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FLORISTIC DIVERSITY, ECOLOGY AND HABITAT CHARACTERISTICS OF COMMUNITIES WITH *BRASSICA TOURNEFORTII* GOUAN IN NORTHERN OF SAUDI ARABIA

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Abstract - The present study aimed to identify the communities with *Brassica tournefortii* Gouan in Al-Jouf areas in northern Saudi Arabia, to determine the ecological amplitude of this species and soil factors controlling its distribution. The plant communities dominated by *B. tournefortii* were investigated in fifteen localities through 15 plots. In each plot the present species were recorded. Data were treated by multivariate analyses. Soils of each community were analyzed using eleven physico-chemical parameters. Analysis of variance and correlation coefficient were performed based on R software package. Three vegetation types have been recognized by the applications of Past program classification. 83 species have been observed. Canonical correspondence analysis demonstrated that soil parameters contributed significantly to the distribution of species. *B. tournefortii* dominated the communities in newly reclaimed lands, where it survived in sandy habitats. It is characterized by high competition with both cultivated plants and associated weeds. This paper represents a study of the diversity of *B. tournefortii* communities in Arabia Saudi.

Keywords: *Brassica tournefortii*; plant associations; ecological gradient; species richness; soil characteristics

Introduction

Asian mustard (B. *tournefortii* Gouan), also known as Saharan mustard, is a member of mustard family Brassicaceae. It is a winter annual species native to the Mediterranean basin and much of the Middle East through to western India (Prain, 1898; Thanos et al., 1991; Aldhebiani & Howladar, 2013). In the southwestern United States, B. *tournefortii* is a highly invasive plant that threatens native annuals (Bangle et al., 2008). This species is a highly successful invader and may be a threat to natural environments, including remote shoreline habitats (Bangle et al., 2008). It is an invasive taxon also throughout much of Australia (Chauhan et al., 2006), South Africa (Mc Geoch et al., 2009), Chile (Teillier et al., 2014), and western North America (Li et al., 2015). It is an endangered, underexploited oilseed crop, which has become naturalized under tropical and subtropical regions of Asia, Africa, Australia and USA (Singh et al., 2015). It is characterized by high competition and a strategy of early and quick growth (Sanders & Minnich, 2000), rapidly expanding and negatively affecting natural ecosystems (Barrows et al., 2009; VanTassel et al., 2014). This invader has become increasingly common in arid and semiarid regions (Sanders & Minnich, 2000). The species is a generalist and, as such, germinates under a wide range of temperatures, light conditions, and soil depths (Thanos et al., 1991; Jurado & Westoby, 1992; Chahuan et al., 2006; Bangle et al., 2008). It is also drought-tolerant (West & Nabhan, 2002) and it possesses allelopathic activity (Patterson, 1983). It is considered an aggressively invasive weed in many countries like the United States (Abella et

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al., 2009) and Australia (Chauhan et al., 2006), where it has been reported that it could reduce yield (AOF, 2015). It is considered a weedy species in agricultural fields in parts of its native range (Ahmed et al., 2015; El-Saied et al., 2015), but it has also traditional dietary uses and economic value in regions where it is cultivated (Singh et al., 2015; Guarrera & Savo, 2016). It has been shown that allelopathy offers great potential to increase agricultural production, decrease the harmful effects of modern agricultural practices, and maintain soil productivity and a pollution-free environment for future generations (Abd El-Gawad, 2014). Winkler et al. (2018) showed that linking life-history strategies, functional traits, and responses to environmental variation can assist in producing a mechanical based predictive framework for ecologists to understand the behavior of invasive species in space and time (Huxman et al., 2013). *B. tournefortii* has been managed by prevention (Trader et al., 2006) and by physical and chemical control (Rice, 1992), but by little to no biological control (Sanders & Minnich, 2000). Bangle et al. (2008) noted that it displays patterns of boom-or-bust years typical of annual plant populations, demonstrating the potential existence of a substantial seed bank. When a substantial seed bank exists, seeds may cycle through different stages of dormancy, depending on environmental conditions. *B. tournefortii* produces numerous seeds which buried in the soil and stay viable for several years (Abd El-Gawad, 2014).

According to Al-Hassan (2006), 458 species were present in the northern sector of the Kingdom of Saudi Arabia, in communities similar to those here described. In north Wadi Arar area, Osman et al. (2014) recorded 196 species. Gomaa (2012) observed a total of 71 species belonging to 22 families and 61 genera in Al-Jouf provenance. These results were conforming to those by Pielou (1975) and Magurran (1988), where the taxonomic diversity is higher in an area in which the species were divided between many genera. The available vegetation data about northern region do not represent an appreciable contribution to the flora of Saudi Arabia with regard to other parts of the country (Al-Turki & Al-Qlayan, 2003). Knowledge on the ecology of this weed would help in implementing effective weed control programs and help in designing suitable weed management programs (Mahajan et al., 2018).

The aim of this study was to identify the main weed communities in Al-Jouf in northern Saudi Arabia and to characterize the associated flora and species diversity, analysing vegetation and habitat conditions.

Materials and Methods

Study area

Al-Jouf is located in the northern part of Saudi Arabia, where it is bordered to the north and east by the Northern Borders province and to the south by Hail and Tabuk provinces and delimited from the north and west by Jordan. The study area is composed of transverse sand dunes that often reach up to a height of about 120 m. According to Gomaa (2012), the study area is characterized by dry climate with hot summer and cool winter, the mean monthly air temperature ranges between 9.8 ^{0}C during January and 33.8 ^{0}C during August. Gomaa (2012) reported that the mean monthly relative humidity varied between 16% during June and 53% during January.

Vegetation analysis

This study was performed from November to April during active plant growth period, when most species were expected to be present. The wild vegetation was sampled in 15 localities through 15 plots (a plot for each locality). The area of the plot was 20x20 m. These plots were chosen, installed and marked. The plots were selected according to the variation in the vegetation structure, floristic composition, and/or change in the habitat of the study area. They represent the various plant formations existing at this date. In each plot, the present species were recorded. Identification and nomenclature of the species are based on Collenette (1999), Cope (1985), Migahid (1996), Chaudhary & Akram (1987), Chaudhary & Al-Jowaid (1999) Chaudhary (1999; 2000; 2001) and Al-Hassan (2006).

Soil analysis

Three soil samples were taken per localities, from a depth of 0-50 cm. The samples were pooled together, forming one composite sample for each stand. The samples were air dried and sieved through a 2 mm sieve before analysis. The physico-chemical analyses carried out are: Sand (%), Silt (%), Clay (%), Porosity (%), pH, OC (organic carbon: %), $CaCO_3$ (%), EC (electrical conductivity: µmhos/cm), Cl^- (%), $SO4^-$(%), $CO3^{--}$(%), HCO_3^- (%), Na^+, K^+, Ca^{++}, Mg^{++}, SAR (sodium adsorption ratio), PAR (potassium adsorption ratio) and WHC (Water holding capacity: %). The physico-chemical analyses methods are according to Jackson (1958; 1962), Pierce et al. (1958) and Allen et al. (1974).

Statistical analysis

Data of soil analyses were subjected to descriptive analysis using the R software package (V.3.4.0). Detrended correspondence analysis (DCA) ordination and Canonical Correspondance Analysis (CCA) biplot of presence-absence data of species and habitat variables were made using the Past program (Geyout & Houllier, 1995). To group the vegetation relevès based on species dissimilarity, cluster analysis was conducted on the Euclidean distance matrix with Ward's method (Past program).

Results

Estimation of floristic diversity

In total 83 plant species (Appendix) belonging to 25 genera were observed in the different surveyed sectors. Figure 1 showed the DCA ordination of the matrix (15 relevés x 83 species) based on presence/absence data. Figure 2 showed the clusters resulting of the classification of the relevès. The application of the classification technique to the species leads to the separation of 3 vegetation types (Figure 1 and Figure 2).

Ordination of the 15 releves given by DCA (Figure 1) indicates that the vegetation groups produced by Past classification are markedly distinguishable and show a clear pattern of segregation on the ordination planes. The vegetation groups (Figure 1) are clearly distinguished and distributed along axis 1 and axis 2. The eigenvalues for the first two DCA axes are 0.545 and 0.435, respectively. The high eigenvalue for DCA axis 1 indicates that it explains the major variation in species composition of the vegetation groups.

The dominant species of the vegetation types are:

– group A: B. *tournefortii*, *Haloxylon persicum*, *Astragalus spinosus* and *Senecio glaucus*,

– group B: *Helianthem aegyptiacum*, *Haloxylon salicornicum* and *Silene arabica*;

– group C: *Artemisia monosperma*, *Stipagrostis plumosa* and *Rhanterium epapposum.*

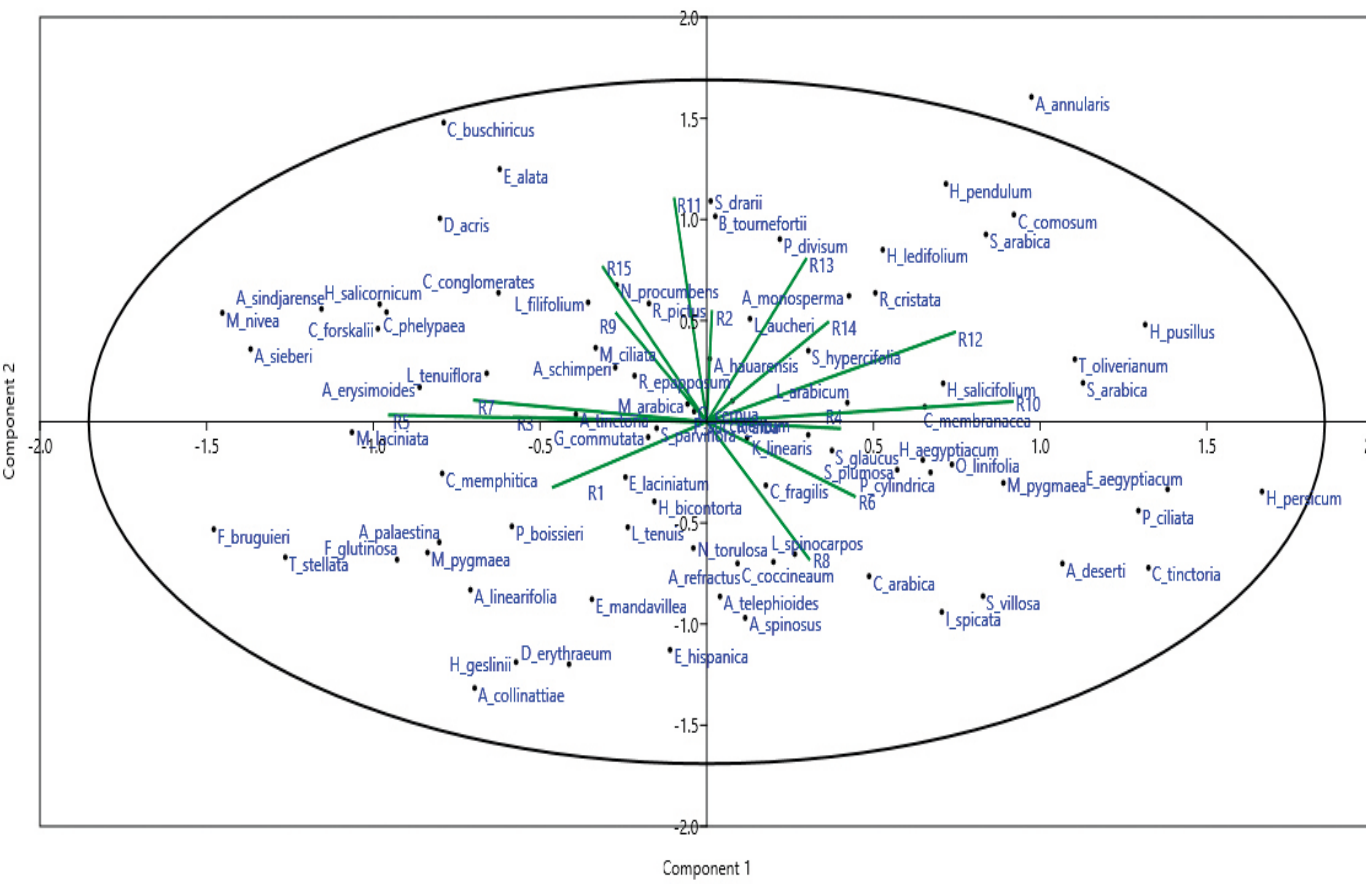
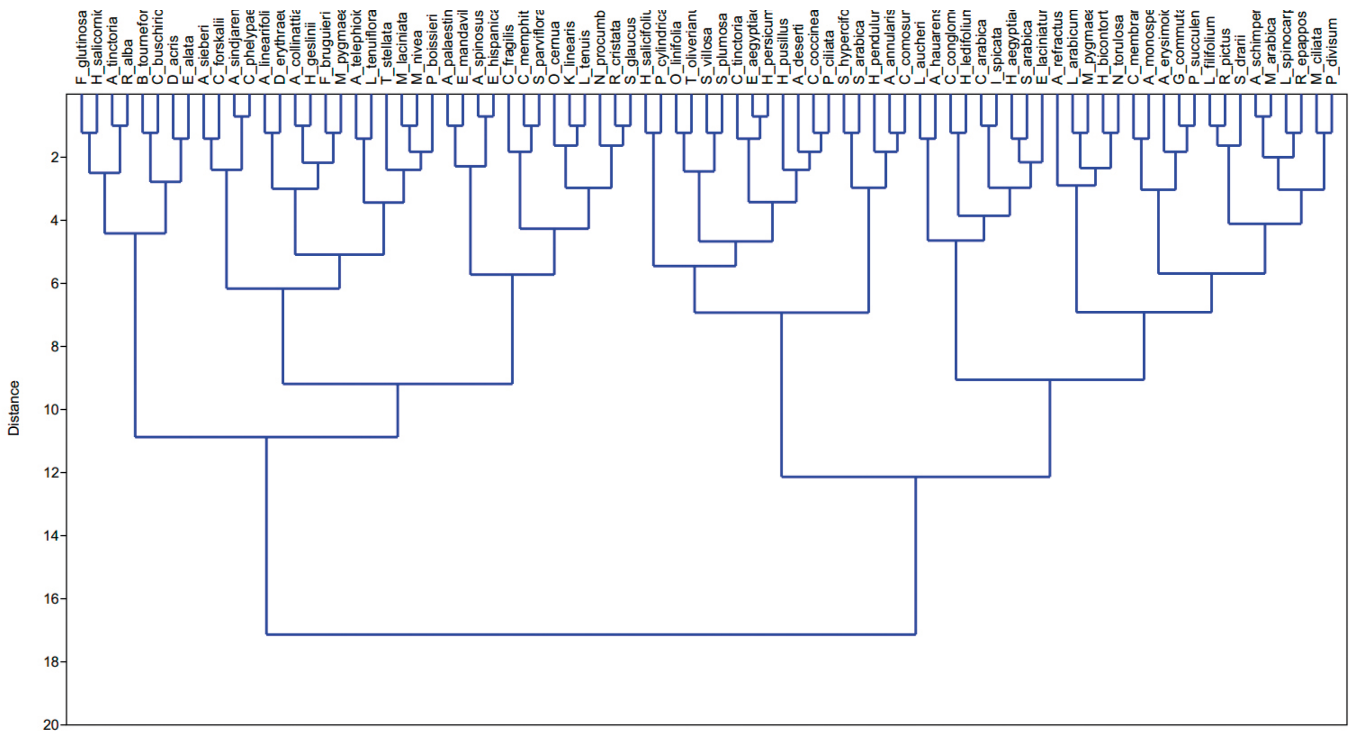
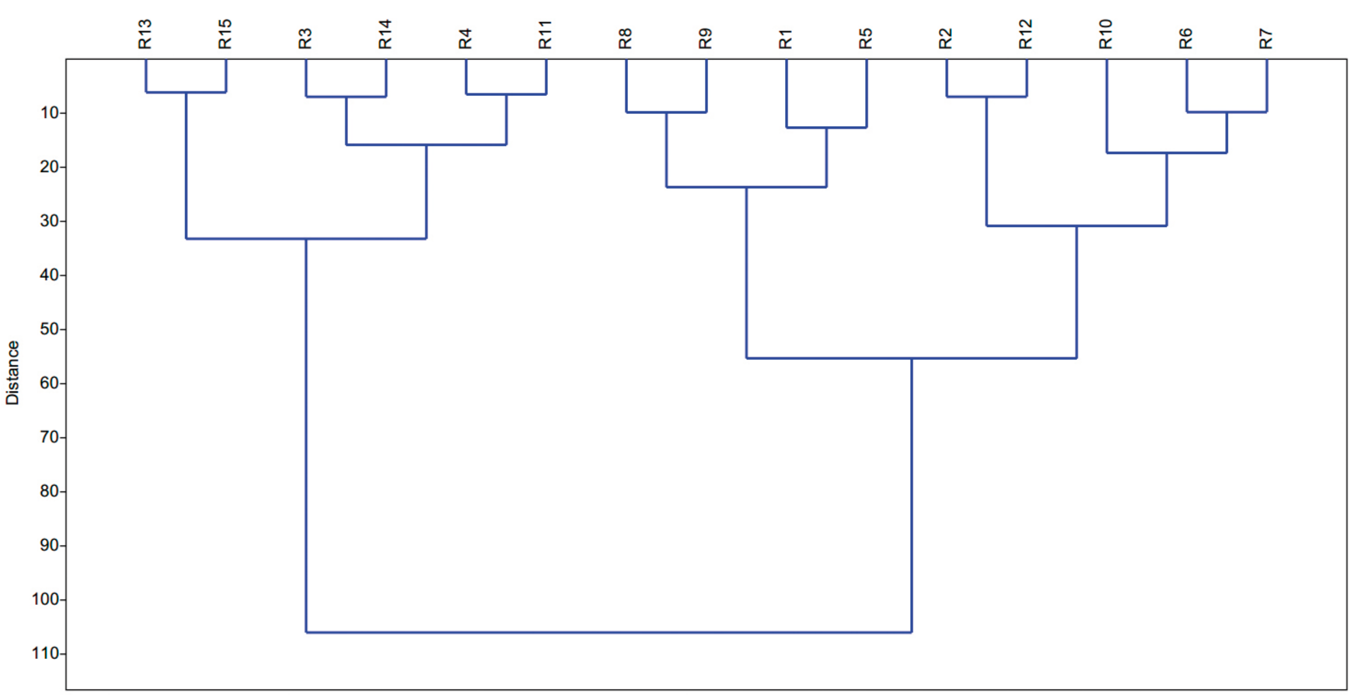


Figure 1. Detrended correspondence analysis (DCA) ordination of the matrix (15 relevés x 83 species) based on presence-absence of species with the vegetation groups resulted from PAST program.



(a)



(b)

Figure 2. (a) Clusters resulting from the classification of the species of the matrix (15 relevés x 83 species) based on presence-absence of species with the vegetation groups resulted from Past program, (b) clusters resulting from the classification of the localities of the same matrix.

Vegetation–soil relationships

Edaphic parameters of the 15 localities are summarized in Table 1. Altitude ranged from 78 to 120 m, electrical conductivity ranged to 186.5 to 257.4 (µmhos/cm), Organic carbon varies between 0.670 and 1.890%. Electrical conductivity (EC) ranged to 186.74 to 255.42, Water holding capacity (WHC) varies between 33.24% and 36.24%. Sodium adsorption ratio (SAR) varies between 39.54 and 56.48. The means of sand, silt and clay is respectively 92.332%, 6.369% and 1.298%. The means of sodium adsorption ratio, potassium adsorption ratio and water holding capacity is respectively 51.088, 11.276 and 34.595% (Table 2).

Table 1. Values of main soil parameters at depths of 0-50 cm in the surveyed 15 localities. Alt (m a.s.l.), Sand (%), Silt (%),Clay (%), Porosity (%), WHC (Water holding capacity: %), pH, OC (organic carbon: %), $CaCO_3$ (%), EC (electrical conductivity: µmhos/cm), Cl^- (%), SO_4^{--} (%), CO_3^{--} (%), HCO_3^- (%), Na^+, K^+, Ca^{++}, Mg^{++}, SAR (sodium adsorption ratio), PAR (potassium adsorption ratio).

Plot	Alt	Sand	Silt	Clay	Poro	WHC	pH	OC	$CaCO_3$	EC	Cl^-	SO_4^{--}	CO_3^{--}	HCO_3^-	Na^+	K^+	Ca^{++}	Mg^{++}	SAR	PAR
R1	100	90.45	8.31	1.24	32.45	34.51	8.45	1.62	7.15	198.24	0.26	0.14	0.01	0.1	132.25	21.35	20.15	18.25	54.25	9.24
R2	80	95.67	2.69	1.64	33.24	33.24	8.25	1.23	8.15	211.24	0.18	0.18	0.02	0.1	154.28	22.12	21.02	17.45	55.24	11.24
R3	85	88.67	9.58	1.75	32.48	34.91	8.15	1.42	7.15	234.15	0.34	0.23	0.01	0.03	135.48	20.14	25.15	18.45	45.26	12.32
R4	95	93.54	5.61	0.85	30.24	35.14	8.01	1.45	9.45	237.58	0.36	0.18	0	0.04	144.25	18.25	24.16	17.25	39.54	8.24
R5	112	91.58	7.45	0.97	32.48	36.24	8.15	1.34	7.68	211.34	0.15	0.19	0.01	0.05	132.45	21.24	25.15	16.35	54.16	9.35
R6	85	94.65	4.03	1.32	33.24	35.48	7.98	1.89	8.46	188.64	0.45	0.21	0	0.08	129.68	23.45	27.15	15.24	55.26	10.24
R7	98	96.54	2.01	1.45	31.45	34.15	8.12	1.46	9.34	186.47	0.35	0.24	0.02	0.07	147.28	22.24	22.54	14.25	57.15	11.15
R8	120	88.64	9.45	1.91	32.48	33.67	8.43	1.75	8.12	201.54	0.45	0.33	0.01	0.01	157.35	23.14	22.23	18.28	48.25	10.24
R9	118	91.25	7.33	1.42	31.42	33.48	8.26	1.26	7.25	188.47	0.25	0.34	0.03	0.01	187.36	19.58	24.15	15.12	49.25	12.34
R10	84	88.49	10.28	1.23	29.58	34.15	8.45	0.88	7.16	195.75	0.36	0.24	0.01	0.06	123.35	18.47	24.15	14.52	48.37	13.45
R11	95	94.57	4.48	0.95	28.49	35.45	8.32	0.67	8.16	234.15	0.24	0.34	0.02	0.05	142.58	22.24	23.21	19.36	47.15	11.02
R12	86	92.48	6.27	1.25	30.24	36.15	8.16	0.96	9.45	212.38	0.54	0.23	0.03	0.04	174.28	25.46	20.15	18.57	51.24	10.25
R13	78	92.49	6.42	1.09	31.25	34.15	8.42	1.37	7.29	255.42	0.45	0.24	0.01	0.08	159.42	25.28	21.42	16.34	52.34	14.25
R14	86	93.19	5.39	1.42	32.45	33.49	8.12	1.67	9.15	234.15	0.27	0.29	0.02	0.1	167.25	24.16	26.31	17.19	52.39	13.24
R15	85	92.78	6.24	0.98	31.98	34.72	7.99	0.96	8.37	257.45	0.28	0.24	0.04	0.1	157.29	26.37	20.15	15.23	56.48	12.58

Table 2. Descriptive analysis of main soil parameters at depths of 0-50 cm in the surveyed 15 localities. Legend as in Tab. 1.

Statistic	Alt	Sand	Silt	Clay	Poro	WHC	pH	OC	$CaCO_3$	EC	Cl^-	SO_4^{--}	CO_3^{--}	HCO_3^-	Na^+	K^+	Ca^{++}	Mg^{++}	SAR	PAR
N	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
Minimum	78	88.49	2.01	0.85	28.49	33.24	7.98	0.67	7.15	186.47	0.15	0.14	0	0.01	123.35	18.25	20.15	14.25	39.54	8.24
Maximum	120	96.54	10.28	1.91	33.24	36.24	8.45	1.89	9.45	257.45	0.54	0.34	0.04	0.1	187.36	26.37	27.15	19.36	57.15	14.25
Mean	93.8	82.33	6.36	1.29	31.56	34.59	8.21	1.32	8.15	216.46	0.32	0.24	0.01	0.06	149.63	22.23	23.13	16.79	51.08	11.27
Stand. dev	13.50	2.51	2.45	0.30	1.38	0.95	0.16	0.34	0.87	24.04	0.11	0.06	0.01	0.03	18.02	2.47	2.27	1.63	4.81	1.72
Coeff. var	14.39	2.72	38.47	23.77	4.39	2.76	2.03	25.89	10.71	11.10	33.52	25.1	70.07	51.87	12.04	11.51	9.85	9.72	9.42	15.30

To explore the relationship between species diversity and soil variables, the species was subjected to a canonical correspondence analysis (CCA) constrained by the soil variables (Figure 3). Species diversity were related to edaphic factors. We found that species diversity decreased with soil acidity and percentage rate of silt and clay. Altitude, soil texture, organic carbon and electrical conductivity are the most controlling soil variables. $CaCO_3$, potassium adsorption ratio, sodium adsorption ratio and porosity attained moderate correlations. Water holding capacity showed low correlation. Electrical conductivity and potassium adsorption ratio were positively correlated with axis 1, while the parameters negatively correlated were altitude and porosity. Axis 2 has positive correlation with $CaCO_3$ and Potassium adsorption ratio, but negatively correlated with clay and clay fraction. The dominant species *B. tournefortii* showed high correlation with sand, silt, clay, porosity and organic carbon (Figure 3).

Discussion

Our analyses revealed that the study area is dominated by annual species, as observed by Osman et al. (2014) in the northern part of the country. The weed vegetation in the study area can be referred to three vegetation types well related to soil variables. These results agree with those of El-Demerdash et al. (1997) and Andersson & Milberg (1998) that pointed out that soil quality contributes to the composition of species community. The weed vegetation in the study area includes desert species that grow in the surrounding natural habitats as *Plantago boissieri*, *Haloxylon salicornicum*, *Reseda alba* and *Stipagrostisplumosa*. Similar observations were documented by Gazer (2011). Soil characters are the major factors that contribute to the distribution of communities along ACP axes. Namely soil

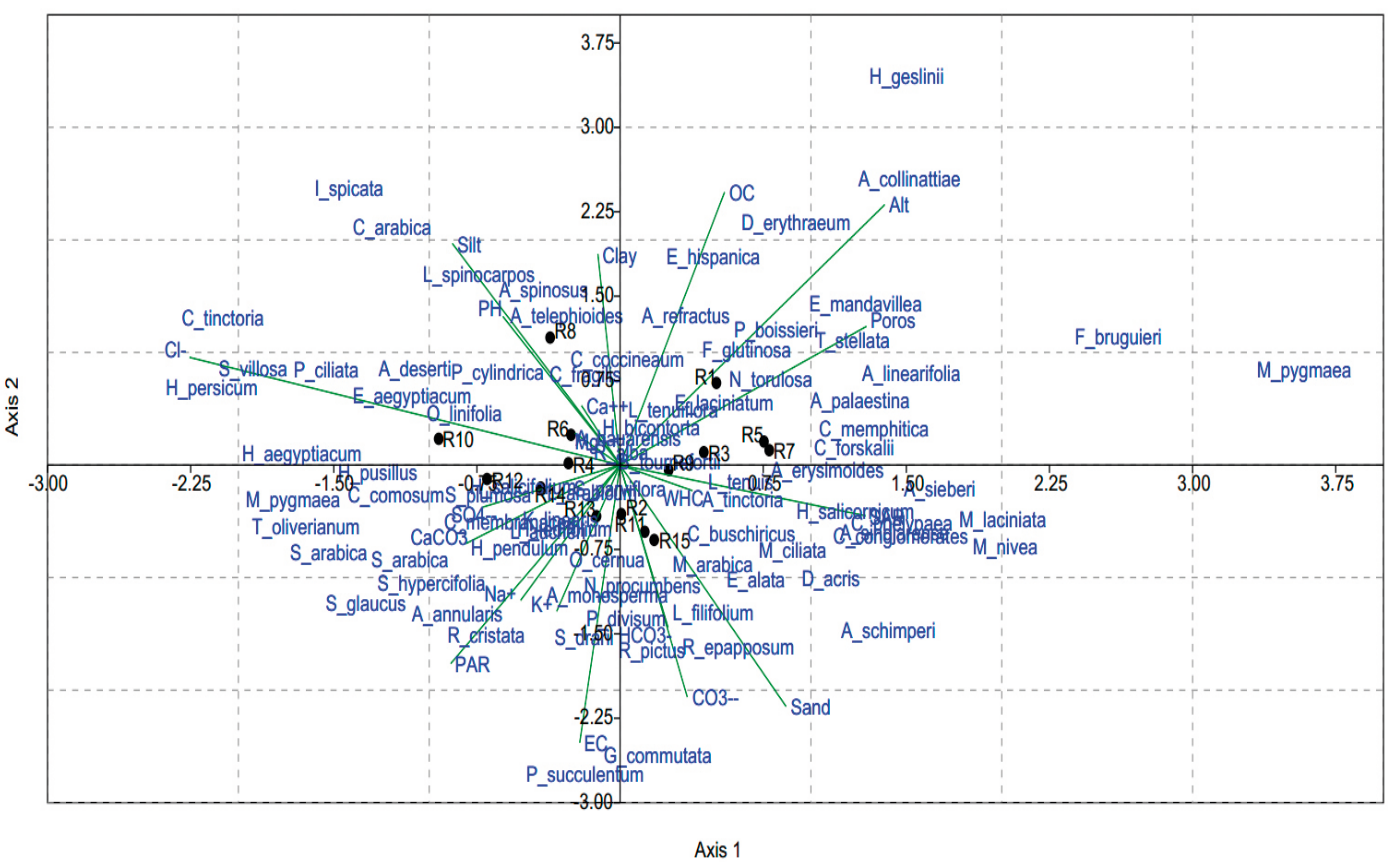


Figure 3. Canonical Correspondance Analysis (CCA) biplot of presence-absence data of species and soil variables (83 species x 15 plots/20 soils parameters). Soil variables: Sand (%), Silt (%), Clay (%), Porosity (%), WHC (Water holding capacity: %), pH, OC (organic carbon: %), $CaCO_3$ (%), EC (electrical conductivity: µmhos/cm), Cl^- (%), SO_4^{--} (%), CO_3^{--} (%), HCO_3^- (%), Na^+, K^+, Ca^{++}, Mg^{++}, SAR (sodium adsorption ratio), PAR (potassium adsorption ratio). For complete names of species see Appendix.

electrical conductivity, organic carbon, coarse and medium sand, silt and clay showed significant correlations with the cover values of some dominant species. The present findings agree with those of Fried et al. (2008), Andreasen & Skovgaard (2009), Pinke et al. (2010), Gomaa (2012) that indicated the importance of soil texture, salinity and organic carbon for the composition and species richness. Organic matter content as a pivotal soil fertility factor can affect plant diversity (Zhang et al., 2010). Moreover, soil texture may affect soil or productivity via influence on the soil water holding capacity, infiltration rate, moisture availability for plants and consequently plant nutrition (Sperry & Hacke, 2002). These results are in agreement with other many previous studies on weed vegetation of many researchers as Hegazy et al. (2004; 2008), El-Halawany et al. (2010), Mashaly et al. (2012; 2013; 2014; 2015a; 2015b; 2015c) and Gomaa (2012). In all localities *B. tournefortii* dominates on sandy soil, congruently with other studies (Brooks et al., 2006; Abd El-Gawad, 2014), that describe *B. tournefortii* as a dominant species in sandy and road side habitats. The community with B. *tournefortii* expressed high significant correlation with sand, calcium carbonate, water holding capacity, and magnesium. Also these results are in agreement with other studies (Mashaly et al., 2009; Salama et al., 2013; Gomaa, 2012; Abd El-Gawad, 2014). In the present study, B. *tournefortii* appears to be highly susceptible to salinity; this is in harmony with the findings of other investigators (Thanos et al., 1991; Sanders & Minnich, 2000; Abd El-Gawad, 2014).

Conclusions

Our results confirmed that plant communities with *B. tournefortii* and their distribution in Al-Jouf areas were impacted by soil properties. Knowledge of the influence of soil properties on the plant communities can be utilized in restoration programs where the choice of suitable species/ communities is required in revegetation. This study increases our understanding of the distribution patterns of arid land plants and the dominating environmental aspects in sandy habitats, and could provide a theoretical basis for the design of sustainable protection and reclamation of arid land ecological environments. In conclusion, B. *tournefortii* dominated communities in newly reclaimed lands, where it survived in sandy habitats, showing high competition with associated weeds.

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Appendix

List of the species and their abbreviations.

Species	Abbreviations of the species
Allium sindjarense	*A. sindjarense*
Ammochloa palaestina	*A. palaestina*
Andrachne telephioides	*A. telephioides*
Anthemis deserti	*A. deserti*
Arabidopsis erysimoides	*A. erysimoides*
Aretmisia sieberi	*A. sieberi*
Artemisia monosperma	*A. monosperma*
Arnebia linearifolia	*A. linearifolia*
Arnebia tinctoria	*A. tinctoria*
Asphodelus refractus	*A. refractus*
Astragalus annularis	*A. annularis*
Astragalus collinattiae	*A. collinattiae*
Astragalus hauarensis	*A. hauarensis*
Astragalus schimperi	*A. schimperi*
Astragalus spinosus	*A. spinosus*
Brassica tournefortii	*B. tournefortii*
Cakile arabica	*C. arabica*
Calligonum comosum	*C. comosum*
Centropodia forskalii	*C. forskalii*
Centropodia fragilis	*C. fragilis*
Chrozophora tinctoria	*C. tinctoria*
Cistanche phelypaea	*C. phelypaea*
Convolvulus buschiricus	*C. buschiricus*
Crucianella membranacea	*C. membranacea*
Cutandia memphitica	*C. memphitica*
Cynomorium coccineaum	*C. coccineaum*
Cyperus conglomerates	*C. conglomerates*
Dipcadi erythraeum	*D. erythraeum*
Diplotaxis acris	*D. acris*
Echinops mandavillea	*E. mandavillea*
Ephedra alata	*E. alata*
Eremobium aegyptiacum	*E. aegyptiacum*
Erodium laciniatum	*E. laciniatum*
Erucaria hispanica	*E. hispanica*
Fagonia glutinosa	*F. glutinosa*
Fagonia bruguieri	*F. bruguieri*
Gagea commutata	*G. commutata*
Haloxylon persicum	*H. persicum*
Haloxylon salicornicum	*H. salicornicum*
Helianthemum aegyptiacum	*H. aegyptiacum*
Helianthemum ledifolium	*H. ledifolium*
Helianthemum salicifolium	*H. salicifolium*
Hippocrepis bicontorta	*H. bicontorta*
Hyoscyamus pusillus	*H. pusillus*
Hypecoum geslinii	*H. geslinii*
Hypecoum pendulum	*H. pendulum*
Ifloga spicata	*I. spicata*
Koelpinia linearis	*K. linearis*
Lappula spinocarpos	*L. spinocarpos*
Leopoldia tenuiflora	*L. tenuiflora*
Lepidium aucheri	*L. aucheri*
Leptalium filifolium	*L. filifolium*
Limeum arabicum	*L. arabicum*
Linaria tenuis	*L. tenuis*
Malcolmia pygmaea	*M. pygmaea*
Maresia pygmaea	*M. pygmaea*
Matthiola arabica	*M. arabica*
Medicago laciniata	*M. laciniata*
Moltkiopsis ciliata	*M. ciliata*
Monsonia nivea	*M. nivea*
Neotorularia torulosa	*N. torulosa*
Neurada procumbens	*N. procumbens*
Oligomeris linifolia	*O. linifolia*
Orobanche cernua	*O. cernua*
Pennisetum divisum	*P. divisum*
Plantago boissieri	*P. boissieri*
Plantago ciliata	*P. ciliata*
Plantago cylindrica	*P. cylindrica*
Polycarpon succulentum	*P. succulentum*
Reseda alba ssp. *decursiva*	*R. alba*
Rhanterium epapposum	*R. epapposum*
Rostraria cristata	*R. cristata*
Rumex pictus	*R. pictus*
Savignya parviflora	*S. parviflora*
Schimpera arabica	*S. arabica*
Scrophularia hypercifolia	*S. hypercifolia*
Senecio glaucus	*S. glaucus*
Silene arabica	*S. arabica*
Silene villosa	*S. villosa*
Stipagrostis drarii	*S. drarii*
Stipagrostis plumosa	*S. plumosa*
Teucrium oliverianum	*T. oliverianum*
Trigonella stellata	*T. stellata*