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# Correlations between soil variables and weed communities in major crops of the desert reclaimed lands in southern Egypt

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**Abstract** The weed flora of the reclaimed desert lands in the eastern and western stretches of Qena Governorate along the Nile Valley was investigated. This study attempted to identify the vegetation groups (communities) prevailing in common winter and summer crops, to recognise the crop–weed relationships, and to assess the role of different soil factors on the distribution and composition of the weed flora in each season. Three major crops were selected: alfa–alfa (winter and summer seasons), wheat (winter season) and millet (summer season). Altogether, 146 studied fields (stands) were monitored, and distributed as follows: 49 in the wheat fields, 38 in alfa–alfa (summer season), 24 in alfa–alfa (winter season), and 35 in millet fields. Frequency (*f* %) of weed species within the different crop farmlands was used as measure of ecological success. The total number of species varied among the studied crops: the highest was 131 species in alfa–alfa (the perennial crop), followed by 111 species in wheat (the winter crop), and the lowest (29 species) was in millet (the summer crop). The relationships between the recorded species and crops were discussed. TWINSPAN as a classification method and DCA as an ordination methods were used to assess differences in floristic composition in different seasons. The resulted TWINSPAN vegetation groups from winter and summer seasons were clearly separated along the first 2 axes of DCA. Canonical correspondence analysis was used to evaluate the relationships between the examined soil factors and the floristic presence/absence data sets in each season.

**Keywords** Egypt · Agro-diversity · Distribution · Soil factors · CCA · Weed flora

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## 1 Introduction

Wealth studies on desert vegetation in Egypt have been conducted (Kassas and Zahran 1962; Shaltout et al. 1992), but studies on the vegetation of the reclaimed areas in Egypt are still limited (Hegazy et al. 2004). One of these studies was that carried out by (Shehata and El Fahar 2000) and concerned with the vegetation of the reclaimed areas northeast of the Nile Delta.

In most of the Egyptian arable lands, usually a 3-year crop rotation is applied. The crop succession during this period is: (1) temporary Egyptian clover (or fallow fields)—cotton; (2) wheat–maize (or rice in the northern Delta), and (3) permanent Egyptian clover (or broad beans)—maize. So, an area is usually divided into three parts in order to have all the crops in the same year (Shaltout and El Fahar 1991). In Egypt, hand pulling and manual hoeing are the most frequent methods of weed control of all the crops, except rice. Weeds of Egyptian croplands differ from season to season because of their ecological requirements. They can be grouped according to their seasonal performance into three main categories (Abd El-Ghani and Amer 1990; Abd El-Ghani and El-Bakry 1992): winter weeds (are more restricted to the cooler months of the year), summer weeds (are more restricted to the warmer months of the year) and all-year weeds (are present and biologically active throughout the year). The all-year weeds, however, can be differentiated into all-year weeds with winter affinity (fare better during winter, i.e., with more abundant populations and more vigorous growth in winter) and all-year weeds with summer affinity (fare better during summer). Unlike the old cultivated lands of the Nile that are irrigated by a well-established network of irrigation system, the reclaimed lands are usually using modern techniques like drip and sprinkle types for irrigation. In most of the Egyptian desert reclaimed lands, agriculture is mainly dependent on underground water which comes to the surface through pumping.

The significance of local site characteristics such as abiotic factors (soil and climate) and management practices for the occurrence of single species, community composition and species richness are profound (e.g., Andersson and Milberg 1998; Menalled et al. 2001; Walter et al. 2002; Andreasen and Skovgaard 2009). Studies of weed communities by numerical methods, such as cluster analysis and correlation analysis, and multivariate technique such as canonical correspondence analysis can be a useful tool to show relationships between weed species and crops (Kenkel et al. 2002; Salonen 1993; Andreasen et al. 1992; Streibig 1979). In Egypt, the application of multivariate analysis techniques in weed studies was also conducted Abd El-Ghani (1981, 1985) in the Oases, El-Amry (1981) in Minya Province on the Nile, El-Bakry (1982) in east of the Delta, Shaltout and El Fahar (1991), Shaltout and El-Sheikh (1993), Shaltout et al. (1994), El-Demerdash et al. (1997) in the Nile Delta and Abd El-Ghani (1998b) in southern Sinai.

Fewer detailed studies have been conducted on the weed flora of governorates of Upper Egypt; amongst others was that of El-Amry (1981) who surveyed the plant life in Minya Governorate which extends for about 120 km in the middle part of the Nile Valley between Beni Suef Governorate and in the north and Assiut Governorate in the south. The plant life in Giza Governorate has been surveyed by Soliman (1989), which comprising a sector of old farmland belonging to the Nile Valley, as well as a sector of newly reclaimed desert belonging to the South Tahrir Project. The plant life of Aswan Governorate has been surveyed by Shaheen (1987), which consists of narrow stripes of old farmlands on both sides of the River Nile. The weed flora of Qena Governorate has been studied by El Hadidi et al. (1999) in the southern part of the Nile Valley; between Sohag Governorate in the north and Aswan Governorate in the south.

The main objectives of this paper are (1) to identify the vegetation groups (communities) prevailing in each season, and (2) to recognise the crop–weed relationships, and (3) to assess the role of different soil factors on the distribution and composition of the weed flora in each season.

## 2 Methods

### 2.1 The study area

The area under investigation include parts of two governorates; Sohag at the north and Luxur at the south. It comprises the reclaimed desert lands extending on both sides (eastern and western) of the Nile Valley between 25°85′ and 26°30′N and 32°00′ and 32°90′E (Fig. 1). The eastern part (referred to as eastern transect) of the study area represents a part of eastern desert, and the western part (referred to as western transect) represents a part western desert road crossing the western desert parallel to the Nile valley. The eastern and western parts of the study area are occupied by desert areas, which are dissected by many wadis; the largest of these wadis is Wadi Qena. The arable lands in the study area can be distinguished into the old cultivated lands which have been

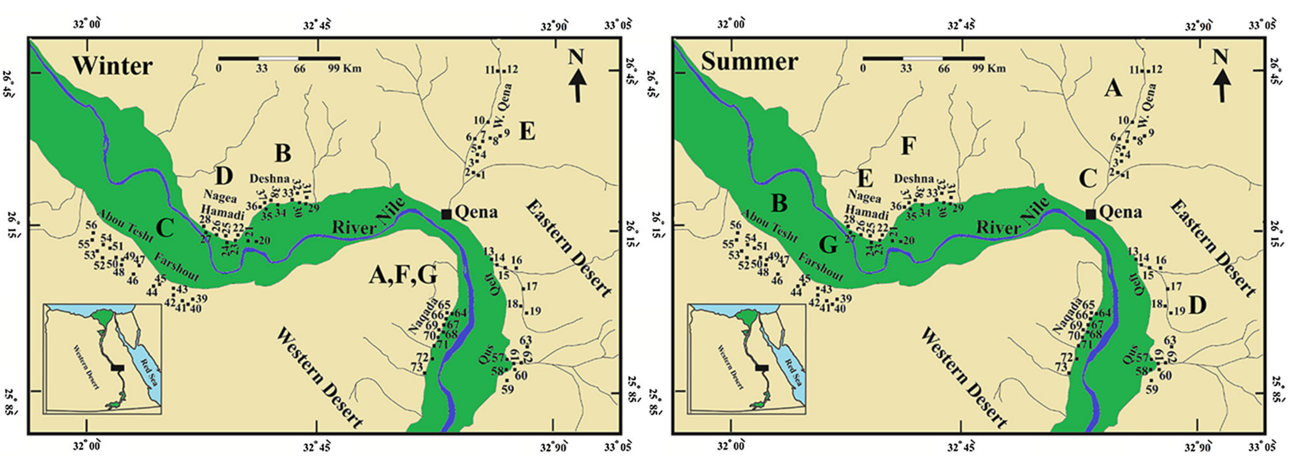


**Fig. 1** Distribution of stands in the study area, showing the resulted vegetation groups (*A*–*G*) of winter and summer crops

cultivated since ancient times, and the reclaimed lands which have been farmed from about 30 years ago.

The area of study is essentially occupied by sedimentary rocks belonging to the Upper Cretaceous, the Tertiary and Quaternary (Abd El Razik 1972). Terraces of the old alluvial plains are composed mainly of Prenile and Neonile sediments where gravel, sands, and shales are the dominant constituents. According to Said (1981, 1991), the Recent, Pleistocene and Pliocene deposits present in the Nile valley can be subdivided into the following sediments: (1) Recent to sub recent alluvial cover, (2) Neonile sediments "Dandara Formation—Pleistocene age", (3) Prenile sediments "Qena Formation-Pleistocene age" and (4) Paleonile sediments (Pliocene age).

According to the meteorological data obtained from two stations (Qena and Luxor) during 2013 and 2014, the temperature is regular in its seasonality. Winter months are cold and summer months are hot. The maximal values were recorded in summer month (July 2014), they were 41.27 and 41.45 °C at Qena and Luxor, respectively, while the minimal values were recorded in winter month (January 2014), they were 8.58 and 8.19 °C at Qena and Luxor, respectively. Negligible average amounts of rainfall were recorded, not exceeding 0.1 mm/year and the area under investigation is considered among the rainless provinces in southern Egypt (Zahran and Willis 2009). The highest values of the relative humidity (RH) were recorded during (December 2014) reached to 73 and 77.9% at Qena and Luxor, respectively, while it reduced to 7.2% at Qena and 11.1% at Luxor in summer of 2014.

### 2.2 Crop–weed relationships

The whole surface of a field was considered as the sampling area (1 acre on average). Sample stands fulfilled the following requirements (Müller-Dombois and Ellenberg 1974) (1) they were large enough to contain all species belonging to the plant community (25–100 $m^2$ for agricultural weed communities); (2) the habitat was uniform within the stand area; (3) the plant cover was homogeneous. Field margins and negative topographic positions were avoided, because they may represent different habitats (e.g., different soil conditions). Furthermore, surveys were also restricted to those field areas which had homogeneous crop cover. Surveys were performed by two or more trained persons who walked across each field during at least 30 min, recording all species observed until no more new species were found.

Weed assemblages associated with 3 major crops were monitored. Permanent stands (fields) were visited seasonally to record the variation in the floristic composition. To get a reasonable estimate of the occurrence of weed species in a crop, more fields (stands) should be included, rather than investigate more plots within a field (Andreasen and Skovgaard 2009). Thus, the 146 studied fields were distributed as follows: 49 in the wheat fields, 38 in alfa–alfa (summer season), 24 in alfa–alfa (winter season), and 35 in millet fields. Frequency ($f$) of weed species within the different crop farmlands was used as measure of ecological success. The frequencies of weed species were classified into 5 frequency classes (I–V) Class I $f = 81$–100%, Class II $f = 61$–80%, Class III $f = 41$–60%, Class IV $f = 21$–40%, Class V $f = 1$–20%. Performance percentage of each species (P) was calculated as the total number of fields where species recorded divided by the total number of the monitored fields. Voucher specimens of each species were collected, identified and deposited in the herbarium of South Valley University. Taxonomic nomenclature was according to Täckholm (1974), updated by Boulos (1995, 1999–2005).

To express variations in growth form (species duration) traits, an arbitrary 8-category system was adopted. These categories were: winter weeds (w), summer weeds (s), all-the-year weeds (a), desert annuals (da), desert perennials (dp), trees (t), crop (c) and margin species (ms). The latter are those recorded at the transition zones separating different agricultural fields from each other or from other landscape elements.

### 2.3 Soil sampling and analysis

Soil samples (0–50 cm depth) were collected at 3 random points from each stand as composite samples. These samples were then air-dried, thoroughly mixed, and pass through a 2 mm sieve to get rid of gravel and debris and then packed in paper bags ready for physical and chemical analysis. Three replicates were analysed for each sample measurement. The weight of gravel in each stand was determined and expressed as a percentage of the total weight of the soil sample. The soil texture was determined using the sieve method; the amount of each fraction (coarse sand, fine sand, silt and clay) was expressed as percentage of the original weight used (Ryan et al. 1996). The soil portion less than 2 mm in size was kept for chemical analysis according to Jackson (1967) and Allen and Stainer (1974). Organic matter was determined in the soil samples by loss on ignition. Ten grams of 2 mm mesh sieved, oven-dried soil, were placed in 40 cc tarred porcelain crucibles and ignited in an electric muffle furnace at 600 °C for 3 h. The crucible was placed in a desiccator, cooled to room temperature, and weighted. Loss was calculated in present of the oven-dried sample (Sparks et al. 1996). Soil water extracts (1:5) were prepared for determination of pH using a glass electrode pH meter and electrical conductivity (EC) using conductivity meter. Sodium and potassium were determined by flame photometer. Calcium and magnesium were estimated by titration against EDTA (Jackson 1967). Chlorides were determined by direct titration against $AgNO_3$ using potassium chromate as an indicator. Sulphates were determined by a turbidimetric technique with barium chloride and acidic sodium chloride solution using spectrophotometer according to Bardsley and Lancaster (1965) also phosphates were determined colour-metrically as phospho-molybdate according to Woods and Mellon (1941).

### 2.4 Vegetation analysis

Classification and ordination techniques were employed to analyse the vegetation. For this purpose, two presence/absence data matrices were used: for winter season (73 stands × 130 species) and for summer season (73 stands × 108 species). Each floristic data matrix was then subjected to classification by Two-Way Indicator Species Analysis (TWINSPAN) using the default settings of the computer programme CAP (Community Analysis Package, version 1.2) for Windows (Henderson and Seaby 1999) using the minimum variance as an algorithm, and a dendrogram was elaborated.

Preliminary analyses were made by applying the default options of the DCA (Hill and Gauch 1980) in the CANOCO programme, to check the magnitude of change in species composition along the first ordination axis (i.e., gradient length in standard deviation units). DCA estimated the compositional gradient in the vegetation data of the present study to be ranged from 3.9 to 4 S.D. units for most subset analysis. Therefore, Canonical Correspondence Analysis was applied using the default option of the computer programme CANOCO software version 4.5 (Ter Braak 1987, 1990). Canonical correspondence analysis (CCA) was performed to determine the association between species composition and examined soil variables. The variables in the CCA biplot were represented by arrows pointing in the direction of maximum variation, with their length proportional to the rate of change (Ter Braak 1986). Two CCA were performed. The first analysis was made to compare the soil variables with winter season, and the second with the summer season. Each arrow determined an axis on which the species point can be projected. A Monte Carlo permutation test (499 permutations; Ter Braak 1990) was used to test for significance of the eigenvalues of the first canonical axis. Prior to analysis, all variables were checked for normality, and transformations were performed when necessary. Fifteen soil variables were included: soil reaction (pH), electric conductivity (EC), organic matter (OM), gravels, coarse sand (CS), fine sand (FS), silt, clay, chlorides (Cl), sulphates ($SO_4$), Mg, Ca, Na, K, and $PO_4$.

The TWINSPAN vegetation groups were subjected to ANOVA (One-Way Analysis of Variance) based on soil variables to find out whether there were significant variations among groups. Analysis of variance provides an insight into the nature of variation of natural events, which is possibly of even greater value than the knowledge of the method as such (Sokal and Rohlfs 1981).

## 3 Results

### 3.1 Crop–weed relationships

In general, a total of 169 species (105 annuals, 64 perennials) of the vascular plants belonged to 121 genera in 39 families constituted the flora of the study area. Table 1 summarises the performance of each species within the studied crops. The total number of species varied among the crops: the highest was 131 species in alfa–alfa (the perennial crop), followed by 111 species in wheat (the winter crop), and the lowest (29 species) was in millet (the summer crop).

Forty-seven species were recorded in all the 3 crops (widest sociological ranges of species). Some species of this category perform best in one (or more) crop than the others where their records were little or a few. For example, *Chenopodium murale, Ch. album, Sonchus oleraceus* and *Malva parviflora* fare well in the wheat fields (winter crop, $P = 73–53\%$); meanwhile *Alhagi graecorum, Echinochloa colona* and *Portulaca oleracea* did this in the millet fields ($P = 49\%$). *Tamarix nilotica* fares well or at least common in alfalfa farmlands, performance was 37%.

Fifty-three species were recorded in two crops. *Bidens pilosa* and *Brassica nigra* were absent from alfa–alfa fields, while another 38 species were absent in millet. Obviously, summer weeds seem to be more common in millet farmlands, especially *Corchorus olitorius* ($P = 51\%$), *Brachiaria eruciformis* and *Amaranthus hybridus* ($P = 20\%$ for each). On the contrary, the winter weeds *Euphorbia peplus, Avena barbata, A. fatua* and *Emex spinosa* were performed in wheat cropland ($P = 10–16\%$).

Sixty-nine species were confined to only one weed assemblage (narrowest sociological range), and distributed as follows: 33 species in alfa–alfa, 24 species in wheat and 12 species in millet farmlands. All species of this category showed low or very low performances ($P = 2–14\%$). Some species showed certain degree of consistency. For example *Brachiaria reptans* and *Dinebra retroflexa* in millet (summer crop), *Sisymbrium irio* in wheat (winter crop), and *Amaranthus viridis, Sida alba* and *Astragalus vogelii* in alfa–alfa (perennial crop). Some desert plant species were also recorded, e.g., *Zilla spinosa,* in millet *Cotula cinerea,*

**Table 1** Sociological ranges of species recorded in the studied crops

| GF | Crops | Alfa–alfa | | Wheat | | Millet | |
|---|---|---|---|---|---|---|---|
| | Total number of species | 131 | | 111 | | 74 | |
| | Number of visited stands (fields) | 62 | P | 49 | P | 35 | P |
| I-Species present in all crops | | | | | | | |
| t | *Acacia nilotica* | 1 | 2 (V) | 1 | 2 (V) | 2 | 6 (V) |
| dp | *Alhagi graecorum* | 8 | 13 (V) | 11 | 22 (IV) | 17 | 49 (III) |
| a | *Amaranthus lividus* | 1 | 2 (V) | 4 | 8 (V) | 4 | 11 (V) |
| a | *Aster squamatus* | 6 | 10 (V) | 3 | 6 (V) | 5 | 14 (V) |
| dp | *Atriplex halimus* | 4 | 6 (V) | 1 | 2 (V) | 1 | 3 (V) |
| da | *Bassia muricata* | 2 | 3 (V) | 1 | 2 (V) | 1 | 3 (V) |
| ms | *Beta vulgaris* | 10 | 16 (V) | 7 | 14 (V) | 1 | 3 (V) |
| t | *Calotropis procera* | 9 | 15 (V) | 5 | 10 (V) | 5 | 14 (V) |
| t | *Casuarina equisetifolia* | 12 | 19 (V) | 5 | 10 (V) | 1 | 3 (V) |
| a | *Chenopodium album* | 11 | 18 (V) | 26 | 53 (III) | 3 | 9 (V) |
| a | *Chenopodium ambrosioides* | 3 | 5 (V) | 2 | 4 (V) | 2 | 6 (V) |
| a | *Chenopodium murale* | 15 | 24 (IV) | 34 | 69 (II) | 1 | 3 (V) |
| a | *Cichorium endivia* | 4 | 6 (V) | 5 | 10 (V) | 1 | 3 (V) |
| a | *Convolvulus arvensis* | 12 | 19 (V) | 15 | 31 (IV) | 10 | 29 (IV) |
| a | *Conyza bonariensis* | 6 | 10 (V) | 3 | 6 (V) | 4 | 11 (V) |
| a | *Cynodon dactylon* | 62 | 100 (I) | 49 | 100 (I) | 35 | 100 (I) |
| a | *Cyperus rotundus* | 8 | 13 (V) | 3 | 6 (V) | 11 | 31 (IV) |
| a | *Dactyloctenium aegyptium* | 11 | 18 (V) | 1 | 2 (V) | 8 | 23 (IV) |
| a | *Desmostachya bipinnata* | 2 | 3 (V) | 1 | 2 (V) | 7 | 20 (V) |
| a | *Dichanthium annulatum* | 7 | 11 (V) | 1 | 2 (V) | 7 | 20 (V) |
| a | *Echinochloa colona* | 15 | 24 (IV) | 6 | 12 (V) | 17 | 49 (III) |
| a | *Euphorbia heterophylla* | 1 | 2 (V) | 1 | 2 (V) | 3 | 9 (V) |
| ms | *Imperata cylindrica* | 2 | 3 (V) | 1 | 2 (V) | 1 | 3 (V) |
| ms | *Lactuca serriola* | 4 | 6 (V) | 3 | 6 (V) | 2 | 6 (V) |
| a | *Malva parviflora* | 19 | 31 (IV) | 34 | 69 (II) | 3 | 9 (V) |
| c | *Medicago sativa* | 3 | 5 (V) | 4 | 8 (V) | 2 | 6 (V) |
| c | *Olea europaea* | 4 | 6 (V) | 1 | 2 (V) | 1 | 3 (V) |
| c | *Opuntia ficus-indica* | 6 | 10 (V) | 3 | 6 (V) | 1 | 3 (V) |
| a | *Oxalis corniculata* | 1 | 2 (V) | 1 | 2 (V) | 3 | 9 (V) |
| t | *Phoenix dactylifera* | 32 | 52 (III) | 11 | 22 (IV) | 20 | 57 (III) |
| ms | *Phragmites australis* | 15 | 24 (IV) | 7 | 14 (V) | 6 | 17 (V) |
| ms | *Pluchea dioscoridis* | 10 | 16 (V) | 4 | 8 (V) | 7 | 20 (V) |
| a | *Polygonum bellardi* | 2 | 3 (V) | 4 | 8 (V) | 1 | 3 (V) |
| ms | *Polygonum equisetiforme* | 9 | 15 (V) | 5 | 10 (V) | 5 | 14 (V) |
| a | *Portulaca oleracea* | 10 | 16 (V) | 4 | 8 (V) | 17 | 49 (III) |
| c | *Psidium guajava* | 3 | 5 (V) | 2 | 4 (V) | 1 | 3 (V) |
| dp | *Caroxylon imbricatum* | 21 | 34 (IV) | 8 | 16 (V) | 5 | 14 (V) |
| a | *Setaria verticillata* | 2 | 3 (V) | 1 | 2 (V) | 4 | 11 (V) |
| a | *Setaria viridis* | 7 | 11 (V) | 3 | 6 (V) | 2 | 6 (V) |
| a | *Solanum nigrum* | 7 | 11 (V) | 7 | 14 (V) | 3 | 9 (V) |
| a | *Sonchus oleraceus* | 27 | 44 (III) | 36 | 73 (II) | 5 | 14 (V) |
| c | *Sorghum bicolor* | 4 | 6 (V) | 4 | 8 (V) | 2 | 6 (V) |
| da | *Suaeda aegyptiaca* | 10 | 16 (V) | 6.0 | 12 (V) | 2 | 6 (V) |
| t | *Tamarix nilotica* | 23 | 37 (IV) | 11 | 22 (IV) | 8 | 23 (IV) |
| c | *Zea mays* | 11 | 18 (V) | 5 | 10 (V) | 4 | 11 (V) |

**Table 1** continued

| GF | Crops | Alfa–alfa | | Wheat | | Millet | |
|---|---|---|---|---|---|---|---|
| | Total number of species | 131 | | 111 | | 74 | |
| | Number of visited stands (fields) | 62 | P | 49 | P | 35 | P |
| t | *Zizphus spina-christi* | 13 | 21 (IV) | 2 | 4 (V) | 4 | 11 (V) |
| dp | *Zygophyllum coccineum* | 8 | 13 (V) | 7 | 14 (V) | 1 | 3 (V) |
| II-Species present in 2 crops | | | | | | | |
| a | *Bidens pilosa* | | | 1 | 2 (V) | 1 | 3 (V) |
| a | *Brassica nigra* | | | 7 | 14 (V) | 1 | 3 (V) |
| c | *Allium cepa* | 1 | 2 (V) | 4 | 8 (V) | | |
| w | *Ammi majus* | 2 | 3 (V) | 1 | 2 (V) | | |
| w | *Ammi vasinga* | 1 | 2 (V) | 1 | 2 (V) | | |
| w | *Anagallis arvensis* | 3 | 5 (V) | 1 | 2 (V) | | |
| c | *Anethum graveolens* | 2 | 3 (V) | 1 | 2 (V) | | |
| w | *Avena barbata* | 3 | 5 (V) | 6 | 12 (V) | | |
| w | *Avena fatua* | 1 | 2 (V) | 5 | 10 (V) | | |
| c | *Avena sativa* | 1 | 2 (V) | 4 | 8 (V) | | |
| da | *Bassia indica* | 1 | 2 (V) | 2 | 4 (V) | | |
| ms | *Brassica tournefortii* | 2 | 3 (V) | 2 | 4 (V) | | |
| c | *Citrus aurantifolia* | 1 | 2 (V) | 1 | 2 (V) | | |
| da | *Diplotaxis acris* | 3 | 5 (V) | 3 | 6 (V) | | |
| w | *Emex spinosa* | 3 | 5 (V) | 6 | 12 (V) | | |
| c | *Eruca sativa* | 2 | 3 (V) | 15 | 31 (IV) | | |
| w | *Euphorbia helioscopia* | 2 | 3 (V) | 2 | 4 (V) | | |
| w | *Euphorbia peplus* | 1 | 2 (V) | 8 | 16 (V) | | |
| dp | *Fagonia arabica* | 2 | 3 (V) | 2 | 4 (V) | | |
| c | *Lathyrus sativus* | 1 | 2 (V) | 2 | 4 (V) | | |
| dp | *Launaea nudicalus* | 3 | 5 (V) | 4 | 8 (V) | | |
| w | *Lolium perenne* | 6 | 10 (V) | 17 | 35 (IV) | | |
| c | *Lycopersicon esculentum* | 2 | 3 (V) | 2 | 4 (V) | | |
| w | *Medicago ciliaris* | 3 | 5 (V) | 2 | 4 (V) | | |
| w | *Melilotus indicus* | 8 | 13 (V) | 19 | 39 (IV) | | |
| ms | *Pennisetum divisum* | 1 | 2 (V) | 1 | 2 (V) | | |
| a | *Phalaris minor* | 5 | 8 (V) | 1 | 2 (V) | | |
| w | *Phalaris paradoxa* | 1 | 2 (V) | 4 | 8 (V) | | |
| ms | *Polygonum plebejum* | 1 | 2 (V) | 1 | 2 (V) | | |
| w | *Polypogon monspeliensis* | 10 | 16 (V) | 11 | 22 (V) | | |
| c | *Raphanus sativus* | 1 | 2 (V) | 7 | 14 (V) | | |
| ms | *Rumex dentatus* | 3 | 5 (V) | 2 | 4 (V) | | |
| da | *Schouwia purpura* | 4 | 6 (V) | 2 | 4 (V) | | |
| da | *Senecio glaucus* | 7 | 11 (V) | 11 | 22 (V) | | |
| w | *Sinapis arvensis* | 1 | 2 (V) | 3 | 6 (V) | | |
| ms | *Sorghum virgatum* | 3 | 5 (V) | 3 | 6 (V) | | |
| w | *Trifolium resupinatum* | 4 | 6 (V) | 3 | 6 (V) | | |
| w | *Urospermum picroides* | 5 | 8 (V) | 2 | 4 (V) | | |
| ms | *Withania somnifera* | 3 | 5 (V) | 3 | 6 (V) | | |
| da | *Tetraena simplex* | 2 | 3 (V) | 1 | 2 (V) | | |
| s | *Amaranthus graecizans* | 2 | 3 (V) | | | 5 | 14 (V) |
| s | *Amaranthus hybridus* | 2 | 3 (V) | | | 7 | 20 (V) |
| s | *Brachiaria eruciformis* | 4 | 6 (V) | | | 7 | 20 (V) |

**Table 1** continued

| GF | Crops | Alfa–alfa | | Wheat | | Millet | |
|---|---|---|---|---|---|---|---|
| | Total number of species | 131 | | 111 | | 74 | |
| | Number of visited stands (fields) | 62 | P | 49 | P | 35 | P |
| s | *Cenchrus biflorus* | 2 | 3 (V) | | | 1 | 3 (V) |
| s | *Corchorus olitorius* | 2 | 3 (V) | | | 18 | 51 (III) |
| s | *Digitaria sanguinalis* | 7 | 11 (V) | | | 6 | 17 (V) |
| t | *Leptadenia pyrotechnica* | 3 | 5 (V) | | | 1 | 3 (V) |
| a | *Leptochloa fusca* | 5 | 8 (V) | | | 1 | 3 (V) |
| dp | *Salsola sp.* | 1 | 2 (V) | | | 2 | 6 (V) |
| dp | *Caroxylon villosum* | 5 | 8 (V) | | | 2 | 6 (V) |
| t | *Sesbania sesban* | 8 | 13 (V) | | | 5 | 14 (V) |
| s | *Sorghum halepense* | 1 | 2 (V) | | | 2 | 6 (V) |
| s | *Trianthema portulacastrum* | 2 | 3 (V) | | | 4 | 11 (V) |
| III-Species present in 1 crop | | | | | | | |
| s | *Brachiaria reptans* | | | | | 3 | 9 (V) |
| s | *Cuscuta pedicellata* | | | | | 2 | 6 (V) |
| ms | *Cynanchum acutum* | | | | | 1 | 3 (V) |
| ms | *Datura stramonium* | | | | | 1 | 3 (V) |
| s | *Dinebra retroflexa* | | | | | 3 | 9 (V) |
| s | *Euphorbia forsskaolii* | | | | | 2 | 6 (V) |
| da | *Euphorbia granulata* | | | | | 1 | 3 (V) |
| s | *Euphorbia hirta* | | | | | 1 | 3 (V) |
| ms | *Euphorbia indica* | | | | | 1 | 3 (V) |
| s | *Euphorbia prostrata* | | | | | 1 | 3 (V) |
| t | *Hyphaene thebaica* | | | | | 1 | 3 (V) |
| dp | *Zilla spinosa* | | | | | 1 | 3 (V) |
| dp | *Aleuropus lagopoides* | | | 1 | 2 (V) | | |
| ms | *Anchusa humilis* | | | 2 | 4 (V) | | |
| w | *Bromus diandrus* | | | 2 | 4 (V) | | |
| c | *Carthamus tinctorius* | | | 1 | 2 (V) | | |
| w | *Cenchrus ciliaris* | | | 1 | 2 (V) | | |
| w | *Cenchrus echinatus* | | | 1 | 2 (V) | | |
| ms | *Chrozophora plicata* | | | 1 | 2 (V) | | |
| w | *Coronopus niloticus* | | | 1 | 2 (V) | | |
| da | *Cotula cinerea* | | | 1 | 2 (V) | | |
| ms | *Datura innoxia* | | | 2 | 4 (V) | | |
| da | *Diplotaxis harra* | | | 1 | 2 (V) | | |
| w | *Erucastrum arabicum* | | | 1 | 2 (V) | | |
| c | *Foeniculum vulgaris* | | | 2 | 4 (V) | | |
| c | *Helianthus annuus* | | | 1 | 2 (V) | | |
| c | *Hibiscus sabdariffa* | | | 1 | 2 (V) | | |
| w | *Lathyrus hirsutus* | | | 1 | 2 (V) | | |
| c | *Lupinus albus* | | | 1 | 2 (V) | | |
| w | *Medicago polymorpha* | | | 1 | 2 (V) | | |
| w | *Orobanche crenata* | | | 2 | 4 (V) | | |
| ms | *Reichardia tingitana* | | | 1 | 2 (V) | | |
| w | *Sisymbrium irio* | | | 7 | 14 (V) | | |
| w | *Spergularia marina* | | | 2 | 4 (V) | | |
| c | *Trigonella foenum-graceum* | | | 1 | 2 (V) | | |

**Table 1** continued

| GF | Crops | Alfa–alfa | | Wheat | | Millet | |
|---|---|---|---|---|---|---|---|
| | Total number of species | 131 | | 111 | | 74 | |
| | Number of visited stands (fields) | 62 | P | 49 | P | 35 | P |
| w | *Trigonella hamosa* | | | 2 | 4 (V) | | |
| t | *Acacia raddiana* | 1 | 2 (V) | | | | |
| w | *Amaranthus viridis* | 2 | 3 (V) | | | | |
| da | *Anthemis pseudocotula* | 1 | 2 (V) | | | | |
| da | *Astragalus vogelii* | 2 | 3 (V) | | | | |
| dp | *Atiplex leucoclada* | 2 | 3 (V) | | | | |
| c | *Citrullus lanatus* | 2 | 3 (V) | | | | |
| c | *Citrus limon* | 1 | 2 (V) | | | | |
| c | *Citrus reticulata* | 2 | 3 (V) | | | | |
| c | *Citrus sinensis* | 2 | 3 (V) | | | | |
| c | *Coriandrum sativum* | 1 | 2 (V) | | | | |
| ms | *Cressa cretica* | 1 | 2 (V) | | | | |
| ms | *Eclipta prostrata* | 1 | 2 (V) | | | | |
| c | *Eucalyptus camaladulensis* | 4 | 6 (V) | | | | |
| dp | *Fagonia indica* | 1 | 2 (V) | | | | |
| c | *Ficus carica* | 2 | 3 (V) | | | | |
| dp | *Hyoscyamus muticus* | 4 | 6 (V) | | | | |
| c | *Lantana camara* | 2 | 3 (V) | | | | |
| da | *Launaea mucronata* | 3 | 5 (V) | | | | |
| dp | *Morettia philaeana* | 2 | 3 (V) | | | | |
| t | *Ochradenus baccatus* | 2 | 3 (V) | | | | |
| w | *Orobanche ramosa* | 2 | 3 (V) | | | | |
| ms | *Panicum coloratum* | 1 | 2 (V) | | | | |
| w | *Plantago lagopus* | 1 | 2 (V) | | | | |
| s | *Polypogon viridis* | 1 | 2 (V) | | | | |
| dp | *Pulicaria undulata* | 2 | 3 (V) | | | | |
| t | *Ricinus communis* | 3 | 5 (V) | | | | |
| da | *Rumex vesicarius* | 2 | 3 (V) | | | | |
| t | *Salix mucronata* | 2 | 3 (V) | | | | |
| dp | *Salsola vermiculata* | 1 | 2 (V) | | | | |
| w | *Sida alba* | 1 | 2 (V) | | | | |
| t | *Tamarix aphylla* | 1 | 2 (V) | | | | |
| c | *Trifolium alexandrinum* | 1 | 2 (V) | | | | |
| c | *Triticum aestivum* | 1 | 2 (V) | | | | |

Values are number of fields where species was recorded. I–V frequency classes, *P* performance percentage, *GF* growth forms (for details, see text). *a* all-the-year weed, *s* summer weed, *w* winter crop, *da* desert annual, *dp* desert perennial, *ms* margin species, *t* tree, *c* crop

in wheat *Ochradenus baccatus, Fagonia indica* and *Pulicaria undulata* in alfa–alfa.

### 3.2 Classification of the vegetation

#### *3.2.1 In winter crops*

Classification of the presence/absence dataset of 130 species recorded in 73 stands in winter crops (24 alfalfa and 49 wheat farmlands) using the two-way indicator species analysis (TWINSPAN) yielded 7 vegetation groups at level 3 of the hierarchy (Figs. 1, 2). Stands of groups D, E and B were located in the eastern part of Qena province (ca. latitude 26°20′). In the meantime, stands of groups A, C, G and F were closer to the western part especially at Abou Tesht and Farshout centres (ca. latitude 26° 00′). The yielded groups named after the dominant species that have the highest presence values *P* %). *Cynodon dactylon,*

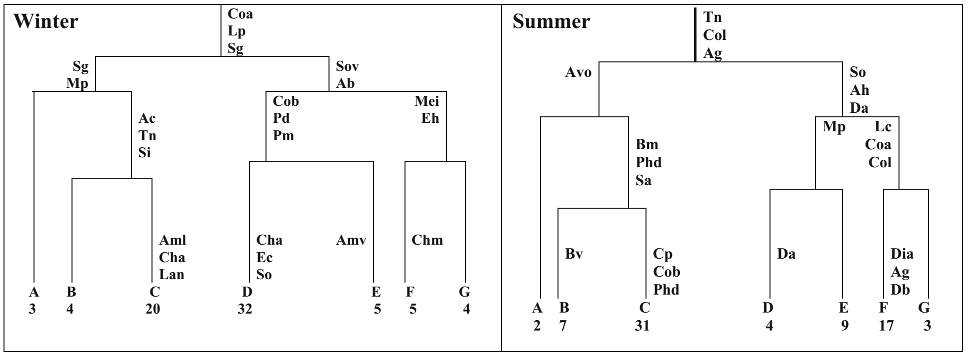


**Fig. 2** TWINSPAN classification of 73 stands of the study area during winter and summer seasons. *A–G* are the seven separated vegetation groups, and the figures denote to the number of stands. Abbreviations of the indicator species: Ab = *Avena barbata*, Ac = *Allium cepa*, Ag = *Alhagi graecorum,* Ah = *Amaranthus hybridus,* Aml = *Amaranthus lividus*, Amv = *Ammi visnaga*, Avo = *Astragalus vogelii*, Bm = *Bassia muricata,* Bv = *Beta vulgaris*, Cha = *Chenopodium album*, Chm = *Chenopodium murale*, Coa = *Convolvulus arvensis*, Cob = *Conyza bonariensis*, Col = *Corchorus olitorius,* Cp = *Calotropis procera,* Da = *Dactyloctenium aegyptium,* Db = *Desmostachya bipinnata*, Dia = *Dichanthium annulatum*, Ec = *Echinochloa colona*, Eh = *Euphorbia heterophylla*, Lan = *Launaea nudicaulis*, Lc = *Lantana camara*, Lp = *Lolium perenne*, Mei = *Melilotus indicus*, Mp = *Malva parviflora*, Pd = *Pennisetum divisum*, Phd = *Phoenix dactylifera*, Pm = *Polypogon monspeliensis*, Sa = *Suaeda aegyptiaca,* Sg = *Senecio glaucus*, Si = *Caroxylon imbricatum*, So = *Sonchus oleraceus*, Sov = *Sorghum virgatum* and Tn = *Tamarix nilotica*

*Chenopodium album* and *Sonchus oleraceus* were recorded with the highest presence values in the studied groups.

Transitions between the vegetation types identified from TWINSPAN analysis were quite clearly marked by higher rates of species turnover. Between neighbouring sites within these sections of these transects (Fig. 1), usually followed by a plateau, or at least a slower rate of turnover, between sites occupying the rest of that vegetation type along the transect.

At the first hierarchical level of TWINSPAN dendrogram (Fig. 2), the 73 stands were classified into two major groups with *Convolvulus arvensis, Lolium perenne* and *Senecio glaucus* as the indicator species. At the second hierarchical level; 46 stands, which comprising the groups D, E, F and G were separated from the main dataset according to two indicator species (*Avena barbata* and *Sorghum virgatum*). On the other hand; *Senecio glaucus* and *Malva parviflora* were the indicator species that separate the other 27 stands of groups A, B and C. At the third hierarchical level of TWINSPAN dendrogram; the groups B and C separated with the indicator species *Allium cepa, Tamarix nilotica* and *Caroxylon imbricatum.* Also, *Conyza bonariensis, Polypogon monspeliensis* and *Pennisetum divisum* were indicators those separate groups D and E. On the other hand, the last two groups (F and G) were classified with *Melilotus indicus* and *Euphorbia geniculata.*

**Group (A)**, included 27 species recorded from 3 stands; mostly associated with wheat fields. The stands of this group inhabited soil rich in its pH, gravels and coarse sand, but had the lowest percentages of silt and clay. It is dominated by *Cynodon dactylon.* Two sporadic weeds *Cenchrus ciliaris C. echinatus* were confined to this group.

**Group (B)** comprised of 26 species recorded from 4 stands. Five xerophytic species were represented in this community (*Caroxylon imbricatum, Suaeda aegyptiaca, Diplotaxis acris, Bassia indica* and *Fagonia arabica*). Its soil had relatively high pH, gravels and fine sand contents, and the lowest contents of Na, K and Ca and OM.

**Group (C)**, the most diversified (81 species, 20 stands) one and separated with *Chenopodium album, Amaranthus lividus* and *Launaea nudicaulis* as indicator species. This community dominated by *Cynodon dactylon* ($f = 100\%$). It inhabited soil with highest salinity (electric conductivity), Na, K and fine sand contents. The high soil contents of Cl, $SO_4$ and $PO_4$ were characteristic to this group. On the other hand it had the lowest OM and silt contents amongst the others. Several xerophytes were also recorded, e.g., *Chrozophora plicata, Leptadenia pyrotechnica* and *Launaea nudicaulis.*

**Group (D)**, its indicator species were *Chenopodium album, Sonchus oleraceus* and *Echinochloa colona.* This community included 64 species recorded in 32 stands with the highest K, Cl and $PO_4$ contents in its soil. The soil of this group of stands characterised by rich contents of Mg, $SO_4$ and clay. The stands of this group were mainly represented in wheat and alfa–alfa, and other crops of minor importance such as Egyptian clover, onions, and broad beans.

**Group (E)**, the size of this group was 5 stands and 31 species, with *Ammi visnaga* as indicator species (Fig. 2). The stands of this group occurred on soil with the highest contents of silt, Ca, Mg and $SO_4$.

**Group (F)**, the indicator species of this group is *Chenopodium murale. Cynodon dactylon, Sonchus oleraceus* and *Avena barbata* represented in the five stands

($f = 100\%$). It comprised of 31 species from 5 stands, with soil of moderately low salinity (electric conductivity), cations and anions contents.

**Group (G)**, included 36 species from 4 stands with the highest silt content. The dominance was for the three weeds (*Cynodon dactylon, Sonchus oleraceus* and *Convolvulus arvensis*).

### 3.2.2 *In summer crops*

Seven vegetation groups were produced after the application of classification using TWINSPAN analysis to the floristic data set in summer crops (108 species × 73 stands) of the study area. Thirty-eight stands of them were planted by alfalfa and the others (35 farmlands) were sown by millet. These seven plant communities were represented on the location map (Fig. 1), illustrating that most stands of groups (A, C and D) were at the eastern part of Qena Governorate. Meanwhile, stands of the vegetation group E and F were positioned at the centre of this study area (Nagea Hamadi and Deshna centre, respectively). Finally, most of stands of groups B and G were located in the western part of the study area (at Farshout and Abou Tesht). *Cynodon dactylon* and *Phoenix dactylifera* were the only ubiquitous species those recorded in the 7 groups with variable presence values. *Pluchea dioscoridis* and *Tamarix nilotica* were represented in 6 groups.

The first TWINSPAN dichotomy differentiated the 73 stands were classified into two major groups with *Alhagi graecorum, Corchorus olitorius* and *Tamarix nilotica* as the indicator species (Fig. 2). At the second hierarchical level; 33 stands, which comprising the groups D to G were separated from the main data-set according to three indicator species *Dactyloctenium aegyptium, Amaranthus hybridus* and *Sonchus oleraceus*. On the meantime *Astragalus vogelii* separated the other 40 stands of groups A, B and C. At the third hierarchical level of TWINSPAN dendrogram; the groups F and G separated with the indicator species *Corchorus olitorius, Convolvulus arvensis* and *Lantana camara*. Also, *Malva parviflora* was the indicator species that separate the 13 stands of groups D and E. On the other hand, groups B and C were classified with *Suaeda aegyptiaca, Phoenix dactylifera* and *Bassia muricata*.

**Group (A)**, It comprised of 20 species recorded from 2 alfa–alfa fields inhabiting soil rich in its content of $SO_4$ and fine sand but had the lowest contents of $PO_4$, pH, gravels and OM. Eighteen species of this community type represented as a dominant species ($f = 100\%$). Most of the recorded species were among the common desert plants (e.g., *Caroxylon imbricatum, Zygophyllum coccineum, Atriplex halimus, Schouwia purpurea, Astragalus vogelii, Diplotaxis acris, Fagonia arabica* and *Pulicaria undulata*). Also there were 8 species showed a degree of consistency (e.g. *Fagonia arabica, Pulicaria undulata*, *Morettia philaeana* and *Tetraena simplex*).

**Group (B)**, it comprised of 32 species from 7 stands with *Beta vulgaris* as the indicator species. The dominant species was *Cynodon dactylon*. The co-dominant species ($f = 86–57\%$) were the salt tolerant species such as *Suaeda aegyptiaca, Tamarix nilotica* and *Phragmites australis*. It occurred on soil with the highest levels of Na, Mg and Cl. On the other hand, these soils recorded low contents in clay.

**Group (C)**, *Phoenix dactylifera, Conyza bonariensis* and *Calotropis procera* were the indicator of this group (63 species and 31 stands) recorded mainly from alfa–alfa and millet fields. *Cynodon dactylon* was the dominant species ($f = 100\%$), with 3 co-dominants ($f = 68-42\%$). It occurred on soil with highest levels of gravels, coarse sand and the lowest contents of silt and K.

**Group (D)**, 31 species sampled from 4 stands with soils rich in $PO_4$, OM, coarse sand and clay contents. This group had 8 characteristic species ($f = 100\%$), and *Dactyloctenium aegyptium* was the indicator species. Nine sporadic species included some weeds such as *Conyza bonariensis* and *Trianthema portulacastrum*, and some xerophytes such as as *Tamarix nilotica, Hyoscyamus muticus* and *Zygophyllum coccineum.*

**Group E**, included 45 species from 9 stands, dominated by *Cynodon dactylon* in millet fields. The stands of this group inhabited soil with the highest pH, with Mg, Cl and $SO_4$ had the lowest contents. The associated co-dominant species ($f = 78–68\%$) were *Echinochloa colona, Phoenix dactylifera, Alhagi graecorum, Portulaca oleracea, Dactyloctenium aegyptium* and *Amaranthus hybridus.* Consistent species to this group were *Datura stramonium, Brassica nigra, Cichorium endivia, Cynanchum acutum* and *Euphorbia hirta.*

**Group (F)**, *Desmostachya bipinnata, Alhagi graecorum* and *Dichanthium annulatum* were the indicator species (Fig. 2). It included 47 species from 17 stands occur on soil rich in silt, clay, pH and OM and the lowest Na contents. Co-dominant species ($f = 77–53\%$) were *Alhagi graecorum, Convolvulus arvensis, Corchorus olitorius* and *Phoenix dactylifera.*

**Group (G)**, it was the least diversified group with 12 species recorded from 3 stands that occured on soil rich in fine sand, silt, and salinity factors (EC, cations and anions), but they had the lowest values of coarse sand content. *Cynodon dactylon* and *Alhagi graecorum* were the dominant species ($f = 100\%$). Sporadic species included *Pluchea dioscoridis, Tamarix nilotica, Calotropis procera* and *Hyoscyamus muticus*.

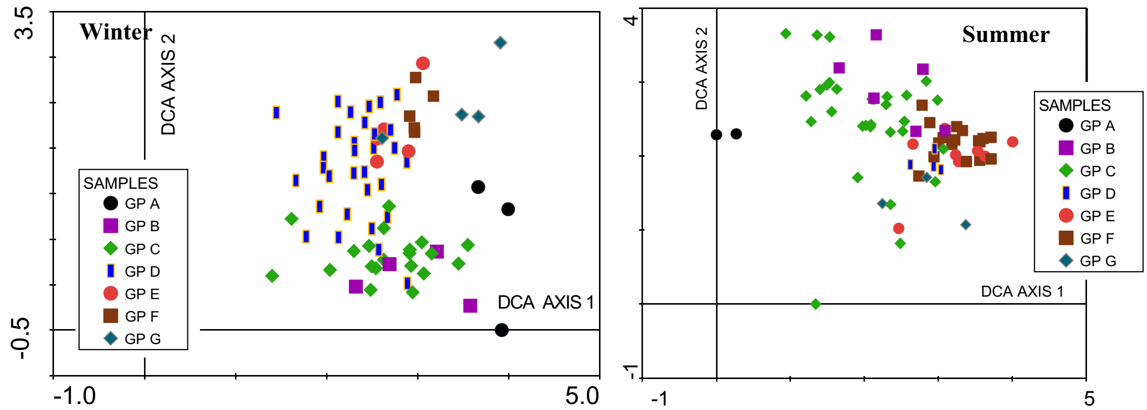


**Fig. 3** DCA diagram showing the distribution of the 73 stands of the study area during winter and summer seasons, together within their vegetation groups

## 3.3 Stand ordination

### *3.3.1 In winter crops*

When plotted on the first two Detrended Correspondence Analysis (DCA) ordination axes, the stands tend to cluster into the 7 vegetation groups which resulted from TWINSPAN and illustrated in Fig. 3. It is obvious from the diagram that groups B and C seperated on axis 1, the other groups had a wide extension along axis 2, and groups E and F overlap. Meanwhile, group G was completely separated toward axis 2. By other meaning; the stands of groups (A, B and C) separated along the positive side of DCA axis 1, while those of groups (D, E, F and G) separated along its positive end of the DCA axis 2. The eigenvalue for the first DCA axis was relatively high (Eigenvalue = 0.524) indicating that it captured the greater proportion of the variations in species composition among stands, followed by the second DCA axis (Eigenvalue = 0.394). The cumulative percentage variance of species data of the first two DCA axes was 15.5%.

### *3.3.2 In summer crops*

The application of DCA on the same set of data of summer crops indicated a reasonable aggregation of these groups along the ordination plane of axes 1 and 2 (Fig. 3). The stands were spread out 4.00 S.D. units along the first axis (Eigenvalue = 0.568), expressing reasonable floristic variation among vegetation groups. Stands of groups D, E, F and G were separated toward the positive end of DCA axis 1, while those of groups A, B and C were separated out along the positive end of DCA axis 2 with an eigenvalue of 0.481 and a less important gradient length (3.65). The cumulative percentage variance of species data of the DCA axes was 17.8%.

## 3.4 Soil–vegetation relationships

### *3.4.1 In winter crops*

Significant differences in the examined soil variables within the separated vegetation groups were noticed (Table 2). Soil fertility and soil texture contents (gravels, coarse sand, fine sand, silt and clay) showed clear significant differences between groups at $P < 0.01$ and $P < 0.05$. The relationship between the vegetation and soil variables was studied using Canonical Correspondence Analysis (CCA). Figure 4 showed the CCA ordination biplot with vegetation groups (A–G), and the examined soil variables. It can be noted that, stands of group A were highly correlated with coarse sand and $PO_4$, while those of group B and C showed a correlation with salinity (EC) and the measured cations and anions. Stands of group D showed some correlation with fertility (OM), silt, clay and soil reactions (pH). The vegetation composition of the groups E, F and G were affected by OM, clay and pH.

The inter-set correlations resulted from Canonical Correspondence Analysis (CCA) of the examined soil variables were displayed in Table 3. The cumulative percentage variance of species-environment correlation was 42.4 for the first two axes. CCA axis 1 was highly positively correlated with coarse sand and highly negatively correlated with OM. So, this axis can be interpreted as coarse sand-OM gradient. CCA axis 2 was highly positively correlated with coarse sand and highly negatively correlated with fine sand. Thus, this axis can be interpreted as coarse sand-fine sand gradient. A test for significance with an unrestricted Monte Carlo permutation test (499 permutation) for the eigenvalue of axis 1 found to be non-significant ($P = 0.114$).

**Table 2** Mean values ± standard error (STE) and ANOVA values of the soil variables in the winter and summer vegetation groups (A–G) of Qena weeds

| Soil factors | Vegetation groups (winter) | | | | | | | Total means | F value | P |
|---|---|---|---|---|---|---|---|---|---|---|
| | A | B | C | D | E | F | G | | | |
| Na | 0.90 ± 0.34 | 0.65 ± 0.09 | 1.36 ± 0.26 | 1.16 ± 0.23 | 0.88 ± 0.34 | 0.68 ± 0.19 | 1.09 ± 0.52 | 1.12 ± 0.13 | 0.44 | 0.849 |
| K | 1.49 ± 0.12 | 0.98 ± 0.15 | 3.91 ± 0.87 | 4.29 ± 0.96 | 3.81 ± 0.55 | 2.82 ± 0.57 | 1.73 ± 0.40 | 3.61 ± 0.49 | 0.686 | 0.662 |
| Ca | 0.35 ± 0.19 | 0.18 ± 0.03 | 1.09 ± 0.30 | 0.91 ± 0.20 | 1.63 ± 0.87 | 0.42 ± 0.16 | 1.05 ± 0.71 | 0.92 ± 0.14 | 0.869 | 0.523 |
| Mg | 0.13 ± 0.07 | 0.22 ± 0.06 | 0.38 ± 0.12 | 0.54 ± 0.22 | 0.57 ± 0.28 | 0.15 ± 0.03 | 0.50 ± 0.35 | 0.44 ± 0.11 | 0.268 | 0.95 |
| Cl | 0.93 ± 0.63 | 0.50 ± 0.10 | 2.44 ± 0.80 | 2.81 ± 1.66 | 2.17 ± 1.14 | 0.35 ± 0.08 | 0.71 ± 0.33 | 2.18 ± 0.76 | 0.202 | 0.975 |
| $SO_4$ | 1.19 ± 0.78 | 0.33 ± 0.10 | 2.94 ± 0.74 | 2.49 ± 0.47 | 3.11 ± 1.78 | 1.20 ± 0.62 | 2.21 ± 2.04 | 2.38 ± 0.34 | 0.741 | 0.618 |
| $PO_4$ | 0.38 ± 0.01 | 0.12 ± 0.04 | 0.22 ± 0.08 | 0.25 ± 0.07 | 0.08 ± 0.02 | 0.12 ± 0.02 | 0.09 ± 0.01 | 0.21 ± 0.04 | 0.493 | 0.811 |
| pH | 9.22 ± 0.18 | 9.11 ± 0.04 | 8.92 ± 0.10 | 8.94 ± 0.06 | 8.75 ± 0.25 | 8.82 ± 0.19 | 9.02 ± 0.22 | 8.94 ± 0.05 | 0.659 | 0.683 |
| EC | 799.47 ± 571.47 | 355.25 ± 78.23 | 2077.00 ± 648.29 | 1215.20 ± 240.50 | 1504.40 ± 779.53 | 578.87 ± 134.41 | 1192.30 ± 677.36 | 1362.10 ± 220.84 | 0.891 | 0.507 |
| OM | 1.19 ± 0.17 | 0.61 ± 0.08 | 1.11 ± 0.20 | 2.15 ± 0.18 | 1.85 ± 0.40 | 3.05 ± 0.25 | 2.53 ± 0.20 | 1.80 ± 0.12 | 6.414** | 0 |
| Gravel | 8.67 ± 2.03 | 8.62 ± 2.74 | 6.95 ± 0.92 | 7.61 ± 0.74 | 1.31 ± 0.15 | 2.64 ± 0.75 | 1.58 ± 0.51 | 6.42 ± 0.51 | 4.201** | 0 |
| CS | 42.47 ± 15.18 | 11.87 ± 4.97 | 12.74 ± 3.90 | 14.13 ± 0.87 | 7.48 ± 1.33 | 9.32 ± 1.87 | 12.33 ± 1.15 | 13.91 ± 1.46 | 3.721** | 0 |
| FS | 30.31 ± 15.43 | 40.18 ± 4.46 | 42.03 ± 3.10 | 32.16 ± 1.37 | 38.80 ± 4.31 | 38.43 ± 3.55 | 29.07 ± 1.87 | 35.94 ± 1.34 | 2.283* | 0.046 |
| Silt | 15.41 ± 2.15 | 35.66 ± 3.66 | 34.14 ± 2.75 | 36.99 ± 1.75 | 46.10 ± 2.58 | 42.20 ± 3.11 | 44.83 ± 2.89 | 36.66 ± 1.30 | 3.965** | 0 |
| Clay | 3.14 ± 0.46 | 3.69 ± 0.73 | 4.14 ± 0.59 | 9.12 ± 0.91 | 6.31 ± 1.21 | 7.41 ± 2.17 | 12.19 ± 3.02 | 7.07 ± 0.57 | 4.679** | 0 |
| Soil factors | Vegetation groups (summer) | | | | | | | Total means | F value | P |
| | A | B | C | D | E | F | G | | | |
| Na | 1.72 ± 0.10 | 2.19 ± 2.59 | 1.00 ± 0.64 | 1.91 ± 1.71 | 0.76 ± 0.35 | 0.68 ± 0.60 | 2.03 ± 1.43 | 1.12 ± 1.12 | 2.822* | 0.017 |
| K | 5.00 ± 0.00 | 5.07 ± 3.79 | 2.48 ± 1.84 | 2.51 ± 1.64 | 3.39 ± 2.25 | 4.39 ± 7.16 | 8.67 ± 6.07 | 3.61 ± 4.22 | 1.464 | 0.204 |
| Ca | 3.77 ± 0.16 | 1.71 ± 1.95 | 0.84 ± 0.89 | 1.24 ± 1.93 | 0.23 ± 0.14 | 0.46 ± 0.58 | 2.27 ± 1.76 | 0.92 ± 1.20 | 5.46** | 0 |
| Mg | 1.20 ± 0.47 | 1.30 ± 2.64 | 0.35 ± 0.37 | 0.36 ± 0.29 | 0.16 ± 0.08 | 0.19 ± 0.14 | 1.17 ± 1.05 | 0.44 ± 0.91 | 2.226 | 0.051 |
| Cl | 4.95 ± 0.27 | 9.37 ± 19.72 | 1.02 ± 0.95 | 4.20 ± 6.58 | 0.45 ± 0.20 | 1.04 ± 1.88 | 4.46 ± 3.66 | 2.18 ± 6.53 | 2.138 | 0.06 |
| $SO_4$ | 7.47 ± 0.01 | 3.66 ± 3.53 | 2.66 ± 2.85 | 3.17 ± 3.44 | 0.75 ± 0.91 | 0.87 ± 1.53 | 5.39 ± 4.30 | 2.38 ± 2.87 | 3.986** | 0.002 |
| $PO_4$ | 0.07 ± 0.01 | 0.09 ± 0.03 | 0.24 ± 0.32 | 0.26 ± 0.33 | 0.24 ± 0.23 | 0.21 ± 0.50 | 0.07 ± 0.01 | 0.21 ± 0.34 | 0.356 | 0.904 |
| pH | 8.16 ± 0.06 | 8.80 ± 0.58 | 8.95 ± 0.35 | 8.90 ± 0.39 | 9.10 ± 0.24 | 9.08 ± 0.27 | 8.46 ± 0.49 | 8.94 ± 0.39 | 3.486** | 0.005 |
| EC | 3.41 ± 0.71 | 2.25 ± 0.21 | 1.11 ± 0.12 | 2.78 ± 0.52 | 0.48 ± 0.32 | 0.89 ± 0.12 | 3.93 ± 0.32 | 1.36 ± 0.18 | 2.966* | 0.013 |
| OM | 1.04 ± 0.05 | 1.22 ± 1.26 | 1.49 ± 0.93 | 2.04 ± 1.21 | 1.99 ± 1.23 | 2.65 ± 0.74 | 1.14 ± 0.51 | 1.80 ± 1.07 | 3.654** | 0.003 |
| Gravels | 1.19 ± 0.11 | 7.85 ± 5.50 | 7.99 ± 4.51 | 8.26 ± 4.23 | 4.19 ± 2.23 | 4.88 ± 3.61 | 3.48 ± 2.76 | 6.42 ± 4.38 | 2.682* | 0.022 |
| CS | 5.55 ± 1.86 | 9.78 ± 5.28 | 18.17 ± 17.44 | 13.62 ± 4.43 | 11.08 ± 6.94 | 12.08 ± 3.13 | 4.24 ± 1.88 | 13.91 ± 12.44 | 1.369 | 0.24 |
| FS | 49.10 ± 0.01 | 38.66 ± 9.75 | 37.00 ± 13.40 | 39.18 ± 11.91 | 36.02 ± 10.40 | 28.69 ± 5.49 | 46.53 ± 3.92 | 35.94 ± 11.47 | 2.416* | 0.036 |
| Silt | 40.72 ± 1.56 | 40.83 ± 6.43 | 30.09 ± 11.87 | 30.26 ± 10.28 | 41.99 ± 7.57 | 44.05 ± 5.85 | 42.70 ± 8.23 | 36.66 ± 11.11 | 5.468** | 0 |
| Clay | 3.45 ± 0.41 | 2.89 ± 0.75 | 6.76 ± 5.22 | 8.67 ± 4.33 | 6.72 ± 2.42 | 10.31 ± 4.90 | 3.05 ± 0.57 | 7.07 ± 4.86 | 3.282** | 0 |

*EC* electric conductivity (mS $cm^{-1}$), soil fractions (%), *CS* Coarse sand, *FS* Fine sand, Na, K, Ca, Mg, Cl, $SO_4$ and $PO_4$ (mg $g^{-1}$ dry wt. soil), OM (%), ** $p < 0.01$ and * $p < 0.05$

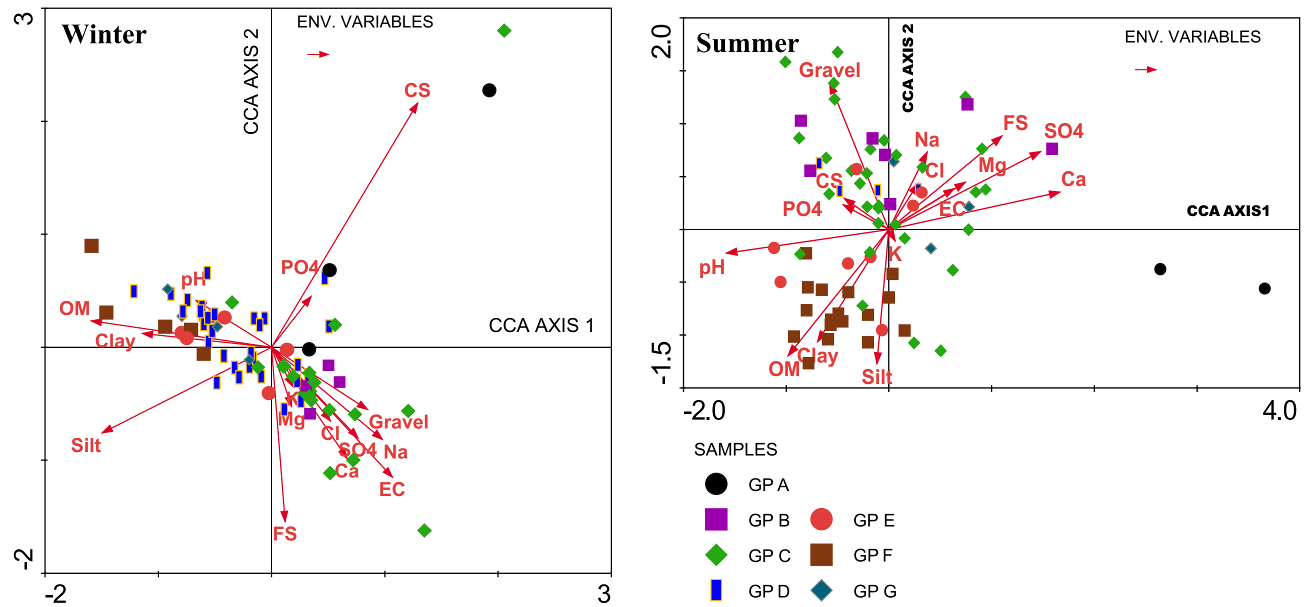


**Fig. 4** Canonical correspondence analysis (CCA) biplot of axes 1 and 2 showing the distribution of the 73 stands of the study area during winter and summer seasons, together with their vegetation groups and soil variables

**Table 3** Inter-set correlation of CCA analysis for the soil variables, together with eigenvalues and species–environment correlations in the study area during winter and summer seasons

| Axes | Winter crops | | Summer crops | |
|---|---|---|---|---|
| | 1 | 2 | 1 | 2 |
| Eigenvalues | **0.328** | **0.304** | **0.45** | **0.327** |
| Species– environment correlations | **0.945** | **0.938** | **0.911** | **0.92** |
| Na (mg $g^{-1}$ dry soil) | 0.3395 | −0.2859 | 0.1275 | 0.267 |
| K (mg $g^{-1}$ dry soil) | 0.0653 | −0.1219 | 0.0201 | −0.0386 |
| Ca (mg $g^{-1}$ dry soil) | 0.2317 | −0.3453 | **0.5694** | 0.1287 |
| Mg (mg $g^{-1}$ dry soil) | 0.0614 | −0.1836 | 0.217 | 0.1412 |
| Cl (mg $g^{-1}$ dry soil) | 0.1803 | −0.2292 | 0.0971 | 0.1587 |
| $SO_4$ (mg $g^{-1}$ dry soil) | 0.2646 | −0.2813 | 0.505 | 0.2695 |
| $PO_4$ (mg $g^{-1}$ dry soil) | 0.1208 | 0.1585 | −0.1506 | 0.0843 |
| pH | −0.2306 | 0.1451 | **−0.5401** | −0.0827 |
| EC (mS $cm^{-1}$) | 0.3706 | −0.4043 | 0.254 | 0.1629 |
| OM (%) | **−0.5518** | 0.0823 | −0.3348 | −0.4368 |
| Gravel (%) | 0.2937 | −0.1932 | −0.1972 | **0.5069** |
| CS (%) | **0.4478** | **0.7607** | −0.1477 | 0.1066 |
| FS (%) | 0.0415 | **−0.5419** | 0.376 | 0.3235 |
| Silt (%) | −0.5189 | −0.2663 | −0.0396 | **−0.4639** |
| Clay (%) | −0.3951 | 0.0431 | −0.2367 | −0.3887 |

For soil abbreviations, see text

Bold values represent highest loading on both axes

### *3.4.2 In summer crops*

Most of the estimated soil variables showed significant differences (Table 2) among the identified vegetation groups of summer crops. Figure 4 showed the CCA ordination biplot with the vegetation groups A-G, and the examined soil variables. It can be noted that stands of group B were highly correlated with Na, $SO_4$, gravels and coarse sand, while stands of group C showed a high correlation with about all of the measured environmental variables. Stands of group D exhibited some correlation with Cl, coarse sand and gravels, meanwhile those of group E showed a correlation with Cl, gravels, pH and OM. Members of group A were not affected by any soil factors.

Stands of group F were correlated to silt, clay, OM and pH. Ca and EC were the main soil factors affecting the vegetation of group G.

The inter-set correlations resulted from CCA of the examined soil variables were displayed in Table 3. The cumulative percentage variance of species-environment correlation was 49.6 for the first two axes. CCA axis 1 was highly positively correlated with Ca and highly negatively correlated with pH, therefore it can be inferred as calcium-pH gradient. CCA axis 2 was highly positively correlated with gravels and highly negatively with silt, and can be identified as gravels-silt gradient. The Monte Carlo permutation test for the eigenvalue of the first axis found to be significant ($P = 0.0240$) indicating that the observed patterns did not arise by chance.

## 4 Discussion

Weed growth, population density, and distributions vary from place to place depending upon soil and climatic factors and farmers' management practices (Dale et al. 1992). In Egypt, the reclaimed lands are situated in areas that have different climatic and edaphic features. In this study, croplands were the main distinguished agro-ecosystems, with variation in the total number of recorded species. Plant species composition and species numbers may vary considerably among them due to differences in ecological conditions and agricultural management (Norderhaug et al. 1999; Marshall and Moonen 2002). The difference in field management practices may also be a factor that explains differences in weed species richness (Stevenson et al. 1997; Sher and Al-Yemeni 2011). The low species richness in wheat and millet crops compared to alfa–alfa can be attributed to the fact that the land of field crops is generally ploughed each season before the sowing of the seeds of crops, a practice that reduces the richness of weeds compared to the perennial alfa–alfa crops which remain for 2 years and rarely ploughed (once a year).

Close to the boundaries of the desert and within the agroecosystem in this study, desert plant species are naturally grow among the weeds of the cultivation. This indicated that these species are native to the natural desert vegetation and can remain after the reclamation process. Also, the availability of irrigation water in newly desert reclaimed land provides habitat for rich populations of several desert plants that are sparse elsewhere, to grow and flourish. This human interference, as indicated by desert reclamation, causes the weedy species to replace the wild plant species in these reclaimed areas (Baessler and Klotz 2006). The analysis of the vegetation components of the agroecosystem of the reclaimed lands consisted mainly of the weed species similar to those growing in the crops of the old cultivated lands, in addition to some desert plant species. This suggests that land reclamation in the study area entails weed species replacing natural plant communities. Therefore, the reclaimed areas of this study can be considered as a transitional phase of the succession process between the habitat of the old cultivated lands and that of the desert. Weeds are the most frequent species that spread in the desert reclaimed areas; therefore there is a banalization of the flora that will spread with crop intensification.

The wide distribution of some weeds in this work may be interpreted as ubiquitous species. Species with wide amplitude (e.g., *Cynodon dactylon, Chenopodium album, Ch. murale* and *Sonchus oleraceus)* are often caused by phenotypic plasticity and heterogeneity (Shaltout and Sharaf El-Din 1988). The restricted distribution of some weeds, such as *Aeluropus lagopoides* and *Suaeda aegyptiaca* in salinized and/or waste lands, and *Acacia nilotica* and *Chenopodium ambrosoides*, *Salix safsaf* and *Pluchea dioscoridis* along canal banks can be attributed to the habitat preference phenomenon. In line with this, Abd El-Ghani and Fawzy (2006) and Abd El-Ghani et al. (2013) discussed this phenomenon in the farmlands of the Egyptian Oases and in the reclaimed desert lands along the Nile Valley. They concluded that each of the 5 distinguished habitats (farmlands, canal banks, reclaimed lands, waste lands, and water bodies) has its own preferential species.

Data-set classification of the recorded species in winter and summer crops using TWINSPAN analysis separated the vegetation into groups at level 3 of the hierarchy. The analysis of species composition of winter crops yielded 7 vegetation groups recorded in 73 stands, also the species composition of summer crops yielded 7 different groups. The main winter crops of this study area were alfalfa and wheat. Groups D, E and B were located in the Eastern part of Qena Province, while groups A, C, G and F are closer to the Western part especially at Abou Tesht and Farshout Centres (highest number of species per stand). The vegetation group C was characterised by many xeric halophytes and salt tolerant plants (e.g. *Chenopodium album, Ch. ambrosioides, Caroxylon imbricatum* and *Phragmites australis*). The presence of these species may be contributed to the soils of these stands which inhabited the highest salinity (electric conductivity), Na and K. This habitat may represent a transitional habitat between moist and dry saline habitats (Abd El-Ghani 2000). In the present study, the vegetation–environment relationships was assessed by CCA, which indicated that salinity, organic matter and soil reactions (pH) were the important factors affecting the distribution of the species composition in winter crops. This has been reported in other relevant studies (e.g., El-Ghareeb and Hassan 1989; El-Demerdash et al. 1995; Shaltout et al. 1997).

The main summer crops were alfalfa and millet. The segregated 7 plant communities showed that most stands of groups (A, C and D) were at the eastern part of Qena Province. Meanwhile, stands of the vegetation groups (E and F) were positioned at the centre of the study area (Nagea Hamadi and Deshna). Finally, most of the stands of groups (B) and (G) were located in the western region of the study area (at Farshout and Abou Tesht). The soils of stands of group (G) (at Farshout centre) seem to prevent the growth of the summer weeds. On the other hand; most of the recorded species in this group were xerophytes such as *Tamarix nilotica, Alhagi graecorum Calotropis procera* and *Leptadenia pyrotechnica*; which indicate its high salinity content. Such salinity stress on floristic diversity in the study area and related areas was reported by Moustafa and Klopatek (1995) and Shaltout et al. (1997).

CCA analysis for the summer crops was highly affected by Ca, pH, silt and gravels. These groups were clearly separated along the first two axes of Detrended Correspondence Analysis (DCA). A clear pattern in the distribution of site groups was evident, suggesting that the floristic variation in the data set was mainly related to environmental differences in the reclaimed lands. However, the application of both classification and ordination methods have resulted in a clear segregation of the different vegetation groups associated with the reclaimed lands in the study area in quantitative terms and in recognising more weed groups than that has been identified in similar studies (Abd El-Fattah 1986; Abd El-Ghani 1994, 1998a; El-Fahar and Sheded 2002; Abd El-Ghani and El-Sawaf 2004). The application of Detrended Correspondence Analysis (DCA) indicated that the vegetation groups yielded by the classification technique of the studied sites were generally interconnected.

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## References

Abd El Razik TM (1972) On the tectonic origin of the Nile valley between Idfu and Qena, Egypt. J Geol 16(2):235–244
Abd El-Fattah RI (1986) Ecological and phytosciological studies on plant communities in Salhiya area. Dissertation, Zagazig University, Egypt
Abd El-Ghani MM (1981) Preliminary studies on the vegetation of Bahariya Oasis, Egypt. Dissertation, Cairo University
Abd El-Ghani MM (1985) Comparative study of the vegetation of Bahariya and Farafra Oases and the Faiyum region, Egypt. Dissertation, Cairo University
Abd El-Ghani MM (1994) Weed plant communities of orchards in Siwa Oasis, Egypt. Feddes Repert 105(5–6):387–398
Abd El-Ghani MM (1998a) Environmental correlates of species distribution in arid desert ecosystems of eastern Egypt. J Arid Environ 38:297–313
Abd El-Ghani MM (1998b) Weed communities of date-palm orchards in the Feiran Oasis (south Sinai, Egypt). Fragm Florist Geobot 43(2):257–271
Abd El-Ghani MM (2000) Floristics and environmental relations in two extreme desert zones of western Egypt. Glob Ecol Biogeogr 9:499–516
Abd El-Ghani MM, Amer AM (1990) Studies on weed assemblages in croplands, Egypt. I. Broad bean fields. Egypt J Bot 33(1):15–30
Abd El-Ghani MM, El-Bakry AA (1992) Studies on weed assemblages in croplands, Egypt. II. Egyptian clover fields. Bull Fac Agric Cairo Univ 43(4):1221–1252
Abd El-Ghani MM, El-Sawaf N (2004) Diversity and distribution of plant species in agro-ecosystems of Egypt. Syst Geogr Pl 74:319–336
Abd El-Ghani MM, Fawzy AM (2006) Plant diversity around springs and wells in five oases of the Western Desert, Egypt. Int J Agric Biol 8:249–255
Abd El-Ghani MM, Soliman A, Hamdy R, Bennoba E (2013) Weed flora in the reclaimed lands along the northern sector of the Nile Valley in Egypt. Turk J Bot 37:464–488
Allen MM, Stainer ST (1974) Chemical analysis of ecological materials. Blackwell, London, p 565
Andersson TN, Milberg P (1998) Weed flora and the relative importance of site, crop, crop rotation, and nitrogen. Weed Sci 46:30–38
Andreasen C, Skovgaard IM (2009) Crop and soil factors of importance for the distribution of plant species on arable fields in Denmark. Agric Ecosyst Environ 133:61–67
Andreasen C, Jensen JE, Haas H (1992) *Setaria viridis* and *Echinochloa*: new grass weed species in Denmark. 9th Danish Plant Protection Conference/Weeds. Statens Planteavlsforsog, beretn. S 2178:49–60
Baessler C, Klotz S (2006) Effects of changes in agricultural land-use on landscape structure and arable weed vegetation over the last 50 years. Agric Ecosyst Environ 115:43–50
Bardsley CE, Lancaster JD (1965) Sulfur. In: Black CA, Evans DD, White JL, Jnsminger LE, Clark FE (ed). Methods of soil analysis. Part 2. Agronomy. Series No. 9. Madison, Wisconsin, American Society of Agronomy, Inc., pp 1102–1116
Boulos L (1995) Flora of Egypt. Checklist. Al Hadara Publishing, Cairo
Boulos L (1999–2005) Flora of Egypt, Vol. 1–4. Al Hadara Publishing, Cairo
Dale MRT, Thomas AG, John EA (1992) Environmental factors including management practices as correlates of weed community composition in spring seeded crops. Can J Bot 70:1931–1939
El Hadidi MN, Hosni HA, El Hadidy AMH, Araffa S (1999) Malvaceae in the flora of Egypt. 1- Systematic revision of the indigenous taxa. Taeckholmia 19:127–146
El-Amry MI (1981) Plant life in Minya Province, Egypt. Dissertation, Cairo University
El-Bakry AA (1982) Studies on plant life in Cairo-Ismailia region. Dissertation, Cairo University
El-Demerdash MA, Hegazy AK, Zailay AM (1995) Vegetation–soil relationships in Tihamah coastal plains of Jazan region, Saudi Arabia. J Arid Environ 30:161–174
El-Demerdash MA, Hosni HA, Al-Ashri N (1997) Distribution of the weed communities in the North East Nile Delta, Egypt. Feddes Repert 108(3–4):219–232

El-Fahar RA, Sheded MG (2002) Weed flora in plantation of recent established tourist resorts in the Western Mediterranean coast of Egypt. Egypt J Biotech 11:330–343

El-Ghareeb R, Hassan IA (1989) A phytosociological study on the inland desert plateau of the Western Desert of Egypt at El-Hammam. J Arid Environ 17:13–21

Hegazy AK, Fahmy GM, Ali MI, Gomaa NH (2004) Vegetation diversity in natural and agro-ecosystems of arid lands. Commun Ecol 5:163–176

Henderson PA, Seaby RMH (1999) Community Analysis Package (CAP) version 1.2. Pisces Conservation Ltd. IRC House, UK

Hill MO, Gauch HG (1980) Detrended correspondence analysis: an improved ordination technique. Vegetatio 42:47–58

Jackson ML (1967) Soil chemical analysis-advanced course. Published by the Washington Department of Soil Sciences

Kassas M, Zahran MA (1962) Studies on the ecology of the Red Sea coastal land. I. The district of Gebel Ataqa and El-Galala El-Bahariya. Bull Soc Geogr d'Egypte 35:129–175

Kenkel NC, Derksen DA, Thomas AG, Watson PR (2002) Multivariate analysis in weed science research. Weed Sci 50:281–292

Marshall EJP, Moonen AC (2002) Field margins in northern Europe: their functions and interactions with agriculture. Agric Ecosyst Environ 89:5–21

Menalled FD, Gross KL, Hammond M (2001) Weed aboveground and seedbank community responses to agricultural management systems. Ecol Appl 11:1586–1601

Moustafa AA, Klopatek JM (1995) Vegetation and landforms of the Saint Catherine area, southern Sinai, Egypt. J Arid Environ 30:385–395

Müller-Dombois D, Ellenberg H (1974) Causal analytical inquiries into the origin of plant communities. In: Mueller-Dombois D, Ellenberg H (eds) Aims and methods of vegetation ecology. Wiley, New York, pp 335–370

Norderhaug A, Austad I, Hauge L, Kvamme M (1999) Skjøtselsboka for kulturlandskap og gamle norske kulturmarker. Landbruksforlaget, Oslo

Ryan PJ, McKenzie NJ, Loughhead A, Ashton L (1996) New methods for forest soil surveys. In: Eldridge KG, Crowe MP, Olds KM (ed) The role of *Eucalyptus* and other fast growing species. Csiro Publishing, Collingwood, Victoria

Said R (1981) The geological evaluation of the River Nile. Springer, New York

Said R (1991) Quaternary in said. Geology of Egypt. A. A. Balkema/Rotterdam/Brookfield, pp 487–511

Salonen J (1993) Weed infestation and factors affecting weed incidence in spring cereals in Finland: a multivariate approach. Agric Sci Finland 2:525–536

Shaheen AM (1987) Studies on the weed flora of the Aswan area. Dissertation, Assiut University

Shaltout KH, El Fahar R (1991) Diversity and phenology of weed communities in the Nile Delta region. J Veg Sci 2:385–390

Shaltout KH, El-Sheikh MA (1993) Vegetation-environment relations along water courses in the Nile Delta region. J Veg Sci 4:567–570

Shaltout KH, Sharaf El-Din A (1988) Habitat types and plant communities along a transect in the Nile Delta region. Feddes Repert 99:153–162

Shaltout KH, Sharaf EL-Din A, EL Fahar RA (1992) Weed communities of the common crops in the Nile Delta region. Flora 187:329–339

Shaltout KH, Sharaf El-Din A, El-Sheikh MA (1994) Species richness and phenology of vegetation along irrigation canals and drains in the Nile Delta, Egypt. Vegetatio 112:35–43

Shaltout KH, El-Halawany EF, El-Garawany MM (1997) Coastal lowland vegetation of eastern Saudi Arabia. Biodivers Conserv 6:1027–1040

Shehata MN, El Fahar RA (2000) The vegetation of reclaimed areas in Salhiya region. In: Proceedings of the 1st international conference on biological science (ICBS), Faculty of Science, Tanta University 1: 315–332

Sher H, Al-Yemeni MN (2011) Ecological investigation of the weed flora in arable and non-arable lands of Al-kharj area, Saudi Arabia. Afr J Agric Res 6(4):901–906

Sokal RR, Rohlfs FJ (1981) Biometry Freeman, San Francisco. USA

Soliman AT (1989) Studies on plant life in the area of South Tahrir. Dissertation, Cairo University, Cairo

Sparks DL, Page AL, Helmke PA, Loeppert RH, Soltanpour PN, Tabatabai MA, Johnston CT, Sumner ME (1996) Methods of soil analysis. Part 3 - chemical methods. Soil Science Society of America Inc

Stevenson FC, Légere A, Simard RR, Angers DA, Pageau D, Lafond J (1997) Weed species diversity in spring barley varies with crop rotation and tillage, but not with nutrient source. Weed Sci 45:798–806

Streibig JC (1979) Numerical methods illustrating the phytosociology of crops in relation to weed flora. J Appl Ecol 16:577–587

Täckholm V (1974) Students' flora of Egypt, 2nd edn. Cairo University Press, Cairo

Ter Braak CJF (1986) Canonical correspondence analysis: a new eigenvector technique for multivariate direct gradient analysis. Ecology 67:1167–1179

Ter Braak CJF (1987) CANOCO—A fortran program or canonical community ordination by [partial] [detrended] [canonical] correspondence analysis, principal components analysis and redundancy analysis, Version 2.1. Wageningen: Agricultural Mathematics Group

Ter Braak CJF (1990) Update notes: CANOCO version 3.1. Wageningen: Agricultural Mathematics Group

Walter AM, Christensen S, Simmelsgaard SE (2002) Spatial correlation between species densities and soil properties. Weed Res 42:26–38

Woods JT, Mellon MG (1941) Chlorostannous-reduced Molybdophosphoric Blue colour method, in sulfuric acid system. In: Jackson ML (ed) Soil chemical analysis. Prentice-Hall International Inc., London, pp 141–144

Zahran MA, Willis AJ (2009) The vegetation of Egypt, 2nd edn. Springer, London