Taiwania, **41**(4): 301-308, 1996

Observations on Nodulation Status of Some Papilionoid Species of Potential Agricultural and Forestry Value from Sacramento Valley, California

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(Manuscript received 29 May 1996; accepted 11 September 1996)

ABSTRACT: Legume-*Rhizobium* symbiosis contribute substantially to nitrogen economy of the soil with global utilization in sustainable agricultural systems. Due to the immense importance of legumes, nodulation was studied in 66 Papilionoid species from Sacramento Valley in California. Majority of the species were abundantly nodulated under natural soil conditions or when grown in uninoculated garden soil indicating distribution of wide range of naturalized rhizobia. Nodulation in 12 species within 6 genera is reported for the first time. The general account presented here is essentially first step in quantifying the contribution of these nodulated species to the nitrogen cycle of the biosphere.

KEY WORDS: Nodulation, Leguminosae (Papilionoideae), California.

INTRODUCTION

California horticulture and gardens are leaders in the use of native plants in their gardens. California flora includes more than 5800 species of which about 24% are endemic (Hickman, 1993). There exists much species diversity because of California' s geological, topographic and climatic diversity. Many of the California native plants are drought-tolerant and well adapted to summer-dry, Mediterranean-type climate found in most California high population areas. Native plants useful in gardens come from all climatic regions within California, which has the widest range of climate and growing conditions of any state (Skinner and Pavik, 1994).

Legumes have world-wide importance for food, fodder, fuelwood, and nitrogen source for natural and agro-ecosystems (Brockwell *et al.*, 1995). They are helpful in improving and maintaining soil fertility because most of the legumes are nodulated and fix atmospheric nitrogen (Allen and Allen, 1981; Thomas, 1995) and some legumes increase phosphorus availability to other plants (O'Dell and Trappe, 1992). Legumes are used in agriculture and forestry as intercropping or crop rotation to improve growth of companion crops (Brockwell *et al.*, 1995).

California flora is abundant in legumes population. There are 69 genera and 491 legume species found in California (Hickman, 1993). Some legumes are indigenous while others are

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introduced and have become widely naturalized (Witham, 1994). Nodulation and nitrogen fixation have been studied in legumes of agricultural importance from various perspectives. However, majority of the legumes found in California have not been examined for their nodulating ability. The present study was conducted to determine the nodulating ability of some naturally occurring or cultivated legume species of California. Due to the limitation of time and logistics, survey was focussed on the Papilionoid species only. Legumes surveyed included small weeds, cultivated plants and herbaceous ornamentals to large woody shrubs.

MATERIALS AND METHODS

Legume species growing under natural growth conditions were surveyed for their nodulating ability from eight counties of Sacramento Valley (38° 35'N, 121° 29'W). Sacramento Valley is in northern sub-region of Great Central Valley of California extending from Red Bluff in Tehama county to the salt marshes of Suisun Slough in southwest Solano county. Sacramento Valley is characterized by hotter, drier summer and by soils ranging from rich loams along Sacramento River to extensive hardpans that permit development of nutrient rich winter-wet but summer-dry vernal pools (Hickman, 1993). Several geological trends from California past are continuing. The most important of these are cold/warm cycles, increasing uplift (and accompanying inland aridity), northward movement of the Pacific Plate, and decreasing volcanism as the Juan de Fuca Plate moves north of California. The climate of the valley is marked by hot dry summer (average maximum and minimum temperature 31.5 and 11.2°C respectively, no precipitation) and cold and wet winter (average maximum and minimum temperature 10.2 and 1.5°C respectively, precipitation 650 mm). Clear sunshiny afternoons prevail during most days in California. But under the influence of the Pacific anticyclone considerable advectional and radiational cooling results in the almost nightly occurrence of low stratus clouds, the California stratus, and often of early morning radiational fog. Both clouds and fog, however, are generally dissipated before noon. The area is primarily agricultural, with vegetables, fruits and other produce crops thriving successfully the year round. Now predominantly under agricultural cultivation, Great Central Valley once supported grasslands, marshes, extensive riparian woodlands and islands of Valley-Oak savanna (Hickman, 1993).

Survey of nodulation among California legumes was conducted from summer 1995 through spring 1996. Wild legumes were examined under natural growth conditions while legumes of agricultural importance were observed from the cultivated fields. Legumes of horticultural significance particularly the lupins were studied from University Arboretum, and Environmental Horticulture Botanical Garden at University of California, Davis. Some legumes were grown in the field or in the greenhouse in pots filled with half and half mixture of UC mix and garden soil. The UC mix consists of equal volumes of sand, composted redwood and peat moss. Temperature in the greenhouse was maintained at 26 °C / 20°C day and night, respectively.

Special care was taken to discriminate root nodules from other kinds of root-malformation such as caused by nematodes, insects or other root-inhabiting parasitic microorganisms. Suspected root nodules were distinguished as described by Truchet *et al.*, (1989). In some cases nodule smears and nodule slices were prepared and examined under the microscope (Somasegaran and Hoben, 1994). Nodulation data were recorded and plant specimens were preserved for legume identification.

RESULTS AND DISCUSSION

The nodulation status of some of the California legume species is presented in Table 1. Most of the species examined were nodulated. Only the positive records of nodulation are reported here. According to compilations of reports on nodulation (Allen and Allen, 1981; Athar and Mahmood, 1980, 1985, 1990; Grobbelaar *et al.*, 1983; Corby, 1988; Faria *et al.*, 1989; Moreira *et al.*, 1992; Mahmood and Iqbal, 1994; Subramaniam and Babu, 1994), root nodules have not previously been reported in 12 legume species within 6 genera and these species form the new records (Table 1). The nodules observed in other species confirmed earlier reports (Allen and Allen, 1981; Athar and Mahmood, 1980, 1985, 1990; Mahmood and Iqbal, 1994).

Table 1. List of legume species examined for nodulation.

Species[1]	Legume Type[2]	Legume Habit[3]	Nodulating status[4]
Aeschynomeneae			
Arachis hypogaea L.	CG	H	A
Cicereae			
Cicer arietinum L.	CG	H	A
Galegeae			
Astragalus gambelianus E. Sheld.	WF	H	B
A. tener A. Gray	WF	H	B
Genisteae			
Lupinus affinis J. Agardh	CG	H	B
L. albifrons Benth.	CG	S	A
L. albus L.	CG	HS	A
L. arizonicus S. Watson	WG	H	B
L. bicolor Lindl.	CF	H	A
L. microcarpus Sims var. *densiflorus* (Beth.) Jepson	CF	H	B
L. nanus Benth.	CF	H	A
L. succulentus Koch.	CF	H	A
Indigofereae			
Cyamopsis tetragonoloba (L.) Taub.	CG	HS	A
Loteae			
Lotus corniculatus L.	WF	H	A
L. purshianus (Benth.) Clem.	WF	H	A
L. wrangellianus F. Muell.	WF	H	A
Millettieae			
Wisteria chinensis DC.	CF	V	A
Phaseoleae			
Cajanus cajan (L.) Millsp.	CG	ST	A
Clitoria ternatea L.	CG	H	A

Table 1. continued.

Species[1]	Legume		Nodulating status[4]
	Type[2]	Habit[3]	
Glycine max (L.) Merr.	CG	H	A
Lablab purpureus (L.) Sweet	CG	H	A
Phaseolus coccineus L.	CG	H	A
P. lunatus L.	CG	H	A
P. vulgaris L.	CG	H	A
Vigna aconitifolia (Jacq.) Marechal.	CG	H	A
V. mungo (L.) Hepper	CG	H	A
V. radiata (L.) Wilczek.	CG	H	A
V. unguiculata (L.) Walp.	CG	H	A
Psoraleeae			
Hoita macrostchaya (DC.) Rydb.	WF	H	B
Thermopsideae			
Thermopsis montana Nutt.	WG	H	A
Robinieae			
Sesbania tripettii (Poit.) Hort. ex F.T. Hubb.	CG	ST	B
Trifolieae			
Medicago lupulina L.	WF	H	A
M. polymorpha L.	WF	H	A
M. sativa L.	CF	H	A
Melilotus alba Medik.	WF	H	A
M. indica (L.) All.	WF	H	A
Trifolium albopurpureum Torr. & A. Gary	WF	H	A
T. barbigerum Torr.	WF	H	B
T. bifidum Gray	WF	H	A
T. campestre Schreb.	WF	H	A
T. ciliolatum Benth.	WF	H	A
T. cyathiferum Lindl.	WF	H	B
T. depauperatum Desv.	WF	H	A
T. dubium Sibth	WF	H	A
T. fragiferum L.	WF	H	A
T. fucatum Lindl.	WF	H	A
T. gracilentum Torr. & A. Gray	WF	H	B
T. hirsutum All	CF	H	A
T. microcephalum Pursh.	WF	H	A
T. microdon Hook. & Arn.	WF	H	A
T. pauciflorum Nutt.	WF	H	A
T. pratense L.	CG	H	A
T. repens L.	CG	H	A
T. subterraneum L.	CG	H	A
T. variegatum Nutt.	WF	H	B
T. willdenovii Spreng.	WF	H	A
Trigonella foenum-graecum L.	CF	H	A
Vicieae			
Lens culinaris Medik.	CG	H	A
Lathyrus jepsonnii E. Greene	WF	H	B
L. odoratus L.	CF	H	A
L. sativus L.	CF	H	A
Pisum sativum L.	CF	H	A

Table 1. continued.

Species[1]	Legume		Nodulating status[4]
	Type[2]	Habit[3]	
Vicia faba L.	CF	H	A
V. hirsuta (L.) S.F. Gray	WF	H	A
V. sativa L.	WF	H	A
V. villosa Roth.	WF	H	A

1. Species are arranged alphabetically within genera. The nomenclature and tribal classification are those following Polhill and Raven (1981). Authors citations are quoted following instructions of Brummit and Powell (1992) as endorsed by International Working Group on Taxonomy Database for Plant Science (TDWG).
2. Plant type:
   C = Cultivated; W = Wild; F = Studied in the field under natural conditions; G = Studied in the greenhouse by growing in garden soil.
3. Plant habit:
   H = Herb; S = Shrub; T = Tree; V = Vine or climber.
4. Nodulating status:
   A = Nodulation previously observed; B = Nodulation reported for the first time.

Nodules were distributed on the main as well as lateral roots and were found in the top 10 cm layer of soil. Nodules of a few legumes, including *Lupinus* spp. sometimes grew on the surface of soil and were covered with a layer of damp litter. Majority of the species were abundantly nodulated under natural soil conditions or when grown in uninoculated garden soil indicating distribution of wide range of naturalized rhizobia in California soil. Nodules occurred singly or in branched forms and were circular to elongate and their shapes coincided very much with the description of Corby (1988) and Mahmood and Iqbal (1994). The size and color of nodules varied for various species as well as within the phenological stage of the plant. Nodules were mostly pink or brown with reddish interior indicating their effectiveness in nitrogen fixation (Somasegaran and Hoben, 1994). Nodule morphology of new nodulating species are presented in Table 2.

There is an increasing interest in exploring nodulated legumes because of their great potential for soil enrichment in agriculture and forestry at adverse sites. However, it is necessary to select well-adapted combinations of legumes and rhizobia in order to exploit their nitrogen-fixing potential. It would also be appropriate to improve the genetic potential of nitrogen fixation by legume breeding and manipulation of rhizobia.

ACKNOWLEDGEMENT

Thanks are due to Dr. Warren Roberts for facilitating the collection from the University Arboretum, and Aroba Hafeez and Fiza Hafeez for their assistance in specimen collection. Special gratitude is expressed to Dr. Jim Harding for providing some of the legume seed, to Dr. Ellen Dean, Dr. Grady Webster and the staff at J. M. Tucker Herbarium for the identification and nomenclature of the plants. Appreciations are extended to Dr. S.M. de Faria, Dr. Janet I. Sprent and Dr. A. Mahmood for their cooperation in checking nodulated legumes against their record.

Table 2. Nodule morphology of new nodulating legume species.

Species	Frequency	Color	Size (mm)	Shape	Distribution
Astragalus gambelianus	++	Brown	2.5	Elongated	Primary root
A. tener	+	Reddish brown	3.0	Elongated	Primary root
Lupinus affinis	++	Pink	3.5	Globose	Primary and secondary roots
L. arizonicus	+	Pink	3.0	Globose	Primary and secondary roots
L. microcarpus var. *densiflorus*	+	Pink	4.0	Globose	Primary and secondary roots
Hoita macrostchaya	++	Brown	2.5	Elongated	Primary root
Sesbania tripettii	+++	Pink	3.5	Semi-globose to globose	Primary and secondary roots
Trifolium barbigerum	+++	Pink	3.0	Elongated	Primary and secondary roots
T. ciliolatum	+++	Pink	3.5	Elongated	Primary and secondary roots
T. cyathiferum	+++	Pink	3.0	Elongated	Primary and secondary roots
T. variegatum	+++	Pink	3.0	Elongated	Primary and secondary roots
Lathyrus jepsonnii	+++	Pink	3.0	Globose	Primary root

+ Indicates sparse nodulation (1 to 5 nodules per plant).
++ Indicates moderate nodulation (6 to 10 nodules per plant).
+++ Indicates abundant nodulation (more than 10 nodules per plant).

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美國加州 Sacramento 山谷地區及森林具有潛力的蝶形花亞科植物之根瘤形成的觀察

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(收稿日期：1996年5月29日；接受日期：1996年9月11日)

摘　　要

豆科植物與根瘤菌的共生對農地土壤中的氮肥力有很大的貢獻。由於豆科植物的重要性，本研究以生長在加州 Sacramento 山谷地區的 66 種蝶形花科植物之根瘤形成狀況加以觀察。生長在自然狀況的土壤中或是生長在未接種根瘤菌的園藝土壤中的品系均有很多根瘤的形成。本研究中有 6 屬 12 種植物是以前未被研究過的豆科植物。本研究初步探討這些具有根瘤的豆科植物於生物圈氮循環中的重要性。

關鍵詞：根瘤、豆科(蝶形花亞科)、加州。

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