



King Saud University

Saudi Journal of Biological Sciences

www.ksu.edu.sa  
www.sciencedirect.com



## ORIGINAL ARTICLE

# 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



Zeeshan Ahmad<sup>a</sup>, Shujaul Mulk Khan<sup>a</sup>, Elsayed Fathi Abd\_Allah<sup>b,\*</sup>, Abdulaziz Abdullah Alqarawi<sup>b</sup>, Abeer Hashem<sup>c,d</sup>

<sup>a</sup> Department of Plant Sciences, Quaid-i-Azam University, Islamabad, Pakistan

<sup>b</sup> Department of Plant Production, Collage of Food & Agricultural Sciences, P.O. Box. 2460, Riyadh 11451, Saudi Arabia

<sup>c</sup> Department of Botany and Microbiology, Faculty of Science, King Saud University, Riyadh 11451, Saudi Arabia

<sup>d</sup> Mycology & Plant Dis. Survey Dept., Plant Pathol. Res. Institute, ARC, Giza, Egypt

Received 15 April 2016; revised 3 July 2016; accepted 11 July 2016

Available online 18 July 2016

## KEYWORDS

Weeds;  
Maize;  
Edaphic factors;  
Farming practices;  
Distribution pattern;  
Two Way Cluster Analyses;  
Indicator species

**Abstract** Weeds are unwanted plant species growing in ordinary environment. In nature there are a total of 8000 weed species out of which 250 are important for agriculture world. The present study was carried out on weed species composition and distribution pattern with special reference to edaphic factor and farming practices in maize crop of District Mardan during the months of August and September, 2014. Quadrates methods were used to assess weed species distribution in relation to edaphic factor and farming practices. Phytosociological attributes such as frequency, relative frequency, density, relative density and Importance Values were measured by placing 9 quadrates ( $1 \times 1 \text{ m}^2$ ) randomly in each field. Initial results showed that the study area has 29 diverse weed species belonging to 27 genera and 15 families distributed in 585 quadrats. Presence and absence data sheet of 29 weed species and 65 fields were analyzed through PC-ORD version 5. Cluster and Two Way Cluster Analyses initiated four different weed communities with significant indicator species and with respect to underlying environmental variables using data attribute plots. Canonical Correspondence Analyses (CCA) of CANOCO software version 4.5 was used to assess the environmental gradients of weed species. It is concluded that among all the edaphic factors the strongest variables were higher concentration of potassium, organic matter and sandy nature of soil. CCA

\* Corresponding author.

E-mail address: [eabdallah@ksu.edu.sa](mailto:eabdallah@ksu.edu.sa) (E.F. Abd\_Allah).

Peer review under responsibility of King Saud University.



Production and hosting by Elsevier

<http://dx.doi.org/10.1016/j.sjbs.2016.07.001>

1319-562X © 2016 The Authors. Production and hosting by Elsevier B.V. on behalf of King Saud University.

This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

plots of both weed species and sampled fields based on questionnaire data concluded the farming practices such as application of fertilizers, irrigation and chemical spray were the main factors in determination of weed communities.

© 2016 The Authors. Production and hosting by Elsevier B.V. on behalf of King Saud University. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

## 1. Introduction

Weeds are the part of dynamic ecosystems, start off in ordinary environment and become obstacle to the crops (Baker, 1974). Weeds are unwanted plant species emergent in the cultivated crops and grow where they are not needed. Out of 8000 only 250 weed species are important for agriculture world (Holm et al., 1979). Weeds cause great destruction to crops as they increase the costs of different cultural practices, decrease the effectiveness of agricultural equipment and excellence of fertile lands, decrease the germination capability of crops seed due to the phytotoxins or allelochemicals (Algandaby and Salama, 2016). Weeds have some pinpointing characters, such as short seed dormancy, high seed germination rate, environmental plasticity, fast seedling growth and reproductive capability, short span of life cycle, self-compatibility, efficient and well organized methods of seed desparation, manufacturing of diverse types of allelochemicals and tolerance to abiotic and biotic stresses (Baker, 1974; El-Sheikh, 2013). It allows the weed species to survive and grow in different ecological habitats. Due to this weeds are becoming dominant all over the world (Holm et al., 1979, 1997) and damage the local biodiversity (Duke, 1983; Tilman, 2000).

*Zea mays* is cross pollinated, annual, short day plant of the earth. In Pakistan maize is progressively gaining more significant position in crop husbandry due to its higher yield potential and short development period (Khan et al., 2011a,b; Olsen et al., 2006). The maize crop faces lots of difficulty because the farmers typically give more importance to a small number of cultural practices and ignore other factors resembling as weed control and seed rate. In Pakistan during 2012–13 maize yields 36.581 m ton production in a total of 0.981 m ha cultivated area and in the same year in KPK maize yields 1.468 m ton product in 0.512 m ha cultivation area. A number of weed species that are the tough competitors, compete for existing resources with the maize crop (Al-Shahwan et al., 2016; Gomaa, 2012; Malik et al., 2006). This competition is most grim and significantly decreases maize product at early crop growing period (Mitchell and Tu, 2005).

The present study analyzed the ecological relationship among the distribution of weed communities and their environmental factor in Shahbaz Ghari, District Mardan, Pakistan. It also reveals the weed species types and its distribution pattern, composition and abundance along with the edaphic factor and farming practices that determine the distribution of the weed species and communities in the study area.

## 2. Materials and methods

Shahbaz Ghari is a Union Council of District Mardan, Khyber Pakhtunkhwa located on mardan sawabi road having an area of 3956 hac. The people of an area mostly depend on agriculture. Important crop of the area includes Maize and wheat. For the

first time the present study was carried out to find out the relationship among weed species, edaphic factors and farming practices in maize crop of Shahbaz Ghari District Mardan during the month of August and September 2014. Different stations were recognized at random intervals on both sides of the road at different distance using quantitative ecological techniques. Quadrat having  $1 \times 1 \text{ m}^2$  size and square shape were placed systematically in the projected area (Shahbaz Garhi) and data collected from different stations (Clements, 1905; Khan et al., 2011a,b, 2012). In each field nine quadrats were positioned and density, frequency, relative density, relative frequency and Importance Values were measured respectively (Curtis and McIntosh, 1950). Associated data i.e., soil data for testing and different methods were based to ask various questions from farmers to collect information concerning farming practices. Weed plant specimens were collected, labeled with tags and pressed in plant presser. After drying the plant specimen were poisoned and mounted on standard herbarium sheets. Specimens were identified using available literature (Ali and Qaiser, 1995; Khan et al., 2014, 2013a,b). The specimens were deposited in the Herbarium of Hazara University Mansehra Pakistan.

### 2.1. Soil collection

A total of sixty-five soil samples were collected up to one feet depth from different fields. These soil samples were placed in plastic bags, brought to laboratory; air dried and ground to form one composite sample. The analysis concerned with the physiochemical properties of these soil samples was carried out in the agriculture research laboratory Mansehra. During soil analysis the soil pH, electrical conductivity (E.C.), organic matter, calcium carbonate concentration, soil texture, phosphorus and potassium parameters were measured. Soil pH and electrical conductivity were measured using 1:5 soil water suspension by pH meter and conductivity meter respectively (Rhoades et al., 1990). Soil texture was determined by the walky-black procedure and texture class was determined with the help of a textural triangle (Adamu and Aliyu, 2012). Organic Matter was determined by the hydrometer method. (Koehler et al., 1984; Nelson et al., 1996).

### 2.2. Data analyses

The data of 585 quadrats were put in MS EXCEL to prepare presence and absence data sheet for Cluster and Two Way Cluster Analysis. The weed data, soil and questionnaire data were analyzed through PC-ORD version 5 to find out the effect of edaphic factor and farming practices on weed species distribution and composition pattern. Through CANOCO software version 4.5 data attribute plots were derived to find out the effect of multivariate environmental, edaphic factor and farming practices on weed species plus the position of indicator species in each region (Khan et al., 2012, 2013b).

3. Results

A total of 29 weed species were collected from 585 quadrats belonging to 27 genera and 15 families in maize crop of Union Council Shahbaz Garhi District Mardan. Poaceae and Amaranthaceae were the leading families having 4 weed species (13.8%) each. The *Cyperus rotundus* and *Urochloa panicoides* are the abundant while *Lactuca dissecta* and *Cucurbita maxima* are the less abundant weed species of study area.

3.1. Two way cluster analysis

Two Way Cluster analysis (TWCA) derived from presence and absence data sheet (1, 0) by Sorensen measures to classify the pattern of weed species at various regions. Four weed communities identified as a result of grouping of stations of fields which might be obviously seen in two major parts of the dendrogram in Two Way Cluster (Fig. 1).

3.2. Environmental gradient

The weed species and environmental data matrix that are with soil data, questionnaire data and questionnaire plus soil data combined were put in CANOCO software version 4.5. It resulted in significant effects of all the environmental variables on weed species composition and diversity. The environmental variables were treated as aspect pH, electrical conductivity, organic matter concentration, calcium carbonate, sand, silt, clay, phosphorous, potassium and textural class. It resulted

that there was a little significant effect of first canonical axis and show full significant effect of all canonical axes. Weed species with questionnaire data was analyzed in CANOCO software version 4.5 and significant effects of first canonical axis on weed species composition and diversity were found. At last all the weed species are compared with environmental data, questionnaire and soil data through CANOCO software version 4.5 that resulted in significant effects of first and test of all canonical axes with soil and questionnaire variables on weed species composition and diversity of study area (Table 1).

**Table 1** Summary table of Canonical Correspondence Analyses (CCA).

Axes	1	2	3	4	Total inertia
Eigen values	0.067	0.051	0.032	0.026	0.638
Species-environment correlations	0.721	0.767	0.680	0.665	
Cumulative percentage variance of species data	10.5	18.4	23.4	27.4	
Species-environment relation	26.4	46.6	59.1	69.3	
Summary of Monte Carlo test (499 permutations under reduced model)					
Test of significance of first canonical axis	Test of significance of all canonical axes				
Eigen value	0.067	Trace			0.252
F-ratio	4.906	F-ratio			1.250
P-value	0.1100	P-value			0.0220

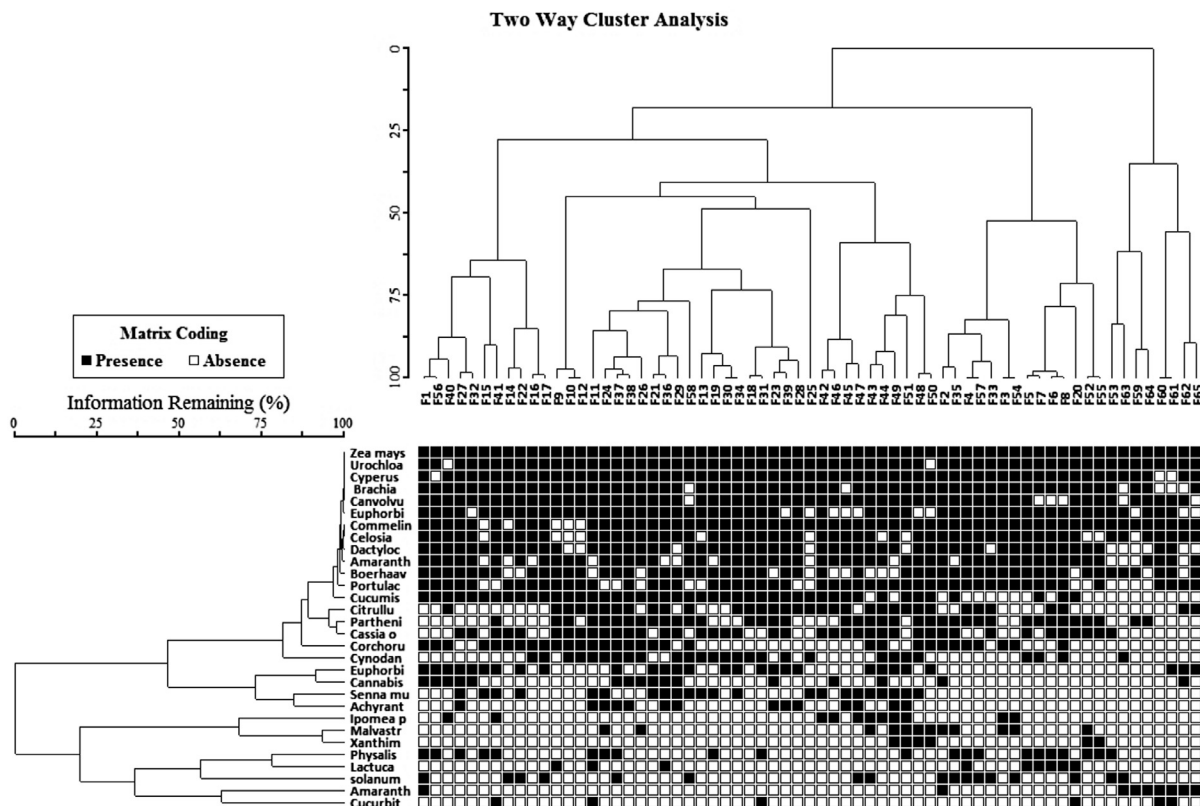


Figure 1 Two Way Cluster Analysis of 65 maize fields and 29 weed species through PC-ORD.

### 3.3. Classification of weed species communities

Four weed communities identified as a result of grouping of stations or fields. By studying the communities one by one in relation to various soil related variables and different farming practices we can draw the following conclusions.

#### 3.3.1. *Celosia* – *Convolvulus* – *Euphorbia* weed community

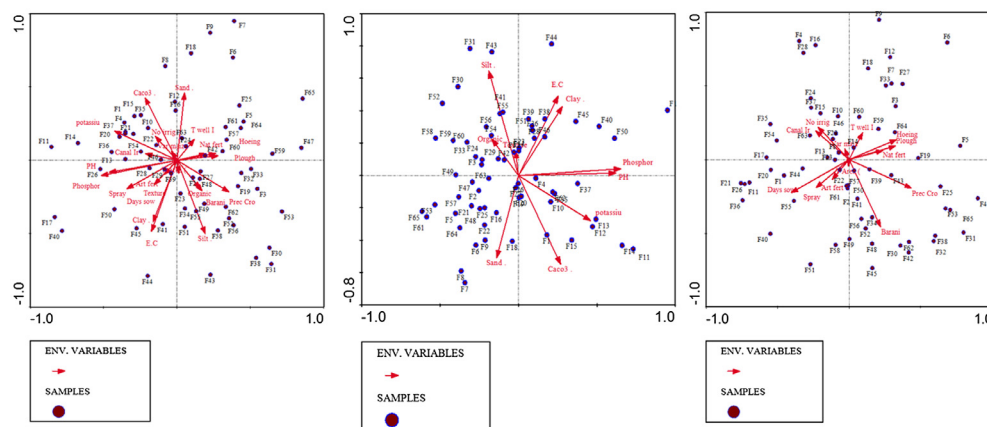
The mainly abundant weed species of this community are *Convolvulus arvensis*, *Dactyloctenium aegyptium*, *C. rotundus*, *Brachiaria ramosa* and *U. panicoides* with high Importance Values, while at the same time less abundant weed species are *Amaranthus blitoides*, *Achyranthes aspera*, *C. maxima*, *Citrullus lanatus* and *Cynodon dactylon* having low Importance Values in the region. When field's data are analyzed by CCA plot, with soil composition data (Fig. 2) it was concluded, the main significant variable of first community are higher concentration of  $\text{CaCO}_3$ , pH and potassium, while CCA plot based on questionnaire data (Fig. 2) shows farming practices such as application of fertilizers (increase in number), chemical spray and early sowing are the main factors in determination of this

community. The CCA of both questionnaire and soil data (Fig. 2) reconfirm the validity of our observations that indicates high concentration of  $\text{CaCO}_3$ , pH, potassium and demonstrate more number of irrigation.

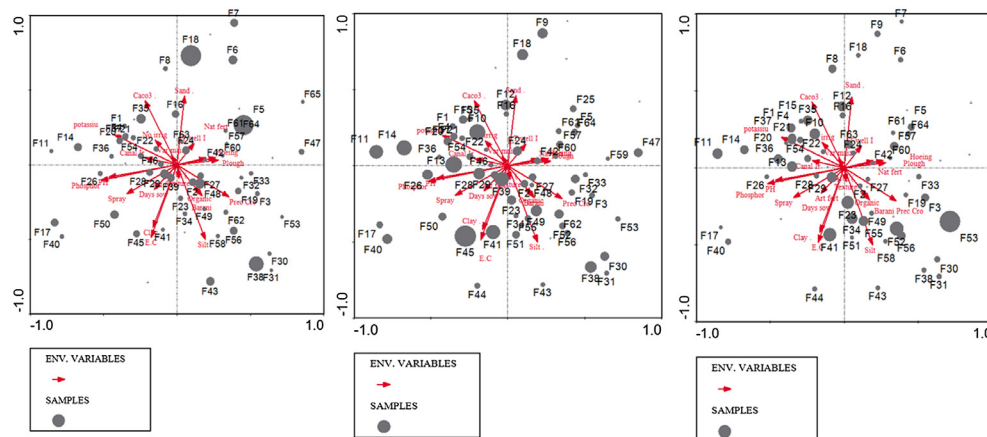
Data attribute plots using CCA for top 3 indicator species of community – 1 i.e., *Celosia argentea* with indicator values 45.9 and 26.6, *C. arvensis* with Indicator value 53.7, 21.2 and *Euphorbia prostrata* 45.9 and 22.2 in the case of pH and phosphorous respectively. Indicator value of *C. argentea* is 47.1, *C. arvensis* with 49.8 and *E. prostrata* with 42.7 in the case of spray farming practices (Appendix Table A) (Fig. 3).

#### 3.3.2. *Archyanthes* – *Ipomea* – *Physalis* weed community

The *U. panicoides*, *C. rotundus*, *D. aegyptium*, *B. ramosa* and *Commelina benghalensis* are the most abundant whereas *X. strumarium*, *Physalis angulata*, *Solanum nigrum*, *L. dissecta* and *C. maxima* are less abundant weed species of 2nd community. The soil data of community 2 were analyzed through CCA (Fig. 2). It results that the main significant variables are higher concentration of electrical conductivity, potassium and clay nature of soil, while questionnaire data (Fig. 2)



**Figure 2** Canonical Correspondence Analysis (CCA) diagram showing distribution of 65 fields in relation to various measured environmental variables with questionnaire and soil data respectively.



**Figure 3** Data attribute plot (from left to right) of *Celosia argentea* (1st indicator species), *Convolvulus arvensis* (2nd indicator species) and *Euphorbia prostrata* (3rd indicator species) showing its position in respect to different fields and associated environmental variables.

concluded higher concentration of moist, application of artificial fertilizers and spray farming practice as compared to others communities. At last CCA plots of both questionnaires and soil data were analyzed (Fig. 2) that again proved the community has high deliberation of electrical conductivity, potassium, clay nature of soil, relevance of artificial fertilizers and chemical spray.

Data attribute plots using CCA for top 3 indicator species of community – 2 i.e., *A. aspera*, *Ipomea purpurea* and *P. angulata* show indicator values of 11.9, 8.6 and 19.9 in the case of electrical conductivity and 11.5, 17.5, 28.1 indicator values of canal irrigation farming practice respectively in the region (Appendix Table A) (Fig. 4).

3.3.3. *Corchorus – Lactuca – Commelina* weed community

The most abundant weed species based on Importance Values are *B. ramosa*, *D. aegyptium*, *C. rotundus*, *C. benghalensis* and *U. panicoides*. Despite the abundant weed species the *I. purpurea*, *A. blitoides*, *C. maxima*, *X. strumarium*, and *Cannabis sativa* are less abundant weed species of community. In light

of CCA plot, where we used only soil data (Fig. 2) it is accomplished that the noteworthy variable are sandy nature of soil and organic matter concentration. With help of CCA then questionnaire data (Fig. 2) of community 3 were analyzed which show the main significant variables of the maximum number of irrigation, irrigated by canal and different varieties of maize crop cultivated. Then the CCA of both questionnaire and soil data (Fig. 2) were analyzed that reconfirm each other's.

The data attribute plots using CCA for top 3 indicators species of community – 3 i.e., *Corchorus olitorius*, *L. dissecta* and *C. benghalensis* show indicator values of 48.9, 11.3 and 41.3 in canal irrigation farming practice and 22.2, 45 and 34.4 indicator values in the case of electrical conductivity environmental variable respectively (Appendix Table A) (Fig. 5).

3.3.4. *Amaranthus – Euphorbia – Parthenium* weed community

The top abundant weed species of community four are *Boerhavia diffusa*, *C. rotundus*, *C. benghalensis*, *C. arvensis* and *U. panicoides*, while *Solanum nigrum*, *Cassia occidentalis*,

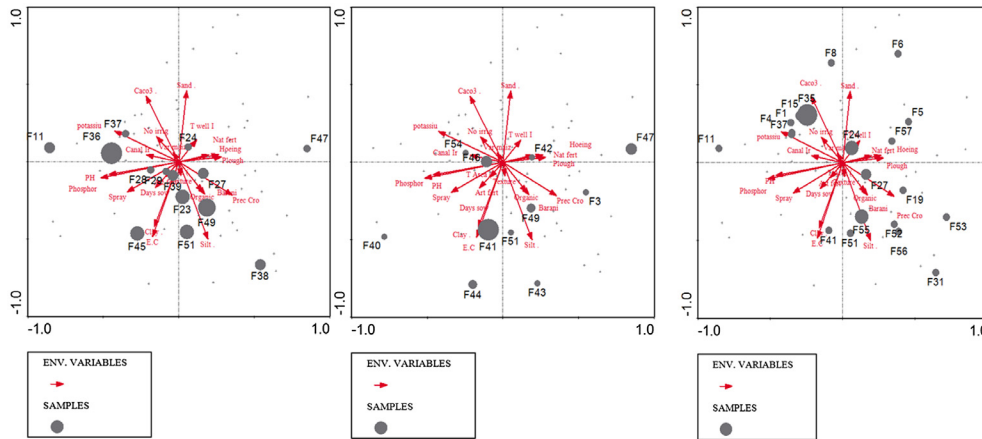


Figure 4 Data attribute plot (From left to right) of *Achyranthes aspera* (1st indicator species), *Ipomea purpurea* (2nd indicator species) and *Physalis angulata* (3rd indicator species) in relation to various fields, soil and farming practices variables.

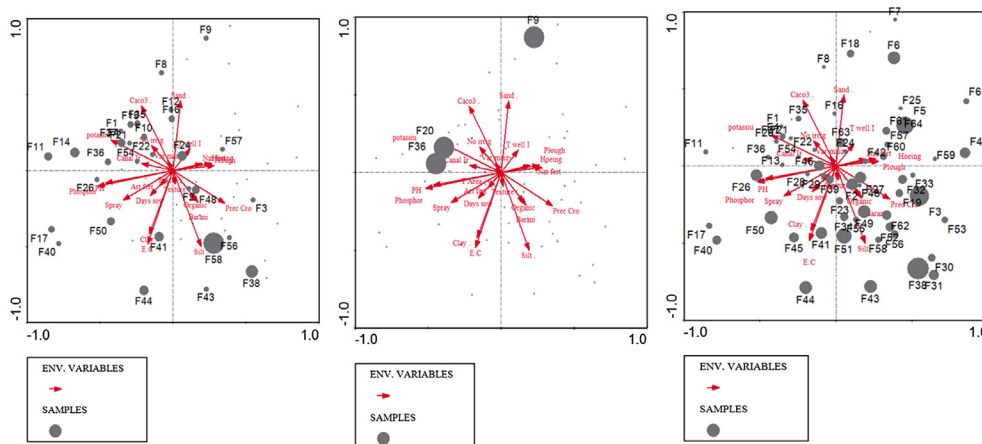
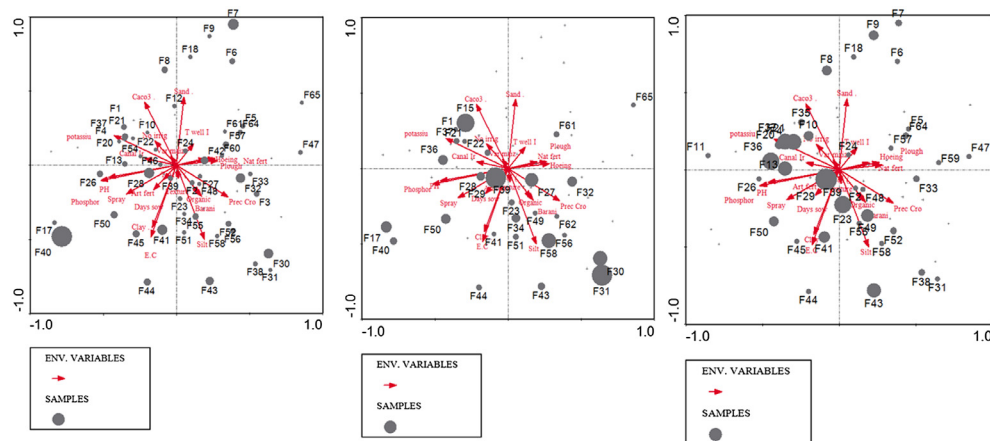


Figure 5 Data attribute plot (From left to right) of *Corchorus olitorius* (1st indicator species), *Lactuca dissecta* (2nd indicator species) and *Commelina benghalensis* (3rd indicator species) presenting its position with environmental variables and various fields.



**Figure 6** Data attribute plot (from left to right) of *Amaranthus viridis* (1st indicator species), *Euphorbia hirta* (2nd indicator species) and *Parthenium hysterophorus* (3rd indicator species) showing its site in respect with different fields and related environmental variables.

*C. sativa*, *C. dactylon*, and *P. angulata* are less abundant weed species of the region that show minimum Importance Values. When only soil data were analyzed in light of CCA plot, (Fig. 2) it is concluded that the main significant variables are higher concentration of organic matters and sandy nature of soil. By observing the CCA plot obtained from questionnaire data (Fig. 2) concluded that the community – 4 having significant environmental variables are moist, natural fertilizers, hoeing and tube well irrigation farming practices. Latter on CCA of both questionnaire and soil data (Fig. 2) reconfirm each other and shows higher concentration of natural fertilizers, hoeing, plough and sandy nature of soil as compared to other communities which indicate high concentration of  $\text{CaCO}_3$ , potassium, phosphorus, pH, artificial fertilizers, electrical conductivity, and show clay nature of soil.

Data attribute plots using CCA for top 3 indicators species of community – 4 i.e., *Amaranthus viridis*, *Euphorbia hirta* and *Parthenium hysterophorus* show 46.5, 29.5 and 32.4 Indicator values respectively in tube well irrigation farming practice (Appendix Table A) (Fig. 6).

#### 4. Discussion

In last several years the study of environmental changes is emergent more swiftly as compared to other few disciplines of studies related to the life sciences. Present study revealed 29 weed species belonging to 27 genera and 15 families distributed in 585 quadrats. *Amaranthaceae* and *Poaceae* were the dominant families followed by *Cucurbitaceae* and *Asteraceae*. CCA bi-plot Analysis shows the pattern of weed species composition, its distribution pattern and relation with ecological factors. Tanveer et al. (2013) suggest that the *C. arvensis* tends to grow better in neutral and slightly acidic soil as compared to alkaline soil environments. Optimum pH range for germination of *C. arvensis* ranged between 6 and 8 cm. Present analysis showed similar results to Tanveer et al. (2013) that *C. arvensis* grows more an acidic soil as compared to alkaline nature of a community. *C. arvensis* is a main problem in cotton, potato, maize, wheat and sugarcane etc (Memon, 2004). It is one of the top harmful weed of the worlds and out of 54 countries it is found in 32 different crops fields (Holm, 1997). Similarly present work

also revealed *C. arvensis* is one of abundant weed species of the region. *C. rotundus* is growing in farmlands, cultivated fields and grasslands, at the boundaries of forests, sandy seashore, riverbanks and irrigation canal banks (Holm et al., 1977; Wiggins et al., 1971). In the same way our study result *C. rotundus* was the most abundant weed species of study area present abundantly almost in all communities facing different edaphic factors like higher pH,  $\text{CaCO}_3$ , potassium, electrical conductivity, organic matter concentration, clay and sandy nature of soil. Likewise Swarbrick (1997) also reported that *C. rotundus* grown well in approximately all type of soil, a wide range of pH, elevation and soil moisture. Present study revealed *B. diffusa* was abundantly found in regions where higher concentration of organic matters, sandy nature of soil, application of natural fertilizers, hoeing and tube well irrigation farming practice occur. Similarly Low (1991) reported in his book named “Wild food plants of Australia” i.e., *B. diffusa* is found in dry sandy nature of soils, plus Abeywardana and Hettiarachchi (2001) also reported that *B. diffusa* is a common weed present in sandy areas, while Chopra (1969) reported that *B. diffusa* grows all over the warmer region up to 2000 m an altitudinal rang of Himalaya and grows easily in fields following the rainy time of year and in wastelands. Chauhan and Mahajan (2014) reported in a book titled, Recent advances in weed Management i.e., Straw mulch sited in the middle of the two crop rows inhibits the appearance of weed and also adds organic matter to the soil. While in the Philippines a residue of  $6 \text{ t ha}^{-1}$  significantly reduced seedling emergence and bio mass of *D. aegyptium*, *Eclipta prostrata*, *Eleusine indica* and *L. chinensis*. Comparing with Chauhan and Mahajan (2014) the present work resulted community 4 has higher concentration of organic matters and sandy nature of soil which doesn't allow *D. aegyptium* to grow abundantly as compared to other communities that contain higher concentration of  $\text{CaCO}_3$ , electrical conductivity, pH, potassium, clay and sandy nature of soil and in addition to application of fertilizers farming practice. In present study *C. benghalensis* is present in three communities in abundance that exposed moderate moist condition, application of fertilizers and irrigation. Kaul et al. (2002), also resulted that *C. benghalensis* is a rainy season weed which require moist soil condition for establishment and after establishment it can also survive dry condition. According to

Britton et al. (1963) that *I. purpurea* prefer to grow in rich moist, well drained and sandy loamy soil situation. Similarly our result also show *I. purpurea* is present in sandy nature of soil, in more number of irrigation fields (moist condition) and in higher concentration of organic matter. It resulted that *C. lanatus* was present less frequently where higher concentration of pH and potassium take place. In the same way Paksoy et al. (2010) resulted that *C. lanatus* is grown at different soil textures and pH of 5.0 to 6.5 (low) respectively. Smith (1981) reported that *A. aspera* weed grown from sea level up to 900 m. In coastal cultivated areas along road sides and frost trails abundantly on rocky seashore, lime stone and grassy slopes. Similarly our study revealed *A. aspera* weed is grown where higher concentration of CaCO<sub>3</sub> present and sandy nature of soil occurred. Costea (1998) reported that *A. blitoides* can grow on sandy soil, fixed and sand dunes, alluvial sands and can tolerate to a wide range of pH, change able from 4.5 to 8.5, but favor to pH values near to 7. Similarly first community of our study area shows higher concentration of pH and sandy nature of soil which results in *A. blitoides* to grow less abundantly.

## 5. Conclusion

It is concluded that among all the edaphic factors the strongest variables were higher concentration of potassium, organic matter and sandy nature of soil. CCA plots of both weed species and sampled fields based on questionnaire data concluded the farming practices such as application of fertilizers, irrigation and chemical spray were the main factors in determination of weed communities.

## Acknowledgments

The authors would like to extend their sincere appreciation to the Deanship of Scientific Research at King Saud University for its funding this Research group No (RG-1435-014).

## Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at <http://dx.doi.org/10.1016/j.sjbs.2016.07.001>.

## References

- Abeywardana, N., Hettiarachchi, J.K.N., 2001. Statistics on the National Demand for Medicinal Plants, Woodl. Ave., Kohuwala.
- Adamu, G.K., Aliyu, A.K., 2012. Determination of the influence of texture and organic matter on soil water holding capacity in and around Tomas Irrigation Scheme, Dambatta Local Government Kano State. Res. J. Environ. Earth Sci. 12, 1038–1044.
- Algandaby, M.M., Salama, M., 2016. Management of the noxious weed; *Medicago polymorpha* L. via allelopathy of some medicinal plants from Taif region, Saudi Arabia. Saudi J. Biol. Sci. Accepted, [http://ac.els-cdn.com/S1319562X16000607/1-s2.0-S1319562X1600-0607-main.pdf?\\_tid=cbfc2e26-02f8-11e6-9475-00000aacb360&acdnat=1460718007\\_ab4a77a15f0ef0240d253809b5c0b02b](http://ac.els-cdn.com/S1319562X16000607/1-s2.0-S1319562X1600-0607-main.pdf?_tid=cbfc2e26-02f8-11e6-9475-00000aacb360&acdnat=1460718007_ab4a77a15f0ef0240d253809b5c0b02b).
- Ali, S.I., Qaiser, M., 1995. Flora of Pakistan.
- Al-Shahwan, I.M., Abdalla, O.A., Al-Saleh, M.A., Amer, M.A., 2016. Detection of new viruses in alfalfa, weeds and cultivated plants growing adjacent to alfalfa fields in Saudi Arabia. Saudi J. Biol. Sci.
- Baker, H.G., 1974. The evolution of weeds. Annu. Rev. Ecol. Syst., 1–24.
- Britton, N.L., Brown, A., Gleason, H.A., 1963. An Illustrated Flora of the United States, Etc. The New Britton and Brown Illustrated Flora of the North-eastern United States and Adjacent Canada. By Henry A. Gleason. With the Assistance of Specialists in Certain Groups. Illustrated by Original Drawings, Etc. New York Botanical Garden.
- Chauhan, B.S., Mahajan, G., 2014. Recent Advances in Weed Management. Springer.
- Chopra, G.L., 1969. Angiosperms. Systematics and Life Cycle. S. Nagin & Co., Jalandhar, Punjab, India, pp. 361–365.
- Clements, F.E., 1905. Research Methods in Ecology. University Publishing Company.
- Costea, M., 1998. Monograph of the Genus *Amaranthus* L. Rom (Ph. D. Diss). Univ. Bucharest, Coll. Biol. Bucharest in Rom.
- Curtis, J.T., McIntosh, R.P., 1950. The interrelations of certain analytic and synthetic phytosociological characters. Ecology, 434–455.
- Duke, J.A., 1983. Handbook of Energy Crops.
- El-Sheikh, M.A., 2013. Weed vegetation ecology of arable land in Salalah, Southern Oman. Saudi J. Biol. Sci. 20, 291–304.
- Gomaa, N.H., 2012. Composition and diversity of weed communities in Al-Jouf province, northern Saudi Arabia. Saudi J. Biol. Sci. 19, 369–376.
- Holm, L., 1997. World Weeds: Natural Histories and Distribution. John Wiley & Sons.
- Holm, L.G., Plucknett, D.L., Pancho, J.V., Herberger, J.P., 1977. The World's Worst Weeds. University Press.
- Holm, L., Pancho, J.V., Herberger, J.P., Plucknett, D.L., 1979. A Geographical Atlas of World Weeds. John Wiley and Sons.
- Kaul, V., Sharma, N., Koul, A.K., 2002. Reproductive effort and sex allocation strategy in *Commelina benghalensis* L., a common monsoon weed. Bot. J. Linn. Soc. 140, 403–413.
- Khan, I.A., Ullah, Z., Hassan, G., Marwat, K.B., Jan, A., Shah, S.M. A., Khan, S.A., 2011a. Impact of different mulches on weed flora and yield of maize. Pak. J. Bot. 43, 1601–1602.
- Khan, S.M., Harper, D.M., Page, S., Ahmad, H., 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., Page, S., Ahmad, H., Shaheen, H., Harper, D.M., 2012. Vegetation dynamics in the Western Himalayas, diversity indices and climate change. Sci. Technol. Dev. 31, 232–243.
- Khan, S.M., Page, S., Ahmad, H., Harper, D., 2013a. Identifying plant species and communities across environmental gradients in the Western Himalayas: method development and conservation use. Ecol. Inform. 14, 99–103.
- Khan, S.M., Page, S.E., Ahmad, H., Harper, D.M., 2013b. Sustainable utilization and conservation of plant biodiversity in montane ecosystems: the western Himalayas as a case study. Ann. Bot. 112, 479–501.
- Khan, S.M., Page, S., Ahmad, H., Harper, D., 2014. Ethno-ecological importance of plant biodiversity in mountain ecosystems with special emphasis on indicator species of a Himalayan Valley in the northern Pakistan. Ecol. Indic. 37, 175–185.
- Koehler, F.E., Moodie, C.D., McNeal, B.L., 1984. Laboratory Manual for soil fertility. Washington State University, Pullman Washington.
- Low, T., 1991. Wild Food Plants of Australia. Sydney Angus Robertson 240p. -illus., col. illus, ISBN: 207169306.
- Malik, M.A., Zahoor, F., Abbas, S.H., Ansar, M., 2006. Comparative study of different herbicides for control of weeds in rainfed maize (*Zea mays* L.). WSSP Absts. Weed Sci. Soc. Pak., 62
- Memon, R.A., 2004. Weed Flora Composition of Wheat and Cotton Crops in District Khairpur. Shah Abdul Latif University, Khairpur, Sindh.

- Mitchell, C.C., Tu, S., 2005. Long-term evaluation of poultry litter as a source of nitrogen for cotton and corn. *Agron. J.* 97, 399–407.
- Nelson, D.W., Sommers, L.E., Sparks, D.L., Page, A.L., Helmke, P. A., Loeppert, R.H., Soltanpour, P.N., Tabatabai, M.A., Johnston, C.T., Sumner, M.E., 1996. Total carbon, organic carbon, and organic matter. In: *Methods Soil Anal. Part 3-Chemical Methods*, pp. 961–1010.
- Olsen, J., Kristensen, L., Weiner, J., 2006. Influence of sowing density and spatial pattern of spring wheat (*Triticum aestivum*) on the suppression of different weed species. *Weed Biol. Manage.* 6, 165–173.
- Paksoy, M., Aydin, C., Turkmen, O., Seymen, M., 2010. Modeling of some physical properties of watermelon (*Citrullus lanatus* (thunb.) mansf.) seeds depending on moisture contents and mineral compositions. *Pak. J. Bot.* 42, 2775–2783.
- Rhoades, J.D., Miyamoto, S., Westerman, R.L., 1990. Testing soils for salinity and sodicity. *Soil Test. Plant Anal.*, 299–336
- Smith, A.C., 1981. *Flora Vitiensis Nova 2. Angiospermae Dicotyledones, Fam.*, pp. 44–116.
- Swarbrick, J.T., 1997. *Environmental Weeds and Exotic Plants on Christmas Island, Indian Ocean.*
- Tanveer, A., Tasneem, M., Khaliq, A., Javaid, M.M., Chaudhry, M. N., 2013. Influence of seed size and ecological factors on the germination and emergence of field bindweed (*Convolvulus arvensis*). *Planta Daninha* 31, 39–51.
- Tilman, D., 2000. Causes, consequences and ethics of biodiversity. *Nature* 405, 208–211.
- Wiggins, I.L., Porter, D.M., Anderson, E.F., 1971. *Flora of the Galápagos Islands.* Stanford University Press.