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DIVERSITY IN WILD OLIVE (*OLEA EUROPAEA* SUBSP. *CUSPIDATA*) COMMUNITIES ALONG ELEVATIONAL GRADIENT

FAAKEHA ISLAM[1], MANSOOR HAMEED[1*], MUHAMMAD SHAHBAZ[1] AND MUHAMMAD ASHFAQ WAHID[2]

[1]Department of Botany, University of Agriculture Faisalabad, Faisalabad 38040, Pakistan
[2]Department of Agronomy, University of Agriculture Faisalabad, Faisalabad 38040, Pakistan
**Corresponding author's email: hameedmansoor@yahoo.com*

Abstract

The Potohar Plateau and Salt Range are considered the lower hills of the Himalayan region. The Potohar region is extraordinarily rich in habitat and floral diversity that is included in the sub-tropical open scrub forests. *Olea europaea* (wild olive, locally known as kao) is an important stress tolerant fuel and fodder species. Different ecozones were selected to evaluate ecological traits of ecotypes of these species. Objective of the current study was to investigate factors that affect distribution range of wild olive plants in the Punjab. The maximum and the minimum relative densities of *O. europaea* subsp. *cuspidata* were in Kanhatti (30.81) and Sodhi (1.4) from Khushab district. The maximum and the minimum relative frequencies were Khabeki (18.18) and Uchala Mor 2 (9.09) from district Khushab. The maximum and the minimum relative cover were in sites Uchala Mor (48.19) and Kanhatti road (14.89) in district Khushab. The maximum and the minimum importance values were of Kanhatti (72.42), in district Khushab and Domeli (31.8) in district Jhelum respectively. It was concluded that distributional range varied greatly along elevation gradient. Higher elevation suited distribution of wild olive.

Key words: Wild olive, Ecology, Poothar region, Distribution, Open scrub forest.

Introduction

A minor change in elevation changes the structure and composition of communities in mountainous regions in entirety. The environment of the Salt Range is semi-arid that is dominated by small trees, shrubs and grasses (Fatima *et al*., 2021). The dominant trees of the region were *Olea europaea* subsp. *cuspidata* (Wall. & G. Don) Cif (wild olive), *Senegalia modesta* (Wall.) P. J. H. Hurter and *Butea monosperma* (Lam.) Taub. The dominant shrubs were *Buxus papillosa* C. K. Schneid., *Dodonaea viscosa* Jacq. subsp. *augustifolia* (L. f.) J. G. West, *Justicia adhatoda* L., *Gymnosporia royleana* Wall. ex M. A. Lawson and *Ziziphus nummularia* (Burm. f.) Wight & Arn. Among grasses, *Aeluropus lagopoides* (L.) Trin. ex Thwaites, *Aristida mutabilis* Trin. & Rupr., *Chrysopogon serrulatus* Trin., *Cynodon dactylon* (L.) Pers., *Dichanthium foveolatum* (Delile) Roberty, *Eulaliopsis binata* (Retz.) C. E. Hubb., *Heteropogon contortus* (L.) P. Beauv. ex Roem. & Schult., *Pennisetum orientale* Rich., *Saccharum griffithii* Munro ex Boiss and *Ochthochloa compressa* (Forssk.) Hilu were the dominant species. *Aerva javanica* (Burm. f.) Juss. ex Schult., *Fagonia indica* Burm. f. and *Otostegia limbata* (Benth.) Boiss. were the important herbs, while dominant sedges included *Cyperus niveus* Retz., *Erioscirpus comosus* (Wall.) Nees and *Schoenoplectus lacustris* (L.) Palla (Chaudhry *et al*., 2001; Ahmad *et al*., 2008; Nawaz *et al*., 2012). Species such as *Dodonaea viscosa* Jacq. subsp. *augustifolia* (L. f.) J. G. West, *Lantana camara* L., *Parthenium hysterophorus* L., *Prosopis glandulosa* Torr.and *P. juliflora* (Sw.) DC. were the invaders (Hameed *et al*., 2012).

Olea europaea subsp. *cuspidata* (Family: Oleaceae), commonly called as wild olive, African olive, kao, and kahu (Besnard *et al*., 2002), grows as either tree or shrub (Nasir & Rafiq, 1995). A subcontinent native, evergreen, broad leaf tree, wild olive, is distributed in Pakistan in dry and moist temperate regions at 500-2000 m with 800-1200 mm average annual rainfall and 14 to 18°C annual temperature (Hines & Karlyn, 1993). It is a dominant species of Murree hills, Swat, Azad Kashmir, Dir, Chitral, Waziristan, Salt Range and Western Balochistan (Sheikh, 1993; Ahmed *et al*., 2006; Zabihullah *et al*., 2006) and Afghanistan (Abbas *et al*., 2011). Wild olives grow most abundantly near 750m elevation (Yousifzai *et al*., 2010). It is known for its capability of growing in soils unfit for other plants.

Conventionally it is used to treat asthma, rheumatism, toothache, backache, burn and diabetes. It is a useful diuretic, astringent rubefacient and antiseptic (Hashmi *et al*., 2015). Fruit is eaten fresh by the local community (Ahmad *et al*., 2006; Zabihullah *et al*., 2006). About 25-40% of total natural broad leaf forest stem density and 27% of standing stock volume is occupied by *Olea* in Pakistan Northern areas (Sheikh, 1993). These forests have established several important natural communities and for centuries have been providing an extensive range of economic and ecological services to local humanity (Khan, 2012).

Relative density, relative frequency, relative cover and importance value are the most important ecological parameters that change considerably with changes in climate (Shuaib *et al*., 2018). Consequently, this modifies plant community structure and composition, particular species' dominance and structural and functional attributes of local species (Lozano *et al*., 2020). It was hypothesized that soil physicochemical characteristics and climatic conditions might have a significant impact on community structure of wild olive along elevation gradient.

Material and Methods

Olea europaea subsp. *cuspidata* is distributed in Margalla Hills and deciduous, Pine and Scrub forests. Soil samples were collected within a meter of each collected plant sample at a depth of 15 to 20 cm its physicochemical characteristics. Plant samples were collected from Domeli, Kalabagh, Diljabba, Lehri, Kanhatti Garden, Kanhatti Track and Kanhatti Road, Kallar Kahar, Daman-e-Koh,

Sodhi, Uchala Mor, Ahmedabad, Khabeki, Jhungewala, Munara, Chambal and Fort Monroe. Community structure and distribution pattern were recorded by various escorted study tours in Punjab, Pakistan during 2018-2020 as indicated in Figs. 1 and 2.

Meteorological data: Maximum and minimum temperature range and annual rainfall were obtained from the Pakistan Meteorological Station, Islamabad. It is regulated by the Government of Pakistan and maintains all substation records, collaborating with other national organizations.

Soil parameters: To study soil physicochemical characteristics of soil, a sample of soil was collected around a meter of the plant from a depth of 15-20 cm from study sites. A saturated paste of completely dried 200g soil sample was prepared and EC, pH, ionic and moisture contents were examined. Soil pH and ECe were measured by the techniques explained in Handbook No. 60 (USDA Laboratory Staff, 1954) with a portable pH/EC Meter (Model: WTW series InoLab pH/Cond 720, USA). Soil Na, Ca and K ions were assessed in 10-100 mg L^{-1} sample set by flame photometer (Jenway, PFP-7, United Kingdom) and standard curves were prepared. The following formula was used to calculate saturation percentage:

Saturation percentage = Weight of saturated paste – Dry weight of soil

Ecological characteristics: Relative density, frequency and percent cover along with importance value were measured according to the method given by Greig-Smith (1983). Five 200m transect lines were laid in three distant habitats to study vegetation. Five sets of five 5 m x 5 m quadrates were laid alongside each transect line (Fig. 1).

Statistical analysis

The data was subjected to principal component analysis (PCA) using Microsoft Excel workbook (version 10).

Results

Climate: At elevations lower than 700m, Kallar Kahar showed the lowest average maximum temperature (37°C). Kalabagh had the lowest annual rainfall (234mm) but highest average maximum (47°C) and minimum (12°C) temperatures. Diljabba showed the highest annual rainfall (732mm) but the lowest minimum temperature (2°C). At elevations between 700-800m, Daman-e-Koh exhibited the highest annual rainfall (1103mm) but the lowest average maximum (31°C) and minimum temperatures (-2°C). Sodhi, on the other hand, exhibited the lowest rainfall (337mm) but the highest average maximum (42°C) and minimum temperatures (2°C). At elevations higher than 800m, Fort Monroe showed the lowest annual rainfall (246mm) and average maximum (32°C) and minimum temperatures (-1°C). Khabeki showed the highest annual rainfall (600mm) and Chambal Sharif showed the highest average maximum (45°C) and minimum temperatures (33°C) (Table 1).

Soil analysis: At low elevations (<700m), soil sample from Domeli showed the maximum pH (8.1), but the minimum ECe (0.91 dSm^{-1}), saturation percentage (30%) and NO_3^- (2.6 mg kg^{-1}). The soil sample collected from Kalabagh showed the maximum K^+ (349.5 mg kg^{-1}) but the minimum PO_4^{3-}(6.3 mg kg^{-1}). Soil from Diljabba showed the maximum NO_3^- (8.4 mg kg^{-1}) while the minimum organic matter (0.62%), saturation percentage (30%), Ca^{2+} (43.9 mg kg^{-1}) and K^+ (69.2 mg kg^{-1}). Soil from Lehri showed the maximum Ca^{2+} (126.4 mg kg^{-1}) and the minimum pH (7.4) and saturation percentage (30%). The soil sample from Kanhatti track showed the maximum organic matter (1.25%), saturation percentage (38%) and PO_4^{3-} (25 mg kg^{-1}) and the minimum Na^+ (177.8 mg kg^{-1}). Kallar Kahar soil showed the maximum pH (8.1), ECe (29 dS m^{-1}) and Na^+ (3723.4 mg kg^{-1}) and the minimum saturation percentage (30%) (Table 2).

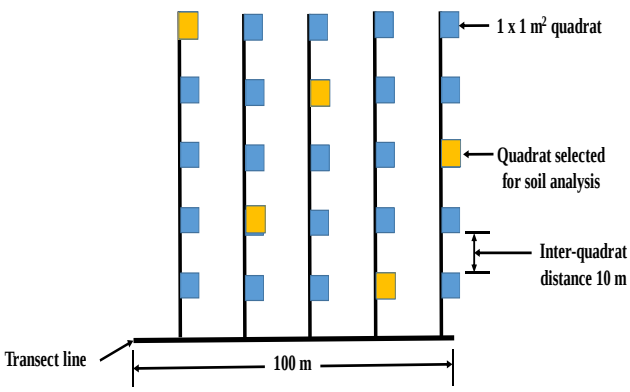


Fig. 1. Layout plan of vegetation studies of *Olea europaea* ssp. *cuspidata* and *Senegalia modesta* collected from different districts in the Punjab.

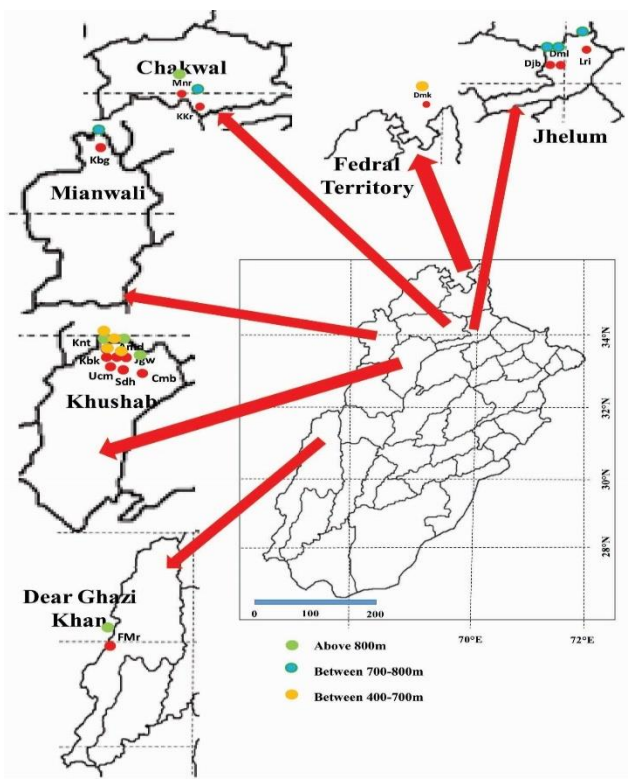


Fig. 2. Map of the Punjab province displaying collection sites of *Olea europaea* subsp. *cuspidate*.
1- Daman-e-Koh, 2- Djb=Diljabba, 3- Domeli, 4- Lehri, 5- Munara, 6- Kallar Kahar, 7- Kanhatti, 8- Khabeki, 9- Ahmedabad, 10- Jhungewala, 11- Uchala Mor, 12- Sodhi, 13-; Chambal Sharif, 14- Kalabagh, 15- Fort Monroe

Table 1. Coordinates and environmental data of *Olea europaea* subsp. *cuspidata* collected from different habitats in the Punjab.

	Sites	Co-ordinates	Altitude (m)	Maximum average temperature (ºC)	Minimum average temperature (ºC)	Rainfall (mm)
Low elevation (<700 m)	Dml	33º 00' 59.01″ N 73º 20' 18.91″ E	319.4	45	8	698
	Kbg	32º 58' 11.10″ N 71º 33' 56.85″ E	335.0	47	12	234
	Djb	32º 54' 30.33″ N 73º 04' 18.56″ E	444.1	37	2	732
	Lri	33º 09' 23.13″ N 73º 35' 50.01″ E	491.0	42	3	729
	Knt tr	32º 41' 09.89″ N 72º 15' 04.09″ E	600.2	38	3	429
	Kkh	32º 46' 02.96″ N 72º 42' 35.27″ E	660.2	31	2	685
Medium elevation (700-800 m)	Kntrd	32º 39' 46.84″ N 72º 14' 43.91″ E	718.1	42	8	412
	Dmk	33º 44' 18.29″ N 73º 03' 14.11″ E	720.5	31	-2	1103
	Sdh	32º 34' 32.59″ N 72º 16' 12.08″ E	745.2	42	2	337
	Ucm	32º 36' 19.61″ N 72º 13' 27.40″ E	770.2	41	6	387
	Knt	32º 40' 18.51″ N 72º 14' 45.56″ E	771.8	35	1	445
	Amd	32º 37' 11.62″ N 72º 16' 18.8″ E	778.5	41	4	390
High elevation (>800 m)	Kbk	32º 36' 45.92″ N 72º 12' 21.11″ E	813.2	44	9	600
	Ucm2	32º 36' 46.51″ N 72º 13' 19.59″ E	845.2	43	7	395
	Jgw	32º 37' 08.55″ N 72º 19' 56.70″ E	849.2	41	7	446
	Mnr	32º 39' 56.73″ N 72º 31' 22.49″ E	871.4	45	5	558
	Cmb	32º 28' 03.18″ N 72º 11' 55.33″ E	896.1	45	33	467
	FMr	29º 55' 38.42″ N 69º 58' 55.29″ E	1838.6	32	-1	246

Abbreviations: Amd-Ahmedabad; Cmb-Chambal Sharif; Djb-Diljabba; Dmk-Daman-e-Koh; Dml-Domeli; FMr-Fort Monroe; Jgw-Jhungewala; Kbg-KalabaghKbk-Khabeki; Kkh-Kallar Kahar; Knt-Kanhatti; Kntrd-Kanhatti road; Knt tr-Kanhatti track; Lri-Lehri; Mnr-Munara;Sdh-Sodhi; Ucm-Uchala Mor.

Table 2. Soil physicochemical characteristics of *Olea europaea* subsp. *cuspidata* collected from different habitats in the Punjab.

	Sites	pH	EC ($dS\ m^{-1}$)	OM (%)	SP (%)	Ca ($mgkg^{-1}$)	K ($mgkg^{-1}$)	Na ($mgkg^{-1}$)	NO_3 ($mgkg^{-1}$)	PO_4 ($mgkg^{-1}$)
Low elevation (<700 m)	Dml	8.1	0.91	1.04	30	56.3	121.6	215.7	2.6	6.5
	Kbg	7.7	10.25	0.77	33	126.1	349.5	1027.7	3.7	6.3
	Djb	8	6.03	0.62	30	43.9	69.2	437.4	8.4	8.4
	Lri	7.4	4.51	0.97	30	126.4	167.5	395.8	2.7	8.5
	Knt tr	7.7	1.88	1.25	38	75.5	121.2	177.8	4.1	25
	Kkh	8.1	29	0.9	30	93.2	135.2	3723.4	3.2	7.6
Medium elevation (700-800 m)	Kntrd	8.2	0.98	0.83	30	63.1	95.3	129.3	2.8	7.9
	Dmk	8.2	2.36	0.79	34	57.8	173.7	225.9	3.8	7.6
	Sdh	8.1	1.35	0.76	32	57.9	173.5	125.7	3.4	7.3
	Ucm	8.1	1.05	0.62	30	54.8	66.8	211.9	3.2	4.4
	Knt	7.5	3.76	1.32	30	63.7	134.7	227.3	3.5	11.2
	Amd	8.2	0.83	1.04	32	58.2	78.7	119.7	8.5	9
High elevation (>800 m)	Kbk	7.5	47	0.83	30	115.4	166.3	5135.2	3.4	4.3
	Ucm2	8	0.75	0.83	32	54.3	144.2	88.6	3.7	7.7
	Jgw	7.3	8.55	0.96	32	127.4	169.5	698.8	2.8	8.4
	Mnr	8	6.27	0.55	30	76.3	133.4	465.5	4.1	3.5
	Cmb	8.2	0.98	0.83	30	63.1	95.3	129.3	2.8	7.9
	FMr	7.5	4.59	0.99	31	127.4	167.4	459.9	3.1	8.4

Collection sites: Amd-Ahmedabad; Cmb-Chambal Sharif; Djb-Diljabba; Dmk-Daman-e-Koh; Dml-Domeli; FMr-Fort Monroe; Jgw-Jhungewala; Kbg-KalabaghKbk-Khabeki; Kkh-Kallar Kahar; Knt-Kanhatti; Kntrd-Kanhatti road; Knt tr-Kanhatti track; Lri-Lehri; Mnr-Munara;Sdh-Sodhi; Ucm-Uchala Mor.

Soil physicochemical traits: Ca-Soil Ca^{2+}; ECe-Soil ECe; K-Soil K^{+}; Na-Soil Na^{+}; NO_3-Soil NO_3^{-}; OM-Organic matter: PO_4-Phosphate PO_4^{3-}; SP-Saturation percentage.

At elevations between 700m and 800m, soil samples from Kanhatti road exhibited the maximum pH (8.2) and the minimum saturation percentage (30%) and NO_3^- (2.8 mg kg^{-1}). Soil from Daman-e-Koh showed the maximum pH (8.2), saturation percentage (34%) and K^+ (173.7 mg kg^{-1}). Soil collected from Uchala Mor exhibited the minimum organic matter (0.62%), saturation percentage (30%), Ca^{2+} (54.8 mg kg^{-1}), K^+ (66.8 mg kg^{-1}) and PO_4^{3-} (4.4 mg kg^{-1}). Kanhatti soil displayed the maximum ECe (3.76 dS m^{-1}), organic matter (1.32%), Ca^{2+} (63.7mg kg^{-1}), Na^+ (227.3 mg kg^{-1}) and PO_4^{3-} (11.2 mg kg^{-1}) and the minimum pH (7.5), and saturation percentage (30%). Soil from Ahmedabad showed the maximum pH (8.2) and NO_3^- (8.5 mg kg^{-1}) but the minimum ECe (0.83 dS m^{-1}) and Na^+ (119.7 mg kg^{-1}) (Table 2).

At elevations higher than 800m, soil from Khabeki displayed the maximum ECe (47 dS m^{-1}) and Na^+ (5135.2 mg kg^{-1}) but the minimum saturation percentage (30%). Soil from Uchala Mor 2 showed the maximum saturation percentage (32%) but the minimum ECe (0.75 dS m^{-1}), Ca^{2+} (54.3 mg kg^{-1}) and Na^+ (88.6 mg kg^{-1}). Jhungewala soil exhibited the maximum saturation percentage (32%), Ca^{2+} (127.4 mg kg^{-1}), K^+ (169.5 mg kg^{-1}) and PO_4^{3-} (8.4 mg kg^{-1}) but the minimum pH (7.3) and NO_3^- (2.8 mg kg^{-1}). Soil sample from Munara displayed the maximum NO_3^- (4.1 mg kg^{-1}) but the minimum organic matter (0.55%), saturation percentage (30%) and PO_4^{3-} (3.5 mg kg^{-1}). The soil sample collected from Chambal Sharif showed the maximum pH (8.2) but the minimum saturation percentage (30%), K^+ (95.3 mg kg^{-1}) and NO_3^- (2.8 mg kg^{-1}). Soil sample from Fort Monroe exhibited the maximum organic matter (0.99%), Ca^{2+} (127.4 mg kg^{-1}), and PO_4^{3-} (8.4 mg kg^{-1}) (Table 2).

Ecological characteristics

Fig. 3 shows the pectoral view of wild olives from different habitats in the Punjab.

Low elevation (<700 m): In Domeli, the maximum (46.6) relative density was *C. serrulatus* and the maximum (11.5) relative frequency was of *O. europaea*. while the maximum (43.7) relative cover and importance value (100.7) was also of *C. serrulatus*. In Kalabagh, the maximum (22.6) relative density was shown by *C. dactylon* and the maximum relative frequency (7.5) was shown by *S. modesta*. Similarly, the maximum (26.6) relative cover was of *O. europaea* and importance value (47.5) was of *D. viscosa*. In Diljabba, *C. dactylon* exhibited the maximum relative density (30.4). *D. viscosa* and *O. europaea* showed the maximum relative frequency (13.7). In Diljabba, *O. europaea* also showed the maximum relative cover (34.3). *D. viscosa* showed the maximum importance value (58.8) (Fig. 4).

The maximum relative density (27.2) in Lehri was shown by *C. jwarancusa* While *O. europaea* displayed the maximum relative density (12.8). *O. europaea* also showed the maximum relative cover (30.4) and *C. jwarancusa* displayed the maximum importance value (59.6) in Lehri. In Kanhatti Track, the maximum (34.09) relative density was *C. serrulatus* and the maximum relative frequency (18.52) was that of *Olea europaea*. The maximum relative cover (36.21) was of *O. europaea* whereas maximum importance value (66.75) found was of *C.* serrulatus. In Kalar Kahar, the maximum (41.51) relative density was of *Chrysopogon serrulatus*. *Olea europaea* and *C. serrulatus* displayed the maximum (12.73) relative frequencies. *D. viscosa* showed the maximum (24.11) relative cover And *C. serrulatus* had the maximum importance value (Fig. 4).

Medium elevation (700-800m): In Kanhatti road, *H. contortus* showed the maximum (24.21) relative density and *O. europaea* and *H. contortus* showed the maximum (14.29) relative frequency. *C. serrulatus* and *H. contortus* showed the maximum (21.28) relative cover and *H. contortus* showed the maximum (59.77) importance value. In Daman-e-Koh, the maximum (21.32) relative density was indicated by *C. serrulatus* while *O. europaea* and *G. royleana* indicated the maximum (12.5) relative frequency. The maximum (29.28) relative cover was indicated by *O. europaea*, while the maximum (45.94) importance value was indicated by *C. serrulatus* in Daman-e-Koh. In Sodhi, the maximum (32.56) relative density was of *Enteropogon dolichostachyus* and the maximum (14.29) relative frequency was that of *C. opaca*. In Sodhi the maximum (34.25) relative cover was of *O. europaea* and the maximum (51.21) importance value was of *E. dolichostachyus* (Fig. 5).

In Uchala Mor, *C. jwarancusa* exhibited the maximum (28.19) relative density and *O. europaea* and *G. royleana* showed the maximum (14.89) relative frequency. *O. europaea* displayed both the maximum relative cover (48.18) and importance value (67.53). In Kanhatti, the maximum (36.97) relative density was of *D. scindicum* and the maximum (14.81) relative frequency was that of *S. modesta*. *O. europaea* displayed both the maximum relative cover (26.79) and importance value (72.42). In Ahmedabad, *C. jwarancusa* showed the maximum (38.82) relative density, while *O. europaea* and *G. royleana* displayed the maximum (14.29) relative frequency. *O. europaea* exhibited the maximum (34.85) relative cover while *C. jwarancusa* displayed the maximum (73.42) importance value (Fig. 5).

High elevation (>800 m): In Khabeki, the maximum (45.75) relative density was of *C. jwarancusa*. whereas the maximum (18.18) relative frequency was of *O. europaea, C. serrulatus, C. jwarancusa* and *D. viscosa*. *D. viscosa* and *C. jwarancusa* showed the maximum relative cover (42.25) and importance value (81.54) in Khabeki. In Uchala Mor 2, the maximum (22.66) relative density was in *C. serrulatus* while the maximum (12.12) relative frequency was of *J. adhatoda* and *G. royleana*. The maximum relative cover (30.39) and importance value (54.78) were of *L. indica*. In Jhungewala, the maximum (16.62) relative density was of *D. scindicum*, the maximum (11.39) relative frequency was of *O. europaea*. *C. serrulatus* showed both the maximum relative cover (25.08) and importance value (72.06) (Fig. 6).

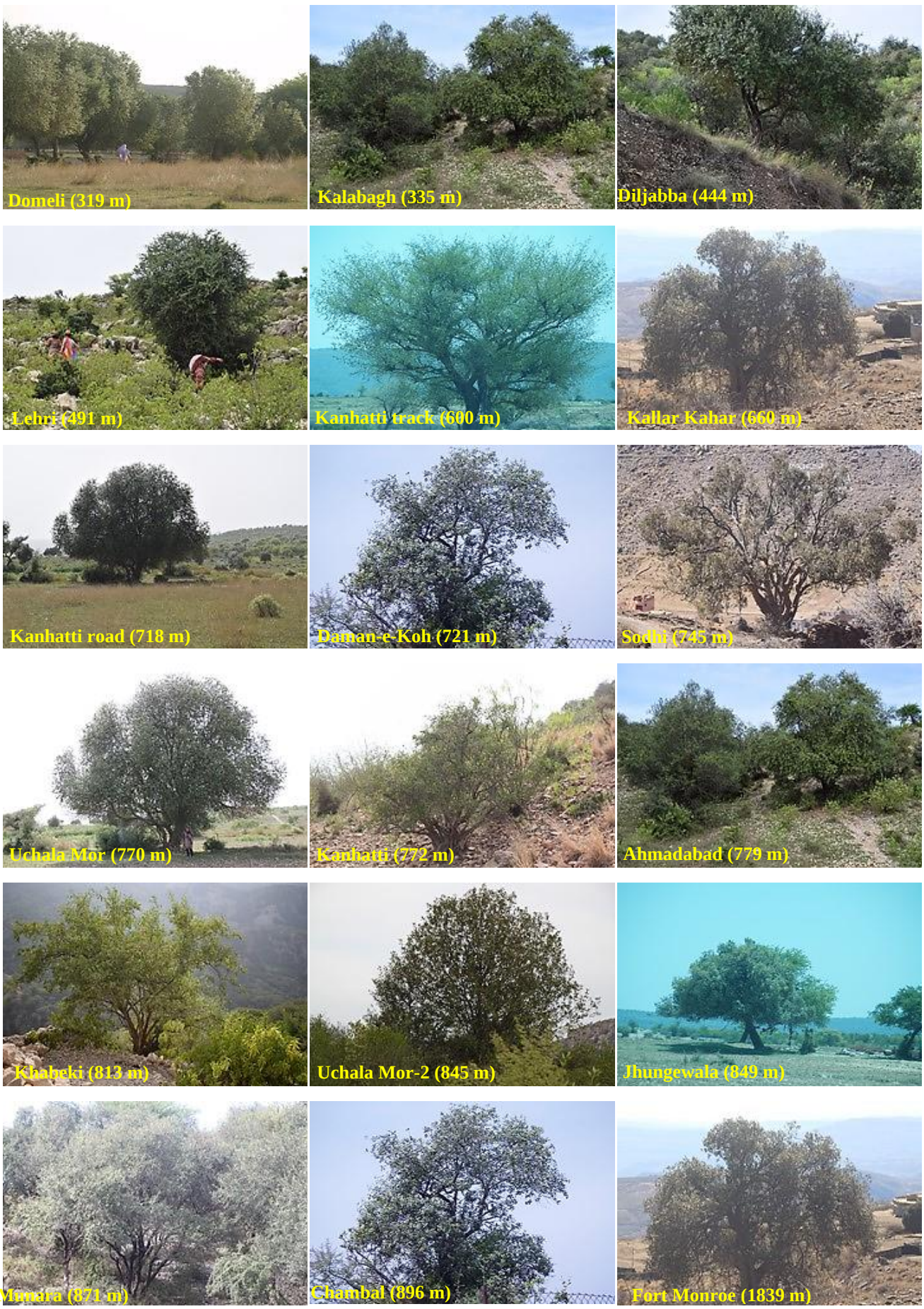


Fig. 3. Pectoral view of *Olea europaea* ssp. *cuspidata* habitat from other habitats in the Punjab.

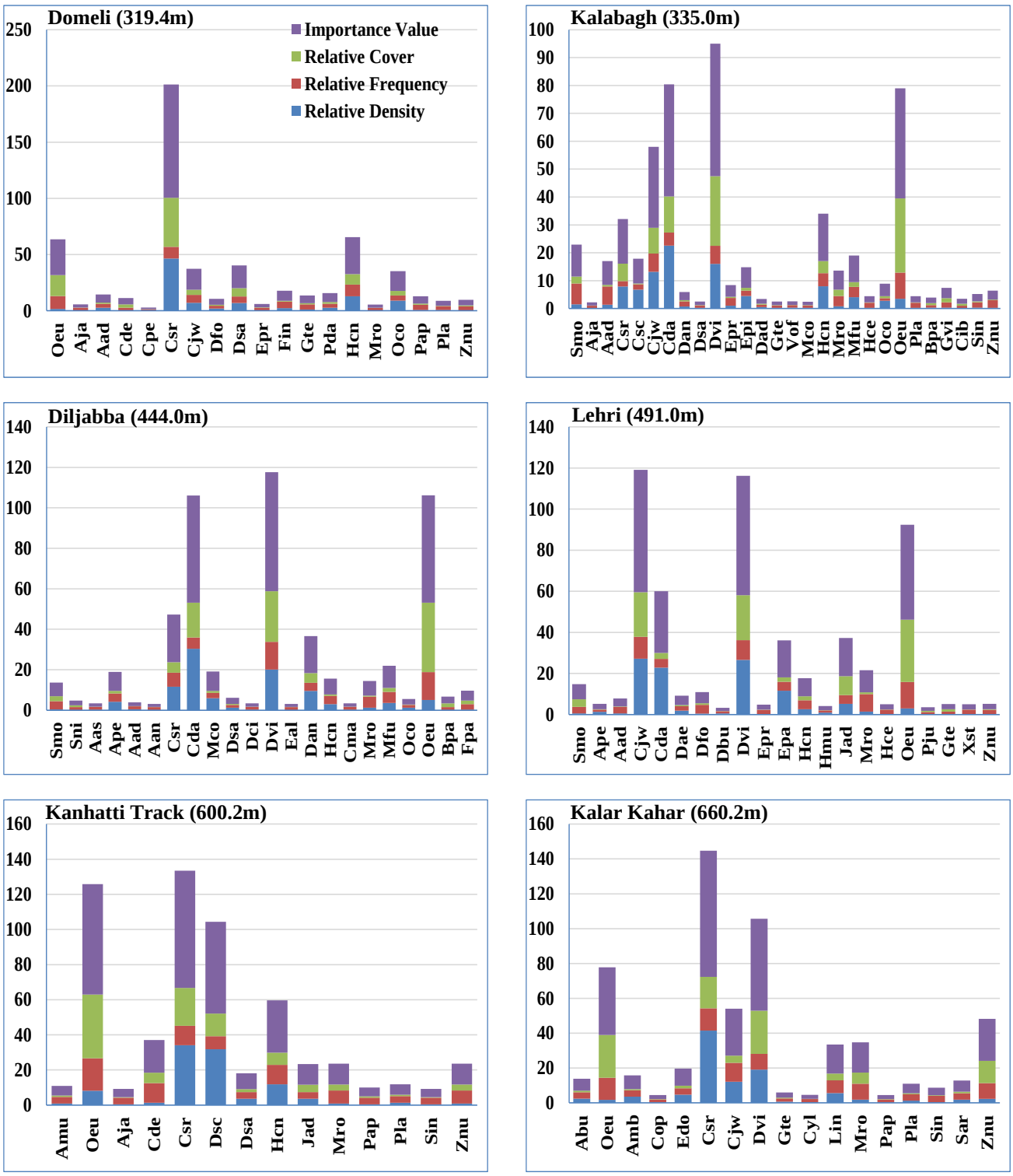


Fig. 4. Ecological studies of *Olea europaea* subsp. *cuspidata* at low elevation (300-700 m).
Amu–*Abutilon muticum,* Aas–*Achyranthes aspera,* Ape–*Adiantum pedatum,* Aja–*Aerva javanica,* Aad–*Aristida adscensionis,* Amb–*Aristida mutabilis,* Aan–*Asparagus adscendens,* Bpa–*Buxus papillosa,* Cde–*Cappais decidua,* Cop–*Carrisa opaca,* Cpe–*Cenchrus pennisetiformis,* Cib–*Centaurea iberica,* Csr–*Chrysopogon serrulatus,* Csc–*Cleome scaposa,* Cjw–*Cymbopogon jwarancusa,* Cma–*Cymbopogon martini,* Cda–*Cynodon dactylon,* Cyl–*Cynoglossumlanceolatum,* Dae–*Dactyloctenium aegyptium,* Dsc–*Dactyloctenium scindicum,* Dan–*Dicanthium annulatum,* Dfo–*Dicanthiumfoveolatum,* Dbu–*Diclipterabupleuroides,* Dad–*Digitaria adscendens,* Dci–*Digitaris ciliaris,* Dsa–*Digitaria sanguinalis,* Dvi–*Dodonaea viscosa,* Epr–*Enneapogonpersicus,* Edo–*Enteropogondolichostachyus,* Epa–*Eragrostispapposa,* Epi–*Eragrostrispilosa,* Eal–*Evolvulusalsinoides,* Fin–*Fagonia indica,* Fpa–*Ficus palmata,* Gte–*Grewia tenax,* Gvi–*Grewia villosa,* Hcn–*Heteropogon contortus,* Hmu–*Hordeum murinum,* Hce–*Hypertelis cerviana,* Jad–*Justicia adhatoda,* Lin–*Lantana indica,* Mco–*Malvastrumcoromendelianum,* Mro–*Gymnosporiaroyleana,* Mfu–*Melhaniafutteyporensis,* Oco–*Ochthochloa compressa,* Oeu–*Olea europaea,* Pda–*Pergulariadaemia,* Pap–*Periploca aphylla,* Pju–*Prosopis juliflora,* Pla–*Pupalialappacea,* Smo–*Senegalia modesta,* Sni–*Senegalia nilotica,* Sin–*Solanum incanum,* Sar–*Sporobolus arabicus,* Vof–*Verbena officinalis,* Xst–*Xanthium strumarium,* Znu–*Ziziphus nummularia*.

Fig. 5. Ecological studies of *Olea europaea* subsp. *cuspidata* at medium elevation (700-800 m).
Amu–*Abutilon muticum,* Aas–*Achyranthes aspera,* Aja–*Aerva javanica,* Aad–*Aristida adcendens,*Amb–*Aristida mutabilis,*Bcr–*Barleria cristata,* Cde–*Capparis decidua,* Cop–*Carissa opaca,* Csr–*Chrysopogon serrulatus,* Cjw–*Cymbopogon jwarancusa,* Cda–*Cynodon dactylon,* Dsc–*Dactyloctenium scindicum,* Dbi–*Desmostachyabipinnata,* Dfo–*Dicantheumfoveolatum,* Dsa–*Digitaria sanguinalis,* Dvi–*Dodonaea viscosa,* Edo–*Enteropogondolichostachyus,* Epa–*Eragrostrispapposa,* Eco–*Eriophorumcomosum,* Fin–*Fagonia indica,* Gte–*Grewia tenax,* Hcn–*Heteropogon contortus,* Jad–*Justicia adhatoda,* Lca–*Lantana camara,* Lin–*Lantana indica,* Lfl–*Lespedeza floribunda,* Mco–*Malvestrumcoromendelanum,* Mro–*Gymnosporiaroyleana,* Nol–*Nerium oleander,* Oeu–*Olea europaea,* Oli–*Otostegialimbata,* Pda–*Pergulariadaemia,* Pap–*Periploca aphylla,* Pla–*Pupalialappacea,* Rtr–*Rhamnus triquetra,* Sgr–*Saccharum griffithii,* Smo–*Senegalia modesta,* Sni–*Senegalia nilotica,* Spu–*Setaria pumila,* Sin–*Solanum incanum,* Sar–*Sporobolus arabicus,* Xst–*Xanthium strumarium,* Znu–*Ziziphus numularia*

In Munara, *C. serrulatus* showed the maximum (35.05) relative density, *O. europaea* and *D. viscosa* exhibited the maximum (12.5) relative frequency. *O. europaea* manifested the maximum (24.48) relative cover, while *C. serrulatus* showed the maximum (64.11) importance value. In Chambal Sharif, *C. serrulatus* displayed the maximum relative density (82.6), relative frequency (20.83), relative cover (50.7) and importance value (154.13). In Fort Monroe, *C. serrulatus* exhibited the maximum (43.1) relative density, *O. europaea* and *C. serrulatus* showed the maximum (12.82) relative frequency. *O. europaea* exhibited the maximum (48.03) relative cover while, *C. serrulatus* displayed the maximum (72.08) importance value (Fig. 6).

Principal component analysis (PCA)

Low elevation (<700 m): *A. adscendens, C. martinii, D. ciliaris, E. alsinoides, F. palmata* and *V. nilotica* were in a close association with NO_3 at Diljabba. *T. villosa, X. strumarium, F. indica, J. adhatoda, D. aegyptium, P. juliflora, C. iberica, V. officinalis, C. dactylon, D. foveolatum, C. jwarancusa, H. cerviana, O. compressa, E. persicus, A. adscendens, G. villosa, C. scaposa, D. bupleuroides, E. pilosa, H. contortus, E. papposa* and *D. ciliaris* were in a close association with Ca^{2+}, K^{+}, and maximum and minimum temperatures in Lehri and Kalabagh. *P. aphylla, C. pennisetiformis* and *G. tenax* were in a close association with organic matter in Domeli. *A. mutabilis, A. muticum, C. opaca, C. lanceulatum, Z. nummularia, S. arabicus, E. dolichostachyus, G. royleana* and *L. indica* were in a close association with elevation, Na^{+}, PO_4^{3-}, pH and ECe (Fig. 7).

Medium elevation (700-800m): *M. coromendelianum, P. daemia, S. incanum, D. foveolatum, S. pumila, G. royleana, P. lappacea, X. strumarium, G. tenax* and *R. triquetra* were in a close association with annual rainfall in Daman-e-Koh. *E. comosum, E. dolichostachyus, N. oleander, C. jwarancusa, L. indica, L. camara, J. adhatoda, V. nilotica* and *C. serrulatus* were in a close association with pH, NO_3^{-} and saturation percentage in Ahmedabad. *A. mutabilis, B. cristata, A. muticum, C. opaca, S. arabicus, D. sanguinalis* and *D. bipinnata* were in a close association with maximum and minimum temperatures in Sodhi (Fig. 7).

High elevation (>800 m): *Olea europaea, E. alsinoides, O. limbata, E. papposa, F. indica, A. adscendens, D. aegyptium, D. sanguinalis, S. arabicus, D. scindicum, E. hirta* and *E. ciliaris* were closely associated to elevation, organic matter, Ca^{2+} and K^{+} in Fort Monroe. *A. psilocentros, G. tenax, C. decidua, E. camaldulensis* and *C. opaca* were closely associated with annual rainfall and maximum temperature in Chambal Sharif and Munara (Fig. 7).

Discussion

Distribution range of wild olive is restricted to the Punjab. Fort Munroe had the highest elevation (1838.6 m) in Punjab and the only wild olive habitat in lower Punjab. Community structure changed along elevation gradient, as was reported by several researchers like Shaheen *et al*. (2011) in Western Himalayan alpine pastures of Kashmir, Pakistan, Xu *et al*. (2014) in Tibetan plateau and Faiz *et al*. (2015) in Tolipir National Park Azad Jammu and Kashmir, Pakistan.

Salt Range is a narrow-elongated channel in East-West direction with Jhelum River on East and Indus River on West. It is saturated with the most important geological and paleontological areas of Pakistan and so is one of the most exceptional and important ground ranges in the world. Therefore, the Salt Range is worth conserving and preserving due to its educational and scientific significance internationally (Sameeni 2009).

Dominant species of the Salt Range are *O. europaea, A. muticum, Z. nummularia, A. adscensionis, C. opaca, C. serrulatus, C. jwarancusa, S. modesta, J. adhatoda, C. dactylon, D. viscosa, D. scindicum, D. foveolatum, D. sanguinalis, H. contortus, L. indica, G. royleanus, P. aphylla, P. lappacea* and *S. incanum* (Nawaz *et al*., 2012). These dominant species are well adapted to arid climate. A significant variation in community structure, association, distribution pattern, richness and composition of species was found along an altitude gradient, particularly at high altitudes, as reported by researchers round the globe (Luo *et al*., 2004; Li *et al*., 2011; Abbasvand *et al*., 2014). Maximum richness was found at moderate elevation (above 700 m) due to better and moderate climatic and growth conditions (Fatima *et al*., 2022).

Temperature, average annual rainfall, availability of nutrients and atmospheric pressure changed abruptly at high altitudes (Adler & Levine, 2007) leading to reduction in species richness (Grytnes & Vetaas, 2002). The high variability in physiography and climate of the region is a strong factor in imposing a radical change in species ecology and distribution pattern in the Potohar Plateau and Salt Range (Mahmood *et al*., 2012). The distribution pattern is predominantly linked to the stress tolerating capacity of species (Le Bagousse-Pinguet *et al*., 2014). The variable degree of tolerance depended on the capacity of species to tolerate single or multiple stress conditions (He & Bertness, 2014).

Even a slight variation in elevation affects the whole structure and composition of mountain communities (Fatima *et al*., 2021). Mountains provide the best opportunity to study how plants respond to certain environmental stresses as they accede to unexpected geographic and climatic changes (Hovenden & Vander Schoor 2006). Increased elevation usually leads to an increase in frequency of abiotic stresses including salinity, drought, nutrients, wind speed, oxygen, UV radiation and atmospheric pressure (Choler *et al*., 2001). Difference in maximum and minimum temperatures is an important factor that control species distribution (Zhang *et al*., 2019), richness (Aynekulu *et al*., 2012), dominance (Bentley & O'Connor, 2018) and community structure.

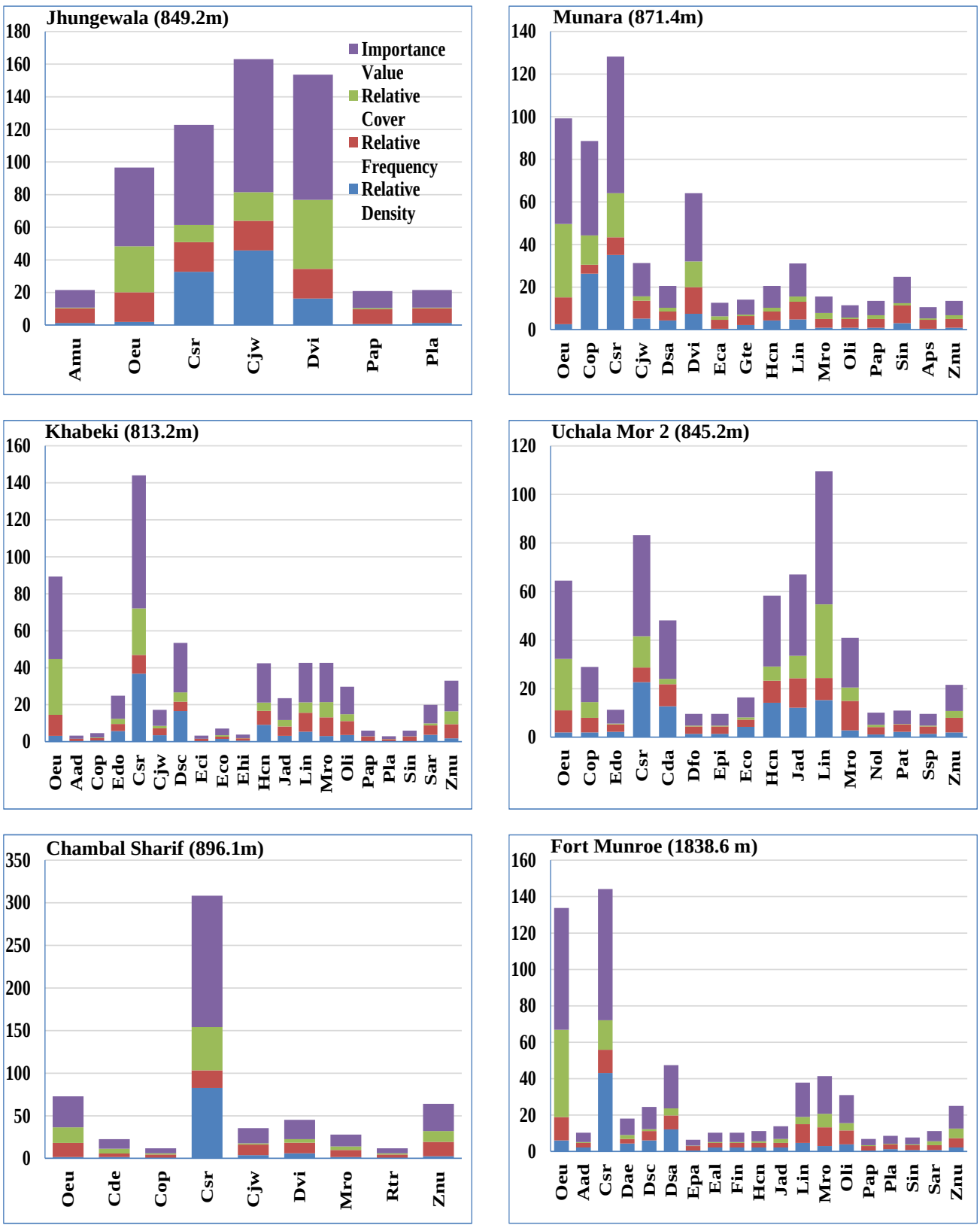
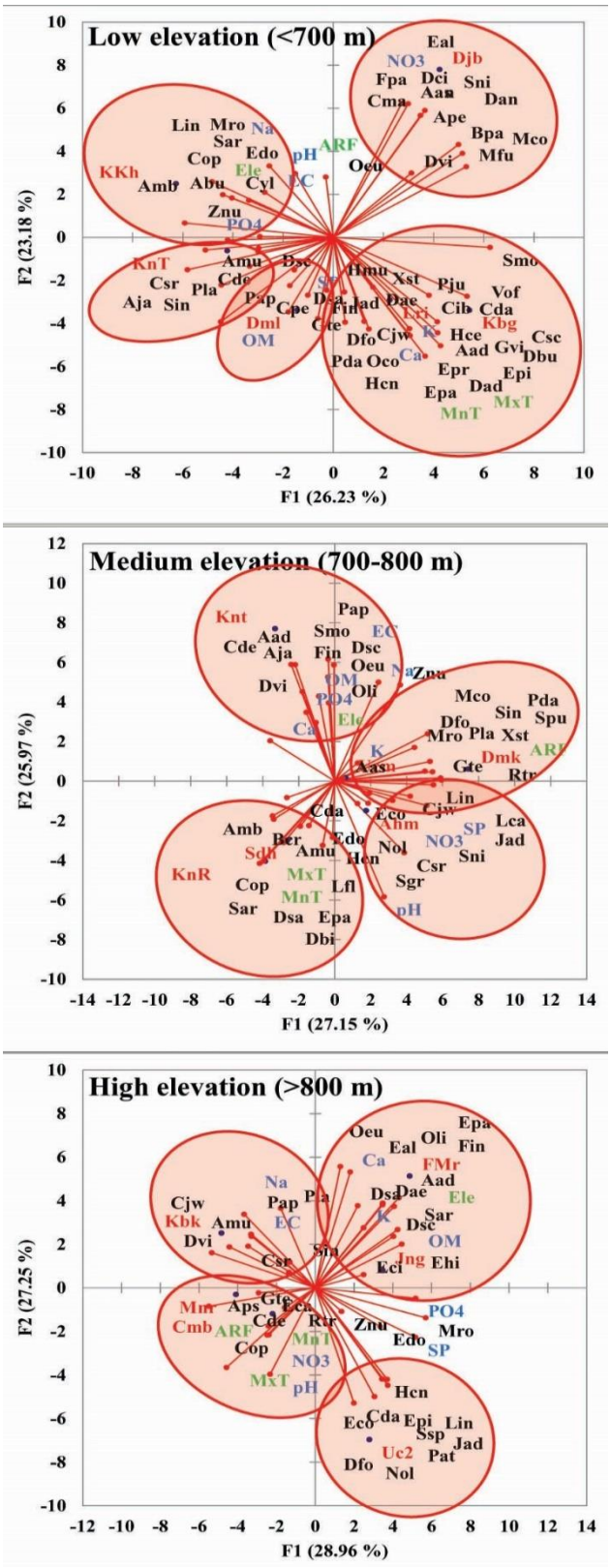


Fig. 6. Ecological studies of *Olea europaea* subsp. *cuspidata* at high elevation (above 800 m)
Amu–*Abutilon muticum,* Aad–*Aristida adscensionis,* Cde–*Capparis decidua,* Cop–*Carissa opaca,* Csr–*Crysopogon serrulatus,* Cjw–*Cympogon jwarancusa,* Cda–*Cynodon dactylon,* Dae–*Dactyloctenium aegyptium,* Dsc–*Dactyloctenium scindicum,* Dfo–*Dicanthiumfoveolatum,* Dsa–*Digitaria sanguinalis,* Dvi–*Dodonaea viscosa,* Edo–*Enteropogondolichostachyus,* Eci–*Eragrostis ciliaris,* Epa–*Eragrostispapposa,* Epi–*Eragrostispilosa,* Eco–*Eriophorumcomosum,* Eca–*Eucalyptus camaldulensis,* Ehi–*Euphorbia hirta,* Eal–*Evolvulusalsinoides,* Fin–*Fagonia indica,* Gte–*Grewia tenax,* Hcn–*Heteropogon contortus,* Jad–*Justicia adhatoda,* Lin–*Lantana indica,* Mro–*Gymnosporiaroyleana,* Nol–*Nerium oleander,* Oeu–*Olea europaea,* Oli–*Otostegialimbata,* Pat–*Panicum atrosanguineum,* Pap–*Periploca aphylla,* Pla–*Pupalialappacea,* Rtr–*Rhamnus triquetra,* Ssp–*Saccharam spontaneum,* Sin–*Solanum incanum,* Sar–*Sporobolus arabicus,* Znu–*Ziziphus nummularia.*



Sites: KKh−Kalar Kahar, KnT−Kanhatti Track, Lri−Lehri, Dlj−Diljabba, Kbg−Kalabagh, Dml−Domeli, Ahm−Ahmadabad, Knt−Kanhatti, Ucm−Uchala Mor, Sdh−Sodhi, Dmk−Daman-e-Koh, KnR−Kanhatti Road, FMr−Fort Munroe, Cmb−Chambal Sharif, Mnr−Munara, Jng−Jhungewala, Uc2−Uchala Mor 2, Kbk−Khabeki. Soil: EC−Electrical conductivity, Ca−Soil Ca^{2+}, K−Soil K^{+}, Na−Soil Na^{+}, NO3−Soil NO_3^{-}, OM−Organic matter, SP−Saturation percentage, PO4−Soil PO_4^{3-}. Environment: Ele−Elevation, MxT−Maximum temperature, MnT−Minimum temperature, ARF−Annual rainfall

Species: Amu−*Abutilon muticum*, Aas−*Achyranthes aspera*, Ara−*Acrachne racemose*, Ape−*Adiantum pedatum*, Aja−*Aerva javanica*, Ast−*Argyrolobiumstenophyllum*, Aad−*Aristida adscensionis*, Amb−*Aristida mutabilis*, Ane−*Arundinellanepalensis*, Aan−*Asparagus adscendens*, Aps−*Asparagus psilocentros*, Bcr−*Barleria cristata*, Bpi−*Bidens pilosa*, Bpr−*Boerhavia procumbens*, Bmr−*Bolboschoenus maritimus*, Bra−*Brachiaria ramose*, Bmo−*Butea monosperma*, Bpa−*Buxus papillosa*, Cpo−*Calligonum polygonoides*, Cpr−*Calotropis procera*, Cde−*Capparis decidua*, Csp−*Capparis spinosa*, Cge−*Caragana gerardiana*, Cop−*Carissa opaca*, Car−*Celosia argentea*, Cpe−*Cenchrus pennisetiformis*, Cse−*Cenchrus setigerus*, Cib−*Centaurea iberica*, Csr−*Chrysopogon serulatus*, Ccl−*Citrullus colocynthis*, Cbr−*Cleome brachycarpa*, Csc−*Cleome scaposa*, Cbu−*Crotalaria burhia*, Cjw−*Cymbopogon jwarancusa*, Cma−*Cymbopogon martini*, Cau−*Cynanchumauriculatum*, Cda−*Cynodon dactylon*, Cyl−*Cynoglossumlanceolatum*, Cya−*Cyperus arenarius*, Cym−*Cyperus michelianus*, Cyn−*Cyperus niveus*, Dae−*Dactyloctenium aegyptium*, Dsc−*Dactyloctenium scindicum*, Dbi−*Desmostachyabipinnata*, Dan−*Dicanthium annulatum*, Dfo−*Dicanthioumfoveolatum*, Dbu−*Diclipterabupleuroides*, Dmu−*Digitaria muricata*, Dad−*Digitaria adscendens*, Dci−*Digitaria ciliaris*, Dsa−*Digitaria sanguinalis*, Dvi−*Dodonaea viscosa*, Epr−*Enneapogonpersicus*, Edo−*Enteropogondolichostachyus*, Eci−*Eragrostis ciliaris*, Epa−*Eragrostispapposa*, Epi−*Eragrostispilosa*, Ete−*Eragrostistenella*, Eco−*Eriophorumcomosum*, Eca−*Eucalyptus camaldulensis*, Ebi−*Eulaliopsisbinata*, Egl−*Euphorbia glomerulata*, Ehi−*Euphorbia hirta*, Eal−*Evolvulusalsinoides*, Fin−*Fagonia indica*, Fru−*Festuca rubra*, Fpa−*Ficus palmata*, Gte−*Grewia tenax*, Gvi−*Grewia villosa*, Hne−*Hedera nepalensis*, Hra−*Heliotropiumrariflorum*, Hco−*Hemarthria compressa*, Hcn−*Heteropogon contortus*, Hca−*Hibiscus caesius*, Hmu−*Hordeum murium*, Hce−*Hypertelis cerviana*, Icy−*Imperata cylindrica*, Ica−*Ipomoea carnea*, Ipu−*Ipomoea purpurea*, Jad−*Justicia adhatoda*, Lca−*Lantana camara*, Lin−*Lantana indica*, Lsc−*Lasiurus scindicus*, Lpr−*Launaea procumbens*, Lfl−*Lespedeza floribunda*, Lju−*Lespedeza juncea*, Lce−*Leucas cephalotes*, Mph−*Mallotusphilippensis*, Mco−*Malvestrumcoromendelianum*, Mro−*Gymnosporiaroyleana*, Mfu−*Melhaniafutteyporensis*, Mbu−*Monothecabuxifolia*, Mma−*Mukiammaderaspatanus*, Nol−*Nerium oleander*, Oco−*Ochthocloa compressa*, Oeu−*Olea europaea*, Ocm−*Oplismenuscompositus*, Ola−*Oplismenuslanceolatus*, Omo−*Opuntia monocantha*, Oli−*Otostegialimbata*, Ocr−*Oxalis corniculata*, Pat−*Panicum atrosanguineum*, Pda−*Pergulariadaemia*, Pap−*Periploca aphylla*, Per−*Polygala erioptera*, Pci−*Prosopis cineraria*, Pgl−*Prosopis glandulosa*, Pju−*Prosopis juliflora*, Pla−*Pupalialappacea*, Rtr−*Rhamnus triquetra*, Rre−*Rhynchelytrum repens*, Rco−*Ricinus communis*, Sbe−*Saccharam bengalense*, Sgr−*Saccharamgriffthii*, Ssp−*Saccharam spontaneum*, Sbr−*Salicornia brachiata*, Sim−*Salsola imbricata*, Smo−*Senegalia modesta*, Spu−*Setaria pumila*, Sco−*Sida cordata*, Sin−*Solanum incanum*, Ssu−*Solanum surattense*, Sha−*Sorghum halepense*, Sar−*Sporobolus arabicus*, Sio−*Sporobolus ioclados*, Tap−*Tamarix aphylla*, Tan−*Themedaanathera*, Tpo−*Trianthemaportulacastrum*, Tlo−*Tribulus longipetalus*, Tte−*Tribulus terrestris*, Tin−*Trichodesma indicum*, Tdo−*Typha domingensis*, Veb−*Vachellia eburnean*, Vni−*Vachellianilotica*, Vof−*Verbena officinalis*, Vci−*Vernonia cinerascens*, Wvo−*Wattakakavolubilis*, Xst−*Xanthium strumarium*, Znu−*Ziziphus nummularia*

Fig. 7. Principal component analysis showing relationship of soil physicochemical traits with species distribution along elevation gradient.

Conclusion

It was concluded that some species (*O. europaea, C. jwarancusa, C. serrulatus, H. contortus, Z. nummularia and G. royleana*) were distributed widely in all elevations (319 m to 1839 m). The dominant species are edible and so support wildlife species. Other species were distributed in specific elevations. This distribution might be associated with climatic and physiographic variables that affect community structure and distribution pattern, richness and dominance of species along elevation gradients.

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