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The impact of five environmental factors on species distribution and weed community structure in the coastal farmland and adjacent territories in the northwest delta region, Egypt

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Abstract

The importance of the soil type and its properties cannot be denied as one of the major environmental factors affecting the weed community structure in an area, but what is the effect of the other environmental factors as the prevailing climate, crop type, urbanization and crop sustainability? What is the order of importance for their impact? The present study aims to measure these concepts. A sample area (3500 km^2) was selected in the Northwest Delta, Egypt. 473 species recorded and four VSG or vegetative sociation groups (weed communities) identified using Agglomerative Hierarchical Clustering (AHC). The diversity of the 4 VSG was calculated. PCA used to get a view for the influence of these five variables (environmental factors) on species distribution and variability of weed community structure, summarize the relationships among variables and investigate the proximity among samples and how they relate to variables. The measurement of the degree of seasonal bias of species added more clarification for the impact of crop type. ANOVA followed by Tukey's test showed the significance of 9 soil

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variables and determined which of the pairs were statistically significant. The results of the study revealed that the prevailing climate was the most impacting factor on species distribution and weed community structure followed by urbanization, crop type, soil type and crop sustainability, respectively.

Keywords: Ecology, Environmental Science, Plant biology

1. Introduction

The plant life in the Northwest of the Delta, Egypt is an interesting subject to study, for its exciting array of ecological habitats that are available for the growth of plants; from the wetlands which are nourished by the Nile to those desert territories subjected to land reclamation. The Deltaic Mediterranean coast of Egypt can be divided ecologically into four main habitats: salt marshes, sand formations, reed swamps and fertile lands (Zahran and Willis, 2009). In the present study several ecological habitats have been surveyed. They comprised farmland adjacent to the Nile Rosetta branch (east border of the area), coastal farmland facing Mediterranean Sea (a strip extending along the coastal belt from Rosetta westward to Abu Qir and Alexandria) and farmland at the fringes of salt marshes (Lake Idku, Lake Mariout; and Abu Al-Matamir and Housh Eissa Sabkhas) and those near desert from the west and southwards to the reclaimed land of Mudereyat El Tahrir. In farmland the performance of a weed species is influenced by a number of factors, the main ones being nutrient availability, competition from the crop and other weeds, the timing of sowing of the crop, herbicides and tillage. In addition, a number of edaphic and climatic factors can have a large influence (Baker, 1974; Andreasen et al., 1991; Salonen, 1993). Hence, the distribution, abundance and biomass production of weeds are governed by a complex system of different, more or less separable factors (Andersson and Milberg, 1996). Although the pioneer phytosociological and floristic studies on the Mediterranean coastal land of Egypt and Delta region date back to early of the last century (Simpson, 1932; Oliver, 1941; Tadros and Atta, 1958); but until this day the pressing need for the study of sociological relationships of weed flora in various ecological habitats continues to be debated. Although several phytosociological studies have been carried out on the Mediterranean region and Delta of Egypt, the topic of the present study has not been adequately addressed (El-Hadidi & Kosinová, 1971; Shaltout and El-Fahar, 1991; El-Demerdash et al., 1997; Mashaly et al., 2010; Shaltout and Ahmed, 2012, 2015; Abd El-Ghani et al., 2013; Ahmed et al., 2014, 2015; Mahgoub, 2017 and Abdelaal et al., 2017). Neither of them aimed to study the order of importance for the impact of the prevailing climate; soil type; crop type; crop sustainability and urbanization on species distribution and diversity of weed community. The present study focused on the impact of these five environmental factors and their order of importance as to aid in developing a beneficial sustainable concept of weed control strategy. To achieve that goal

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both clustering and Multivariate analyses have been employed. It is often that ecologists use multivariate analysis and ordination techniques to describe the relationship between a set of samples based on their attributes (Streibig, 1979; Salonen, 1993; Andersson and Milberg, 1998; Anderson, 2001, 2006; Clarke and Warwick, 2001a). Also, analysis of the spatial variation in multispecies weed communities together with environmental factors are beneficial for developing a sustainable long term weed control and soil management strategy (Kenkel et al., 2002).

2. Methodology

2.1. The study area

The study area is a triangle with an area of 3500 km^2. Its base (northern side) is 70 km line from Rosetta (Beheira Province, coordinates: Latitude: 31.400809, Longitude:30.417189) to El-Dekhela (Alexandria Province, coordinates: Latitude: 31.135078, Longitude: 29.823031) and equilateral 106 km lines extending southwards to Kom Hamada (Beheira or Al-Buhayrah Province, coordinates: Latitude: 30.757382, Longitude: 30.703379), see Fig. 1.

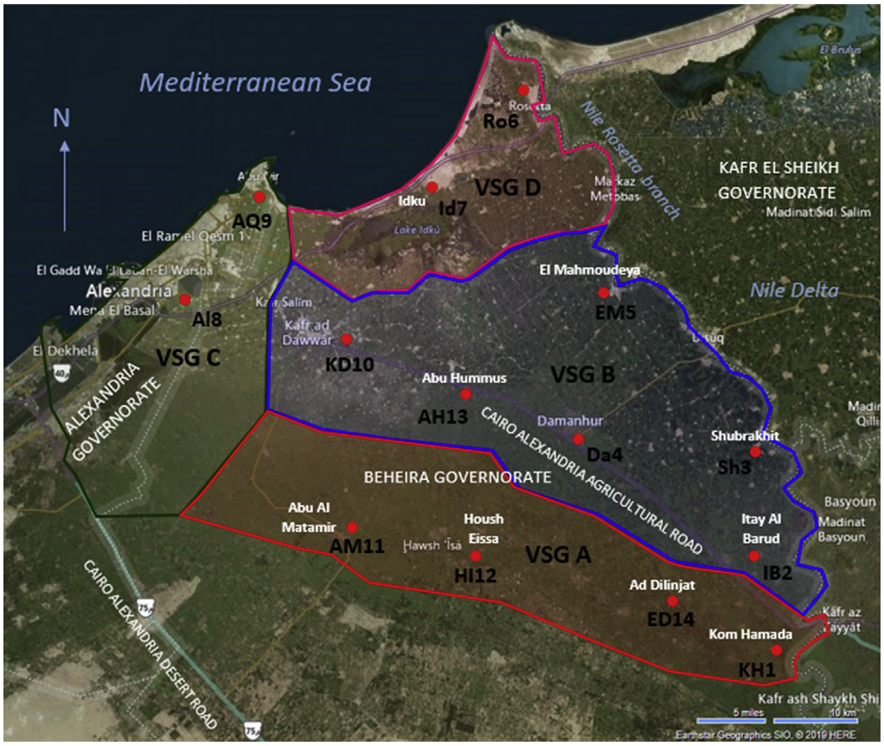

Fig. 1. Location Map of the surveyed area; within the administrative boundaries of each of the monitored fourteen sampling sites (districts), 5 localities (villages) were selected, in each of them number of stands were surveyed as to represent the various farmland in the different ecological habitats. The boundaries of the four weed communities or VSG (A-D) were superimposed on the map (for legend of sampling sites, see Fig. 3). "Map adapted from Bing Maps. Microsoft product screen shot(s) reprinted with permission from Microsoft Corporation. © 2019 Microsoft".

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The Meteorological records of the area obtained as a courtesy from the Egyptian Meteorological Authority (EMA), they included the records of the monthly averages of rainfall (mm), temperature (°C), relative humidity and evaporation from six stations from 1931 to 2015.

The chemical and mechanical analyses are quoted from the records of Ministry of Agriculture and Land Reclamation (MALR), Department of soil survey, Egypt, for respect of its authority and property of farmers. The reports included the analyses of soil samples of the localities (stands) and the weighted average was calculated to express the soil properties which dominate the sampling site (district). The depth of soil horizon profiles were 0−30, 30−60, 60−90, 90−120 cm, in them the following soil properties were measured: 1) soil texture expressed as percentage for clay, silt, clay + silt, fine sand, coarse sand, 2) Water holding capacity (100 gm soil %), 3) Hydrolytic conductivity (cm./hour), 4) Soil reaction (PH), 5) Main salts in water saturated soil extract: for cations (Ca, Mg, Na, K), and for anions (CO3, HCO3, Cl), 6) Total soluble salts (%) and 7) Calcium carbonate content (CaCO3). The values of separate % for clay, silt and sand for localities and sampling sites were applied in a soil texture triangle Fig. 3. In terms of soil texture, the soil type was identified according to USDA soil taxonomy (USDA classification system, Soil Survey Staff, 1999; 2006) and the identified four VSG were superimposed on sample points.

2.2. Field sampling design and data collection

Stratified sampling technique (Müller-Dombois and Ellenberg, 1974: pp. 177−209) was used as an ecological sampling design method. Through this method the samples are located randomly but allocating samples deliberately to each of the recognized different environmental patches in the sample area. The number of samples in a patch type should be proportional to the area of the patch type or possibly the diversity and the agricultural potentialities. Accordingly, within the administrative boundaries of each governorate, number of samples or sampling sites (districts) were randomly selected in each transect. But the allocating samples were deliberately to each of the recognized different ecological habitats. These samples (14 sampling sites) have represented the farmland in the different ecological habitats that have been recorded in the surveyed area. These habitats were: farmland nearby the Nile; at the fringes of salt marshes; those facing Mediterranean Sea; nearby the littoral sand dunes and those near to desert in the west side. Within the administrative boundaries of each sampling site (district), five localities (villages or stands) were designated (a total of 70 localities). In each locality (stand) field plots (*relevés*) for the cultivated crops were surveyed, each of which 1000−1500 m^2. These 14 georeferenced sampling sites visited regularly and the associated species recorded and the presence of a species was taken to indicate its degree of ecological success and sociological performance. The records of plant life in each sample-field also

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included notes on phenology (timing of life cycle events e.g. flowering, fruiting, … etc.) and characterization of margin species that seemed to be frequently observed outside boundaries of the cultivated fields in general water-channels, canal-banks and the irrigation/drainage network canals. The presence of species was recorded in the different seasons through sequential seasonal excursions during year 2015. The sampling sites were visited 6 times; three visits during the winter half of the year from December to May (in January, March and April) and the other three visits in the summer half of the year from June to November (in June, August and September) to follow the frequencies of weeds, their spatial distribution and their seasonal aspects. During the winter half of the year 563 field plots (*relevés*) were surveyed and during the summer half 605 field plots were surveyed. A total of 25 agroecosystems (croplands and orchards) were monitored in the surveyed area. The number of agroecosystems monitored differs from one sampling site to the other, it ranges from 13 to 22. The 25 agroecosystems were classified into categories according to their seasonality into: eight winter crops (sown in Autumn and harvested in early Summer), eight summer crops (sown in Spring and harvested in Autumn), two perennial crops (occupy the field for one or more than one year) and seven orchard crops. These crops included: Clover (*Trifolium alexandrinum* L.), Broad bean (*Vicia faba* L.), Wheat (*Triticum aestivum* L.), Flax (*Linum usitatissimum* L.), Potato (*Solanum tuberosum* L.), Artichoke (*Cynara scolymus* L.), Tomato “winter” (*Solanum lycopersicum* L.), Vegetables “winter”, Cotton (*Gossypium barbadense* L.), Maize (*Zea mays* L.), Rice (*Oryza sativa* L.), Tomato “summer” (*Solanum lycopersicum* L.), Peanut (*Arachis hypogaea* L.), Watermelon (*Citrullus vulgaris* Schrad.), Sweet-melon (*Cucumis melo* L.), Vegetables “summer”, Taro (*Colocasia antiquorum* Schott), Sugarcane (*Saccharum officinarum* L.), *Citrus* (*Citrus sinensis* (L.) Osbeck., *Citrus reticulata* Blanco and other cultivated *Citrus sp.*), Guava (*Psidium guajava* L.), Pear (*Purus communis* L.), Banana (*Musa paradisiaca* L.), Mango (*Mangifera indica* L.), Date palm (*Phoenix dactylifera* L.) and Grape (*Vitis vinifera* L. and other cultivated *Vitis sp*.). Some crops have two types of cultivations, e.g. Tomato plantings which are cultivated as a winter crop in sandy soils and as a summer crop in clay and clay loamy soils. The raw data sets were summarized in a final data table for species *versus* sites (Appendix 1); it included two main categories of information about the species performance in the 14 sampling sites and the 25 crops (agroecosystems) cultivated.

To measure the performance of species in the 14 sampling sites the number of fields in which a species was recorded in each sampling site was calculated as percentage of the total number of fields surveyed. The figures indicate the resulted recurrence index percentage (**RI%**) and from these records **R** and **ARI%** were calculated (number of sites in which the species was recorded and average of RI%, respectively). According to these records species were grouped into five classes of constancy ranges and arranged from highest to lowest values: I. High constancy weed species

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(80.1−100%; species that were recorded in 12−14 of the sites), II. Moderately high constancy weed species (60.1−80%; species that were recorded in 9−11 of the sites), III. Intermediate constancy weed species (40.1−60%; species that were recorded in 6−8 of the sites), IV. Low constancy weed species (20.1−40%; species that were recorded in 3−5 of the sites) and V. Rare constancy weed species (1−20%; species that were recorded in 1−2 of the sites). The performance of species in the 14 sampling sites was described by three other importance values as well. These importance values were: **LS** (life span) = maximum average of the record of species in the four seasons, represented in a 1−4 point-scale; **SS** (seasonal aspect of species or species seasonality), being described as all-the-year-round weeds (A), winter weeds (W), early-appearing winter weeds (Ws), summer weeds (S) and early-appearing summer weeds (Sw) and **Sb%** (Seasonal bias percentage) = average degree of its seasonal bias calculated as percentage for the difference between its winter records and summer records to its total records. The + and − values represent the degree of seasonal bias to the winter or to the summer respectively and closer bias values to zero indicated a less significant bias for the species than others that had higher values and 0.0 means not biased). For the determination of the five categories of **SS** (species seasonality), WRI% and SRI% were calculated for each species. The WRI% (winter recurrence index %) was calculated as percentage of fields in which a species was recorded during the winter half of the year (December−May) relative to total number of fields surveyed. The SRI% (summer recurrence index %) was calculated as percentage of fields in which a species was recorded during the summer half of the year (June−November) relative to total number of fields surveyed. According to these values the species were designated as: all-the-year-round weeds (A) if WRI% = or ≈ SRI%, winter weeds (W) if WRI% ≥ 2 SRI% or WRI% higher than the yearly RI% and summer weeds (S) if SRI% ≥ 2 WRI% or SRI% higher than the yearly RI%. The species which belong to the last two classes and showed some tangible growth in the corresponding other half of the year (≥¼ % of their total records) were marked (Ws) and (Sw). These are the early-appearing winter weeds which started their growth before the end of the summer half of the year or from the beginning of Autumn and the early-appearing summer weeds which started their growth before the end of the winter half of the year or from the beginning of spring, respectively. The above rules can't be strict rules as the records of species vary from year to year, as climatic factors do; they also related to their seasonal aspects, life span, phenology and the likely association between the cultivated crops and weed assemblages.

To describe the performance of species in the 25 agroecosystems monitored in the surveyed area, the number of agroecosystems in which a species was recorded has been calculated and denoted by **CR.** In addition to the relative abundance of species in the four categories of agroecosystems was determined (winter crops (**CW**), summer crops (**CS**), perennial crops (**CP**) and orchards (**CO**)). These abundance values

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were expressed in a simple somewhat subjective scale consisting of a series of numbers from 1 to 5 and a plus sign as follow: 5 (very common, 80−100%), 4 (common, 50−79%), 3 (Frequent, 20−49%), 2 (Occasional, 10−19%), 1 (rare or scarce, 5−9%) and + (very rare, >0−4%).

To indicate the variability in species performance and the likely association of species with certain sampling sites in certain agroecosystems, the maximum records of species were represented in bold text values. The last column relate species to their vegetation sociation group or VSG (A-D) and denote VSG dominants.

The margin species were marked by * (asterisk) and an empty figure means that the species was not recorded. It should be noted that the tree species were recorded as saplings within crop fields, and they were eventually removed through weeding.

To give an insight about the effect of seasonality on the floristic composition in each sampling site the rate of weed seasonality was calculated = the difference between number of species recorded in the winter half of the year and those recorded during the summer half (absolute value).

The indicative scores of the five environmental factors (prevailing climate, soil type, crop type, crop sustainability and urbanization) were calculated for each sampling site and deposited at the end of respective column. These parameters were used to measure the impact of the five environmental factors on species distribution and weed community structure during multivariate analyses. The following concepts were accepted to represent the sampling site's indicative scores. Number of species which belong to Mediterranean element either pure or with extensions into other territories calculated as percentage relative to total number of species recorded, to measure impact of prevailing Mediterranean climate. Number of identified soil type calculated as percentage of total number of recorded soil types in terms of soil texture according to USDA soil taxonomy, to measure impact of soil type. Number of cultivated crops and number of cultivated perennial crops and orchards calculated as percentage of total number of agroecosystems monitored, to measure impacts of crop type and crop sustainability, respectively. Number of introduced species to the area calculated as percentage of total number of species recorded in site's group (VSG) was accepted as an indirect measurement for the degree of human disturbance and effect of urbanization on vegetation structure. The previous concept expresses the number of new species recorded in the study area compared to those species collected during Täckholm's time and deposited as Herbarium specimens in *Cairo University Herbarium (CAI)*. From 1926 where Täckholm and her collaborators had started to collect information about the Egyptian wild flora to launch a project to establish the nucleus of the present Herbarium until fifties of the 20 th century where "Flora of Egypt" has begun to appear. The chorotype abbreviations are those applied by Wickens (1976). The Botanical Nomenclature of the recorded species have been updated from that appeared in the checklists of Täckholm (1974) and

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Boulos (2009) to a more recent Plant List, created by the Collaboration between the Royal Botanic Gardens (Kew), Missouri Botanical Garden (MO) and other collaborated institutions (Version 1.1, September 2013). It is an Internet encyclopedia project launched in 2010 to compile a comprehensive list of botanical nomenclature which provides an accepted Latin name for most species, with links to all Synonyms by which that species has been known. Accordingly, the Nomenclature of the plant species have been updated to the names denoted by "Accepted" in the list, if available, or the Synonym that match an assessment of medium to high confidence level. Voucher specimens of each recorded species were collected and identified earlier in *Cairo University Herbarium (CAI),* where they deposited as Herbarium specimens and numbered by a serial collecting number (*MAHGOUB'S collecting number*).

2.3. Diversity and multivariate analyses

The following software were used during **Multivariate analyses (MVA)**: Vegan packages (Oksanen et al., 2013) in R environment (version 3.2.3, 2015), IBM SPSS Statistics ver.22 (2013) and XLSTAT (2015). **Agglomerative Hierarchical Clustering (AHC)** was employed as a clustering technique using Euclidean distance as a measure of dissimilarity and Ward's method (Minimum-variance clustering) as an agglomeration criterion (Orlóci, 1978). It was used to classify the sampling sites based on the variation in their floristic composition into groups and the Center/Reduce option selected to avoid having group creation influenced by scaling effect. The sites were ordered first and then the species were clustered based on the classification of sites. The identified four weed communities or vegetation sociation groups (VSG A- D) were named after the two most dominant species in each group in light with the conclusion that a plant community type is defined by the dominance of one or more species and these species are usually the most important ones in the uppermost stratum of the plant canopy (Whittaker,1962). The **diversity** of the 4 VSG (weed communities) was measured (including Alpha (α) and Beta (β) diversity). The diversity indices were calculated from the following formulas: Species richness (S) "*Taxa_S*": counted as the average number of species per stand (Magurran, 2003, Magurran and McCarthy, 2004, see also Chao, 2005); Shannon−Wiener diversity index (H) "Shannon_H": $H = -\sum_{i=1}^{S}(Pi*\ln Pi)$, where H is the Shannon diversity index, Pi = fraction of the entire population made up of species i, S = numbers of species encountered, $\sum$ = sum from species 1 to species S and *ln* is a natural logarithm of the number (Shannon and Weaver, 1949, see also Pielou, 1975); Equitability (E) "Equitability_J": Shannon diversity divided by the logarithm of number of taxa (Hill, 1973 see also Harper, 1999). and Dominance (D) "Dominance_D": = *1-Simpson index*, $D = sum((ni/n)^2)$ where ni is number of individuals of taxon i and n is the total number of individuals (Simpson, 1949, see also Harper, 1999 and Magurran and McCarthy, 2004). Beta (β) diversity was calculated

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following described metrics for Whittaker (1960) and Lande (1996), reviewed in Koleff et al. (2003) [$\beta w = S/\alpha$], where S = the total number of species recorded in the system (i.e. γ diversity); α = the average sample diversity; which is measured as species richness found within the samples. **Principal Component Analysis** (**PCA**, Hotelling, 1933**)** was used to get a view for the influence of the five variables (environmental factors) on species distribution and variability of weed community structure for the identified VSG, summarize the relationships among variables and investigate the proximity among samples and how they relate to variables. Hill and Gauch (1980); had used PCA to identify the main gradients that influence species distribution, as an indirect gradient analysis technique. Prior to analysis the data were standardized and Pearson (n)/PCA was used. The variables analyzed during PCA were the five environmental factors, rate of weed seasonality, diversity indices values and the number of species belonging to the more represented chorotype (paleotropical chorotype) in each sampling site. The four resulted VSG have been superimposed upon the sample points (sites) and convex hulls have been drawn in the resulted PCA biplot to confirm the validity of the segregation into four groups.

The four identified VSG (A-D) were subjected twice to **Analysis of Variance (ANOVA)** followed by **Tukey's test (HSD)**. **T**he first of which was depending on soil properties as explanatory variables and the second was depending on the indicative scores as explanatory variables. The coefficient of determination (R^2) and the Tukey's test (HSD) has been applied to significant variables in both analyses. The data of the indicative scores of sites for the five environmental factors were standardized and the sample variance (S^2) has been calculated from the following formula: $S^2 = \sum (x_i - x)^2/n\text{-}1$, where S^2 is sample variance, $\sum$ is sum, x_i is the term in data set (indicative scores of sampling sites), x is sample mean, and n is sample size.

The results of ANOVA (R^2, F, P), the sample variance (S^2) and the other multivariate analyses have been taken to express for the impact of the environmental factors and their order of importance, on species distribution and weed community structure in the farmland of the surveyed area.

3. Results

3.1. Environmental factors

3.1.1. The prevailing climate

The meteorological data obtained from "EMA" indicated that the prevailing climate is characterized by heavy rainy winters and dry summers. This Mediterranean climate strongly affects the vegetation of the coastal Mediterranean region of the area under study. Usually, with the beginning of winter season, at the end of October until the early beginning of May the study area subjected to 21 squalls. They are

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usually accompanied with lightning thunderstorms, low temperature, high wind speed and cloud bursts that produce heavy showers of rains. During the year 2015, the main winter rain extended from November to March and summer was almost rainless. Minimum temperature records usually don't seem to reach freezing, winter was warm and summer was hot (Fig. 2). It should be noted that the records of the southern stations away from the water bodies of the Mediterranean was an express of drier atmosphere and higher rates of evaporation.

3.1.2. Soil type

The analyses of soil samples of the localities of the 14 sampling sites surveyed had indicated that: (1) near the banks of the Rosetta branch, the soil particles were coarse and finer progressively towards the west and become the finest clay in the extreme west; (2) along the edge of the western desert, the soil is rich in silica, coarse-textured and become finer eastward until they merge with alluvial clay in the median longitudinal area and (3) along the Mediterranean coast i.e. the northern limit for the study area, the soil is rich in calcium carbonate and of high salt content, coarse-textured and decrease gradually southward away from the coast. According to the USDA soil taxonomy classification system which uses 12 textural qualitative classes

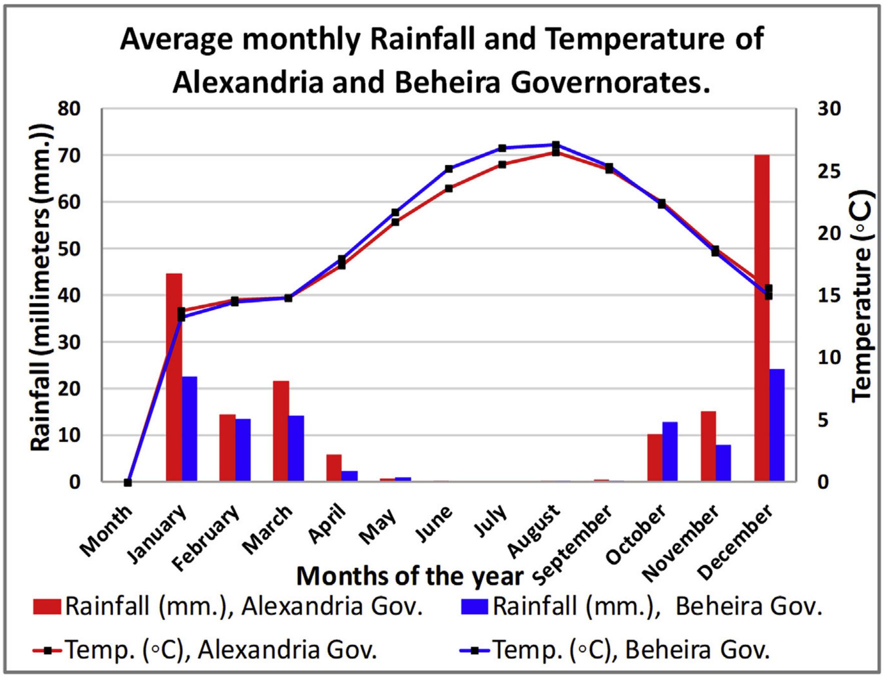

Fig. 2. Climate Graph for the surveyed area (2015). Legend for sampling sites and their localities:Kom Hamada (KH1, 1−5);Itay Al Barud (IB2, 6−9); Shubrakhit (Sh3, 10−12); Damanhour (Da4, 13−16); El-Mahmoudeya (EM5, 17−18); Rosetta (Ro6, 19−22); Idku (Id7, 23−25); Alexandria (Al8, 26−28); Abu Qir (AQ9, 29−30); Kafr El-Dawar (KD10, 31−32); Abu Al Matamir (AM11, 33−35); Housh Eissa (HI12, 36−38); Abu Hummus (AH13, 39−41);Ad Dilinjat (ED14, 42−44).

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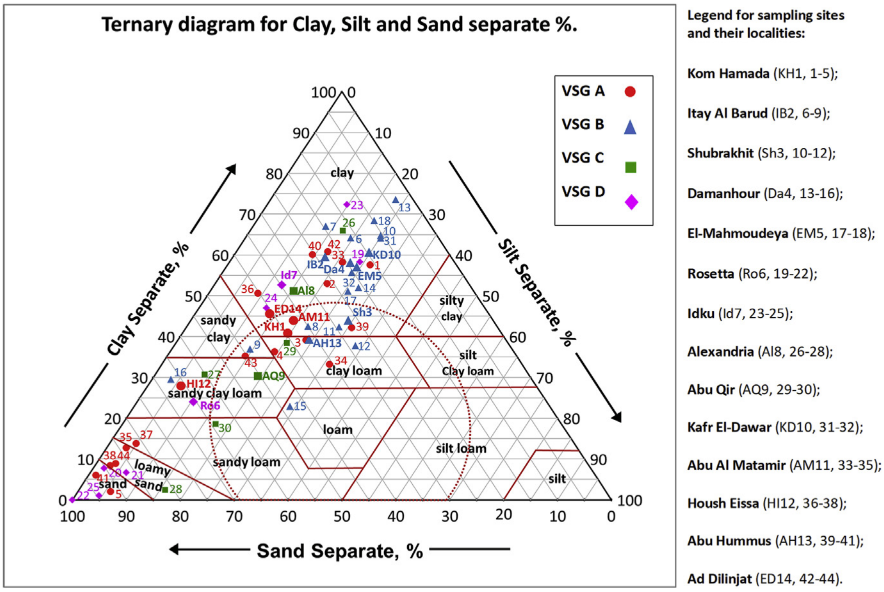

Fig. 3. Soil texture triangle showing the classification of the 14 sites and their 70 localities according to USDA soil taxonomy; A- D are the four clusters i.e. VSG (A-D) or vegetative sociation groups resulted from AHC analysis.

(Soil taxonomy: A Basic System of Soil Classification for Making and Interpreting Soil Surveys, Soil Survey Staff, 1999, 2006), eight soil texture types have been defined in the surveyed area: clay soils, clay loam, loam soils, loamy sand, sandy clay, sandy clay loam, sandy loam and sandy soils (refer to Fig. 3). Of these, to three soil types were defined from the soil samples in each sampling site. But in general, the measurement of the weighted average indicated that the clay - loamy soil types dominate the main bulk of the middle and southern parts of the surveyed area while sandy soils dominate the coastal part and the west borders.

3.1.3. Crop type and crop sustainability

The records of the cultivated crops revealed that usually in each sampling site, a cereal and a leguminous crop is cultivated. The type/amount of crop cultivated among each set of winter crops, summer crops, perennial crops and orchards depended on the available natural resources. The highest number of cultivated crops was recorded in Ro6 (VSG D) which was one of the sampling sites which had scored the highest value of crop sustainability. In this sampling site horticulture was widely recorded, particularly Date palm orchards which had been cultivated on a wide scale.

3.1.4. Urbanization

The governmental reports showed that urbanization is a general character for the area. The most affected sampling sites are the two littoral sampling sites of VSG

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C (Al8 and AQ9), where Alexandria, the main port of Egypt and the second largest city exists.

3.2. Species distribution

A total of 473-plant species was recorded, they include specific and infraspecific taxa (20 species). They belong to 58 families (45 Eudicots, 11 Monocots, one Pteridophyte and one Gymnosperm) and 268 genera (Table 1). The chorological analyses in Table 2 (a & b) revealed that the recorded species belong to 19 chorotypes and more than half of them were Mediterranean species ($\approx$59%) either pure or with extensions into other territories. The results of the seasonality analysis indicated that winter weeds (W + Ws) constitute the main bulk of the recorded species ($\approx$63%) and most of them from annuals. The results also indicated that the highest rates of weed seasonality were scored by the two littoral sampling sites Id7 and Ro6, respectively. This rate decreases in the less affected sites by the heavy rainy winters. According to the records of the performance and spatial distribution of weeds 78 species out of the 473 recorded in Appendix 1 were classified as high constancy weed species (Class I), 42 as moderately high constancy weed species (Class II), 33 as intermediate constancy weed species (Class III), 76 as low constancy weed species (Class IV) and 244 as rare constancy weed species (Class V). The 78 weeds which belong to “Class I” were the most widespread and 9 of them could be described as *ubiquitous*. These 9 species were recorded in all sampling sites, in all agroecosystems and during the four seasons. The most common of them were *Cynodon dactylon*, *Convolvulus arvensis*, *Cyperus rotundus* and *Sonchus oleraceus*. Although these species showed high records in most of the sites but their seasonal aspects and performance in the agroecosystems had differed; as in the case of the other less common species which have been recorded in this class and in the subsequent classes. As for example, despite of the first three species were recorded all-the-year-round (A) but the performance of the perennial-sedge differed, it was better represented during the summer half of the year (Sb% = -26.1). In comparable to such performance the common sow-thistle showed its best performance during the winter half of the year with some tangible growth during the summer half (Ws). They were common in perennial crops and orchards and either being common or rarely represented in other agroecosystems. The records also showed that the best performance for five species was correlated by soil type. *Aster squamatus*, *Solanum americanum* and *Malva parviflora* were better represented in the sites dominated by clay and loam soils while *Chenopodium album* and *Phragmites australis* (the common reed) scored the higher presence estimates in the sites dominated by sandy soil and at the fringes of salt marshes and sabkhas (refer to Figs. 1 and 3). The rest 27 species which are recorded in all sites had showed a variable performance in response to the impact of these factors and other environmental factors as well. For example, some of them had been more influenced by the crop type (e.g. *Brassica*

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Table 1. Families recorded in the surveyed area. Figures represent number of genera included in each family (Gen.) and the total number of species belonging to each family, calculated as absolute number (Sp.) and relative number (Sp.% = % of the total number of species recorded in the surveyed area).

Family Name	Gen.	Sp.	Sp.%
Poaceae Barnhart	49	84	17.8%
Asteraceae Bercht. & J.Presl	41	61	12.9%
Amaranthaceae Juss.	18	42	8.9%
Fabaceae Lindl.	16	36	7.6%
Brassicaceae Burnett	16	25	5.3%
Apiaceae Lindl.	10	12	2.5%
Caryophyllaceae Juss.	9	23	4.9%
Geraniaceae Juss.	8	8	1.7%
Cyperaceae Juss.	7	20	4.2%
Solanaceae Juss.	6	10	2.1%
Malvaceae Juss.	6	7	1.5%
Polygonaceae Juss.	5	13	2.7%
Boraginaceae Juss.	5	7	1.5%
Convolvulaceae Juss.	4	10	2.1%
Zygophyllaceae R.Br.	4	6	1.3%
Plantaginaceae Juss.	3	13	2.7%
Euphorbiaceae Juss.	3	10	2.1%
Papaveraceae Juss.	3	6	1.3%
Aizoaceae Martinov	3	4	0.8%
Araceae Juss.	3	4	0.8%
Hydrocharitaceae Juss.	3	4	0.8%
Lamiaceae Martynov	3	3	0.6%
Tamaricaceae Link	2	7	1.5%
Ranunculaceae Juss.	2	4	0.8%
Potamogetonaceae Bercht. & J.Presl	2	3	0.6%
Onagraceae Juss.	2	2	0.4%
Urticaceae Juss.	2	2	0.4%
Verbenaceae J.St.-Hil.	2	2	0.4%
Asparagaceae Juss.	2	2	0.4%
Juncaceae Juss.	1	6	1.3%
Orobanchaceae Vent.	1	4	0.8%
Lythraceae J.St.-Hil.	1	3	0.6%
Gentianaceae Juss.	1	2	0.4%
Oxalidaceae R.Br.	1	2	0.4%
Plumbaginaceae Juss.	1	2	0.4%

(*continued on next page*)

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Table 1. (*Continued*)

Family Name	Gen.	Sp.	Sp.%
Nymphaeaceae Salisb.	1	2	0.4%
Apocynaceae Juss.	1	1	0.2%
Cistaceae Juss.	1	1	0.2%
Cleomaceae Bercht. & J.Presl	1	1	0.2%
Frankeniaceae Desv.	1	1	0.2%
Lentibulariaceae Rich.	1	1	0.2%
Molluginaceae Bartl.	1	1	0.2%
Neuradaceae Kostel.	1	1	0.2%
Nitrariaceae Lindl.	1	1	0.2%
Portulacaceae Juss.	1	1	0.2%
Primulaceae Batsch ex Borkh.	1	1	0.2%
Rosaceae Juss.	1	1	0.2%
Rubiaceae Juss.	1	1	0.2%
Santalaceae R.Br.	1	1	0.2%
Thymelaeaceae Juss.	1	1	0.2%
Ceratophyllaceae Gray	1	1	0.2%
Amaryllidaceae J.St.-Hil.	1	1	0.2%
Pontederiaceae Kunth	1	1	0.2%
Typhaceae Juss.	1	1	0.2%
Xanthorrhoeaceae Dumortier	1	1	0.2%
Cynomoriaceae Endl. ex Lindl.	1	1	0.2%
Ephedraceae Dumort.	1	1	0.2%
Marsileaceae Mirb.	1	1	0.2%
Total number = 58	268	473	100%

nigra and *Cichorium pumilum*), soil type (*Erigeron bonariensis*) and seasonality (e.g. *Chenopodium murale*). The records of species and the measurement of their seasonality and their seasonal bias (%) indicated that 39 species were designated as early appearing winter weeds (Ws) and 23 as early appearing summer weeds (Sw). Of them ≈42% were recorded in class I (Ws = 16, Sw = 10). The maximum records of species (figures in bold text values) indicated that the variability in performance of weeds can be traced in all the five constancy classes. As to name a few; *Cakile maritima* and *Arthrocnemum macrostachyum* which represent the two most dominant species of VSG D belong to class V and class III, respectively. They were frequent in weed community associated with orchards in VSG D sites (Id7 & Ro6) and were recorded in 3 seasons; while they were very rare or absent in the other sites. In general, the measurements of seasonality of species and the rate of weed seasonality for the sampling sites presented in Appendix 1 emphasized

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Table 2. (a): ChorologicaL Analyses of the Flora recorded in the surveyed area. The first two columns present the chorotypes and the total number of species which belong to each chorotype. The following columns include the numbers of: A (All-the-year weeds), W (Winter weeds), S (Summer weeds) and those which belong to the four VSG (A - D); maximum values in bold text).

Chorotypes	Total number of species		Seasonality of species							Chorological analysis for VSG			
	Sum	%	A	W	Ws	W+Ws	S	Sw	S+Sw	VSG A	VSG B	VSG C	VSG D
COSM	55	11.6%	10	19	8	**27**	14	4	18	**48**	43	34	45
PAL	67	14.2%	12	11	1	12	35	8	**43**	**51**	47	25	46
PAN	28	5.9%	4	7	3	10	12	2	**14**	**24**	20	16	23
Monoregional													
ME	65	13.7%	11	51	2	**53**		1	1	29	19	14	**52**
S-Z	7	1.5%		4		**4**	1	2	3	**6**	**6**	5	1
Endemic	3	0.6%		1	1	**2**	1		1	**2**	**2**		**2**
Biregional													
ME+IR-TR	75	15.9%	7	54	7	**61**	4	3	7	45	39	28	**59**
ME+SA-SI	51	10.8%	9	37	5	**42**				29	8	12	**39**
IR-TR+SA-SI	17	3.6%	3	13		**13**		1	1	**12**	2	1	9
S-Z+SA-SI	14	3.0%	6	5	1	**6**	2		2	**12**	6	6	10
ME+ER-SR	11	2.3%	1	6	3	**9**	1		1	7	6	6	**10**
S-Z+IR-TR	1	0.2%	1							**1**	**1**	**1**	**1**
SA-SI+Ethiopia	1	0.2%		1		**1**				**1**			**1**
SA-SI+Madagascar	1	0.2%					1		1	**1**	**1**		
Triregional													
ME+IR-TR+ER-SR	52	11.0%	5	32	7	**39**	6	2	8	**39**	33	22	36
ME+IR-TR+SA-SI	18	3.8%	3	14		**14**	1		1	10	6	5	**15**
ME+SA-SI+S-Z	4	0.8%	1	3		**3**				**3**	**3**		2
ME+ER-SR+SA-SI	2	0.4%		2		**2**				1			**2**
ME+IR-TR+S-Z	1	0.2%			1	**1**				**1**	**1**	**1**	**1**
Total number = 19	473	100%	73	260	39	299	78	23	101	322	243	176	354

Legend for Chorotypes: COSM = Cosmopolitan, PAL = Paleotropical, PAN = Pantropical, ME = Mediterranean, S-Z = Sudano-Zambezian, IR-TR = Irano-Turanian, SA-SI = Saharo-Sindian, ER-SR = Euro-Siberian, Endemic.

that seasonality is an evident feature of the weed plant growth as it is equally evident in the cropping rotation.

3.3. Multivariate analyses and diversity

Based on their floristic composition, the fourteen sampling sites were clustered using Agglomerative Hierarchical Clustering (AHC). Four groups were identified at a distance threshold indicated by the dotted line in Fig. 4. These clusters i.e. weed communities or vegetative sociation groups (VSG) were as follows: VSG A or group

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Table 2. (b): Chorological analyses for the Flora of the surveyed area. Figures indicated number of species which belong to Phytochoria (floristic, phytogeographic zones, regions & Kingdoms). The first two columns present the Phytochoria and the total number of species which belong to each of them. The following columns include the numbers of: A (All-the-year weeds), W (Winter weeds), S (Summer weeds) and those which belong to the four VSG (A - D); maximum values in bold text.

Species/Phytochoria	**Total number of species**		**Seasonality of species %**							**Chorological analysis for VSG (%)**			
	Sum	**%**	**A**	**W**	**Ws**	**W+Ws**	**S**	**Sw**	**S+Sw**	**VSG A**	**VSG B**	**VSG C**	**VSG D**
Mediterranean sp.	279	58.99	50.7	76.5	64.1	**74.9**	15.4	26.1	17.8	50.9	47.3	50.0	**61.0**
Cosmopolitan sp.	55	11.63	13.7	7.3	20.5	9.0	17.9	17.4	**17.8**	14.9	17.7	**19.3**	12.7
Paleotropical sp.	67	14.16	16.4	4.2	2.6	4.0	44.9	34.8	**42.6**	15.8	**19.3**	14.2	13.0
Pantropical sp.	28	5.92	5.5	2.7	7.7	3.3	15.4	8.7	**13.9**	7.5	8.2	**9.1**	6.5
Other chorotypes sp.	44	9.30	13.7	9.2	5.1	**8.7**	6.4	13.0	7.9	**10.9**	7.4	7.4	6.8
Total	473	100	100	100	100	100	100	100	100	100	100	100	100

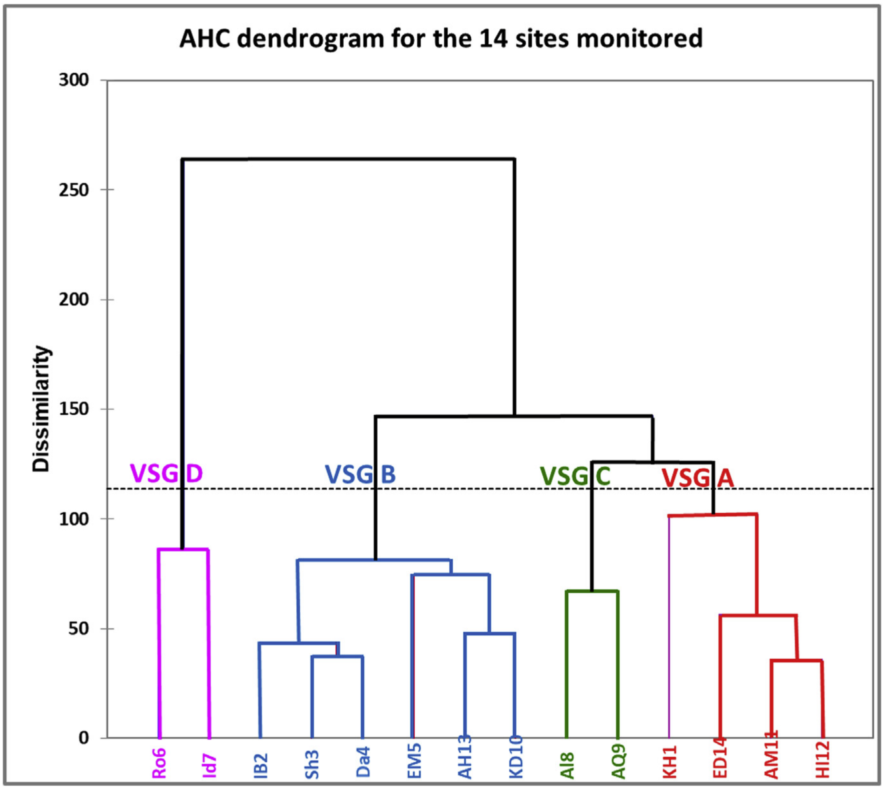

Fig. 4. AHC dendrogram for the 14 sites & the 4 VSG resulted (for sites legend, see Fig. 3).

Cynodon dactylon-Convolvulus arvensis and it was distinctive for 4 sites (KH1, AM11, HI12 and ED14); VSG B or group *Sonchus oleraceus-Erigeron bonariensis* and it was distinctive for 6 sites (IB2, Sh3, Da4, EM5, AH13 and KD10); VSG C or group *Chenopodium murale-Cyperus rotundus* and it was distinctive for 2 sites (Al8 and AQ9) and VSG D or group *Cakile maritima-Arthrocnemum macrostachyum* and it was distinctive for 2 sites (Ro6 and Id7). Although dendrograms only tell us a bit about the similarities of objects, but the geometry of the dendrogram (Fig. 4) indicated that the cluster of VSG B was the larger in size and was the more homogenous than VSG A. This was confirmed when looking at the within-class variable which was a lot higher for the latter. It should be also noted that the chunks (sites) AM11 and HI12 were the most similar in the clade. The clades of VSG C and VSG D were *bifolious* and the latter cluster was more unique and had been completely separated.

The values of the diversity indices reflected the variability in the weed community structure of the four VSG (A-D). The highest total species richness (S) was scored by the sites of VSG D (S = 354), followed by VSG A, B, C (S = 322, 243 and 176, respectively) and number of species belonging to each group was; 184, 127, 128, 34,

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respectively. It happens very often that species have their records shared among the groups this intermingle was expected and it was accepted. The measurement of the diversity indices revealed that the two VSG which comprised the littoral sampling sites showed heterogeneity in their plant composition. VSG D scored the highest species richness (S) and Shannon Wiener diversity index (H) and the lowest value of dominance (D), while VSG C scored the lowest values of S and H and the highest values of E and D. The two other VSG were less dissimilar where VSG A earned intermediate values of all diversity indices as VSG B did, but it scored the lowest equitability (E) value (Fig. 5). The pairwise beta diversity index presented in Table 3 revealed that VSG D gained the highest heterogeneity in species composition as compared pairwise with most of the other groups. It also revealed that VSG C was less dissimilar in species composition as compared pairwise with VSG B than if it is compared pairwise with VSG A. The most similar group to the latter group (VSG A) in species composition, was VSG B (the Global β diversity (Whittaker = 0.837).

Principal Components Analysis (PCA) was successful in separating the sites dominated by sandy soil along PC1 positive end, from those where clay and loamy soils dominated along its negative end. The sites of VSG B which represent the middle part of the surveyed area and those farmlands facing the Nile (Rosetta branch)

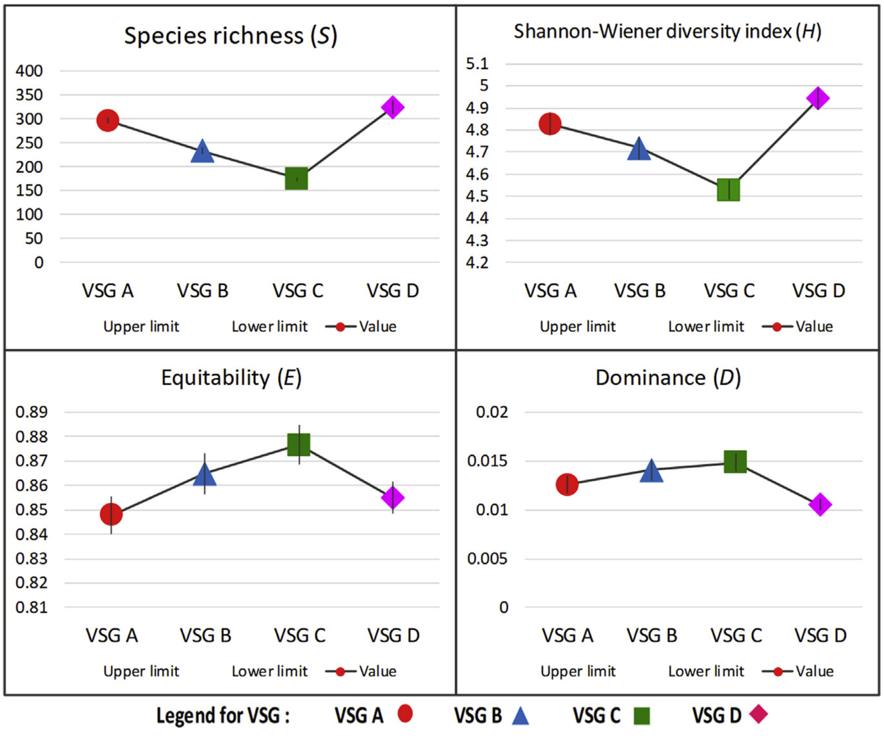

Fig. 5. Scatter charts showing the diversity indices of the 4 VSG (A - D).

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Table 3. Whittaker's Beta (β) diversity Index for the four VSG (A - D) or vegetaitve sociation groups, pairwise comparisons.

	VSG A	VSG B	VSG C	VSG D
VSG A	0			
VSG B	0.2919	0		
VSG C	0.39407	0.29095	0	
VSG D	0.42029	0.4086	0.37475	0

occupied the far negative end of PC1, while those belonging to VSG D which represent the farmland nearby the littoral sand dunes, facing the Mediterranean Sea, were located at the far positive end of PC1. Upon visualizing the PCA correlation biplot we also can notice that the sites of VSG C and VSG A had occupied an intermediate position and on drawing the convex hulls no overlap identified (refer to Fig. 6). The eigenvalue of F1 (first axis or PC1) was 6.94 and of F2 (second axis or PC2) was 2.51. The first axis explained about half of the total variability (= 49.56%) and together with the second axis they explained 67.50%, which is a good result. The right-angled projections of the object points (sites), on the clay's vector, silt's vector and sand's vector in the F1/F2 map indicated that the frequencies of species in VSG B sites were affected by soil content of clay and silt more than the other sites. They also indicated that the frequencies of species in VSG D sites and in VSG A sites were affected by soil content of sand more than the other sites while the frequencies of species in VSG C sites were the less affected by these variables. The length of the vectors revealed that most of the variables were well represented in the plan F1/F2. It seems that some information might be hidden in the next factors for the variables of crop sustainability and urbanization. Looking at the table of the squared cosines of the variables indicated that they were well linked with the third component

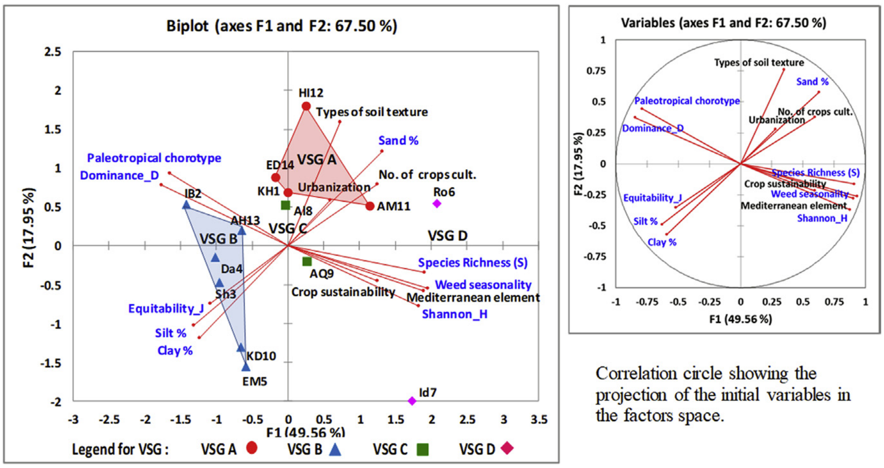

Fig. 6. Biplot representing PCA for the 14 sites, the environmental variables, the 4 VSG superimposed and the convex hulls drawn (for legend of sites refer to Fig. 3).

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(F3 or PC3) and they would best be viewed on map F1/F3. Furthermore, we could see that the first principal component correlated most strongly with the prevailing climate (Mediterranean climate = no. of Mediterranean species recorded) and crop type (F1 = 0.903 and 0.594). Depending on these results we could state that based on the correlation of 0.903, this principal component is primarily a measure for the impact of the prevailing climate. On this component the sites of VSG D scored the highest positive scores and most of the sites of VSG A and VSG C scored positive values as well, while those of VSG B scored negative ones. The second principal component increases with the number of identified ssoil type in the VSG sites and hence it is viewed as a measure for the impact of soil type. Most of VSG A sites scored the higher positive factor scores comparable to sites of the other groups. The acute angles in the correlation circle between the vectors of prevailing climate and crop type with those of species richness (S), Shannon_H, rate of weed seasonality and soil type indicate that they were significantly positively correlated with each other (r close to 1). The angles between the vectors approximate their (linear) covariance/correlation. The orthogonal angles between the vectors of soil type/crop type and the vector of Dominance_D indicate that they were not correlated (r close to 0), while the obtuse angles between them and the vector of Equitability_J. indicate that they were significantly negatively correlated (r close to -1).

The mean scores of the soil properties for the four VSG sites in Table 4 indicated that VSG B sites characterized by the highest soil content of clay, silt, the highest water holding capacity and the lowest soil salinity. The sites of the other groups were characterized by a higher soil content of fine sand, coarse sand, lower water holding capacity and higher soil salinity. VSG D sites scored the highest soil content for fine sand and all the measured cations and most of anions (Ca, Mg, Na, K and Cl). The PH in the soil was usually alkaline and the highest values of hydrolytic conductivity and total soluble salts were scored by the VSG D′ sites. Comparing the p-value to the significance level (P-value $\leq$: $\alpha = 0.05$) indicated that 9 soil variables are statistically significant and applying Tukey’s test (HSD) for these variables indicated that clay significant for VSG B versus all other VSG, respectively. HC significant for VSG D versus all other VSG, respectively and CaCO3 significant for VSG C versus all other VSG, respectively. Silt significant for VSG B vs D & A, Coarse sand significant for VSG A vs B, K significant for VSG D vs B, and the other cations and anions significant for D vs B & A.

The figures in bold text values which denote the maximum of the mean of the VSG sites’ indicative scores for the five environmental factors presented in ANOVA-Table 5 had indicated that soil type was the most impacting factor on the diversity of VSG A (weed community) comparable to other groups. The prevailing climate (Mediterranean climate) and crop sustainability were the most impacting factors on the diversity of VSG D comparable to other groups. Crop type, crop sustainability and urbanization were the most impacting factors on the diversity of VSG C

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Table 4. "ANOVA" for the 4 VSG depending on soil properties as explanatory variables; figures included: the means ± standard errors of the soil variables for the VSG's sites (A - D; maximum in bold text), coefficient of determination (R2), F ratio (F), P value (Pr > F) and Tukey's test (HSD). Confidence interval = 95% (P* < 0.05).

Soil Variables	Vegetative sociation Groups				R2	F	P value (Pr > F)	Tukey's test (HSD), Cr.V.= 4.327 (significant VSG)
	VSG A	VSG B	VSG C	VSG D				
	4	6	2	2				
Clay (%)	30.4±4.2	**48.4** ± 3.4	28.1 ± 5.9	27.8 ± 5.9	0.65	6.16	**0.012***	**B vs A; B vs C; B vs D**
Silt (%)	12.5 ± 2.4	**21.0** ± 2.0	14.1 ± 3.5	9.1 ± 3.5	0.559	4.220	**0.036***	**B vs D; B vs A**
Fine sand (%)	27.5 ± 3.8	22.4 ± 3.1	36.9 ± 5.4	**37.8** ± 5.4	0.478	3.057	0.078	**No**
Coarse sand (%)	**21.8** ± 4.3	4.8 ± 3.5	5.7 ± 6.1	21.5 ± 6.1	0.560	4.234	**0.036***	**A vs B**
Water holding capacity (WHC = 100 gm soil %)	55.6 ± 7.8	**79.5** ± 6.4	53.9 ± 11.0	60.4 ± 11.0	0.436	2.581	0.112	**No**
Hydrolytic conductivity (HC = cm / hour)	3.8 ± 1.3	1.0 ± 1.1	5.0 ± 1.9	**12.6** ± 1.9	0.740	9.484	**0.003***	**D vs B; D vs A; D vs C**
PH	**7.8** ± 0.1	7.7 ± 0.1	**7.8** ± 0.2	7.5 ± 0.2	0.202	0.845	0.500	**No**
Ca (m Eq / L)	13.4 ± 2.0	9.3 ± 1.7	14.6 ± 2.9	**16.6** ± 2.9	0.390	2.127	0.160	**No**
Mg (m Eq / L)	8.8 ± 1.8	7.0 ± 1.5	12.9 ± 2.6	**18.8** ± 2.6	0.630	5.676	**0.016***	**D vs B; D vs A**
Na (m Eq / L)	33.5 ± 17.1	33.1 ± 13.9	97.4 ± 24.1	**113.5** ± 24.1	0.565	4.331	**0.034***	**D vs B; D vs A**
K (m Eq / L)	1.2 ± 0.4	0.6 ± 1.6	0.3 ± 0.5	**2.6** ± 0.5	0.531	3.772	**0.048***	**D vs B**
HCO3 (m Eq / L)	**4.5** ± 1.2	2.3 ± 0.9	2.4 ± 1.6	1.7 ± 1.6	0.219	0.937	0.458	**No**
Cl (m Eq / L)	18.1 ± 15.3	24.3 ± 12.5	77.7 ± 21.7	**122.2** ± 21.7	0.675	6.917	**0.008***	**D vs A; D vs B**
Total soluble salts (TSS = %)	0.7 ±0 .4	0.6 ± 0.3	1.1 ± 0.5	**2.5** ± 0.5	0.505	3.402	0.062	**No**
Calcium carbonate (CaCO3)	6.9 ± 2.3	2.9 ± 1.9	**12.7** ± 3.2	1.6 ± 3.2	0.565	2.899	**0.008***	**C vs D; C vs B; C vs A**

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Table 5. "ANOVA" for the 4 VSG depending on the 5 enviromental factors and species richness (S) as explanatory variables; figures included: the means ± standard errors of the enviromental variables for the VSG's sites (A - D; maximum in bold text), coefficient of determination (R2), F ratio (F), P value (Pr > F) and Tukey's test (HSD). (P* < 0.1).

Environmental Variables	Vegetative sociation Groups				R2	F	P value (Pr > F)	Tukey's test(HSD), Cr.V. = 3.704 (significant VSG)
	VSG A	VSG B	VSG C	VSG D				
	4	6	2	2				
Prevailing climate	44.88 ± 1.75	40.86 ± 1.43	48.80 ± 2.48	**60.99** ± 2.48	0.836	17.046	**0.0003 ***	**D vs B, D vs A, D vs C, C vs B**
Soil type	**37.50** ± 3.87	22.92 ± 3.16	31.25 ± 5.47	31.25 ± 5.47	0.469	2.940	**0.085 ***	**A vs B**
Crop type	81.00 ± 5.04	64.67 ± 4.12	**84.00** ± 7.13	80.00 ± 7.13	0.493	3.242	**0.069 ***	**C vs B**
Crop sustainability	22.00 ± 3.87	18.00 ± 3.16	**26.00** ± 5.48	**26.00** ± 5.48	0.206	0.863	0.491	**No**
Urbanization	22.64 ± 2.93	13.54 ± 2.39	**44.12** ± 4.14	19.29 ± 4.14	0.805	13.760	**0.001 ***	**C vs B, C vs D, C vs A**
Species Richness (S)	37.90 ± 2.91	29.81 ± 2.37	29.70 ± 4.11	**56.03** ± 4.11	0.769	11.087	**0.002 ***	**D vs C, D vs B, D vs A**

comparable to other groups. The five environmental factors had scored their least indicative scores i.e. their least impact, on the vegetation structure of VSG B sites. The ANOVA test also indicated that 4 parameters (environmental variables) were statistically significant. Tukey's test (HSD) had revealed that the prevailing climate statistically significant for VSG D versus all other groups and for VSG C vs B as well. Soil type statistically significant for VSG A vs B and crop type statistically significant for VSG C vs B. Urbanization statistically significant for VSG C versus all other groups. The p-value of species richness (S) indicated that it was statistically significant and Tukey's HSD test revealed that it is statistically significant for VSG D versus all other groups. Given R^2 results, 83.6% of the variability of the dependent variable is explained by the explanatory variable for the prevailing climate; 80.5% for urbanization; 49.3% for crop type; 46.9 % for soil type and 20.6% for crop sustainability. It should be also pointed out that the values of the sample variance (S^2) of the sites' indicative scores had declared that the prevailing climate gained the least spread-out of the data points which means that the vegetation structure for most sites was more affected by this factor than the impact of other environmental factors.

4. Discussion

The earliest plant collections form the surveyed area were dated back to the beginning of the last century (1903), and among the old collections known to the author are those of MÜSCHLER, G. MAIRE, GUNNAR TÄCKHOLM, CHAMPS, HASSIB, HARTMANN, HEFNAWY, PALMAR BASHA, RÜNKEWITZ, VIVI

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TÄCKHOLM, M. N. EL-HADIDI, L. BOULOS and others; all kept in *Cairo University Herbarium* (*CAI*). The chorological analyses had revealed that *Poaceae, Asteraceae, Amaranthaceae*, *Fabaceae* and *Brassicaceae* constitutes more than 50% of the total flora recorded in the area. Quézel (1978), had reported that these families represent the most common ones in the Mediterranean North African flora. The high number of the recorded species (473- species) as compared with earlier studies (Zahran et al., 1990 and Mashaly et al., 2010, 2011, 2013), may be mainly attributed to the large number of new recorded species to the study area or introduced species, that recently recorded (101 species). This number could act as a bioindicator in response to human impacts. This number emphasized that the species composition and plant diversity of the area have been changed in the last years. The ratio of species which belong to class V (rare constancy weed species) which constituted about 52% of the recorded flora and the result of ANOVA indicated the heterogeneity of plant composition and the diversity of the identified vegetation sociation groups (VSG). This was obvious through the results of cluster analysis and multivariate analyses and the complete separation of the sampling sites of VSG D in cluster analysis and through multivariate analyses is a direct reflection of this concept. This remarkable heterogeneity is a result of the impact of the surrounding environmental factors. In fact, vegetation groups are determined by the combined effects of a whole range of ecological factors (Gholinejad et al., 2012).

The relationship between vegetation and climate is absolute. Each is entirely dependent on the other. It is predicted that climate change will remain one of the major drivers of biodiversity patterns in the future (Sala et al., 2000; Duraiappah, 2006 and Dadamouny and Schnittler, 2015). The meteorological records of the study area had revealed that the climate is influenced by Mediterranean Sea, moderating its temperatures, causing variable rainy winters and moderately hot summers. The most affected regions by this prevailing climate (Mediterranean climate) are the northern parts facing the sea which are subjected to 21 squalls accompanied with heavy rainfall. This climate which engulfs the area accompanied by heavy rainy winters enhances the growth of annuals winter weeds, particularly those belonging to the Mediterranean element more than those belonging to other chorotypes within the different ecological habitats. The results showed a noticeable increase in species richness (S) and rate of weed seasonality in the more affected sites. VSG D had scored the highest values, it comprises the north littoral sites facing Mediterranean Sea (Ro6 & Id7). The impact of the prevailing climate (Mediterranean climate) was reflected obviously through the results of chorological analyses as well. Despite that flora of the area originates from several adjacent areas (19 chorotypes), but the Mediterranean chorotypes (either pure element or with extensions of other territories) constitute the main bulk of the mono-, bi- and tri-regional chorotypes ($\approx$59%) and clear majority of them were winter weeds (annuals). The low sample variance ($S^2 = 0.07$) indicates that the vegetation structure for most sites was

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affected by the prevailing climate (Mediterranean climate). ANOVA for the four identified VSG based on environmental variables indicated that the prevailing climate is the most significant environmental factor and the most affected group was VSG D. The percentage of Mediterranean species which were recorded in the four VSG indicated that the weed community structure of VSG D was the most affected (ME *sp.* $\approx 74\% = 113$ *sp.*, half of them pure ME *sp.*). This ratio decreased gradually as we head south away from the water bodies of the Mediterranean to the sites of the middle and southern parts of the surveyed area which are occupied by VSG B and VSG A. The measurements of the α and β diversity indices indicated that VSG D was the most diverse one. It gained the highest values of S & H, lowest D and upon measuring β-diversity it had the highest heterogeneity in species composition in comparable with all the other groups. This gives a main reason for its complete separation during cluster analysis (AHC). It is obvious that the plant community in an area is the most sensitive indicator of climate.

In their studies on the status of Wadi Hagul Mashaly (1996) and Abdelaal (2016) highlighted the number of introduced species as an indirect measure for the degree of human disturbance and urbanization. The urban-gradient studies showed that, for many taxa, for example, plants (Kowarik, 1995), the number of non-native species increases toward centers of urbanization, while the number of native species decreases. Most urbanized areas not only persist but continue to expand and threaten other local ecosystems (Stein et al., 2000) and this urban growth replaces the native species that are lost with widespread "weedy" nonnative species. This replacement constitutes the process of biotic homogenization that threatens to reduce the biological uniqueness of local ecosystems (Blair, 2001). In fact, urbanization is among the many human activities that cause habitat loss (Czech et al., 2000) and it is often more lasting than other types of habitat loss. The governmental reports revealed that the north of Egypt, where the major cities are located and most economic activity takes place, is generally more prosperous than the south. This leads to substantial migration from the rural south to urban areas in the north, particularly Cairo, Giza and Alexandria. Out of the total population, about 42.6 percent of the population lives in urban areas, the same proportion as ten years ago. However, the reports also indicated that urban growth is a general character of the area. ANOVA based on environmental variables indicated that urbanization was the second significant variable. This urban development produces some of the greatest local extinction rates and frequently eliminates the large majority of native species (Vale and Vale, 1976; Luniak, 1994; Kowarik, 1995 and Marzluff, 2001). The results indicated that the highest number of new species recorded in the study area i.e. introduced species to the area (alien species or non-native species), has been recorded in the two sampling sites of VSG C. The exclusion of these littoral sites (Al8 & AQ9) from a convergent behavior with the former group (VSG D) could be attributed to impact of urbanization. The group included Alexandria, which is considered as the main

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port of Egypt, the second-largest city and a major economic center. The increasing high urban effect such as residential and commercial buildings, factories, houses, etc. in these two sites and among several of their rural areas (localities) affected biodiversity. The number of introduced species calculated as percentage relative to total number of species recorded had scored more than twice as its value for any of the other monitored sites ($S^2 = 0.10$). The group has only included 34 species and more than half of them were from the high to moderately high constancy weed species. It has also scored the lowest values of diversity indices for S & H, highest D & E and upon measuring β-diversity, it was more similar in species composition as compared pairwise with VSG B. These findings coincided with those results obtained by Kowarik (1990) and Shaltout et al. (2010) whom reported that vegetation with low degree of human interference is more diverse than undisturbed one. In fact, the urban element impact results in change in habitat conditions with subsequent alteration in the expected vegetation structure and greatly decreases the sustainability of the natural ecosystems that were reported earlier in the area. It should be also added that the urban development affects spatial distribution of the species and decreases the spread of disturbance and this change in ecological conditions that resulted from human actions in urban areas degrades the natural habitats, simplifies, and homogenizes species composition.

The importance of the soil type and its properties can’t be denied as one of the major environmental factors affecting the weed community structure in an area. Dale et al. (1992) and Tamado and Milberg (2000), had concluded that weed flora is often structured by the soil type. Andreasen et al. (1991), had examined soil properties affecting the distribution of 37 weed species in Danish fields. They had concluded that, “Crop type and soil clay content were generally those explanatory variables that had the greatest influence on occurrence of the weed species, but all other factors examined (sample year, loss on ignition, pH, P, K, Mg and Mn) also had an effect on the occurrence of some weed species”. However, an eco-factor may be a dominant determining factor for weed community structure in one region and cofactor in another. The impact of soil type on species distribution and weed community structure was obvious through the results of Multivariate analyses as follows: 1) the separation of the sampling sites dominated by loam and clay soils from those dominated by sandy soil along PCA1, 2) the sites of VSG B characterized by the highest soil content of clay and silt, highest water holding capacity and low soil salinity gained the lowest negative factor scores while the sites of VSG D characterized by the highest soil content of fine sand, lowest water holding capacity and high soil salinity gained the highest positive factor scores on PC1 and 3) ANOVA based on soil variables indicated that 9 out of 15 soil variables were statistically significant for the identified VSG. The test of ANOVA also declared that impact of soil type was the highest on VSG A. The cluster analysis (AHC) of sampling sites based on their floristic composition revealed that chunks of AM11 and HI12 which belong to VSG

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A were the most similar in the clade. This could be attributed to that the vegetation of several localities included in the two sites have been under the impact of convergent soil properties (saline soils, farmland at fringes of salt marshes and those which border the area near desert). In fact, some species thrive well at the same soil conditions (Ellenberg et al., 1992), and the increase of convergent ecological conditions between sampling areas affects their floristic composition which depends on the species phenotypic plasticity. The measurement of the sample variance for the indicative scores of the sampling sites had scored high value ($S^2 = 0.12$). This spread out for the data may be a cause for that the order of importance of soil type expressed by the results of ANOVA based on environmental variables is not as expected.

The records of the cultivated crop type had indicated that their number, type and quantity differ from one site to the other and the cultivation of a certain crop type is a conclusion of what is available from natural resources as, soil type, quantity of farmland suitable for cultivation, plentiful of water, prevailing climatic conditions, ecological amplitude of the crop, human requirements, …etc. Fried et al. (2008), had concluded that the type of crop has the most significant impact on species composition in western Europe, with Atlantic and Mediterranean climates. Holzner (1978) had reported that crop is a more important factor in southern Europe than in central and northern Europe, as weed species in southern Europe are in their optimal climatic conditions. In Egypt, 2 crops are usually grown in a seasonal sequence: a winter crop and a summer crop and it follows that a crop rotation is accompanied by a weed−flora rotation (El Hadidi and Kosinová, 1971). The measurement of the degree of seasonal bias (Sb%) of species had added more clarification for the impact of crop type in the present study. Most of the 62 species which are designated as early appearing weeds (39 Ws and 23 Sw) often associated with the early cultivations of winter and summer crops (e.g. clover, tomato, cotton, watermelon…. etc.). They were usually well represented in the weed communities associated with perennial crops (CP) and in orchards (CO) as well. These species constitute ≈33% of the high-constancy weeds characterized by wider ecological amplitude. The notes of their phenology (timing of life cycle events) indicated that most of them have more than one seasonal growth cycle during the season of crop cultivation i.e. produce several generations. The extent of persistence and resistance of these weeds against weed control plans (weeding, hoeing, ploughing, herbicides, Stale seed bed, farming practices, ……etc.) as the case of other weeds depend mainly on the genetically inherited characters and the mutations and gene flow which contribute to genetic variability and provide resistant alleles. ANOVA depending on site's indicative scores for environmental factors showed that crop type was the third significant variable and its impact was clearer in VSG C.

The impact of crop sustainability is a matter of discussion in ecological researches (Palmer et al., 1999; Firehun and Tamado, 2006). The records of the cultivated crop type emphasize the importance of the ratio of crop sustainability. About 36%

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of the total agroecosystems monitored were perennial crops and orchards. In these perennial agroecosystems 359 species were recorded, of them 92 species confined their records to orchards. This could be mainly attributed to that orchards exhibited two different micro-habitats, a shaded micro-habitat below the crowns of trees and a sunny micro-habitat between trees. This environmental microheterogeneity enhances the growth of Shade loving species whereas the sunny areas support the growth of other species. Moreover, the shade effect keeps the soils moist for a longer period which allows the growth of certain species that are characteristic to moist places more than in other croplands. The low to medium scores for sample variance of site's indicative scores for crop type and sustainability ($S^2 = 0.03, 0.08$) indicated that the floristic composition for most of the sites was affected. Its impact was prominent in the northern littoral sites of VSG C and VSG D where horticulture was widely recorded.

5. Conclusion

The impact of the five variables was noticeable on species distribution and weed community structure in the farmland of the surveyed area and the heavy rains during the winter season caused a remarkable increase of the total species richness γ-diversity, Whittaker. We can conclude that, the prevailing climate was the most impacting factor on species distribution and weed community structure followed by: urbanization, crop type, soil type and crop sustainability, respectively. This order of importance of the impact of these environmental factors is realistic for the sample area under study, but it is not a strict rule, as an ecological factor may be the dominant in determining the vegetation structure in a certain region and co-factor in another one depending on the available natural resources and extent of human intervention.

Declarations

Author contribution statement

Alaa M. M. Amer-Mahgoub: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

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