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Evaluation of Changes in Weed Flora in Response to Agricultural Practices in the Arable Lands of El-Menoufia Governorate, Nile Delta, Egypt

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Abstract

In Egypt and during the last 50 years, several changes in agricultural practices have affected different components of agro-ecosystems including weed flora. The aim of the present study was to evaluate changes in the weed flora of El-Menoufia Governorate, South of the Nile Delta of Egypt during the period from 1984 to 2018, in response to different agricultural practices. A total of 240 stands were investigated in both spring and summer seasons in order to document the present status of the weed flora. The obtained results were compared to results obtained by other authors in 1984. Results showed major shifts in the weed flora of El-Menoufia Governorate where 67 species out of 146 species were recorded in our study while only 42 species out of 121 species were present in 1984 survey. Changes in the family composition, life form, life span, and chorology were reported. Reasons responsible for such changes have been discussed. Changes in the crop composition, cultivation area of each crop, excessive use of fertilizers and pesticides, changes in irrigation water quality and quantity are the leading change promoters. The high economic importance of the weed flora and the potential threats facing agriculture in Egypt necessitate the formulation of a sustainable strategy for maintaining agro-ecosystems of Egypt and its biodiversity.

Keywords: weed flora, arable lands, agricultural practices, Nile Delta.

Introduction

Agriculture in Egypt is as old as history and agricultural practices remained with no major changes for millennia (Bowman and Rogan, 1999). Modern agriculture in Egypt may be divided into two episodes separated by the establishment of the High Dam of Aswan (HDA), after which several transformations in agricultural practices took place (Biswas, 1993). Water availability allowed more areas to be cultivated and more crops to expand, especially those with high water needs such as rice and sugarcane (Abu-Zeid and El-Shibini, 1997). Even after liberalization of crop cultivation in 1990 this trend continued to increase (Barnes, 2014) (Table 1).

On the other side, around 130 million tons of mineral–rich sediments used to enrich the fertile arable lands of Egypt annually were trapped in Lake Nasser since 1969 (White, 1988). In order to compensate the degraded soil fertility, farmers started to rely heavily on chemical fertilizers which in return increased soil salinity and with the lack of proper drainage system, many areas were vulnerable to be salinized and ruined (Zaghloul, 2013). More areas were cultivated with salt tolerant crops such as rice but with its high water needs, salinity and water waste problem increased. Richards and Waterbury (1990) estimated that Egypt has spent more money on building drainage system than the money spent on building the HDA itself.

Population growth has also increased very rapidly from 30 million inhabitants in 1965 to around 98 million inhabitants in 2017 (World Bank, 2018). Egypt has the lowest arable land per capita of any country in Africa (Biswas, 1993). The population increase has triggered a strong wave of urban encroachment on the agricultural lands, especially after the 2011 revolution (Khamis *et al*., 2015 and Mohamed, 2017). These encroachments took place mainly in the most productive parts of the old lands of Egypt (Zaghloul, 2013). This has led to the reclamation of new lands in order to compensate the loss in the old lands, nevertheless of the fact that reclamation of new land is costing much more money and less effective than conserving the old productive one (Biswas, 1993 and Storkey *et al*., 2012). Lacking of proper infrastructure to contain these anthropogenic activities, especially in the heavily populated areas, has led to several environmental problems (Nagajyoti *et al*., 2010; Alloway, 2012; Wu *et al*., 2016 and Steffan *et al*., 2017). Consequences include water and soil contamination by sewage and industrial wastes and the accumulation of heavy metals in agricultural soil and subsequently in various plantations (Zhou *et*

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al., 2016; Wang *et al.*, 2017; Chen *et al.*, 2018 and Khalifa and Gad, 2018). These problems have also provided a better environment for pests and disease vectors to flourish and accordingly the use of pesticides has also intensified (Biswas, 1993 and El-Nemr, 2017). It is estimated that one million ton of pesticides has been injected into the Egyptian environment since the establishment of the HDA (Mansour, 2008). All of the previously mentioned changes have severely affected agriculture in Egypt (Hegazy *et al*., 2004; Brand *et al.,* 2007 and El-Nemr, 2017).

In an agroecosystem, nothing could be a better indicator of changes than weeds. Weeds are the only component of the agroecosystems to resist human activities. Their persistence against elimination endeavors is truly remarkable (El-Demerdash *et al*., 1997). Survival techniques that weeds may use include high seed germination rate, short life cycle, efficient seed dispersal methods, allelopathy, and tolerance to different biotic and abiotic stresses (Baker, 1974). On the other hand, the heavy anthropogenic activities are severely affecting weed distribution and existence. Changes in the weed flora have been used to track the footprints of the past by several authors. Fahmy (1997) studied archeological weed flora of Egypt from Predynastic to Graeco-Roman times (4500 B.C. – 395 A.D.) and related his findings to old agricultural practices. El-Hadidi (1993) studied the weed flora during the Neolithic / Predynastic period (4500-3100 B.C.) and concluded that the presence of some geographical elements today may be due to the former contact between different civilizations in Egypt's history. Recently, several studies have related the changes in the weed flora of arable lands to agricultural practices. Baessler and Klotz (2006) studied the effects of farming practices after World War II on the weed flora of Central Germany and for 50 years period. Andreasen and Streibig (2010) studied the changes in the weed flora of arable lands of Nordic countries in relation to changes after the World War II and the modern reformations in agricultural practices. El-Saied *et al*. (2015) studied the changes in the weed flora in Siwa Oasis in relation to farming practices. Richner *et al*. (2015) reported that the arable flora has dramatically altered in response to changing in agricultural practices since the Second World War. Ramôa *et al*. (2017) studied the weed flora changes in response to the modern reformations in agriculture in Portugal. Changes in agriculture practices don't only affect the weed flora of agroecosystems but extends to all biotic and abiotic components (Chamberlain *et al*., 2000).

Weed flora surveys in Egypt date back to the first half of the twentieth century (Simpson, 1932 and Andrews, 1945). Several studies have followed this early attempts by investigating the weed flora of some parts of the old lands of Egypt (Boulos, 1966 and 1967; El-Shayeb, 1989; Shaltout *et al*., 1992; Mashaly, 2003; Sadek, 2008 and El-Halawany *et al.,* 2010) while others have investigated the weed flora of the reclaimed lands (Abd El-ghani *et al*., 2013) and others have investigated the weed flora of the Egyptian Oases (Abd El-Ghani, 1981, 1985 and 1998; Elsaied, 2012; El-Saied *et al*., 2015). Some studies have dealt with weeds associated with certain crops or plantations (Tadros and Atta, 1958; Imam and Kosinova, 1972; El-Kady *et al.*, 1999; Turki and Sheded, 2002 and Mashaly and Awad, 2003) while others have dealt with seasonality of weeds (Zaki and Mashaly, 1992; El-Shayeb, 1984 and Ziada *et al.*, 2007). Some studies gave a general view of the whole weed flora of the country (El-Hadidi and Kosinova, 1971; Boulos and El-Hadidi, 1984 Abd El-Ghani and El-Sawaf, 2004 and Shaltoot *et al*., 2010).

Several objectives and methodologies applied in various surveys made it hard to have a trustworthy comparison. One of the early studies of the weed flora in the Nile Delta is the study carried out by El-Shayeb (1984). El-Shayeb (1984) studied the weed flora of El-Menoufia Governorate after 15 years of the establishment of the HDA where water availability and soil quality have changed agricultural practices, permitted more crop diversity, and consequently enriched the weed flora of the arable lands of Egypt. Agricultural practices remained very dynamic in response to the later deterioration in soil quality and water availability and quality. The present study aims at studying changes in the weed flora of El-Menoufia Governorate, south of the Nile Delta of Egypt after 34 years of El-Shayeb study in 1984 and around 50 years after the establishment of the HDA. Changes in the number of species, family composition, and geographical elements and life forms are to be detected and potential reasons for such changes if present, are to be investigated.

Table 1. Cultivated areas of the major crops (feddans), total cultivated area of Egypt (feddans) and total population (millions) at three time points (1965, 1985, and 2016).

	1965	1985	2016
Rice	641,000	1,042,000	1,353,477
Sugarcane	111,000	248,000	325,912
Wheat	1,500,000	1,345,000	3,353,151
Maize	1,850,000	1,831,000	1,741,000
Clover	2,362,000	2,834,000	1,562,000
Cotton	1,791,000	1,296,000	241,000
Total cultivated area	5,500,000	5,943,000	8,961,000
Total population	30,875,964	50,204,985	95,688,681

Sources: (Richards, 1982; CAPMAS, 2017; World Bank, 2018 and SIS, 2018)

Study area

According to (FAO, 2005) arable lands of Egypt may be divided into four groups: 1- Old lands of the Nile Valley and Delta, 2- Newly reclaimed lands around the Nile, 3- Oases lands irrigated by the Nubian Sandstone Aquifer System (NSAS) and 4- Rain-fed lands along the Mediterranean coast of Egypt to the East and West of Nile Delta. El-Menoufia Governorate is located in the southern part of the Nile Delta of Egypt between long 30° 15’ and 31° 15’ E and Lat. 30° 10’ and 30° 45’ N with a total area of 2543 km^2 and 3,941,293 inhabitants (El-Menoufia Governorate information Center, 2017). El-Menoufia is located between the two branches of the Nile Rosetta and Damietta. El-Menoufia Governorate bounded by Gharbiya Governorate to the north, Al Qalyubia Governorate to the east, Giza Governorate to the South and El Beheira Governorate to the west. El-Menoufia Governorate includes nine centers; Tala, El-Shohadaa, Menouf, Qwaisna, Berket AlSaba, Shebeen El-Koum, Al-Bagour, Ashmoun and El-Sadat. Main crops in El-Menoufia Governorate are wheat, clover, maize, and potato in addition to cotton, vegetables, and fruits. The agricultural land in El-Menoufia Governorate is of high quality (FAO, 2005). Common problems of agriculture in El-Menoufia are not isolated from Egypt’s agricultural problems. Water shortage, soil degradation, blockage of drainage and irrigation networks, excessive use of plant hormones, chemical fertilizers, and pesticides.

Materials and methods

The present study of El-Menoufia Governorate was conducted between October 2016 and March 2018 to represent the flora of El-Menoufia agroecosystems. A total of 240 stands were selected to investigate the weed flora of the study area (120 stands in spring and another 120 in summer) (Fig. 1). Stands were chosen to represent different crops growing in the study area. Spring stands included 46 clover stands, 30 wheat stands, 26 potato and vegetables stands, and 18 orchards. Summer stands included 77 maize stands, 27 potato and vegetables, and 16 orchards. Stands were distributed along the nine centers according to the size of the cultivated area within each center. Each stand encompassed four quadrates (5m*5m). GPS coordinates of each stand were recorded. Presence/absence data have been recorded for each species in each stand. All plant species existing in each stand were listed after complete identification according to Täckholm (1974) and Boulos (1999–2009). Voucher herbarium specimens were incorporated in the herbarium of the Department of Botany, Faculty of Science, Al-Azhar University. Life form categories were identified after Raunkiaer (1934). Variation in the life form in the field was not considered. Phytogeographical affinity of each species was identified after the system of Eig (1931). Records of 1984 were acquired from El-Shayeb (1984) and species list was prepared for further comparison with the present study findings.

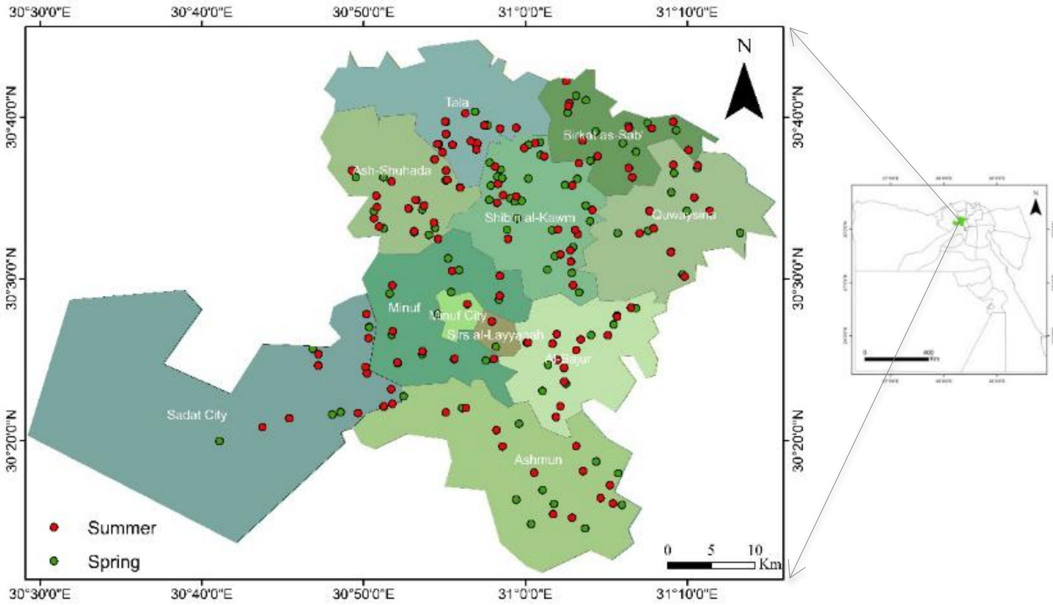

Fig. 1. Administrative map showing nine centers of El-Menoufia Governorate and the 240 selected stands in both spring and summer seasons.

Results

Weed flora present status (2018)

A total of 146 taxa belonging to 36 families and 105 genera were recorded in El-Menoufia Governorate in the present study (Table 1). Poaceae, Asteraceae, and Fabaceae were the most common families with 29 species (19.86%), 19 species (13%) and 11 species (7.53%) of species composition, respectively. Brassicaceae, Amaranthaceae, Solanaceae, Chenopodiaceae, Euphorbiaceae and Convolvulaceae were represented by five to ten taxa each. Nine families were represented by two to four taxa while the rest 18 families were represented by only one species (Table 2 and Fig. 2).

With regard to life span, the majority of the recorded species in this study were annuals with 100 species (68.5%), followed by the perennials with 44 species (30.1%). Only two biennial species was recorded (*Petroselinum crispum* and *Silybium marianum*) (Table 2).

According to the classification of Raunkiaer (1934), eight life forms were recorded; therophytes were the most abundant life form and constituted 69.2% of total recorded species (101 species), followed by hemicryptophytes (21 species = 14.4%), chamaephytes (6 species = 4.1%), geophytes (5 species = 3.4%), phanerophytes (4 species = 2.7%), , four species from four different genera were helophytes. (*Lemna gibba*, *Eichhornia crassipes*, *Typha domingensis* and *Ranunculus rionii*) and parasites were represented by two species (*Cuscuta campestris* and *Orobanche cernua*) (Tables 2 and Fig. 3).

From a phytogeographical point of view, cosmopolitan species represented 18.5% of the recorded species with 27 species followed by paleotropical species with 25 species (17.1%) and pantropical with 12 species (8.2%) in addition to a single endemic (*Sonchus macrocarpus*) and neotropical (*Amaranthus spinosus*) species. The rest 80 species were classified into three groups; monoregional, biregional or pluriregional. A total of 19 species representing 13% of the total number of recorded species were monoregional of different affinities. Biregional geoelements were represented by 31 species forming 21.2% of recorded species. Pluriregional geoelements were represented by 30 species forming 20.5% of recorded species (Tables 2 and Fig. 4).

Changes in the weed flora (1984 - 2018)

Results of El-Shayeb (1984) were used to evaluate changes in weed flora during the period from 1984 to 2018. Number of species recorded in the present study was 146 while 121 species were recorded in 1984. Number of shared species was 79 while 67 species were recorded only in the present study and 42 species were recorded only in 1984.

Table 2. List of species recorded in the agro–ecosystem of El-Menoufia Governorate. The species referred to their families, and life span; Annual=Ann, Biennial=Bie, Perennial=Per. according to Boulos (1999–2009), life forms according to (Raunkiaer, 1934); Therophyte=Th, Hemicryptophyte=Hem, Chamaephyte=Cha, Phanerophyte=Ph, Parasite=Par, Geophyte=Geo, Helophyte=Hel, Hydrophytes= Hyd. Phytogeographical affinities according to the system of Eig (1931); COSM=Cosmopolitan, ER-SR=Euro-Siberian, IR-TR= Irano-Turanian, ME=Mediterranean, NEO=Neotropical, PAL=Paleotropical, PAN=Pantropical, SA-SI=Saharo-Sindian, S-Z=Sudano-Zambesian. Species were categorized into three groups; species recorded in the present study only (A), species recorded in 1984 only (B), Species recorded in both studies (A, B). Families are arranged alphabetically within each category; genera and species are in alphabetical order within their respective families.

Species	Family	Life span	Life form	Floristic categories	Record
Alternanthera sessilis (L.) DC.	Amaranthaceae	Per.	Hel.	PAN	A
Amaranthus caudatus L.	Amaranthaceae	Ann.	Th.	COSM	A
Amaranthus spinosus L.	Amaranthaceae	Ann.	Th.	NEO	A
Amaranthus tricolor L.	Amaranthaceae	Ann.	Th.	PAL	A
Petroselinum crispum (Mill.) Nyman ex A.W. Hill	Apiaceae	Bie.	Th.	ME	A
Cynanchum acutum L.	Asclepiadaceae	Per.	Hem.	ME + IR-TR + ER-SR	A
Anthemis retusa Delile	Asteraceae	Ann.	Th.	ME + IR-TR + SA-SI	A
Bidens pilosa L.	Asteraceae	Ann.	Th.	PAN	A
Glebionis coronaria (L.) Tzvelev	Asteraceae	Ann.	Th.	ME	A
Launaea mucronata (Forssk.) Muschl.	Asteraceae	Ann.	Th.	SA-SI	A
Launaea nudicaulis (L.) Hook. f.	Asteraceae	Per.	Hem.	IR-TR	A
Pluchea dioscoridis (L.) DC.	Asteraceae	Per.	Ph.	SA-SI + S-Z	A
Pulicaria undulata (L.) C.A.Mey.	Asteraceae	Per.	Cha.	SA-SI + S-Z	A
Scolymus maculatus L.	Asteraceae	Ann.	Th.	ME	A
Senecio aegyptius L.	Asteraceae	Ann.	Th.	SA-SI	A
Sonchus macrocarpus Boulos & C.Jeffrey	Asteraceae	Ann.	Th.	Endemic	A
Camelina rumelica Velen.	Brassicaceae	Ann.	Th.	ME	A
Stellaria pallida (Dumort.) Murb.	Caryophyllaceae	Ann.	Th.	ME + ER-SR	A
Vaccaria pyramidata Medik.	Caryophyllaceae	Ann.	Th.	ME + IR-TR + ER-SR	A
Atriplex lindleyi Moq.	Chenopodiaceae	Per.	Cha.	ME + SA-SI	A
Chenopodium glaucum L.	Chenopodiaceae	Ann.	Th.	ME + ER-SR	A
Cuscuta campestris Yunck.	Convolvulaceae	Ann.	Par.	PAN	A
Ipomoea cairica (L.) Sweet	Convolvulaceae	Per.	Hem.	PAL	A
Ipomoea eriocarpa R. Br.	Convolvulaceae	Ann.	Th.	PAL	A
Cyperus alopecuroides Rottb.	Cyperaceae	Per.	Hel.	PAN	A
Cyperus articulatus L.	Cyperaceae	Per.	Hel.	PAN	A
Cyperus digitatus Roxb.	Cyperaceae	Per.	Geo.	ME + IR-TR + ER-SR	A
Ricinus communis L.	Euphorbiaceae	Per.	Ph.	PAL	A
Alhagi graecorum Boiss.	Fabaceae	Per.	Hem.	PAL	A
Medicago sativa L.	Fabaceae	Per.	Hem.	ME + IR-TR + ER-SR	A
Scorpiurus muricatus L.	Fabaceae	Ann.	Th.	ME	A
Trigonella sp	Fabaceae	Ann.	Th.	ME	A
Mentha longifolia (L.) Huds.	Lamiaceae	Per.	Hem.	PAL	A
Mentha pulegium L.	Lamiaceae	Per.	Hem.	ME + IR-TR + ER-SR	A
Lemna gibba L.	Lemnaceae	Per.	Hyd	COSM	A
Glinus lotoides L.	Molluginaceae	Ann.	Th.	ME + IR-TR	A
Orobanche cernua Loefl.	Orobanchaceae	Per.	Par.	ME + IR-TR	A
Bromus catharticus Vahl	Poaceae	Ann.	Th.	ME + IR-TR + ER-SR	A
Bromus diandrus Roth.	Poaceae	Ann.	Th.	ME + IR-TR	A
Dactyloctenium aegyptium (L.) Willd.	Poaceae	Ann.	Th.	PAL	A
Desmostachya bipinnata (L.) Stapf	Poaceae	Per.	Hem.	SA-SI + S-Z	A

Echinochloa crusgalli (L.) P. Beauv.	Poaceae	Ann.	Th.	PAL	A
Hordeum marinum L.	Poaceae	Ann.	Th.	ME + IR-TR + ER-SR + PAL	A
Imperata cylindrica (L.) Raeusch.	Poaceae	Per.	Hem.	ME + IR-TR + SA-SI	A
Leptochloa fusca (L.) Kunth	Poaceae	Per.	Hem.	PAL	A
Lolium perenne L.	Poaceae	Per.	Hem.	COSM	A
Panicum coloratum L.	Poaceae	Per.	Geo.	ME	A
Paspalum distichum L.	Poaceae	Per.	Hem.	PAL	A
Pennisetum divisum (J.F.Gmel.) Henrard	Poaceae	Per.	Hem.	SA-SI	A
Phalaris paradoxa L.	Poaceae	Ann.	Th.	ME + IR-TR	A
Phragmites australis (Cav.) Trin. ex Steud.	Poaceae	Per.	Geo.	PAL	A
Sorghum bicolor (L.) Moench	Poaceae	Ann.	Th.	PAL	A
Polygonum maritimum L.	Polygonaceae	Per.	Hem.	ME	A
Polygonum plebeium R. Br.	Polygonaceae	Per.	Cha.	PAL	A
Eichhornia crassipes (C. Mart.) Solms	Pontederiaceae	Per.	Hyd	PAL	A
Ranunculus rionii Lagger	Ranunculaceae	Ann.	Th.	ME + ER-SR	A
Rosa sp	Rosaceae	Per.	Ph.	IR-TR	A
Veronica persica Poir.	Scrophulariaceae	Ann.	Th.	COSM	A
Hyoscyamus muticus L.	Solanaceae	Per.	Hem.	ME	A
Physalis angulata L.	Solanaceae	Ann.	Th.	PAN	A
Solanum villosum (L.) Mill.	Solanaceae	Ann.	Th.	ME + IR-TR + ER-SR	A
Withania obtusifolia Täeckh.	Solanaceae	Per.	Ph.	ME + IR-TR	A
Withania somnifera (L.) Dunal	Solanaceae	Per.	Cha.	SA-SI + S-Z	A
Reaumuria hirtella Jaub. & Spach.	Tamaricaceae	Per.	Cha.	IR-TR	A
Tamarix nilotica (Ehrenb.) Bunge	Tamaricaceae	Per.	Ph.	SA-SI + S-Z	A
Typha domingensis (Pers.) Poir. ex Steud.	Typhaceae	Per.	Hel.	PAN	A
Tribulus pentandrus Forssk.	Zygophyllaceae	Ann.	Th.	SA-SI	A
Tribulus terrestris L.	Zygophyllaceae	Ann.	Th.	IR-TR + ER-SR + S-Z	A
Trianthema portulacastrum L.	Aizoaceae	Ann.	Th.	PAN	A, B
Amaranthus hybridus L.	Amaranthaceae	Ann.	Th.	COSM	A, B
Amaranthus retroflexus L.	Amaranthaceae	Ann.	Th.	COSM	A, B
Amaranthus viridis L.	Amaranthaceae	Ann.	Th.	COSM	A, B
Ammi majus L.	Apiaceae	Ann.	Th.	ME + IR-TR	A, B
Ammi visnaga (L.) Lam.	Apiaceae	Ann.	Th.	ME + IR-TR	A, B
Foeniculum vulgare Mill.	Apiaceae	Ann.	Th.	ME + IR-TR	A, B
Cichorium endivia L.	Asteraceae	Ann.	Th.	ME + IR-TR	A, B
Conyza bonariensis (L.) Cronquist	Asteraceae	Ann.	Th.	ME	A, B
Pseudognaohalium luteo–album (L.) Hilliard & B. L. Burtt.	Asteraceae	Ann.	Th.	ME + IR-TR + SA-SI	A, B
Senecio glaucus L.	Asteraceae	Ann.	Th.	IR-TR + SA-SI	A, B
Senecio vulgaris L.	Asteraceae	Ann.	Th.	ME + IR-TR + ER-SR	A, B
Silybum marianum (L.) Gaertn.	Asteraceae	Bie.	Th.	ME + IR-TR + ER-SR	A, B
Sonchus oleraceus L.	Asteraceae	Ann.	Th.	COSM	A, B
Urospermum picroides (L.) Scop. ex F.W.Schmidt	Asteraceae	Ann.	Th.	ME + IR-TR	A, B
Xanthium spinosum L.	Asteraceae	Ann.	Th.	PAL	A, B
Brassica nigra (L.) K.Koch	Brassicaceae	Ann.	Th.	ME + ER-SR	A, B
Brassica rapa L.	Brassicaceae	Ann.	Th.	ME + ER-SR	A, B

Capsella bursa-pastoris (L.) Medik.	Brassicaceae	Ann.	Th.	COSM	A, B
Coronopus didymus (L.) Sm.	Brassicaceae	Ann.	Th.	COSM	A, B
Coronopus squamatus (Forssk.) Asch.	Brassicaceae	Ann.	Th.	ME + IR-TR + ER-SR	A, B
Eruca sativa Mill.	Brassicaceae	Ann.	Th.	ME + IR-TR + ER-SR + SA-SI	A, B
Raphanus raphanistrum L.	Brassicaceae	Ann.	Th.	ME + ER-SR	A, B
Sisymbrium irio L.	Brassicaceae	Ann.	Th.	ME + IR-TR + ER-SR	A, B
Silene rubella L.	Caryophyllaceae	Ann.	Th.	ME	A, B
Spergularia marina (L.) Griseb.	Caryophyllaceae	Ann.	Th.	COSM	A, B
Beta vulgaris L.	Chenopodiaceae	Ann.	Th.	ME + IR-TR + ER-SR	A, B
Chenopodium album L.	Chenopodiaceae	Ann.	Th.	COSM	A, B
Chenopodium ambrosioides L.	Chenopodiaceae	Ann.	Cha.	PAL	A, B
Chenopodium murale L.	Chenopodiaceae	Ann.	Th.	COSM	A, B
Convolvulus arvensis L.	Convolvulaceae	Per.	Hem.	PAL	A, B
Ipomoea carnea Jacq.	Convolvulaceae	Per.	Ph.	ME + IR-TR	A, B
Cyperus rotundus L.	Cyperaceae	Per.	Geo.	PAN	A, B
Euphorbia helioscopia L.	Euphorbiaceae	Ann.	Th.	COSM	A, B
Euphorbia heterophylla L.	Euphorbiaceae	Ann.	Th.	PAN	A, B
Euphorbia indica Lam.	Euphorbiaceae	Ann.	Th.	SA-SI	A, B
Euphorbia peplus L.	Euphorbiaceae	Ann.	Th.	COSM	A, B
Euphorbia prostrata Aiton	Euphorbiaceae	Ann.	Th.	COSM	A, B
Lotus glaber Mill.	Fabaceae	Per.	Hem.	ME + IR-TR + ER-SR	A, B
Medicago intertexta (L.) Mill.	Fabaceae	Ann.	Th.	ME + ER-SR	A, B
Melilotus indicus (L.) All.	Fabaceae	Ann.	Th.	PAL	A, B
Melilotus messanensis (L.) All.	Fabaceae	Ann.	Th.	ME + IR-TR	A, B
Trifolium resupinatum L.	Fabaceae	Ann.	Th.	ME + IR-TR + ER-SR	A, B
Vicia monantha Retz.	Fabaceae	Ann.	Th.	ME + IR-TR	A, B
Vicia sativa L.	Fabaceae	Ann.	Th.	ME + IR-TR + ER-SR	A, B
Fumaria densiflora DC.	Fumariaceae	Ann.	Th.	ME + IR-TR + ER-SR	A, B
Lamium amplexicaule L.	Lamiaceae	Ann.	Th.	ME + IR-TR + ER-SR	A, B
Emex spinosa (L.) Campd.	Loranthaceae	Ann.	Th.	ME + SA-SI	A, B
Abutilon theophrasti Medik.	Malvaceae	Ann.	Th.	ME + IR-TR + ER-SR	A, B
Hibiscus trionum L.	Malvaceae	Ann.	Th.	PAL	A, B
Malva parviflora L.	Malvaceae	Ann.	Th.	ME + IR-TR	A, B
Oxalis corniculata L.	Oxalidaceae	Ann.	Th.	COSM	A, B
Plantago major L.	Plantaginaceae	Per.	Hem.	COSM	A, B
Avena fatua L.	Poaceae	Ann.	Th.	COSM	A, B
Avena sativa L.	Poaceae	Ann.	Th.	COSM	A, B
Brachiaria eruciformis (Sm.) Griseb.	Poaceae	Ann.	Th.	ME + IR-TR	A, B
Cynodon dactylon (L.) Pers.	Poaceae	Per.	Geo.	PAN	A, B
Digitaria sanguinalis (L.) Scop.	Poaceae	Ann.	Th.	PAL	A, B
Dinebra retroflexa (Vahl) Panz.	Poaceae	Ann.	Th.	PAL	A, B
Echinochloa colona (L.) Link	Poaceae	Ann.	Th.	ME + IR-TR + PAL	A, B
Phalaris minor Retz.	Poaceae	Ann.	Th.	ME + IR-TR	A, B
Poa annua L.	Poaceae	Ann.	Th.	ME + IR-TR + ER-SR	A, B
Polypogon monspeliensis (L.) Desf.	Poaceae	Ann.	Th.	COSM	A, B
Polypogon viridis (Gouan) Breistr.	Poaceae	Ann.	Th.	ME + IR-TR + ER-SR	A, B
Setaria verticillata (L.) P. Beauv.	Poaceae	Ann.	Th.	COSM	A, B
Setaria viridis (L.) P. Beauv.	Poaceae	Ann.	Th.	COSM	A, B
Sorghum virgatum (Hack.) Stapf	Poaceae	Ann.	Th.	PAL	A, B
Persicaria salicifolia (Brouss. ex Willd.) Assenov	Polygonaceae	Per.	Hem.	PAL	A, B

Rumex dentatus L.	Polygonaceae	Ann.	Th.	ME + IR-TR + ER-SR	A, B
Portulaca oleracea L.	Portulacaceae	Ann.	Th.	COSM	A, B
Anagallis arvensis L.	Primulacae	Ann.	Th.	COSM	A, B
Veronica anagallis-aquatica L.	Scrophulariaceae	Per.	Hel.	COSM	A, B
Veronica polita Fr.	Scrophulariaceae	Ann.	Th.	ME + IR-TR + ER-SR	A, B
Datura stramonium L.	Solanaceae	Ann.	Th.	PAL	A, B
Solanum nigrum L.	Solanaceae	Ann.	Th.	COSM	A, B
Corchorus olitorius L.	Tiliaceae	Ann.	Th.	PAN	A, B
Urtica urens L.	Urticaceae	Ann.	Th.	ME + IR-TR + ER-SR	A, B
Phyla nodiflora (L.) Greene	Verbenaceae	Per.	Hem.	PAL	A, B
Amaranthus graecizans L.	Amaranthaceae	Ann.	Th.	COSM	B
Torilis nodosa (L.) Gaertn.	Apiaceae	Ann.	Th.	ME + IR-TR + ER-SR	B
Centaurea calcitrapella Bornm. & Dinsm.	Asteraceae	Bie.	Cha.	ME + ER-SR	B
Eclipta prostrata (L.) L.	Asteraceae	Ann.	Th.	PAL + NEO	B
Ethulia conyzoides L.f.	Asteraceae	Ann.	Th.	PAL	B
Sonchus asper (L.) Hill.	Asteraceae	Ann.	Th.	ME + IR-TR	B
Symphyotrichum squamatum (Spreng.) G.L.Nesom	Asteraceae	Per.	Cha.	NEO	B
Xanthium pungens Wallr.	Asteraceae	Ann.	Th.	S-Z	B
Xanthium strumarium L.	Asteraceae	Ann.	Th.	S-Z	B
Brassica tournefortii Gouan	Brassicaceae	Ann.	Th.	ME + SA-SI	B
Lepidium sativum L.	Brassicaceae	Ann.	Th.	COSM	B
Sinapis alba L.	Brassicaceae	Ann.	Th.	ME + IR-TR + ER-SR	B
Sinapis allionii Jacq.	Brassicaceae	Ann.	Th.	Endemic	B
Sinapis arvensis L.	Brassicaceae	Ann.	Th.	IR-TR + ER-SR + ME	B
Sinapis turgida (Pers.) Delile	Brassicaceae	Ann.	Th.	Endemic	B
Stellaria media (L.) Vill.	Caryophyllaceae	Ann.	Th.	COSM	B
Cuscuta pedicellata Ledeb.	Convolvulaceae	Ann.	Par.	IR-TR + ME	B
Cuscuta planiflora Ten.	Convolvulaceae	Ann.	Par.	PAL	B
Chrozophora plicata (Vahl) A.Juss. ex Spreng.	Euphorbiaceae	Ann.	Th.	S-Z + PAL	B
Euphorbia terracina L.	Euphorbiaceae	Per.	Hem.	ME	B
Lathyrus hirsutus L.	Fabaceae	Ann.	Th.	ME + IR-TR + ER-SR	B
Lotus arabicus L.	Fabaceae	Ann.	Th.	S-Z + SA-SI	B
Medicago polymorpha L.	Fabaceae	Ann.	Th.	ME + IR-TR + ER-SR	B
Vicia cinerea M.Bieb.	Fabaceae	Ann.	Th.	ME + IR-TR	B
Vicia lutea L.	Fabaceae	Ann.	Th.	ME	B
Vicia peregrina L.	Fabaceae	Ann.	Th.	ME + IR-TR	B
Mentha microphylla K.Koch	Labiatae	Per.	Geo.	PAL	B
Althaea ludwigii L.	Malvaceae	Ann.	Th.	SA-SI + IR-TR + S-Z	B
Sida alba L.	Malvaceae	Ann.	Th.	PAN	B
Orobanche crenata Forssk.	Orobanchaceae	Per.	Par.	ME + IR-TR	B
Avena sterilis L.	Poaceae	Ann.	Th.	ME + IR-TR	B
Brachiaria reptans (L.) C.A.Gardner & C.E.Hubb.	Poaceae	Ann.	Th.	PAL	B
Dichanthium annulatum (Forssk.) Stapf	Poaceae	Per.	Hem.	PAL + NEO	B
Echinochloa stagnina (Retz.) P.Beauv.	Poaceae	Per.	Hel.	PAL	B
Leptochloa panicea (Retz.) Ohwi	Poaceae	Ann.	Th.	PAL	B
Lolium multiflorum Lam.	Poaceae	Ann.	Th.	ME + ER-SR + IR-TR	B
Lolium temulentum L.	Poaceae	Ann.	Th.	ER-SR + ME + IR-TR	B
Panicum repens L.	Poaceae	Per.	Geo.	PAL + NEO + ME	B
Phalaris canariensis L.	Poaceae	Ann.	Th.	ME	B
Polygonum bellardii All.	Polygonaceae	Ann.	Th.	IR-TR + ME + ER-SR	B
Veronica anagalloides Guss.	Scrophulariaceae	Per.	Geo.	ER-SR + ME + IR-TR	B
Verbena supina L.	Verbenaceae	Ann.	Th.	ME + IR-TR + SA-SI	B

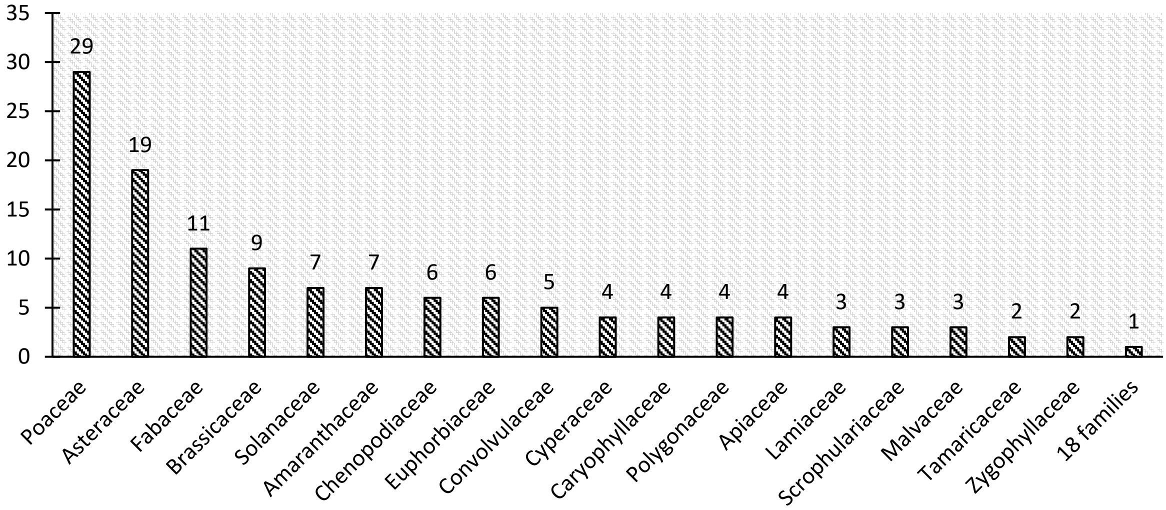

Fig. 2. Number of species recorded in each family collected from El-Menoufia Governorate in the present study.

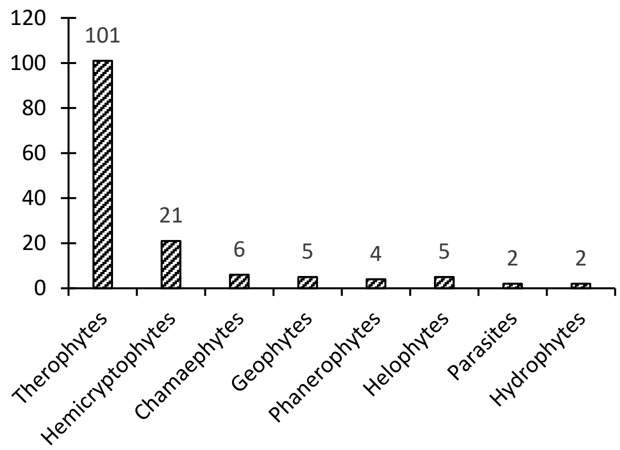

Fig. 3. Life forms of the species recorded in El-Menoufia Governorate in the present study

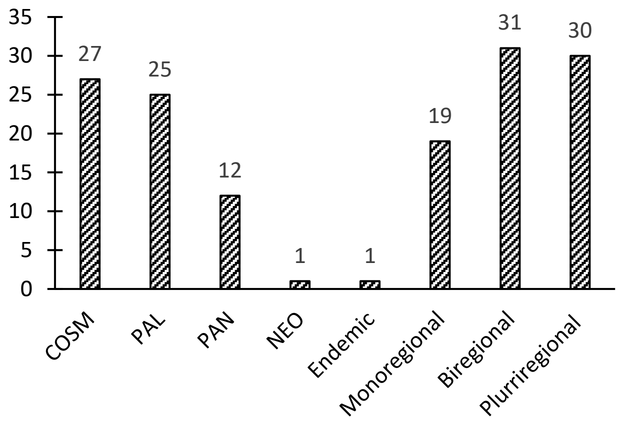

Fig. 4. Floristic categories of the species recorded in El-Menoufia Governorate in the present study

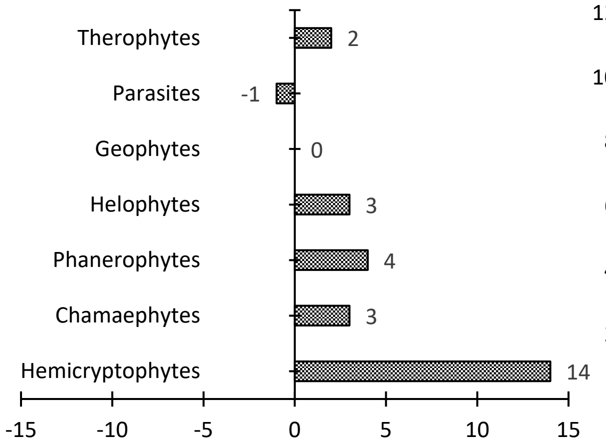

Fig. 5. Changes in the number of species belonging to different life forms during the period 1984- 2018

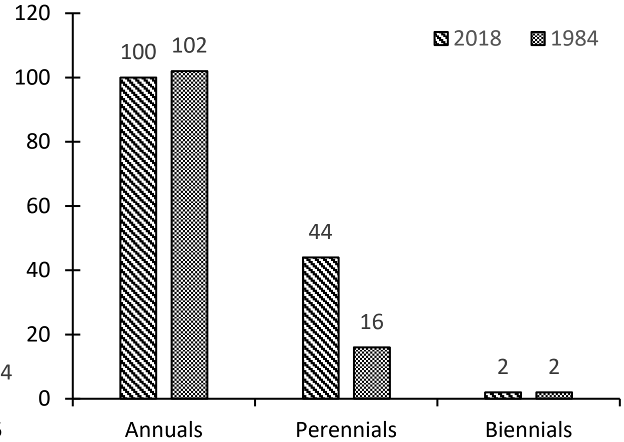

Fig. 6. Changes in the number of species belonging to different life spans during the period 1984- 2018

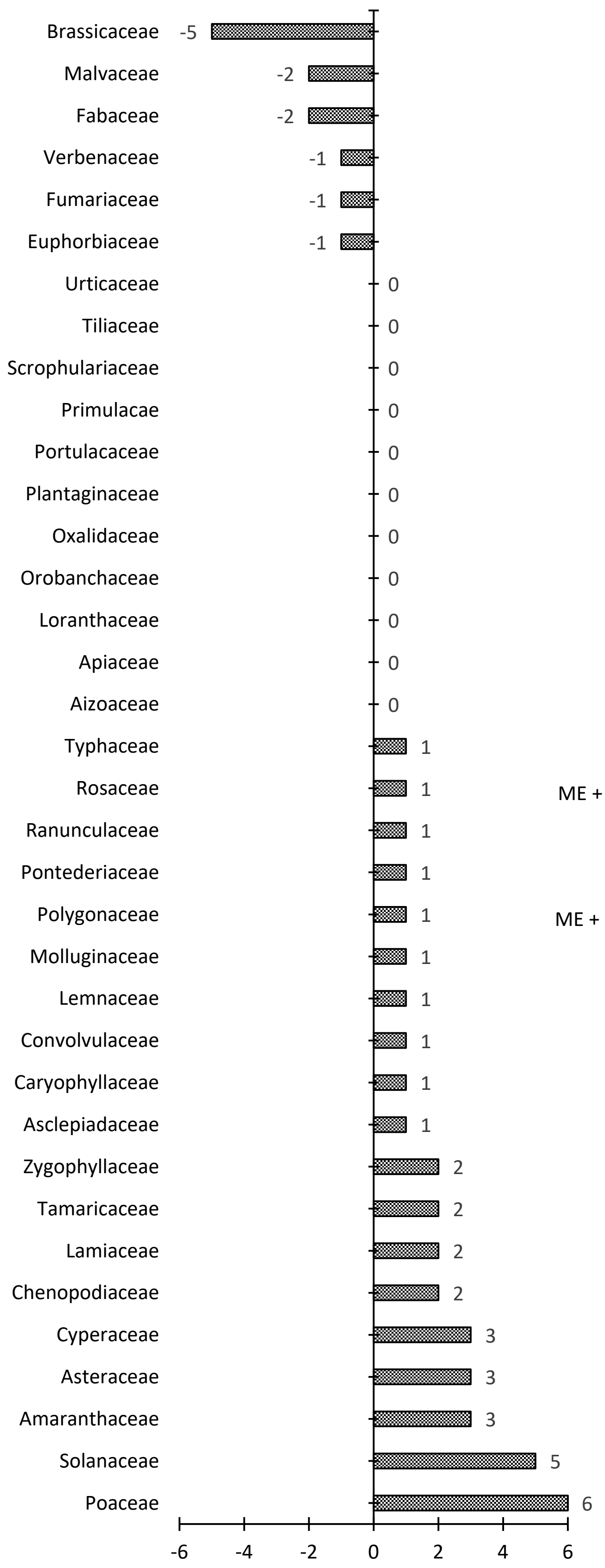

Fig. 7. Changes in the number of species belonging to different families during the period 1984- 2018

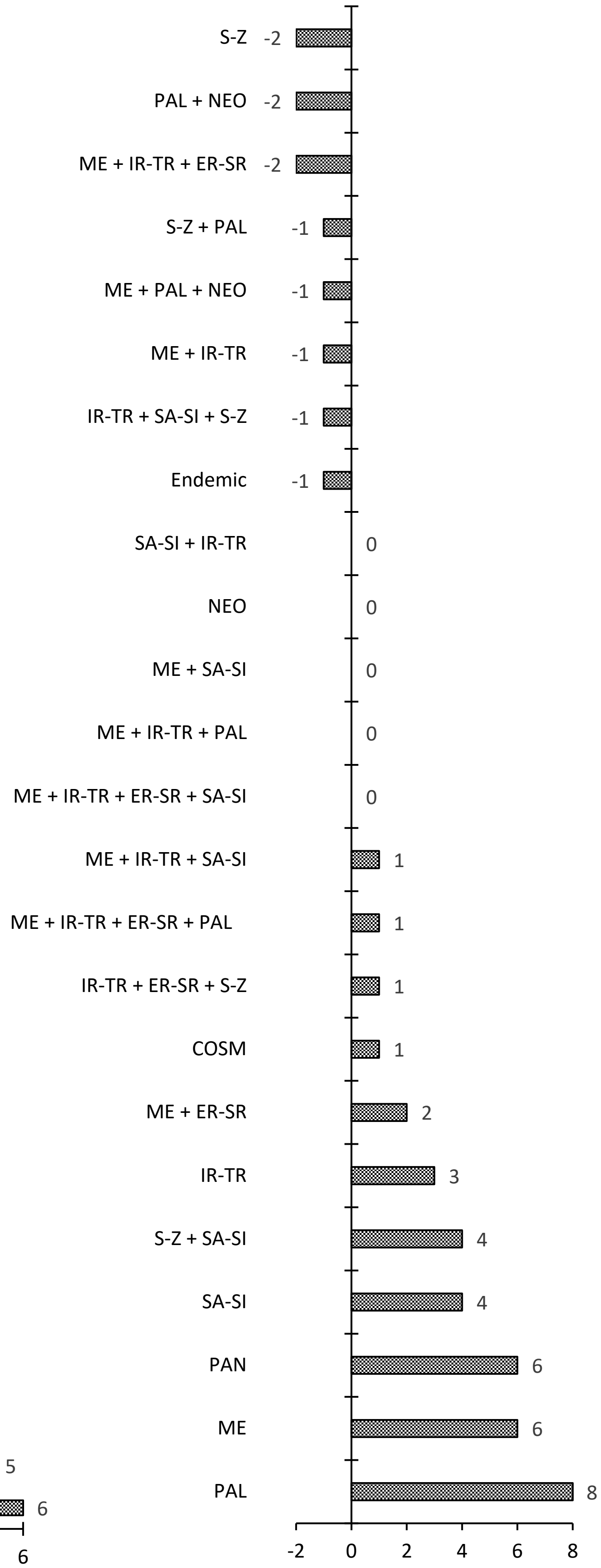

Fig. 8. Changes in the number of species belonging to different floristic categories during the period 1984- 2018

A total of 27 families were recorded in 1984 while 36 families were recorded in 2018. Nine families have been recorded only in this study (Tamaricaceae, Zygophyllaceae, Asclepiadaceae, Lemnaceae, Molluginaceae, Pontederiaceae, Ranunculaceae, Rosaceae, and Typhaceae). Poaceae, Asteraceae, Fabaceae and Brassicaceae were the most common families in both studies. However, number of species belonged to different families has changed where Brassicacea, Fabaceae and Malvaceae showed significant decrease while Poaceae, Solanaceae, Astraceae, Amaranthaceae and Cyperaceae showed a significant increase (Fig. 7 and Table 2).

Number of perennial species increased from 16 (1984) to 44 (2018) while number of annuals and biennials remained constant (Fig. 5). Hemicryptophytes have significantly increased from 7 in 1984 to 21 species in 2018 with 200 % increase, while chamaephytes have doubled the number of species recorded in 1984 (Fig. 6).

Phytogeographical affinities showed various changes among different categories. Generally, Pantropical, Paleotropical, Saharo-Sindian and Mediterranean elements have increased significantly. On the level of monoregional elements, species belonging to Sudano-Zambesian region were recorded in El-Shayeb study only while Irano-Turanean elements were only recorded in the present study. On the level of the biregional and plurriregional elements, no major changes have been detected except for the Saharo – Sindian elements that increased from 8 to 13 species (Fig. 8).

Discussion

The present study aimed at evaluating the weed flora changes in El-Menoufia Governorate, south of the Nile Delta of Egypt in response to different agricultural practices during the period from 1984 to 2018. El-Shayeb (1984) studied the weed flora of El-Menoufia Governorate after 15 years of the establishment of the HDA where new agricultural practices have been adopted while some of the old practices were still in action. After five decades of establishing the HDA and after three decades of El-Shayeb's study, the present study seemed to be a logical point in time to evaluate changes that took place in the agro-ecosystems of Egypt especially in the most fertile part of the country.

Results showed that significant changes took place in the weed flora during this period on the level of family composition, number of species, life forms, life spans, and chorology. Several reasons may explain these alterations:

1- Total cultivated area in 1984 was 320,000 feddan with 88% of El-Menoufia Governorate (1512 km^2) while today the total cultivated area has increased to 391,037 feddan with around 65 % of El-Menoufia Governorate (2543 km^2) after the inclusion of El-Sadat center in 1992 with a total area of around 1000 km^2. The xero-halophyte species, *Reaumuria hirtella*, was only recorded in the fields of El-Sadat, which is quite understandable as it is the desert back of El-Menoufia Governorate and the only place that may provide similar conditions to *Reaumuria hirtella* natural habitat. On the other side, urban encroachment on the expense of arable lands has replaced one fifth of the old fertile lands of El-Menoufia Governorate (Abd El-Fatah, 2013) which may contribute to the disappearance of the 42 species recorded in 1984 only.

2- Major crops cultivated in El-Menoufia in 1984 were wheat, clover, potato, soybean, broad bean and flax in winter and rice, cotton, soybean and maize in summer. In 2018 major crops are wheat, clover, and potato in winter while maize and potato are the major crops in summer. Broad bean, soybean, flax, cotton, and rice are cultivated in very limited scattered areas. El-Shayeb (1984) recorded *Sinapis* sp. as a unique associate species to flax. *Sinapis* sp. was not recorded in the present study and flax cultivation has declined in El-Menoufia Governorate to less than 100 feddans in 2018 and in the whole country from 60 thousand feddans in 1980s to 7 thousand feddans in 2016 (El-Nagdy *et al.*, 2010 and CAPMAS, 2017). Cotton was reported as the cash crop of El-Menoufia Governorate in 1984 but governmental control of prices and problems related to production have forced farmers to replace cotton by crops like clover where they could get the best benefit of it. Accordingly the area of cotton cultivation has declined from 1.3 million feddans in 1985 to 241 thousand feddans in 2016 (Zaghloul, 2013 and CAPMAS, 2017). On the other hand, rice cultivation was banned in El-Menoufia Governorate in 2013 because of water scarcity. The ban was expanded in 2018 to restrict rice cultivation in the whole country from 1.4 million feddans in 2016 to 700 thousand feddans because of the potential water problems related to the establishment of the Ethiopian Renaissance Dam (CAPMAS, 2017).

3- Water scarcity have forced some farmers to use both drainage water and sub-surface water in the irrigation process. After liberalization of crops in 1990s, farmers choose to cultivate water intensive profitable crops like rice that led to the increase of water demands and forced farmers to use drainage water (Barnes, 2014).

4- After the blockage of Nile sediments, the use of chemical fertilizers has increased. According to FAO, the use of fertilizers in Egypt has increased from 750 ton/year in the 1990s to 2000 ton /year in the last ten years. Excessive use of chemical fertilizers has serious impacts on agroecosystems including reducing number of micro-fauna as well as increasing the concentrations of potassiun, phosphorus, calcium and magnesium in the top soils while reducing nitrate, calcium and magnesium in the sub-soils (Edmeades, 2003) and subsequently affecting the weed flora. Several studies have reported the bad effects on soil, crops, animals and human health (WQU, 2004; Taha *et. al.*, 2012 and El-Bady, 2014).

5- Excessive use of herbicides to control weeds has a major role in determining weed flora composition, diversity and abundance (Sher and Al-Yemeny, 2011). Andreasen *et al*., (1996) stated that the intensive use of herbicides resulted in massive shifts in the weed flora of Europe. On the other side, the use of herbicides has developed herbicide-resistant weeds (Binimelis *et al*., 2009 and Heap 2010). Results showed significant increase in the number of hemicryptophytes and Poaceae members which may refer to the environmental deterioration in the Egyptian agroecosystems (Londe and Silva, 2014). Hemicryptophytes are considered the most resistant life form (Liddle and Greig-Smith, 1975; Hall and Kuss, 1989 and Cole, 1995) while Poaceae is a well-known family for its tolerance against drought, salinity, freeze and different abiotic stresses (Céccoli *et. al.*, 2015; Fabbri *et. al.*, 2016 and Landi *et. al.*, 2017).

6- The establishment of the HDA has affected the flow of seeds from Africa towards Egypt. Results showed the absence of Sudano-Zambesian elements recorded by El-Shayeb in 1984. Fahmy (1997) stated that the establishment of dams along the Nile River has affected the distribution of weeds like *Ceruana pratensis* and *Potentilla supine* that disappeared from the silty banks of the river. On the other side, results showed the increase of the Mediterranean and Irano-Turanean elements. Willcox (2012) reported the increase of weed migration among Europe, Middle East and Mediterranean region in the last decades because of the increase of transcontinental commerce and migration.

7- Other reasons may include the methodology and prospective of each study. El-Shayeb (1984) has investigated 40 stands with five stands for each center of El-Menoufia on a monthly basis for a whole year in order to investigate the reproductive capacity of El-Menoufia Governorate weed flora. In our study, 240 stands were investigated during spring and summer seasons with 120 stands for each season distributed along the nine centers of El-Menoufia Governorate in order to document the present situation of the weed flora. This may explain part of the large number of the newly recorded species (67) but does not explain the absence of 42 species, which may be due to the previously mentioned reasons.

Hassib (1951) recorded 395 species in Nile Delta while Shaltout *et al.* (2010) recorded 534 species. The present study added 18 new species to the flora of the Nile Delta (*Amaranthus caudatus, Amaranthus tricolor, Petroselinum crispum*, *Anthemis retusa*, *Launaea mucronata*, *Pulicaria undulata*, *Scolymus maculatus*, *Camelina rumelica*, *Atriplex lindleyi*, *Scorpiurus muricatus*, *Mentha pulegium*, *Polygonum maritimum*, *Rosa sp.*, *Veronica persica*, *Solanum villosum*, *Withania obtusifolia*, *Reaumuria hirtella* and *Tribulus pentandrus*) and 67 species to El-Menoufia. On the other side, one third of the weed flora recorded by El-Shayeb in 1984 was not recorded in the present study in spite of the large number of investigated stands (Table 2). Different agricultural practices discussed above may have led to these results. Several studies have reported similar results from different areas around the world (Andreasen *et al.*, 1996; Heap, 2010; Richner *et al.*, 2015 and Ramôa *et al*., 2017).

Conclusion and Recommendations

Dramatic changes in the weed flora of El-Menoufia Governorate during the last thirty-four years necessitate the sustainable management of the arable lands of Egypt. Several problems are facing agriculture and without controlling such problems, serious impacts on the weed flora are to be expected. Saving this rich arable flora is not a luxury and should be a priority as a part of our role in conserving biodiversity and within the frame of the Egyptian Government commitment to Rio de Janeiro Convention on Biological Diversity (CBD) and the UN 2030 Agenda for sustainable development.

It is very important to note that in spite of the fact that the heavy use of herbicides and other chemicals since 1984 may have eliminated number of sensitive weed species but the total number of weeds in the study area has increased. The current agricultural practices are neither helping farmers protecting their crops from weeds nor helping the survival of the weed flora. It became clear that the more destructive methods farmers use against weeds, the more weed resistance they get back. Several countries have developed various balanced strategies that took into consideration farmers' interests and conservation of biodiversity at the same time. Examples include compensation of farmers, prohibiting chemical spraying of field margins to give some space for the weed flora of the arable lands and strictly managing the use of different pesticides to avoid weed resistance development and all related environmental problems (Kleijn and Sutherland, 2003, Kleijn *et al.*, 2011 and Richner *et al.*, 2015).

A new chapter in the history of agriculture in Egypt is about to begin after the establishment of Ethiopian Renaissance Dam which threaten Egypt's share of Nile water (Zenawi, 2011a & b). Egyptian Government is already taking steps forward to minimize water waste and consumption in agriculture but it is crucial to have a sustainable strategy to manage the entire agro-ecosystem biotic and abiotic components.

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