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NODULATION STATUS OF LEGUMINOUS PLANTS IN SINDH

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Abstract

A survey of 115 leguminous plants comprising of 79 species of Papilionaceae, 16 of Mimosaceae and 20 of Caesalpiniaceae was made for their nodulation status. Nodules were found in all the species of Papilionaceae, all the species of Mimosaceae except *Adenanthera pavonina* but not in Caesalpiniaceae. *Vigna dalzelliana* (O. Kuntze) Verde., *V. mungo* (L.) Hepper var. Sialkot; *V. radiata* (L.) Wilezek. Pak.17, *V. radiata* (L.) Wilczek var. 71-17, *V. radiata* (L.) Wilczek var. 3854, *V. radiata* (L.) Wilczek var. 6601, *V. unguiculata* (L.) Walp. Tvx-02F.3871 and *V. unguiculata* (L.) Walp 1182 E-13 of the family Papilionaceae are reported for the first time as nodule bearing. *Caesalpinia gilliesii* (Hook) Dietr, *Cassia italica* (Mill). F.P. Andr, ssp. *italica* and *C. italica* ssp. *micrantha* Brenan of the family Mimosaceae are reported for the first time as non-nodulating. The shapes of nodules were mainly elongate, globose and branched whereas semi-globose and irregular shapes were also observed. The colour of the nodules varied from white to brown and pink. Pink coloured nodules were mainly associated with members of Papilionaceae.

Introduction

Leguminosae is the third largest family of Angiosperms with 16,000-19,000 species distributed in about 750 genera (Allen & Allen, 1981). The ability of many of the species to form nodules and fix atmospheric nitrogen symbiotically as a response to infection by *Rhizobium*, imparts considerable ecological and agronomic importance to the family. The global records of nodulation compiled by Allen & Allen (1981) show that at species level only 15% of legume species have been examined. Since the classic work of Allen & Allen (1981) many more leguminous species have been looked for nodulation and the data compiled between 1981-89 indicates that the percentage of legume species examined has risen to 20% (Faria *et al.*, 1989).

The flora of Pakistan is rich in Leguminosae which ranks as the third largest family in order of abundance (Ali & Qaiser, 1986) where 107 genera and 530 species have been reported (Ali, 1973a,b; 1977). Ather & Mahmood (1978, 1980, 1985, 1990) and Mahmood & Athar (1985) have contributed to the studies on nodulation status of legumes of Pakistan where a total of 318 species of Pakistani legumes have been examined in their natural habitats. In the present paper nodulation status of legumes of Sindh together with observations on the size, shape and colour of their nodules are presented.

Materials and Methods

Periodic field trips were made to various parts of Sindh during 1983-85. Both wild and cultivated species of legumes were examined for nodules in their natural habitats. Altogether 115 species comprising weeds, herbs, shrubs, climbers and trees were collected. Plants were pressed and dried and herbarium specimen were prepared. Plants found without nodules were grown from seeds in pots containing soils obtained from

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their natural habitats. The plants were inoculated at seedling stage with a *Rhizobium*/ Bradyrhizobium suspension containing a mixture of *Rhizobium trifolii*, *R. leguminosarum*, *R. phaseoli* and *B. japonicum* using the method of Grobbelaar *et al.*, (1967). The pots were kept under natual environment. In case of trees young plants of 2-6 months, usually growing close to adult plants of the same species were collected with the entire root system and nodules were obtained from their roots. Special care was taken to distinguish root nodules from root malformations such as those caused by nematodes, insects or other root inhabiting pathogenic microorganisms. The presence or absence and degree of nodulation on the root systems were noted. The size, colour, shape and distribution of nodules on roots was recorded. The nodules were preserved in vials containing anhydrous $CaCl_2$ (Somasegaran & Hoben, 1985) for future use.

Results and Discussion

Observations on nodulation survey are presented in Table 1. The nomenclature and classification follow those adopted by Ali (1973a,b; 1977). Among the leguminous plants growing in Sindh, members of the family Papilionaceae constitute the largest group. Of the 115 species examined, 79 belonged to Papilionaceae, 16 to Mimosaceae and 20 to Caesalpiniaceae. All the 79 species of Papilionaceae and 15/16 of Mimosaceae were found nodulated whereas all the members of Caesalpiniaceae were found non-nodulated (Table 1). The results were compared with the existing data summarized for the world by Allen & Allen (1981) and Halliday & Nakao (1982). The results of investigations were also checked against Faria *et al.*, (1989). Among the nodulating species *Vigna dalzelliana* (O. Kuntze) Verd., *V. mungo* (L.) Hepper var. Sialkot, *V. radiata* (L.) Wilczek var. Pak. 17, *V. radiata* (L.) Wilczek var. 71-17, *V. radiata* (L.) Wilczek var, 3854, *V. radiata* (L.) Wilczek. var. 6601, *V. unguiculata* (L.) Walp. TVX- 02F. 3871 and *V. unguiculata* (L.) Walp. 1182 E-13 are recorded for the first time to bear root nodules (Table 1). Among the species found as non-nodulating, *Caesalpinia gilliesii* (Hook) Dietr, *C. italica* (Mill) F.P. Andr. ssp. *italica* and *C. italica* spp. *micrantha* Brenan have not been reported before (Table 1).

The findings of the survey are similar to that of Allen & Allen (1981), Athar & Mahmood (1978, 1980, 1985, 1990), Lim & Burton (1982) and Faria *et al.*, (1989) that nodule formation is more commonly present than absent in Mimosaceae and Papilionaceae; the reverse is true in Caesalpiniaceae.

Failure to find nodules on a given plant at any one time does not necessarily mean that the plant is always non-nodulated. All the 20 species of Papilionaceae and *Adenanthera pavonina* of Mimosaceae found non-nodulating (Table 1) when grown in pots containing natural soil and inoculated with a mixture of *Rhizobium*/*Bradyrhizobium* strains showed that nodules were not produced on their roots and they were accepted as lacking nodulation ability. Our findings corroborate with Allen & Allen (1981) and Faria *et al.*, (1989) that species belonging to Caesalpinioid genera viz., *Bauhinia, Caesalpinia, Cassia, Delonix, Parkinsonia, Peltophorum* and *Tamarindus* are generally non-nodulating. Factors contributing to non-nodulation behaviour of Caesalpinioid legumes have been reviewed by Allen & Allen (1976). These include uncommon, sparse and thick walled root hairs; cortical root tissue much reduced; roots dark brown or black and wiry; occurrence of phenolic compounds, tannins, quinones and

Table 1. Nodulation Status and nodule morphology of legumes of Sindh.

S. No.	Legume Species	Habit	Nature	Nodulation status	Morphological characters of Nodule			
					Colour	Shape	Size (mm)	Distribution
1	2	3	4	5	6	7	8	9
	Caesalpiniaceae							
1.	*Bauhinia purpurea* L.	Tree	C	-				
2.	*B. variegata* L.	Tree	C	-				
3.	*Caesalpinia bonduc* (L.) Roxb.	Shrub	W	-				
4.	*C. gilliesii* (Hook.) Dietr.	Shrub	C	-				
5.	*C. pulcherrima* (L.) Swartz	Shrub	C	-				
6.	*Cassia alata* L.	Shrub	C	-				
7.	*C. auriculata* L.	Shrub	C	-				
8.	*C. fistula* L.	Tree	W	-				
9.	*C. holosericea* Fresen	Herb	W	-				
10.	*C. italica* ssp. *micrantha* Brenan	Herb	W	-				
11.	*C. italica* (Mill) F.W. Andr. ssp. *italica*	Herb	W	-	Not applicable			
12.	*C. occidentalis* L.	Shrub	C	-				
13.	*C. roxburghii* DC.	Tree	C	-				
14.	*C. senna* L.	Herb	W	-				
15.	*C. siamea* Lamk.	Tree	C	-				
16.	*C. surattensis* Burm. f.	Shrub	W	-				

Table 1 Cont'd)

1	2	3	4	5	6	7	8	9
17.	*Delonix regia* (Bojer) Rafin	Tree	W	-				
18.	*Parkinsonia aculeata* L.	Small Tree	C	-				
19.	*Peltophorum pterocarpum* (DC.) Backer ex. K. Heyne		Tree	C				
20.	*Tamarindus indica* L.	Tree	W	-				
	Mimosaceae							
1.	*Acacia farnesiana* (L.) Willd.	Tree	W	+ + +	Brown	Elongated	2.5	Primary & secondary roots
2.	*A. nilotica* (L.) Delile	Tree	W	+ +	Dark brown	-do-	2.0	-do-
3.	*A. nilotica* ssp. *hemispherica* Ali & Faruqi	Tree	W	+	Brown	-do-	3.0	-do-
4.	*A. nilotica* ssp. *indica* (Benth.) Brenan	Tree	W	+	Brown with pink apex	-do-	2.5	-do-
5.	*A. nilotica* ssp. *subalata* (Vatke) Brenan	Tree	W	+	Dark Brown	-do-	3.5	-do-
6.	*A. senegal* (L.) Willd.	Tree	W	+	Brown	-do-	3.5	-do-
7.	*Adenanthera pavonina* L.	Tree	W	-	-	-	-	-

Table 1 Cont'd)

1	2	3	4	5	6	7	8	9
8.	*Albizia lebbeck* (L.) Benth.	Tree	C.	+	Brown	Globose	2.0	Secondary roots
9.	*Leucaena leucocephala* (Lam.) dewit	Tree	W	+ + +	Pink	Elongated clusters	3.0	Primary & secondary roots
10.	*Mimosa hamata* Willd.	Shrub	W	+	Brown	Globose	2.0	-do-
11.	*M. pudica* L.	Shrub	W	+ +	Brown	Globose	2.5	Secondary roots
12.	*Pithecellobium dulce* (Roxb.) Benth.	Tree	C	+ + +	Brown with pink apex	Elongated	3.0	Primary & secondary roots
13.	*Prosopis cineraria* (L.) Druce	Shrub	W	+	Brown	Globose	2.5	Secondary roots
14.	*P. glandulosa* Torr.	Tree	W	+ + +	Brown	-do-	3.5	-do-
15.	*P. juliflora* (Swartz.) DC.	Shrub	W	+ + +	Brown	-do-	1.5	-do-
16.	*Samania saman* (Jacq.) Merr.	Tree	C	+ +	Dark brown	Elongated clusters	3.0	-do-
	Papilionaceae							
1.	*Alhagi maurorum* Medic.	Shrub	W	+ +	White	Semi globose	2.0	-do-
2.	*Alysicarpus bupleurifolius* (L.) DC.	Herb	W	+ +	White	Globose	2.0	-do-
3.	*A. heterophyllus* (Baker) Jafri & Ali	Herb	W	+ +	Brown	Globose with reticulate surface	2.0	Primary & secondary roots

Table 1 Cont'd)

1	2	3	4	5	6	7	8	9
4.	*A. longifolius* (Rottl. ex. Spreng.) Wight & Arn.	Herb	W	+	White	Globose with reticulate surface	4.0	-do-
5.	*A. monilifer* (L.) DC.	Herb	W	+ +	Brown	Semi-globose	2.0	Secondary roots
6.	*A. ovalifolius* (Sch.) J. Leonard	Herb	W	+ +	Pink	-do-	2.5	Primary & secondary roots
7.	*A. rugosus* (Willd) DC.	Herb	W	+ +	Brown	-do-	2.0	-do-
8.	*A. tetragonolobus* Edgeworth	Herb	W	+ +	White	Globose	2.5	-do-
9.	*Arachis hypogaea* L.	Herb	C	+ + +	Pink	-do-	4.5	-do-
10.	*Atylosia platycarpa* Benth.	Herb	W	+ + +	White	-do-	2.0	Secondary roots.
11.	*Cajanus cajan* (L.) Millsp.	Herb	W	+ +	White	Elongated	3.0	Primary & secondary roots.
12.	*Cicer arietinum* L.	Herb	C	+ + +	Pink	Elongated branched	3.0	-do-
13.	*Clitoria ternatea* L.	Woody	W	+	Brown	Semi-globose with reticulate surface	1.5	-do-

Table 1 Cont'd)

1	2	3	4	5	6	7	8	9
14.	*Crotalaria juncea* L.	Herb	W	+ +	White	Irregular	3.0	Primary roots
15.	*Crotalaria* medicaginea Lank.	Herb	W	+ + +	White	Elongated	3.0	Primary & Secondary roots
16.	*C. medicaginea* Lamk. var. *medicaginea*	Herb	W	+	White	Elongated branched	3.5	Primary & Secondary roots
17.	*Cyamopsis tetragonoloba* (L.) Taubert	Herb	C	+ +	White	Semi-globose	1.5	Secondary roots
18.	*Dalbergia latifolia* Roxb.	Tree	W	+ + +	Brown	Globose	2.0	-do-
19.	*D. sissoo* Roxb.	Tree	C	+ + +	Brown	-do-	3.5	-do-
20.	*Erythrina* sp.	Shrub	W	+ +	White	Semi-globose	3.2	-do- roots
21.	*Glycine max* (L.) Merroll.	Herb	C	+ + +	Whitish pink	Globose	4.0	Secondary
22.	*Indigofera argentea* Brum. f.	Herb	W	+	White	-do-	2.5	-do-
23.	*I. cordifolia* Heyne ex. Roth	Herb	W	+	White	-do-	4.0	-do-
24.	*I. hochstetteri* Baker	Herb	W	+	White	Semi-globose	2.0	Primary & Secondary roots
25.	*I. linifolia* (L.f.) Retz.	Herb	W	+ +	White	-do-	3.5	Secondary roots
26.	*I. oblongifolia* Forsk.	Shrub	W	+	White	Globose	2.0	Primary & secondary roots
27,	*I. sessiliflora* DC.	Herb	W	+ + +	Whitish pink	-do-	4.0	Secondary roots

Table 1 Cont'd)

1	2	3	4	5	6	7	8	9
28.	*Lablab purpureus* (L.) Sweet	Herb	C	+ + +	Pink	Globose	4.5	Primary & secondary roots
29.	*Lathyrus aphaca* L.	Trailing herb	W	+ +	Pink	Irregular	2.5	Primary roots
30.	*L. odoratus* L.	Herb	W	+ +	Pink	Elongated	2.0	Secondary roots
31.	*L. sativus* L.	Herb	W	+ +	Pink	-do-	3.0	Primary & secondary roots
32.	*L. sphaericus* Retz.	Herb	W	+ +	Pink	-do-	2.5	Secondary roots
33.	*Lens culinaris* Medic.	Herb	C	+ + +	Pink	-do-	2.5	Primary & secondary roots
34.	*Macroptilium lathyroides* (L.) Urb.	Herb	W	+ +	White	Semi-globose	2.5	-do-
35.	*Medicago lupulina* L.	Herb	W	+	Pink	Elongated	3.0	-do-
36.	*M. polymorpha* L.	Herb	W	+ + +	Pink	Elongated branched	3.0	-do-
37.	*M. sativa* L.	Herb	C	+ + +	Pink	-do-	2.5	-do-
38.	*Melilotus alba* Desr.	Herb	W	+ + +	Pink	-do-	2.5	-do-
39.	*M. indica* (L.) All.	Herb	W	+ + +	Pink	-do-	2.5	-do-
40.	*Phaseolus lunatus* L.	Herb	W	+ + +	Whitish pink	Globose	4.0	-do-
41.	*Pisum sativum* L.	Climber	C	+ + +	Pink	Elongated	3.0	-do-
42.	*Psophocarpus tetragonolobus* (L.) DC.	Herb	C	+ + +	Pink	Globose	4.0	Primary & secondary roots
43.	*Rhynchosia minima* (L.) DC.	Herb	W	+	Light brown	Semi-globose	2.0	-do-

Table 1 Cont'd)

1	2	3	4	5	6	7	8	9
44.	*R. pulverulenta* Stocks	Herb	W	+ +	White	Globose	1.5	Secondary roots
45.	*Sesbania bispinosa* (Jacq.) W.F. Wight	Tree	W	+ +	Pink	-do-	5.0	Primary & secondary roots
46.	*S. grandiflora* (L.) Poir.	Tree	W	+	White	-do-	3.0	-do-
47.	*S. concolor* Gillett	Unarmed shrub	W	+ + +	Pink	Globose with reticulate surface	3.0	-do-
48.	*S. sesban* (L.) Merrill	Tree	C	+ + +	Pink	-do-	2.5	-do-
49.	*S. sesban* (L.) Merrill var. *muricata* Baquar	Tree	W	+ + +	Pink	Globose to semi-globose with reticulate surface	5.5	-do-
50.	*S. sesban* (L.) Merrill var. *sesban*	Tree	C	+ + +	Pink	-do-	4.0	-do-
51.	*Taverniera lappacea* (Forssk) DC.	Shrub	W	+ +	White	Irregular	3.0	Primary & secondary roots
52.	*Tephrosia strigosa* (Dalz.) Sant. & Maheshw.	Herb	W	+ +	White	Globose	2.0	-do-
53.	*T. subtriflora* Baker	Herb	W	+ +	White	Semi-globose	2.0	-do-
54.	*T. uniflora* Pers. ssp. *uniflora*	Herb	W	+ +	White	-do-	2.0	Secondary roots
55.	*Trifolium alexandrianum* L.	Herb	C	+ + +	Pink	Elongated	2.0	Primary & secondary roots

Table 1 Cont'd)

1	2	3	4	5	6	7	8	9
56.	*T. pratense* L.	Herb	W	+ + +	Pink	-do-	3.0	-do-
57.	*Trifolium repens* L.	Herb	W	+ +	Pink	-do-	4.0	-do-
58.	*T. resupinatum* L.	Herb	W	+ +	Pink	-do-	3.5	-do-
59.	*Trigonella corni-culata* L.	Herb	W.	+	Pink	-do-	3.0	Secondary roots
60.	*T. foenum-graecum* L.	Herb	C	+ + +	Pink	-do-	5.0	Primary & secondary roots
61.	*T. gracilis* Benth.	Herb	W	+ +	Pink	-do-	3.0	-do-
62.	*T. monantha* C.A. Meyer	Herb	W	+	Pink	-do-	3.5	-do-
63.	*Vicia monantha* Retz.	Herb	W	+ +	Pink	Coralloid	5.0	Primary & secondary roots
64.	*V. sativa* L.	Herb	W	+ +	White	Elongated bi forked	2.0	-do-
65.	*Vigna aconitifolia* (Jacq.) Marechal	Herb	W	+ +	Pink	Globose	4.0	-do-
66.	*V. dalzelliana* (O.Kuntze) Verdc.	Herb	W	+ + +	White	-do-	4.5	-do-
67.	*V. mungo* (L.) Hepper	Herb	C	+ +	White	-do-	3.0	-do-
68.	*V. mungo* (L.) Hepper var. 48	Herb	C	+ + +	Whitish pink	Irregular	2.5	-do-
69.	*V. mungo* (L.) Hepper var. Sialkot.	Herb	C	+ + +	Pink	Globose	4.0	-do-

Table 1 Cont'd)

1	2	3	4	5	6	7	8	9
70.	*V. radiata* (L.) Wilczek	Herb	C	+ + +	Whitish pink	-do-	4.5	-do-
71.	*V. radiata* (L.) Wilczek var. Pak.17	Erect herb	C	+ + +	White	-do-	2.5	-do-
72.	*V. radiata* (L.) Wilczek var.71-17	Erect herb	C	+ + +	Pink	-do-	3.0	-do-
73.	*V. radiata* (L.) Wilczek var. 3854	Erect	C	+ + +	White	-do-	2.5	-do-
74.	*V. radiata* (L.) Wilczek var. 6601	Erect herb	C	+ + +	Pink	Globose	2.5	Primary & secondary roots
75.	*V. trilobata* (L.) Verdc.	Herb	C	+ +	Pink	-do-	2.0	-do-
76.	*V. unguiculata* (L.) Walp.	Herb	C	+ +	White	-do-	2.0	-do-
77.	*V. unguiculata* (L.) Walp. Tvx.-02F 3871	Herb	C	+ + +	White	-do-	2.5	-do-
78.	*V. unguiculata* (L.) Walp. 1182E-13	Herb	C	+ + +	Pink	-do-	3.0	-do-
79.	*V. vexillata* (L.) A. Rich.	Herb	W	+	White	-do-	4.0	-do-

-, indicates absence of nodulation, +, indicates sparse nodulation (1 to 5 nodules) per cm.

+ +, indicates moderate nodulation (6-15 nodules) per cm., + + +, indicates abundant nodulation (more than 15 nodules) per cm.

C, denotes cultivated plant, W, denotes wild plant.

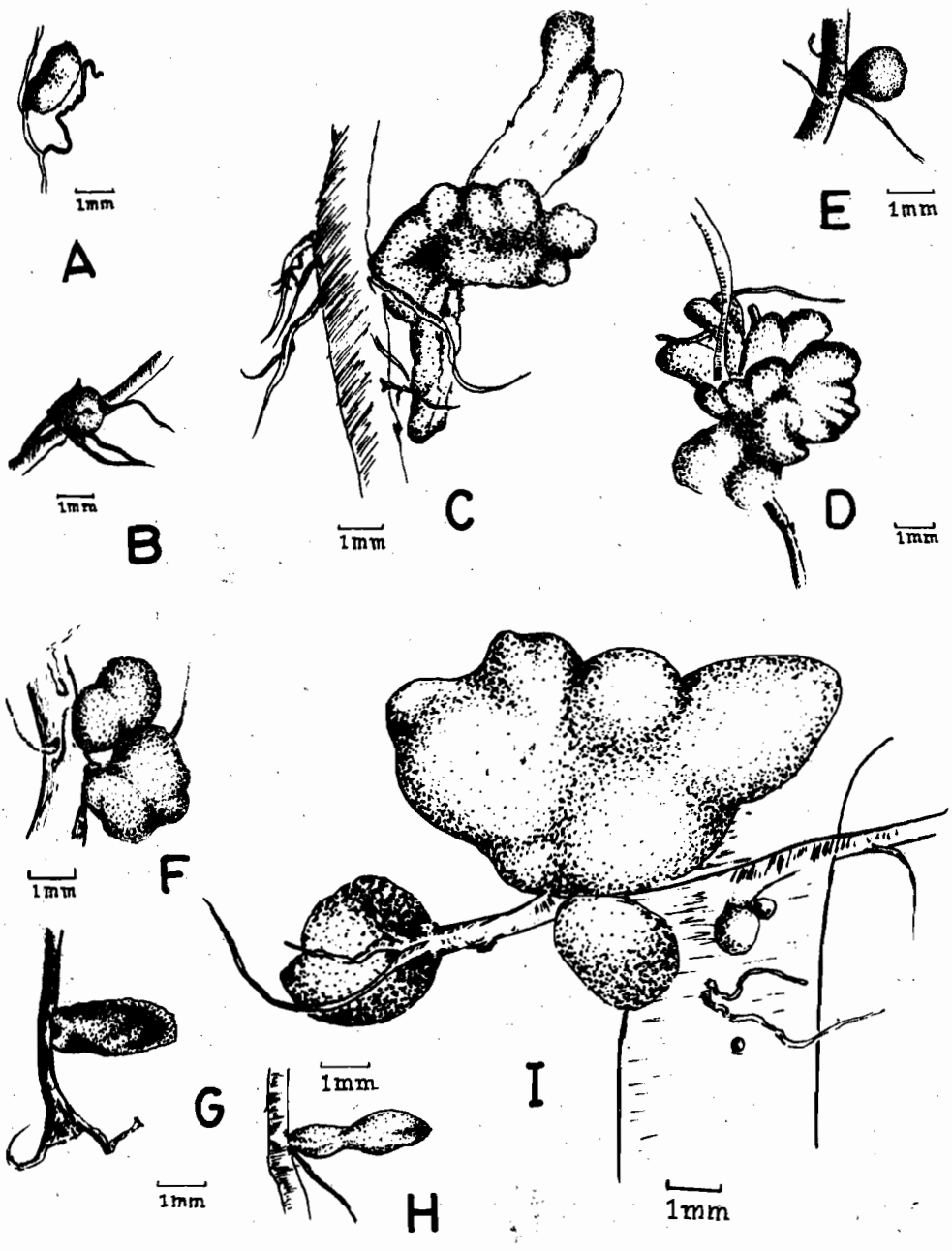

Fig. 1. Elongate: *Acacia nilotica* (L.) Delile. B. Semi globose: *Alysicarpus monilifer* (Linn.) DC: C. Elongate with branching, robust: *Pithecellobium dulce* (Roxb.) Benth: D. Elongate with short branching: *Alhagi maurorum* Medic., *E. Globose*: *Sesbania sesban* (Linn.) Merrill: F. Semi globose with short branching: *Rhynchosia minima* (Linn.) D.C., G. Elongate: *Cicer arietinum* Linn.: H. Elongate and constricted: *Medicago sativa* Linn.: H. semiglobose and lobed: *Sesbania concolor* Gillett.

derivatives in layers of cortical cells of the roots which presumably form a physiochemical barrier to infection by rhizobia (Allen & Allen, 1976). The degree of nodulation in nodulated species ranged from sparse to abundent in members of both the families Mimosaceae and Papilionaceae (Table 1) and the colour of the nodules varied between white, brown to pink.

The shape of the nodules conformed mainly to three types viz., elongate, globose and branched. However semiglobose and irregular shapes were also observed (Fig.1). These observations corroborate with Lim & NG (1977) who described similar nodule shapes for tropical legumes growing in Singapore. The nodule shape in Mimosaceae varied from globose to elongate, the elongate forms being branched. They were usually robust about 2-3 mm in diameter and upto several times as long as exemplified by nodules of *Pithecellobium dulce* (Fig.1C). Branched nodules of this type are shown in *Acacia* spp., by Allen & Allen (1936) and Corby (1971).

The nodules had a smooth surface except *Clitoria ternatea, Alysicarpus heterophyllus, Alysicarpus longifolius, Sesbania sesban* and *Sesbania concolor* which showed white fluffy streaks on their surface. This feature has been reported for nodules of *Calpogonium mucunoides* by Lim & NG (1977).

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References

Ali, S.I. 1973a. Mimosaceae, *Flora of Pakistan*, 36: 1-41. Department of Botany, University of Karachi.

Ali, S.I. 1973b. Caesalpiniaceae. *Flora of Pakisan*, 54: 1-47. Department of Botany, University of Karachi.

Ali, S.I. 1977. Papilionaceae. *Flora of Pakistan*, 100: 1-389. Department of Botany, University of Karachi.

Ali, S.I. and M. Qaiser, 1986. A phytogeographical analysis of the Phanerogams of Pakistan and Kashmir. *Proc. Royal Society of Edinburgh*, 89B: 89-101.

Allen, O.N. and E.K. Allen. 1936. Plants in the sub-family Caesalpinioideae observed to be lacking nodules. *Soil Sci.*, 42: 61-77.

Allen, O.N. and E.K. Allen. 1976. The nodulation profile of the genus *Cassia*. In: Symbiotic Nitrogen Fixation (Ed.) P.S. Nutman. Camb. Univ. Press, London: 113-122.

Allen, O.N. and E.K. Allen. 1981. *The Leguminosae, a source book of characteristics, uses and nodulation*. Univ. of Wisconsin Press, Madison.

Athar, M. and A. Mahmood. 1978. A qualitative study of the nodulating ability of legumes of Pakistan: List 1. *Pak. J. Bot.*, 10: 59-99.

Athar, M. and A. Mahmood. 1980. A qualitative study of the nodulating ability of legumes of Pakistan: List 2. *Trop. Agric.* (Trinidad), 57: 319-324.

Athar, M. and A. Mahmood. 1985. A qualitative study of the nodulating ability of legumes of Pakistan: List 3. *Trop. Agric.* (Trinidad) 62: 49-51.

Athar, M. and A. Mahmood. 1990. A qualitative study of the nodulating ability of legumes of Pakistan: List 4. *Trop. Agric.*, (Trinidad) 67: 53-56.

Corby. H.D.I. 1971. The shape of leguminous nodules and the colour of leguminous roots. *Plant and Soil*, Special volume. 305: 305-314.

Faria, S.M.DE., G.P. Lewise, J.I. Sprent and J.M. Sutherland. 1989. Occurence of nodulation in the Leguminosae. *New Phytol.*, 111: 609-619.

Grobbelaar, N., M.C. Van Beijma and C.M. Todd. 1967. A qualitative study of nodulating ability of legume species. List 1. Publ. Univ. Pretoria, N.S. 38: 1-9.

Halliday. J. and P.L. Nakao. 1982. *The symbiotic affinities of woody species under consideration as nitrogen-fixing trees*. A source document. NiFTAL Project and Mircen, University of Hawaii.

Lim, G. and H. L.NG. 1977. Root nodules of some tropical legumes in Singapore. *Plant & Soil*, 46: 317-327.

Lim, G. and T.C. Burton. 1982. *Nodulation Status of the Leguminosae*. In: *Nitrogen fixation* (Ed.) W.J. Broughton. Vol.2: 1-34. Clarendon Press, Oxford.

Mahmood, A. and M. Athar. 1985. Nodulation studies on legumes of Pakistan. In: *Nitrogen and Environment* (Eds.) K.A. Malik, M.Naqvi and M.I.H. Aleam, NIAB, Faisalabad, Pakistan, 225- 236.

Somasegaran, P. and H.J. Hoben. 1985. *Methods in Legume-Rhizobium technology*. University of Hawaii, NifTAL and Mircen. pp: 1- 367.

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