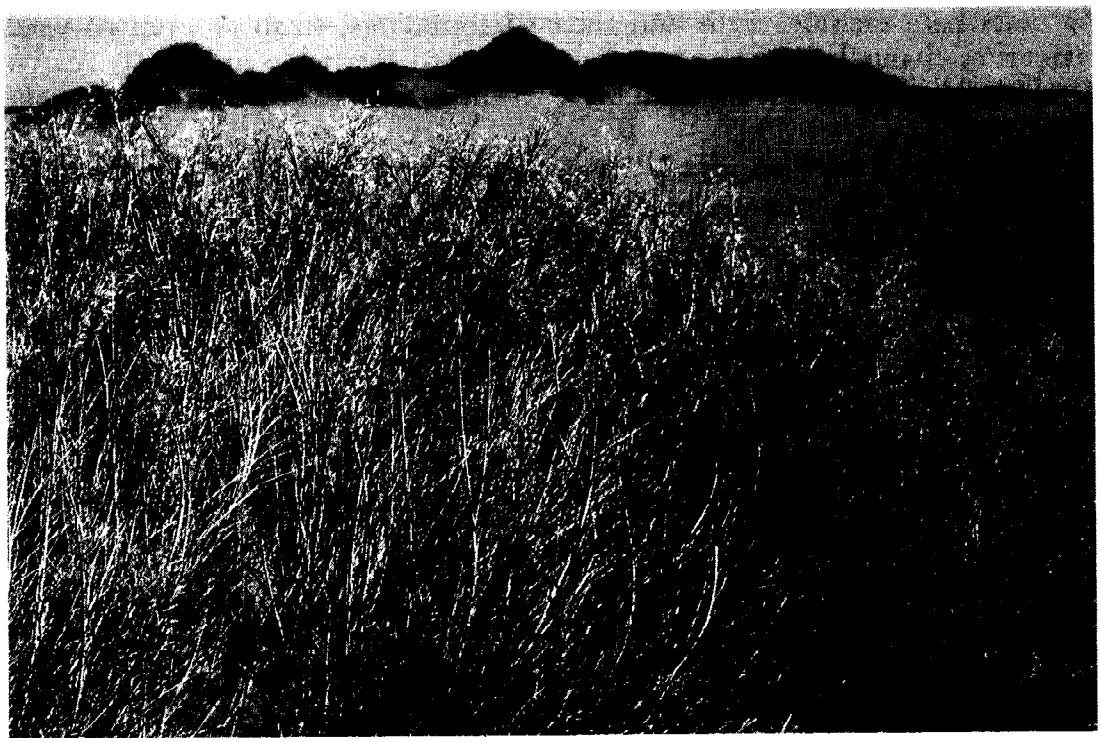

Photo 18. Stand of *Stipagrostis vulnerans* (79) at Bir Dibis, *Tamarix nilotica* (64) in the back.

only rarely. In Bir Kiseiba *Hyphaene* forms an outer ring around a center settled by *Phoenix* (BORNKAMM 1986). But this Bir had a great importance as resting places for caravanes (as the only occurrence of *Imperata cylindrica, Typha domingensis* and *Cynodon dactylon* in this region indicates). Who ever reads the report of COMYN (1911) will be astonished what activity in sowing seeds has taken place over the times: Not even the remotest vegetations are completely undisturbed. Nevertheless under the extreme climatic conditions prevailing in South Egypt these nearly natural stands are of extraordinary great value and deserve protection.

All the groundwater-dependent plant communities are arranged in series according to the depth of the seapage. By KEHL (1987) a number of uninhabited oases in Egypt and North Sudan was compared and for Egypt the following sequence was established: *Typha domingensis - Phragmites australis - Juncus rigidus - Cyperus laevigatus - Imperata cylindrica - Phoenix dactylifera - Alhagi mannifera - Sporobolus spicatus - Stipagrostis vulnerans - Tamarix* spec. - *Nitraria retusa - Zygophyllum album - Francoeuria crispa* (see also ABU ZIADA 1980, GIRGIS et al. 1981). The role of the two last species as components of the outer margins of vegetation islands has already been discussed in the preceding chapter.

3.5.3.3. Oases with traditional land use system

Most studies of the oasis vegetation deal with the land under traditional land use (e.g. MIGAHID et al. 1960, ABU ZIADA 1980, ABD EL GHANI 1985). The main

habitats here include: wells and their surroundings, small or even covered irrigation channels leading to orchards, later to the fields and finally to the Sebkha. Many of the wells date back to the Greek-Roman period (FAKHRI 1983, ABD EL-GHANI 1985).

Around wells grow stands of *Phoenix dactylifera* (46) and *Hyphaene thebaica* (Kharga oasis, 47), whereas along the outlets one finds the Phragmites australis ass. subass. of Typha domingensis (81), *Cyperus laevigatus* stands (57), and, in the vicinity, stands of *Tamarix* (in most cases *Tamarix nilotica*, 64). Along the channels the Imperata cylindrica subass. of the Phragmites australis ass. (72), the Alhagi mannifera ass. (75) and *Prosopis farcta* stands (74) are frequent. The palm stands seem to be characteristic for the old oasis system, as do plantations of *Acacia nilotica* (Table 17: 83) and *Balanites aegyptiaca* (Table 17: 85; see also ABD EL-GHANI 1985) and a large number of aquatic plants (MIGAHID et al. 1960).

Table 17. 82 Plantations of *Casuarina equisetifolia* (C); 83 plantations of *Acacia nilotica* (A); 84 plantations of *Prosopis juliflora* (P); 85 plantations of *Balanites aegyptiaca* (B). For further explanation see Table 1.

	-82-			-83-			-84-			-85-		
	C			A			P			B		
average species number	3.6			3.4			1.7			1.8		
average height (dm)	138			94			48			50		
number of relevés	5			7			3			4		
vitality	100/0/0			84/0/16			100/0/0			100/0/0		
	T	C	P	T	C	P	T	C	P	T	C	P
Casuarina equisetifolia	5	82.5	100									
Acacia nilotica				5	69.3	100						
Prosopis juliflora							5	87.5	100			
Balanites aegyptiaca										5	75.0	100
Phoenix dactylifera	+	1.1	60	2	6.9	57					0.1	25
Imperata cylindrica	2	4.6	80		0.1	29						
Sonchus oleraceus		0.1	20	+	0.1	29.0						
Tamarix nilotica		0.1	20								9.4	25
Alhagi mannifera		0.1	20								0.1	25

In only one of the units occurred: C: Sporobolus spicatus -/0.1/20; Phragmites australis -/0.1/20; Melilotus indicus -/0.1/20; A: Prosopis farcta -/0.1/14; Juncus rigidus -/0.2/43; Calotropis procera -/0.1/4; Lolium rigidum +/0.1/14; Cynodon dactylon -/0.1/29; Zizyphus spina-christi -/1.4/14; Ambrosia maritima -/0.1/14. Pj: Salsola baryosma ssp. baryosma -/3.3/33.

The weed vegetation is rather diverse. The floristic composition of weedy plant communities varies among the oases and with the crops (ABD EL-GHANI 1985). According to the seasonality of crop production a winter aspect and a summer aspect can be discerned (MIGAHID et al. 1960, EL-HADIDI & KOSINOVÁ 1971, ABU ZIADA 1980). KOSINOVÁ (1975) described the Astragalo corrugati-Plantaginetum lagopodis as a weed community from the Kharga and Dakhla oases (see also BOULOS & EL-HADIDI 1984; EL-HABIBI et al. 1981, 1982). We have seen this association in the old oasis system, but not in the new one. Our own relevés are sampled in the new system (see chapter 3.5.3.4.).

Settlements provide ruderal habitats where only a few ruderal plant communities are developed which live from waste water. The most important

Table 18. Cynodon dactylon-Melilotus indicus ass. (CM): 86 CM-n pure *Cynodon* stands; 87/88 CM-t typical subass., 87 CM-tt typical var., 88 CM-tl var. of Imperata cylindrica; 89 CM-S subass. of Scirpus tuberosus.
Locality: B Bulaq, Kharga Oasis, EO experimental farm East Oweinat (data from BORNKAMM 1985).
For further explanation see Table 1.

		-86a-			-86b-			-87a-			-87b-			-88-			-89-	
		CM-n			CM-n			CM-tt			CM-tt			CM-tl			CM-S	
average species number		2.2			2.3			7.9			4.2			7.5			5.8	
locality		B			EO			B			EO			B			EO	
number of relevés		5			8			14			42			8			49	
vitality	T	C	P	T	C	P	T	C	P	T	C	P	T	C	P	T	C	P
Cynodon dactylon	3	39.0	100	2!	8.9	100	1	1.7	64		0	2	2	1.9	88	+	0.6	71
Melilotus indicus							2!	8.3	100	1	0.7	33	1	4.1	100		0.0	6
Lolium rigidum							1	2.0	79	+	0.3	48		1.3	25		0.1	20
Imperata cylindrica		0.1	20								0.0	5	1	1.1	88		0.0	6
Scirpus tuberosus											0.0	2				+	0.8	84
Phoenix dactylifera, juv.		0.1	20	+	0.0	50								0.1	13			
Sonchus oleraceus		0.1	20				2!	2.1	71				+	0.3	63	+	0.0	24
Brassica tournefortii		0.5	20				+	0.0	14		0.2	2					0.0	6
Launaea capitata		0.5	20					0.0	14									
Ammi majus		0.0	7					0.1	25								0.0	2
Malva parviflora								0.0	29		0.0	5						
Sinapis allionii								0.0	7		0.0	2						
Avena fatua							+	0.0	7	+	0.2	29					0.0	2
Vicia monantha							1	0.4	21					0.1	13		0.0	2
Chenopodium album								0.0	7				+	0.1	13		0.0	4
Chenopodium rubrum							(+)	0.5	50				+	0.1	13			
Sorghum virgatum							+	0.0	7					0.1	13		0.2	18
Trigonella hamosa								0.0	7								0.0	2
Phragmites australis								0.0	7					0.1	25			
Lathyrus hirsutus								0.7	14					0.1	25			
Digitaria sanguinalis							+	0.2	14					3.8	38		0.0	2
Anagallis arvensis														0.1	13		0.0	2

In only one of the units occurred: CM-tt (B): Cyperus laevigatus -/0.0/7; Launaea cassiniana -/0.0/21; Spergularia diandra -/0.0/7; Plantago lanceolata -/0.1/29; Rumex dentatus subsp. callosissimus -/0.0/7; Astragalus hamosus -/1.1/36; Polygonum bellardii -/0.0/14; Convolvulus fatmensis -/0.0/2; Cassia italica -/0.0/14; Asphodelus fistulosus -/0.0/14; Cressa cretica -/0.0/14; CM-tt (EO): Beta maritima var. foliosa -/0.0/2; Emex spinosus -/0.0/2 Tamarix of. tetragyna-/0.0/2; Cuscuta pedicellata (on Medicago sativa) -/0.0/5; CM-tl: Conyza linifolia -/0.2/50; Dactyloctenium aegyptiacum -/0.1/38. CM-S: Euphorbia peplus +/0.2/31; Conyza aegyptiaca -/0.0/2; Lathyrus of. sphaericus -/0.0/2; Solanum nigrum -/0.0/2; Convolvulus arvensis -/0.0/2; Polypogon monspeliensis -/0.0/8: Polypogon fugax -/0.0/2; Tagetes minuta -/0.0/2.

vegetation types are the Cynodontetum nudum (pure *Cynodon* stands, Table 18: 86), the Alhagietum nudum (75) and the Alhagi mannifera ass. subass. of Cressa cretica (76). Such ruderal vegetation is widespread in Egypt (e.g. EL-HADIDI & SPRINGUEL 1978, SPRINGUEL 1985).

3.5.3.4. Oases with new land use system

The new agricultural systems in oases are fed by water from deep groundwater layers. This system is frequently described in the agricultural literature but its bearing for vegetation science has not been studied sufficiently. The main habitats are drilling holes, larger irrigation channels, fields, which are surrounded by windebreaking tree plantations, and, of course, sebkhas.

A special feature of this new type of village is the physiognomy brought about by the *Casuarina* plantations which can be seen from a distance. It is interesting to note that the *Casuarina* forests (Table 17: 82), although narrow, provide a new type of habitat which has not been known before: it is shady, the soil surface is thickly covered by organic matter in form of *Casuarina* twig litter. In the understory *Imperata cylindrica* copes best with the new conditions.

The new oasis system is not bound any more (like the old one) to natural geomorphological features. Irrigation can take place everywhere as long as a source of irrigation water is provided and the soils are suited for agricultural use (ALAILY et al. 1987b). The floristic composition of the new farm lands depend on the age of cultivation (EL-HADIDI & KOSINOVÁ 1971), but new species invade quickly. This can be shown by observations made in the experimental farm East Oweinat in the very south of Egypt, situated appr. 400 km south of Mut at 22°27'N, 28°42'E (Table 18; see also BORNKAMM 1985). Most of the weeds presumably are imported from the Dakhla Oasis, where most of the crops came from (H. EL-SHAZLY, pers. comm.).

In our relevés stemming mainly from the Bulaq in the Kharga osasis, *Melilotus indicus* and *Cynodon dactylon* were the most frequent species. They dominate the Melilotus indicus-Cynodon dactylon ass. (Table 18: 86–89). This association was also found at the farm East Oweinat. Here a typical subass. (87/88) in fields irrigated with small channels (in BORNKAMM 1985 called *Melilotus indicus-Lolium rigidum* community) and subass. of Scirpus tuberosus (89) in furrows of plantations with dribbling irrigation (in BORNKAMM 1985 called *Scirpus tuberosus* community) can be discerned with mostly plurizonal species (Table 19).

In Fig. 19 a vegetation transect through the Kharga oasis, appr. 4 km south of the town of Bulaq is presented which covers both oasis types. On the steep slope of the escarpment scattered vegetation spots of the Zygophyllum coccineum-Salsola baryosma ass. (40) can be detected. This type of accidental vegetation is scattered distributed along the wadi leading to the center of the oasis, interrupted by large vegetation-free areas. The wadi lead to ancient farmland of the old systems; some of the small irrigation channels are dried up and some of the farm houses are abandoned. *Tamarix nilotica* (64) stands are the prevailing vegetation type, but stands of *Alhagi mannifera* (75), *Cressa cretica* (77), *Sporobolus spicatus* (78) and *Hyphaene thebaica* (47), and weed communities also exist. Separated by large dunes, void of vegetation, the transect crosses another area of farmland of the old system. Tree stands here comprise *Phoenix dactylifera, Hyphaene thebaica* and *Acacia nilotica*, with stands of different *Tamarix* species developed at the deepest part of the oasis in

Table 19. Phytogeographical analysis and life forms expressed in % of total presence (the total of all records of all species = 100 %).

I. Plurizonal species (PL)

II. Geoelements (M = Mediterranean, IT = Irano-Turanian, SA = Saharo-Arabian, SU = Sudanian

III. Life forms (T = trees, S = shrubs, C = chamaephytes s.l. comprising low shrubs, dwarf shrubs, half shrubs and shrubby perennials; P = perennial herbs; A = annuals or biennals).

			I			II			III			
No.	code	table	PL	M	IT	SA	SU	T	S	C	P	A
1	AL-Ph	1	35	**33**	21	**44**	2	-	17	9	16	**58**
2	AL-t	1	34	**31**	15	**52**	2	-	**46**	**34**	9	11
3	AL-S	1	**68**	11	31	**56**	2	-	10	**38**	19	**33**
4	Al-PL	1	**50**	21	28	**51**	0	-	27	18	16	**39**
5	TP-AA	2	45	27	23	**50**	0	-	8	7	23	**62**
6	TP-At	2	47	24	19	**57**	0	-	8	11	17	**64**
7	TP-TT	2	29	3	17	**78**	2	-	17	**39**	17	27
8	TP-TP	2	**58**	24	22	**53**	1	-	13	14	17	**56**
9	TP-Tt	2	47	15	21	**62**	2	-	14	**35**	**30**	21
10	TP-SA	2	42	21	18	**60**	1	-	18	26	23	**33**
11	TP-St	2	15	7	4	**88**	1	-	3	**59**	27	11
12	AC-T	3	36	15	16	**66**	3	-	21	**40**	**33**	6
13	AC-A	3	43	11	15	**67**	7	-	16	**55**	20	9
14	AC-tt	3	12	1	18	**76**	5	-	2	**59**	**35**	4
15	AC-tH	3	37	3	23	**65**	9	-	14	**61**	18	7
16	PG-Z	3	31	0	8	**85**	7	-	2	**62**	**30**	6
17	PG-t	3	22	-	11	**87**	2	-	5	**45**	23	27
19	A-At	4	18	1	2	**89**	8	-	2	**51**	11	**36**
20	A-AB	4	22	1	3	**76**	20	-	3	29	20	**48**
21	CR	4	**35**	11	12	**70**	7	-	11	**67**	7	15
23	ZS-nZ	5	41	-	12	**79**	9	-	-	18	82	-
24	ZS-Zt	5	29	-	10	**55**	**35**	-	1	16	**30**	**53**
25	ZS-ZP	5	26	-	9	**62**	29	-	14	20	23	**43**
26	ZS-tt	5	26	0	2	**64**	**34**	-	-	14	21	**65**
27	ZS-tC	5	21	-	9	**65**	26	-	-	**33**	**30**	**37**
28	ZS-tA	5	20	0	4	**62**	**34**	-	12	21	18	**39**
29	St-t	6	**57**	-	19	**65**	16	-	5	**35**	**58**	2
30	St-F	6	47	-	15	**74**	11	-	4	**61**	27	8
31	S-t	6	15	-	5	**87**	8	-	-	**58**	**34**	8
32	S-Ft	6	23	-	14	**69**	17	-	1	**60**	16	23
33	S-FC	6	31	-	21	**60**	19	-	13	**58**	12	17
35	CF-P	7	29	-	22	**68**	10	-	-	**74**	26	-
36	CF-Z	7	45	-	5	**76**	19	1	4	**52**	**38**	5
38	C	7	36	0	15	**82**	3	-	28	**43**	21	8
40	ZS-t	8	3	-	2	**82**	16	-	18	12	**58**	12
41	ZS-Z	8	23	-	3	**71**	26	-	**34**	**32**	**32**	2
42	ZS-T	8	40	-	11	**51**	**38**	-	21	16	**34**	29
43	ZS-A	8	7	-	4	40	**56**	-	4	28	27	**41**
44	F-t	8	**77**	-	8	**58**	**34**	-	12	**68**	20	-
45	F-T	8	**69**	-	17	**63**	20	-	**31**	**44**	25	-
46	P	14	26	6	8	**82**	4	**50**	17	7	26	
48	ZA	14	21	1	6	**48**	**45**	27	2	9	22	**40**
54	SZ-t	9	-	-	-	**75**	25	-	15	19	**56**	-
55	SZ-F	9	21	4	-	24	**72**	2	10	**30**	29	29
57	C	12	**93**	21	25	**40**	14	-	13	-	**80**	7
59	J-A	12	**86**	21	25	**49**	5	-	**38**	-	**62**	-
61	L-t	12	25	**31**	12	**55**	2	-	3	**35**	**41**	21
62	L-Z	12	45	**37**	11	**50**	2	-	14	**57**	29	-
65	Tn-P	13	**52**	10	14	**64**	12	5	**37**	6	**52**	-
66	Tt	13	**77**	19	13	**51**	17	-	**52**	12	**36**	-
67	Tp	13	**69**	2	15	**55**	28	-	**49**	14	**32**	5
72	I-P	10	**85**	10	27	43	20	-	5	14	**75**	6
73	I-A	10	**97**	13	28	28	**31**	-	-	**45**	**52**	3
76	A-C	10	**84**	18	28	**37**	17	8	4	21	**46**	21
77	C	10	**100**	21	23	23	**33**	-	-	9	**91**	-
78	Sp	11	**50**	4	16	24	**56**	-	8	28	**64**	-
81	P-T	11	**83**	17	26	**37**	20	3	11	-	**86**	-
86a	CM-n	16	**58**	28	19	**39**	14	10	-	-	**68**	23
86b	CM-n	16	**100**	25	25	25	25	-	-	-	**100**	-
87a	CM-tt	16	**66**	**50**	22	18	10	-	-	-	27	**73**
87b	CM-tt	16	49	**70**	22	5	2	-	-	-	12	**88**
88	CM-tI	16	**69**	**47**	21	16	16	-	-	-	**36**	**64**
89	CM-S	16	**89**	**34**	27	20	19	-	-	-	**50**	**50**

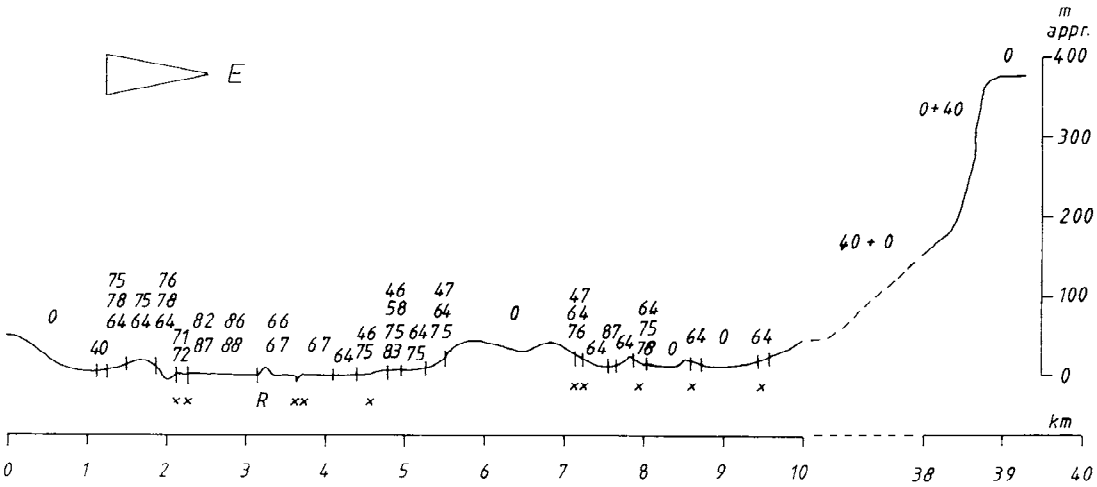

Fig. 19. Transect through the Kharga Oasis 4 km south of Bulaq, 25°11'N, 30°29'–30°55'E (60 relevés, 12.–15.3.84). – x = old irrigation channel, xx = recent irrigation channel, R = road.
Plant communities:
40 Zygophyllum coccineum-Salsola baryosma ass.; 46 Phoenix dactylifera ass.; 47 *Hyphaene thebaica* stands; 58 Juncus rigidus ass. typical subass.; 64 Tamarix nilotica ass. typical subass.; 66 Tamarix tetragyna ass.; 67 Tamarix passerinoides ass.
Imperata cylindrica ass.: 71 Imperatetum nudum; 72 Phragmites australis subass.
Alhagi mannifera ass.: 75 Alhagietum nudum; 76 Cressa cretica subass.; 78 *Sporobolus spicatus* stands; 82 *Casuarina equisetifolia* plantations; 83 *Acacia nilotica* plantations
Cynodon dactylon-Melilotus indicus ass.: 86 Cynodontetum nudum; 87 typical subass. typical var.; 88 typical subass. var. of Imperata cylindrica. 0 vegetation-free.

sebkhas on both sides of the road. West of the road the new type of oasis can be observed: a relatively large area covered with small fields bearing the Melilotus indicus-Cynodon dactylon ass. (86–89) in all the subunits, surrounded by *Casuarina* stands (82). The agricultural land is bordered by an irrigation channel with warm water accompanied by the Imperata cylindrica ass. in both subunits (71/72). A gentle slope towards the first dunes exhibits the Alhagi ass. Cressa subass. (76) on the foot, the Alhagietum nudum (75) at the top, accompanied by stands of *Tamarix nilotica* (64) and *Sporobolus spicatus* (78). In the small depression between the first dune ridge and the very large dunes, which form the western border of the Kharga oasis as a whole the vegetation fades out with a very small belt of the accidental Zygophyllum coccineum-Salsola baryosma ass. (40). All vegetation types inside the oasis seem to be in quick change because they depend critically on the irrigation system (Abu Ziada 1980, Abd El-Ghani 1985).

4. Discussion

4.1. The higher phytosociological units

In the literature concerning our area under investigation and its neighbourhood a large number of higher phytosociological units is provided (Quézel

1965; KNAPP 1965, 1968; ZOHARY 1973, 1982). In most of the field investigations cited in the preceding chapters no reference is made from the associations or community types described in a given region to the classes. In order to fill this gap between the levels of the phytosociological research a great amount of careful synsystematic work still is needed. This is especially true for the groundwater-dependent vegetation because here the higher units are azonal or, at least, plurizonal. The comparative work, therefore, has to be extended over a very large geographical area as has been pointed out clearly by DEIL (1986) for the group of the *Tamarix nilotica* communities.

For this reason and since the present papers aims primarily at the desert vegetation and only secondarily to the oasis vegetation, the higher ranks of the groundwater-dependent shrubby or herbaceous vegetation will not be discussed further. With respect to the irrigated vegetation, KOSINOVÁ (1975) described the weed alliance Melilotion indici. Without doubt our Melilotus-Cynodon ass. belongs to this unit.

The tree-bearing vegetation shows relationships to the regions further south and further east. The Western Desert contains only a few traces of pseudosavanna, which are described as Zygophyllum-Acacia ass., and as stands *Acacia ehrenbergiana, Capparis decidua* and *Balanites aegyptiaca.* They form species-poor outposts of the Acacietea tortilis in the sense of KNAPP (1968) or the Acacietea tortilis subsudanica (in the sense of ZOHARY 1973, 1982; see also Acacietalia tortilis Eig 1939), at the northern or northwestern border of this class. Likewise the *Hyphaene* stands in the southeast of our investigated area can be attributed to the class Hyphaenetea thebaicae, order Hyphaenetalia thebaicae Knapp 1968. The sociology of the *Phoenix dactylifera* stands is still unclear, and is obscured by the anthropogenic influence.

The remaining desert vegetation is fully developed in the Western Desert and provides a base for the discussion of the higher phytosociological units. A synthesis of the most important species of these communities and number of other desert communities is given in Table 20. First of all it can be seen, that all our associations (Table 20, 1–4 and 11–18) have several species in common. This allows the conclusion that all of them belong to the same class. A differentiation into two groups, a northern one (Table 20, 1–10) and a southern one (Table 20, 11–32) can easily be recognized. In the Negev desert ZOHARY (1973, 1982) discerned two classes of (dwarf-)shrubby desert vegetation: Anabasetea articulatae Zohary 1952 and Hammadetea salicornicae. The psammophytic vegetation is separated as class Retamo-Tamaricetea fluviatilia. In the western Sahara QUÉZEL (1965) also names two classes: Asterisco-Forskhaletea (with the order Gymnocarpo-Atractyletalia in the north and the order Aerveto-Fagonietalia in the center) and the class Pergulario-Pulicarietea in the southwest. A small number of common species like *Anabasis articulata, Haloxylon scoparium, Reaumuria hirtella, Bassia* (= Chenolea) *arabica, Lappula spinocarpos, Erodium hirtum, Trigonella stellata*, and *Filago deesertorum* allow us to place our communities in the class Anabasetea articulatae. On the other hand a regional differentiation is very evident,

Table 20. Comparison of desert (dwarf-)shrub communities in the Western Desert. Frequencies: 1 = 1–20 %, 2 = 21–40 %, 3 = 41–60 %, 4 = 61–80 %, 5 = 81–100 %.

	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
number of relevés		1	1										1			1															
	34	01	17	68	90	16	66	30	45	25	56	18	55	48	68	36	86	02	58	28	59	22	18	60	33	33	25	20	00	12	58
Anabasetea and Pituranthetalia tortuosi:																															
Anabasis articulata	2	3	1	2			1	4	2	3	4		1	1		1	1		4	2				2							
Pituranthos tortuosus	2	3	5	3	3	3	3	3	3	3	2	4	1	1	1	1				3	1	3	4	2							
Helianthemum lippii	2	2	3	2						5	1		1						2					1						
Salsola tetrandra	2	2	1	2	1		2	4	1	2	1	1	1																		
Trigonella stellata	2	2	1	1			4				3	2	2																3		
Launaea nudicaulis	1	1	3	2	1		4		2	3			1	1					1	1	1	1	2	1	1	1			3	1	
Astragalus trigonus	1	1	2	2						1	1	1	1	1	1	1	1														
Echinops spinosissimus	1	2	1	1	1	5	2	2	1	2						1			1	2	1	2	3	1		1					
Salvia aegyptiaca		1	1	1	1		1		1	1	1			1					1		1	1	2	1		1					
Heliotropium bacciferum		1		1							1			1											1			2		
Zilla spinosa s.l.		1	2	1			1		1			2	1				1	1	2	4	1	5	3	4	5	4	4	1	5	5	5	4
Gymnocarpus decandrum		3	2	3	3	1	2	4	2	4									1	2	2	2	2	2							
Reaumuria hirtella		1			1	3	3	4	1											2	4	4		2							
Farsetia aegyptiaca		1	2	1									1	1					2	3	3	4	3		1						
Stipagrostis plumosa			1	1	1					4	1	1	1	4		1	1		5		2	4	1	1	1			1		1		
Salsola baryosma s.l.			1	2							2	1	2	2	3	1	2	2							2			2	3		4	
Other important species:																															
Zygophyllum album		1	1	3		4	1		1		1		1	1	1	1			2	1		1		2			1				1
Francoeuria crispa			1	1							1		1	1		1	1					1			2	1		1	2	3		1
Calligonum comosum			1	1							1		1	1		1	1		1			1	1	1	1	1				1		1
Cornulaca monacantha				1						1	1		1	1	2	4	1		1					1	1					1		
Thymelaeion hirsutae:																															
Lycium europaeum	5	1			1	2	1		2																						
Malva parviflora	3	2	1		1		2		1																				2		
Adonis dentatus	2	3					2																								
Thymelaea hirsuta	2	4	2		3	4	3	4	5	4																					
Plantago albicans	2	2	1		3	4	2		2	1																					
Ifloga spicata	2	2	1	1	2				1														2								
Anacyclus alexandrinus	2	2	1		2		2		2																						
Salsola vermiculata	2	1																													
Noaea mucronata	2	1			3		2	3	2	3																					
Salsola schweinfurthii	1	2	1	1																1											
Verbascum letourneuxii	1	1	1				1	1	1		1																				
Haloxylon scorparium	1	2	1	1			2	1	1																						
Erodium hirtum	1	1	1	1	3		2	1													1										
Iris sisyrhinchium	1	1	1		2		2		1																						
Scorzonera alexandrina	1	3	1	1	1		3		2	1																					
Salvia lanigera	1	3	1		4	3	3	1	3	1																					
Echiochilon fruticosum	1	1	1		2	5	1	2	1	3									1				2	1							
Filago desertorum	1	2	1																										1		
Kickxia aegyptiaca	1	1	1	1																									1		
Stipa parviflora	1	1							1																						
Artemisia inculta	1	1	5	1	2		3	1		1														1							
Asphodelus microcarpus	1	1			4		4	1	3																						
Other important species:																															
Atriplex halimus	4	3	2			2	2	5	2											3		1		1							
Zygophyllion coccinei:																															
Zygophyllum coccineum											2	1	5			2	3			3	5	5		3	3	4			5	4	5	3
Pergularia tomentosa											1		1							1			2	1	1	1	3			1		1
Cotula cinerea			1								1		3	1	3	1	1												3		5	
Anastatica hierochuntica											5	1	1																2			
Atriplex leucoclada s.l.											1	2	2								1	3	1	1	1	1				1		
Fagonia arabica											1	1	1	2	3	2			2			1	2	1		3						
Oligomeris linifolia											1		1																3			
Randonia africana		1	1									3	1																			
Pulicaria undulata												1	1						1					1	1	1	5		3	3	3	2
Fagonia bruguieri			1										1	1	1	1	1				1	1	1	1	3		3		1	3	3	1
Cleome africana													1															1	1			1
Cleome droserifolia													1															1	1			1
Schouwia thebaica													2				1												4		5	1
Zygophyllum simplex													2																2	1	5	
Astragalus vogelii													2		2		2	1													1	
Monsonia nivea													1	1					2					1		1						
Convolvulus pilosellifolius													1		3	1																
Reseda kahirina													1																			
Fagonia glutinosa													1	1					2			1	3	1								
Farsetia ramosissima													1				1	1							1			1				
Fagonia indica																	2								1			3				
Psoralea plicata																	1															
Morettia philaeana																	1								1			2	3		3	
Other important species:																															
Trichodesma africanum																	1	1			1	1		1	1	1			4	1	2	1
Stipagrostis acutiflora																		3														

Table 20. (cont.)

1. Atriplex halimus-Lycium europaeum ass. (see Table 1).
2. Thymelaea hirsuta-Plantago albicans ass. (see Table 2).
3. Artemisia inculta-Carduncelus mareoticus ass. (see Table 2).
4. Pituranthos tortuosus-Gymnocarpos decandrum ass. (see Table 3).
5. Associations of *Salsola tetrandra, Gymnocarpus decandrum, Plantago albicans* and *Echiochilon fruticosum, Artemisia alba*, and *Anabasis articulata* at Maktila near Sidi Barrani (from MIGAHID et al. 1974).
6. Plant communities of the rocky ridges, slopes, and sand plains at Ras El-Hikma (from MIGAHID et al. 1955).
7. Associations of *Salsola tetrandra, Ononis vaginalis, Gymnocarpus decander, Plantago albicans* and *Anabasis articulata* at Fuka and South Ras El-Hikma (from TADROS & EL-SHARKAWI 1960).
8. Associations of *Anabasis articulata, Ononis vaginalis, Plantago albicans, Salsola tetrandra, Gymnocarpus decander* and *Artemisia herba-alba* at Bagoush (from EL-SHARKAWI 1961).
9. Associations of *Gymnocarpos decander, Plantago albicans*, and *Anabasis articulata* in the Mareotis (from TADROS & ATTA 1958b).
10. *Helianthemum lippii* community and *Anabasis articulata* community, Cairo-Alexandria desert road (BATANOUNY & ABU-EL-SOUOD 1972, estimated values from Table 2).
11. Anastatica hierochuntica-Anabasis articulata ass. (see Table 5).
12. Capparis aegyptia-Randonia africana ass. (see Table 5).
13. Zygophyllum coccineum-Schouwia thebaica ass. (see Table 6).
14. Stipagrostis plumosa ass. (see Table 7).
15. Suaeda fruticosa ass. (see Table 7).
16. Cornulaca monacantha-Fagonia arabica ass. (see Table 8).
17. Zygophyllum coccineum-Salsola baryosma ass. (see Table 9).
18. *Salsola baryosma* stands, *Fagonia arabica* stands, Stipagrostis acutiflora-Zilla spinosa ass. (see Table 12).
19. Communities of *Stipagrostis plumosa, Pituranthos tortuosus* and *Artemisia monosperma*, Cairo-Alexandria desert road (BATANOUNY & ABU EL-SUOUD 1972, estimated values from Table 2).
20. *Lycium arabicum* community and *Atriplex halimus* community from the Northern part of the Eastern Desert (from KASSAS & GIRGIS 1965, Table 1, I, X and XI).
21. Vegetation of cliffs and runnels in the limestone area of the Eastern Desert, 29°–30°N (from KASSAS & GIRGIS 1964, II–VII).
22. Zilletum spinosae and vegetation on shallow soil. Northern part of the Eastern Desert (from KASSAS & IMAM 1954, Tables 2 and 3).
23. Communities of *Zilla spinosa* and *Artemisia monosperma*. Northern part of the Eastern Desert (from KASSAS & IMAM 1959).
24. Community types of *Zygophyllum coccineum, Anabasis articulata, Zilla spinosa* and *Haloxylon salicornicum* from the northern and middle parts of the Eastern Desert (from KASSAS & GIRGIS 1965, table I, III, VI, VII and VIII).
25. *Zilla spinosa* and *Zygophyllum coccineum* community types from the northern and middle parts of the Eastern Desert (from KASSAS & GIRGIS 1970, table 1, V and IX).
26. Plant communities of the Minya Eastern Desert area, appr. 28°N (from EL-SHARKAWI & RAMADAN 1983).
27. Plant communities in Wadi Bir El-Ain, Eastern Desert, appr 26°30'N (from EL-SHARKAWI & FAYED 1975).
28. *Indigofera argentea, Aerva persica* and *Cassia senna* community types from the southern part of the Eastern Desert (from KASSAS & GIRGIS 1970, table 1 I, IIC and III).
29. Plant communities in Wadi Qassab, Eastern Desert, appr. 26°30'N (from EL-SHARKAWI et al. 1984).
30. *Zilla spinosa* community type, Eastern Desert between 27°30' and 25°30'N (from KASSAS & GIRGIS 1968/69).
31. Plant communities in Wadi El-Matuli and Wadi El-Qarn, Eastern Desert, appr. 26°N (from EL-SHARKAWI et al. 1982a).
32. Plant communities in Wadi Gimal and Wadi El-Miyah, Eastern Desert, appr 25°N (from EL-SHARKAWI et al. 1982b).

to some extent made up by vicariating species of the same genus (e.g. *Zygophyllum, Anabasis, Artemisia, Salsola, Lycium, Thymelaea, Pituranthos*). As a consequence of this differentiation the Egyptian associations do not fit in one of the orders described from the Negev or from the western Sahara. The Western Desert generally is poor in species, many plants show a distributional gap in this region. One of the reasons may be the relatively uniform geomorphological structure. This suggests there might also be a simple solution for the definition of the phytosociological units. All associations described can be comprised into one new order Pituranthetalia tortuosi, which – at the present state of knowledge – contains the following characteristic or differentiating species:

Pituranthos tortuosus
Helianthemum lippii
Astragalus trigonus
Salvia aegyptiaca
Farsetia aegyptiaca
Stipagrostis plumosa.

Most of the species show maximum occurrence in this order but contribute also to other types of communities e.g. *Stipagrostis plumosa* to grasslands of the class Brachiario-Aristidetea Knapp 1965, see also BAIERLE et al. (1985), and KÖNIG (1986) for *Stipagrostis plumosa* and *Salvia aegyptiaca* in Saudi-Arabia. The role of the two subspecies of *Salsola baryosma* (ssp. *gaetula* and *ssp. baryosma*) remains obscure.

Within this order, the northern communities can be attributed to the alliance Thymelaeion hirsutae Eig 1946, and the southern ones to the alliance Zygophyllion coccinei El-Sharkawi et al. 1984. EIG (1946) discerned with the alliance Thymelaeion more psammophytic vegetation types (Retamo-Tamaricetea Zohary 1973) from other habitats, where the Anabasidion articulatae Eig 1946 grows. As discussed above (see 3.2.3.), such a strong differentiation cannot be made in our region. *Thymelaea hirsuta* itself is not at all restricted to sandy habitats, and the effects of grazing are at least as important as the habitat features. In the following years (e.g. TADROS & ATTA 1958b) the name Thymelaeion hirsutae was used by most of the Egyptian researchers. Table 20 shows that the Thymelaea-Plantago ass., Artemisia-Carduncellus ass. and Pituranthos-Gymnocarpos ass. can be subsumed under this alliance. It also can be seen that the Thymelaeion hirsutae is widely distributed along the Mediterranean coast and extends southward to the region of Cairo (Table 20, 5–10).

All other communities comprised in Table 20 can be attributed to the Zygophyllion coccinei. Within this alliance the Anastatica-Anabasis ass. and the Capparis-Randonia ass. form the northwesternmost border. The latter contains *Randonia africana*, a more westernly distributed species. The other Zygophyllion communities of the Western Desert are free from Thymelaeion species. Southward, in parallel with the general decrease of species numbers, the characteristic species of the class and order become less and less frequent (Table 20, 11–18).

In the Eastern Desert, too, there is only a small overlap of Thymelaeion and Zygophyllion species. Studying the data from the literature (Table 20, 19–32) it has to be taken into account that usually the sampling plots were much larger than in the present investigation. In the southern part of the Eastern Desert, the Zygophyllion species are very well represented (Table 20, 28–32; see also KASSAS & GIRGIS 1969/70), whereas the number of species representing the class and order decrease. At the same time a number of Sudanian species appear, which are not comprised in Table 20. Further studies are needed to elucidate where the borderline to the more tropical desert vegetation has to be delineated. The same uncertainty exists at the south-western edge of our investigated area: It may be discovered that it is unreasonable to discuss the *Stipagrostis acutiflora* stands of the Great Sand Sea and the vicinity of the Gilf Kebir plateau (Fig. 7) in connection with Zygophyllion communities, but to regard them instead as an outpost of the psammophilic vegetation of the South Sahara (e.g. Aristida acutiflora-Indigofera semitrijuga ass. Quézel 1965).

A great number of problems remain to be solved. The alliance Thymelaeion was described first as a psammophytic vegetation unit (EIG 1946). In fact, the northern Negev *Thymelaea hirsuta* and some of its companions form a dune vegetation (Retama raetam-Thymelaea hirsuta ass., class Retamo-Tamaricetea fluviatilia Zohary 1973, see ZOHARY 1982). The Thymelaeion in our sense shows some, but not a very close, relationship to the Thymelaeo-Herniarion (order Gymnocarpeto-Atractyletalia, class Asteriscato-Forskhaletea Quézel 1965) in the Western Sahara.

The differentiation into a northern alliance Thymelaeion and a southern Zygophyllion can be seen in parallel to the differentiation between the classes Anabasetea and Hammadetea salicornicae in the Negev, or between the orders Gymnocarpeto-Atractyletalia and Aerveto-Fagonietalia within the class Asterisceto-Forskhaletea or even this class and the class Pergulario-Pulicarietea in the Western Sahara. In our area the separation is performed on the level of two alliances only, whereas in neighbouring region it is performed on the level of orders and classes. This is very likely due to the fact that our area under investigation includes the driest part of the Sahara as a whole. It remains to be proved by further studies, however, whether and how the simplest possible differentiation proposed here has to be revised in future.

4.2. The desert zones

The entire area investigated – outside the oasis – is desert. It has been shown that inside this desert a considerable shift of species takes places along the 1000 km transect from the Mediterranean to the Sudanian border (see also KASSAS 1971, p. 482). On the basis of the maps given in Fig. 3, 6, 9, 11, 12, 13 and 15, the Western Desert can be separated into 5 desert zones, most of them bearing the characters of extreme desert. These zones (Fig. 20) show not

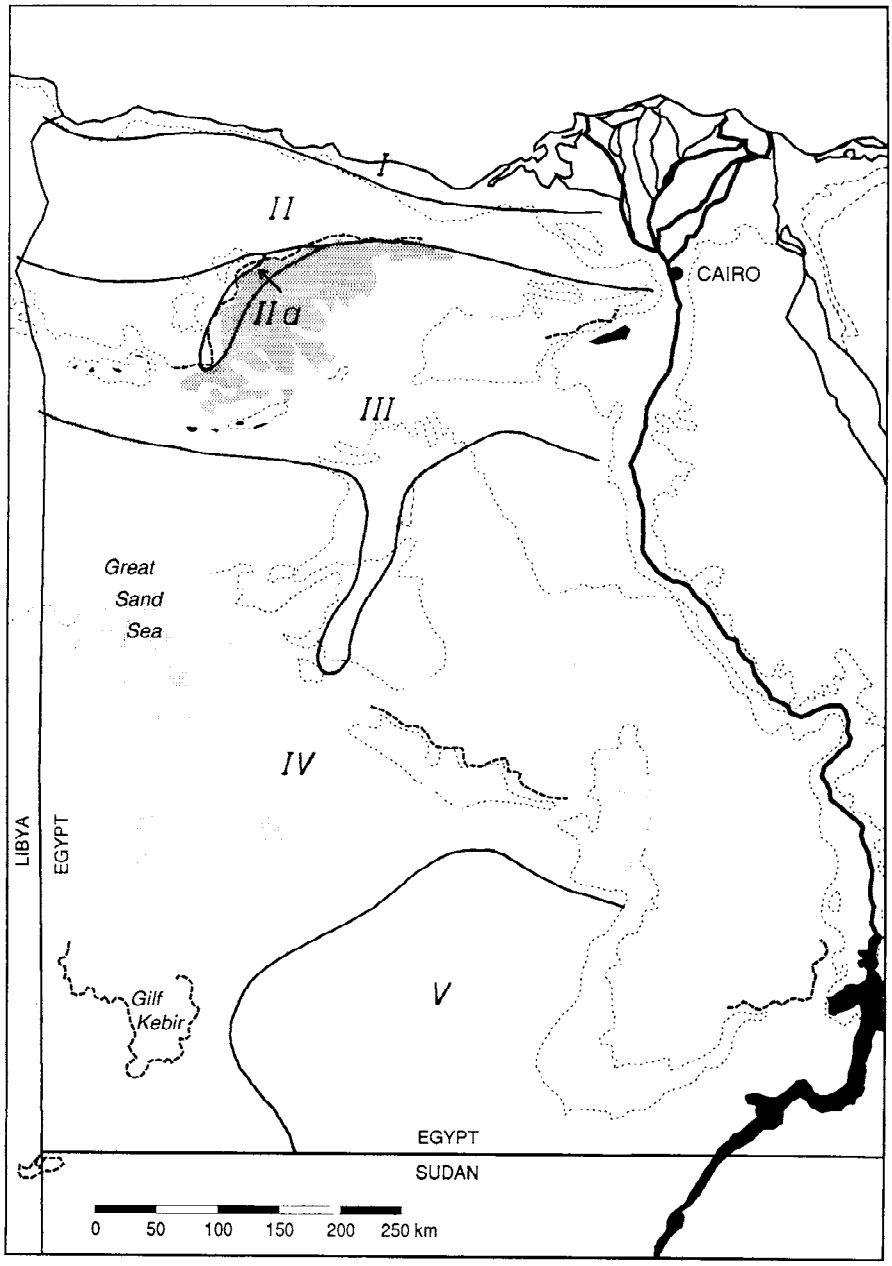

Fig. 20. The vegetation zones in the Western Desert: I semidesert, II full desert, IIa northwest Qattara region, III extreme desert 1, IV extreme desert 2, V extreme desert 3. For further information see Fig. 2.

only a change along the precipitation gradient but also some features caused by geomorphology.

The zones can be defined as follows (see also BORNKAMM & KEHL 1985, STAHR et al. 1985, BORNKAMM & KEHL 1989):

Zone I can be classified as semidesert. The precipitation ranges between 100 and 150 mm. The desert vegetation (Atriplex halimus-Lycium europaeum ass., Thymelaea hirsuta-Plantago albicans ass. Ammochloa aubass., and typical subass. – see Fig. 3)

contains shrubs, is permanent and diffuse, and is grazed by goats, sheep and sometimes cattle. The area is settled, and around the settlements ruderal and weedy vegetation exists. Farmland (irrigated and dry farming) covers the lower parts of the wadis. In this zone I, which comprises zones I (= littoral zone) and II with STAHR et al. (1985), in our 77 relevés we made 1193 records of 153 species. Since not all vegetation types were sampled the species list is by no means complete and the most frequent species in our relevés are doubtless no really identical with the most frequent species of the whole area. We tried to make relevés in all representative stands we could visit. In comparison with the other zones, we attempted to characterize zone I not only by its vegetation but

Table 21. Floristic characterization of the zones I–V (see Fig. 20) by the most frequent species in our relevés. R = rank; P = percentage of records.

Zone	I		II		IIa		III		IV	
number of species	143		90		49		53		39	
number of relevés	77		246		178		421		211	
number of species records	1193		1692		894		1233		461	
number of species per relevé	15,5		6,9		5,0		2,9		2,2	
	R	P	R	P	R	P	R	P	R	P
Thymelaea hirsuta	1)	3,8	6)	4,3						
Adonis dentatus	2)	3,5								
Malva parviflora	3)	3,1								
Atriplex halimus	4)	3,0	7)	4,1						
Lycium europaeum	5)	2,9								
Cutandia dichotoma	6)	2,8								
Ifloga spicata	7)	2,8								
Trigonella stellata	8)	2,7			11)	3,8	13)	1,9		
Pituranthos tortuosus	9)	2,5	1)	11,7			8)	4,9		
Anacyclus alexandrinus	10)	2,4								
Anabasis articulata	11)	2,2	10)	3,6			5)	5,9	14)	2,4
Traganum nudatum	12)	2,2								
Plantago albicans	13)	2,1	15)	2,4						
Filago desertorum	14)	2,0								
Gymnocarpus decandrum	15)	1,9	8)	4,1						
Carduncellus mareoticus			2)	7,1						
Artemisia inculta			3)	6,1						
Helianthemum lippii			4)	5,0						
Launaea nudicaulis			5)	4,4						
Salsola tetrandra			9)	4,1						
Scorzonera alexandrina			11)	3,6						
Haloxylon scoparium			12)	2,6						
Astragalus trigonus			13)	2,6			11)	3,5		
Salsola schweinfurthii			14)	2,5						
Zygophyllum coccineum					1)	13,0	15)	1,5	2)	13,5
Cotula cinerea					2)	7,5	7)	5,0		
Salsola baryosma ssp.gaetula					3)	6,3	1)	10,8		
Schouwia thebaica					4)	6,0			13)	2,4
Zygophyllum simplex					5)	5,7				
Stipagrostis plumosa					6)	5,5				
Astragalus vogelii					7)	4,7			4)	8,5
Acacia raddiana					8)	4,7				
Atriplex leucoclada					9)	4,1				
Anastatica hierochuntica					10)	3,9	9)	4,5		
Pulicaria undulata					12)	3,8				
Oligomeris linifolia					13)	3,5				
Fagonia bruguieri					14)	2,0			11)	3,0
Monsonia nivea					15)	2,0				
Cornulaca monacantha							2)	10,7	12)	2,8
Fagonia arabica							3)	9,0	5)	6,9
Zygophyllum album							4)	8,4		
Suaeda vermiculata							6)	5,3		
Calligonum comosum							10)	3,9		
Convolvulus pilosellifolius							12)	2,3		
Tamarix nilotica							14)	1,9	15)	1,7
Stipagrostis acutiflora									1)	13,7
Salsola baryosma ssp.baryosma									3)	10,8
Fagonia indica									6)	4,6
Zilla spinosa									7)	4,3
Franoeuria crispa									8)	4,3
Trichodesma africanum									9)	3,9
Farsetia ramosissima									10)	3,9

also floristically (Table 21). The species number per relevé (15.5) is relatively high. The 15 most frequent species are listed in Table 21. *Thymelaea hirsuta*, although the most frequent species, comprises only 3.8 % of the total record number, again indicating the relatively high diversity.

Zone II can be classified as full desert. The precipitation ranges from 50–80 mm. The shrubby vegetation is contracted into the wadis (Thymelaea hirsuta-Plantago albicans ass., Salsola schweinfurthii subass., and Artemisia inculta-Carduncellus mareoticus ass. Thymelaea subass. and Atriplex subass., see Fig. 3 and 6). The dwarf shrub vegetation is still diffuse in the northern half of this zone but changes to the contracted mode in the southern half (Artemisia inculta-Carduncellus mareoticus ass. typical subass., Pituranthos tortuosus-Gymnocarpus decandrum ass.). Zone II, which comprises zone III–V of STAHR et al. 1985, is not settled any more, and is grazed normally by camels. The vegetation is permanent, but vegetation-free zones become more and more evident. In our relevés 90 species were found; this, again, is not a complete list, but is presumably closer to the total species number as it was in zone I (the same is true for the following zones). The species number per relevé is less than half the number of zone I (see Table 21). *Pituranthos tortuosus* becomes the most frequent species (11.7 % of all records), and 6 of the 15 most frequent species share this rank with the first zone.

A special type of the full desert is developed in the Qara region (zone IIa, Fig. 20). Here, at altitudes around or below sea level, and with good run-off conditions caused by the escarpment of the Qattara depression, a number of Sudanian species grow in isolation from their main area and form permanent and contracted vegetation with dwarf shrubs, shrubs and even trees (*Acacia raddiana*). These form the Zygophyllum coccineum-Schouwia thebaica ass. (Fig. 9) in a variety of subunits, the Zygophyllum coccineum-Acacia raddiana ass. (Fig. 13) and, of course, oasis vegetation. Zone IIa comprises zones VII + VIII of STAHR et al. 1985, and is grazed by camels. The species number per relevé (5.0) is similar to the number in zone II, likewise the most frequent species, *Zygophyllum coccineum*, comprises more than 10 % of the total record number. The list of the 15 most frequent species shows a spectacular change: just one species is in common with zone I, and not even one with zone II.

All remaining zones are extreme deserts. Extreme desert 1 (zone III) can be found mainly between 28° N and 30° N, i.e. in the south Qattara, Siwa, Sitra and Bahariya regions. But it extends, under favourite geomorphological conditions, south through the Farafra basin (Fig. 20). The vegetation is completely contracted and covers usually not more than 1 % of the landscape. A great deal of the vegetation is accidental (see zone IV), but regularly some specimens of plants are permanent. Whereas in the full desert the vegetation islands shows a concentric differentiation (e.g. Fig. 4A–D), the stands in extreme desert I tend to be uniform (e.g. Fig. 4E–G). Zone III still shows many vegetation units. In contact with the Qattara depression (= zone VI of STAHR et al. 1985), the Capparis aegyptia-Randonia africana ass. forms the north-

western, and the Anastatica hierochuntica-Anabasis articulata ass. the northern border of the alliance Zygophyllion coccinei (Fig. 6). The Stipagrostis plumosa ass., the Suaeda fruticosa ass., and the Cornulaca monacantha-Fagonia arabica ass. (the latter also in the Qara region) grow in this zone south of the Qattara depression (Fig. 11). Furthermore stands of *Calligonum comosum*, *Zygophyllum album*, and especially in the Farafra region, *Traganum nudatum*, *Francoeuria crispa*, *Imperata cylindrica* and rarely *Cocculus pendulus* have to be mentioned (cf. Fig. 12). No agricultural land use is carried out in zone III. In our relevés 53 species were found. The average species number per relevé is only half as high as in zones II and IIa. The flora is fading out but not changing so much: 8 out of 15 most frequent species are in common with zones II and/or IIa (Table 21).

Zone IV (= extreme desert 2) fills the greatest area of all zones (Fig. 20). The vegetation here is developed in traces: it is strictly contracted, covers much less than 0,1 % of the landscape and is in its overwhelming majority accidental. There is not much known about the growth of accidental vegetation (BORNKAMM 1987a). Only under extremely favorable run-off and soil conditions (ALAILY et al. 1987a) do the seed banks receive enough moisture, to wash out the inhibiting substances (BATANOUNY & ZIEGLER 1971a, b; BATANOUNY et al. 1972), so that the seeds can germinate. The life form of the species of accidental vegetation was described by HAINES (1951) as potential annuals. Perhaps, one should rather say potential perennials. According to recent investigations in the Assuan region (SPRINGUEL & SHEDED 1988), a short cyclic succession takes place: Fast growing plants show up first, others follow and many stay longer. Depending on the situation, the difference between accidental and permanent vegetation may be eliminated. Typical accidental vegetation types of zone IV are the Zygophyllum coccineum-Salsola baryosma ass., the Stipagrostis acutiflora-Zilla spinosa ass., and stands of *Salsola baryosma* and *Fagonia arabica*. In our relevés 39 species were found, the average species number per relevé is as low as 2.2 (Table 21). Although the vegetation is vanishing, some new plants, too, are among 15 most frequent species. The low diversity is indicated by the fact, that the three most important species together amount for 38 % of all records.

Zone V, finally (= extreme desert 3) is practically void of vegetation. Two factors are here acting together: The rainless climate with supposed precipitation of less than 1 mm/year, and the uniformity of the Selima Sand Shield. In the only limestone hill in this region (near Six Hills, see Fig. 15) remains of *Fagonia arabica* were found. In spite of the lack of producers, animal life exists. Small food chains, based on litter, and other ecosystem functions can be observed. Because these ecosystems derive from imported organic material they are termed allochthonous ecosystems (BORNKAMM 1987b, BORNKAMM & KEHL 1989). Many ecosystems are at least partially fed by allochthonous (airborne or waterborne) input (ODUM 1971), but the allochthonous ecosystems in our sense have no autochthonous carbon source at all. Large parts of zones II, III and especially IV are, as parts of other deserts of the world, covered with allochthonous ecosystems, but in zone V it is the only ecosystem

type existing. The entire Western Desert was not well sampled. The extreme west and the regions closer to the Nile deserve further investigations.

Zones III–V are virtually without agricultural land use. This does not mean that the human impact is low (BATANOUNY 1983). Since the organic functions are weak, further knowledge is needed to protect these vulnerable ecosystems (DRAZ 1961, ALAILY et al. 1987a, BORNKAMM & KEHL in 1989).

Acknowledgements. We thank Prof. Dr. M. KASSAS, Prof. Dr. K.H. BATANOUNY, Prof. Dr. N. EL-HADIDI (all Cairo) and Prof. Dr. M. AYYAD (Alexandria) for their advice, Prof. EL-HADIDI also for the allowance to work in the Cairo Herbarium. We thank Prof. Dr. H. SCHOLZ (Berlin/W.) for determination and revision of the Poaceae, and Prof. Dr. H. FREITAG (Kassel) of the Chenopodiaceae. We thank Mr. F. DARIUS and U. SCHNEIDER for sharing parts of the field work, F. DARIUS also for assistance in preparing the manuscript. We thank our colleagues from the soil science for friendly company in the field investigations and helpful discussions, namely Doz. Dr. F. ALAILY (Berlin/W.), Prof. Dr. H.P. BLUME (Kiel), Dr. M. MESHREF (Mansoura), Dr. J. POHLMANN, Prof. Dr. M. RENGER, J. GAUER and W. REINKE (Berlin/W.), Prof. Dr. K. STAHR (Stuttgart-Hohenheim). We thank Prof. Dr. O. WILMANNS (Freiburg) for critical remarks, Prof. Dr. Don WALLER (Madison/Wisconsin) for lingual revision of the manuscript and M. KAPPEL, C. MONIAK, R. SCHLICHT, U. SCHNEIDER, R. WEIDEMANN and A. DECKER for technical assistance. We thank the General Petroleum Company (Cairo) and many of their employees for cooperation, and the Deutsche Forschungsgemeinschaft for the grant which made this investigation possible.

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