Pak. J. Bot., 49(6): 2371-2382, 2017.

DISTRIBUTION PATTERN AND SPECIES RICHNESS OF NATURAL WEEDS OF WHEAT IN VARYING HABITAT CONDITIONS OF DISTRICT MALAKAND, PAKISTAN

MUHAMMAD IQBAL[1], SHUJAUL MULK KHAN[2*], MUHAMMAD AZIM KHAN[3], ZEESHAN AHMAD[2], ZAHEER ABBAS[1], SHAH MASAUD KHAN[4] AND MUHAMMAD SALEEM KHAN[5]

[1]Department of Botany, Hazara University of Mansehra, Pakistan
[,2]Department of Plant Sciences, Quaid-i-Azam University Islamabad, Pakistan*
[3]Department of Weed Science, University of Agriculture Peshawar, Pakistan
[4]Department of Agricultural Sciences, University of Haripur, Pakistan
[5]Department of Botany, Islamia College University Peshawar, Pakistan
[*]Corresponding author's email: shuja60@gmail.com & smkhan@qau.edu.pk

Abstract

Quantitative ecological techniques in winter wheat fields were used to assess weed species richness, distribution pattern and abundance under the influence of varying environmental conditions in the District of Malakand KP, Pakistan. A total of 1200 quadrats (1x1 m^2 size) were established in 120 randomly selected wheat fields. Using quadrat data phytosociological attributes i.e., density, frequency, cover, relative density, relative cover, relative frequency and importance values were calculated for each weed species. Preliminary 132 weed species were recorded from 1200 quadrats. Cluster and Two Cluster Analyses using PCORD Version 5 gave rise to five major weed communities via Sorenson distance measurements. These weed communities were: (1) *Emex-Vicia-Lathyrus* weeds community (2) *Alysum-Cannabis-Lithospermum* weeds community (3) *Oxalis- Lathyrus-Chenopodium* weeds community (4) *Euphorbia-Cerastium-Capsella-bursa* weeds community and (5) *Alopecuris-Mazus-Persicaria* weeds community. Over all top five abundant weed species were *Anagallis arvensis, Poa annua, Medicago denticulata* L, *Veronica polita* and *Fumaria indica* with Importance Values Index (IVI) of 1101.45, 1050.30, 916.23, 782.57 and 664.76 respectively in the region. Among the less abundant weed species with minimum IVI in the region *Lamium amplexicaule* (94.6435), *Papaver rhoeas* L. (94.1686), *Lathyrus aphaca* (94.0310), *Medicago polymorpha* (93.2877) and *Lithospermum erythrorhizon* (90.8317) were noteworthy. The weed species *Boerhavia procumbens* (1.2350), *Saussurea heteromalla* (1.2055), *Verbascum Thapsus* (1.1217), *Mentha longifolia* (1.0738) and *Juncus biflorus* (1.0605) having IVI less than 2 were considered as rare weeds of wheat in the study area. While *Acanthophyllum grandiflora*, *Boerhavia procumbens*, *Carex fedia*, *Dicliptera roxburghiana* and *Eryngium caeruleum* were among the least common species (LCS) showing their presence in one field only. It was concluded that electrical conductivity, soil texture, pH, organic matter, $CaCO_3$, phosphorous and high nitrogen concentration were the strong environmental variables that gives rise to diverse weed species composition, richness and distribution pattern.

Key word: Weed plants; Distribution; Species abundance; Wheat crop; Environmental conditions; Malakand Pakistan.

Introduction

Weeds are the part of dynamic ecosystems growing in ordinary environment and become obstacle to the crops (Baker, 1965; Iqbal *et al.,* 2015; Ahmad *et al.,* 2016a). Weeds are not needed plant species in agricultural fields and grown where they are not wanted. In a total of 8000 weed species only 250 species were important for an agriculture world (Holm *et al*., 1979; Ahmad *et al.,* 2016b). Weed species ecological attributes varies from place to place. Its spatial distribution pattern and richness received an increased attention since last few years. Most of the weed communities studies focus on to identify species composition and its distribution pattern regarding with presumed environmental variables. The gradients that mostly account to build up weed communities included biotic factor i.e., competition with crop and abiotic factor included physicochemical properties of soil or climatic factors (Weibull *et al.,* 2003; Boutin *et al.,* 2008). In addition to, weed management practices including crop type, succession as well as tillage system were the recognized factors to explain variation in weeds richness and distribution pattern over massive range of soil covering (Lososova *et al.,* 2004; Ali *et al.,* 2016; Zhou *et al.,* 2016). Plant scientists usually study the economically important and wild plant species separately. Studies along this aspect show in developing countries where weed scientists especially work on a single or limited number of weed species for possible control. Such species were associated with a specific crop for example wheat, maize, sugar cane, rice, etc. These kinds of studies were often related to the production of crops (Khan *et al.,* 2016; Saeed *et al.,* 2016; Sun *et al.,* 2017). In Khyber Pakhtunkhwa impacts of herbicides and different seed rates was investigated for integrated weeds management in different crops (Ali *et al.,* 2016; Rahman *et al.,* 2017) and few environmental gradients (Kashmir *et al.,* 2016). In addition to, wheat crop is also studied for the alleviation of its drought induced effects. For example, Canada thistle (*Cirsium arvense* L.) was considered as the most dangerous species for wheat crop. It was investigated for their controls through the use of two biologically control agents and through use of herbicides. The integrating control methods were the most effective in suppressing the growth of *C. arvense* L., than the use of a single approach for the control of this weed (Sciegienka *et al*., 2011).

Like other natural vegetation, weeds also grow in association with each other's. There is widespread study going on in analyzing the natural vegetation and on the formation of natural communities by the use of multivariate statistical analysis such as Cluster analysis, DCA, TWINSPAN classification etc. Such multivariate statistical analyses are underway to explore weed communities and their relationship with various environmental, edaphic factors and farming practices. For example, a multivariate statistical analysis was applied on the diversity and composition of weed communities in wheat fields by using TWINSPAN and Polar ordination by (Gupta *et al*., 2008; Khan *et al.*,2016; Iqbal *et al*., 2018; Ijaz *et al.,* 2016; Mehmood *et al.,* 2017; Noor *et al.,* 2017; Khan *et al.*, 2017; Abbas *et al.*, 2017). In Iran weed species of wheat was investigated for its relative dominance in the Tabriz County (Hassannejad & Ghafarbi., 2013). In Iran a study of similar nature was carried out to investigate the weed population indices in irrigated wheat fields (Kakhki *et al*., 2013; Khan *et al.*, 2011b). In addition, the grass communities were studied by using the relative dominance of the species in the wheat crop. In such studies a new grass as a new weed species was investigated for the flora of Iran (Hassannejad & Ghisvandi, 2013).

The main objective of current study was to recognize the distribution pattern, richness, assessment, abundance and rareness of weed species and communities in relation to various environmental variables in wheat crop of District Malakand, KP, Pakistan. It will also helpful to know about weed species diversity and their structure in various kinds of wheat fields regarding with edaphic characters. Furthermore, this study can be used as baseline for various management practices exploit for increase in crop production and yield of the wheat crop in future.

Material and Methods

Study area: The study area (District Malakand) lies in the northern parts of the Khyber Pakhtunkhwa Province, Pakistan. It is located at 34° 35´ North latitude and 71° 57´ East longitude. The primary income source of the local population is agriculture. The major economic crops of the area include wheat, sugarcane, tobacco, rice and maize. Wheat is the dominant crop in the project area and occupies leading part of agricultural land in which weeds of different kinds grow and flourish. A total of 26727 hectares area was cultivated of which 9715 hectares were irrigated and 17012 hectares was un-irrigated land. In Tehsil Dargai total estimated area sown for wheat crop was 10440 hectares in which 5465 hectares was un-irrigated and 4975 hectares was irrigated during 2013-14 (Statistical Officer Dargai Agri Deptt) (Fig. 1).

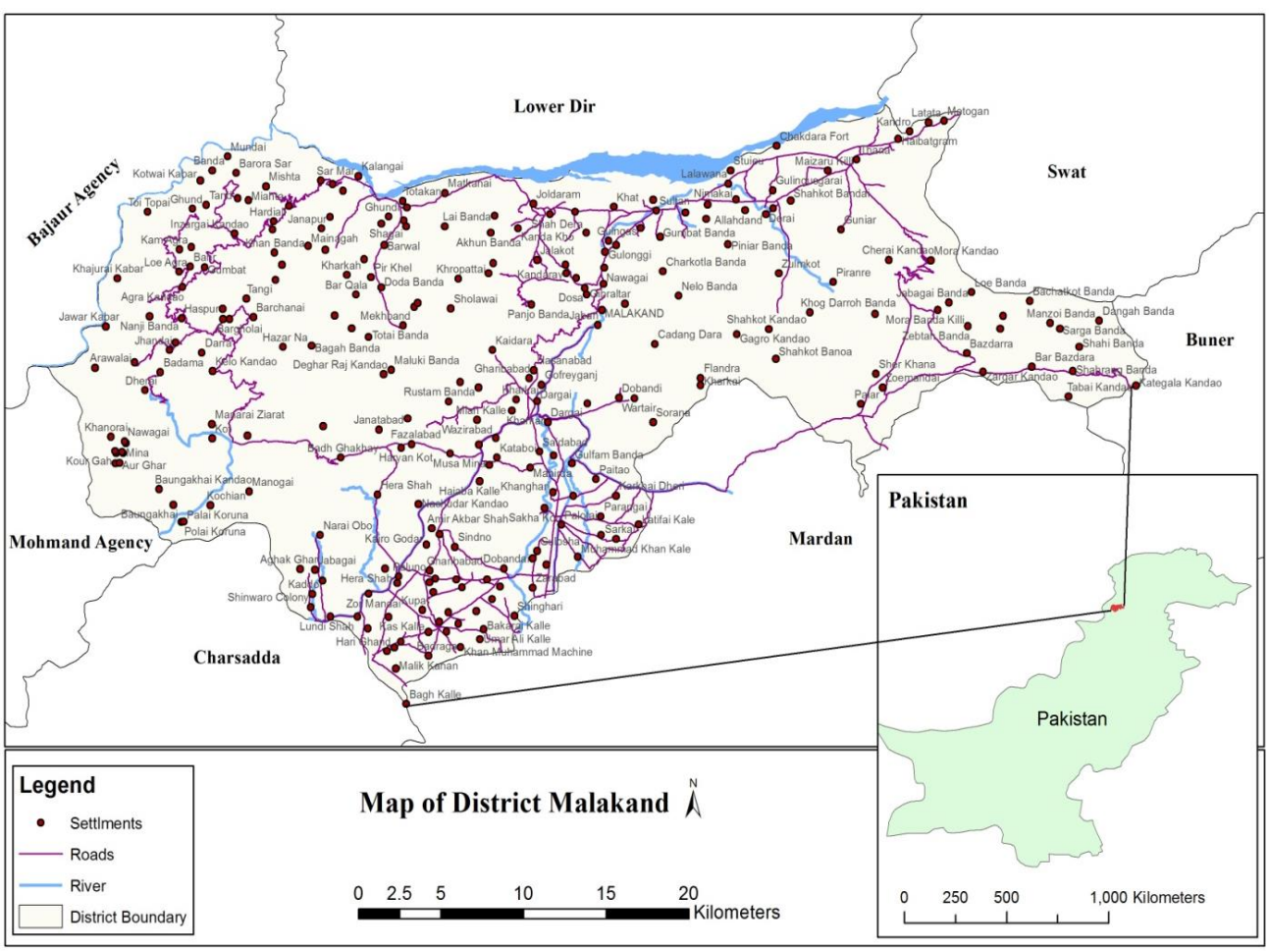

Fig. 1. Map of the study area showing various settlements - District Malakand, Pakistan.

Analytical data: A quantitative ecological technique i.e., quadrate method was used to analyze the distribution pattern, richness, assessment, abundance and rareness of weed species in relation to various edaphic factors and environmental gradients inhabiting the wheat crop. A total of 120 wheat fields were selected randomly. At each field ten square shaped quadrat (a total of 1200 quadrats) having size of 1×1m² were placed systematically (Clements, 1905; Khan *et al.,* 2012). In each quadrats number of weed species were counted and its phyto-sociological attribute i.e., density, relative density, frequency, relative frequency, cover, relative cover and importance values index were measured (Curtis & McIntosh, 1950, Khan *et al.,* 2013a). The IVI value for each species were obtained and compared with other species in order to obtain the dominant species in series of dominance for the formation of a specific community (Khan *et al.,* 2012; Khan *et al.,* 2013b; Khan *et al.,* 2014). All weed species were identified with the help of Flora of Pakistan and other literature (Nasir & Ali, 1972; Ali & Qaiser, 2004).

Soil analyses: A composite soil samples at 20 cm of soil depth were taken from each wheat field for physical and chemical analysis. During analysis soil pH, Electrical conductivity, organic matter, calcium carbonate concentration, soil texture, phosphorus, potassium, nitrogen, clay, silt, sand and TSS were measured through different techniques. Soil electrical conductivity and pH were measured by conductivity meter and pH meter using 1:5 soil water suspensions (Rhoades, 1996). It was determined by the Walky-Black procedure (Nelson & Sommers, 1982).The AB-DTPA extractable K and P in soils were determined by the method as described by Soltanpour (1985). Whereas soil textures were measured by hydrometer method given by Koehler *et al.* (1984).

Results

Preliminary results of present study revealed 132 weed species belongs to 42 plant families and 110 genera during spring season, 2014. The family Asteraceae was leading family having 17 genera with 18 species, followed by Poaceae (16 genera and spp. each), Brasicaceae (10 genera and 16 spp.), Boraginaceae (5 genera and 7 spp.) and Caryophyllaceae (6 genera and spp. each). Furthermore, the weed species i.e., *Cirsium arvense, Emex spinosa* and *Silybum marianum* of families Asteraceae and Polygonaceae were the supreme threatening weed species for wheat crop during harvesting period.

Total abundance of weed species in the study area: The weed species present in wheat fields with higher Important Value (IV) were documented by adding relative density and relative frequency of each species and obtained numerical values. The total weed species of the region were classified as top most abundant, less abundant and rare weed species. The top most abundant weed species with highest importance value (IVI) ranging from 100 and above. While less abundant weed species were those having IVI ranging from 02-100 and that of rare weed species has below 02 IV in the project area. These three categories were described as under in detail.

Top abundant weed species of the study area: The topmost abundant weed species of the region were *Anagallis arvensis* having IVI of 1101.45 followed by *Poa annua* with 1050.307 IVI. While other weed species in this succession were *Medicago denticulata* L., *Veronica polita, Fumaria indica, Coronopsis didynamia, Stellaria media, Scandix pecten-veneris, Cerastium fontanum, Cynodon dactylon, Vicia monantha* L., *Avena fatua, Arenaria serpyllifolia, Melilotus indicus, Galium aparine, Alyssum desertorum, Euphorbia helioscopia, Ranunculus muricatus, Cyperus rotundus, Cannabis sativa, Emex spinosa, Alopecurus myosuroides, Silene conoidea, Rumex dentatus, Oxalis corniculata, Capsella bursa-pastoris, Tullipa stelata, Convolvulus arvensis, Cirsium arvense* and *Vicia sepium* with IVI in order of succession were 916.2359, 782.5716, 664.7635, 646.7425, 421.9075, 390.7689, 382.2372, 352.904, 321.8395, 310.0684, 281.5621, 265.1194, 247.0972, 202.072, 194.548, 192.7295, 179.9345, 164.0622, 146.2605, 135.8298, 133.148, 130.6331, 126.7569, 118.9461, 113.4542, 110.4942, 103.2328 and 100.6085 respectively. These species were considered as the abundant weed species of the study area having IVI above 100 (Fig. 2).

Less abundant weed species of the region: The less abundant weed species were those having IVI above 1 up to 100 in the study area. A total of 61 weed species with highest to lowest Importance Value were observed. Among these *Lamium amplexicaule* (94.6435), *Papaver rhoeas* L. (94.16861), *Lathyrus aphaca* (94.03108), *Medicago polymorpha* (93.28775), *Lithospermum erythrorhizon* (90.8317), *Ranunculus arvensis* (88.51448), *Lathyrus sphaericus* (65.18547), *Chenopodium album* (59.27601), *Sisymbrium erysimoides* (54.28197), *Phleum paniculatum* (52.57824), *Calendula arvensis* (51.6082), *Phalaris minor* (50.90681), *Sorghum halepense* (49.48173), *Medicago minima* (40.31329), *Lolium temulentum* (36.05953), *Chenopodium murale* (35.77952), *Goldbachia laevigata* (34.80854), *Silybum marianum* (33.68665), *Lepidium pinnatifidum* (32.17223), *Mazus pumilus* (31.34474), *Persicaria glabra* (29.55596), *Artemisia vulgaris* (23.19904), *Bromus pectinatus* (22.82999), *Polygonum aviculare* (21.13378), *Polygonum plebeium* (20.1881), *Polygonum patulum* (19.57424), *Parthenium hysterophorus* (19.45669), *Spergula fallax* (19.24075), *Aristida adscensionis* (16.83564), *Plantago amplexicaulis* (15.94721), *Asphodelus tenuifolius* (15.02438), *Hypecoum pendulum* (14.4567), *Amaranthus viridis* (13.81813), *Carbenia benedicta* (13.0906), *Vicia benthamiana* (12.91644), *Swertia ciliata* (12.22907), *Launaea procumbens* (12.16989), *Carthamus oxyacantha* (11.40684), *Papaver hybridum* (10.84097), *Malcolmia africana* (10.16832), *Sonchus asper* (9.716043), *Sisymbrium altissimum* (9.586859), *Salvia hians* (9.2841), *Arnebia guttata* (7.373418), *Torilis nodosa* (6.628875), *Arnebia euchroma* (6.09949), *Ixiolirion tataricum* (5.998977), *Carthamus lanatus* (5.857494), *Taraxacum officinale* (4.882936), *Lactuca dissecta* (4.526365), *Rorippa montana* (3.841528), *Veronica anagallis-aquatica* (3.841528), *Malva neglecta* (3.78), *Valerianella muricata* (3.7442), *Dichanthium annulatum* (3.60599), *Cenchrus ciliaris* (2.5791), *Carex fedia* (2.5651), *Solanum surattense* (2.46), *Centaurea calcitrapa* (2.3538), *Heliotropium cabulicum* (2.02182) and *Sporobolus diander* (2.001064) were the less abundant weed species of the region (Fig. 3).

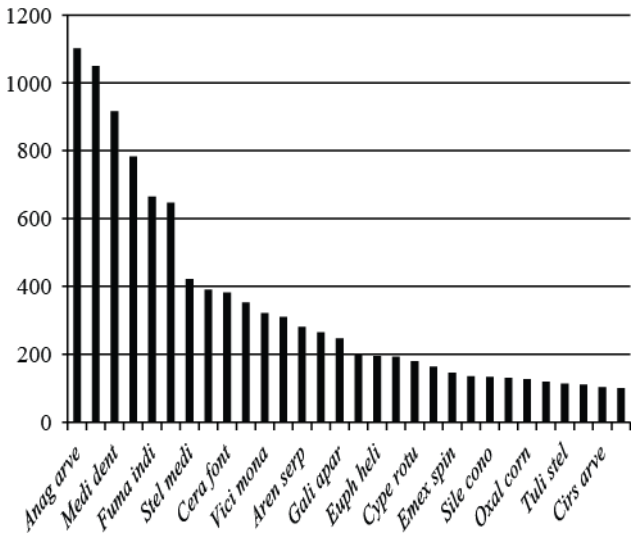

Fig. 2. Topmost abundant weed species of wheat crop in the District Malakand, Pakistan (with IVI=100 and above).

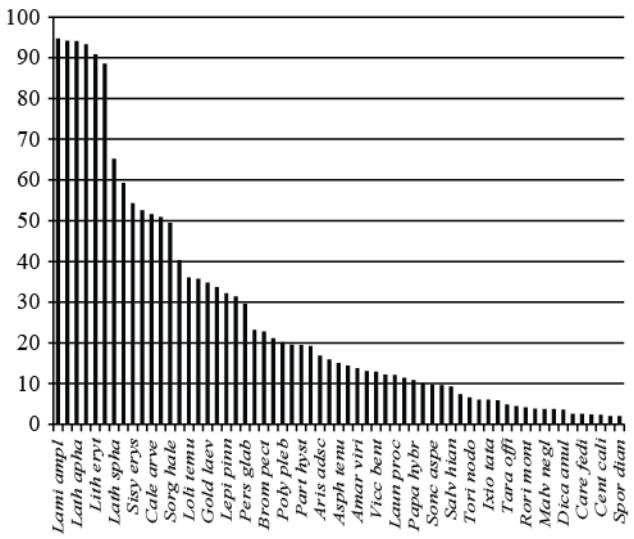

Fig. 3. Less abundant weed species in the winter wheat fields of District Malakand of KP, Pakistan.

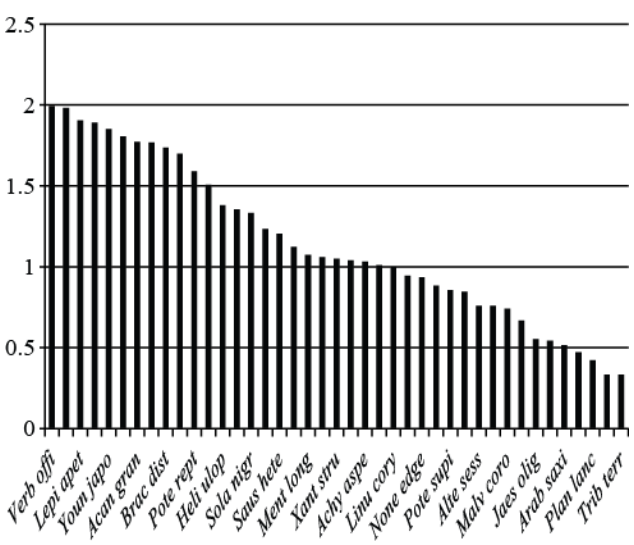

Fig. 4. Rare weed species of wheat crop in the District Malakand of Pakistan with minimum Importance Values.

Rare weed species in winter wheat crop of the district Malakand region: Species having IVI less than two were considered as rare species. It included *Verbena officinalis* (1.992041), *Geranium rotundifolium* (1.9819), *Lepidium apetalum* (1.9050), *Moraea sisyrinchium* (1.891096), *Youngia japonica* (1.8504), *Rottboellia exaltata* (1.8050), *Acanthophyllum grandiflora* (1.77211), *Oenothera rosea* (1.7671), *Brachypodium distachyon* (1.7358), *Lathyrus latifolius* (1.70022), *Potentilla reptans* (1.5895), *Nasturtium officinale* (1.5049), *Heliotropium polyphyllum* (1.3804), *Pseudognaphalium affine* (1.3535), *Solanum nigrum* (1.3315), *Boerhavia procumbens* (1.23500), *Saussurea heteromalla* (1.2055), *Verbascum Thapsus* (1.1217), *Mentha longifolia* (1.0738), *Juncus biflorus* (1.0605), *Xanthium strumarium* (1.0506), *Euphorbia prostrata* (1.0414), *Achyranthes aspera* L. (1.0303), *Sisymbrium heteromallum* (1.0097), *Linum corymbosum* (0.9970), *Verbena tenuisecta* (0.9442), *Nonea edgeworthii* (0.9354), *Polypogon fugax* (0.8835), *Potentilla supina* (0.8550), *Conyza bonariensis* (0.8454), *Alternanthera sessilis* (0.7592), *Lindelofia anchusoides* (0.7589), *Malvastrum coromandelianum* (0.7414), *Dicliptera roxburghiana* (0.6676), *Jaeskia oligosperma* (0.5543), *Iris decora* (0.5414), *Arabis saxicola* (0.5151), *Linum perenne* (0.4721), *Plantago lanceolata* (0.4233), *Tribulus terrestris* (0.3322) and *Eryngium caeruleum* (0.3322) (Fig. 4).

Weed species distribution pattern and occurrence in relation to number of fields: The species which occur in more than 100 fields were considered as most common species i.e., *Medicago denticulata* (112) and *Anagallis arvensis* (110). It was followed by dominant weed species that included *Fumaria indica* (99), *Veronica polita* (96), *Poa annua* (85), *Vicia monantha* (80), *Stellaria media* (79), *Coronopus didymus* (77), *Cynodon dactylon* (73) and *Scandix pecten-veneris* (70) with specific number of fields in succession. While the species that show their presence in one field only were considered as rare species. Rare weed species that were recorded during study includes *Achanthopylum grandiflorum, Achyranthes aspera, Alternanthera sessilis, Amaranthus viridis, Arabis saxicula, Boerhavia procumbense, Brachypodium distachya, Carex pendula, Xanthium strumarium* and *Malvastrum coromandelianum* (Appendix Table 1).

Communities of weed species: Cluster and Two way analyses of PC-ORD version 5 result five major weed communities. The detailed description of these weeds communities showing weed species composition, abundance and distribution pattern in the sampled area in relation to various environmental variables.

1. *Emex-Vicia-Lathyrus* weeds community: A total of twelve fields included in this community which mostly revealed plain area. It includes F1, F5, F6, F8, F9, F12, F13, F14, F22, F23, F30 and F31 fields of the study area. The highest numbers of weed species were recorded in field number 31 (a total of 22 weed species) having pH 8.1, electrical conductivity 0.06 dsm^{-1}, TSS 0.019%, Phosphorous 7.1 ppm, Potassium 8.1 ppm, Nitrogen 0.025%, organic matter 0.51%, $CaCO_3$ 5% with silt loam nature of soil. It was followed by fields number F22, F5, F9, F30, F12, F23, F13, F14, F1, F8 and F6 with 19, 18, 17, 17, 16, 16, 15, 15, 14, 13 and 12 weed species each in succession (Fig. 5).

Appendix table 1. A total of 132 weed species with number of presence in fields.

S. No.	Species	No of fields	S. No.	Species	No of fields
1.	*Medicago denticulata* L.	112	67.	*Arnebia guttata* Bung.	5
2.	*Anagallis arvensis* L.	110	68.	*Ixiolirion tataricum* (Pall.) Herb.	5
3.	*Fumaria indica* L.	99	69.	*Salvia hians* Royle ex Benth.	5
4.	*Veronica polita Fr.*	96	70.	*Swertia ciliata* (G. Don) B. L. Burtt	5
5.	*Poa annua* L.	85	71.	*Aristida adscensionis* L.	4
6.	*Vicia monantha* L.	80	72.	*Artemisia vulgaris* L.	4
7.	*Stellaria media* (L.) Vill.	79	73.	*Chenopodium murale* L.	4
8.	*Coronopis didynamis* L.	77	74.	*Lactuca dissecta* D.Don	4
9.	*Cynodon dactylon* (L.) Pers.	73	75.	*Sisymbrium altissimum* L.	4
10.	*Scandix pecten-veneris* L.	70	76.	*Torilis nodosa* (L.) Gaertn.	4
11.	*Galium aparine* L.	69	77.	*Lathyrus latifolius* L.	3
12.	*Cerastium fontanum* Baumg.	66	78.	*Taraxacum officinale* (L.) Weber ex F.H. Wigg	3
13.	*Avena fatua* L.	65	79.	*Valerianella muricata*	3
14.	*Alyssum desertorum* Stapf	59	80.	*Arnebia euchroma* (Royle) I.M. Johnst.	2
15.	*Cyperus rotundus* L.	59	81.	*Carthamus lanatus* L.	2
16.	*Euphorbia helioscopia* L.	57	82.	*Conyza bonariensis* L.	2
17.	*Ranunculus muricatus* L.	51	83.	*Dichanthium annulatum* (Forssk.) Stapf	2
18.	*Rumex dentatus* L.	50	84.	*Geranium rotundifolium* L.	2
19.	*Silene conoidea* L.	50	85.	*Malva neglecta* Waller.	*2*
20.	*Convolvulus arvensis* L.	47	86.	*Mentha longifolia* (L.) Huds.	2
21.	*Medicago polymorpha* L.	47	87.	*Moraea sisyrinchium* Ker Gawl.	2
22.	*Melilotus indicus* (L.) All.	46	88.	*Nonea edgeworthii* A.DC.	2
23.	*Arenaria serpyllifolia* L.	40	89.	*Sporobolus diander* (Retz.) P. Beauv	2
24.	*Capsella bursa-pastoris* (L.) Medik.	39	90.	*Verbascum thapsus* L.	2
25.	*Cannabis sativa* L.	38	91.	*Veronica anagallis-aquatica* L.	2
26.	*Lathyrus aphaca* L.	38	92.	*Xanthium strumarium* L.	2
27.	*Emex spinosa*	37	93.	*Acanthophyllum grandiflora* Desf.	1
28.	*Oxalis corniculata* L.	36	94.	*Achyranthes aspera* L.	1
29.	*Lithospermum erythrorhizon* Siebold & Zucc.	34	95.	*Alternanthera sessilis* (L.) R.Br. ex DC.	1
30.	*Ranunculus arvensis* L.	34	96.	*Amaranthus viridis* L.	1
31.	*Calendula arvensis* (Vaill.) L.	28	97.	*Arabis saxicola* Edgew.	1
32.	*Cirsium arvense* (L.) Scop.	28	98.	*Boerhavia procumbens* Banks ex Roxb	1
33.	*Vicia sepium* L.	27	99.	*Brachypodium distachyon* (L.) P.Beauv.	1
34.	*Chenopodium album* L.	24	100.	*Carex fedia Nees*, Contr. Bot	1
35.	*Lamium amplexicaule* L.	24	101.	*Cenchrus ciliaris* L.	1
36.	*Silybum marianum* (L.) Gaertn.	22	102.	*Centaurea calcitrapa* L.	1
37.	*Lolium temulentum* L.	20	103.	*Dicliptera roxburghiana* (L.) Juss.	1
38.	*Sorgham halipense* (L.) Pers.	20	104.	*Eryngium caeruleum* L.	1
39.	*Tulipa stellata* Red.	19	105.	*Euphorbia prostrata* Aiton	1
40.	*Phalaris minor* Retz.	18	106.	*Heliotropium cabulicum* Bunge in Bull. Soc.	1
41.	*Golbachea laevegata*	17	107.	*Heliotropium polyphyllum* Lehm.	1
42.	*Hypecoum pendulum* L.	16	108.	*Iris decora* Wallich, Pl. Asiat. Rar.	*1*
43.	*Papaver rhoeas* L.	16	109.	*Jaeskia oligosperma*	1
44.	*Lathyrus sphaericus* Retz.	13	110.	*Juncus biflorus* Elliott	1
45.	*Parthenium hysterophorus* L.	13	111.	*Lindelofia anchusoides* (Lindl.) Lehm.	1
46.	*Asphodelis tenupolies*	12	112.	*Linum corymbosum* Reichenb.	1
47.	*Lepedium penatipedum*	12	113.	*Linum perenne* L.	1
48.	*Mazus pumilus* Lour.	12	114.	*Lepidium apetalum* Willd., Sp	1
49.	*Carbenia benedicta* L.	10	115.	*Malvastrum coromandelianum* (L.) Garcke.	1
50.	*Persicaria glabra*	10	116.	*Nasturtium officinale* R. Br. in Aiton,	1
51.	*Polygonum plebeium* R.Br.	10	117.	*Oenothera rosea* L' Her. ex Ait.	*1*
52.	*Sisymbrium erysimoides* Desf.	10	118.	*Plantago lanceolate* L.	1
53.	*Alopecurus myosuroides* Huds.	9	119.	*Polypogon fugax* Ness ex Steud.	1
54.	*Malcolmia Africana* (L.) R.Br.	9	120.	*Potentilla supina* Linnaeus, Sp.	1
55.	*Medicago minima* L.	9	121.	*Potentilla reptans* L.	1
56.	*Plantago amplexicaulis* Cav.	9	122.	*Pseudognaphalium affine* (D. Don) Anderberg	1
57.	*Sonchus asper* (L.) Hill	9	123.	*Rorippa montana* (Wall. ex Hook. f. & T.)	1
58.	*Bromus pectinatus* Thunb., Prodr.	8	124.	*Rottboellia exaltata* L.	1
59.	*Polygonum aviculare* L.	8	125.	*Saussurea heteromalla* (D.Don) Hand.	1
60.	*Carthamus oxyacantha* L.	7	126.	*Sisymbrium heteromallum* C. A. Meyer	1
61.	*Launaea procumbens* Roxb.	7	127.	*Solanum nigrum* L.	1
62.	*Phleum paniculatum* Hudson, Fl. Angl	7	128.	*Solanum surattense* Burm.	1
63.	*Spergula fallax* L.	7	129.	*Tribulus terrestris* L.	1
64.	*Vicia benthamiana* Ali	7	130.	*Verbena officinalis* L.	1
65.	*Papaver hybridum* L.	6	131.	*Verbena tenuisecta* Briq.	1
66.	*Polygonum patulum* M. Bieb.	6	132.	*Youngia japonica* (L.) DC.	1

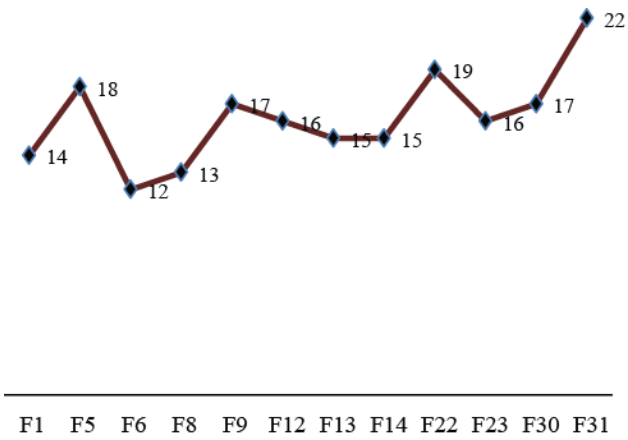

Fig. 5. Total number of fields showing number of species in the 1st weed species community.

The most abundant weed species of this community were *Fumaria indica* with IVI of 195.97, *Anagallis arvensis* (127.12), *Scandix pecten-veneris* (115.24), *Cynodon dactylon* (101.44), *Emex spinosa* (95.08), *Vicia monantha* L. (91.37), *Avena fatua* (68.93), *Vicia sepium* (54.30), *Lathyrus sphaericus* (53.90) and *Galium aparine* (50.58). At the same time the top 10 rare weed species of the community were *Solanum nigrum* (1.33), *Lolium temulentum* (1.16), *Verbena tenuisecta* (0.94), *Papaver hybridum* (0.72), *Malcolmia africana* (0.67), *Dicliptera roxburghiana* (0.667), *Verbascum thapsus* (0.667), *Conyza bonariensis* (0.50) and *Linum perinea* (0.47).

The soil state of this community comprehend $CaCO_3$ 2-6.5%, organic matter 0.2-0.51%, Nitrogen 0.01-0.026%, phosphorous 2.2-7.6 ppm, potassium 80–150 ppm, pH 7.7–8.3, electrical conductivity 0.01–0.07 dsm^{-1} and TSS 0.003–0.022% (Fig. 6).

2. *Alysum-Cannabis-Lithospermum* weeds community: A total of 39 fields included in this community belong to Tehsil Dargai and Tehsil Batkhila, mostly comprise plain as well as mountainous area of the district Malakand. It includes F3, F17, F20, F21, F25, F26, F29, F32, F33, F81, F82, F83, F84, F85, F86, F87, F88, F89, F90, F91, F92, F93, F94, F95, F96, F97, F100, F101, F108, F109, F110, F112, F113, F114, F115, F116, F117, F119 and F120 fields. The highest numbers of various weed species were recorded in field number 83 (a total of 35 weed species) with pH 8, electrical conductivity 0.38 dsm^{-1}, Phosphorous 8.31 ppm, Potassium 66 ppm, Nitrogen 0.0034%, organic matter 0.069%, $CaCO_3$ 2.5% with sandy loamy nature of soil. It was followed by F81, F93 (with 33 different weed species each) and F87 (32 species) (Fig. 7).

Quantitative analyses of weed species via calculating IV the top most abundant weed species of this community were *Anagallis arvensis* (374.41 IVI), *Veronica polita* (299.29), *Medicago denticulata* L. (256.08), *Arenaria serpyllifolia* (195.10), *Avena fatua* (184.67), *Scandix pecten-veneris* (177.73), *Fumaria indica* (170.92), *Vicia monantha* L. (166.10), *Alyssum desertorum* (146.25) and *Poa annua* (144.77) correspondingly in succession. The top 10 rare weed species were *Chenopodium murale* (0.529 IVI), *Polygonum plebijam* (0.504), *Moraea sisyrinchium* (0.4699), *Verbascum thapsus* (0.454), *Plantago lanceolata* (0.4233), *Swertia ciliata* (0.382), *Torilis nodosa* (0.357), *Conyza bonariensis* (0.343), *Eryngium caeruleum* (0.332) and *Tribulus terrestris* (0.332).

Soil nature of this community revealed $CaCO_3$ which ranges from 0.5-15%, organic matter 0.6-1.03%, Nitrogen 0.003-0.05%, Phosphorous 4.2–25.1 ppm, Potassium 24–200 ppm, pH 7–8.5 and electrical conductivity 0.02–1.10 dsm^{-1} which play a vital role in weed species distribution and its richness of this community (Fig. 8).

3. *Oxalis-Lathyrus-Chenopodium* weed community: This weed community revealed a total of 23 winter wheat fields i.e., F2, F4, F7, F10, F11, F15, F24, F28, F35, F36, F39, F40, F41, F44, F45, F46, F47, F48, F49, F51, F54, F64, and F111, respectively. The highest number of species was found in field number F11 (22 various weeds) with pH 8, electrical conductivity 0.07 dsm^{-1}, Phosphorous 6.8 ppm, Potassium 150 ppm, Nitrogen 0.02%, organic matter 0.41%, $CaCO_3$ 8% and TSS 0.022% with silt loam of soil. It was followed by F24, F40 and F64 with 19 weed species each (Fig. 9).

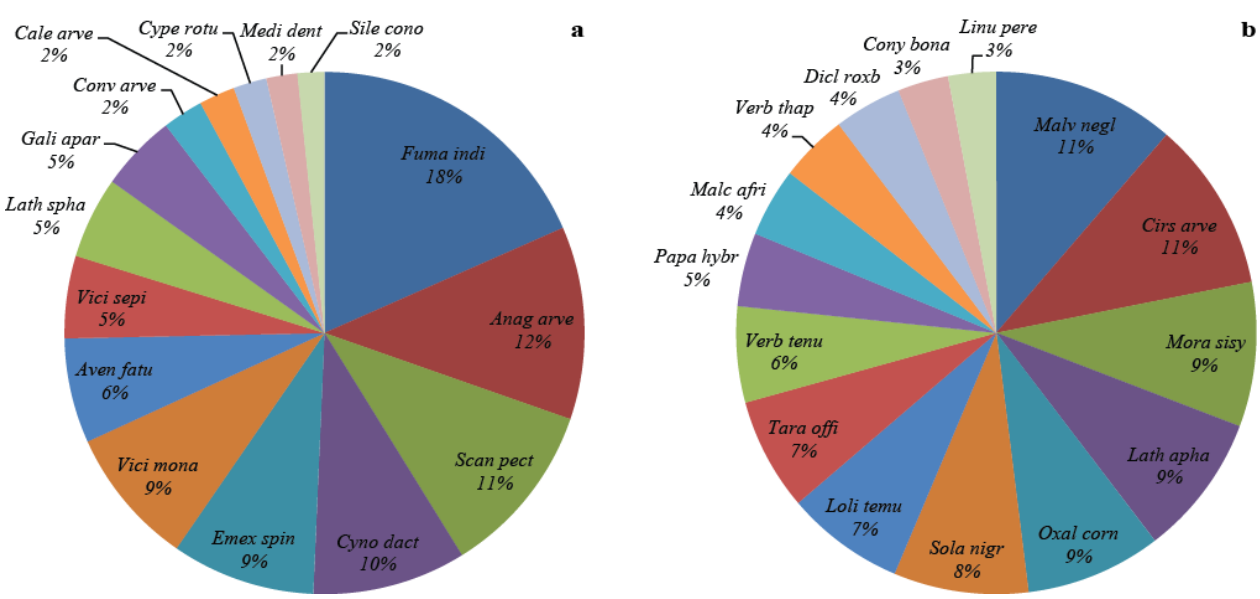

Fig. 6. Percentage of topmost abundant (a) and rare (b) weed species of 1st weeds community.

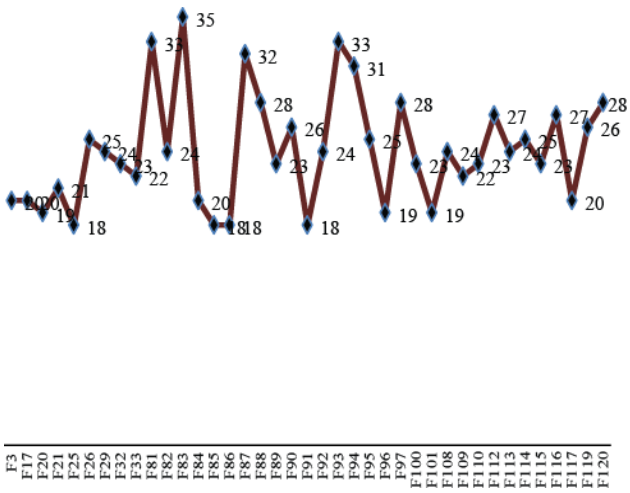

Fig. 7. Total number of weed species in different fields of 2nd weeds community in the region of Malakand Pakistan.

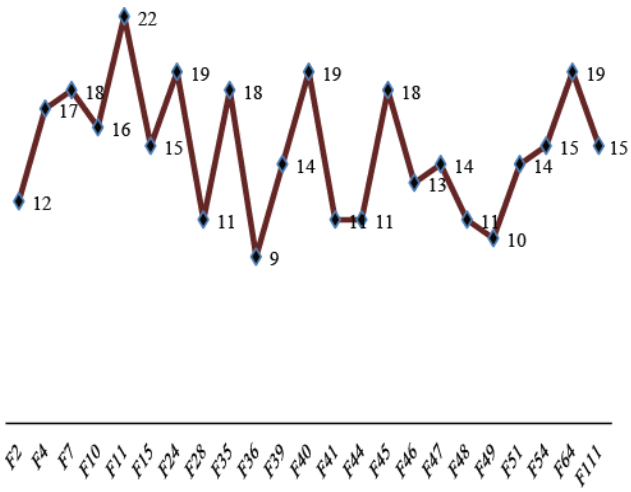

Fig. 9. Distribution of weed species in different fields community-3.

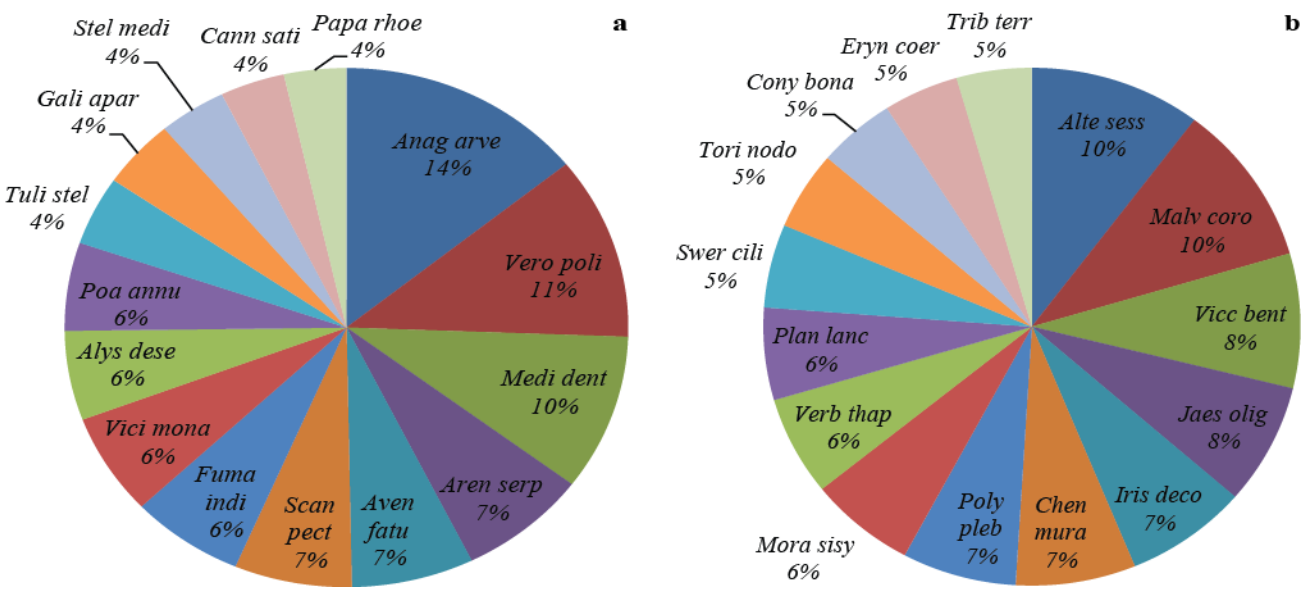

Fig. 8. Percentage of (a) abundant and (b) rare weed species of the 2nd weed community.

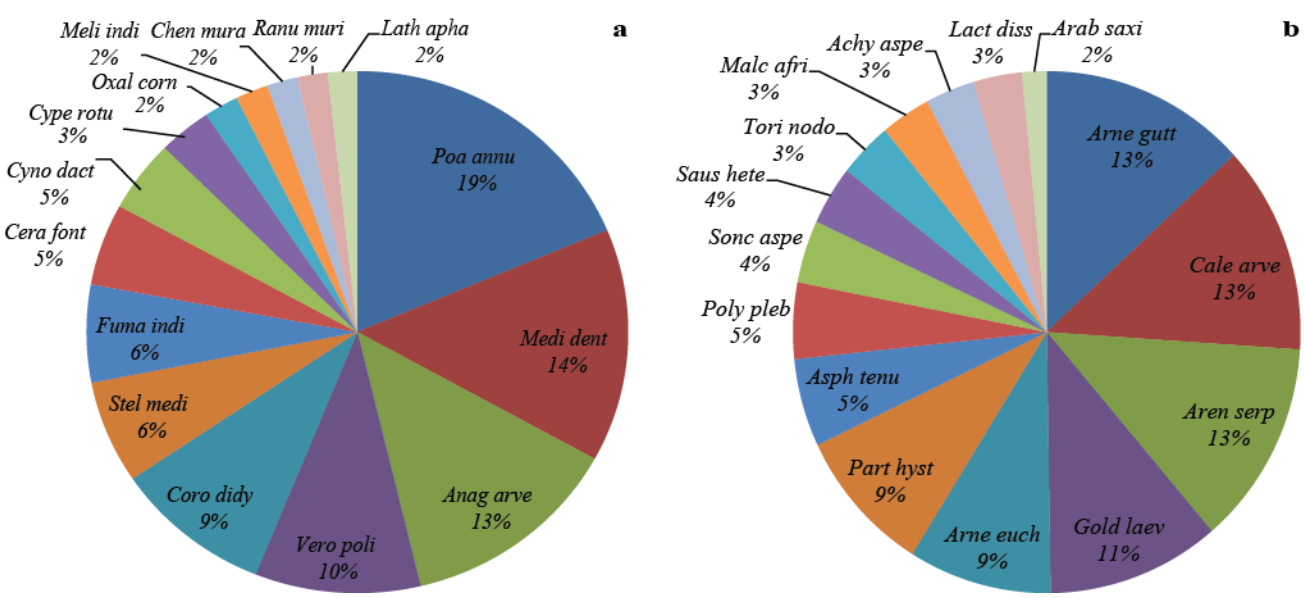

Fig. 10. Percentage of (a) abundant and (b) less abundant weed species of the 3rd weeds community.

The most abundant weed species of this community included *Poa annua* with IVI of 356.30, *Medicago denticulata* L. (275.83), *Anagallis arvensis* (252.04), *Veronica polita* (188.744), *Coronopus didymus* (180.20), *Stellaria media* (121.52), *Fumaria indica* (115.54), *Cerastium fontanum* (96.78), *Cynodon dactylon* (85.09) and *Cyperus rotundus* (60.04). While at the same time the rare weed species were *Parthenium hysterophorus* with IVI (2.976), *Asphodelus tenuifolius* (1.808), *Polygonum plebijam* (1.557), *Sonchus asper* (1.281), *Saussurea heteromalla* (1.205), *Torilis nodosa* (1.138), *Malcolmia africana* (1.048), *Achyranthes aspera* L. (1.030), *Lactuca dissecta* (1.026) and *Arabis saxicola* (0.515) with minimum IVI in succession.

The soil concentration revealed $CaCO_3$ 0.5-8.7%, organic matter 0.6-0.75%, Nitrogen 0.003-0.034%, phosphorous 2.2–11.4 ppm, potassium 44–200 ppm, pH 7.5–8.2, electrical conductivity 0.0021–1.66 dsm^{-1} and TSS 0.002–0.028% which play a vital role in weed species distribution (Fig. 10).

4. *Euphorbia-Cerastium-Capsella-bursa* weed community: The entire thirty seven fields revealed this community. It includes F16, F18, F19, F27, F34, F37, F38, F42, F43, F50, F52, F53, F55, F56, F57, F58, F59, F60, F61, F62, F64, F65, F66, F67, F68, F69, F70, F71, F72, F73, F74, F75, F76, F77, F78, F79 and F80. The highest numbers of weed species were found in field number F80 with a total of 30 species. The edaphic condition of this field showed pH 7.5, electrical conductivity 0.09 dsm^{-1}, Phosphorous 8.1 ppm, Potassium 141 ppm, Nitrogen 0.027%, organic matter 0.23%, $CaCO_3$ 8.7% and TSS 0.032% with sandy loam. It was followed by the fields number F53, F63, F69 and F79 with 28 weeds species each (Fig. 11).

The most abundant top 10 weed species of the community were *Poa annua* with total IVI (384.59), *Coronopus didymus* (377.36), *Anagallis arvensis* (325.38), *Medicago denticulata* L. (282.26), *Veronica polita* (274.24), *Cerastium fontanum* (199.86), *Melilotus indicus* (193.26), *Stellaria media* (183.70) and *Fumaria indica* (178.77) respectively in succession. In addition to, the rare weed species with minimum IVI were *Linum perenne* with IVI (0.997), *Torilis nodosa* (0.996), *Carbenia benedicta* (0.933), *Lithospermum erythrorhizon* (0.826), *Launaea procumbens* (0.761), *Lindelofia anchusoides* (0.758), *Mentha longifolia* (0.642), *Plantago amplexicaulis* (0.630), *Carthamus oxyacantha* (0.613) and *Lepidium pinnatifidum* (0.549).

The soil analyses of this community comprehend $CaCO_3$ 2.5-11.5%, organic matter 0.23-0.82%, Nitrogen 0.012- 0.044%, phosphorous 1.7–27.1 ppm, potassium 90–450 ppm, pH 7.5–8.4, electrical conductivity 0.01–1.66 dsm^{-1} and TSS 0.006–0.038% (Fig. 12).

5. *Alopecurus-Mazus-Persicaria* weed species community: A total of nine fields belong to Tehsil Batkhila were included in this community. It includes F98, F99, F102, F103, F104, F105, F106, F107 and F118 wheat fields. The highest numbers of weed species were recorded in F118 (28 weeds) having pH 6.6, electrical conductivity 0.059 dsm^{-1}, Phosphorous 7.9 ppm, Potassium 34 ppm, Nitrogen 0.0069%, organic matter 0.138% and $CaCO_3$ 0.5%. It was followed by the fields number F103 with 27 weed species (Fig. 13).

The most abundant weed species of this community were *Poa annua* with total IVI (164.63), *Alopecurus myosuroides* (135.82), *Medicago denticulata* L. (81.394), *Scandix pecten-veneris* (56.18) *Coronopus didymus* (48.142), *Ranunculus muricatus* (33.438), *Arenaria serpyllifolia* (30.556), *Rumex dentatus* (30.270), *Ranunculus arvensis* (27.493) and *Mazus pumilus* (22.847). The top 10 rare weed species of the community with IVI below one were *Medicago polymorpha* (1.365), *Pseudognaphalium affine* (1.353), *Polypogon fugax* (0.883), *Potentilla supina* (0.855), *Lamium amplexicaule* (0.641), *Silene conoidea* (0.641), *Medicago minima* (0.470), *Mentha longifolia* (0.430) and *Sonchus asper* (0.430) respectively in region.

The soil analyses of this community realized $CaCO_3$ 0.5-3.5%, organic matter 0.06-1.65%, Nitrogen 0.034-0.082%, phosphorous 5.81–10 ppm, potassium 34–162 ppm, pH 6.6–7.8 and electrical conductivity 0.05–0.33 dsm^{-1} that have a significant role in weed species composition and abundance (Fig. 14).

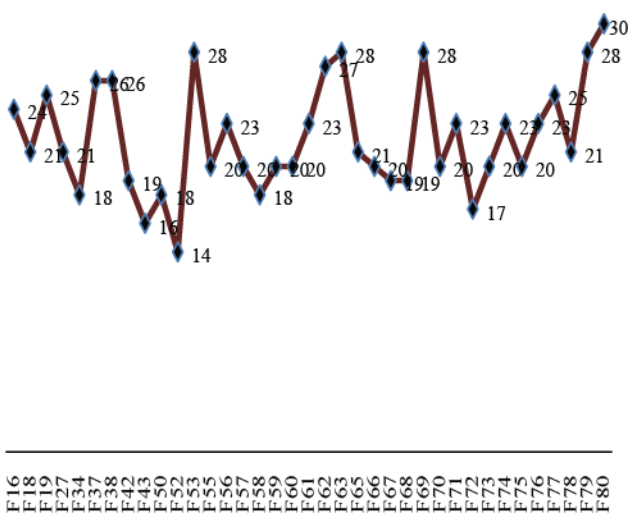

Fig. 11. Distribution of total weed species in the fields constituting community-4.

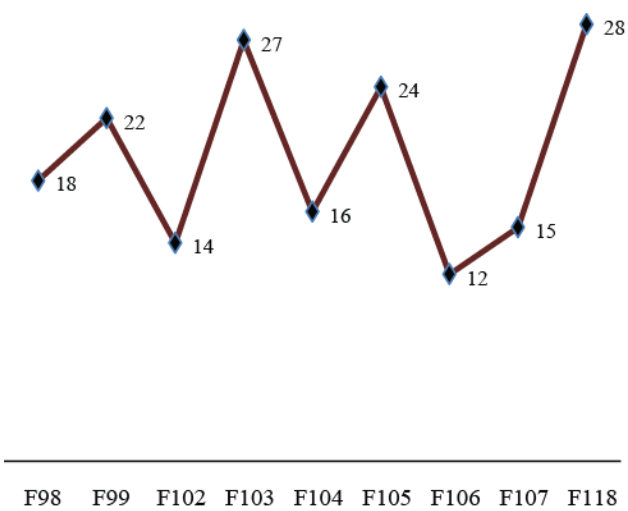

Fig. 13. Total number of weed species in relation to each fields of the fifth weed community.

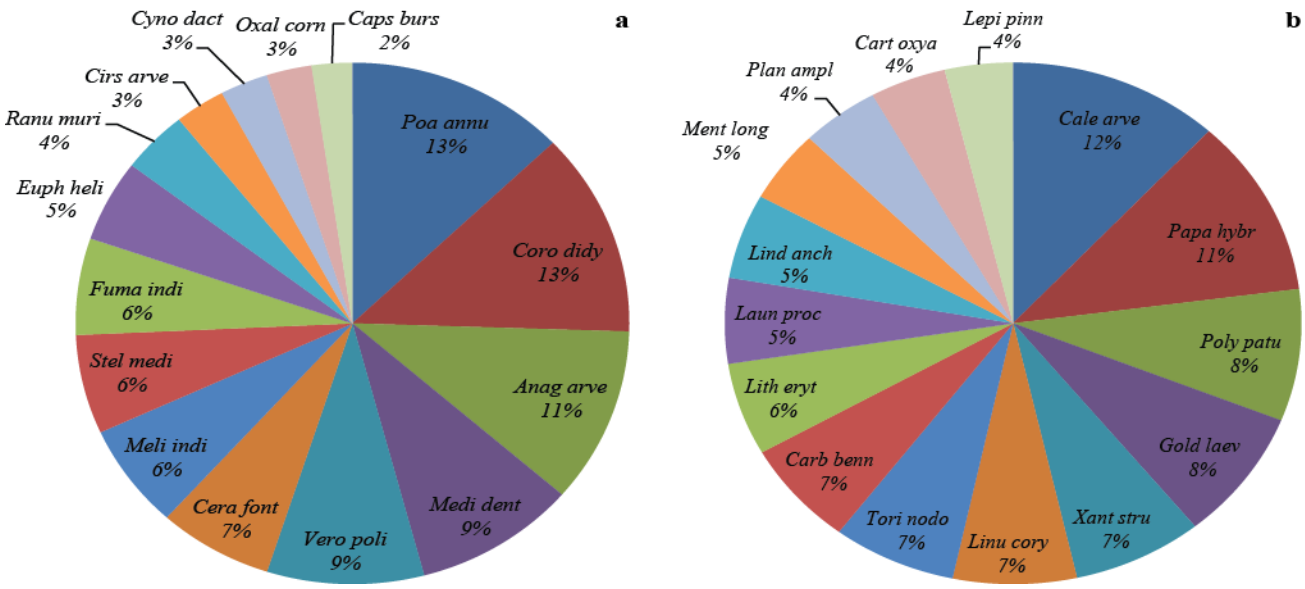

Fig. 12. (a) abundant and (b)less abundant weed species of 4th weed community.

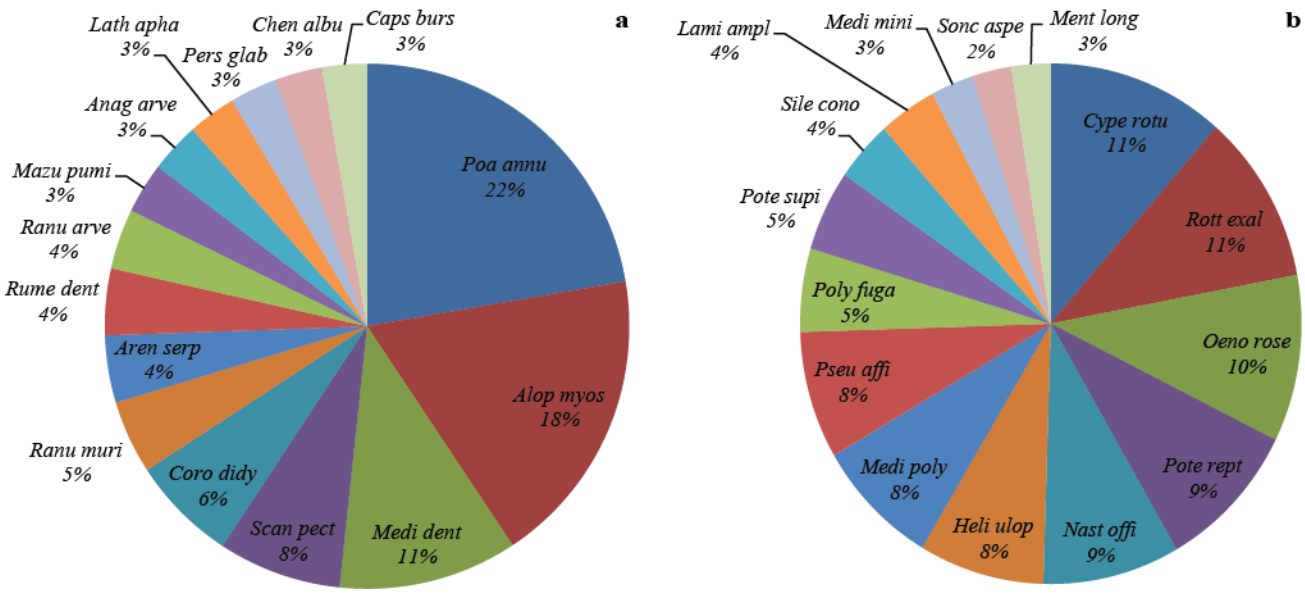

Fig. 14. Percentage composition of (a) abundant and (b) rare weed species of the community - 5 in winter wheat crop of Malakand.

Discussion

Weed species distribution, composition, grouping and classification were attributed to various parameters of environment. Weeds comprehend variability in different kinds of winter wheat fields in District Malakand. It was owing to different kinds of edaphic conditions, soil geography and farming practices. The finding of present study could be helping hand to recognize various kinds of weed species, their distribution and abundance. Such kind of scientific approach could further help the agriculture department to sort out novel scientific management practices for the control of weed species. Because, different weed species need various type of management techniques/practices. Present study revealed a total of 132 weed species belongs to 42 plant families and 110 genera in winter wheat crop of District Malakand. The family Asteraceae was leading family having 17 genera with 18 species, followed by Poaceae (16 genera and spp. each), Brasicaceae (10 genera and 16 spp.), Boraginaceae (5 genera and 7 spp.) and Caryophyllaceae (6 genera and spp. each). Furthermore, the weed species *Cirsium arvense, Emex spinosa* and *Silybum marianum* of families Asteraceae and Polygonaceae were the supreme threating weed species for wheat crop during harvesting period. Comparing with Hadi *et al.* (2014) where they recorded a total of 31 weeds belonged to 15 families and 27 genera from the upper Chitral, Pakistan. In addition, Ahmad *et al.* (2016a) reported 29 weed species belonging to 15 families. Among them Poaceae, Amaranthaceae were the most dominant families followed by Asteraceae and Cucurbitaceae with *Cyperus rotundus* (IVI more than 2000) highly abundant weed species from district Mardan. Whereas, Ibrar *et al.* (2003) reported 36 weed species from Abbottabad district that can be compared with present finding in terms of species diversity and distribution pattern. In present study *Parthenium hysterophorus* (19.45669 IVI) was among the rare species in the study area with $CaCO_3$ 0.5-8.7%, organic matter 0.6-0.75%, Nitrogen 0.003-0.034%, phosphorous 2.2–11.4 ppm,

potassium 44–200 ppm, pH 7.5–8.2, electrical conductivity 0.0021–1.66 dsm^{-1} and TSS 0.002–0.028% soil condition. Comparing with Khan *et al.* (2013) and Ahmad *et al.* (2016) where they reported *Parthenium hysterophorus* was well abundant weed (IVI ≥ 115). Wazir *et al.* (2014) reported *Portulaca oleracea* and *Amaranthus viridis* with higher electrical conductivity form N. Waziristan Agency, like present work also reported *Amaranthus viridis* as a rare and less abundant (13.81813) weed species. The present study revealed *Cynodon dactylon* (101.44 IVI), *Stellaria media* (121.52 IVI), *Fumaria indica* (115.54 IVI), *Cyperus rotundus* (60.04 IVI) and *Achyranthes aspera* L. (1.030 IVI) with $CaCO_3$ 0.5-8.7%, Nitrogen 0.003-0.034%, potassium 44–200 ppm, pH 7.5–8.2 and electrical conductivity 0.0021–1.66 dsm^{-1} environmental variables. Similarly Khatam *et al.* (2013) and Ahmad *et al.* (2016b) reported the same plant species under the influence of higher pH, electrical conductivity, canal irrigation and artificial farming practice variables.

In addition to, environmental variables like phytogeography, soil chemical and physical composition, climatic factors, season, type of crops, sowing time in combination with various kind of farming practices were the various parameters effecting weed species composition. Many such kinds of studies have been undertaken to study the composition of weeds in arable land. Like Hallgren *et al.* (1999), Lososova *et al.* (2004), Silc, (2008) have attributed weed species differences on arable land to the type of crop, farming practices and its management. Numerous research have been undertaken to point out the weed species differences in cereal and root crops (Ferro, 1990, Hüppe & Hofmeister, 1990, Glemnitz *et al.*, 2000, Lososová *et al.*, 2006). Other studies of such kind were also conducted on single weed species. Hanaa *et al.* (2014) investigated the effect of various environmental variables on the distribution of *Malva parviflora* by the application of TWINSPAN and DECORANA as classification and ordination techniques. The present study revealed the dominant, abundant, less abundant and rare weed species on the basis of IVI. Such kind of study was conducted in Iran on grasses distribution on the basis of relative dominance of grass species (Hassannejad & Ghisvandi, 2013). The soil moisture contents, pH, E.C, $CaCO_3$, phosphorus and altitude shows variance for different kinds of fields. Thus, it indicates similar results to find such indicator variables for the variation in distribution and diversity of weed species in wheat fields of the District Malakand Pakistan. Our findings also matches with the study conducted in Dun valley of India in which six weeds communities were identified on the basis of TWINSPAN (Gupta *et al*., 2008). In such study the soil moisture, soil pH and altitude were considered as the most influential factor in recognizing weed species diversity and distribution. In current study more weed diversity was observed when increase in the number of fields within 200 meters of area. In our finding there is much diversity in habitat and landscape. Such diversity is in the form of irrigated wheat fields and un-irrigated wheat fields. Another factor in the distribution and abundance of weed species in our study is presence of mountainous and plain area in the region. Like, Landscape heterogeneity also effects the distribution and diversity of the weed species (Gaba *et al*., 2010).Such kind of variety of habitat types increases the chance of survival of weed species.

It was concluded that among edaphic factor electrical conductivity, soil texture, pH, organic matter, $CaCO_3$, phosphorous and nitrogen concentration were the strong environmental variables that gives rise to diverse weed species richness, abundance and their distribution pattern. Our findings suggest a revised management farming practices plan and the recognition and identification of various weed species and communities in the District Malakand, Pakistan.

Acknowledgement

To conduct these studies, the partial financial support through project No. 4047/NRPU of HEC and URF-QAU is greatly acknowledged.

References

Abbas, Z., S.M. Khan, J. Alam, S.W. Khan and A.M. Abbasi. 2017. Medicinal plants used by inhabitants of the Shigar Valley, Baltistan region of Karakorum range-Pakistan. *J. Ethnobiol. Ethnomed*., 13(1): 53.

Ahmad, Z., S.M. Khan, E.F. Abd_Allah, A.A. Alqarawi and A. Hashem. 2016. Weed species composition and distribution pattern in the maize crop under the influence of edaphic factors and farming practices: A case study from Mardan, Pakistan. *Saudi J. Biol. Sci*., 23(6): 741-748.

Ahmad, Z., S.M. Khan, S. Ali, I.U. Rahman, H. Ara, I. Noreen and A. Khan. 2016a. Indicator species analyses of weed communities of maize crop in district Mardan, Pakistan. *Pak. J. Weed Sci. Res.*, 22(2): 227-238.

Ali, A., M.A. Khan, A. Saleem, K.B. Marwat, A. U. Jan, D. Jan and S. Sattar. 2016. Performance and economics of growing maize under organic and inorganic fertilization and weed management. *Pak. J. Bot*., 48(1): 311-318.

Ali, A., M.A. Khan, A. Saleem, K.B. Marwat., A.U. Jan., D. Jan and S. Sattar. 2016. Performance and economics of growing maize under organic and inorganic fertilization and weed management. *Pak. J. Bot.*, 48(1): 311-318.

Ali, S. and M. Qaiser. 2004. Flora of Pakistan, Department of Botany, University of Karachi.

Baker, H.G. 1965. Characteristics and mode of origin of weeds. In: *The genetics of colonizing species*, (Eds.): Baker, H.G. and G.L. Stebbins. Academic Press New York, USA, pp. 147-172.

Boutin, C., A. Baril and P.A. Martin. 2008. Plant diversity in crop fields and woody hedgerows of organic and conventional farms in contrasting landscapes. *Agric. Ecosyst. Environ.*, 123: 185-193.

Clements, F.E. 1905. *Research methods in ecology*. University Publishing Company.

Curtis, J.T. and R.P. McIntosh. 1950. The interrelations of certain analytic and synthetic phytosociological characters. *Ecology*, 31(3): 434-455.

Ferro, G. 1990. Revisione della vegetazione segetale mediter-ranea ed europea dell'ordine Secalietalia.–*Braun-Blanquetia*., 6: 1-59.

Gaba, S., B. Chauvel, F. Dessaint, V. Bretagnolle and S. Petit. 2010. Weed species richness in winter wheat increases with landscape heterogeneity. *Agric. Ecosyst. Environ.*, 138(3): 318-323.

Glemnitz M., G. Czimber, L. Radics and J. Hoffmann. 2000. Weed flora composition along a north-south climate gradient in Europe. *Acta Agronom. Óváriensis*., 42: 155-169.

Gupta, A., S.P. Joshi and R.K. Manhas. 2008. Multivariate analysis of diversity and composition of weed communities of wheat fields in Doon Valley, India. Ecological Research

Laboratory, Department of Botany, D.A.V. (PG) College, Dehra Dun, 248007(Utterkhand). *India. J. Tropic. Ecol.*, 49(2): 103-112.

Hadi, F., M. Ibrar, G. Dastagir, M. Arif, K. Naveed and M. Adnan. 2014. Weed diversity in wheat and maize with special reference to their ethnomedicinal uses at rich valley, Hindukush range, Chitral, Pakistan. *Pak. J. Weed Sci. Res.*, 20(3): 335-346.

Hallgren, E., W.M. Palmer and P. Milberg. 1999. Data diving with cross-validation: An investigation of broad-scale gradients in Swedish weed communities. *J. Ecol*., 87: 1037-1051.

Hanaa, S., Shehata and T.M. Galal. 2014. Phytosociology and phytochemical screening of the medicinal weed *Malva parviflora* L. *Life Sci. J*., 11(6): 458-468.

Hassannejad, S. and B. Ghisvandi. 2013. Grasses distribution in wheat fields Tbriz-Iran and recorded Schlerochloa woronowii (Hack.) Tzvelev as a new weed species for flora of Iran. *Technical J. Engg. Appl. Sci.*, 22(3): 3119-3124.

Hassannejad, S. and S.P. Ghafarbi. 2013. Weed flora survey of Tabriz wheat (*Triticum aestivum* L.). *J. Biodivers. Environ. Sci.*, 3(6): 118-132.

Holm, L.G., J.V. Pancho, J.P. Herberger and D.L. Plucknett. 1979. *A Geographic Atlas of World Weeds.* Wiley- Inter science, New York.

Hüppe, J and H. Hofmeister. 1990. Syntaxonomische Fassung und Übersicht über die Ackerunkrautgesellschaften der Bundesrepublik Deutschland. – Ber. d. Reinh. *Tuexen-Ges.*, 2: 61-81.

Ibrar, M. 2003. Ethobotanic study of the weeds of five crops in district Abbottabad, N-W Pakistan. *Pak. J. Weed Sci. Res.*, 9(3-4): 229-240.

Ijaz, F., Z. Iqbal, I.U. Rahman, J. Alam, S.M. Khan, G.M. Shah, K. Khan and A. Afzal. 2016. Investigation of traditional medicinal floral knowledge of Sarban Hills, Abbottabad, KP, Pakistan. *J Ethnopharmacol.*, 179: 208-233.

Iqbal, M., S.M. Khan, M.A. Khan, I.U. Rahman, Z. Abbas and Zahidullah. 2015. Exploration and inventorying of weeds in wheat crop of the district Malakand, Pakistan. *Pak. J. Weed Sci. Res*., 21(3): 435- 452.

Iqbal, M., S.M. Khan, M.A. Khan, Z. Ahmad and H. Ahmad. 2018. A novel approach to phytosociological classification of weeds flora of an agro-ecological system through Cluster, Two Way Cluster and Indicator Species Analyses. *Ecol. Indic.*, 84: 590-606.

Kakhki, S.H.N., M.M. Moeini, S.H. Najad, H. Jafary and M. Aleefard. 2013. Weed population indices in irrigated wheat fields of Zanjan Province of Iran. Pak. *J. Weed Sci. Res*., 19(2): 123-156.

Kashmir, S., M.A. Khan, A. A. Shad, K.B. Marwat and Haroon Khan. 2016. Temperature and salinity affect the germination and growth of *Silybummarianum* Gaertn and *Avenafatua* L. *Pak. J. Bot*., 48(2): 469-476.

Khan, M.A., R.A. Afridi, S. Hashim, A.M. Khattak, Z. Ahmad, F. Wahid and B.S. Chauhan. 2016. Integrated effect of allelochemicals and herbicides on weed suppression and soil microbial activity in wheat (*Triticum aestivum* L.). *Crop Protec*., 90: 34-39.

Khan, M.A., S. Kakar, K.B. Marwat and I.A. Khan. 2013. Differential response of *Zea mays* L. in relation to weed control and different macronutrient combinations. *Sains Malaysiana*., 42(10): 1405-1411.

Khan, M.A., S.M. Khan, S.M. Khan, I. Hussain, S.A. Khan, M. Liaqat, M. Saeed and S. Ali, 2017. Species diversity and ethno botanical study of Allai valley in the Western Himalayan region of Pakistan. *Pak. J. Weed Sci. Res*., 23(2): 207-220.

Khan, S.M. 2012. Plant communities and vegetation ecosystem services in the Naran Valley, Western Himalaya (Doctoral dissertation, University of Leicester).

Khan, S.M., D.M. Harper, S. Page and H. Ahmad. 2011b. Residual value analyses of the medicinal flora of the western Himalayas: The Naran Valley, Pakistan. *Pak. J. Bot.*, 43: 97-104.

Khan, S.M., H. Ahmad, H. Shaheen and D. Harper. 2014. Ethno-ecological importance of plant biodiversity in mountain ecosystem with special emphasis on indicator species of a Himalayan valley in the northern Pakistan. *Ecol. Indic.*, 37: 175-185.

Khan, S.M., S. Page, H. Ahmad and D.M. Harper. 2013. Identifying plant species and communities across environmental gradients in the Western Himalayas: Method development and conservation use. *J. Ecol. Inform.*, 14: 99-103.

Khan, S.M., S. Page, H. Ahmad and D.M. Harper. 2013b. Sustainable utilisation and conservation of plant biodiversity in mountain ecosystems; using the Western Himalayas as a case study. *Ann. Bot.*, 112: 479-501.

Khan, S.M., S. Page, H. Ahmad H. Shaheen and D. Harper. 2012. Vegetation dynamics in the western Himalayas, diversity indices and climate change. *Sci. Tech. and Dev.*, 31: 232-243.

Khan, S.M., S. Page, H. Ahmad, Z. Ullah, H. Shaheen, M. Ahmad and D.M. Harper. 2013a. Phyto-climatic gradient of vegetation and habitat specificity in the high elevation Western Himalayas. *Pak. J. Bot.*, 45: 223-230.

Khan, W., S.M. Khan, H. Ahmad, Z. Ahmad and S. Page. 2016. Vegetation mapping and multivariate approach to indicator species of a forest ecosystem: A case study from the Thandiani sub Forests Division (TsFD) in the Western Himalayas. *Ecol. Indic.*, 71: 336-351.

Khatam, A., M. Zafarullah, K. Nawab, I.A. Main and W. Ahmad. 2013. Effect of various herbicides and Manual control on yield, yield components and weeds of maize. *Pak. J. Weed Sci. Res.*, 19(2): 209-216.

Koehler, F., C. Moudre. and B. McNeal. 1984. Laboratory manual for soil fertility. *Washington State University Pulman, USA*.

Lososova, Z., M. Chytry, I. Kuhn, O. Hajek, V. Horakova, P. Pysek and L. Tichy. 2006. Patterns of plant traits in annual vegetation of man-made habitats in central Europe. *Perspect. Plant Ecol.*, 8: 69-81.

Lososova, Z., M. Chytry, S. Cimalova, Z. Kropac, Z. Otypkova, P. Pysek and L. Tichy. 2004. Weed vegetation of arable land in Central Europe: gradients of diversity and species composition. *J. Veg. Sci.*, 15: 415-422.

Mehmood, A., A.H. Shah, A.H. Shah, S.M. Khan, I.U. Rahman and H. Ahmad. 2017. Floristic List and Indigenous Uses of Poaceae Family in District Tor Ghar, Khyber Pakhtunkhwa, Pakistan. *J. Appl. Environ. Biol. Sci*., 7(6):169-177.

Nasir, E. and S.I. Ali. 1972. Flora of West Pakistan. Karachi, Pakistan: Fakhri Printing Press, 1-1028.

Nelson, D. and L. Sommers. 1982. Total carbon, organic carbon, and organic matter. *Methods of soil Analysis, part 2. ASA 9, 2nd edition.*

Noor, R., S.M. Khan, F. Ahmad, M. Hussain, E.F. Abd_Allah, A.A. Alqarawi, A. Hashem and A. Aldubise. 2017. The morpho-agronomic characterization study of Lens culinaris germplasm under salt marsh habitat in Swat, Pakistan. *Saudi J. Biol. Sci*.

Rahman, A., F. Korejo, V. Sultana, J. Ara and S. Ehteshamulhaque. 2017. Induction of systemic resistance in cotton by the plant growth promoting rhizobacterium and seaweed against charcoal rot disease. *Pak. J. Bot*., 49: 347-353.

Rhoades, J.D. 1996. Salinity: Electrical conductivity and total dissolved solids.*Methods of Soil AnalysisPart 3-Chemical Methods*, (methodsofsoilan3), pp. 417-435.

Saeed, M., Z. Huang, H. Huang, S. Wei, C. Zhang, S. Hashim and K.B. Marwat. 2016. Effect of spatial arrangement and density on weed infestation and yield of maize (*Zea mays* L.). *Pak. J. Bot*., 48(3): 1203-1207.

Sciegienka, J.K., E.N. Keren and F. D. Menalled. 2011. Interaction between two Biological control agents and an herbicide for Canada Thistle (*Circium arvence*) suppression. Invasive Plant Sci. Manage.

Silc, U., S. Vrbničanin, D. Božić, A. Čarni and Z. D. Stevanović. 2008. Classification of weed vegetation in the north western Balkans. *Phytocoenologia*, 38: 241-254.

Soltanpour, P. 1985. Use of ammonium bicarbonate DTPA soil test to evaluate elemental availability and toxicity 1. *Communications in Soil Science & Plant Analysis*,16(3): 323-338.

Sun, Y., S. Zheng, J.K. Lee and S.K. Hong. 2017. Genetic variations and relationships of cultivated and weedy types of Perilla species in Korea and Japan using multi DNA markers. *Pak. J. Bot.*, 49(4):1449-1458.

Wazir, R., A. Muhammad, M. Subhan, I. Khan, M. Ali and M.S. Khan. 2014. Morpho-anatomical features of weed flora of rainfed Maize fields in Mir ali, North Waziristan Agency, Pakistan. *Pak. J. Weed Sci. Res*., 20(3): 385-403.

Weibull, A.C., O. Ostman and A. Granqvist. 2003. Species richness in agroecosystems: The effect of landscape, habitat and farm management. *Biodivers.Conserv.*, 12: 1335-1355.

Zhou, P., T.X. Tang., P. Zhao and J. Chen 2016. Soil microbes and successful invasions of an exotic weed Eupatorium adenophorum L. *Pak. J. Bot.*, 48(2): 753-762.

(Received for publication 17 September 2016)