OBSERVATIONS ON THE NODULATION OF LEGUMINOUS PLANTS OF THE SOUTHWEST

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by

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Why the Investigations and Observations Were Made

Plants of the family Leguminosae are found widely distributed in the Southwest and often constitute an appreciable part of the flora of a given site, whether it be desert or high mountain meadow. An important characteristic of these plants is that they often contain root nodules in which are growing in symbiotic relationship nitrogen-fixing bacteria of the genus Rhizobium. Leguminous plants therefore are considered to be "soil builders" because they can, in association with the root-nodule bacteria, take nitrogen from the atmosphere and eventually add it to the soil where it can be used by associated non-leguminous plants.

Leguminous plants have been considered to be of particular importance by the soil conservationist since they may flourish in badly eroded soils where nitrogen is a limiting factor for the growth of other plants. It has often not been realized, however, that nodulation and subsequent nitrogen-fixation cannot be taken for granted in the development of a leguminous plant. The proper species of bacteria must be present in the soil to produce root nodules or must be supplied artificially by way of inoculation. The bacteria which produce nodules on different leguminous plants are not universally distributed in the soil. In addition to this, it is now well known that many of the bacteria which do produce nodules are not active nitrogen fixers and may in certain instances even be parasitic on the plant. There are some leguminous plants which do not produce nodules under any circumstances. Cursory examination of many leguminous plants in the field, extending over several years, did not show root nodules to be present and abundant in many instances. Most nodules observed did not appear to be healthy and were thinly scattered over the root system. It was consequently thought desirable to study the nodulation of leguminous plants native to the Southwest and of certain introduced species which are being tested out in Soil Conservation Service nurseries for possible use in this area.

A preliminary report on some of the results of these investigations follows:

1/ Soil Conservation Service and University of Arizona, cooperating.

2/ Now forest ecologist, Southwestern Forest and Range Experiment Station, Forest Service, U. S. Department of Agriculture.

Procedure

The method of procedure was threefold:

(a) Field trips were taken into different parts of Arizona and New Mexico for the purpose of collecting soil samples from the different environments where leguminous plants were found. The collected soil samples were to be used as inoculants for seed to be grown in the greenhouse. At the time of soil sample collection, leguminous plants were identified or collected for later identification and insofar as possible the root systems were examined for the characteristic root nodules. This method of examination was not entirely successful since the soils were often dry and difficult to break away from the root systems without destroying them. Furthermore, the plants were found in different stages of maturity.

(b) Consequently, when available, seed of the various leguminous plants were obtained primarily from the Soil Conservation Service but also from the field and grown in a greenhouse under more or less idealized conditions. Greenhouse sand was mixed with soil which had been collected in the field from the roots of the same plant growing under natural conditions. When the plants had reached satisfactory size, generally the seedling stage or just beyond, the entire root system was examined after carefully washing away the sand and soil particles. In most instances several soils were used which represented the range of environmental conditions observed in the field to support the growth of the particular leguminous plant being tested.

(c) The third method of procedure was to grow plants at the Soil Conservation Service Nursery in Tucson from seed and inoculate them with pure cultures of the bacteria in the usual manner. The cultures used, however, were of a "shotgun" variety made up of species of several of the cross-inoculation groups, since it was not known in most instances to which cross-inoculation group the different species belonged. During growth the plants on several occasions were dug up from the sandy soil of the nursery, the roots washed out against a screen, using a gentle stream of water, and examined for the presence of nodules. In all instances adjective descriptions of the judgment of the observer on the kind of nodulation were noted, i.e., "good to excellent," "poor to fair." This was based on number of nodules, whether or not they were in healthy condition, and whether or not they were scattered thinly through the smaller rootlets or clustered around the major tap root or principal arteries. This work was initiated by and under the immediate direction of Louis P. Hamilton, Soil Conservation Service Nursery manager at Tucson.

Results

The following three lists have been prepared more or less as check lists for the results obtained in these experiments. It is realized that the investigation has by no means been exhaustive and that many changes will subsequently have to be made as more observations are obtained or greater experience is had with the different species under natural growth conditions. Some of the plants which did not here contain nodules may, under a proper combination of environmental conditions, support a large number of them. Some of the plants which

showed poor nodulation may, under other circumstances, show excellent nodulation. However, these results are considered of importance in that they will tend to emphasize the fact that the nodulation of native legumes is not something which can be taken for granted; that the native legume is not always a soil builder; and that for their best use for erosion control, these plants may be enhanced by the proper nodulation. To determine how to obtain proper nodulation in all instances will require much additional study and investigation.

List No. 1:

Species of leguminous plants observed to have root nodules under one or more of the following conditions:

1 - Under natural conditions in the field.
2 - At the SCS Nursery, either with or without inoculation of the seed with commercial inoculant (a mixture of cultures from several "cross inoculation" groups) or
3 - In greenhouse pots after inoculation of the seed with soil collected from roots of the "wild" legume.

	Species	SCS Accession Number of Seed
1/	†Aeschynomene americana	
1/	†Amorpha fruticosa	A 2926
	†Astragalus sp.	A 2101, A 1850, A 2102, A 2103
	†Astragalus austrinus	A 9655
1/	†Astragulus lonchocarpus	A 9684
1/	†Astragalus nuttallianus	A 9653
	†Crotalaria lupulina	A 1907
1/	*Coronilla varia	
	†Dalea frutescens	A 8163
	†Dalea lagopus	
	†Dalea lumholtzi	A 2812
	†Dalea ordeae	A 8250
	†Dalea parryi	A 8274
	†Dalea pogonanthera	A 2323
	*Dalea sanctae crucis	A 8917

†Native to Southwest
*Good to excellent nodulation, both in field and greenhouse.
1/ Species also reported by others to bear nodules. See Appendix I for explanation.
Unstarred species, poor to fair nodulation

List No. 1, continued

	Species	SCS Accession Number of Seed
1/	†Desmanthus virgatus	A 9033
	†Desmodium sp.	A 8866, A 9137, A 11358
	†Desmodium batocaulis	A 9312
1/	†Hedysarum coronarium	A 3141
1/	*Lathyrus latifolius	A 9998
1/	Leucaena glauca	A 11618
	†Lotus alamosanus	A 9372
1/	*†Lotus corniculatus	A 8945
	†Lotus corniculatus var. ciliatus	A 422
	†Lotus greenei	A 9371
	Lotus grandiflorus	A 9988
	†Lotus humistratus	
	†Lupinus sp.	
	†Lupinus sparsiflorus	
1/	*Medicago orbicularis	A 11171
1/	*Mililotus alba	A 11697
	Onobrychis chorissanica	A 1574 and 1733
	*Onobrychis vulgaris	A 2123
	Phaseolus sp.	A 9650
	†Rynchosia texana	A 11345
	†Thermopsis montana	A 8258
	†Trifolium brandegei	A 9421
1/	*Trifolium dubium	A 11698
1/	*Trifolium fragiferum	A 11258
1/	*Trifolium lappaceum	A 1162
	*Trifolium resupinatum	A 11688
1/	*Trifolium subterraneum	A 11634
1/	Trigonella foenum graecum	A 10601
	*Vicia amoena	A 9626
1/	*Vicia cracca	A 9623
	*†Vicia exigua	A 3150
1/	*†Vicia noeana	A 1727
	*Vicia villosa	A 5518

List No. 2

Species of leguminous plants not containing root nodules. Plants examined in the field after inoculation of seed with commercial inoculant and in greenhouse after inoculation of the seed with soil collected in the field from roots of the same species growing under natural conditions.

	Species	SCS Accession Number of Seed
	†Acacia greggi	A 10211
	†Acacia suffrutescens	A 4
	Astragalus alopecios	A 1678
	Astragalus ammodendron-confirmans	A 1680
	Astragulus campyloninchus	A 1525
	Astragulus chirvensis	A 1683
2/	Astragalus cicer	A 9630
	Astragalus filicaulis	A 1527
2/	Astragalus rubyi	A 11257
	†Benthamantha edwardsi	A 8713
	†Cassia covesi	A 9661
	†Cassia leptocarpa	A 9559
	†Cercidium torreyanum	A 3270
2/	Coronilla glauca	A 287
	Coronilla juncea	A 288
	Dalea sp.	A 8165
	†Dalea albiflora	A 9515
	†Dalea amoena	A 8871
	Dalea batocaulis	A 11358
	†Dalea mollis	A 9502
	†Dalea wrighti	A 9543
2/	Desmodium purpureum	A 9923
	Desmodium supina	A 11496
	†Eysenhardtia orthocarpa	A 9520
	†Galactia wrighti	A 9175
	†Hedysarum pabulare	A 9403

2/ Species which have been reported by others to bear nodules. See Appendix 1 for explanation.

List No. 2, continued

	Species	SCS Accession Number of Seed
	†Hoffmannseggia densiflora	A 8908
	†Hoffmannseggia microphylla	A 2899
2/	Indigofera endecaphylla	A 11457
	Indigofera reticulata	A 3052
	†Indigofera sphaerocarpa	A 9798
	†Lotus rigidus	A 2773
	Lotus uliginosus	A 8947
	†Lotus wrighti	
2/	†Lupinus luteus	A 11497
2/	†Mimosa dysocarpa 3/	A 8990
	†Mimosa lemmoni	A 9339
	†Olneya tesota	A 3282
2/	†Parkinsonia aculeata	A 454
	Petalostemon sp.	A 8172, A 8226
	Petalostemon compactum	A 11337
	Petalostemon flavescens	A 9164
	†Phaseolus acutifolius	A 9165
	†Phaseolus metcalfei	A 129
	†Prosopis pubescens	A
	†Prosopis velutina	A 10222
	†Psoralea sp.	A 11367, A 9543
	†Sophora arizonica	A 9554
2/	†Tephrosia purpurea	
	Trigonella noeana	A 1625

3/ What may have been nodules were observed on one rootlet.

List No. 3

Species of leguminous plants examined in the field only and without observable root nodules; not checked in greenhouse either because of lack of seed or because seed on hand did not germinate.

	Species	SCS Accession Number of Seed
	†Astragalus nothoxys	A 9376
2/	†Astragalus wootoni	
	†Calliandra eriophylla	A 8857
	†Calliandra humilus	A 11582
	†Cassia bauhinioides	
	†Cassia wislizeni	A 9158
	†Chamaecrista leptadenia	A 9790
	†Chamaecrista wrighti	
	†Dalea formosa	A 2361
	†Krameria glandulosa	A 2284
	†Lathyrus decaphyllus	A 6089
	†Lathyrus graminifolius	
	†Lotus salsuginosus	
	†Lupinus concinnus	
	†Lupinus succulentus	
	†Prosopis glandulosa	
- 2/	†Psoralea tenuiflora	A 8731

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Leslie N. Goodding of the Soil Conservation Service, who helped initiate the project and who cooperated on it from the beginning. Many of the samples of soil in the field were collected by Mr. Goodding and some of the seed used in later greenhouse experiments were furnished by him. Root systems of naturally growing plants in the field were examined for the presence of root nodules.

Louis P. Hamilton, manager of the Soil Conservation Service Nursery at Tucson, who very kindly furnished most of the seed used in these experiments and who made many of the examinations of plants growing in the nursery. The "shot-gun" inoculation of seed planted in the nursery was also made by Hamilton and staff.

Lyman Benson, taxonomist of the University of Arizona, with whom many field trips were made and who made an accurate identification of plants in the field at the time of examination. Questionable plants were checked by him in the University Herbarium.

Joel E. Fletcher, project supervisor of the Soil Conservation Service Experiment Station, who assisted with the collection of soil samples and some of the greenhouse experiments.

O. N. Allen and Ethel K. Allen, Department of Agricultural Bacteriology, University of Wisconsin, who very kindly furnished the material contained in Appendix I after comparing the results of this experiment with those of other investigators on file in an exhaustive card catalogue at the University.

References

It is suggested that the following references be consulted for additional information on this important subject:

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* A complete and comprehensive work on the root-nodule bacteria of leguminous plants. Reference should be made to literature supplements published since 1932 in order to keep the publication up to date.

APPENDIX I

Dr. and Mrs. O. N. Allen of the Department of Agricultural Bacteriology, University of Wisconsin, are currently maintaining a card file on the nodulation of leguminous plants. They now have listed some 1,049 species of which 917 have been reported to bear root nodules and 132 none. This report was very kindly perused by them for comparison with current listings. It was found that 77 of the plants contained herein (24 nodulated and 53 non-nodulated) have not been reported upon in previous nodulation studies. Of the remainder, 11 species listed as non-nodulated under the conditions of this experiment have been reported by others to bear nodules and 18 species reported as nodulated confirm previous reports of nodule presence. These species are appropriately noted in the listings on pages 3 through 7.

Current information about the nodulation of leguminous plants may be obtained directly from Dr. and Mrs. Allen.

ACCELERATED EROSION PATTERN IN THE SOUTHWEST