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Distribution of the Naturalized Species *Dalbergia sissoo* Roxb. ex DC. in Nile Delta, Egypt

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Seventy six stands were sampled to represent the variation among *Dalbergia sissoo* populations in Nile Delta. These stands represent the distribution of the naturalized populations of *Dalbergia sissoo* in five urban habitats (canal edges, road sides, road dividers, field edges and drain banks) recognized in the study area. Fourteen vegetation groups were recognized after the application of TWINSPAN. *Phragmites australis* (P= 52.6 %) was the main associated species in nine groups, while each of *Imperata cylindrica* (P = 38.2 %) and *Pluchea dioscoridis* (P = 35.5%) in two groups. The significant edaphic variables which affected the distribution of *Dalbergia sissoo* were: iron, manganese, magnesium and potassium. These results suggest that urban vegetation in Nile Delta region is favored where disturbance, nutrient and water resources are more abundant.

***Key words*:** Disturbance, Multivariate analysis, Nile Delta, Species richness, *Dalbergia sissoo*.

Introduction

Human impact has been recognized as the most important influence on the composition of the flora and vegetation during the last 5000 years. This impact has been a dominant environmental factor in the arid environments of the world, particularly in the Middle East for thousands of years (Zohary, 1983). The world's landscapes are now occupied by human altered (and in part by human-created) floras. Natural disturbances could be at the scale of

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catastrophes (e.g., storms or floods) or in similar and long-term scale (e.g., drought and pathogenic agents). Anthropogenic disturbances (created by human activities) include ploughing, moving, burning, grazing and treading by livestock. The construction and use of tracks, roads, canals, railways and airports have involved many changes, some of them are direct and others are indirect. A few alien species have taken advantage of these networks but no serious attempts have been made to study their effect on native plant communities (Lousley, 1970).

Biological invasions, boosted by human activities and movements across the planet, represent one of the main threats to the world's biodiversity (Mooney and Cleland 2001, Sakai *et al.*, 2001, Lee, 2002). In addition, invasions do not always result in a reduction of biodiversity: at a regional scale the number of naturalizations sometimes balances or even exceeds the number of extinctions (Sax *et al.*, 2002). Most invasive exotic trees had been introduced deliberately for dune fixation (e.g. *Acacia saligna* in Egypt), as ornamentals (*Quercus robura* in South Africa, *Acer negundo* in Europe), for timber plantations (*Pinus radiata* and *Pinus pinaster* in the southern hemisphere, *Eucalyptus* spp. in regions with a Mediterranean climate) or for a combination of these (*Quercus rubra*, first planted in parks and then used for wood production in Europe). Reichard and Hamilton (1997) estimated that 85% of invasive woody plants from the US had been introduced for various landscape and ornamental purposes and another 14% for agricultural purposes including forestry.

Dalbergia sissoo was introduced to Egypt by Ibrahim Pasha in the age of Mohamed Ali (1805-1848) for ornamental and timber purposes (Othman, 1939). The area of natural distribution of this plant is the foothills of the Himalayas from eastern Afghanistan through Pakistan and India to Nepal (Appanah *et al.*, 2000). El-Sheikh (1989 and 1996) recorded *Dalbergia sissoo* along the terraces of highway roads and canals in Nile Delta, but not along the drain banks. Slima (2006) recorded it along the canal terraces and slopes in Nile Delta. This plant reproduces by seeds and root suckers (Neelu *et al.*, 2002, James, 2002). The strategy of reproduction by seeds and root suckers and the rapid growth rate lead to increase the plant dissemination into new regions. Now, this tree spreads naturally in other terrestrial habitats in Nile Delta such as roadsides, railways and wastelands (Fahmy, 2007).

Humans have influenced the natural flora and vegetation of Egypt from prehistoric times, chiefly in a destructive manner. By draining marshes and lakes, the marsh and aquatic communities have been reduced. New habitats have been provided by agriculture and by the more or less permanent occupation of sites for urbanization. Therefore, Nile Delta region supports many types of habitats; some of which are natural and the others are human made (Shaltout and Sharaf El-Din, 1988). The present study aims to determine the distribution of *Dalbergia sissoo* in different habitats in Nile Delta and to assess the environmental factors that affect its distribution.

Study area

Nile Delta region has a classic triangular shape, broader at its northern base than along the sides (Fig. 1). It has an area of approximately 22,000 km^2, which represents about 60% of Egypt's productive area (Abu Al-Izz, 1971). Soils of Nile Delta are mostly heavy in texture and rather compact at the surface. All of these soils, with exception of the northernmost part, are man made and are regarded as entropic variants of the Gleysols and Fluvisols (El-Gabaly *et al.* 1969). Nile Delta contains one of the biggest semi-confined groundwater reservoirs in Egypt. This region, which occupies a great tectonic depression, is bounded on the eastern and western sides by the sandy and gravelly plains at about 100 m above sea level which are bordered with upland area of more than 200 m above sea level. The eastern elevated area is dissected by numerous wadies, which drain their water during the winter rainy season into Nile Delta basin. To the south; Nile Delta is bounded by a large rift as natural recharging area. The irrigation system including the discharging and recharging of the aquifer affects, to a great extent, the water occurrences in Delta reservoir (Shaltout *et al.*, 2010).

Climatologically, December and January are the coldest and wettest months, while July and August are the hottest and driest. Mean annual temperature increases from 23°C in the north at Damietta to 25°C in the south at Cairo. The relative humidity decreases from 71% in the north to 55% in the south. Evaporation increases from 4 mm/day in the north to 11 mm day^{-1} in the south, with minimum values in December and maximum in June. About 75% of the total amount of rain falls from November to February with December and January as the rainiest months. The gradient in the annual rainfall is obvious comparing the north of the study area (159.6 mm $year^{-1}$) with its south (24 mm $year^{-1}$); this is associated with an inverse evaporation gradient, which indicates the increase of aridity from north of the study area to its south (Shaltout and EL-Sheikh, 2002)

Materials and methods

Sampling methods

Seventy six stands were sampled to represent the variation among *Dalbergia sissoo* populations in Nile Delta. These stands represent the distribution of *Dalbergia sissoo* in five urban habitats (canal edges, road sides, road dividers, field edges and drain banks) (Fig. 1). The area of each stand ranged from 6 to 500 m^2 according to the extension of the plant cover and/or the type of the selected habitats. In each stand, the present species were listed indicating the first and second dominant species. Nomenclature was according to and the Latin names were updated Boulos (1999, 2000, 2002, 2005 and 2009).

Soil analysis

Three soil samples were collected as profiles (0–50 cm) from each of the sampled stands. Soil texture analysis was carried out by the Bouyoucos hydrometer method. Organic carbon and total organic matter was determined by loss-on-ignition at 450°C. Determination of calcium carbonate was carried out using Bernard's calcimeter. Soil water extracts of 1:5 were prepared for the determination of soil salinity (EC) and soil reaction (pH) using electric conductivity (mS cm^{-1}) and pH meters. Chlorides were determined by direct titration against 1/35.5 N Silver Nitrate solution and 5% Potassium Chromate as indicator (Jackson, 1960). Soil extracts of 5 gm air-dried soil samples were prepared using 2.5% v/v glacial acetic acid for estimating P, K, Ca, Na Mg and Fe. Nitrogen was determined by Micro- Kjeldahl apparatus. Flame photometer was used to determine K, Ca and Na concentration. Molybdenum blue and Indo-phenol blue methods were applied for the determination of P and N contents using a spectrophotometer. Magnesium and Fe concentrations were determined using atomic absorption (Allen *et al.*, 1974).

Data analysis

Two-way indicator species analysis (TWINSPAN) and detrended correspondence analysis (DECORANA) were applied to the matrix of the presence abscence of 61 species in 76 stands (Hill 1979a and b). In DCA the environmental variables are correlated with the axes after the ordination procedure. The direct ordination was performed using CANOCO program for windows version (4.5). CANOCO is a constrained ordination technique, where results are simultaneously trained based on species abundance and environmental variables (Kent and Coker, 1992). Species richness (α–

diversity) for vegetation groups was calculated as the average number of species per stand. Species turnover (β-diversity) was calculated as the ratio between the total number of species recorded in a certain vegetation group and its species richness. The variation in the soil variables in relation to vegetation types was assessed using one-way analysis of variance (ANOVA). The probable environmental significance of the DCA ordination axes 1 and 2 were investigated by the simple linear correlation analysis. The simple linear correlation coefficient (r) was calculated for assessing the type of relationship between the spatial variations of the estimated soil variables with each other. All data were subjected to analysis of variance (ANOVA-1 and ANOVA-2) and means were separated ($P \leq 0.05$), where appropriate, by Duncan's new multiple range test (LSR). These techniques were according to SAS software for windows version (6.12) (SAS, 1985).

Results

The wild species associated with the distribution of *Dalbergia sissoo* populations in the 76 sampled stands were 61 species (Table 1) belong to 22 families and 54 genera (Fig. 2). They comprise 26 perennials (42.6 %) and 35 annuals (57.4 %). Gramineae has the highest contribution to the total associated species (16 species = 26.2 %), followed by Compositae (9 species = 14.8 %), Chenopodiaceae and Leguminosae (each comprises 4 species = 6.6 %); Cyperaceae and Amaranthaceae (each comprises 3 species = 4.9 %); Solanaceae, Polygonaceae and Convolvulaceae (each comprises 2 species = 3.3 %) (Fig. 3).

The species inhabiting the canal edges had the highest contribution to the total associated species (55 species = 94.8 %), followed by the field edges (19 species = 32.8 %), roadsides (13 species = 22.4 %), road dividers (11 species = 19 %) and drain banks (7 species = 2.1 %) (Fig. 4 and Table 2). *Phragmites australis* was recorded in 40 stands (52.6 %). Three species were recorded in 30-40 % (*Imperata cylindrica*, *Pluchea dioscoridis* and *Cynodon dactylon*), while nine species were recorded in 10-20 % (*Echinochloa stagnina*, *Rumex dentatus*, *Chenopodium murale*, *Polypogon monspeliensis*, *Ethulia conyzoides*, *Sonchus oleraceus*, *Convolvulus arvensis*, *Cyperus alopecuroides* and *Malva parviflora*). Canal edge has the highest values of total species and species richness (55 and 0.95 species $stand^{-1}$), while drain bank has the lowest (7 and 0.12 species $stand^{-1}$) (Table

2). On the other hand, road side has the highest species turnover 59.1, while field edge has the lowest 57.6 (Fig. 7).

The application of TWINSPAN classification technique on the floristic composition of the 76 naturalized stands led to classify them into 21 vegetation groups at level 6, 18 at level 5 and 14 at level 4 (Fig. 4). Segregation between the 14 groups along DCA axes 1 and 2 is indicated in Fig. 5. The species composition of the 14 vegetation groups identified at level 4 of TWINSPAN is indicated in Table 2, while their main characteristics are presented in Table 3. *Phragmites australis* (P = 52.6 %) is the main associated species in nine groups, each of *Pluchea dioscoridis* (P = 35.5%) and *Imperata cylindrica* (P = 38.2 %) in two groups, and *Salix tetrasperma* (P = 6.6 %) in only one group. It is clear that vegetation group 10 has the highest species richness (29 species = 50 % of the total number of species), followed by vegetation group 6 (24 species = 41.4 %).

The means of the soil characteristics of the 5 habitats supporting the 76 naturalized stands of *Dalbergia sissoo* populations in Nile Delta are indicated in Table 4. On the other hand, the means of the soil characteristics of the 14 vegetation groups (1 – 14) derived after the application of TWINSPAN on the same set of stands are indicated in Table 5. The CANOCO ordination plot indicates that iron, manganese, magnesium and potassium are the most important factors that affecting the distribution of *Dalbergia sissoo* (Fig. 6).

Discussion

A striking characteristic of invasions is that there is usually a lag between the time when a species is introduced and when its population growth explodes (Crooks and Soule, 1999). Time lags can sometimes be quite long; for example, *Pinus strobus* was not considered invasive in Central Europe until more than 250 years after it was introduced for forestry (Rejmanek, 1996). In Britain, *Lactuca virosa* and *Lactuca scariola* were considered rare from the 1960s; when they were introduced, to the mid of 1900s when their abundance increased as they spread into gravel pits (Crooks and Soule, 1999). The lag phase commonly lasts from 20 to 100 years (Wade, 1997). In case of *Dalbergia sissoo*, it was introduced to Egypt by Ibrahim Basha in the age of Mohamed Ali (1805-1848) for ornamental purposes (Othman, 1939), and its first record as a naturalized plant in Egypt may that of El-Sheikh (1989) along the terraces of highway roads and canals banks in Nile Delta, thus the time lag for this plant is about 160 years. The potential invasiveness of a species cannot be measured by its lack of a time lag, for example, of three non-native *Impatiens* introduced to Britain, *Impatiens glandulifera* had the longest time lag, but was the most invasive (Perrins *et al.*, 1993). On the other hands, *Impatiens parviflora* and *Impatiens capensis* increased faster initially, but did not spread as far (Booth *et al.*, 2003). The present study indicated that sissoo has spreaded rapidly along the canal banks of Nile Delta and some terrestrial habitats such as roadsides, road dividers, field edges and wastelands. The abundant moisture and lack of competition is the key to its successful regeneration; it is therefore found in river in environments where sunlight and moisture are plentiful (Hocking, 1993).

Dalbergia sissoo has been introduced in various countries throughout the world, but it has known to be invasive in Australia and Florida (PIER, 2006). Sissoo has a unique property in that it hardly regenerates under the old mother trees. It is pioneer in nature and often grows in clumps in new well-drained alluvial sites near river and stream beds (Napier and Robbins, 1989). It is increasingly planted as a street tree in southern Florida and is becoming invasive (Parrotta, 1989). Field observation in the present study revealed no growth for *Dalbergia sissoo* under the mother trees and this may be due to their large canopy that prevents other seedlings from growing under them. This result may be supported by the study of Nadkarni (1954) which indicated that the seedlings of sissoo are shade intolerant.

The 21 groups identified at the level 6 of TWINSPAN, in the present study, are considered to represent 14 vegetation groups at level 4, each of definite floristic and habitat characteristics. Nine of these groups are characterized by *Phragmites australis*. In Nile Delta, *Phragmites australis* association occupies a wide environmental gradient and could be classified into wet, mesic and arid sub-association based on the hydric adaptation: a- wet sub-association occupies the open water and water edge of the canals and drains. b- mesic sub-association occupies the water edge and banks of canals, drains and lakes, and c- arid sub-association occupies the terraces, depressions and slopes of the railways and highways, terraces and slopes of the canals, drains and abandoned fields (Shaltout *et al.*, 2010).

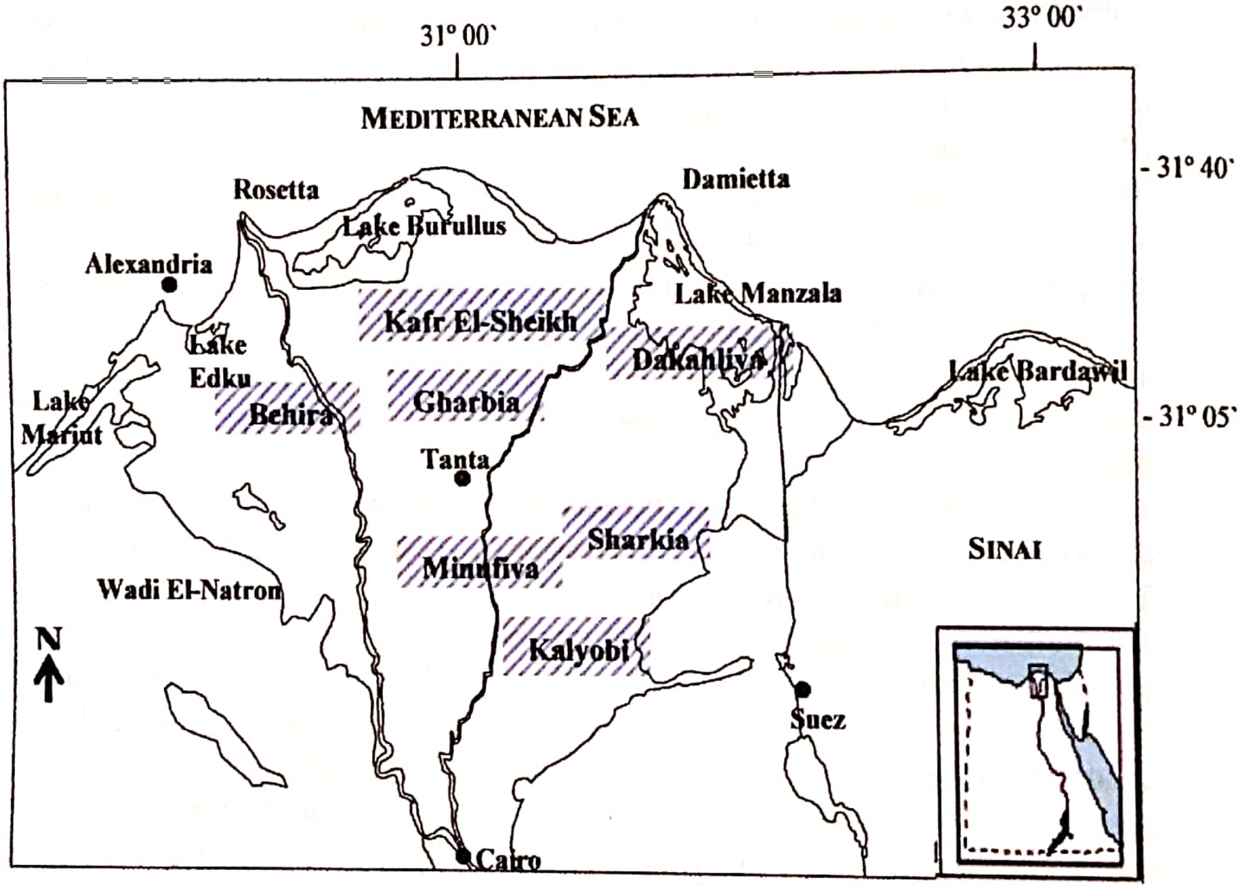

Fig. 1. Map of Nile Delta (Egypt) indicating the location of sampling sites of study area

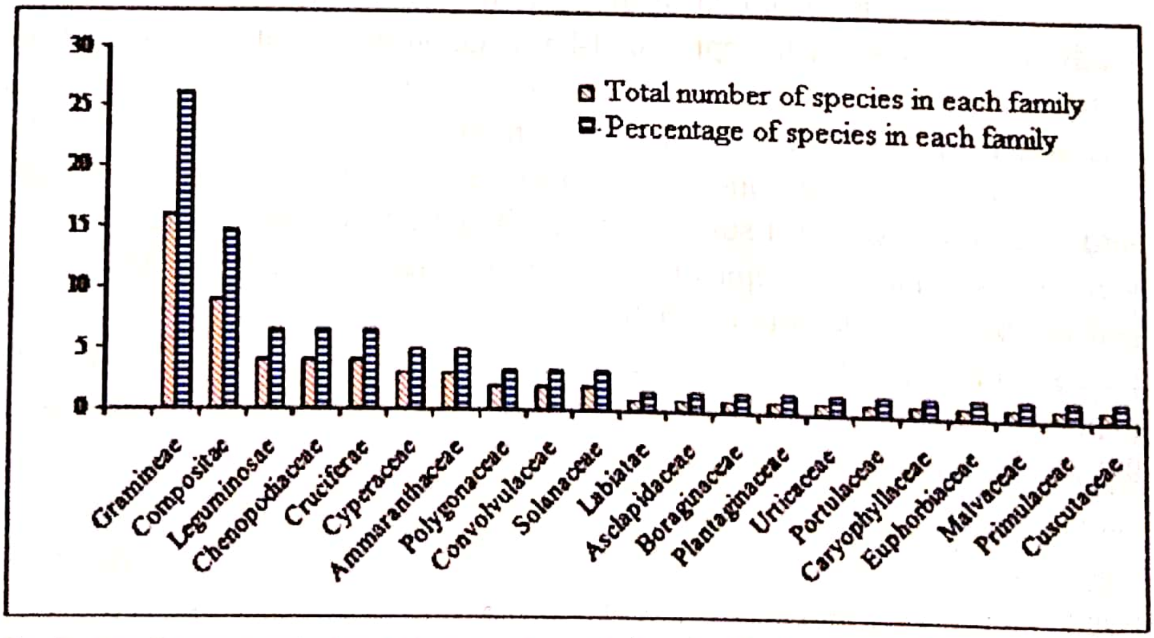

Fig. 2. Family representation of the species associated with the distribution of *Dalbergia sissoo* in Nile Delta.

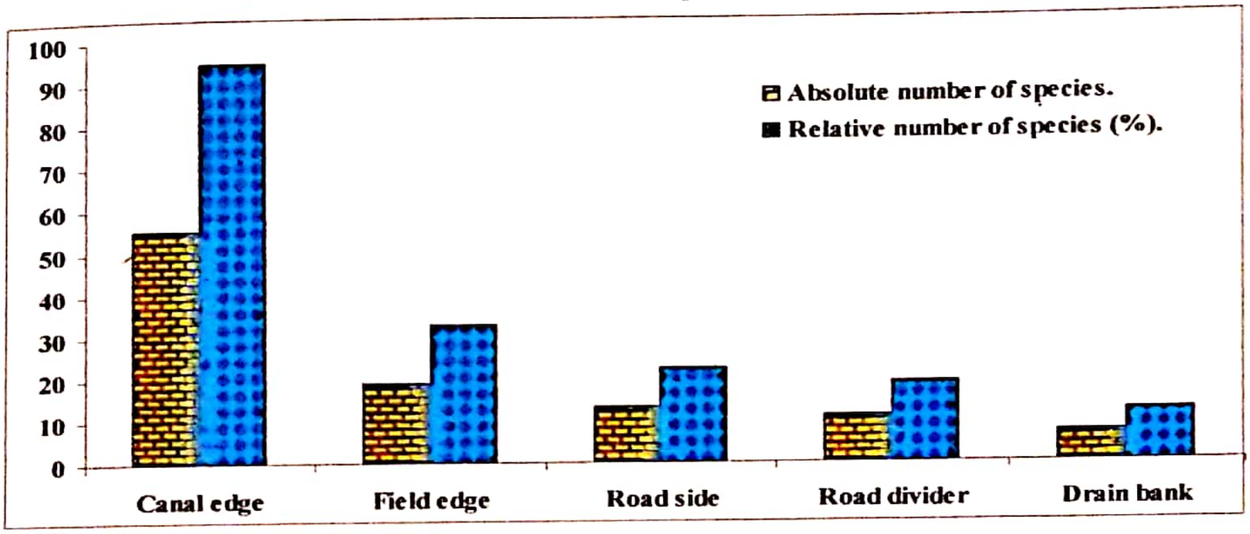

Fig. 3. Absolute and relative (%) number of species associated with the distribution of *Dalbergia sissoo* populations in five habitats in Nile Delta.

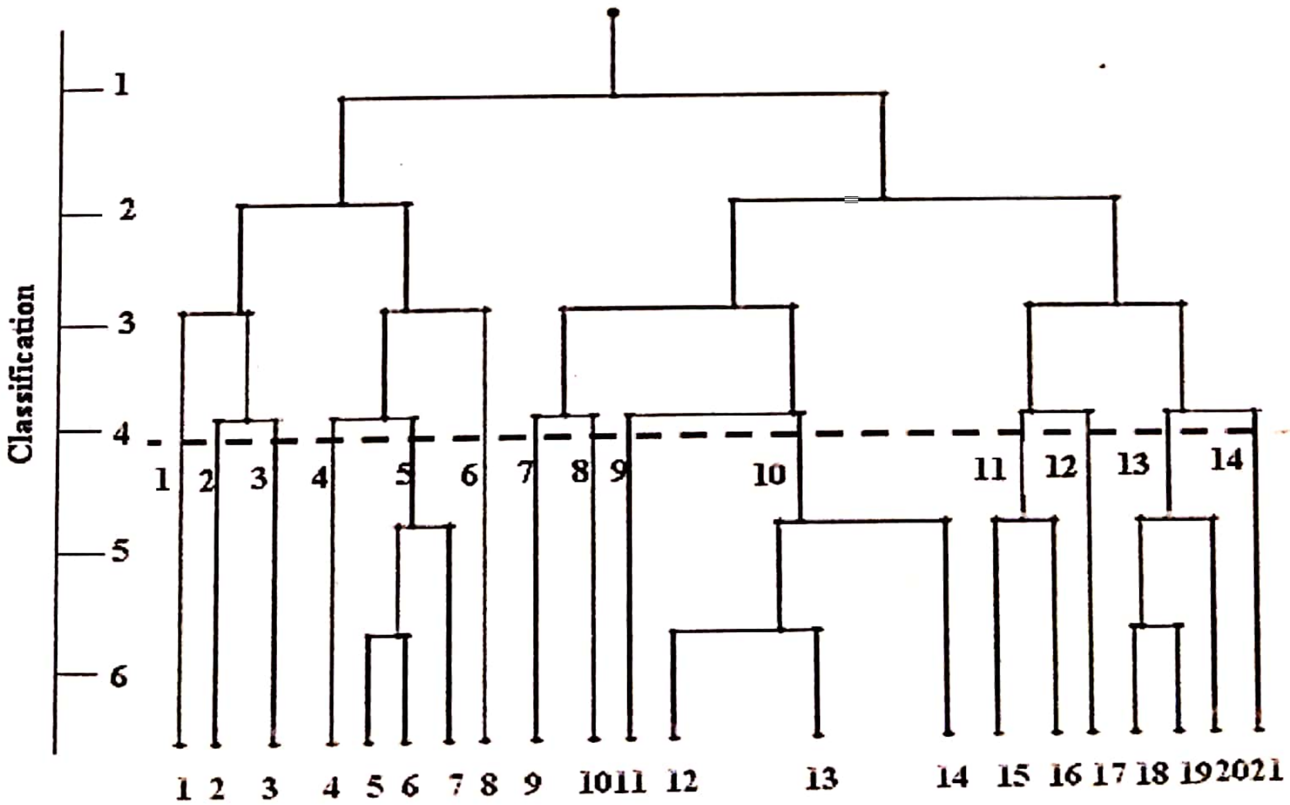

Fig. 4. Dendrogram resulting from the Two-Way Indicator Species Analysis (TWINSPAN) of the 76 naturalized stands of *Dalbergia sissoo* populations in Nile Delta, the 21 vegetation groups at level 6 and the 14 vegetation groups at level 4 are indicated.

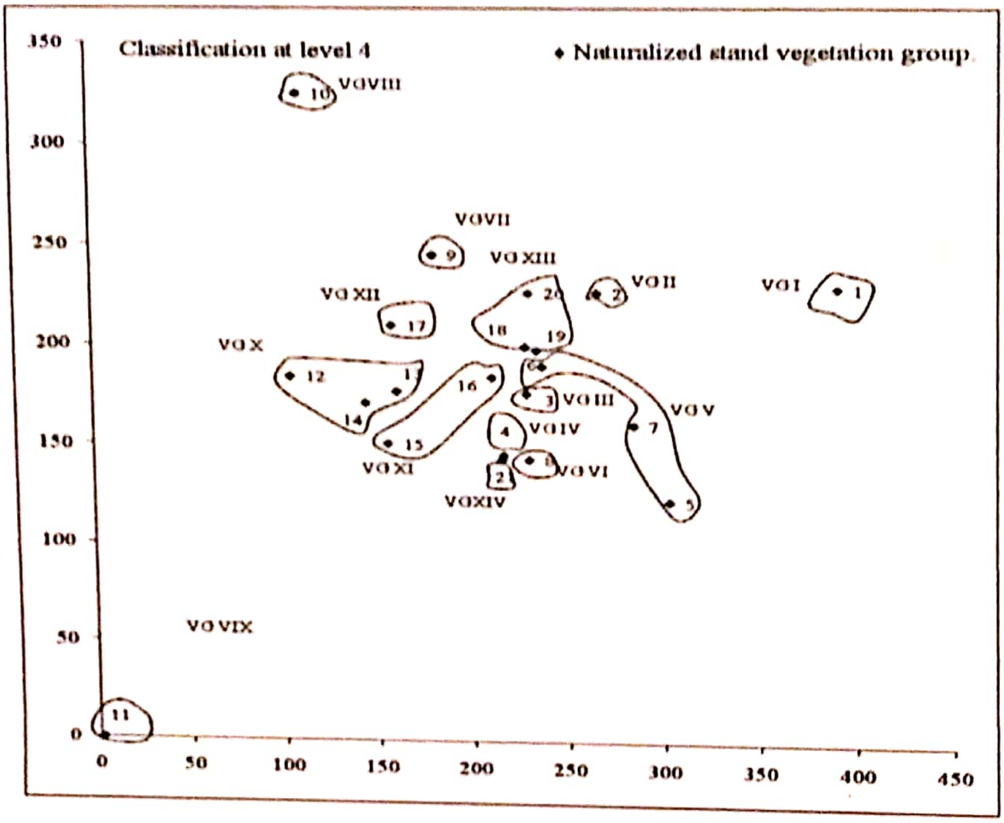

Fig. 5. Cluster centroids of the 14 vegetation groups (VG) of the 76 naturalized stands of *Dalbergia sissoo* in Nile Delta.

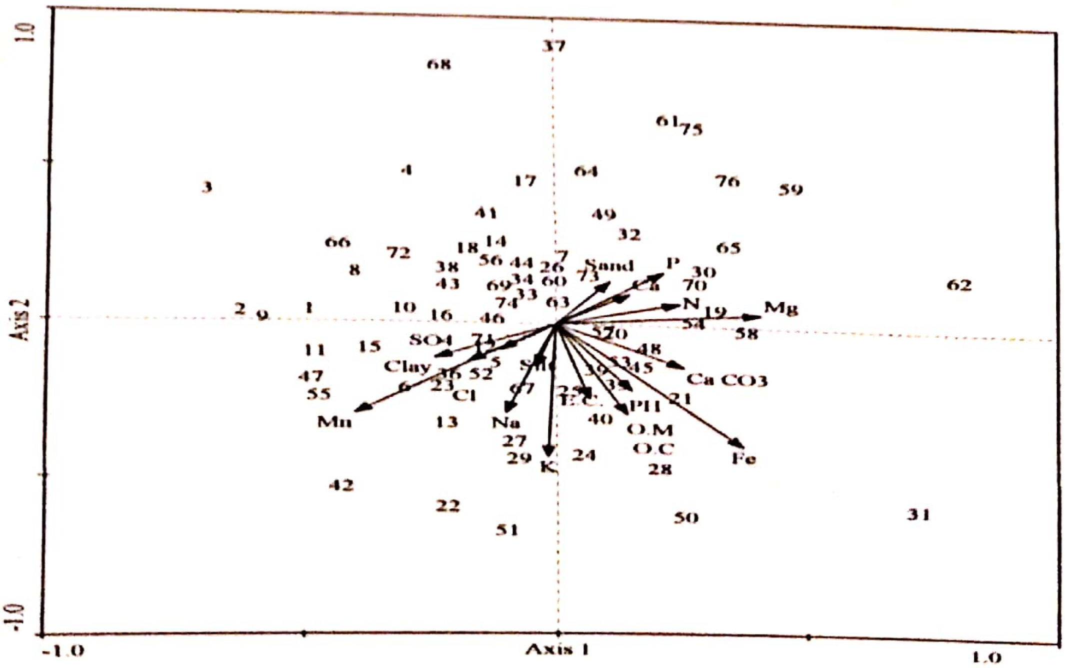

Fig. 6. CANOCO ordination plot for the edaphic variables (represented by lines). One to 76 indicate the position of 76 the sampled stands of *Dalbergia sissoo* on the ordination plane.

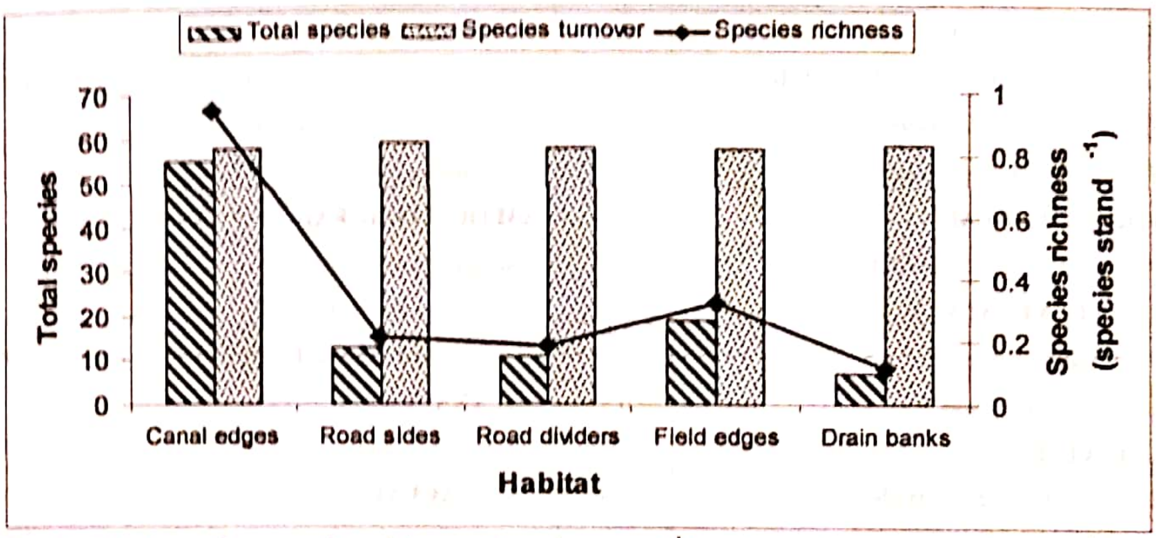

Fig. 7. Total species, species richness (species stand^{-1}) and species turnover for the species composition of *Dalbergia sissoo* populations in Nile Delta.

Table 1. Presence percentage of the wild species associated with *Dalbergia sissoo* populations in Nile Delta.

Species	P (%)	Species	P (%)
Perennials		*Poa annua* L.	3.8
GRAMINEAE		*Phalaris minor* Retz.	1.9
Phragmites australis (Cav.) Trin. ex Steud.	55.7	*Phalaris paradoxa* L.	0.9
Imperata cylindrica (L.) Raeusch.	28.3	*Sorghum bicolor* (L.) Moench	0.9
Cynodon dactylon (L.) Pers.	27.4	**COMPOSITAE**	
Echinochloa stagnina (Retz.) P. Beauv.	11.3	*Pseudognaphalium luteoalbum* (L.) Hilliard & B.L. Burtt	10.4
Arundo donax L.	1.9	*Sonchus oleraceus* L.	10.4
Bromus catharticus Vahl	1.9	*Ethulia conyzoides* L.	9.4
Oryzopsis miliacea (L.) Asch. & Schweinf.	0.9	*Cichorium endivia* L.	1.9
Paspalum distichum L.	0.9	*Conyza bonariensis* (L.) Cronquist	1.9
COMPOSITAE		*Aster squamatus* (Spreng.) Hieron.	0.9
Pluchea dioscoridis (L.) DC.	29.2	*Senecio aegyptius* L.	0.9
Silybum marianum (L.) Artn.	0.9	**CHENOPODIACEAE**	
CYPERACEAE		*Chenopodium murale* L.	11.3
Cyperus alopecuroides Rottb.	8.5	*Chenopodium album* L.	5.7
Cyperus rotundus L.	1.9	*Bassia indica* Wight.	5.7
Cyperus longus L.	0.9	*Bassia muricata* (L.) Asch. in Schweinf.	0.9

LEGUMINOSAE		**CRUCIFERAE**	
Alhagi graecorum Boiss.	1.9	*Sisymbrium irio* L.	5.7
Lagonychium farctum (Banks&Sol.)Bobr.	0.9	*Rorripa palustris* (L.)Besser	4.7
Sesbania sesban (L.) Merr.	1.9	*Diplotaxis acris* (Forssk.) Boiss.	0.9
Vigna luteola (Jacq.) Benth.	0.9	*Eruca sativa* Mill.	0.9
POLYGONACEAE		**AMARANTHACEAE**	
Persicaria salicifolia (Willd.) Assenov	4.7	*Amaranthus hybridus* L.	7.5
CONVOLVULACEAE		*Amaranthus viridis* L.	4.7
Convolvulus arvensis L.	9.4	*Alternanthera sessilis* (L.) DC.	0.9
Ipomoea carnea Jacq.	0.9	**SOLANACEAE**	
LABIATAE		*Solanum nigrum* L.	7.5
Mentha longifolia (L.) Huds.	1.9	**URTICACEAE**	
ASCLEPIADACEAE		*Urtica urens* L.	1.9
Cynanchum acutum L.	5.7	**POLYGONACEAE**	
BORAGINACEAE		*Rumex dentatus* L.	14.2
Heliotrobium curassavicum L.	0.9	**PORTULACACEAE**	
PLANTAGINACEAE		*Portulaca oleracea* L.	1.9
Plantago major L.	0.9	**CARYOPHYLLACEAE**	
SOLANACEAE		*Silene aegyptiaca* (L.) L.	2.8
Withania somnifera (L.)Dunal	2.8	**EUPHORBIACEAE**	
SALICACEAE		*Euphorbia helioscopia* L.	1.9
Salix tetrasperma Roxb.	6.6	**MALVACEAE**	
Annuals		*Malva parviflora* L.	9.4
GRAMINEAE		**PRIMULACEAE**	
Polypogon viridis (Gouan) Breistr.	28.3	*Anagallis arvensis* L.	2.8
Polypogon monspeliensis (L.) Desf.	17	**CUSCUTACEAE**	
Echinochloa colona (L.) Link	5.7	*Cuscuta planiflora* Ten.	1.9
Avena fatua L.	3.8		

Table 2. Species presence in the 14 vegetation groups of the 76 naturalized stands of *Dalbergia sissoo* populations in Nile Delta. Habitats are coded as follows: CE: canal edges, RS: roadsides, RD: road dividers, FE: field edges and DB: drain banks.

Classification level	**Vegetation group**														**Habitat**
Level 4	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	
T. No. of stands	**1**	**4**	**4**	**4**	**7**	**3**	**4**	**4**	**1**	**23**	**8**	**1**	**10**	**2**	
Dalbergia sissoo	+	+	+	+	+	+	+	+	+	+	+	+	+	+	**All habitats**
Phragmites australis			+	+		+		+		+	+	+	+	+	**CE, RS, DB**
Imperata cylindrica						+	+		+	+	+				**CE, RD, FE**
Pluchea dioscoridis		+	+	+	+	+				+	+				**CE, RS, FE**
Cynodon dactylon		+	+				+	+		+	+		+		**All habitats**
Echinochloa stagnina		+	+		+					+	+				**CE, FE, DB**
Rumex dentatus		+	+		+	+	+			+					**CE, FE, DB**
Chenopodium murale			+	+						+	+			+	**CE, RS, DB**
Polypogon monspeliensis				+	+	+									**CE, RS, FE**
Ethulia conyzoides						+		+		+					**CE**
Sonchus oleraceus		+	+		+	+				+			+		**CE, FE**
Convolvulus arvensis		+				+	+			+	+				**CE, RD, FE**
Cyperus alopecuroides			+		+	+				+			+		**CE, RS**
Malva parviflora		+					+			+	+	+			**CE, FE**
Pseudognaphalium luteoalbum		+		+		+		+				+			**CE, RS**
Amaranthus hybridus						+	+	+							**CE, RS, FE**
Cynanchum acutum				+		+							+		**CE, RS**
Bassia indica						+	+		+	+	+				**CE, RD**
Chenopodium album			+			+				+					**CE**
Persicaria salicifolia						+				+	+				**CE**
Polypogon viridis		+		+						+				+	**CE, RS**
Rorripa palustris		+	+	+						+					**CE**
Salix tetrasperma			+			+				+					**CE, FE**
Solanum nigrum	+				+	+					+		+		**CE, DB**
Amaranthus viridis				+					+		+				**CE, RD**
Echinochloa colona		+					+								**CE, RD, FE**
Sisymbrium irio						+					+	+	+		**CE**
Avena fatua		+				+				+					**CE, FE**
Alhagi graecorum		+								+					**CE**
Anagallis arvensis						+								+	**CE**
Bromus catharticus	+	+													**CE, FE**
Cichorium endivia					+		+								**CE**
Conyza bonariensis						+			+						**CE, RD**
Cyperus rotundus								+		+					**CE, RS**
Euphorbia helioscopia			+				+								**CE, FE**
Mentha longifolia										+		+			**CE**
Phalaris minor							+							+	**CE, RD**
Poa annua					+					+				+	**CE, FE**
Portulaca oleracea							+				+				**CE, FE**

Sesbania sesban		+								+					CE
Silene aegyptiaca		+										+			CE
Urtica urens							+				+				CE, [illegible]
Withania somnifera					+								+		CE
Alternanthera sessilis		+													CE
Arundo donax															CE
Bassia muricata									+						RD
Cuscuta planiflora								+							RS
Cyperus longus										+					CE
Diplotaxis acris									+						RD
Heliotropium curassavicum										+					CE
Ipomoea carnea													+		CE
Lagonychium farctum	+														CE
Paspalum distichum										+					CE
Plantago major		+													CE
Senecio aegyptius						+									CE
Silybum marianum				+											CE
Sorghum bicolor						+									CE
Vigna luteola										+					CE

Table 3. Characteristics of the 14 vegetation groups at level 4 identified after the application of TWINSPAN on the 76 naturalized stands of *Dalbergia sissoo* in Nile Delta.

VG	No. of stands	P % stands	No. of Species	P % species	Dominant species	P %
1	1	1.3	4	6.9	*Salix tetrasperma*	6.6
2	4	5.3	19	32.8	*Pluchea dioscoridis*	35.5
3	4	5.3	13	22.4	*Phragmites australis*	52.6
4	4	5.3	11	19	*Phragmites australis*	53.6
5	7	9.2	11	19	*Pluchea dioscoridis*	35.5
6	3	3.9	24	41.4	*Phragmites australis*	53.6
7	4	5.3	14	24.1	*Imperata cylindrica*	38.2
8	4	5.3	8	13.8	*Phragmites australis*	53.6
9	1	1.3	7	12.1	*Imperata cylindrica*	38.2
10	23	30.3	29	50	*Phragmites australis*	53.6
11	8	10.5	16	27.6	*Phragmites australis*	54.6
12	1	1.3	7	12.1	*Phragmites australis*	55.6
13	10	13.2	10	17.2	*Phragmites australis*	56.6
14	2	2.6	7	12.1	*Phragmites australis*	57.6

Table 4. Mean of the soil characteristics of the 5 habitats supporting the 76 naturalized stands of *Dalbergia sissoo* populations in Nile Delta. O.C.: organic carbon, O.M.: organic matter.

Character		CE (64)	RS (4)	RD (3)	FE (4)	DB (1)	Total (76)	F	P
pH		7.0^{B}	7.0^{B}	6.7^{B}	7.4^{A}	7.3^{A}	7.03	4.71	0.001
EC mS cm^{-1}		2.1^{A}	2.5^{BA}	1.8^{A}	1.6^{A}	2.3^{C}	2.12	0.79	0.535
Cl	%	0.1^{A}	0.2^{A}	0.1^{A}	0.1^{A}	0.1^{A}	0.15	0.85	0.492
SO_4^{-2}	%	0.3^{BA}	0.4^{A}	0.3^{BA}	0.1^{B}	0.3^{BA}	0.3	3.14	0.015
O.C.	%	6.1^{A}	5.5^{BA}	4.7^{BA}	4.0^{B}	4.5^{BA}	5.84	4.98	< 0.001
O.M.	%	10.5^{A}	9.4^{BA}	8.0^{BA}	6.9^{B}	7.7^{BA}	10.08	4.98	< 0.001
Ca CO_3	%	1.6^{BC}	1.1^{C}	2.4^{A}	1.3^{BC}	2.0^{BA}	1.58	3.41	0.01
Silt	%	45.4^{A}	43.8^{B}	43.9^{B}	43.0^{B}	43.9^{B}	45.11	10.3	< 0.001
Clay	%	42.9^{A}	41.6^{B}	41.1^{B}	41.3^{B}	41.0^{B}	42.04	13.93	< 0.001
Sand	%	12.4^{B}	14.8^{A}	15.0^{A}	15.7^{A}	15.1^{A}	12.85	12.18	< 0.001
Fe	mg 100 g^{-1}	0.8^{A}	0.5^{A}	0.5^{A}	0.5^{A}	0.2^{A}	0.71	1.18	0.321
Mn	mg 100 g^{-1}	26.1^{A}	23.9^{A}	17.8^{A}	14.9^{A}	20.4^{A}	25.03	2.93	0.021
Mg	mg 100 g^{-1}	127.0^{A}	120.1^{A}	121.9^{A}	128.8^{A}	107.3^{A}	126.27	0.11	0.978
K	mg 100 g^{-1}	134.9^{A}	160.0^{A}	89.6^{A}	156.6^{A}	75.3^{A}	134.81	0.89	0.472
Na	mg 100 g^{-1}	24.9^{A}	15.9^{BA}	12.1^{B}	21.2^{BA}	25.3^{A}	23.69	4.96	< 0.001
Ca	mg 100 g^{-1}	2247.4^{B}	1609.5^{B}	5607.93^{A}	2670.6^{B}	3044.1^{B}	2379.2	5.82	< 0.001
Total nitrogen	mg 100 g^{-1}	4.9^{A}	0.6^{C}	1.5^{BC}	5.9^{A}	3.7^{BA}	4.59	8.49	< 0.001
PO_4^{-3}	mg 100 g^{-1}	1.6^{BA}	1.4^{B}	2.4^{A}	1.7^{BA}	1.1^{B}	1.65	1.79	0.13

The values between brackets are the number of stands in each habitat. Maximum and minimum values are underlined. F values and their probabilities (P) are indicated. Means with the same letter are not significantly different according to Duncan's multiple range test (LSR). The habitats are CE: canal edges, RS: road sides, RD: road dividers, FE: field edges, DB: drain banks.

Table 5. Mean of the soil characteristics of the 14 vegetation groups (1-14) derived after the application of TWINSPAN on the 76 naturalized stands of *Dalbergia sissoo* in Nile Delta. O.C.: organic carbon, O.M.: organic matter.

Character		Vegetation Group 1(1)	2(4)	3(4)	4(4)	5(7)	6(3)	7(4)	8(4)	9(1)	10(23)	11(8)	12(1)	13(10)	14(2)	T(76)	F	P
pH		6.9	7.0	7.3	7.3	7.3	7.1	7.0	6.8	6.7	7.0	6.9	7.1	6.9	7.0	7.0	3.9	< 0.001
EC mS cm		1.0	3.0	2.6	1.6	2.3	1.6	1.4	2.7	2.3	1.7	1.9	4.1	2.8	2.5	2.3	3.8	< 0.001
Cl		0.0	0.1	0.2	0.1	0.2	0.1	0.1	0.2	0.1	0.1	0.1	0.4	0.3	0.2	0.2	3.0	< 0.001
SO		0.1	0.5	0.4	0.2	0.3	0.2	0.2	0.3	0.5	0.3	0.3	0.4	0.4	0.2	0.3	3.2	< 0.001
O.C.		4.2	5.3	5.1	4.7	5.3	6.6	5.3	6.5	2.6	5.8	5.7	7.6	7.2	7.6	5.7	4.1	< 0.001
O.M.	%	7.2	9.1	8.8	8.1	9.1	11.4	9.2	11.3	4.5	9.9	9.8	13.0	12.4	13.0	9.8	4.1	< 0.001
CaCO		0.9	2.9	1.7	1.0	1.4	1.4	2.2	1.3	1.8	1.6	1.3	2.2	1.6	1.1	1.6	4.3	< 0.001
Silt		44.8	44.3	44.1	45.2	43.4	47.0	45.1	45.4	41.9	45.3	46.1	45.0	45.4	46.2	44.9	6.1	< 0.001
Clay		41.9	41.4	41.3	42.0	41.7	42.5	41.7	42.0	40.7	42.3	42.5	41.7	42.0	42.3	41.90	6.8	< 0.001
Sand		13.3	14.2	14.6	12.7	15.0	10.5	13.2	12.6	17.4	12.4	11.4	13.2	12.7	11.5	13.2	6.4	< 0.001
Fe		0.6	0.5	0.2	1.1	1.0	2.7	0.3	0.8	0.7	0.6	0.8	1.1	0.5	0.0	0.8	9.2	< 0.001
Mn		36.8	13.7	24.9	14.6	23.5	26.3	19.7	23.6	9.3	29.0	24.9	35.5	27.1	26.6	24.0	2.9	< 0.001
Mg		34.8	15.7	124.8	89.3	103.2	297.2	139.6	154.4	131.6	108.0	118.6	189.7	136.5	84.8	134.0	11.4	< 0.001
K	mg 100 g	60.6	158.0	114.8	136.1	167.7	62.3	91.6	107.3	52.8	128.0	97.6	500.3	170.4	205.5	147.0	5.3	< 0.001
Na		8.1	24.9	26.0	19.2	25.2	23.2	16.0	24.8	10.3	22.5	24.6	42.8	28.5	25.5	23.0	3.0	< 0.001
Ca		363.3	4589.6	1951.4	1531.0	1398.9	2735.3	4081.3	2300.1	5144.1	1824.1	3532.9	3739.1	2357.9	584.3	2588.0	4.6	< 0.001
Total nitrogen		3.4	5.9	2.5	3.0	6.7	5.1	3.4	2.4	0.2	4.7	3.3	4.4	5.9	8.3	4.2	4.4	< 0.001
PO		0.9	2.2	1.3	1.3	1.7	1.0	2.4	1.3	1.6	1.8	1.1	3.0	1.9	1.7	1.7	3.7	< 0.001

The values between brackets are the number of stands in each vegetation group. Maximum and minimum values are underlined. F values and their probabilities (P) are indicated.

Dalbergia sissoo, as a naturalized tree, was recorded in 76 stands that reflect their distributions in seven Governorates (Kafr El-Sheihk, Minufiya, Kalubia, Gharbia, Sharkia, Dakahliya and Behira) and five habitats (canal edges, road sides, road dividers, field edges and drain banks) in Nile Delta. Canal edge habitat was represented by 64 stands (84.2 % of the total stands); this indicates that this plant prefers to grow along river banks. Drain bank habitat was represented by only one sissoo stand, which may indicate that sissoo is a low salt tolerant species (Black and Meerow, 1993). The identified 14 vegetation groups in the present study are inhabited by vegetation groups comparable to those of the polluted water courses and other urban habitats in Nile Delta region (e.g., *Echinochloa stagnina, Pluchea dioscoridis, Cynodon dactylon, Panicum repens, Phragmites australis, Chenopodium murale, Imperata cylindrica* groups) in many of the pervious studies (e.g. Simpson, 1932, Hassib, 1951, Kosinova, 1975, Hejny and Kosinova, 1977, Springuel, 1985, Shaltout and Sharaf El-Din, 1988, El Sheikh, 1989, Zahran, *et al.*, 1990, Shaltout and El-Sheikh, 1993 and Shaltout *et al.*, 1994).

The strategy of reproduction by root suckers and the rapid growth rate of *Dalbergia sissoo* lead to increase the plant dissemination into new regions (Neelu *et al.*, 2002, James, 2002 and Fahmy, 2007). In the present study, the association between this plant and most of the recorded species is low, this may be due to that the naturalized *Dalbergia sissoo* usually grows in dense populations which prevent any other species to grow with it (i.e. smothering plant). *Phragmites australis* had a relatively high association with *Dalbergia sissoo* (52.6 %), which may interpret in the view that both species prefer the same habitat (banks of the water courses). The correlation analyses between the soil variables and ordination axes in the present study indicated that iron, potassium, manganese, phosphorus, magnesium, and organic matter are the most effective in the stand ordination; which may be reflect the importance of these elements for the distribution of sissoo.

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