of the timing and causes of repeated biological phenomena with respect to non-living and living factors and the relationship between the phases of different or the same species” [9, 10]. Small variations in climate can have a great effect on vegetation [11], while vegetation can be characterized by different patterns of phenological events [12].

Flowering can be induced by a change in a variety of climatic factors such as significant rain in the months of winter and summer, temperature differences, changes in photoperiodism, and drought both at community or species level [56, 57]. In the investigated area, the majority of plant species initiated flowering at the end of March which may be due to the onset of warmer weather [58]. Flower initiation and development and other growth activities are generally at their peak during rainy and early spring season in Caatinga [59], which is in line with our findings.

In the investigated area, the peak time for flowering was April-September. Less flowering was observed from November to February. Kakim and Yadava [60] similarly reported that in the sub-tropical forests of Manipur India flowering occurred during the months of April to September, while Jadeja and Nakkar [11] reported that in Gujrat India maximum flowering occurred in the months of January and February. This difference might be due to climatic effects and differences in altitude and latitude. Our results are also in contrast with Malik and Malik who reported that maximum flowering occurred during July and August in the Ganga Chotti and Beddori hills of Azad Kashmir, which again may be due to a higher altitude, rainfall and saturation in their study area [61].

With a change in climatic conditions, the flowering period of plant species can be affected. A change in temperature can cause a shift in the reproductive phenology of plant species [62]. An increase in temperature advances the phenology of many plant species [63]. In the investigated area many herbaceous species were in flowering condition in the month of March when there was a slight increase in temperature otherwise flowering occurred in the month of April. So our findings are in accordance with previous reports.

Nautiyal and his coworkers reported that flowering in many plant species of the alpine zone occurred after snow fall [64]. In the investigated area flowering started in the month of March for the majority of the woody plant species so our findings in this regard are in accordance with this study. The majority of tree species were in flower during April which is also in accordance with Dar and Malik, who reported maximum flowering among the tree species during April while working in Lawat district, Azad Kashmir [65].

Golluscio and his coworkers observed that grasses, members of Poaceae, had the majority of their phenological activities during the autumn and winter seasons as compared to the non-grass plant species which had different starting and ending dates of vegetative and reproductive growth [66]. In our case too most of the grasses bloomed in autumn and early winter so our finding is in line with this.

Changes in climatic factors such as temperature and humidity can produce changes in the phenology of the plant species. Similarly urbanization is a major factor of global climatic change. There was an uneven fluctuation in temperature throughout the year in urban areas of Canada which has direct impact on vegetation phenology [67]. Similarly in our case, rise in temperature from March to May favored the flowering of plants and further increase in temperature caused onset and maturation of fruits from June – September. Biotic factors can also have a profound influence on the plant phenological events [68]. This has been observed in our case as temperatures generally decreased during October and November to promote leaf fall and in June and July the grazing pressure increased which facilitated the second dormant phase. The grazing of annual herbaceous plant species prior to flowering will restrict the population because in this case seeds will be the only propagation source for regeneration and survival. Therefore it is essential to coordinate the grazing period with the flowering cycle in order to promote sustainable use of plant resources.

Conclusion

The district Kotli is rich in biodiversity. The high percentage of therophyte and nanophyllous species are due to the subtropical climate of area. The high proportion of therophyte also reflect that area is under sever biotic pressure due to

deforestation and overgrazing Majority of species are becoming endangered in the area, therefore immediate conservations measures are needed to preserve the endangered flora. The grazing of annual herbaceous plant species prior to flowering will restrict the population because in this case seeds will be the only propagation source for regeneration and survival. Therefore it is essential to coordinate the grazing period with the flowering cycle in order to promote sustainable use of plant resources.

Authors' contributions

Conceived and designed the experiments: M Arshad, R Qureshi & SN Mirza, Methodology: MS Amjad & M Arshad, Performed the experiments: MS Amjad, Analyzed the data: MS Amjed & S Page, Contributed reagents/ materials/ analysis tools: MS Amjed & M Arshad, Wrote the paper: MS Amjad & S Page.

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