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9. ABSTRACT

Bibliography of selected articles on legume/rhizobium symbiosis research, primarily compiled from computer and manual searches conducted for the University of Hawaii's NifTAL project. The listing consists of 1181 articles which appeared in specialized journals from 1971 through mid-1978. The citations are arranged by subject; 826 are annotated. Subjects include, among others, inoculation, nitrogen fixation, nodulation, rhizobium characteristics, and the effect of temperature and climate on growth rate and yield.

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THE LEGUME/*RHIZOBIUM* SYMBIOSIS IN TROPICAL AGRICULTURE: A Selective Bibliography with Annotations

NifTAL

Compiled for the
University of Hawaii NifTAL Project
United States Agency for International Development
by
John Bose, II

COLLEGE OF TROPICAL AGRICULTURE & HUMAN RESOURCES MISCELLANEOUS PUBLICATION 181
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THE LEGUME/*RHIZOBIUM* SYMBIOSIS IN TROPICAL AGRICULTURE:

A Selective Bibliography with Annotations

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1978

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Abstract: A subject arranged listing of selected articles appearing mainly in specialized journals from 1971 through mid-1978. Of the 1181 entries, 826 have been annotated to elicit their relevance to the subject of the bibliography.

PREFACE

Most of the items in this bibliography were located by a computer search of magnetic tapes of the National Agricultural Library Catalog (CAIN). Retrieval service was provided by the University of Hawaii College of Tropical Agriculture and Human Resources under a contract agreement with the U.S. Department of Agriculture Research Service. The CAIN retrievals were augmented by manual searches, offprint requests from listings in *Current Contents*, and by numerous articles received through the mail from cooperating workers.

The annotations were written after perusal of the full text of the articles. For this reason, only those items rather immediately available in Hawaii were annotated. An effort was made to relate all materials to the subject confines of this bibliography. In some cases this has involved a shift in emphasis from that expressed in the original article.

The subject assignments are admittedly arbitrary, intended not to isolate discrete areas of work but rather to facilitate a relating of the areas one to another. The syndetic suggestions at the conclusion of some sections should be consulted to broaden the search for certain kinds of information.

Institutional affiliations of authors as indicated on their individual papers are provided for identification only, and are by no means intended to give either current or complete addresses.

Unless otherwise indicated by an abbreviated language notation in parenthesis after the title, all articles are in English. Most of the non-English language publications include English summaries or abstracts.

This compilation is limited in scope, and claims neither inclusiveness nor comprehensiveness. Monographic works and publications of proceedings and symposia deserve fuller coverage to do justice to their contribution to the literature. Omissions are nevertheless regretted, and written suggestions for additions to be included in future supplements will be gratefully received. The regular mailing of offprint copies of relevant articles would be of greatest value to this continuing project.

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August, 1978.

01.* BIBLIOGRAPHIES, GENERAL REVIEWS, RESEARCH SURVEYS.

0101 Annotated bibliography of Australian work on *Rhizobium* published during 1948-1972.
Brockwell, J. (CSIRO, Canberra, Australia) and N. L. Murray.
CSIRO Div Plant Indus Tech Paper no. 33, 152 p., 1975.
Approximately 700 entries, with brief summaries of work conducted by Australians or by visitors working in Australia. Supplements are to be published at 5 year intervals.

0102 Biological nitrogen fixation, 1924-1974.
Burris, R. H. (U Wisconsin, Madison, WI, USA).
Plant Physiol 54(4):443-449, 1974.
Rotation of legumes with other crops was practiced in ancient times. It was not until the 1830's, when Boussingault established one of the earliest agricultural experiment stations, that an explanation for the benefit was offered. This review emphasizes advances in our understanding of the biochemistry of nitrogen fixation.

0103 List of theses and dissertations on peanuts and peanut related research.
Cheek, E. (Coastal Plain Stn, Tifton, GA, USA).
U Georgia Col Agr Exp Stn Res Rpt no. 107, 20 p., 1971.
An international, alphabetical listing of 97 theses and dissertations, with a subject index which includes some 175 key words. Four entries relate directly to the legume/*Rhizobium* symbiosis. This list is a continuation of an earlier, lengthier report (no. 54, 1969) by the same compiler. A subsequent report (no. 164, 1973) contains 83 entries under 139 subjects, but none on nitrogen fixation.

0104 Division of Tropical Agronomy annual report 1974-75.
CSIRO Div Trop Agron, Brisbane, Australia, 157 p., 1975.
A summary of research activities, with author index to research reports. There are sections on legume bacteriology and grain legume crops. See also previous and subsequent DTA-CSIRO annual reports.

0105 Pasture and forage research in tropical America.
Crowder, L. V. (Cornell U, Ithaca, NY, USA).
Cornell Int'l Agr Bul no. 28, 53 p., 1974.
"One in a series of publications designed to disseminate information concerned with international agricultural development." This bulletin contains 15 brief reports on recent research findings and improved

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* The first two digits preceding each entry designate the subject assignment, and the final two digits enumerate the individual entries under that subject. Entries are arranged alphabetically by author, then chronologically by date of publication.

practices, including one on legumes and nitrogen fixation. A bibliography, which updates the 1948 review by Roseveare, lists some 500 articles covering the literature to 1971.

0106 Le soja: physiologie appliquee. Bibliographie. (Fre)
Egli, N. (IRAT, Paris, France).
IPAT doc no. B 367, 145 p., 1975.
Contains 379 references, 1961-1974, including some on nitrogen fixation and the nodulation of soybeans.

0107 New progress in the research of symbiotic nitrogen fixation. (Chi)
Feng, C. L.
Acta Microbiol Sinica 16(2):183-184, 1976.

0108 Australian legume nodulation research, 1948--70.
Gibson, A. H.
In Pimats for sheep in Australia, p. 99-125; 294-319, 1972.

0109 The recent achievements in the study of the biological nitrogen fixation. (Rus)
Mishustin, E. N., Ed. (Akad Nauk, Moscow, USSR).
IBP Sov Natl Committee, Moscow, 215 p., 1971.
Has added title page, table of contents and summary in English.

0110 Bibliography of soils of the tropics. Volume 2: Tropics in general and tropical South America.
Orvedal, A. C. (Cornell U, Ithaca, NY, USA).
USAID Tech Ser Bul 17, 242 p., 1977.
A selection of entries from the National Agricultural Library catalog, US Department of Agriculture. Section 1, Tropics in general, was originally published seperately as Volume I. The present work contains some additions to that volume, plus 200 pages of references arranged by geographic areas, with brief notations as to contents and publication status of the cited materials.

0111 Bibliography of mungbean research.
Poehlman, J. M. (U Missouri, Columbia, MO, USA) and F. F-M. Yu-Jean.
U Mo Agr Exp Stn Spec Rept 184, 15 p., 1972.
Approximately 350 references, arranged alphabetically by author. The literature includes journal articles, monographs, reports, proceedings, theses, dissertations and reference works published from about 1890 through 1970.

0112 Bibliography of ground covers, green manuring and soil improvement of rubber.
Library, Rubber Research Institute of Malaya.
RRIM Libr Rept no. 28, 20 p., 1973.
Part 1, Ground covers and green manuring, 146 references up to 1970. Part 2, Green manuring and soil improvement, has 19 entries. In most cases abstracts are included.

0113 Nitrogen fixation.
Skinner, K. J. (Chem & Engr News staff, Washington, DC, USA).
Chem & Engr News 54(41):22-35, 1976.
A concise report on current research on biological nitrogen fixation (aerobic, anaerobic and facultative anaerobic), with numerous diagrams and illustrations. In a comparison of energy inputs for chemical (catalytic) and biological systems of N fixation, it remains uncertain which may prove to be the most practicable.

0114 Seed inoculation and nitrogen fertilization with Egyptian clover (*Trifolium alexandrinum* L.) and Persian clover (*Trifolium resupinatum* L.); a review of literature. (Ger)
Uehling, R.
Arch Acker Pflanz Bodenkd 15(12):999-1005, 1971.

0115 Nitrogen from microbes: Farrer Memorial Oration, 1972.
Vincent, J. M. (U New South Wales, Australia).
J Austral Inst Agr Sci, p. 236-249, Dec., 1972.
About 98% of the Earth's nitrogen is locked up in rocks, but at very low concentrations (about 50 ppm). Most of the remainder is atmospheric dinitrogen. Only 0.0007 of one percent is available to life. The role of microorganisms in the N economy is explained, with information toward the utilization of the legume/*Rhizobium* symbiosis. This paper is a general review, with extensive references.

In addition to the above bibliographies and reviews, the following references within this bibliography include extensive literature lists on the subjects indicated:

0507 Genetics & biochem of N fixation
1305 Pigeon pea (agronomy)
1335 Biochemistry of legume seed proteins
1336 Pigeon pea (general)
2231 Biological nitrogen fixation
2313 N fixation (detection & measurement)
2404 Nitrogenase
3408 *Rhizobium* physiology
3428 *Rhizobium* in the soil.

02. CARBON AND CARBON COMPOUNDS.

0201 The study of polysaccharides of *Rhizobium lupini* in pure culture and in symbiosis. (Rus)
Chermenskaia, I. E., A. N. Petrova and V. L. Kretovich.
Dokl Akad Nauk SSSR 215(2):481-483, 1974.

0202 Carbon dioxide fixation by lupin root nodules. I. Characterization, association with phosphoenolpyruvate carboxylase, and correlation with nitrogen fixation during nodule development.
Christeller, J. T. (DSIR, Palmerston N., New Zealand), W. A. Laing and W. D. Sutton.
Plant Physiol 60(1):47-50, 1977.
CO_2 fixation and PEP carboxylase levels were greater in nodule tissue than in either primary or secondary root tissue, increasing about 3-fold with

the onset of N_2 fixation. The maximum rate of CO_2 fixation was similar to rates of N_2 fixation and to reported values for amino acid translocation. Results suggest that the PEP carboxylase reaction rather than the tricarboxylic acid cycle provides the oxaloacetate used in the primary "carbon skeleton" acceptor for ammonia assimilation and amino acid synthesis.

0203 The extracellular polysaccharides of *Rhizobium japonicum*: compositional studies.
Tuckman, W. F. (CSIRO, Canberra City, Australia).
Carbohyd Res 46(1):97-110, 1976.
Examination of extracellular polysaccharides of 7 strains of *R. japonicum* by gas chromatograph showed more heterogeneity of composition than those of any other species yet examined. Five strains produced polysaccharides containing the same constituents, but in varying relative quantities. Investigations to determine possible relationships between polysaccharide types and interactions with soybean lectins are suggested.

0204 Influence of sucrose spraying on nodulation and yield of *Phaseolus aureus* L.
Iswaran, V. (IARI, New Delhi, India), A. Sen and N. P. Singh.
Plant Soil 36(3):717-718, 1972.
Weekly spraying with 1% sucrose increased nodulation, grain yield and nitrogen uptake in sterilized soil pot experiments.

0205 Isolation of 3-*O*-methyl-D-ribose from a *Rhizobium* polysaccharide.
Kennedy, L. D. (DSIR, Palmerston N., New Zealand).
Carbohyd Res 52:259-261, 1976.
Slow-growing, non-acid producing rhizobia produced extracellular polysaccharides which were markedly heterogeneous compared to those of fast-growing rhizobia. The third of three previously reported sugars has been identified as 3-*O*-methyl-D-ribose.

0206 Dynamics of carbohydrates in lupine plants in connection with symbiotic nitrogen fixation. (Rus)
Manorik, A. V. and L. P. Vlasenko.
Fiziol Biokhim Kul't Rast 4(1):16-19, 1972.

0207 The carbon balance of a legume and the functional economy of its root nodules.
Minchin, F. R. (Queen's U, Belfast, N Ireland) and J. S. Pate.
J Exp Bot 24(79):259-271, 1973.
Of the C gained photosynthetically by the shoot from the atmosphere, 26% is incorporated directly into its dry matter; 32% is translocated to the nodules, and 42% to the supporting root. Of the nodules' share, 5% is consumed in growth, 12% in respiration and 15% returned to the shoot via the xylem as amino acid compounds generated in N fixation. The nodules require 4.1 mg C (≡ 10.3 mg carbohydrate) for each mg of N fixed.

0208 The study of sugar and some enzymes on the carbohydrate metabolism of *Rhizobium lupini* in symbiosis. (Rus)

Petrova, A. N., I. E. Chermenskaia and V. L. Kretovich.
Dokl Akad Nauk SSSR 217(2):479-480, 1974.

0209 The effect of CO_2 enrichment on root nodule development and symbiotic N_2 reduction in *Pisum sativum* L.
Phillips, D. A. (Indiana St U, Terre Haute, IN, USA), K. D. Newell, S. A. Hassell and C. E. Felling.
Amer J Bot 63(3):356-362, 1976.
Acetylene reduction was significantly increased when plants were grown in the light with 6 hours of CO_2 enrichment. There may be a direct correlation between increased nodule mass and N fixation, however, such that the N reduced per unit of root nodule was not affected by the CO_2 enrichment.

0210 Translocation patterns in soybeans exposed to $^{14}CO_2$ at four different time periods of the day.
Russell, W. J. (U Missouri, Columbia, MO, USA) and D. R. Johnson.
Crop Sci 15(1):75-77, 1975.
After 1 hour exposures to $^{14}CO_2$ at either 9 AM, 11 AM, 1 PM or 3 PM, field grown soybeans at mid-bloom were harvested 0, 1, 3, 6 and 24 hours after labeling. Following the hour of exposure, 16.9% of the total recovered ^{14}C had been exported from the leaves. After 24 hours, 36.9% had been exported. Highest net C fixation and export rates occurred between 11-12 AM and 3-4 PM.

0211 Carbon-14 assimilate translocation in nodulated and nonnodulated soybeans.
Russell, W. J. (U Missouri, Columbia, MO, USA) and D. R. Johnson.
Crop Sci 15(2):159-161, 1975.
Leaves of plants totally dependent on symbiotically fixed N exported 14% more ^{14}C to the roots and nodules than was exported to the roots of non-nodulating plants. At harvest time, the nodule component contained no more than 2% of the total recovered ^{14}C.

0212 A comparison of the effect of straw incorporation and CO_2 enrichment on the growth, nitrogen fixation and yield of soya beans.
Shivashankar, K. (Katholieke U Leuven, Heverlee, Belgium), K. Vlassak and J. Livens.
J Agric Sci (Camb) 87:181-185, 1976.
Incorporation of straw increased the CO_2 content of the soil and air, improving plant growth. The straw is a partial substitute for expensive carbon dioxide enrichment for improving N fixing capacity.

0213 Energy requirement for symbiotic nitrogen fixation.
Silsbury, J. H. (U Adelaide, Glen Osmond, S Australia).
Nature 267(5607):149-150, 1977.
To test the hypothesis that the energy required for either symbiotic N fixation or soil nitrate assimilation is about the same, the CO_2 flux associated with each was measured. From CO_2 exchange, it was concluded that the energy requirement for symbiotic N fixation by subterranean clover is substantially greater than that required for the assimilation of mineral nitrogen from the soil.

0214 Fragmentation analysis of extracellular acid polysaccharides from seven *Rhizobium* strains. I. D-glucuronic acid-containing oligosaccharides.
Sæma, R. (Agr U of Norway).
Carbohyd Res 43(1):145-149, 1975.
Characterization of the components indicated the presence of chains containing two β-(1→4)-linked D-glucoronic acid residues, β-linked to D-glucose at position 4.

0215 Carbohydrates in soybean nodules: identification of compounds and possible relationships to nitrogen fixation.
Streeter, J. G. (Ohio Agr Res & Dev Ctr, Wooster, OH, USA) and M. E. Bosler.
Plant Sci Ltr 7(5):321-329, 1976.
Seven carbohydrates were identified by gas-liquid chromatography. The concentrations of sucrose and (+)-pinitol were positively correlated to acetylene reduction. Methods for thin layer chromatogram separations are given.

For additional references with information on carbon and carbon compounds, see relevant listings under:
Inoculant materials
Photosynthesis and photosynthates
Rhizobium cultures and culture media.

03. COMPETITION (MICROBIAL).

0301 Competition between *Rhizobium leguminosarum* strains for the formation of nodules on field beans caused by inoculation and indigenous strains. (Fre)
Amarger, N.
C R Hebd Seances Acad Sci Ser D Sci Nat 279(6):527-530, 1974.

0302 Persistence and competition aspects of *Rhizobium japonicum* observed in soil by immunofluorescence microscopy.
Bohlool, B. B. (U Minnesota, St. Paul, MN, USA) and E. L. Schmidt.
Proc Soil Sci Soc Am 37(4):561-564, 1973.
A fluorescent antibody specific to strain 110(USDA) was used to evaluate persistence and competitive ability in 3 soils. This strain is important in midwestern US soils. Relatively high inoculant,resident ratios were required to overwhelm the resident population.

0303 Host-*Rhizobium* interaction between *Phaseolus vulgaris* L. and *Rhizobium phaseoli*.
Das, S. N. (B. K. Chandra Col, Calcutta, India) and P. N. Bhaduri.
Proc Ind Natl Sci Acad Pt B Biol Sci 40(5):554-561, 1974.
In various combinations of multi-strain inoculation, it was noted that the presence of a new strain may affect the competitiveness of one strain over

the other. Differential host preference for particular strains was observed, confirming that host preference constitutes a primary limiting factor in inter-strain competition.

0304 Competitive ability of *Rhizobium lupini* strains. (Rus)
Dorosinskii, L. M. and N. M. Makarova.
Mikrobiologiia 46(1):143-148, 1977.

0305 Competition amongst rhizobial strains for the colonization and nodulation of two tropical legumes.
Franco, A. A. (U New South Wales, Australia) and J. M. Vincent.
Plant Soil 45(1):27-48, 1976.
Inter-strain competition in association with *Macroptilium atropurpureum* and *Stylosanthes guianensis* was studied. Related substrains competed more with one another than did strains of less similar growth habit. Competetive success could not be related to any single feature of the symbiosis. In limited cases, competitiveness was inversely related to effectiveness, particularly with stylo.

0306 Competition among strains of rhizobia.
Ham, G. E. (U Minnesota, St. Paul, MN, USA).
In Proc World Soybean Res Conf p. 144-150, 1976.
The search for more effective strain-variety combinations is academic unless a way to enhance competition of applied rhizobial strains can be found. The competition occurs between strains of the natural soil population, between naturalized strains and inoculum strains and between strains in a mixed inoculum. Competitive success probably depends on many interacting factors for survival, rhizosphere colonization, and for infection sites on the host roots.

0307 Residual effects of different strains of *Rhizobium japonicum*.
Kabi, M. C. (Burdwan U, India).
Proc Ind Natl Sci Acat Pt B Biol Sci 42(1):46-52, 1976.
Enrichment of soil with specific rhizobia produced only short durational effects in boosting nodule numbers in 4 varieties of soybeans. Exotic strains lost their nodulating ability to local strains over a 3 year period.

0308 Competitive relations among races of nodule bacteria during formation of nodules and effectiveness of [nitrogens]. (Rus)
Kalnin'sh, A., V. Klasens and I. Leimane.
In Khimiia I Biologiia pt 2, p. 81-83, 1971.

0309 Competing ability of *Rhizobium trifolii* strains and effectiveness of clover inoculation on cutover peatland. (Rus)
Krylova, L. N. and A. T. Novikova.
Mikrobiologii 45(4):704-709, 1976.

0310 Competition between an introduced strain and native Uruguyan strains of *Rhizobium trifolii*.

Lobandera, C. A. (U New South Wales, Australia) and J. M. Vincent.
Plant Soil 42(2):327-347, 1975.
The effective introduced strain TA 1 dominated the ineffective native strain on *Trifolium repens* and *T. subterraneum*, but was less dominant and ineffective on *T. polymorphum*. Field tests for competition and persistence under varying environmental conditions are needed to augment these laboratory tests.

0311 Nodulating competitiveness amongst strains of *Rhizobium meliloti* and *Rhizobium trifolii*.
Marques Pinto, C. (U New South Wales, Kensington, NSW, Australia), P. Y. Yao and J. M. Vincent.
Aust J Agric Res 25(2):317-329, 1974.
An attempt to assess the relative success of competing strains of rhizobia in the formation of nodules with their by means of their relative representation on the root surface These ratios yielded a 'competitive index' defined as the ratio of nodules due to each strain under conditions of equal representation on the root.

0312 Nodulation of *Trifolium subterraneum* by introduced rhizobia.
Roughley, R. J. (Hort res stn, Gosford, NSW, Australia). W. M. Blowes and D. F. Herridge.
Soil Biol Biochem 8(5):403-407, 1976.
Four introduced rhizobial strains were used singly or as mixed strain inocula on 2 varieties of clover at 5 sites. Marked differences in competitive ability were seen, but these were modified by the host and site. In a location where there were no native rhizobia, 100% of the nodules were formed by the inoculum strain the first year, but by the second year invasion of serologically unrelated strains had occurred. By the third year, these formed almost all the nodules. The proportion of nodules formed by inoculum strains declined markedly by the second year at all sites.

0313 Morphophysiological peculiarities of nodule bacteria as related to their competitive capacity. (Rus)
Shil'nikova, V. K. and A. M. Shatta.
Izv Timiriazevsk S-kh Akad 3:9-14, 1975.

0314 Competition between inoculum strains of *Rhizobium japonicum* in the process of soybean nodulation during three planting periods.
Skrdleta, V. (Res Inst Crop Produc, Prague, Czechoslovakia).
Folia Microbiol 18(4):341-347, 1973.
The infectivity of strains D 216 and 311 B was practically the same. However, in subsequent tests for residual survivors, a statistically significant nodulation shift in favor of D 216 was recorded.

For additional references with information on microbial competition, see relevant listings under:
Inoculation effects and requirements
Microorganisms (other than rhizobia)
Specificity and promiscuity
Survival (microbial)

04. ENZYMES (OTHER THAN NITROGENASE).

0401 Relation between glutamine synthetase and nitrogenase activities in the symbiotic association between *Rhizobium japonicum* and *Glycine max*.
Bishop, P. E. (U Wisconsin, Madison, WI, USA), J. G. Guevara, J. A. Engelke and H. J. Evans.
Plant Physiol 57(4):542-546, 1976.
A role in the regulation of nitrogenase by glutamine synthetase, as has been reported in *Klebsiella spp.*, was not found in *R. japonicum*.

0402 Enzymes of nitrogen metabolism in legume nodules: purification and properties of N A D H-dependent glutamate synthase from lupin nodules.
Boland, M. J. (DSIRO, Palmerston N, NZ) and A. G. Benny
Eur J Biochem 79(2):355-362, 1977.
The enzyme, purified 500-fold from the plant cytoplasm fraction of *Lupinus augustifolius* nodules, consisted of a single polypeptide chain with a molecular wt of 235,000 ±10%. The interaction of this enzyme with others involved in ammonia metabolism in the cytoplasmic fraction of the N-fixing nodule is to be investigated.

0403 Certain carbohydrate-metabolism enzymes in the nodules of yellow lupine.
Chermenskaia, I. E. and A. N. Petrova.
Appl Biochem Microbiol 10(2):219-223, 1974.

0404 Hydrogenase in legume root nodule bacteroids: occurrence and properties.
Dixon, R. O. D. (U Edinburgh, Scotland).
Arch Microbiol 85(3):193-201, 1972.
A comparison of the hydrogenase found in *Rhizobium* bacteroids with that found in *Azotobacter* revealed similarities in all respects examined. The enzyme is apparently present in relatively few rhizobial strains. Hydrogenase appears to enhance the nitrogen fixing process, but the precise function was not determined.

0405 The effect of nitrogen addition on N_2 fixation and on glutamate dehydrogenase and glutamate synthase activities in nodules and roots of soybeans inoculated with various strains of *Rhizobium japonicum*.
Duke, S. H. (U Minnesota, St. Paul, MN, USA) and G. E. Ham.
Plant Cell Physiol 17(5):1037-1044, 1976.
Glutamate dehydrogenase (GDH) activity was decreased in root nodules, but increased in roots, by the addition of urea. Greatest inhibition was in the bacteroid mitochondral fraction. In general, rhizobial strains producing nodules with high GDH activity produced bacteroids with low glutamate synthase activity. Those with low GDH had the highest GOGAT activity.

0406 Catalase activity and nitrogen fixation in legume root nodules.
Francis, A. J. (Cornell U, Ithaca, NY, USA) and M. Alexander.
Can J Microbiol 18(6):861-864, 1972.
Significant differences in the catalase content of nodules and bacteroids

of varying degrees of effectiveness were found, but establishing the validity of the correlation will require further testing. A possible implication of hydrogen peroxide in rhizobia effectiveness is discussed.

0407 Accumulation of 4-aminobutyrate in *Trifolium subterraneum* root nodules: effect of *Rhizobium trifolii* strain on aminotransferase activity.
Freney, J. R. (CSIRO, Canberra City, ACT, Australia) and A. H. Gibson.
Aust J Plant Physiol 2(4):663-668, 1975.
A study of the metabolism of 4-aminobutyrate in root nodules as it affects the differential accumulation of this amino acid in nodules formed by two strains of *R. trifolii* - NA30 (accumulating) and TA1 (non-accumulating). Further work will be required to substantiate suggestions as to possible causes for the greater or lesser accumulation, which affect the quantity of fixed N available to the host plant.

0408 Studies on the dehydrogenase capacity, glucose consumption, and phosphorus utilization by strains of rhizobia.
Gupta, K. B. (Panjab U, India), K. S. Dadhich, L. K. Gupta and S. Ahuja.
Zentralb Bak Par Infek Hyg Abt 2 ... 125(7):670-674, 1971.
A wide variation among strains from the same species was observed. In some strains exhibiting normal glucose consumption and P utilization, the dehydrogenase capacity was very low.

0409 Physiological levels and properties of polynucleotide phosphorylase of *Rhizobium meliloti*.
Hunt, R. E. (U Houston, TX, USA) and J. R. Cowles.
J Gen Microbiol 102(2):403-411, 1977.
Polynucleotide phosphorylase activity of symbiotic *R. meliloti* was about 50% of that of free living *R. meliloti* and remained almost constant throughout nodule development. The enzyme had a pH optimum of 8.0 and a requirement of Mg^{2+} for maximum activity.

0410 A possible new nucleoside diphosphatase from the cytosol of soybean and alfalfa nodules.
Hunt, R. E. (U Houston, TX, USA), J. L. Haynes and J. R. Cowles.
Plant Physiol 59(4):773-774, 1977.
This newly-reported enzyme differs from other diphosphatases in that it does not exhibit a strong preferance for one nucleoside diphosphate over another. Very little, if any, diphosphatase activity was detected in root extracts of the legume seedlings.

0411 Ammonia assimilation and nitrogen fixation in *Rhizobium meliloti*.
Kondorosi, A. (Biol Res Ctr, Szeged, Hungary), Z. Svab, G. B. Kiss and R. A. Dixon.
Mol Gen Genet 151(2):221-226, 1977.
Glutamine synthetase and glutamate synthase were present at relatively high levels in cells grown in media containing either low or high

concentrations of ammonia. NADP-linked glutamate dehydrogenase could not be detected. A mutant lacking glutamate synthase (GOGAT) activity was effective in N fixation, while a mutant lacking glutamine synthetase (GS) activity was ineffective. GS is suggested as a controlling factor in N metabolism.

0412 Citric acid cycle enzymes and nitrogenase in nodules of *Pisum sativum*.
Kurz, W. G. (Prairie Reg Lab, Saskatoon, Sask., Canada) and T. A. LaRue.
Can J Microbiol 23(9):1197-1200, 1977.
The fact that isocitric dehydrogenase activity in bacteroids is highest at the time of maximum N fixation is presumptive evidence that the enzyme provides the reductant for N fixation.

0413 Glutamine synthetase and control of nitrogen fixation in *Rhizobium*.
Ludwig, R. A. (Mass. Inst Technol, Cambridge. MA, USA) and E. R. Signer.
Nature 267(5608):245-248, 1977.
Since nitrogen fixation by free living rhizobia seems to occur only at the end of exponential growth, bacterial growth cannot be shown to be dependent on nitrogenase activity. In *Klebsiella pneumoniae*, nitrogenase expression is regulated by glutamine synthetase. GS also appears to be involved in the control of nitrogenase expression by rhizobia, and may affect the shift in nodule metabolism from bacterial to plant cell utilization of ammonium.

0414 Galactomannan structure and β-mannanase and β-mannosidase activity in germinating legume seeds.
McCleary, B. V. (U Sydney, NSW, Australia) and N. K. Matheson.
Phytochem 14:1187-1194, 1975.
Galactomannans are a major component of the endosperm in the seeds of a number of families, including *Leguminosae*. Structural changes and enzymatic activity during germination were studied.

0415 The purification and properties of the glutamine synthetase from the cytosol of soybean root nodules.
McParland, R. H. (Oregon St U, Corvallis, OR, USA), J. G. Guevara, R. R. Becker and H. J. Evans.
Biochem J 153(3):597-606, 1976.
Glutamine synthetase is one of the enzymes involved in ammonium utilization by plants. From analytical data and measurement of electron micrographs, it is concluded that glutamine synthetase from nodule cytosol consists of 8 subunits arranged in 2 sets of planar tetramers forming a cubical configuration about 100 Å across each side. Enzyme activity is strikingly influenced by the relative proportion of Mg^{2+} and Mn^{2+} in the assay medium.

0416 Light and electron microscopic localization of peroxidase during the development of root nodules of *Pisum sativum* L.
Mennes, A. M. (Rijksuniversiteit, Leiden, The Netherlands), H. Oostrom and F. E. Treurniet,

In Plant growth substances; proceedings of the international conference, 8th, p. 655-662, 1974.

All the IAA-oxidase isoenzymes separated from root cortex and nodules exhibited peroxidase activity, but localization showed absence of activity in the bacteroid cytoplasm. This may account for hyperauxiny in root nodules. Peroxidase activity in the infected area of the root cortex was unexpectedly increased in early nodulation, raising the question whether enough IAA from the infection thread reaches the target cells in the cortex without being degraded unless the IAA oxidase is carefully regulated.

0417 Amide-amino acid synthetases of *Phaseolus aureus* - *Rhizobium phaseoli* symbiotic system.
Nainawatee, H. S. (Haryana Agr U, Hissar, India), S. Rathee and D. S. Wagle.
Plant Biochem J 4(1):10-13, 1977.

Enzyme activities of both glutamine synthetase and asparagine synthetase were high, and proportionately constant in ratio, in nodules compared to root and leaves. A tentative pathway for ammonia assimilation is proposed, although several aspects remain unknown.

0418 Role of polygalacturonase in legume-*Rhizobium* symbiosis.
Rao, A. V. and V. Iswaran.
Ind J Exp Biol 14(3):204-206, 1976.

0419 Connection between nitrate reductase activity of *Rhizobium lupini* bacteroids and respiration and nitrogen fixation.
Romanov, V. I. (A. N. Bakh Inst Biochem, Moscow, USSR), V. L. Kretovich, N. G. Fedulova and A. V. Korolev.
Sov Plant Physiol 23(3):521-524, 1976.

A close correlation between nitrate reductase activity and symbiotic N fixation was confirmed in these studies. Effective bacteroids had a respiration rate twice that of ineffective bacteroids. The nitrate reductase and reductase of bacteroids apparently have a common molybdenum containing component, which may participate in the synthesis of one or the other enzyme.

0420 Distribution of the proteinaceous inhibitor of ethylene synthesis in leguminous seeds.
Sakai, S. (Okayama U, Kurashiki, Japan).
Plant Cell Physiol 16:529-532, 1975.

Four inhibitors were identified by chromatographic elution profiles. Those with molecular weights of 112,000 and 56,000 were contained in extracts from all 6 legume seeds tested.

0421 Fructose 1,6-biphosphate aldolase activity of *Rhizobium* species.
Siddiqui, K. A. (U Burdwan, India) and A. K. Banerjee.
Folia Microbiol 20(5):412-417, 1975.

This key enzyme of the EMP pathway of glucose dissimilation was found in all species of the genus *Rhizobium*. The enzyme activity was studied

in 3 representative species. Optimum temperature for adolase activity was 55°C, sharply falling above 60°. The enzyme may be said to belong primarily to the class II type, but with some important deviations.

0422 Activity of dehydrogenases in lupine nodule bacteria. (Ukr)
Skochinskaia, N. M., R. M. Kantseliaruk, T. T. Dolgopolova, V. M. Solonin and V. V. Stepaniuk.
Mikrobiol Zh 37(4):427-432, 1975.

0423 Distribution of nitrate reductase in ageing bean seedlings.
Srivastava, H. S. (U Gorakhpur, U. P., India).
Plant Cell Physiol 16:995-999, 1975.
In vivo measurements at different ages of seedlings showed that the leaves always had higher levels of the enzyme than did the roots or stem. The level increased in the leaves until day 10 or 11, then declined.

0424 Asparaginase and asparagine transaminase in soybean leaves and root nodules.
Streeter, J. G. (Ohio Agr Res & Dev Ctr, Wooster, OH, USA).
Plant Physiol 60(2):235-239, 1977.
Asparagine was a major component of the bleeding sap of excised soybean root nodules and the principal component of stem exudate. Nodule asparaginase was concentrated in the bacteroids, suggesting that the enzyme is of bacterial origin. The possibility that this allows asparagine synthesis to occur in uninfected nodule tissue, perhaps the cortex near vascular bundles, is suggested. Metabolism of asparagine in leaves is probably much more affected by asparagine transaminase than by asparaginase.

0425 Investigations into the specific activities of two enzymes of N-metabolism in *Glycine max/Rhizobium japonicum* symbiosis in tissue culture and nodules. (Ger)
Stripf, R. (U Marburg, Germany) and D. Werner.
Specific activities of the transaminases GOT and GPT in nodules and in a plant tissue/*Rhizobium* culture were compared. Nodules have significantly higher GOT and GPT activity than uninfected root tissue. Transaminase could become a wider criterion of nodule activity along with nitrogenase activity. Transaminase activity did not increase in tissue culture after addition of rhizobia.

0426 Regulation of uricase activity in developing roots of *Glycine max*, non-nodulating variety A62-2.
Tajima, S. (Nagoya U, Japan) and Y. Yamamoto.
Plant Cell Physiol 18(1):247-253, 1977.
Nodulated soybeans accumulated a large quantity of allantoin in the stem internodes. The distribution of related enzymes suggested that allantoin is formed in the nodules. The non-nodulated soybeans produced allantoin in small quantities by root uricase. The cofactor requirement of root uricase differs from that of the *Rhizobium* uricase.

See NITROGENASE for references dealing primarily with that enzyme alone.

05. GENETIC FACTORS.

0501 Some morpho-physiological and symbiotic properties of polyploid forms of pea nodule bacteria. (Rus)
Avvakumova, E. N., M. V. Ovsepian and T. U. Stepanian.
Dokl Akad Nauk SSSR 225(4):974-977, 1975.

0502 Interactions between soybean (*Glycine max* [L.] Merr.) genotypes and different isolates of *Rhizobium japonicum*.
Balasundaram, V. R. (IARI, New Delhi, India), V. Iswaran and W. V. B. Sundara Rao.
Ind J Agr Sci 42(5):367-389, 1972.
Eight isolates and Nitragin showed varying abilities to nodulate 6 varieties of soybean. Many isolates were incompatible with vars. 'Hardee' and 'Gedold'. Evidence suggests the existence of another strain-specific gene in 'Gedold'.

0503 Chromosomal recombination and mapping in *Rhizobium leguminosarum*.
Beringer, J. E. (John Innes Inst, Norwich, England) and D. A. Hopwood.
Nature 264(5583):291-293, 1976.
Although gene transfer by transformation and transduction has been reported, a good system for genetic mapping is still lacking. R68.45, a derivative of the P and R factors (R68), which has been reported to have a better sex factor than R68 and other R factors in *Pseudomonas aeruginosa*, behaves in a similar manner in modulating strains of *Rhizobium leguminosarum* and can be used for genetic mapping in this species. A recombination system utilizing R68.45 is described.

0504 The isolation of conditional ineffective mutants of *Rhizobium leguminosarum*.
Beringer, J. E. (John Innes Inst, Norwich, England). A. W. B. Johnston and B. Wells.
J Gen Microbiol 98(2):339-343, 1977.
An effective strain mutagenized with NTG yielded about 3% ineffective mutants. Two mutants were temperature sensitive, and were ineffective, with abnormal nodular morphologies, at 26°C, but effective at 13°.

0505 Intergeneric transfer of genes involved in the *Rhizobium*-legume symbiosis.
Bishop, P. E. (U Wisconsin, Madison, WI, USA), F. B. Dazzo, E. R. Appelbaum, R. J. Maier and W. J. Brill.
Science 198(4320):938-940, 1977.
Mutant strains of *Azotobacter vinelandii* unable to fix N were transformed into N fixing strains with crude DNA preparations from an effective *Rhizobium* strain. Such intergeneric transformations may facilitate studies of the genes involved with the nitrogen-fixing symbiosis.

0506 Regulation and genetics of bacterial nitrogen fixation.
Brill, W. J. (U Wisconsin, Madison, WI, USA).
Ann Rev Microbiol 29:109-129, 1975.
Major advances reviewed include: a) recognition of ATP and electron requirements of N^2 fixation *in vitro*; b) separation of the 2 protein

components of nitrogenase, and c) use of the acetylene reduction assay. Brill expresses hope that biochemical and genetic studies with *Klebsiella* will provide basic insights applicable to the *Rhizobium*-legume symbiosis. This review includes an extensive reference list.

0507 Genetics of nitrogen fixation.
Brill, W. J.
Microbiol (Washington, DC) p. 565-567, 1976.

0508 Genetics of the bacterium, *Rhizobium japonicum*.
Brill, W. J. (U Wisconsin, Madison, WI, USA).
In Proceedings of the World Soybean Research Conference, p. 151-155, 1976.

Suitable gene-transfer systems for *R. japonicum* must be described before mutations found in the genes specific for N_2 fixation or legume infection can be mapped. Then it will be possible to design experiments to increase the N fixing ability of the symbiont. Interactions between the bacterium and plant may require modification of plant genes or growth conditions to allow maximum effective expression of the *nif* genes.

0509 Induction of mutation in *Rhizobium japonicum* by ultra violet radiation and selection of 'agronomically superior' serotypes.
Chandra, A. K. (Burdwan U, W Bengal, India).
Proc Ind Natl Sci Acad Pt B Biol Sci 40(5):491-498, 1974.

A moderately effective wild strain was irradiated with UV, then incubated on plates containing antiserum. Antigenic variants failed to agglutinate and grow freely. Fifteen sero-types were tested for nodulation ability. Streptomycin sensitivity was not related to effectiveness, and total nodule volume did not serve as an index of effectivity in these tests.

0510 Influence of ultraviolet rays on the activity of clover nodule bacteria.
Cheverda, M. G. (All-Union Sci Res Inst Agric Microbiol, USSR) and N. N. Fedulina.
Microbiol 44(5):830-832, 1975.

Positive and negative variants with respect to effectiveness were obtained. Clover yield was increased 21 to 60% by the positive variants, and decreased 18.3 to 35% by the negative variants in comparison with the initial strain. The frequency of encounter of variants with less slime formation and high effectiveness (48-60%) was greater at higher doses of UV irradiation (up to 22,900 erg/mm^2).

0511 Genetic mapping of leucine and isoleucine-valine loci in *Rhizobium japonicum*.
Doctor, F. (U Baroda, India) and V. V. Modi.
J Bac 126(2):997-998, 1976.

Unlike *Escherichia coli* and *Salmonella typhimurium*, transformation data suggests that the leucine loci in *R. japonicum* are not clustered in one region. A common pathway for isoleucine-valine biosynthesis is suggested by transformation analysis.

0512 Symbiotic variability in *Vicia faba*. 1. Genetic variation in the *Rhizobium leguminosarum* population.
El-Sherbeeny, M. H. (Welsh Plant Br Stn, Aberystwyth, Wales), L. R. Mytton and D. and D. A. Lawes.
Euphytica 26(1):149-156, 1977.
Plants of a standard variery associated with random indigenous isolates exhibited large differences in dry matter yield, N content, efficiency of N utilization and date of first flower. The capacity of nodules to supply N was the controlling factor, and was 8 times as much in the best compared to the poorest. A differential production of growth hormones by nodules could also be important.

0513 Symbiotic variability in *Vicia faba*. 2. Genetic variation in *Vicia faba*.
El-Sherbeeny, M. H. (Welsh Plant Br Stn, Aberystwyth, Wales), D. A. Lawes and L. R. Mytton.
Euphytica 26(2):377-383, 1977.
Significant interaction and large differences in dry matter yield and N parameters between 8 varieties and between *Rhizobium* and N treatments demonstrated good posibility for crop improvement through plant breeding and *Rhizobium* selection.

0514 Host plant control of the inheritance of dinitrogen fixation in the *Pisum-Rhizobium* symbiosis.
Holl, F. B. (Natl Res Council Canada, Saskatoon, Sask, Canada).
Euphytica 24:767-770, 1975.
Host-determined genetic variation in dinitrogen fixation was found by examining more than 2,000 samples. Genetic analysis of a mutant, nodulation-resistant line of *Pisum* yielded genes affecting nodulation and fixation.

0515 Host genetics and nitrogen fixation.
Holl, F. B. (Prairie Reg Lab, Saskatoon, Sask, Canada) and T. A. LaRue.
In Proc of the World Soybean Res Conf p. 156-163, 1976.
Most of the available data is for soybean, clover and peas. The data on these hosts in which a specific genetic effect has been reported is tabulated. The possibility of enhancing symbiotic N fixation through host breeding appears more promising than research on microbial genetics.

0516 Mutability and selection of nodule bacteria. (Rus)
Imshenetskii, A. A. and A. N. Pariiskaia.
Akad Nauk SSSR Vestnik 5:53-60, 1972.

0517 Methods of selecting nodule bacteria.
Imshenetskii, A. A. (Inst Microbiol, Acad Sci, USSR), A. N. Pariskaya, V. V. Alferov, A. V. Kuptsova and O. P. Gorelova.
Microbiol 45(3):448-453, 1976.
Criteria for selecting bacteria for inoculants, and methods for identifying strains, are discussed. Selection by plants with the use of mutagens

to obtain mutants of nodule bacteria resulted in the isolation of superior strains. Genetic marking was used to study the adaptability of introduced strains to field conditions. Strains with a high frequency of neomycin-resistant mutants are likely to be less stable in their symbiotic behavior, so preference should be given to strains with a low index in that characteristic.

0518 Phenetic similarity and DNA base sequence homology of root nodule bacteria from New Zealand native legumes and *Rhizobium* strains from agricultural plants.
Jarvis, B. D. W. (Massey U, Palmerston N, NZ), T. S. MacLean, I. G. C. Robertson and G. R. Fanning.
N Z J Agric Res 20(2):235-248, 1977.
Rhizobia from 65 indigenous New Zealand legumes and 45 reference strains were classified into 10 clusters on the basis of 37 morphological, cultural and physiological tests. DNA base sequence homology confirmed the broad relationship between indigenous rhizobia and acid-producing *Rhizobium lupini* as indicated in the phenetic classification.

0519 Isolation and characterization of U V induced mutants of rhizobia.
Kaushik, B. D. (IARI, New Delhi, India), P. Bose and G. S. Venkataraman.
Proc Ind Natl Sci Acad Pt B Biol Sci 40(5):486-487, 1974.
Five mutants of *Rhizobium trifolii* and 7 of *R. leguminosarum* were obtained. Two mutants with enlarged cells had lost their nodulating property; the others remained rod-shaped and formed nodules. No specific correlation between drug resistance and nodulating capacity was observed.

0520 Evidence for common genetic determinants of nitrogenase and nitrate reductase in *Rhizobium meliloti*.
Kondorosi, A. (Biol Res Ctr, Szged, Hungary), I. Barabas, Z. Svab, L. Orosz, T. Sik and R. D. Hotchkiss.
Nature (New Biol) 246:153-154, 1973.
Independently determined nitrate reductase activity in induced bacteria and nitrogenase activity in root nodules indicates an apparent pleiotropy which may be explained either by the existence of a common protein subunit or by other mutation effects. Reversion studies are in progress.

0521 Loss of symbiotic capacity in commercially useful strains of *Rhizobium trifolii*.
Labandera, C. A. (U New South Wales, Kensington, Australia) and J. M. Vincent.
J Appl Bac 39:209-211, 1975.
Evidence of the remarkable genetic instability of strains of *R. trifolii* was investigated. The results point up the need for extreme care in the maintenance and testing of cultures used for the manufacture of inoculants. Quantitative assesment using several dilutions is advised.

0522 Effects of nonnodulating gene (*rj1*) on seed protein and oil percentages in soybeans with different genetic backgrounds.
Liu, M-C. (Taiwan Sugar Res Inst) and H. H. Hadley.

Crop Sci 16(3):321-325, 1976.
Studies of nod- and nonnod- crosses in various combinations suggested that N fixation may act as a 'buffer' obscuring the segregation of genes for utilization of combined N. Possible breeding strategies for increased protein production are discussed.

0523 Nitrogen fixation: prospects for genetic manipulation.
Marx, J. L.
Science 196(4290):638-641, 1977.
This author offers evidence to support the conclusion that recombinant DNA techniques and other forms of genetic engineering are unlikely to pay off in greater biological N fixation in the near future. Some obstacles are energy demands and oxygen sensitivity of the process, plus the difficulty of introducing functional new genes into plants. Greater efficiencies are possible by utilizing superior rhizobial strains, such as those that waste less energy through hydrogen production. Knowledge of the diversity of N-fixing organisms and beneficiary plants, and the application of traditional genetics and biochemistry, offer more immediate hope for advancement.

0524 Genetic mapping of *Rhizobium meliloti*.
Meade, H. M. (Mass. Inst Technol, Cambridge MA USA) and E. R. Signer.
Proc Natl Acad Sci USA 74(5):2076-2078, 1977.
Transfer of a drug resistance factor originally isolated in *Pseudomonas* to rhizobia, and subsequent mating, yielded an empirical, linear linkage map. The mating system devised is expected to be of great value in the analysis of *Rhizobium* genetics and physiology, and in the isolation of strains with useful combinations of markers.

0525 Occurrence of streptomycin resistant and dependent mutations in *Rhizobium lupini* under the influence of nitrous acid.
Mishra, A. K., P. Roy and S. K. Das.
Curr Sci 44(8):267-269, 1975.

0526 The use of spontaneous antibiotic resistant mutants for the ecological study of *Rhizobium*.
Obaton, M.
Bul Ecol Res Comm Swed Natl Sci Res Counc 17:170-171, 1973.

0527 Preliminary studies on the rhizobial nodulation of induced mutants of blackgram.
Oblisami, F. (Tamil Nadu Agr U, Coimbatore, India), N. M. Ramaswamy, D. Purushothaman and G. Rangaswami.
Madras Agr J 60(4):259-261, 1973.
Nodulation of 8 mutants of Co. 1 var *Phaseolus mungo* L. was found to be significantly lower than that of the parent. The distribution of nodules on lateral and taproots indicate a change in the inter-relationship between the plant root and soil rhizobia.

0528 Control of symbiotic nitrogen fixation in rhizobia; regulation of NH_4^+ assimilation.

O'Gara, F. (Plant Growth Lab, U Cal, Davis, CA, USA) and K. T. Shanmugam.
Biochim Biophys Acta 451(2):342-352, 1976.
Rhizobia are able to assimilate ammonium for growth only when supplemented with certain organic N sources. The assimilation can normally be blocked by glutamate. Glutamate synthase activity is always present in cells that are capable of assimilating NH_4^+. Mutants were selected in which glutamate inhibition was no longer present, and the levels of glutamate synthase activity in these mutants was twice that of the parent strain. The mutants did not require organic nitrogen supplementation for growth in media containing inorganic N. The possibility of genetic construction of rhizobia no longer inhibited by available N is raised.

0529 Genetic factors affecting symbiotic nitrogen fixation of nodule bacteria and leguminous plants. (Rus)
Pariiskaia, A. N.
In Novoe v Izuchenii Biologicheskoi Fiksatsii Azota p. 54-62, 1971.

0530 A comparison of DNA from free living and endosymbiotic *Rhizobium leguminosarum* (strain P R E).
Reijnders, L. (Agric U Wageningen, The Netherlands), L. Visser, A. M. J. Aalbers, A. Van Kammen and A. Houwers.
Biochim Biophys Acta 414(2):206-216, 1975.
The bacteroid DNA was increased three-fold over the free living bacteria. No significant difference between DNA from the two forms could be detected.

0531 Variation among alfalfa genotypes for rate of acetylene reduction.
Seetin, M. W. (U Minnesota, St. Paul, MN, USA) and D. K. Barnes.
Crop Sci 17(5):783-787, 1977.
Two thousand plants of 6 alfalfa cultivars were evaluated for nodulation with a mixture of *Rhizobium meliloti* strains. Plants representing extremes in nodulation were cloned, then 6 clones were crossed in all possible combinations. Crosses between clones with high acetylene reduction values produced progenies with double the reduction rates of the low x low crosses. Numerous fibrous roots, many nodules and high top and root weights were traits associated with high levels of acetylene reduction.

0532 Solar protein.
Shanmugam, K. T. (Calif Agr Exp Stn, Davis, CA, USA), and R. C. Valentine.
Calif Agric 30(11):4-7, 1976.
A brief report on genetic engineering achievements and possibilities for enhancing both symbiotic and asymbiotic biological N fixation.

0533 Control of gene action in nitrogen-fixing bacteroids.
Sutton, W. D. (DSIR, Palmerston N, NZ) and J. G. Robertson.
Bull R Soc NZ 12:23-30, 1974.
Evidence suggests that bacteroids retain a full bacterial DNA complement, which is neither degraded nor modified. There is no evidence for the transfer of plant DNA into bacteroids. A highly restricted protein synthesis capacity may explain why bacteroids are not able to resume independent lives.

0534 Plasmid deoxyribonucleic acid in *Rhizobium vigna* and *Rhizobium trifolii*.
Tshitenge, G. (CEN/SCK Mol, Belgium), N. Luyindula, P. F. Lurquin and L. Ledeux.
Biochim Biophys Acta 414(3):357-361, 1975.
Evidence for the presence of plasmid DNA in several strains of effective and ineffective rhizobia.

0535 Isolation and partial characterization of DNA in capsular preparations of *Rhizobium trifolii*.
Mullstein, L. H. (U Utah, Salt Lake City UT, USA), M. L. Bruening, B. M. Mullstein and M. Sherwood.
Physiol Plant 35:129-134, 1975.
The possibility that *Rhizobium* DNA plays a direct role in legume nodulation continues to be of interest. This study was made to attain a better understanding of the nature of DNA occurring in capsular polysaccharide preparations of rhizobia.

0536 Transformation as a method for increasing the activity of lucerne nodule bacteria. (Rus)
Zaretskaia, A. N.
Mikrobiologiia 45(5):873-878, 1976.

0537 Intraspecific variability for dinitrogen fixation in cowpea *(Vigna unguiculata* [L.] Walp).
Zary, Z. W. (Texas A & M U, College Station, TX, USA) and J. C. Miller.
Hortsci 12(4):34, 1977.
A tenfold variability in dinitrogen fixation parameters among several hundred breeding lines, varieties and introductions is reported as evidence for the possibility of breeding for N fixing traits.

0538 [^{3}H]dihydrostreptomycin accumulation and binding to ribosomes in *Rhizobium* mutants with different levels of streptomycin resistance.
Zelazna-Kowalska, I. (Maria Curie Sklodowska U, Lublin, Poland).
J Bac 132(1):8-12, 1977.
Mutants selected at a high level of streptomycin resistance (1,000 µg/ml) showed pleiotropic changes, including loss of spheroblast formation and infectivity, while mutants selected with low doses (10-100 µg/ml) retained properties of the parent strain. Observations led to the conclusion that modification at a high level of strep-R affects ribosomal structure, whereas low-level resistance involves a change in membrane permeability.

06. HORMONES.

0601 Some aspects of practical application of kinetin for plant growth and the formation of nodules and tubers. (Rus)
Artamonov, V. I.
Fiziol Rast (Mosk) 22(6):1283-1290, 1975.

HORMONES *continued*

0602 Hormones in plants bearing nitrogen-fixing root nodules: the distribution of cytokinins in *Vicia faba* L.
Henson, I. E. (U Glascow, Scotland) and C. T. Wheeler.
New Phytol 76(3):433-439, 1976.
Cytokinin levels were high in nodules and leaves, but much lower in roots and stems. The zeatin riboside-like peak was the main cytokinin detected in the root nodules and roots. A cytokinin with properties distinguishing it from any of the known cytokinins was predominant in the leaves.

0603 Influence of giberellic acid on yield of three tropical pastures.
Herrera, D. and J. J. Suarez
Cuban J Agric Sci 9:213-218, 1975.

0604 Foliar spray of growth regulators on nodulation in three legume plants and its relation to *Rhizobium* population.
Kandasamy, D. (Annamalai U, Annamalainagar, India) and N. N. Prasad.
Ind J Exp Biol 14(6):737-739, 1976.
Gibberellic acid, 2,4-Dichlorophenoxy acid and indole acetic acid caused variations in nodulation in green gram, black gram and sunhemp. GA decreased nodule number in both green gram and black gram, but increased the number in sunhemp. 2,4-D at 5 ppm increased nodulation in green gram, but caused a decrease in the other plants.

0605 Effects of growth regulators and combined nitrogen on growth and nodulation of soybean.
Lazam, H.
Malays Agr Res 5(1):9-17, 1976.

0606 *In vitro* effects of some growth regulators in *Rhizobium*.
Rao, V. R., N. S. Subba Rao and K. G. Mukerji.
J Gen Appl Microbiol (Tokyo) 19(1):55-58, 1973.

0607 Cytokinin production in relation to the development of pea root nodules.
Syono, K., W. Newcomb and J. G. Torrey (Cabot Fndn, Harvard U, MA, USA).
Can J Bot 54(18):2155-2162, 1976.
Cytokinin activity was highest in 2- and 3-week-old nodules, when the growth rate was high, and decreased in older nodules. It is proposed that cytokinins influence nodule morphogenesis by regulating the mitotic activity of the nodule meristem.

0608 Identification of cytokinins of root nodules of the garden pea, *Pisum sativum* L.
Syono, K. (Cabot Fndn, Harvard U, Petersham, MA, USA) and J. G. Torrey.
Plant Physiol 57(4):602-606, 1976.
The presence of cytokinins in root nodules and their changing concentration during nodule development support the idea that cytokinins play a critical role in nodule development, particularly in relation to cell division activity. Zeatin and its ribosides were the most active cytokinins found in pea root nodules.

07. INOCULANT MATERIALS.

0701 Granular inoculants produce new payoffs for growers across peanut belt.
Berkshale, W. E.
Peanut Farmer 13(4):42, 44 1977.

0702 Sodium glutamate in relation to survival of *Rhizobium leguminosarum* on pea seed.
Chhonkar, P. K. (IARI, New Delhi, India) and V. Iswaran.
Israel J Agr Res 22(1):41-42, 1972.
Addition of 1% sodium glutamate to the adhesive improved survival of the rhizobia, thereby increasing growth, nodulation and N uptake.

0703 Suitability of a coal-bentonite base as a carrier of rhizobia in inoculants.
Deschodt, C. C. (Plant Protection Res Inst, Pretoria, S Africa) and B. W. Strijdom.
Phytophylactica 8(1):1-5, 1976.
Rhizobium meliloti survived equally well on either peat or a coal-bentonite-lucerne meal carrier at 33 and 37° C. *R. trifolii*, *R. japonicum* and a 'cowpea' strain survived less well at 37°, at which temperature the peat was slightly superior.

0704 Growth of some strains of *Rhizobium* sp. on solid carriers.
Farag, F. A. (Agr Res Ctr, Egypt), M. A. El-Nady, A. F. T. Haroun, and M. Lotfi.
Agric Res Rev (Egypt) 54(5):221-226, 1976.
Erection of the High Dam in Egypt resulted in loss of the silt supply formerly used as an inoculant carrier. Sterilized clay loam proved satisfactory as a substitute carrier, and was superior to either rice straw, maize stalks or cotton stalks.

0705 Excipients and adhesives of possible use in inoculation of legumes in Colombia. (Spa)
Graham, P. H., V. M. Morales and R. Cavallo.
Turrialba 24(1):47-50, 1974.

0706 Plant compost as a substitute for peat for legume inoculants.
Iswaran, V. (IARI, New Delhi, India), A. Sen and R. Apte.
Curr Sci 41(8):299, 1972.
Since peat was not readily available as a carrier for inoculants in India, leaves from wayside trees were composted and ground as a substitute. Laboratory tests showed that the leaf compost is as good a carrier as peat.

0707 Tests to be applied to *Rhizobium* prior and after preparation of legume inoculants.
Iswaran, V. (IARI, New Delhi, India).
Feed Farming Agric 7(8):13-15, 1976.
Relatively simple tests for determination of the *Rhizobium* species (serology), then quantitative and qualitative tests to be used in preparation of inoculants are described. The agar tube method (for small seeded legumes) and modified Leonard jar (for large seeded legumes) are also described.

INOCULANT MATERIALS *continued*

0708 Lignite as a carrier of rhizobia.
Kandasamy, R. (Annamalia U, Annamalainagar, Tamil Nadu, India) and N. N. Prasad.
Curr Sci 40(18):496. 1971.
The highest rhizobium count obtained using powdered lignite as the carrier was 13.14 X 10^8, much superior to the highest count obtained using soil. The lignite carrier was further improved by amendment with 1% soybean powder.

0709 Rice husk as the medium for legume inoculants.
Khatri, A. A. (Fld Res Stn, Amar Hill, Bombay, India), M. Choksey and E. D'Silva.
Sci Cult 39(4):194-196, 1973.
India is lacking in large deposits of peat, so substitutes are sought for inoculum carriers. The highest counts were reached after 4 weeks of incubation, declining thereafter, but at rates still satisfactory for inoculation purposes over a period of a few weeks for most *Rhizobium* species.

0710 Filter mud as a carrier for *Rhizobium* inoculants.
Philpotts, H. (Agr Res Ctr, Wollongbar, NSW, Australia).
J Appl Bac 41:277-281, 1976.
Filter mud from sugar cane mills proved to be a suitable inoculant carrier, provided it had not been oven dried. The high nutrient content allows good multiplication. This is enhanced by sterilization to reduce competition from other micororganisms. Filter mud was not compared to other carriers in this study.

0711 Cellulose powder as legume inoculant base.
Pugashetti, B. K. (U Agr Sci, Bangalore, India), H. S. Gopalgowda and R. B. Patil.
Curr Sci 40(18):494-495, 1971.
In comparative studies of soil, coconut shell powder and cellulose powder as substitutes for peat, the cellulose powder showed promise for both survival of the bacteria and ease of seed treatment. Cotton linter-pulp dust, which is discarded by acetate factories, could provide material for the cellulose powder.

0712 Response of lucerne to the peat base as well as the molybdenum and boron added to the peat used in the production of *Rhizobium* inoculum. in pot and field experiments. (Hun)
Szabos, T., E. Manninger and Mrs. E. Bakondi-Zamory.
Novenytermeles 25(1):17-22, 1976.

0713 Sodium chloride as a cause of low numbers of *Rhizobium* in legume inoculants.
Steinborn, J. (Biol & Chem Res Inst, Rydalmere, NSW, Australia) and R. J. Roughley.
J Appl Bac 37(1):93-99, 1974.
Peat containing more than 0.2% of chloride (as a percentage of dry peat) may cause considerable loss of viability of rhizobia.

INOCULANT MATERIALS *continued*

0714 The effect of gum arabic on infection and nodulation of cluster clover by *Rhizobium*.
Subba Rao, N. S. (IARI, New Delhi, India), S. P. Magu and K. S. B. Sarma
Arch Microbiol 77(1):96-98, 1971.
This study shows that gum arabic generally enhances the number of infected root hairs, promotes early nodulation and significantly increases the number of leaves during initial nodulation of cluster clover inoculated under bacteriologically controlled conditions.

For additional references with information on inoculant materials, see relevant listings under:
Inoculation methods
Pelleting
Rhizobium effectiveness, infectiveness.

08. INOCULANT PRODUCTION AND DISTRIBUTION.

0801 Legume inoculant service.
Atkinson, J. D.
N Z J Agr 122(6):61. 1971.
Describes the inoculant service in New Zealand.

0802 *Rhizobium:* Produccion de inoculantes. (Spa)
Camacho, M.
Inf Conf Cursos Reun Interamer Inst Agr Sci 80:J1-J9, 1975.
Additional key words: Forage crops.

0803 Production of legume inoculants using modified lignite impregnated with broth as a carrier.
Dube, J. N., S. L. Namdeo and M. S. Johar.
Res Indus 18(3):94-95, 1973.

0804 Methods of breeding nodule bacteria. (Rus)
Imshenetskii, A. A., A. N. Pariiskaia, V. V. Alferov, A. V. Kuptsova and O. P. Gorelova.
Mikrobiologiia 45(3):520-525, 1976.

0805 Preparation and quality of legume inoculants.
Iswaran, V. and A. Sen.
Ind Agr News Dig 2(8/12):267-270, 1971.

0806 The symbiosis of dehydrated and nondehydrated *Rhizobium meliloti* with alfalfa. (Rus)
Klintsare, A. I. A.
Latv Pasr Zinat Akad Mikrobiol Inst Mikroorg Rast 5:87-99, 1972.

0807 Inoculant production for soybeans: comparative study on cellular growth and nitrogen fixation capacity of a *Rhizobium japonicum* strain. (Spa)

Lopreto, C. R., L. A. Mazza and A. P. Balatti.
Rev Fac Agron U Nac Plata 49(2):201-212, 1973.

0808 Production of soybean inoculants: growth and survival of *Rhizobium japonicum* strains on different carriers. (Spa)
Lopreto, C. R., L. A. Mazza and A. P. Balatti.
Rev Fac Agron U Nac Plata 51(1):35-41, 1975.

0809 Legume inoculant usage in New Zealand.
MacKinnon, P. A. (DSIR, Palmerston N., NZ), J. G. Robertson, D. J. Scott and C. N. Hale.
N Z J Exp Agr 5(1):35-39, 1977.
Inoculants and seed coating materials valued at $400,000 were utilized in New Zealand in 1973 and in 1974. Important legumes and associated rhizobial strains are listed, and the potential of the inoculant industry is discussed.

0810 Mass scale production of *Rhizobium* culture.
Nandi, P. (Bose Inst, Calcutta, India) and N. Sinha.
Proc Ind Natl Sci Acad Pt B Biol Sci 40(5):479-481, 1974.
Molasses proved a superior carbon source for rhizobial growth, followed by liquid malt extract and a combination of sucrose and mannitol. The latter medium offers advantages due to gum production, which protects the bacteria in storage. The sucrose-mannitol also has a moderate cost.

0811 The preparation and use of legume seed inoculants.
Roughley, R. J. (Dept Agr, Rydalmere, NSW, Australia).
Plant Soil 32:675-701, 1970.
A full, general treatment of the subject, with detailed steps on preparation, quality control, selection, inoculation, pelleting and conclusions on the present (1970) status of inoculation.

0812 The Australian Inoculants Research and Control Service.
Roughley, R. J. (AIRCS, Rydalmere, NSW, Australia).
Agr Gaz of NSW 83(4):210-211, 1972.
Describes funding, facilities and activities of the new organization which replaced the University-Department of Agriculture Laboratory Service in 1970. Possibly a useful model for other nations.

0813 Inspection of legume seed inoculants and pre-inoculated seeds.
Schall, E. D. (Indiana St Chemist, Indianapolis, IN, USA), L. C. Schenberger and A. Swope.
Purdue U Agr Exp Stn, Inspection Rept 106, 8 p., 1975.
An annual report by the state chemist, who is charged by law to inspect and test materials subject to the Legume Inoculant Law of 1937. Summary of tests indicates Nitragin Sales Corp., Milwaukee, WI received 100% good rating at 14 commercial outlets for pre-inoculated alfalfa and red clover seed, and for 4 outlets for inoculants. This was significantly higher than any other supplier.

0814 The *Rhizobium* supply service in Papua New Guinea.
Shaw, D. E. (Dept Agr, Stock & Fisheries, Port Moresby, New Guinea), M. J. Trinick, W. A. Layton and E. G. Cartledge.
Papua New Guinea Agr J 23(1/2):12-26, 1972.
From its beginning in 1956 up to June, 1971, nearly 18,000 bottles of inoculum were supplied to local and overseas growers. While some cultures were isolated from local nodules, many were obtained from Australia. A survey of results obtained by growers is included.

0815 Growth and survival of rhizobia in commercial bacterial inoculants.
Singh, A. (Punjab Agr U, Ludhiana, India) and P. B. Sharma.
J Res Punjab Agr U 10(1):95-98, 1973.
The effect of temperature was found to be highly significant for the survival of inoculant rhizobia in storage. Commercial legume bacteria may be stored up to 4 weeks at 25° C, or for longer at 5°. Since the soil-muck medium acts as a nutrient source, enrichment with additional nutrients would help the growth of bacteria for a longer period.

0816 The production of *Rhizobium* inoculum in Cuba and results obtained in practice. (Hun)
Soos, T. and M. V. Mir.
Agrartud Kozl 33(1):77-80, 1974.

0817 *Rhizobium* inoculants for soybean cultivation.
Subba Rao, N. S. (IARI, New Delhi, India) and V. R. Balasundaram.
Indian Farming 21(8):22-23, 1971.
A non-technical report on the need to step up the production of inoculants in India.

09. INOCULATION EFFECTS AND REQUIREMENTS.

0901 Effects of inoculation and nitrogen fertilization on nodulation, seed yield and quality of soya beans.
Abu-Shakra, S. (American U, Beirut, Lebanon) and A. Bassiri.
J Agr Sci (London) 78(2):179-182, 1972.
Land upon which inoculated soybeans had been grown the previous year produced more nodules and a greater yield than did land planted previously with non-inoculated seed.

0902 The effect of inoculation of seeds with effective strains of species of *Rhizobium* on the yields of alfalfa, red kidney beans and sainfoin under irrigated conditions in Erzurum. (Tur)
Aksoy, N.
Ziraat Derg 2(4):68-74, 1971.

0903 Inoculation--worth it or not?
American Soybean Assoc., Hudson, IA,

Soybean Dig 34(2):10-12, 1973.
In this discussion, the consensus was that the cost of perhaps unnecessary inoculation is less than the risk of not inoculating when it may be needed.

0904 Artificial inoculation of bean seeds *(Phaseolus vulgaris)* with a bacterial strain of *Rhizobium phaseoli*. (Dut)
Anthonissen, J.
Inacol 22(1/2):1-24, 1971.

0905 Effect of inoculation of lupine on enzymatic activity of the soil and its nitrogen accumulation. (Bel)
Apanasenka, I. P.
Izv Akad Nauk BSSR Ser Biol Nauk 4:46-51, 1973.

0906 Effect of seed inoculation with *Rhizobium* strains on the yield of leguminous crops.
Bajpai, P. D. (Uttar Pradesh Inst Agr Sci, Kanpur, UP, India), L. K. Lehri and A. N. Pathak.
Proc Ind Natl Sci Acad, Pt B Biol Sci 40(5):571-575, 1974.
Berseem, lobia and groundnut crops showed yield increases of 74, 46 and 21 per cent respectively when inoculated with strains of *Rhizobium* isolated at U. P. Institute. Similar results were also reported with gram, pea and soybean.

0907 Studies on the use of bacterial cultures for increased yield in cotton and groundnut crops.
Balakrishna, N.
Farm Front 8(2):6-10, 1974.

0908 Use of *Rhizobium* culture to increase the yield level of pulses.
Basavaraj, T. V.
Farm Front 8(7):7-8, 1974.

0909 Response of soybean to inoculation with various cultures of *Rhizobium japonicum*.
Bhargava, J. K. (G. B. Pant U, Pantnagar, India), M. C. Saxena and K. V. B. R. Tilak.
Proc Ind Natl Sci Acad Pt B Biol Sci 40(5):471-475, 1974.
Inoculation with effective strains produced better nodulation. Application of N adversely affected nodulation. Some indigenous strains proved as effective as imported cultures. Combinations of strains can improve efficiency, but some strains are antagonistic to one another.

0910 Inoculation of legumes in Rwanda. (Fre)
Cameman, A. and G. Deschutyener.
Bul Agr Rwanda 6(2):86-92, 1973.

0911 Inoculate moong and get more yield.
Chahal, V. P. S. (Punjab Agr U, Ludhaina, India), R. B. Rewari and M. S. Pandher.
Prog Farming 12(9):17, 1976.
Moong beans were chosen for testing of effects of inoculation and phosphate because they are an important short-duration crop. Superphosphate was applied at 100 kg/ha to beds in which inoculated, healthy moong seeds had been sown. The nodules increased both in the presence and absence of P application. Yield increases were 13.5% by inoculation, 19.6 by P and inoculation.

0912 Inoculate and get more yield of gram.
Chahal, V. P. S. (Punjab Agr U, Ludhaina, India), R. P. Gupta and M. S. Pandher.
Prog Farming 13(2, spec issue):24-25, 1976.
Inoculation increased the yield of var. G-130 by 15%, and of 'Hare Chhole' by 17%. Applied N suppressed nodule formation, lead to excessive vegetative growth, and adversely affected yield.

0913 Performance of soybeans in Guyana as affected by inoculum *Rhizobium japonicum* and nitrogen.
Chesney, H. A. D., M. A. Khan and S. Bisessar.
Turialba 23(1):91-96, 1973.

0914 Response of soybean to rhizobial inoculation with different strains of *Rhizobium japonicum*.
Chhonkar, P. K. (Uttar Pradesh Agr U, Pantnagar, India) and P. S. Negi.
Ind J Agr Sci 41(9):741-744, 1971.
Inoculation of var 'Bragg' were conducted in rhizobia free soils. Single strains were not found to be better than the multiple-strain commercial inoculum, but indigenously produced single-strain, peat-based culture was found to be as effective as imported peat-based culture containing more than one strain.

0915 Studies on nodulated and mycorrhizal peanuts.
Daft, M. J. (U Dundee, Scotland) and A. A. El-Giahmi.
Ann Appl Biol 83:273-276, 1976.
Peanuts dually infected with *Glomus* and *Rhizobium* given various P treatments produced more fruit, dry matter and nodules compared to non-mycorrhizal plants. When grown in sand containing bonemeal, the plants infected with both mycorrhizae and rhizobia removed more P but increased the N content of the sand.

0916 *Lotus* needs inoculation.
Distloff, A. (Queensland Dept Primary Indus, Australia).
Queensl Agr J 99(12):642-644, 1973.
Inoculation with CRGl has proven effective in soils with pH 5, but less acidity is preferred. Uninoculated plants have much less chance of overcoming weed competition and becoming established.

INOCULATION EFFECTS AND REQUIREMENTS *continued*

0917 Legume inoculation.
Diatloff, A. (Dept Primary Indus, Indooroopilly, Qld., Australia) and D. G. Hutton.
Qld Agr J 103(2):144A - 144D, 1977.
Illustrated, non-technical article on the needs for proper inoculation of certain legumes while certain others become naturally nodulated by effective rhizobia.

0918 Influence of inoculation on nitrogen fixation by chickpea, its yield, and the protein content of the crop.
Dorosinskii, L. M. and A. A. Kadyrov.
Microbiol 44(6):998-1001, 1975.
Inoculation with *Rhizobium cicer* [the species name used in this translation] increased the aerial mass of chickpea by 25-36% and protein content by 2-6%. N contribution of the symbiosis was computed by the "inoculation" method, and ranged from 41 to 60% for effective strains of rhizobia.

0919 Inoculation of *Trifolium subterraneum* L.: A study in establishing new pastures.
Fuentes Sanchez, C.
Agric Rev Agropecu 41(448):780-784, 1972.

0920 Problem regarding groundnut (*Arachis hypogaea* L.) inoculation in tropics with special reference to India.
Gaur, Y. D. (IARI, New Delhi, India), A. N. Sen and N. S. Subba Rao.
Proc Ind Natl Sci Acad Pt B Biol Sci 40(5):562-570, 1974.
India leads the world in groundnut acreage, but the yields are relatively poor. Nodulation occurs naturally from inefficient soil rhizobia of the 'cowpea' group. Successful introduction of efficient strains requires a systematic adherence to all steps of selection: invasiveness, efficiency, survival under particular conditions, dominancy in competition, and effectiveness with the particular host.

0921 Growth and development of indeterminate bush and climbing cultivars of *Phaseolus vulgaris* L. inoculated with *Rhizobium phaseoli*.
Graham, P. H. (CIAT, Cali, Colombia) and J. C. Rosas.
J Agric Sci (Camb) 88(2):503-508, 1977.
Nodule activity in 20 cultivars was similar to or better than those reported in other grain legumes, and exceeded that achieved by a soybean cultivar. Two climbing vars., Cargamento and Sangretoro, were outstanding in fixation. Exploitation of superior cultivars and inoculants could provide N gains of considerable importance.

0922 On the inoculation of legumes.
Gupta, K. G. (Panjab U, Chandigarh, India), Singh, H. and R. K. Sud.
Plant Soil 38(3):667-669, 1973.
Flowers sprayed with a heavy inoculum produced seeds having the same

Rhizobium. These seeds showed the capacity to nodulate on germination in sterile soil.

0923 Nodulation of seeds in the Sudan. III. Response of Haricot bean to inoculation.
Habish, H. A. and H. M. Ishag.
Exp Agr 10(1):45-50, 1974.

0924 Effect of inoculating soybeans with *Rhizobium japonicum* at Crookston.
Hum, G. E. and L. J. Smith.
Soil Ser Dep Soil Sci U Minn 95:37-38, 1975.

0925 Effect of inoculating soybeans with *Rhizobium japonicum*.
Hum, G. E., S. D. Evans, G. W. Randall.
Soil Ser U Minn Agr Ext Serv 97:178, 1976.

0926 Report on soybean inoculation trials.
Hum, G. E., W. C. Lindemann, C. K. Kvien and G. W. Randall.
Soil Ser U Minn Agr Ext Serv 99:190-191, 1977.

0927 Inoculation, liming and fertilization of peanuts on Lakeland fine sand.
Hickey, J. M. (U Florida, Gainesville, FL, USA), W. K. Robertson, D. H. Hubbell and E. B. Whitty.
Proc Soil Crop Sci Soc Fla 33:218-222, 1974.
In N deficient soil, inoculated plants showed a 92% increase in peanut yield compared to uninoculated control. Lime at 750 ppm also enhanced yield in greenhouse experiments.

0928 Legume inoculation in Florida.
Hubbell, D. H., D. Jones and G. D. Thornton.
Fla U Ext Circ 376, 10 p., 1972.

0929 Effect of *Rhizobium* inoculation and molybdenum treatment on nodulation and yield of garden pea (*Pisum sativum* L.).
Halemani, N. C., G. S. Sulikeri, S. D. Nelogi and R. B. Patil.
Mysore J Agr Sci 6(2):202-204, 1972.

0930 Is inoculation necessary?
Iswaran, V.
Ind Agr News Dig 2(6/7):228-229, 1971.

0931 Soybean inoculation in the Philippines.
Iswaran, V.
Sci Rev 18(1):24-25, 1974.

0932 Inoculation experiment with different bacterial cultures on soybean.
Jain, M. K. (IARI, New Delhi, India) and M. B. Rewari.
Curr Sci 43(21):748-750, 1973.
Soybeans in pot culture were inoculated with 2 strains of *Rhizobium japonicum* and one of *Azotobacter chroococcum*. At 14 weeks growth, the per cent N of the plants inoculated with rhizobia was increased

significantly, but no significant increase was obtained by *Azotobacter* inoculation.

0933 Effect of inoculation with specific and nonspecific nodule bacteria on the content of physiologically active substances in legume plants.
Kaladzhian, N. L. and M. Kh. Chailakhian. (Rus)
Biol Zh Arm 28(10):11-19, 1975.

0934 Effects of inoculation and Nitrogen fertilizer on soybean in Western Nigeria.
Kang, B. T. (IITA, Ibadan, Nigeria).
Exp Agr 11(1):23-31, 1975.
For maximum yield and to avoid stunting in early growth, the addition of 30 kg N/ha was necessary even on well nodulated plants when grown on low fertility soil. Without inoculation, 60 kg N/ha was required. Relative oil content of the seeds decreased with inoculation and N application.

0935 Lentil yield increases with *Rhizobium* inoculation.
Kaul, J. N. and H. S. Sekhon.
Prog Farming 12(3):17, 1975.

0936 The effect of seed inoculation with nodule bacteria on the content of three amino acids in the alfalfa plant mass. (Rus)
Kaziev, S. M., T. Kulimbetov and V. P. Shin.
Uz Biol Zhur 3:69-70, 1971.

0937 Studies on oversowing on natural grasslands in Kenya. II. Effect of seed inoculation on the nodulation and productivity of *Desmodium uncinatum* (Jacq.) DC.
Keya, N. C. O. (Natl Agr Res Stn, Kitale, Kenya) and C. L. M. Van Eijnatten.
E Afr Agr For J 40(4):351-358, 1975.
The most promising pasture legume, *Desmodium uncinatum*, did not respond well to inoculation under Western Kenya conditions. Seeds pelleted with lime, rock phosphate and gypsum were planted in potted field soil and in plots. In the pot experiment, inoculated seeds showed an initial advantage, but this did not last beyond 20 weeks. The field experiment showed no advantage from inoculation, due to infection by indigenous, ineffective strains of rhizobia.

0938 Response of different genotypes of soybean to inoculation with various composite cultures of *Rhizobium japonicum*.
Kumar, S., H. P. Singh and K. V. B. R. Tilak.
Pantnagar J Res 1(1):30-32, 1976.

0939 Effect of inoculation with *Rhizobium* and *Azotobacter* on nodulation, growth and yield of soybean.
Kumar Rao, J. V. D. (U Agr Sci, Hebbal, Bangalore, India) and R. B. Patil.
Cur Sci 45(14):523-524, 1976.

The *Azotobacter* alone did not affect plant weight, and when applied with *Rhizobium* did not affect nodule weight. Although *Azotobacter* increased bean yield by 90.6%, the plants so treated showed N deficiency symptoms during plant growth. The increase in bean yield may be attributed to initial stage growth stimulation from biologically active compounds.

0940 Preliminary tests in the inoculation of lupine. (Fre)
Lagacherie, B., P. Ginies and N. Amargar.
Acad Agr Fr C R Seances 62(13):987-994, 1976.

0941 Effect of inoculation [with] *Rhizobium phaseoli* on the production of kidney beans *(Phaseolus vulgaris)*. (Por)
Leal, N. R., C. A. De Mendonca and J. Döbereiner.
Lavoura 77(5):8-9, 1974.

0942 Bacterization experiments with *Rhizobium*.
Lehri, L. K. (Uttar Pradesh Inst Agr Sci, Kanpur, UP, India), B. K. Gangwar and C. L. Mehrotra.
J Ind Soil Sci 22(1):66-69, 1974.
Inoculation and P_2O_5 application significantly increased the yields of gram, urd, lobia and soybean.

0943 Inoculation of soybean *(Glycine max* Merr.); inoculation effect on yield, protein and oil content of the grain. (Spa)
Longeri, S. L. (U de Concepcion, Chile) and O. A. Herrera.
Agr Tec 32(3):132-137, 1972.
No nodulation was observed in non-inoculated plants, indicating an absence of indigenous soybean rhizobia. Yield and content for inoculated plants increased between 165 and 226% compared to control plants. N fertilization had a much smaller effect on yield.

0944 Factors affecting the response of clover establishment to inoculation and pelleting.
Louther, W. L. (Invermay Agr Res Ctr, Mosgiel, NZ).
Proc N Z Grassl Assoc Conf 38(1):175-181, 1977.
The standards required for inoculants were influenced by environmental conditions, indicating the importance of field testing in addition to lab testing of inoculants and inoculation methods. On some acid soils, effective pelleting was essential to clover establishment.

0945 Alfalfa: effects of seeding rates and *Rhizobium* inoculations.
McClellan, W. D. (California Agr Exp Stn, Berkeley, CA, USA).
Calif Agr 29(2):13, 1975.

0946 Soybean inoculation studies.
Miller, R. H.
Ohio Agr Res Dev Ctr Res Sum 55:14-16, 1971.

0947 Effect of fertilizers and *Rhizobium* culture on yield of pea *(Pisum sativum* L.).
Mandpuri, K. S. (Punjab Agr U, Ludhiana, India), H. Singh and J. C. Kumar.
J Res Punjab Agr U 10(2):141-144, 1973.

Inoculation did not improve the yield of peas (var Bonneville) during 5 years of investigation in all possible combinations of N, P, with and without inoculation. No information is given on indigenous soil rhizobia or nodulation.

0948 Responses of two legumes to *Rhizobium* inoculation and trace elements.
Partridge, I. J. (Dept Agr, Fiji).
Fiji Agr J (New Ser) 37(2):69-70, 1975.
Plots of mission grass were oversown with siratro or centro. One pair of each plots was inoculated with rhizobia. All centro plantings showed the need for inoculation, but siratro was suitably infected by indigenous strains. No response to trace elements was shown in these trials. Previous reports to the contrary probably were related to a sulphur deficiency which was overcome by sulphate salts in the absence of superphosphate.

0949 Seed inoculation studies in gram (*Cicer arietinum* L.) with different strains of *Rhizobium* spp.
Patil, P. L. (Coll Agr, Poona, India) and N. S. Medhane.
Plant Soil 40(1):221-223, 1974.
Isolates giving significantly higher yield were identified in pot culture and field experiments.

0950 Soybean inoculation research.
Rabb, J. L. (Agr Exp Stn, Bossier City, LA, USA), L. D. Willis and E. P. Dunigan.
Ann Res Rept Red River Valley Agr Exp Stn Louisiana p. 116-117, 1976.
Inoculation with liquid, granular and peat inoculum applied at rates up to 50 times recommended rate did not significantly affect the yield of soybeans. The control (no inoculum) plants produced more nodules with greater nodule weight per 3 plants than all except soil implant granular inoculum tested plants, but yields in these were lower than in the control.

0951 A short note on the effect of rhizobial inoculation on the yield of soybean on a lateritic latosol.
Rajaratnam, J.
M A R D I (Malays Agr Res Dev Inst) Res Bul 1(1):51-54, 1973.

0952 A study on the response of fenugreek (*Trigonella foenum-graecum* L.) to seed inoculation with *Rhizobium meliloti*.
Ramakrishnan, V., M. Nagarajan, M. Thangaraj and S. Giridharan.
S Indian Hort 24(2):60-61, 1976.

0953 Benefits of inoculating peanuts on newly cleared land.
Robertson, W. K. and E. B. Whitty.
Sunshine St Agr Res Rep 18(3):12-13, 1973.

0954 Effect of *Rhizobium* inoculation and phosphate application on black gram (*Phaseolus mungo*) and horse gram (*Dolichos biflorus*).
Sahu, S. K. (Irrig Res Ctr, Chakulia, India).
Madras Agr J 60(8):989-993, 1973.

The nitrogen statur of the sandy loam soil (P_2O_5 content 0.0023%) and other growth and yield factors improved by inoculation and phosphate amendment at 22.4 kg P_2O_5/ha (P).

0955 Studies on the effect of different rhizobial strains on *Phaseolus lunatus* in sand culture.
Saono, S. (Natl Biol Inst, Bogor, Indonesia), H. Karsono and D. Susano.
Ann Bogor 6(2):83-95, 1976.
Of 90 strains tested, 88 produced nodules, but only 51 significantly affected plant growth. Of these, 5 inhibited and 33 enhanced the growth of the whole plant, while 4 inhibited and 36 enhanced the growth of the aboveground part. Others inhibited or enhanced the underground part. The effect was correlated to nodule mass rather than number. Symbiotic capacity (Sc) values larger than 0.33 may be used as a criterion for strain selection.

0956 Response of pigeonpea to inoculation and pelleting.
Saxena, M. C., K. V. B. R. Tilak and D. S. Yadav.
Ind J Agron 20(4):321-324, 1975.

0957 Response to inoculation in soybean and its residual effect on wheat.
Saxena, M. C. (G B Pant U Agr & Technol, Pantnagar, India) and K. V. B. R. Tilak.
Ind J Agron 20(4):369-370, 1975.
Inoculation of seeds, and field inoculation with soil from a field where inoculated soybean had previously grown, both produced 73-94% greater yield compared to control. Without application of N, the yield of wheat following an inoculated soybean crop was more than 65% higher than wheat following an uninoculated soybean crop. The response was equivalent to about 30 kg/N ha.

0958 Effect of seeding rate, inoculation and nitrogen fertilization on yield of fenugreek.
Shalaby, Y, Y, and L. K. Mohamed.
Ann Agr Sci (Moshtohor) 6:71-78, 1976.

0959 Inoculation--a cheap source of nitrogen to legumes.
Singh, P. (JNKV Vidalaya, Jabalpur, India) and S. D. Choubey
Ind Farming 20(10):33-34, 1971.
A brief explanation, with supporting experimental data, of the advantages to be gained from proper inoculation. Inoculation of mung and groundnut, using a jaggery solution, is described.

0960 Multiply forage legume yields with a small investment.
Singh, S. (UP Agr U, Pant Nagar, Nainital UP, India).
Gosanvardhana 20(2)7-9+, 1972.
Non-technical article explaining why proper selection of rhizobia is important, with information on the advantages of biological N fixation and on inoculation methods.

0961 Inoculation of alfalfa (*Medicago sativa* L.) and berseem clover (*Trifolium alexandrinum* L.) with commercial inoculants.
Sistachs, E.
Cuban J Agr Sci 8(1):79-84, 1974.

0962 The effect of *Rhizobium* inoculation on four soybean varieties grown in Cuba. (Hun)
Soos, T., L. Papp and M. V. Mir.
Agrokem Talajtan 25(1/2):139-144, 1976.

0963 Bacterial culture boosts pulse yields.
Subba Rao, N. S.
Intensive Agr 10(1):2-3, 1972.

0964 Nitrogen nutrition of cowpea *(Vigna unguiculata)*. I. Effects of applied nitrogen and symbiotic nitrogen fixation on growth and seed yield.
Summerfield, R. J. (U Reading, England), P. J. Dart, P. A. Huxley, A. R. J. Eaglesham, F. R. Minchin and J. M. Day.
Exp Agr 13(2):129-142, 1977.
The effectively nodulated plants were vegetatively equal to non-nodulated plants supplied with 60 ppm N throughout the 88 day growth period. The nodulated plants produced significantly greater seed yields.

0965 Performance of peat-based single strains of *Rhizobium japonicum* on soybean *(Glycine max)*.
Tilak, K. V. B. R. (G B Pant U, Pantnagar, India) and M. C. Saxena.
Proc Ind Natl Sci Acad Pt B Biol Sci 40(5):476-478, 1974.
In a comparison of indigenous strains, differences in yield were not significant. Those with greater viability and higher respiration rates also recorded better nodulation and yields.

0966 Effect of application of *Rhizobium* inoculum on the yield of gram (*Cicer arietinum* L.) varieties in Chambal Commanded area of Rajasthan.
Tripathi, R. S. (Reg Res Stn, Kota, India), C. S. Dubey A. W. Khan and K. B. Agarwal.
Sci Cult 41(6):266-269, 1975.
Three gram varieties were tested in heavy soil. Inoculation alone increased yields by 25% over control, and 48% with fertilizer. The increase with fertilizer alone was 38%. This same trend was seen in all varieties tested. The fertilizer treatments delayed flowering. [The terms 'Culture' and 'Fertilizer' were apparently transposed in Table 2, causing disagreement with the text.]

0967 Response of kudzu *(Pueraria phaseoloides)* to inoculation and to phosphorus in a calcium-rich soil. (Spa)
Valdez Hidalgo, M.
Rev Latinoam Microbiol 15(3):139-141, 1973.

INOCULATION EFFECTS AND REQUIREMENTS *continued*

0968 *Rhizobium* inoculation and oil content of soybean seeds *Glycine max* (L.) Merrill.
Varma, A. K. (IARI, New Delhi. India) and P. N. Tiwari.
Cur Sci 45(20):725, 1976.
While oil content showed an initial decrease in relation to yield, at much higher yields the percentage became nearly constant. Due to the higher total yield, inoculated plants produced a greater net yield of oil per hectare.

0969 Nitrogen increases in a non-nodulating soybean genotype grown with nodulating genotypes.
Vest, G. (ARS, USDA, Beltsville, MD, USA).
Agron J 63(3):356-359, 1971.
Seeds of non-nodulating genotype A62-8 were mixed 1:1 with seeds of 2 nodulating genotypes and inoculated with 7 different strains or combinations of strains of *Rhizobium japonicum*. Seed protein of all the cultivars was higher when the mixtures were inoculated. The highest yield was produced by A62-8 mixed with Delmar and with certain inoculum treatments.

0970 Inoculation and nitrogen fertilization of soybeans.
Weaver, R. W. and G. M. Dornhoff.
Tx Agr Exp Stn Prog Rep (Consol Prog Rep) 3136/3148:27-29, 1972.

0971 Effects of inoculation and fertilizers on *Desmodium intortum* at Serere, Uganda.
Wendt, W. B. (Dep Agr Serere Res Stn, Uganda).
E Afr Agr Fores J 36(4):317-321, 1971.
Inoculation improved nodulation but not herbage yield or N content in pot trial and field trial investigations. Both nodulation and yield were increased greatly by P, but there was no response to S. The effectiveness of the inoculant and natural *Rhizobium* strains was not determined, but there is no evidence that N deficiency limited growth or protein content.

0972 The effects of inoculation and nitrogen application on seedling growth and nodulation of *Glycine wightii* and *Phaseolus atropurpureus* in the field.
Whiteman, P. C. (U Queensland, St. Lucia Qld, Australia).
Trop Grassl 6(1):11-16, 1972.
Glycine established slowly and nodulated poorly in field tests. Siratro nodulated fully and grew more rapidly. N application and higher levels of inoculant did not improve the growth of *Glycine*.

For additional references with information on inoculation effects, see relevant listings under:
Nitrogen fixation
Polycrop systems
Rhizobium effectiveness, infectiveness
Symbiosis

10. INOCULATION METHODS (OTHER THAN PELLETING).

1001 Problems in obtaining adequate inoculation of soybeans.
Burton, J. C. (Nitragin Co., Milwaukee, WI, USA).
In World soybean research, p. 170-189, Sept., 1976.
Rhizobium japonicum is very persistent in soils, making it very difficult to overcome naturalized populations of ineffective strains. In areas where soybeans are planted for the first time, it is important to effect a good establishment of the most effective rhizobia available. Peat base inoculum in a slurry with maltose or sucrose, applied in large doses under good conditions, is probably the best method for introducing rhizobia. Granular inoculum for soil can be placed at a depth where the soil is moist if it is necessary to plant when the soil is dry.

1002 Another approach to the inoculation of legumes.
Gupta, K. G., J. S. Sandhu and R. K. Sud.
Inst Pasteur Ann 120(5):665-670, 1971.

1003 Note on the comparative efficacy of slurry and sprinkle methods of legume inoculation.
Iswaran, V. (IARI, New Delhi, India) and P. K. Chhonkar.
Gum arabic proved to be a superior adhesive for survival of rhizobia. The slurry method produced a low viability, but this may be attributed to a restricted aeration and possibly to seed diffusates. Sowing immediately after inoculation is advantageous.

1004 Inoculation of legumes in arid and semi-arid regions.
Iswaran, V.
Mod Agric 3(1):11, 1972.

1005 Legume seed inoculation and seed pelleting.
Iswaran, V.
Mod Agric 3(4/5):13-15, 1972.

1006 Effect of inoculant dosage on the adaptation and effectiveness of Nitragin strains. (Rus)
Kalnin'sh, A. D. and I. I. A. Leimane.
Latv P#SR Zinat Akad Mikrobiol Inst Mikroorg Rast 5:3-15, 1972.

1007 Influence of inoculum size on *Rhizobium japonicum* serogroup distribution frequency in soybean nodules.
Kapusta, G. (S Illinois U. Carbondale, IL, USA) and D. L. Rouwenhorst.
Agron J 65(6):916-919, 1973.
Ultra-high inoculation rates may be used to establish superior strains should they be developed. In these tests, inoculation did not influence yield or quality above that provided by resident populations of rhizobia.

1008 Effect of mixing *Rhizobium japonicum* with soil and different amounts of nitrogen fertilizers on soybean yield. (Per)
Karbachsch, M.
Iranian J Plant Pathol 8(2):68-74, 1972.

1009 Effects of seed inoculation methods with peat-based *Rhizobium meliloti* on alfalfa.
Kamelius, H. T. (Res Stn, Agr Can, Charlottetown, PEI, Canada) and U. C. Gupta.
Can J Plant Sci 55(2):555-563, 1975.
Addition of Mo did not consistently improve nodulation or yield. Alfalfa benefited from inoculation and lime coating of seeds.

1010 Inoculation of soybeans. (Fre)
Lagacherie, M. B.
Bul Cent Tech Interprof Ol Metrop 53:61- , 1973.

1011 Influence of inoculation method and soil liming in Carimagua (Llanos Orientales, Colombia) on nodulation in legumes. (Spa)
Morales, V. M., P. H. Graham and R. Cavallo.

1012 Effect of sowing date, inoculation level, and pelleting on the establishment of oversown lucerne.
Musgrave, D. J. (Tera Hills High Country Res Stn, Omarama, NZ)
NZ J Exp Agr 4(1):65-70, 1976.
A 3 year investigation in a semi-arid region indicated that successful establishment of lucerne can be expected only on damper, shady sites unless sowing is followed by rain. Under favorable conditions, some sowings showed large responses to lime pelleting and inoculation rates up to 50 times the recommended rates.

1013 Relative preponderance of *Rhizobium japonicum* serotypes in soil inoculum.
Namdeo, S.L.(Jawaharlal Nehru U, Jabalpur, India), J. N. Dube and U. K. Vaishya.
Proc Ind Natl Sci Acad Pt B Biol Sci 40(5):488-490, 1974.
Nutrient fortified field soil, which had been inoculated over four years, was protected with mineral oil and used as an inoculant at 200 g/ha. Serological studies revealed that fortification caused a shift in strains on the seeds, but not in the nodules. The technique shows possibilities, but further work will be required to ensure the predominance of effective strains.

1014 Effect of inoculation method on *Rhizobium* survival and plant nodulation under adverse conditions.
Philpotts, H. (Dept Agr, Wollongbar, NSW, Australia).
Austral J Exp Agric Anim Husb 17:308-315, 1977.
Survival rates of rhizobia under conditions of high temperature (with and without high relative humidity), exposure to sunlight, and contact with superphosphate was compared under different inoculating methods. In general, lime pelleting gave the best results, but offered no advantage over gum arabic at high temperature.

1015 *Rhizobium* inoculation of soybeans for sub-tropical and tropical soils. I. Initial field trials.
Scudder, W. T. (Agr Res & Educ Ctr, Sanford, FL, USA).

Proc Soil Crop Sci Soc Fla 34:79-82, 1975.
Inoculation problems resulting from high temperature and dry conditions were overcome by soil placement of the inoculum in the seed furrow, or at depths of 2.5 to 5.0 cm below the seed.

1016 The effect of delayed inoculation on nodulation and symbiotic nitrogen fixation in soybean. (Cze)
Skrdleta, V.
Rostlinna Vyroba 17(3):309-316, 1971.

1017 Relationship between soybean cultivars and *Rhizobium japonicum* serotypes with single- and multi-strain inoculants. I. Greenhouse pot experiments.
Skrdleta, V. (Inst Plant Nutr, Prague, Czechoslovakia).
Zent Bak Parasit ... 2 Nat Abt 128:543-550, 1973.
Single strain inocula were significantly better than double-strain or triple-strain. Nodulation and N fixation for Adepta X D216 and Chippewa X D216 were superior to other associations.

1018 Relationship between soybean cultivars and *Rhizobium japonicum* serotypes with single- and multi-strain inoculants. II. Field experiments.
Skrdleta, V. (Inst Plant Nutr, Prague, Czechoslovakia) and J. Pelikan.
Zent Bak Parasit ... 2 Nat Abt 128:745-752, 1973.
A high competetive ability of strain 311B did not correlate with its relative effectivity. Single-strain inoculants were generally better.

1019 Inoculate the soil instead of the seed.
Stoddard, C. D.
Farm Chem 139(6):50, 52, 1976.
On new soybean land, soil inoculation below the seed with granular inoculants produced the highest crop yield.

1020 Preinoculation of legume seed.
Thompson, J. A. (Hort Res Stn, Gosford, NSW, Australia), J. Brockwell and R. J. Roughley.
J Aust Inst Agr Sci 41(4):253-254, 1975.
Preinoculated seed in Australia was examined in 1972, and all samples were below minimum standards for number of rhizobia/seed. In the USA, "grow out" tests showed 23% rating 'good' in 1971, 66% in 1972. The following recommendations for preparing and marketing preinoculated seed were made: prominently displayed dating; knowledge of storage principles by retailers; an absolute 1 month expiry period (until an acceptable expiry period based on studies can be determined) and discontinuation of the preinoculation practice if standards are not practicable.

1021 "Soil" inoculation for soybeans investigated - a new inoculation method with new strains of nodulating bacteria.
Thompson, L. (U Arkansas, Fayetteville, AR, USA) and P. Pongaskul.
Ark Farm Res 25(2):15, 1976.

INOCULATION METHODS *continued*

Efforts to replace indigenous rhizobia with superior strains by soil inoculation were not successful, but seed inoculation increased nodulation and yield.

1022 Sucrose and application of *Rhizobium* on seed.
Varma, A. K. (IARI, New Delhi, India) and N. S. Subba Rao.
Plant Soil 38(1):227-230, 1973.
Peanut and soybean had tolerance limits for good germination of 2.5 and 5% respectively for sucrose in the slurry of peat-based inoculants. Qualitative and quantitative data on fungi in the rhizosphere in relation to inoculation and sucrose levels are included.

1023 Effect of inoculum size on nodulation of *Glycine max* (L.) Merrill, variety Ford.
Weaver, R. W. (Iowa Agr & Home Ec Exp Stn, Ames, IA, USA) and L. R. Frederick.
Agron J 64(5):597-599, 1972.
Soil grown plants achieved maximum total N fixed in plant tops at an inoculation level of $2X10^3$ cells per seed. Sand grown plants required $1X10^5$ cells per seed. Taproot nodulation may be a useful qualitative criterion for determining the adequacy of nodulation and abundance of rhizobia.

1024 Effect of inoculum rate on competitive nodulation of *Glycine max* L. Merrill. I. Greenhouse studies.
Weaver, R. W. (Texas A & M U, College Station, TX, USA) and L. R. Frederick.
Agron J 66(2):229-232, 1974.
Soybeans grown on soils containing 1,000 or more rhizobia/g are not likely to be extensively nodulated by inoculum rhizobia applied at normal rates (less than 10,000 cells per seed).

1025 Effect of inoculum rate on competetive nodulation of *Glycine Max* L. Merrill. II. Field studies.
Weaver, R. W. (Texas A & M U, College Station, TX, USA) and L. R. Frederick.
Agron J 66(2):233-236, 1974.
An inoculation rate of $3.3X10^6$ rhizobia/seed in soils with fewer than 12 rhizobia/g produced 65% of the nodules. In soils containing $1X10^3$ rhizobia/g, that inoculation rate produced 35% Of the nodules. An inoculum rate 1000 times the soil population must be used to competitively establish 50% of the nodules. Commercial inoculants in the U. S. are not supplying adequate numbers of rhizobia for competitive nodulation in soils previously cropped to soybeans.

1026 Nitrogen fixation by soybeans as influenced by inoculum placement.
Wilson, D. O. (U of Georgia Agr Exp Stn, Experiment, GA, USA).
Agron J 67(1):76-78, 1975.
Inoculation depth below the soil surface strongly influenced the pattern of nodule development. At higher greenhouse temperatures (37-41°C daily maxima), deeper placement of the inoculum had a negative effect on N

fixation. The need for field tests was recognized.

1027 Inoculating alfalfa and clover seed.
Youngberg, H.
Oreg St U Ext Fs 184, 2 p., 1972.

For additional references with information on inoculation methods, see relavent listings under:
Inoculant materials
Pelleting
Temperature and climate
Water factors.

11. LEAVES.

1101 Nodulation of rooted leaves in legumnious plants.
Lie, T. A. (Agr U, Wageningen, The Netherlands).
Plant Soil 34(3):663-673, 1971.
Root formation on the petioles of detached leaves of several legumes was easily obtained in artificial light at 22 to 24°C. Nodulation on the rooted leaves was inhibited by combined N and high temperatures. A low light intensity is optimal for rooted leaf nodulation studies.

1102 Populations of Mexican bean beetles in relation to leaf protein of nodulating and non-nodulating soybeans.
Todd, J. W. (U Georgia Exp Stn, Tifton, GA, USA), M. B. Parker and T. P. Gaines.
J Econ Entomol 65(3):729-731, 1972.
A direct correlation of percentage of leaf protein and the numbers of bean beetles *(Epilachna varivestis)* was found on non-nodulating soybeans, but not on nodulating soybeans. N applications increased the leaf protein significantly only on non-nodulating soybeans, but beetle infestation increased significantly in both the nodulating and non-nodulating plants.

1103 Rooting of detached *Vigna sinensis* leaves for use in physiological studies.
Wilson, L. A. (U West Indies, St Augustine, Trinidad).
Trop Agr (Trinidad) 50(4):341-343, 1973.
The rooted leaf is a useful tool for studying the effectiveness of symbiotic nitrogen fixation. Copious rooting occurred without rooting hormone treatment when leaves excised at the ends of the petioles were placed in moist sand in a mist propagator.

1104 The use of rooted leaves of *Vigna unguiculata* for evaluating the effectiveness of nodulation in single plant lines.
Wilson, L. A. (U West Indies, St Augustine, Trinidad).
Euphytica 23(2):267-271, 1974.
Rooted leaves provided a simple, reliable means for evaluating strains of *Rhizobium* species.

12. LEGHAEMOGLOBIN.

1201 Characterization and improved separation of soybean leghemoglobins.
Appleby, C. A., N. A. Nicola and J. G. R. Hurrell.
Biochem (Easton) 14(20):4444-4450, 1975.

1202 Studies of the physiological role of leghaemoglobin in soybean root nodules.
Bergersen, F. J. (CSIRO, Canberra, Australia), G. L. Turner and C. A. Appleby.
Biochim Biophys Acta 292(1):271-282, 1973.
Leghaemoglobin does not have a direct role in the nitrogen-fixing system, but may act by facilitating the diffusion of O_2 into the nodule tissue under the low pO_2 existing in the dense tissue.

1203 Leghaemoglobin and the supply of O_2 to nitrogen-fixing root nodule bacteroids: studies of an experimental system with no gas phase.
Bergersen, F. J. (CSIRO, Canberra, Australia) and G. L. Turner.
J Gen Microbiol 89:31-47, 1975.
The presence of leghaemoglobin allowed maximum rates of O_2 uptake to continue to a much lower range of concentration.

1204 Leghaemoglobin and the supply of O_2 to nitrogen-fixing root nodule bacteroids: presence of two oxidase systems and ATP production at low free O_2 concentration.
Bergersen, F. J. (CSIRO, Canberra, Australia) and G. L. Turner.
J Gen Microbiol 91(pt 2):345-354, 1975.
A high-affinity oxidase system which was most active when dissolved oxygen was between 0.01 and 0.1 micromoles, and a low-affinity system, active at concentrations of 1 µM O_2 and above, were shown to be present. The high-affinity pathway produced up to 5 times greater bacteroid ATP concentrations than the other system in the absence of leghaemoglobin.

1205 Synthesis and turnover of leghaemoglobin in lupin root nodules.
Coventry, D. R. (U Western Australia, Nedlands) and M. J. Dilworth.
Biochim Biophys Acta 447(1):1-10, 1976.
When bacteroid protein synthesis was inhibited, leghaemoglobin and soluble plant protein synthesis were unaffected. This result is consistent with leghaemoglobin being synthesized on plant ribosomes rather than on bacterial ribosomes. The leghaemoglobin had an apparent half life of 18 days when tested with $^{14}CO_2$, and is a stable protein in N-fixing yellow lupin nodules.

1206 Nodule formation and haemoglobin content in some species of Papilionaceae.
Iyer, N. R. (U de Oriente, Cumana, Venezuela).
Plant Soil 44(2):451-454, 1976.
Of the 14 legumes (11 genera) studied, *Dolichos lablab* had the highest haemoglobin content per unit nodule volume. This may show a greater potential for symbiotic activity with rhizobia, and is probably related to the volume of active bacteroid tissue in the nodule.

1207 Effect of legoglobin on respiration and nitrogen-fixing activity of lupine bacteroids.
Melik-Sarkisyan, S. S. (A N Bakh Inst Biochem, Moscow, USSR), M. V. Raikhinshtein, L. P. Vladzievskaya, N. F. Bashirova and V. L. Kretovich.
Sov Plant Physiol 23(2):231-235, 1976.
Hemoproteins in the oxidized form increased the rate of acetylene reduction, while respiratory chain inhibitors significantly reduced acetylene reduction activity. It is suggested that legoglobin has an indirect effect on N-fixing activity by regulating the influx of oxygen.

1208 Heme synthesis in soybean root nodules. I. On the role of bacteroid δ-aminolevulinic acid synthase and δ-aminolevulinic acid dehydrase in the synthesis of the heme of leghemoglobin.
Nadler, K. D. (Michigan St U, E Lansing MI, USA)and Y. J. Avissar.
Plant Physiol 60(3):433-436, 1977.
Results are reported which support the contention that bacteroid ALAS and ALAD activities, rather than those activities of the plant, are directly involved in formation of leghaemoglobin heme. It is suggested that the bacteroids may be solely responsible for heme synthesis in the nodule symbiosis. Bacteroid ALAD activity was detected only in effective nodules, and this, but not plant ALAD activity, correlated with Lb accumulation in the nodules.

1209 Leghemoglobins and nitrogenase activity during soybean root nodule development.
Nash, D. T. (Lady Davis Inst Med Res, Montreal, Que, Canada) and H. M. Schulman.
Can J Bot 54(24):2790-2797, 1976.
A slower rate of increase of leghemoglobin content compared with that of nitrogenase activity results in a progressive decline in the ratio of the former to the latter throughout plant development and senescence. At flowering, leghemoglobin content represented 40% of the total soluble protein of the nodules. Nitrogenase activity was induced in free-living rhizobia in the absence of detectable leghemoglobin.

1210 The absence of oxidized leghemoglobin in soybean root nodules during nodule development.
Nash, D. T. (Lady Davis Inst Med Res, Montreal, P.Q., Canada) and H. M. Schulman.
Biochim Biophys Res Comm 68(3):781-785, 1976.
Spectrophotometric examination of leghemoglobin extracted from soybean root nodules at different ages in an atmosphere of carbon monoxide revealed no oxidized leghemoglobin. It was concluded that the decline of nitrogenase activity in older root nodules could not be attributed to the accumulation of oxidized leghemoglobin.

1211 Observations on vegetative growth and leghemoglobin contents of root nodules of pea and bean plants after flower bud removal. (Ita)

Pagnotti Cappelletti, E. M. and M. T. Lora.
Nuovo Gior Bot Ital 106(4):197-210, 1972.

1212 A procedure for obtaining leghemoglobin from lupine nodules by fractional salting out with $(NH_4)_2SO_4$.
Peive, Ya. V. (K. A. Tamiryazev Inst Plant Physiol, Moscow, USSR), B. P. Atanasov, G. I. A. Zhiznevskaya and N. N. Krasnobaeva.
Sov Plant Physiol 20(4):723-727, 1973.
Good separation of the leghemoglobin macrocomponent from Lb was achieved, and the components were purified using simple materials and equipment.

1213 Indole-3-acetic acid (IAA) oxidation by leghemoglobin from soybean nodules.
Puppo, A. (Lab de Biol Veg, Nice Cedex, France) and J. Rigaud.
Physiol Plant 35:181-185, 1975.
The ferric form of leghemoglobin was found to be most active in catabolising IAA. Degradation by the ferrous form, as normally found in nodules, was significantly lower. This is possibly due to rapid autoxidation of the leghemoglobin during the experiments.

1214 The effect of ageing on the leghemoglobin of cowpea nodules.
Swaraj, K. (Haryana Agr U, Hissar, Haryana, India) and O. P. Garg.
Physiol Plant 39(2):185-189, 1977.
In fully senescent green nodules, the total protein had decreased to a very low level, while heme proteins were almost absent. Host senescence resulted in a reduction in the number of leghemoglobin proteins in all types of nodules and a drastic change in their electrophoretic mobility.

1215 Changes in the protein composition of leghemoglobin in greening nodules of Bengal gram (*Cicer arietinum* L.).
Swaraj, K. (Haryana Agr U, Hissar, Haryana, India) and O. P. Garg.
Z Pflanzenphysiol 81:180-183, 1977.
The heme containing proteins of red nodules were absent in green, non-functioning nodules. It was concluded that greening is accompanied by destruction of the heme porphyrin ring as well as denaturation of the protein. Genetic diversity in the number of proteins constituting leghemoglobin was confirmed.

1216 Intracellular site of synthesis and localization of leghemoglobin in root nodules.
Verma, D.P.S. (McGill U, Montreal, PQ, Canada) and A. K. Bal.
Proc Natl Acad Sci USA 73(11):3843-3847, 1976.
Analysis showed that free polysomes contain more immunoreactive material than do membrane-bound polysomes. Antibodies conjugated with ferritin for immunocytochemical localization of leghemoglobin showed that the antibody conjugates were strictly localized in the host cell cytoplasm and adjacent to the outer surface of the membrane surrounding the bacteroids. No ferritin was found within the membrane sac containing the bacteroid.

1217 Study of structure of leghemoglobin from lupine nodules.
Zhiznevskaya, G. Ya. (K. A. Timiryazev Inst, Moscow, USSR), B. P. Atanasov, L. I. Borodenko and N. N. Krasnobaeva.
Sov Plant Physiol 23(6):933-940, 1976.
Multiple investigations revealed a unity of a common type of steric myoglobin-like structure in vertebrate, invertebrate and legume globins. The aromatic environment of the heme in soybean differs significantly from that of the lupine leghemoglobin.

13. LEGUMES: EVALUATION, PHYSIOLOGY, TAXONOMY.

1301 A numerical classification of *Cajanus cajan* (L.) Millsp. accessions based on morphological and agronomic attributes.
Akinola, J. O. (U Queensland, Australia) and P. C. Whiteman.
Aust J Agric Res 23:994-1005, 1972.
Thirty-one attributes were used to classify 95 accessions from 11 countries into 15 groups. Two attributes (hard seededness and an unusual inflorescence formation pattern) were newly recorded. The agronomic importance of the classification is discussed.

1302 Agronomic studies on pigeon pea (*Cajanus cajan* (L.) Millsp.). I. Field responses to sowing time.
Akinola, J. O. (U Queensland, Australia) and P. C. Whiteman.
Aust J Agric Res 26:43-56, 1975.
Optimum sowing times (southern hemisphere) were late November-mid January for dry seed production in late-maturing accessions, and not later than December for early-maturing accessions grown for periodic green pod picking. Ripe pods were picked 240 days after early season sowing of early-maturing accessions, and 280 days after early sowing of the late maturing accessions.

1303 Agronomic studies on pigeon pea (*Cajanus cajan* (L.) Millsp.). II. Responses to sowing density.
Akinola, J. O. (U Queensland, Australia) and P. C. Whiteman.
Aust J Agr Res 26:57-66, 1975.
Per plant yield declined with increasing density, while the per hectare yield increased until a density of about 108,000 plants/ha was reached. The optimum density for seed production was lower than that giving maximum yield of dry matter, and the per cent N in all plant components increased with density. This led to the suggestion of high density planting for green manuring.

1304 Agronomic studies on pigeon pea (*Cajanus cajan* (L.) Millsp. III. Responses to defoliation.
Akinola, J. O. (U Queensland, Australia) and P. C. Whiteman.
Aust J Agr Res 26:67-79, 1975.
Evidence suggested that 8- and 12-week defoliation frequencies could be successfully integrated to incorporate cattle grazing and forage cropping along with seed production into a single management system. Late-maturing accessions were better adapted to cutting, provided that basal green leaves always remained on the stubble.

1305 The agronomy of the pigeon pea (*Cajanus cajan*).
Akinola, J. O. (U Queensland, Australia), P. C. Whiteman and E. S. Willis.
Commonwealth Bur Pastures & Fld Crops, Rev Ser no. 1, 57 p., 1975 [Published by Commonwealth Agricultural Bureaux, UK, 1975]
A review of the botany and agronomy of the pigeon pea, with information on utilization in human nutrition, animal production and in crop rotations. The bibliography includes more than 230 references.

1306 The purification of the glycoprotein lectin from the broad bean (*Vicia faba*) and a comparison of its properties with lectins of similar specificity.
Allen, A. K. (Charing Cross Hosp Med Sch, London, UK), N. N. Desai and A. Neuberger.
Biochem J 155:127-135, 1976.
The composition and nature of the subunits of lectin from the broad bean were compared to concanavalin A and to the lectins from pea and lentil. The four lectins differ in specificities towards monosaccharides, disaccharides and glycoproteins.

1307 Improving pasture systems with clovers and other legumes.
Allen, L. R. (Clemson U Ext Serv, GA, USA).
Circ Clemson U Coop USDA Agr Ext Srv 549: 6 p., 1975.

1308 Register of Australian herbage plant cultivars.
Barnard, C. (compiler). (CSIRO, Canberra, Australia).
Div Plant Ind, CSIRO, 260 p., 1972.
Origin, description, agronomic characters and references are given for each cultivar. Legumes are listed on pages 105-234

1309 Bayani [Giant ipil-ipil (*Leucaena leucocephala*)] a source of fertilizer, feed and energy for the Philippines.
Benge, M. D. (Magsaysay Ctr, Manila, Philippines) and H. Curran.
USAID Agr Dev Ser, 22 p., 1976.
'Hawaiian giant' vars. K-8 and K-28 are prolific in both wood and foliage production, yielding high density straight lumber and growing as much as 16.66 meters in height in 6 years. As a green manure, the leaves and young stems may offer the answer to providing fertilizers for the rural poor.

1310 The role of legumes in soil fertility maintenance in the lowlands of Papua New Guinea: a legume evaluation study at Keravat, New Britain; and notes on the use of legumes as food in Papua New Guinea.
Bourke, R. M.
Sci New Guinea U Papua 2(1):63-69, , 1974.

1311 'Hawaiian giant' koa haole.
Brewbaker, J. L. (U of Hawaii, Honolulu, HI, USA).
Col Trop Agr Hawaii Agr Exp Stn Misc Pub 125 4 p. [ca. 1975].
An arboreal variety of *Leucaena latsiliqua (=leucocephala)*, or Hawaiian koa haole, with exceptional size and vigor, has been released.

Spaced every 4 feet as a windbreak, the trees grew to 13½ feet in 6 months, 30 feet in 2 years and 55 feet in 6 years. Plantings harvested for forage yielded double that of the local strain and averaged 28% protein in the leaf meal.

1312 Studies on soya beans in the Manawatu.
Brown, N, S., B. R. Watkin, G. S. Robinson and R. M. Greenwood.
N Z Agr Sci 5(5):6-11, 1971.

1313 An improved seed programme for maintaining disease-free seed of field beans (*Phaseolus vulgaris*).
Copeland, L. O. (Michigan St U, E Lansing, MI, USA), M. W. Adams and D. C. Bell.
Seed Sci Technol 3:719-724, 1975.
A certification scheme with strict disease standards enabled the production of high quality seed in an area with potential widespread disease infestation.

1314 A survey of indigenous tropical legumes in Puerto Rico.
Dubey, H. D. (U Puerto Rico - Mayaguez, Rio Piedros, PR), R. Woodbury, G. L. Spain and R.L. Rodriguez.
J Agr U Puerto Rico 58(1):87-98, 1974.
Forty-nine nodulated indigenous legumes showing potential for agriculture are listed, with descriptions of the nodules. Habitat descriptions and growth habits are included.

1315 Immunochemical behaviour of legumin and vicilin from *Vicia faba*: a survey of related proteins in the Leguminosae subfamily Faboideae.
Dudman, W. F. (CSIRO, Canberra, Australia) and A. Millerd.
Biochem Systematics Ecol 3:35-33, 1975.
Contrary to earlier serological investigations on the relationship of the storage proteins legumin and vicilin, in which the latter was reported to be more widely distributed among the taxa, this study of 55 species found that legumin is distributed in a wider range. Indications of a third, intermediate protein are also reported. The need for the most stringent methods of antigenic analysis is pointed out.

1316 The symbiotic effectiveness and geographic origin of morphological-agronomic groups of *Stylosanthes* accessions.
Edye, L. A. (CSIRO, Townsville, Qld, Australia), R. L. Burt, D. O. Norris and W. T. Williams.
Aust J Exp Agr Anim Husb 14(68):349-357, 1974.
The response of 241 accessions of 15 *Stylosanthes* species to a *Rhizobium* strain was related to morphological-agronomic groups and the broad geographic origin of each accession. The possibility that M-A groups may provide a convenient base from which to sample large collections against *Rhizobium* strains is suggested.

1317 Classification of the *Stylosanthes* collection, 1928-1969.
Edye, L. A. (CSIRO Pastoral Res Lab, Townsville, Qld, Australia), R. L. Burt, C. H. L. Nicholson, R. J. Williams and W. T. Williams.
CSIRO Div Trop Agron Tech Pa 15, 28 p., 1974.

287 accessions were classified into 53 groups and subgroups based on morphological-agronomic values. The country of origin with latitude and altitude, as well as M-A characters, are given for each accession.

1318 A comparison of twenty-seven introduced grasses in two dry-tropical environments in northern Queensland.
Edye, L. A. (CSIRO, Qld., Australia)
Austr J Exp Agr Anim Husb 15:788-794, 1975.
In portions of the 4 year experiment, grasses grown with associated legumes were higher in N than when fertilized with urea.

1319 Protein content and protein quality of tuberous roots of some legumes determined by chemical methods.
Evans, I. M. (U Durham, England), D. Boulter, F. R. J. Eaglesham and P. J. Dart.
Qualitas Plantarum 27(3-4):275-285, 1977.
Chemical data on African yam bean, Mexican yam bean, winged bean and cultivated cowpea tubers are presented. Crude protein values ranged from 3.9% to 14.1%. Except for the sulphc-amino acids, the amino acid profiles were nutritionally acceptable by FAO standards.

1320 A qualitative study of the nodulating ability of legume species. 2.
Grobbelaar, N. (U Pretoria, S Africa) and B. Clarke.
J S Afr Bot 38(4):241-247, 1972.
Continuation of a 1967 report by Grobbelaar (Pub U Pretoria, n. s. No. 38). The present list contains nodulating data on 215 indigenous species, of which only 3 species of the *Caesalpinoideae* were consistently found to be without nodules.

1321 A qualitative study of the nodulating ability of legume species: list 4.
Grobbelaar, N. and B. Clarke.
Agroplantae 6(3):59-64, 1974.
Not available for annotation, but assumed to be a continuation of 1320+.

1322 N, P, & K percentages in soybean (*Glycine max* (L.) Merrill) plant parts.
Hanway, J. J. and C. R. Weber.
Agron J 63:286-290, 1971.

1323 Accumulation of N, P, & K by soybean (*Glycine max* (L.) Merrill) plants.
Hanway, J. J. and C. R. Weber.
Agron J 63:406-408, 1971.

1324 Collection and evaluation of tropical and subtropical Brazilian forage legumes.
Hymowitz, T. (U Illinois, Urbana, IL, USA).
Trop Agr (Trinidad) 48(4):309-315, 1971.
To solve the problem of providing pasture forage during the dry season, a search for vigorous, drought tolerant legumes growing alone or in association with grasses was conducted. Forty-four indigenous and

naturalized species were collected, including nodules whenever possible. *Stylosanthes gracilis* was found to be extremely drought tolerant, and was the only legume studied which thrived during the dry, cool season. It appeared to grow well in soils of relatively low fertility with a pH between 4.5 and 5.5.

1325 The indigenous South African clovers (*Trifolium africanum* Ser. and *Trifolium burchellianum* Ser.) and their potential as pasture legumes.
Jones, R. M. (CSIRO, Qld., Australia), B. W. Strijdom and E. P. Theron.
Trop Grassl 9(1):7-16, 1974.
Although these species have shown some promise, it is yet to be proved that they can be persistent and productive pasture legumes. Their potential appears to be where climate or soil limit white clover, and not as alternatives to it. There are indications that it may be possible to select wide spectrum strains of rhizobia for inoculant production for these clovers, but this is still being studied.

1326 Subterranean clover as a winter forage crop in a subtropical environment.
Kemp, D. R. (Dep Agr, Taree, NSW, Australia).
Aust J Exp Agr Anim Husb 15:631-636, 1975.
A 3 year study of the feasibility of using sub clover rather than oats or ryegrass as a low cost winter forage crop led to the conclusion that sowing the clover at high rates in early autumn provided a suitable alternative. Clover offered the additional advantage of not requiring nitrogen fertilizer.

1327 Legumes pay big dividends in pasture programs.
Knight, W. E. (Mississippi Agr & Fores Exp Stn) and V. H. Watson.
USDA-ARS, Miss Agr & Fores Exp Stn Tech Rel C-15, 8 lvs., 1973.
Legume forage is highly digestible and more nutritious than grass. It requires less fertilization, and can reduce beef production costs by up to 40% when all advantages are considered.

1328 The role of legumes in alleviating protein deficiency in Papua New Guinea.
Korte, R. (Dep Pub Health, Konedobu, New Guinea).
Sci in New Guinea 2(1):6-14, 1974.
Protein intakes have been found to be generally inadequate. Greater production and consumption of legumes should be encouraged.

1329 The origin of chickpea as indicated by seed protein electrophoresis.
Ladzinsky, G. (Hebrew U, Rehovot, Israel) and A. Adler.
Israel J Bot 24:183-189, 1975.
Although 88 cultivars of *Cicer arietinum* displayed wide variation in seed shape, size and color as well as in numerous other morphological and physiological characteristics, they all possessed the same basic seed protein profile. This indicates that the species has a rather monophyletic origin. Profiles of *C. judaicum* and *C. pinnatifidum* support the separate species status of those plants. The study indicated *C. reticulatum* as the probable wild progenitor of the cultivated chickpea.

1330 Effect of harvesting practices on foliage and root development, digestibility, cold hardiness and nodulation of birdsfoot trefoil.
Langille, J. E. (Can Dep Agr Exp Farm, Nappan, Nova Scotia, Canada) and F. W. Calder.
Can J Plant Sci 51(6):499-504, 1971.
Harvesting at maximum growth stage produced the most dry matter, the greatest etiolated regrowth and best nodulation, but the lowest digestibility. Production at the vegetative stage produced the least forage, but it was the most digestible. Plants harvested at 7.5 cm stubble height had significantly more nodules than plants harvested at the 2.5 cm height, especially when harvested in the vegetative stage.

1331 Nodulation of tropical legumes in Singapore.
Lim, G. (U of Singapore).
Trop Agr (Guildford) 54(2):143-147, 1977.
Twenty-seven members of the family Caesalpinoideae, 13 of Mimosideae, 27 of Papilionoideae and 1 of Swartzoideae were examined for nodulation. Of the 68, 37 did not have root nodules, mainly from the family Caesalpinoideae . The Papilionoideae showed 81.5% nodulated species. No correlation between nodulation and whether indigenous or introduced was noted.

1332 How to exploit alfalfa stands for high plant and protein yield. (Ger)
Martin, B. and L. Hass.
Feldwirtschaft 15(7):313-315, 1974.

1333 Distribution and change in the contents of allantoin and allantoic acid in developing nodulating and non-nodulating soybean plants.
Matsumoto, T. (Nagoya U, Japan), M. Yatazawa and Y. Yamamoto.
Plant Cell Physiol 18(2):353-359, 1977.
In nodulated plants, the allantoin level in stems, roots and nodules was raised with growth, attaining a maximum at green pod stage and then decreasing. In non-nodulating soybean plants, allantoin was constant at very low levels with little accumulation over the growth period.

1334 Breakthrough in alfalfa research.
Miller, P. E. (Minn Agr Exp Stn, Minnesota, USA)
Minn Sci 32(3):4-7, 1976.

1335 Biochemistry of legume seed proteins.
Millerd, A. (CSIRO, Canberra, Australia)
Ann Rev Plant Physiol 26:53-72, 1975.
Prospects for improving the protein quality of crops must be preceded by an understanding of their protein structure and synthesis, then on the genetic controls involved. This review describes the groundwork for advancement in those areas, and includes 106 references.

1336 The pigeon pea (*Cajanus cajan* Millsp.), a high-protein, tropical bush legume.
Morton, J. F. (Morton Collectanea, U Miami, Coral Gables, FL. USA).
Hortsci 11(1):11-19, 1976.

The pigeon pea is one of the oldest and most important food crops, ranking fifth among edible legumes in the world. While its importance has been recognized in parts of Africa and the Caribbean, in many other tropical areas it remains a neglected crop with an unrealized potential. This comprehensive review cites 124 references.

1337 The relative performance of white clover genotypes with rhizobial and mineral nitrogen in agar culture and soil.
Mytton, L. R. (Welsh Plant Br Stn, Aberystwyth, Wales).
Ann Appl Biol 82:577-587, 1976.
The relationship of data obtained from tube and pot experiments in evaluating the effectiveness of *Rhizobium*-host associations was investigated. Environmental effects were found to be relatively small compared to the main genotype effects. The need to relate N fixing ability to the growth potential of the host genotype is made apparent by these experiments.

1338 The winged bean: a high-protein crop for the tropics.
Board on Science & Technology for International Development, NAS. (Natl Acad Sci, Washington, D. C., USA)
NAS Advis Studies Spec Repts 17, 41 p., 1975.
A report focusing on the exceptional promise offered by *Psophocarpus tetragonolobus*, an edible tropical legume which produces beans, pods and tubers of high nutritive value. The agronomy, nutritive value and recommendations for further exploitation are discussed in this non-technical publication.

1339 Estimated profitability of investment in legume pasture development in far northern Queensland.
Robinson, I. B. (Qld Dep Primary Indus, Brisbane, Australia) and N. C. Sing.
Trop Grassl 9(3):199-207, 1975.
Economic factors make it unlikely that graziers beyond about 400 road kilometers from Cairns would undertake pasture development. A 25% reduction in the annual superphosphate requirement would extend the "zone of profitability" an additional 150 km. The upgrading of roads could further extend the profitability zone.

1340 Forage legume production trials at the Volcano Research Station, Island of Hawaii.
Rotar, P. P. (U Hawaii, USA), Y. N. Tamimi, O. R. Younge and T. Izuno.
Hawaii Agr Exp Stn Res Rept 206, 30 p., 1976.
Trials were conducted over a 4 year period in volcanic ash soil, pH range 4.5 to 6.7, at 4000 foot elevation. Ladino clover fixed an average of 637 pounds of N per acre per year, followed (in order) by big trefoil, Kenland red clover, strawberry clover, crimson clover, New Zealand red clover and Persian clover. Big trefoil had the highest overall harvest and crude protein production.

1341 Climatic range of grasses and legumes used in pastures: results of a survey conducted at the 11th international grassland congress.
Russell, J. S. (CSIRO Cunningham Lab, St. Lucia, Qld., Australia) and H. R. Webb.
J Aust Inst Agr Sci 42(3):156-163, 1976.
The survey involved 99 stations in 26 countries, and showed that a wide diversity of species had been studied in a range of climates. Of the 483 species reported, data was analyzed for 35 important legumes and 31 grasses. Means and standard deviations for latitude, rainfall, temperature and mean minimum temperature were tabulated for these 66 species.

1342 Effect of bean variety on nodule development and nitrogen fixation using a number of strains of *Rhizobium phaseoli* of Brazillian origin.
Saito, S. M. T.
Ann Rept Bean Improv Coop 19:67-68, 1976.

1343 Symbiotic nitrogen fixation by winter legumes. 1. A comparative efficiency between an Indian and an Australian variety of lucerne *(Medicago sativa)*.
Sharma, P. B. (Punjab Agr U, Ludhaina, India), A. Singh and R. Singh.
Ind J Agr Res 7(3/4):159-163, 1973.
The quick-growing Indian variety fixed about 14% more N, but the Australian variety had a higher crude protein content as indexed by percentage of N content.

1344 Safari ... a new pasture legume for the sub-tropics.
Shaw, K. A. (Agr Branch, Queensland, Australia), and T. J. Quinlan.
Qld Agr J, May-June p. 251-255, 1976.
Kenya white clover (*Trifolium semipilosum* cv. 'Safari') combined well with kikuku and other grasses, produced good liveweight gains in grazing beef cattle, and showed great potential as a pasture legume. Once established, Safari grows year round, tolerates soil acidity, drought and relatively heavy grazing better than white clover.

1345 Role of legumes and *Rhizobium* culture in fodder development programme[s].
Singh, H. S. (Indo-German Agr Dev Proj, Almora, India), R. J. Singh and R. P. S. Yadava.
Food Farming Agr 7(5):29-30, 1975.
Practical advice on the advantages and methods of using inoculated legumes in fodder programmes. Dehydrated ground leaves of certain legumes can replace protein concentrates in cattle and poultry ration.

1346 Catalogue of seed available at the Southern Regional Plant Introduction Station: *Cajanus cajan*.
SRPIS (Experiment, Georgia, USA)
Regional Proj S-9, 81 p., 1977.
A list of seeds and vegetative stock available in small quantities to research workers. Approximately 5650 introductions are listed in tabular form, with information on origin, morphological characters and agronomic data.

1347 Effect of germination on the carbohydrates, proteins, trypsin inhibitor, amylase inhibitor and hemagglutinin in horsegram and mothbean.
Subbulakshmi, G. (Cent Fd Technol Res Inst, Mysore, India), K. GaneshKumar and L. V. Venkataraman.
Nutr Repts Int'l 13(1):19-31, 1976.
In vitro protein digestibility increased with germination (24-72 hrs.) in both legumes. Starch content decreased while reducing sugars increased correspondingly. Cooking inactivated the trypsin inhibitor considerably, but germination for 72 hours only slightly decreased the trypsin inhibitor content. Hemagglutinin was decreased markedly by germination and was inactivated somewhat by cooking.

1348 Integrated field and greenhouse screening for environmental sensitivity in cowpea (*Vigna unguiculata*).
Summerfield, R. J. (U Reading Plant Environ Lab, Shinfield, UK), H. C. Wien and F. R. Minchin.
Exp Agr 12(3):241-248, 1976.
Close agreement between field and glasshouse trials was obtained in automatically controlled glasshouses in determining the effects of daylight and nighttime temperatures on the onset of flowering. An integrated approach, using field screening for daylight effects and glasshouse screening for day and night temperature effects can be used to accelerate the screening of cowpea cultivars for sensitivity to environmental factors.

1349 *Centrosema pubescens* in Australia.
Teitzel, J. K. (Queensland Dept Primary Indus, S Johnstone, Aust.) and R. L. Burt.
Trop Grassl 10(1):5-14, 1976.
Release of a new cultivar has demonstrated that certain deficiencies which have limited the exploitation of this versatile legume can be overcome. Greater production efficiency could be realized through a better understanding of optimum soil requirements and grazing management.

1350 Effects of germination on the biological value, digestibility coefficient and net protein utilization of some legume proteins.
Venkataraman, L. V. (Cent Fd Res Inst, Mysore, India), T. V. Jaya and K. S. Krishmurthy.
Nutr Rpts Int'l 13(2):197-205, 1976.
Ungerminated greengram showed a lower biological value than cowpea. Cooking significantly reduced the biological value of ungerminated cowpea and chickpea. Germination produced no improvement in biological value in any of the three legumes, but decreased the digestibility of cowpea and chickpea while increasing the digestibility of greengram. New protein utilization values were highest for cowpea.

1351 Domestication of pulses in the old world.
Zohary, D. (Hebrew U of Jerusalem, Israel) and M. Hopf.
Science 182:887-894, 1973.
Legumes are universal companions of cereal grains wherever old-type agriculture is still practiced in the Mediterranean Old World belt.

Peas, lentils and other pulses were utilized in the Neolithic. It is probable that the wild progenitors of the founder cereals and their companion pulses were collected by man long before the initiation of agriculture.

1352 Young plant vigour and nodulation studies in diploid forms of *Trifolium ambiguum* Bieb.
Zorin, M. (CSIRO, Canberra, Australia), B. S. Dear and F. W. Hely.
Fld Stn Rec CSIRO 15(2):35-40, 1976.
Desirable characters of productivity, cold hardiness and drought hardiness were bred to produce a line that shows promise for highland pasture improvement and for soil conservation. Effective nodulation has been achieved on most plants.

14. LIGHT FACTORS.

1401 Plant growth substances and effects of photoperiod on flower bud development in *Phaseolus vulgaris*.
Bentley, B. (U Cambridge, England), C. B. Morgan, D. G. Morgan and F. A. Saad.
Nature 256(5513):121-122, 1975.
The application of abscisic acid (ABA) to differentiating flower buds of plants in short days resulted in inhibition and abscission of many of the buds. Flower buds also absciss when the plants are grown in day lengths longer than 13-14 hours. Leaves and buds of plants grown in long days contained more exogenous ABA than those growing in short days.

1402 Energy state and dinitrogen fixation in soybean nodules of dark-grown plants.
Ching, T. M. (Oregon St U, Corvallis OR, USA), S. Hedtke, S. A. Russell and H. J. Evans.
Plant Physiol 55:796-798, 1975.
Dark treatment for 1 day reduced ATP by 70%, sucrose by 60% and nitrogenase activity by 50% in the nodules of 25-day-old greenhouse plants. It was concluded that the limitation of photosynthetic activity reduces the supply of sucrose to the nodules, leading to decreased phosphorylation of ADP and less synthesis of nucleotides. Pools of ATP and total adenosine were both thus decreased in the dark.

1403 The effects of shading and defoliation on nodulation and nitrogen fixation by white clover.
Chu, A. C. P. (Massey U, Palmerston N., NZ) and A. G. Robertson.
Plant Soil 41(3):509-519, 1974.
Severe defoliation caused degradation of leghemoglobin within 3 days. Shading (15% reduction) caused only a temporary reduction in nodule N content. Loss of nodules occurred when roots were sloughed off, while nodule number per unit root weight remained constant. Full fixing capacity of nodules of defoliated plants was restored well before bacteroidal tissue (as indicated by nodule N content) and visual color assessment reached apparently normal values.

1404 Growth and development of soyabean cv. TK5 as affected by tropical daylengths, day/night temperatures and nitrogen nutrition.
Huxley, P. A. (U Reading, England), R. J. Summerfield and A. P. Hughes.
Ann Appl Biol 82:117-133, 1976.
Longer daylength produced taller, more branched, later flowering plants, but seed yield was hardly affected. A day temperature kept at 33°C with a night temperature of 24° adversely affected all yield components. The experiments showed that night temperature, which promotes early vegetative growth and induces early flowering, is a factor of major importance for the growth of this cultivar.

1405 Photomorphogenetic effects of lamp type on growth of some species of tropical grain legumes in controlled environment cabinets.
Huxley, P. A. (U Reading, England) and R. J. Summerfield.
Plant Sci Ltrs 6:25-33, 1976.
Evidence in these studies indicated that "Daylight" fluorescent tubes alone are a suitable source of illumination for soybean IGm87 and TK5. Lima beans performed best with "Warm White" tubes alone, while pigeon peas were most typical when grown woth "Warm White" tubes supplemented with 10% tungsten. "Northlight" tubes are generally to be avoided.

1406 Growth and nitrogen fixation in *Lupinus arboreus* as affected by shading and water supply.
Sprent, J. I. (U Dundee, Scotland).
New Phytol 72(5):1005-1022, 1973.
In shading experiments, growth was proportional to the logarithm of relative irradiance, with roots affected more than shoots. Photosynthetic efficiency increased with moderate shading, the compensation point estimated at 7-8% full daylight. Nodule number and weight were reduced by shading. Since the amount of nodule tissue formed was in equilibrium with the growth of other parts of the plant, nodule senescence was not observed. Shaded plants responded to similar levels of moisture stress as unshaded plants. Water potentials of leaves were correlated with acetylene-reducing activity of nodules.

1407 The role of photoperiod and temperature in determining the efficiency of legume--*Rhizobium* symbiosis in cluster clover *(Trifolium glomeratum)*.
Subba Rao, N. S.
Ind Acad Sci Proc Sect B 74(2):106-111, 1971.

1408 The influence of shading on nodulation and nitrogen fixation of soybean (Jpn)
Yoshida, S.
Crop Sci Soc Japan Proc 42(1):135-136, 1973.

For additional references with information on light effects, see relevant listings under:
Photosynthesis and photosynthates.

15. MACRONUTRIENTS (other than Nitrogen alone).

1501 Effect of liming and phosphorus and nitrogen fertilizers on nodulation and yield of kidney beans *(Phaseolus vulgaris)*. (Por)
Almeida, D. L. De, G. G. Pessanha and A. De F. Penteado.
Pesq Agropec Bras, ser Agron 8(7):127-130, 1973.

1502 Effect of calcium, pH and nitrogen on the growth and chemical composition of some tropical and temperate pasture legumes.
I. Nodulation and growth.
Andrew, C. S. (CSIRO Cunningham Lab, St. Lucia, Qld., Aust.)
Aust J Agr Res 27(5):611-623, 1976.
Within both tropical and temporate legumes, variation in the response to acid soil conditions exist. *Macroptylium lathyroides* and *Lotonis bainesii* produced maximum nodulation over the full range of pH treatments (4.0-6.0) and $CaSO_4$ substrate concentrations (0.125 and 2.0 μM), while *Medicago sativa* had little or no nodulation below pH 5.0.

1503 Effect of calcium, pH and nitrogen on the growth and chemical composition of some tropical and temperate pasture legumes.
II. Chemical composition (calcium, nitrogen, potassium, magnesium, sodium and phosphorus).
Andrew, C. S. (CSIRO, St. Lucia, Qld., Aust) and A. D. Johnson.
Aust J Agr Res 27(5):625-636, 1976.
The chemical composition of nodulating and non-nodulating plants was analyzed and the data related to nodulation efficiency, dry matter production and nutrient interaction. Increasing the pH raised the N concentrations in the tops of nodulated plants in most species, while reducing the pH increased the P concentrations in the tops of tropical species.

1504 Effect of sulphur application on nodule formation in legumes.
Anonymous.
Agric Agro-Ind J 5(1):11-12, 1972.

1505 Fertilizer studies with groundnuts on the brown sands of Guyana.
I. Effect of nitrogen, inoculum, magnesium and fritted micronutrients.
Chesney, H. A. D. (Cent Agr Stn, Mon Repos, Guyana).
Agron J 67(1):7-10, 1975.
Highly leached acid soils were studied for suitability to large-scale groundnut cultivation. Yields were not significantly affected by soil amendments or inoculation with *Rhizobium japonicum* as employed in these field experiments.

1506 Effects of N, P, liming, and Mo on nutrition and grain yield of pigeon pea.
Dalal, R. C. (U West Indies, St. Augustine, Trinidad) and P. Quilt.
Agron J 69(5):854-857, 1977.
The concentration of Zn in pigeon peas was significantly reduced by P application. Otherwise, N, P and lime treatments did not affect micronutrient uptake. N fixation was significantly decreased by N application. It was suggested that fertilizer N should be applied to pigeon peas only when mineral N in the soil is very low, and that liming acidic soils may not always be beneficial.

MACRONUTRIENTS (other than Nitrogen alone) *continued*

1507 Nodulation and nitrogen fixation by two soybean varieties as affected by phosphorus and zinc nutrition.
Demetrio, J. L. (Michigan St U, E Lansing, MI, USA), R. Ellis and G. M. Paulsen.
Agron J 64(5):566-568, 1972.
Zinc deficiency and excess P had adverse effects on the plants and on N fixation. Indirect evidence suggested that Zn is required directly for N fixation within the nodules.

1508 A note on the effect of application of nitrogen, phosphorus, lime and inoculant on drybean crop (*Phaseolus vulgaris* L.). (Por)
Fontes, L. A. N.
Rev Ceres 19(103):211-216, 1972.

1509 Effects of magnesium, micronutrients and lime on the growth and symbiotic nitrogen fixation of perennial soybeans *(Glycine wightii)* variety Tinaroo in scrubland soil. (Por)
Franca, G. E. De, A. F. C. Bahia Filho and M. M. De Carvalho.
Pesq Agropec Bras ser Agron 8(8):197-202, 1973.

1510 Nodule and plant development in *Stylosanthes humilis* H. B. K.: symbiotic response to phosphorus and sulphur.
Gates, C. T. (Cunningham Lab, St. Lucia, Qld., Aust.)
Aust J Bot 22(1):45-55, 1974.
Phosphorus had a beneficial effect on initiation, growth and effectiveness of nodules, and increased nitrogen assimilation by the plant. Sulphur had a smaller effect in the plants.

1511 The interaction of nitrogen and phosphorus on the growth, nutrient status and nodulation of *Stylosanthes humilis* H. B. K. (Townsville stylo).
Gates, C. T. (CSIRO, St. Lucia, Brisbane, Qld., Aust) and J. R. Wilson.
Plant Soil 41(2):325-333, 1974.
Phosphorus greatly stimulated growth and nodulation at all of 6 levels of P X S levels of N, but there was only minor response to K. N depressed nodulation at P Ø to P 125 kg/ha, but was beneficial at P 250 to P 1000. Balanced combinations of N and P stimulated nodulation and allowed stylo to achieve higher yield and N content than could symbiotic N alone.

1512 Accumulation of N, P and K by soybean (*Glycine max* (L.) Merrill) plants.
Hanway, J. J. (Iowa St U, Ames, IA, USA) and C. R. Weber.
Agron J 63(406-408, 1971.
Nodulated soybeans accumulated 244 kg/N ha with P and K but without N fertilizer, while the non-nodulating isoline accumulated only 64 kg. Accumulation of N, P and K was slow early in the season, increasing rapidly with maturity. About 50% of the N, P and K in the mature seeds was translocated from other plant parts. Accumulation of these macronutrients was increased with fertilization.

MACRONUTRIENTS (other than Nitrogen alone) *continued*

1513 Competition between grass and clover for phosphate. I. Effect of browntop (*Agrostis tenuis* Sibth) on white clover (*Trifolium repens* L.) growth and nitrogen fixation.
Jackman, R. H. (DSIR, Palmerston N, NZ) and M. C. H. Mouat.
NZ J Agr Res 15(4):653-656, 1972.
Superphosphate at 15 rates, from 0 to 897 kg/ha, was applied to white clover alone and with browntop on soil deficient in N and P. When the P limitation was removed as a competitive factor, other factors, including shading of clover by the browntop, became more important.

1514 Uptake of phosphate by intact soybean roots: mediated by a single multiphasic mechanism.
Joseph, R. A. (U Catholique de Lovain, Belgium) and Tang van Hai.
Z Pflanzenphysiol 78:222-227, 1976.
A single uptake isotherm can be represented by 3 phases. The constant for phase 1 is a value of the same order as the phosphate concentration of tropical soil solution. The kinetic constants increased with increasing concentrations.

1515 Effect of phosphorus and molybdenum on nodulation in berseem crop (*Trifolium alexandrinum*).
Khamparia, R. S. and S. S. Khanna.
J NKVV Res [J] 6(2)129-131, 1972.

1516 The effect of potassium on the fixation of molecular nitrogen by root nodules of *Vicia faba*.
Mengel, K. (Bünteho f Agr Res Stn, Hannover, Germany), M. R. Haghparast and K. Koch.
Plant Physiol 54(4):534-538, 1974.
Isotopic studies revealed that potassium favored the provision of reduced N. The content of carbohydrates and amino acids in the root nodules was increased by supplying K to the host plant.

1517 Soybean growth and composition as affected by K, Ca and Mg rates and corn rotation.
Mugwira, L. M. (Alabama A & M U, Normal, AL, USA) and K. I. Patel.
Comm Soil Sci Plant Anal 7(3):319-330, 1976.
In pot experiments covering 6 growth periods of 6 weeks each of corn-soybean rotation, significant two-factor interactions were shown for K x Mg only. No mention of nodulation or possible N contribution by symbiotic fixation is made in this report.

1518 Effect of phosphorus and molybdenum on the growth and nodulation of groundnut.
Muralidharan, A. and C. M. George.
Agr Res J Kerala 9(2):48-53, 1973.

1519 Effect of application of N, P and K on nodulation of groundnut plants.
Muthusamy, S. (Sugarcane Res Stn, Sirugamani, Tamil Nadu, India).
Fert News 18(2):45-47, 1973.

MACRONUTRIENTS (other than Nitrogen alone) *continued*

In a pot culture experiment it was found that applications of N at the rate of 15 and 30 kg/ha reduced the nodule numbers at 45 days. P at the rate of 30 kg/ha along with K at 90 kg/ha without added N increased the nodule numbers.

1520 Nitrogen and phosphorus response of *Desmodium uncinatum* on seed production at Mount Cotton, South-eastern Queensland.
Nicholls, D. F. (U Queensland, St. Lucia, Qld., Australia), T. A. Gibson, L. R. Humphreys, G. D. Hunter and L. M. Bahnisch.
Trop Grassl 7(2):243-248, 1972.
Good responses to high levels of phosphate and to application of urea were recorded in 2 of 3 years. Nodulation was suppressed by high N treatment in the absence of applied P, but P increased both nodule number and size when applied alone, showing less benefit to nodules when applied with N in the third year.

1521 The effect of phosphate and lime on the establishment, productivity, nodulation and persistence of *Desmodium intortum*, *Medicago sativa* and *Stylosanthes gracilis*.
Olsen, F. J. (Makarere U, Kampala, Uganda) and P. G. Moe.
E Afr Agr Fores J 37(1):29-37, 1971.
The rate of establishment of the legumes was accelerated and dry matter and nodulation increased by phosphate treatment. *Desmodium* and *Stylosanthes* showed no significant response to liming, but productivity of *Medicago* was increased by lime treatment.

1522 Effects of sources and doses of phosphorus on nodulation of soybeans (*Glycine max* (L.) Merrill) and on their uptake of nutrients from a scrubland soil. (Por)
Pereira, J., J. M. Braga and R. F. De Novais.
Rev Ceres 21(115):213-226, 1974.

1523 Effects of sources and doses of phosphorus in the fertilization of soybeans (*Glycine max* (L.) Merrill) in a scrubland soil.
Pereira, J., J. M. Braga and R. F. De Novais.
Rev Ceres 21(115):227-246, 1974.

1524 Effect of different levels of phosphate on growth, nodulation and nitrogen fixation by urid (*Phaseolus mungo* Roxb.) and mung (*Phaseolus aureus* L.).
Ravankar, H. N., N. N. Badhe and R. S. Kadwe.
Coll Agr Mag Nagpur 45:50-55, 1973.

1525 Massive accumulation of calcium carbonate and its relation to nitrogen fixation by sainfoin.
Ross, W. D. (U Wyoming, Laramie, WY, USA) and R. H. Delaney.
Agron J 69(2):242-246, 1977.
Inoculated plants in sterilized soil showed root distortion accompanied by massive accumulation of $CaCO_2$. Levels of Ca up to 35% in the roots were accompanied by low levels of Ca in the plant foliage. Distorted

roots have also been observed in established sainfoin fields, and may be associated with reduced N-fixation and less persistent plants. A sevenfold increase in available N in the soil in the form of NH^+_4 was produced by autoclaving.

1526 The effect of nitrogen and molybdenum on the forming of kidney bean nodules (*Phaseolus vulgaris* L.). (Cze)
Rubes, L.
Rostl Vyroba 19(2):165-176, 1973.

1527 The effect of nitrogen and molybdenum on nodule formation in soybeans (*Glycine max* L. Merr.). (Cze)
Rubes, L.
Rostl Vyroba 20(1/2):31-42, 1974.

1528 Effect of phosphorus and molybdenum fertilization on the nodulation of cowpea.
Sharma, A. K. (IARI, New Delhi, India) and K. P. Garg.
Agr Agro-ind J 6(2):23-24, 1973.
The beneficial effect of P fertilization was immediately clear and continued up to the 45th day after sowing. The maximum number of nodules occurred when P was applied at the rate of 74 to 111 kg/ha. Application of Mo did not bring a sizable difference in the number or weight of nodules.

1529 Effect of phosphate fertilization on growth and phosphorus uptake in cowpea for green manuring.
Sharma, C. B. (Ind Inst Hort Res, Bangalore, India), V. Shukla, T. R. Subramanian and H. K. Srinivasamurthy.
Ind J Hort 31(1):82-85, 1974.
Production and P uptake were significantly increased by P_2O_5 at 60 and 90 kg, with a resulting increase in available P for subsequent crops from green manuring.

1530 Response of inoculated soybean varieties to levels of nitrogen and phosphorus in Tarai region of U. P.
Singh, J. N. (U P Agr U, Pantnagar, Uttar Pradesh, India), P. S. Negi and S. K. Tripathi.
Ind J Agron 16(3):305-308, 1971.
A 2-year field experiment revealed that no applied N is required for inoculated soybeans under Tarai conditions. The protein content of seed tended to increase with increased levels of P, but the yield was not otherwise affected by varying doses of P.

1531 Effect of nitrogen, phosphorus and *Rhizobium* inoculation on growth and yield of pigeon pea under rainfed conditions.
Singh, K. (IARI, New Delhi, India), R. Prasad and S. L. Chowdhury.
Ind J Agron 21(1):49-53, 1976.
Highest grain yield was obtained with an application of 100 kg P_2O_5/ha, but one fourth that rate is recommended for optimum cost/benefit ratio.

MACRONUTRIENTS (other than Nitrogen alone) *continued*

Inoculation also increased yields, with the greatest effects shown in the presence of phosphate. Starter N application had an adverse effect, possibly due in part to promotion of rank vegetation and consequent moisture loss.

1532 Effect of nitrogen, phosphorus and *Rhizobium* inoculation on protein content and nutrient uptake of pigeonpea.
Singh, K. (IARI, New Delhi, India) and R. Prasad.
Ind J Agron 21(3):266-270, 1976.
The P content in grain was not affected by P application, but N uptake and crude protein production were increased with each successive dose of 25 kg P_2O_5/ha. On an average, pigeon pea crop removed 115 kg P/ha. Inoculated plots showed higher values of P uptake in the first year only.

1533 Effects of phosphate and molybdenum on growth, nodulation and seed yield of dhaincha (*Sesbania cannabina* (Retz.) Pers.).
Singh, R. G. (Sugarcane Res Stn, Shanjahanpur, U P, India).
Ind J Agr Sci 41(3):231-238, 1971.
Increasing doses of phosphate up to 67.4 kg/ha increased significantly the dry weight of stem, roots and leaves. Mo up to 680 g/ha also increased growth of foliage, but had little effect on growth of roots. Nodulation was rapid after 40th day. Number and dry weight of nodules, and N fixation, increased significantly with application of phosphate up to 101.1 and 67.4 kg/ha respectively. Application of Mo had practically no effect on nodulation, but it also increased significantly the percentage and total N contents of the plants.

1534 Effect of phosphate and boron on growth, nodulation and seed yield of dhaincha (*Sesbania cannabina* (Retz.) Pers.).
Singh, R. G. (Banaras Hindu U, Varanasi, India).
Ind J Agr Sci 42(2):139-144, 1972.
Application of 67.4 kg P_2O_5/ha and 0.85 kg B/ha significantly increased the growth and yield, and enhanced the chemical composition of dhaincha. Both nutrients also increased nodulation and N fixation significantly, but the effect of phosphate was more pronounced than that of boron.

1535 Tropical legume response to lime and superphosphate in Oldsmar fine sand.
Snyder, G. H. (Agr Res Stn, Belle Glade, FL, USA) and A. E. Kretschmer, Jr.
Proc Soil Crop Sci Soc Fla 34:63-66, 1974.
To obtain optimum early top growth in 4 tropical forage legumes, about the same lime and P rates were required as would be used for most temperate legumes, particularly during the establishment period.

1536 Effects of the applications of calcium plus magnesium, phosphorus, molybdenum and boron on the production and nitrogen fixation in four tropical legumes. (Spa)
Trigoso, R. and H. W. Fassbender.
Turrialba 23(2):172-180, 1973.

16. METHODS, TECHNIQUES, ETC.

1601 Scope of fluorescence microscopy in *Rhizobium japonicum* cytology.
Bhanja, P. and D. N. De.
Botanique 6(1):15-18, 1975.

1602 Aseptic culture of soybean and peanut embryonic axes to improve phytosanitation of plant introductions.
Braverman, S. W. (E Afr Plant Quaran Stn, Nairobi, Kenya).
Seed Sci Technol 3:725-729, 1975.
Soybean and peanut varieties which failed preliminary pathogen tests were grown by plating embryonic axes on artificial media. "Knop" agar was most successful of 4 tried. 75% of the plantlets survived, and all indexed negatively for viruses and were grown to maturity.

1603 Device for the formation of wells in agar gel.
Gault, R. R., J. Koci and J. Brockwell.
Lab Prac (January):11-13, 1974.
For gel diffusion serology, a double-walled punch of concentric metal tubes can be employed for preparing up to 500 arrays (3,500 wells) per hour, with the bottom seals of the individual wells remaining intact.

1604 Control of nutrient solution pH with an ion exchange system: effect on soybean nodulation.
Harper, J. E. (Illinois Agr Exp Stn, Urbana, IL, USA) and J. C. Nicholas.
Physiol Plant 38:24-28, 1976.
The pH of a growth solution was controlled by a cation exchange resin in a recirculating ion exchange system. The optimum pH range for nodule mass and N_2 fixation was between 5.2 and 7.0 with urea nutrition. Both nitrate- and ammonia-N sources were inhibitory to acetylene reduction, although urea allowed extensive nodule development and activity.

1605 Determination of total nitrogen in plant tissue, using a block digester.
Isaac, R. A. (U Georgia, Athens, GA, USA) and W. C. Johnson.
J Assoc Offic Anal Chem 59(1):98-100, 1976.
A Technicon BD-40 digester was found to give results comparable to AOAC method 2.049. The method is rapid and requires minimal space. An AutoAnalyzer determines the ammonia, using automated continuous-flow methodology. Up to 300 samples/day may be analyzed with a single system.

1606 Use of stem cuttings to reduce plant variation in *Rhizobium*-leguminous plant investigations.
Lindsay, C. R. (U Guelph, Ontario, Canada) and D. C. Jordan.
Can J Soil Sci 56(4):495-497, 1976.
Asexual propagation can provide genetically identical plants for studying symbiotic associations. The technique for establishing a clone of alfalfa, then inoculating and testing nodulating and acetylene reduction, is described.

1607 Lyophilic drying of nodular bacteria of peas. (Rus)
Nalbandian, A. D., V. A. Avetisian and R. G. Meliksetian.
Akad Nauk Armenian SSR 24(3):24-29, 1971.

1608 An improved large-scale isolation procedure for bacteroids of *Rhizobium leguminosarum* Frank.
Plant Soil 45(1):309-315, 1976.
Planque, K. (St U Leiden, The Netherlands) and A.A.N. Van Brussel.
A procedure for concentrating nodules on a small part of the main root by manipulating the growth medium level is described. This permits isolation of bacteroids on a large scale while handling a minimum of root material. By freezing the nodulated roots in liquid nitrogen, then grinding them, the material could be homogenized easily.

1609 The methodology of determining the amount of symbiotically fixed atmospheric nitrogen. (Rus)
Posypanov, G. S. and L. D. Kniazeva.
Izv Timiriazevsk S-Kh Akad 6:41-46, 1975.

1610 Fluorescent antibody techniques for the study of microbial ecology.
Schmidt, E. L.
Bul Ecol (Stockholm) 17:67-76, 1973.
Methodology, controls and applications are discussed. A model system for *Rhizobium* autoecological studies is detailed, with references.

1611 Quantitative autoecological study of microorganisms in soil by immunofluorescence.
Schmidt, E. L. (U Minnesota, St. Paul, MN, USA).
Soil Sci 118(3):141-149, 1974.
By permitting specific microorganisms to be identified in their natural habitat, the FA technique opens a new dimension in autoecological studies. This article describes a method for enumerating soil populations of particular bacteria.

1612 The determination of nitrogen in soils by rapid high-temperature Kjeldahl digestion and autoanalysis.
Comm in Soil Sci Plant Anal 7(3):229-239, 1976.
Skjemstad, J. O. (Cunningham Lab, St. Lucia, Qld, Australia) and R. Reeve.
Comm Soil Sci Plant Anal 7(3):229-239, 1976.
A 10-minute procedure giving satisfactory agreement with a standard 5-hour digestion procedure is described. The method, which uses a phosphoric-sulphuric acid mixture, is adaptable to either nitrate or nitrite.

1613 A method for separation of slow-growing strains of nodule bacteria from their mucus.
Starchenko, E. P., V. K. Datsenko and N. S. Yakoleva.
Appl Biochem Microbiol 10(2):264-265, 1974.

1614 Error mean squares of protein yield of alfalfa grass mixtures computed by five methods.
Torrie, J. H. (U Wisconsin, Madison, WI, USA), D. Smith and S. K. Bollman.
Agron J 66(2):324-326, 1974.
The most reliable data of a composite trait are obtained from all replicates. When this is not possible, computation from the weighted average percentage protein and herbage yields of replicates 1 and 2 and of 3 and 4 is preferred because this uses information based on all replicates.

1615 A simple and inexpensive culture tube method for assaying acetylene reduction by facultative and anaerobic nitrogen-fixing bacteria.
Tu, C. M.
Soil Sci Plant Anal 9(3):243- , 1978.

1616 Improved method for preparing anaerobic bacteroid suspensions of *Rhizobium leguminosarum* for the acetylene reduction assay.
Van Straten, J. (Agr U, Wageningen, The Netherlands) and W. Roelofsen.
Appl & Environ Microbiol 31(6):859-863, 1976.
A level of acetylene reduction comparable to that of intact nodules was obtained by using ethylnediaminitetraacetate (EDTA) and toluene-treated pea bacteroid suspensions. Preliminary experiments indicate that this method might be applicable to other legumes.

1617 Simple, rapid assay for screening nitrogen-fixing ability in soybean.
Wacek, T. J. (U Hawaii NifTAL Proj, Maui, HI, USA) and W. J. Brill.
Crop Sci 16(4):519-523, 1976.
Seeds were sterilized, germinated, and then inoculated and individually planted in sterile bottles containing vermiculite wetted with an N-free nutrient. After 14 days, nitrogenase activity was determined by gas-chromatograph measurement of the reduction of acetylene to ethylene. Using this procedure, one technician can set up and assay 4,000 seeds in 20 working days.

1618 A manual for the practical study of the root-nodule bacteria.
Vincent, J. M. (U N.S.W., Australia).
IBP Handbook No. 15, London, 164 p., 1970.
[Published by Blackwell Sci, Oxford and Edinburg. U. S. publisher, Lippincott, N. Y.]
A self-contained account of basic methods, intended for those with a background in bacteriology. Sections cover the cultivation, isolation, maintenance, characterization, enumeration, evaluation and use of rhizobia.

1619 Growing plants for *Rhizobium* effectiveness tests.
Weaver, R. W. (Texas A & M U, College Stn, TX, USA).
Soil Biol Biochem 7(1):77-78, 1975.

A system of pots connected to a reservoir bottle by tubes was used successfully as an alternative to Leonard jars.

Additional information on methodology may be found under most of the subjects in this bibliography. See in particular the relevant listings under:
Inoculation methods
Nitrogen fixation (detection and measurement)
Pelleting
Rhizobium cultures and culture media.

17. MICRONUTRIENTS AND TOXIC ELEMENTS.

1701 Effect of uranium on microbial nitrogen fixation.
Bahadur, K. (U Allahabad, U. P., India) and U. Jaisal.
Zentralb Bak Paras ... 2 Nat Abt 128(7/8):758-763, 1973.
Uranyl acetate at between 25 and 50 micromolar concentrations in the culture medium increased nitrogen fixation while decreasing carbon consumption.

1702 Development of alfalfa strains with differential tolerance to aluminum toxicity.
Devine, T. E. (ARS, USDA, Beltsville, MD., USA), A. L. Fleming, C. H. Hanson, T. A. Campbell, J. E. McMurtrey, III, and J. W. Schwartz.
Plant Soil 44:73-79, 1976.
This study indicated that Al tolerance is a heritable trait and that recurrent selection can be used effectively to develop strains having differential tolerance to Al-toxic soils.

1703 Manganese toxicity in an acid soil affecting the soybean-*Rhizobium* symbiosis. (Por)
Franco, A. A. (EMBRAPA, Rio de Janeiro, Brasil) and J. Döbereiner.
Pesqui Agropec Bras, Ser Agron 6(4):57-66, 1971.
The host plants showed a high sensitivity to soil Mn. Dilution of the soil with sand increased N fixation and plant growth 4 to 6 times, and the addition of lime 2 to 3 times. Nodule number, weight and size were even more affected by Mn toxicity. Soybean varieties and *Rhizobium* strains varied as to tolerance.

1704 Effect of zinc on nodulation and yield of two mung varieties.
Ghildiyal, M. C. (IARI, New Delhi, India), A. D. Saini and G. S. Sirohi.
Ind J Plant Physiol 18(1):12-15, 1975.
In Zn deficient soil, dry matter yield and nodulation were increased by $ZnSO_4$ applications. Varieties tested showed differential response to Zn and inoculation. Whether the Zn had a primary or secondary effect on the rhizobia was not determined.

1705 Influence of molybdenum and tryptophane on nodulation in cluster-bean (*Cyamopsis tetragonoloba* (L.) Taub.).
Ghonsikar, C. P. (Rajasthan Coll Agr, Udaipur, India) and S.N. Saxena.
Ind J Agr Sci 43(10):938-941, 1974.
Spraying the foliage with 0.2% Mo 15 days after emergence increased dry weight 4.5 times and N content of grain 2.5 times. Tryptophane treatment of seeds offered benefits at lower Mo levels (to 0.1%). The results relate to the native population of rhizobia in the soil, since inoculants were not used.

1706 Effect of foliar sprays of manganese sulphate and copper sulphate on nodule development, shoot and root length.
Gupta, V. K. (Narain Coll, Shikohabad, Mainpur, U. P., India) and S. B. Agarwal.
Ind Phytopath 26(4):726-727, 1974.
Maximum nodule number increase was noted at 50 ppm $MnSO_4$ and 25 ppm $CuSO_4$ foliar spray on *Trifolium foenum-graecum*. The latter spray was found to be more toxic.

1707 Effect of sodium molybdate with inoculant on the yield of pea crop.
Iswaran, V. (IARI, New Delhi, India), A. V. Rao and A. Sen.
Zentralb Bak Parasit ... 2 Nat 126(7):778-779, 1971.
Using sodium molybdate in the inoculant adhesive proved an effective means of improving N fixation and supplying Mo to the plant.

1708 Influence of zinc on symbiotic nitrogen fixation by soybean (*Glycine max* Linn.) in silt loam soil.
Kapur, O. C. (G. M. Pant U, Pantnagar, India), M. S. Gangwar and K. V. B. R. Tilak.
Ind J Agr Res 9(1):51-56, 1975.
$ZnSO_4$ at 5 and 10 ppm increased yield and N fixation. Significant increases in leghaemoglobin content and number of bacteroids in nodules were also recorded, but the amount of nitrogen fixed declined with the heavier Zn application.

1709 The role of cobalt in the physiology of nitrogen-fixing microorganisms and the fixation of molecular nitrogen.
Koleshko, O. I. (V. I. Lenin Belorussian St U, Minsk, Belorus Rep.).
Appl Biochem Microbiol 8(4):399-402, 1972.
Cobalt in concentrations of 0.1-0.01 mg/liter introduced into the nutrient medium had a stimulatory effect on N fixation and prolonged the physiological youth of symbiotic and asymbiotic bacteria.

1710 The influence of soil zinc on nodulation, mycorrhizae, and ozone-sensitivity of pinto bean.
McIlveen, W. D. (Pennsylvania St U, Univ. Park, PA, USA), R. A. Spotts and D. D. Davis.
Phytopathol 65(5):645-647, 1975.
Nodule number/gram shoot was greatest in soils having the lowest rates of Zn (0.60-0.66 micrograms/g available). Zn amendments reduced nodulation and micorrhixal infections. The percent ozone injury on foliage increased with increasing soil Zn concentrations.

1711 Influence of some trace elements on the growth of *Rhizobium* from peanut (*Arachis hypogaea* L.) and gram (*Cicer arietinum* L.).
Pillai, R. N. (IARI, New Delhi, India) and A. Sen.
Zentralb Bak Paris ... 2 Nat 127(6):612-617, 1972.
The influence of B, Mo, Mn, Zn, Cu and Co on growth of 4 strains of *Rhizobium* was studied. Certain amounts of B and Mo were required for maximum growth, but an excess had an adverse effect. Traces of Mn, Zn, Cu and Co (0.05-0.1 ppm) improved the growth of the strains.

1712 Nitrogen metabolism in soybean tissue culture. II. Urea utilization and urease synthesis require Ni^{2+}.
Polacco, J. C. (Connecticut Agr Exp Stn, New Haven, CT, USA).
Plant Physiol 59:827-830, 1977.
Low levels of $NiSO^4$ overcame urea-dependent citrate toxicity and stimulated urea-supported growth in suspension cultures. Ni^{2+} is presumably a limiting factor in the growth of soybean cells in a basal medium with urea N source.

1713 Effect of foliar molybdenum sprays on nitrogen fixation in *Phaseolus vulgaris* L.
Robitaille, H. A.
Ann Rept Bean Improv Coop 18:65, 1975.

1714 Effect of cobalt on the formation of nodules in inoculated peas and kidney beans. (Rus)
Sadovskaia, E. N. and A. V. Peterburgskii.
Dokl TSKhA Timiriazevsk S-Kh Akad 213:36-42, 1975.

1715 Effect of soil Al saturation on nutrient concentration of soybean tops, roots, and nodules.
Sartain, J. B. (U Florida, Gainesville, FL, USA) and E. J. Kamprath.
Agron J 69(5):843-845, 1977.
Soil Al saturation levels, as established by addition of varying amounts of lime, had no effect on the P concentration of tops, but root P concentration was significantly higher at 81% Al than at 28 or 4%. The nodules had a higher P concentration than other plant parts. It was concluded that growth response to reduction of soil Al saturation below 28% is probably due to to pH effects and/or Ca supply rather than Al saturation level.

1716 Effect of zinc on nodulation and yield of soybean (*Glycine max.*)
Tilak, K.V.B.R. and M.S. Gangwar.
Acta Agron (Budapest) 22:185-188, 1973.

1717 Influence of molybdenum and cobalt on nitrogen fixation in peas. (Cze)
Vanek, V. and K. Knop.
Rostlinna Vyroba 18(5):521-529, 1972.

1718 Micronutrient content in fractions of nodules and their effect on nitrogen fixation. (Rus)
Yagodin, B. A., M. S. Savich and G. A. Ovcharenko.
In Novoe V Izuchenii Biologicheskoi Fiksatii Azota, p. 38-42, 1971.

1719 The effect of cobalt on enzymes of the hydrogen-donor system of symbiotic nitrogen fixation. (Rus)
Yagodin, B.A. and G.V. Petrovskaia.
In Novoe V Izucheniii Biologicheskoi Fiksatii Azota, p. 42-47, 1971.

1720 The role of molybdenum in activating the hydrogen-donor system of symbiotic nitrogen fixation. (Rus)
Yagodin, B. A. and G. I. A. Zhiznevskaia.
In Biologicheskaia Rol'molibdena (Trudy) p. 73-77, 1972.

Certain references listed under Macronutrients also include information on Micronutrients. See also relevant listings under Soil Factors.

18. MICROORGANISMS (other than *Rhizobium*).

1801 Cultures of *Rhizobium* inoculants with those of *Beijerinckia* and *Azotobacter*.
Apte, R. (IARI, New Delhi, India) and V. Iswaran.
Proc Ind Natl Sci Acad Pt B Biol Sci 40(5):482-485, 1974.
Better nodulation and yield of soybeans was achieved when *R. japonicum* was cultured with highly mucoid strains of *Beijerinckia indica* and *Azotobacter chroococcum*.

1802 Note on the stimulatory and inhibitory effects of some rhizosphere bacteria of Bengal-gram (*Cicer arietinum* L.) on its specific *Rhizobium*.
Bhalla, H. (IARI, New Delhi, India) and A.N. Sen.
Ind J Agr Sci 41(12):1126-1127, 1971.
Fifty-one rhizosphere isolates belonging to 10 genera of bacteria were identified. Within 8 genera, some species were stimulatory and others were inhibitory to the *Rhizobium* of Bengal-gram.

1803 Effect of rhizosphere bacteria of gram (*Cicer arietinum*) of different morphological, nutritional and physiological groups of *Rhizobium* nodulating the same host.
Bhalla, H. (IARI, New Delhi, India) and A.N. Sen.
Sci Cult (India) 39(4):191-193, 1973.
One hundred and two isolates obtained from the rhizosphere of inoculated and uninoculated gram were grouped to their gram character and nutritional requirements. Among physiological groups, the cellulose decomposers were more stimulatory while the ammonifiers tended to be more inhibitory. The number of N fixers causing stimulation or inhibition was proportional (31% vs 31%. Bacterial isolates from inoculated gram had greater effects than from uninoculated, suggesting an effect from root exudates.

1804 Regulation of predation by prey density: the protozoan-*Rhizobium* relationship.
Danso, S.K.A. (Cornell U, Ithaca, NY, USA) and M. Alexander.
Appl Microbiol 29(4):515-521, 1975.

MICROORGANISMS (other than *Rhizobium*) *continued*

Although large populations of rhizobia were reduced by predatory protozoa, many of the prey cells were not eliminated. Feeding slowed and ceased when the bacterial density fell to a critical value beyond which prey extinction (and thus predator extinction) might occur. The simultaneous presence in soils of edible bacteria and protozoa suggests that coexistence rather than extinction is characteristic of predator-prey relationships among indigenous species.

1805 Inhibitory effect of *Streptomycea antibioticus* and other microorganisms on *Rhizobium*.
Foo, E.L. (IARI, New Delhi, India) and A.K. Varma.
Folia Microbiol 21(4):315-319, 1976.

In general, occurrence and inhibition from bacterial and fungal strains was lower in *Rhizobium* than in the actinomycetes. All rhizobial strains tested were inhibited by *Streptomyces antibioticus* and *Bacillus brevis*, especially those nodulating Bengal-gram.

1806 Effect of soil activators on crop yields and soil microorganisms.
Forbes, R.B. and D.H. Hubbell.
Soil Crop Sci Soc Fla Proc 34:68-70, 1974.

Neither crop yields of soybeans and peanuts nor soil populations of bacteria fungi or actinomycetes were affected by "Soil Life", "Medina" or "Supernate" treatments in Florida. Similar determinations have been made in several other states. No distinction between rhizobia and other bacteria was made in this particular study.

1807 Development of *Phytophthora* root rot of alfalfa in the field and association of *Rhizobium* nodules with early root infection.
Gray, F.A. (Farm Seed Res Corp, San Juan Bautista, CA, USA) and R.B. Hine.
Phytopath 66(12):1413-1417, 1976.

In sterilized soil, seedling death was 24% higher when both *Phytophthora megasperma* and *Rhizobium meliloti* were introduced compared to infection by the root rot fungus alone. In field studies, early root rot infections were associated with *Rhizobium* nodules. Root exudates released during nodule formation may stimulate germination of dormant oospores or attract motile zoospores to the nodule surface.

1808 Presence of *Agrobacterium tumafaciens* in nodules of alfalfa roots.
Imshenetskii, A.A., A.N. Pariiskaya and O.P. Gorelova.
Microbiol 45(3):484-486, 1976.

The possibility of either penetration of *A. tumefaciens* coincident with rhizobial infection, or the production of mutants of *A. tumefaciens* with changed specificity and with nodule forming capability in the absence of *Rhizobium* was investigated. Small nodules could be induced in about 50% of inoculation attempts with induced mutants, but no nitrogenase activity was detected in the non-rhizobial nodules.

1809 Isolation of seed-borne microflora from leguminous crops and their antagonistic effect on *Rhizobium*.

Jain, M.K. (IARI, New Delhi, India) and R.B. Rewari.
Curr Sci 43(5):151, 1973.
Bacteria, fungi and actinomycetes were isolated from several leguminous crops, and these were checked for their antagonistic effects on the *Rhizobium* specific to the particular crop. Every crop had some antagonistic isolates *in vitro*, but it remains to be determined how these effects will persist *in vivo*.

1810 Regulation of parasitism by host density: the *Bdellovibrio-Rhizobium* interrelationship.
Keya, S.O. (Cornell U, Ithaca, NY, USA) and M. Alexander.
Soil Biol Biochem 7(3):231-237, 1975.
Rhizobium populations containing $6x10^8$ ml^{-1} cells stimulated parasite replication. The rhizobia were lysed rapidly, but persisted when vibrio feeding abated. It was hypothesized that an equilibrium permits both host and parasite to be maintained in the same environment at suitably low population densities.

1811 Inhibition of groundnut *Rhizobium* in Indian soils.
Kumara Rao, J.V.D. (IARI, New Delhi, India), A. Sen and S.T. Shende.
Proc Ind Natl Sci Acad Pt B Biol Sci 40(5):535-539, 1974.
Antagonistic fungi were present throughout growth of the crop, but bacterial antagonists did not appear until after two months. At three months, the bacterial antagonists were restricted to the rhizosphere. Water extracts from sterilized soil also had a depressing effect on the rhizobia.

1812 Effect of rhizosphere bacteria of *Aristida oligantha* on *Rhizobium* and *Azotobacter*.
Leuck, E.E., II (U Oklahoma, Norman, OK, USA) and E.L. Rice.
Bot Gaz 137(2):160-164, 1976.
Revegetation of abandoned fields followed 4 stages in which N requirements and suppression of biological N fixation were controlling factors leading to the climax tall grass prairie at stage IV. In the climax stage, *Aristida* may persist in almost pure stands for 30 years or more. Extracts of some stage I and II plants have been shown to inhibit the growth of *Rhizobium* and *Azotobacter* as well as N-fixing algae. Several rhizosphere microorganisms have also been shown to be antagonistic to N-fixing bacteria, while only a few showed evidence of stimulation of the nitrogen fixers.

1813 *Bacillus polymyxa*, an organism responsible for the inhibition of *Rhizobium japonicum* in a soybean culture. (Por)
Lima, A., G. Pereira, J. Abrahao and B.S. Oliveira, Jr.
Biologico 40(7):214-215, 1974.

1814 Plant growth and responses to vesicular-arbuscular mycorrhiza. IX. Interactions between V A mycorrhiza, rock phosphate and symbiotic nitrogen fixation.
Mosse, B. (Rothamsted Exp Stn, Harpenden, Herts., England), C. Ll. Powell and D.S. Hayman.
New Phytol 76:331-342, 1976.

MICROORGANISMS (Other than *Rhizobium*) *continued*

In some P-deficient soils, inoculated legumes nodulated only when they were also mycorrhizal. VA endophytes greatly improved the utilization of rock phosphate in acid soils, but had no effect in neutral or alkaline soils.

1815 On the positive effect of soil amoeba on the activity of nodule bacteria of alfalfa. (Rus)
Nikoliuk, V.F. and M.V. Shetalova.
Uz Biol Zhur 4:75-77, 1971.

1816 Survival of two pathogens of cowpea over the dry season.
Onesirosan, P.T. (U Ife, Ile-Ife, Nigeria) and S.O. Sagay.
Plant Disease Rept 59(12):1018-1020, 1975
Colletotrichum lindemuthianum and *Rhizoctonia solani* are the 2 most important fungal pathogens of cowpea in southern Nigeria. The former survived the dry season in diseased stem tissue either on the soil surface or plowed under. The latter pathogen survived only in diseased leaves on the soil surface.

1817 *Rhizoctonia-Rhizobium* interactions in relation to yield parameters of soybean.
Orellana, R.G. (USDA, Beltsville, MD, USA), C. Sloger and V.L. Miller.
Phytopathol 66(4):464-472, 1976.
The fungus caused a 63% decrease in fixed N per plant in inoculated 'Lee' soybeans. Nodulation by *Rhizobium japonicum* increased at 30° C, while *Rhizoctonia solani* had a lesser effect at that temperature.

1818 Response of nodulating and nonnodulating soybeans to a species of *Endogone* mycorrhiza.
Schenck, N.C.(Florida Agr Exp Stn, Gainesville, FL, USA) and K. Hinson.
Agron J 65:849-850, 1973.
Nodulating and nonnodulating isolines of 'Hardee' soybeans in fumigated fields were inoculated with *Endogone*.Seed yield and other traits of the nodulating, but not the nonnodulating isolines, were significantly increased over non-fumigated and non-inoculated plots.

1819 Interactions between growth, phosphate content and nitrogen fixation in mycorrhizal and non-mycorrhizal *Medicago sativa*.
Smith, S.E.(U Dundee, Scotland) and M.J. Daft.
Aust J Plant Physiol 4(3):403-413, 1977.
From 2 weeks onward, mycorrhizal plants showed more extensive nodulation and higher nitrogenase activity. Phosphate content and % of N were higher for mycorrhizal plants at harvest (12 weeks) and after 7 weeks, respectively. Important time-factor implications in the tripartite symbiosis are pointed out.

19. NEMATODES.

1901 Root-knot nematodes and bacterial nodulation in soybean.
Balasubramanian, M. (Anamalai U, Anamalainagar, India).
Cur Sci (Bangalore) 40(3):69-70, 1971.
A study to determine whether *Meloidogyne icognita*, *M. javanica* and *M. hapla* could cause reduction of nodulation in soybean revealed that all three species had such an effect, with that of *M. javanica* being the most pronounced.

1902 Studies of relationships between free-living nematodes and nodule bacteria of leguminous [plants]. (Fre)
Cayrol, J.C., C. Couderc and I. Evrad.
Rev Zool Agr Pathol Veg 76(3):77- , 1977.

1903 Antagonistic interaction between *Heterodera glycines* and *Rhizobium japonicum* on soybean.
Barker, K.R.(N Carolina St U, Raleigh, NC, USA), D. Huisingh and S.A. Johnston.
Phytopathol 62(10):1201-1205, 1972.
Soybean cyst nematodes have been shown to interfere with nodule development. To determine the basis of this antagonistic interaction, seedlings were inoculated with various combinations of nematodes and rhizobia. A 14 day delay in inoculating with the cyst nematodes resulted in only slight to moderate inhibition of nodulation. The greatest inhibition occurred with simultaneous inoculation of the soybeans with *Rhizobium japonicum* and race I of the soybean cyst nematode.

1904 *Pristionchus lheritieri* as a carrier of *Rhizobium japonicum*.
Jatala, P., H.J. Jensen and S.A. Russell.
J Nematol 6(3):130-131, 1974.

1905 Interaction of *Acrobeloides buetschilii* and *Rhizobium leguminosarum* on wando pea.
Westcott, S.W., III (N Carolina St U, Raleigh, NC, USA) and K.R. Barker.
Phytopathol 66(4):468-472, 1976.
Infection of nodules by the nematodes depressed nitrogen fixation by 80 to 90%. The microbivorous nematodes were found in large numbers in the central portion of nodules, where they were apparently feeding on bacteroids and reproducing themselves.

20. NITROGEN CYCLE.

2001 Ammonia assimilation by *Rhizobium* cultures and bacteroids.
Brown, C.M.(U Newcastle-upon-Tyne, England) and M.J. Dilworth.
J Gen Microbiol 86(1):39-48, 1975.
Low glutamine synthetase activities suggest that bacteroids are not N limited. An absence of evidence for the operation of the glutamine synthase/glutamate synthase system in ammonia assimilation in root nodules is taken as evidence that ammonia produced by N fixation in the bacteroid is assimilated by enzymes of the plant system.

2002 The energy costs of the nitrogen fertilisers used in Britain, the returns received and some savings that are possible.
Cooke, G.W. (Rothamsted Exp Stn, Harpenden, Herts., England).
J Sci Food Agr 26:1065-1069, 1975.
About one third of the energy required for intensive agriculture may be used to produce nitrogen fertilizers. Careful management can reduce the loss of N due to leaching, volatilization and denitrification, but alternatives to manufactured fertilizers are needed for long term solution of food problems. The legume/*Rhizobium* symbiosis can help, but research into other forms of biological nitrogen fixation is encouraged.

2003 Nitrogen, a major limitation in the productivity of natural communities, crops and pastures in the Pacific area.
Date, R.A. (CSIRO, St. Lucia, Qld., Australia).
Soil Biol Biochem 5(1):5-18, 1973.
Because agricultural plants extract nitrogen from the soil faster than it can be mineralized from organic forms, a nitrogen deficiency in plants with a subsequent protein deficiency in animals may occur. The introduction of legumes to new areas, with proper inoculation, can help to overcome this imbalance. A greater research effort should be chanelled toward an integrated system of biologically and chemically fixed nitrogen to provide a steady supply for plant growth. A brief review of the nitrogen cycle and legume bacteriology is included.

2004 Ammonia flux into the atmosphere from a grazed pasture.
Denmead, O.T., J.R. Simpson and J.R. Freney.
Science 185:609-610, 1974.

2005 Nitrogen nutrition of cowpea *(Vigna unguiculata)*. III. Distribution of nitrogen within effectively nodulated plants.
Eaglesham, A.R.J. (U Reading, England), F.R. Minchin, R.J. Summerfield, P.J. Dart, P.A. Huxley and J.M. Day.
Exp Agr 13:369-380, 1977.
Symbiotic fixation supplied over 80% of the total plant N throughout growth. Irrigation of pot-grown nodulated plants with only 20-30 ppm of inorganic N produced yields which could not be significantly improved by larger amounts of applied N. Symbiotic fixation supplied 83-89% of the plants' total N content at all stages. At maturity, 63% of the total N was in the seeds. A potential for very large seed yields from symbiotic associations clearly exists.

2006 Nitrogen balance studies in the central plain of Thailand.
Firth, P., H. Thitipoca, S. Suthipradit, R. Wetselaar and D.F. Beech.
Soil Biol Biochem 5:41-46, 1973.

2007 Non-protein nitrogen accumulation in legume nodules.
Freney, J.R. (CSIRO, Canberra City, Australia) and A.H. Gibson.
Bull R Soc N Z 12:37-40, 1974.
An inverse relationship between high-level accumulations of y-aminobutyric acid and fixed N for transferrance to the host plant was found. In mixed planting, this could make more N available to associated grasses.

2008 The nature of non-protein nitrogen accumulated in *Trifolium subterraneum* root nodules.
Freney, J.R.(CSIRO, Canberra City, Australia) and A.H. Gibson.
Soil Biol Biochem 6(5):313-318, 1974.
The accumulation of non-protein nitrogen in nodules, accompanied by a greater development of nodule tissue, is a characteristic of certain strains of *Rhizobium trifolii*. "Bound" y-aminobutyric acid was identified as the principal component. Those strains are considered less effective because of the export of a lower proportion of the fixed N to the host.

2009 The control of dinitrogen assimilation by nodulated legumes.
Gibson, A.H.(CSIRO, Canberra City, Australia).
Bull R Soc N Z 12:13-22, 1974.
Additional physiological processes involved in nodule initiation and development, dinitrogen fixation, and transport of amino acids from the nodules of legumes greatly increase the number of factors controlling nitrogen assimilation in the symbiosis. The importance of environmental variables and genetic compatability between the symbionts was studied. Despite the complexity of the symbiotic association, a degree of flexibility was noted which offers possibilities for further enhancement and utilization of biological N fixation.

2010 Determination by ^{15}N of the uptake of green manure nitrogen by ryegrass. (Fre)
Guiraud, G. and J.C. Fardeau.
Trans Int Congr Soil Sci 10th 9:106-116, 1974.

2011 Comparative study of relation between accumulation of nitrogen in lupine plants and mass of its root nodules. (Rus)
Krikunets, V.M., A.V. Manorik, E.G. Tomashevskaia, E.I.A. Lugovskaia and Z.I.U. Dan'ko.
Fiziol Biokhim Kult Rast 5(6):563-569, 1974.

2012 Effectiveness of strains of bean nodule bacteria as a function of mineral nitrogen content of soil.
Microbiol 42(1):104-108, 1973
Lapinskas, E.B. (Litvosk Sci-Res Inst Agr, USSR).
Nitrogen requirements of bean plants were satisfied better by rhizobia than by large doses of mineral nitrogen.

2013 Incorporation of ^{15}N-tagged mineral nitrogen into stable forms of soil organic nitrogen.
Legg, J.O.(ARS, USDA, Beltsville, MD, USA), F.W. Chichester, G. Stanford and W.H. Demar.
Soil Sci Soc Amer Proc 35(2):273-276, 1971.
On the basis of information derived from eight cropping periods of oats, it was concluded that about half of the indigenous N in the soil studied was biologically unavailable.

2014 Determination of molecular nitrogen in studying gaseous losses.
Makarov, B.N.(Dokuchayev Soil Inst, Moscow, USSR).
Sov Soil Sci 7(3):368-370, 1975.
Fertilizers tagged with N^{15} were used to determine gaseous molecular N losses in field and laboratory investigations. An air sample from the isolating vessel was collected in a gas pipette which was then connected to a mass spectrometer to determine the content of N_2^{15} released. The losses were shown to reach 20-40% of the applied nitrogen.

2015 Incorporation of ^{15}N into allantoin in nodulated soybean plants supplied with $^{15}N_2$.
Matsumoto, T. (Nagoya U, Japan), M. Yatazawa and Y. Yamamoto.
Plant Cell Physiol 18(2):459-462, 1977.
The fact that nodules produce allantoin was confirmed by determining that the incorporation of isotopes of N into allantoin was slightly higher in the nodules than in the roots.

2016 Soybeans for forage and green manure.
Miller, M.D., R.T. Edwards and W.A. Williams.
Calif Agr Exp Stn Bull 862:60-63, 1973.

2017 Nitrogen in nature and soil fertility.
Mishustin, E.N. (Inst Microbiol, Akad Nauk, USSR).
Akad Nauk SSSR Izv Ser Biol 3(1):5-22, 1972.
An investigation to elucidate the paths of penetration of N compounds into the soils and the processes causing the loss of N containing substances from the soils. General enrichment by abiotic processes was rather low. Slight enrichment occurs from the activity of free-living organisms, but symbiotic N fixation appeared to be far more effective and should be further exploited.

2018 Denitrification.
Payne, W.J. (U Georgia, Athens, GA, USA).
Trends Biochem Sci 1(4):220-222, 1976.
Bacterial denitrification of ammonia and nitrate in soils contributes heavily to the loss of available N. All the known denitrifiers are aerobes, with the greatest number in the genus *Pseudomonas*. More research on the biochemistry, ecology and physiology of bacterial denitrification is needed.

2019 Effect of increased nitrogen fixation on stratospheric ozone.
Pratt, P.F.(U California, Riverside, CA, USA) "and task force members."
In D. Reidel, Climatic change, Dordrecht-Holland, p. 109-135, 1977.
The equiblibrium between stratospheric ozone production and destruction could be influenced by increased entry of nitrous oxide (a product of anaerobic denitrification of nitrate) into the ozone layer, leading to the conversion of ozone to molecular oxygen. The possibility of a hazard and need for additional information is discussed.

2020 Natural nitrogen-15 abundance in soil and plant samples.
Rennie, D.A.(U Saskatchewan, Canada), E.A. Paul and L.E. Johns.
Can J Soil Sci 56:43-50, 1976.

Data suggesting that variations in natural ^{15}N abundance in soils and soil horizons may be of use in evaluating stresses placed on the N cycle by human activity. Differences in the abundance of the isotope in soil, legumes and the atmosphere may also provide data on symbiotic N fixation.

2021 Grow legumes for green manure.
Rohweder, D.A., R. Powell.
U Wisc Agr Ext Serv, Coop Ext Prog Pub No. 2477, 3 p., 1973.

2022 Ammonia assimilation in lupine nodules in the process of vegetation. (Rus)
Radiukina, N.A., A.V. Pushkin, Z.G. Evstigneeva and V.L. Kretovich.
Dokl Akad Nauk SSSR 234(5):1209-1212, 1977.

2023 Synergism of nitrogen uptake from soil and symbiotic nitrogen fixation for increasing total nitrogen in soybean *(Glycine max)*. (Por)
Ruschel, A.P. and R. Ruschel.
Pesqui Agropecu Bras, Ser Agron 10(11):37-40, 1975.

2024 Effect of *Rhizobium* and mineral nitrogen on the content of nitrogenous compounds in bleeding sap and organs of beans. (Bel)
Samtsevich, S.A. and L.S. Revinskaia.
Izv Akad Nauk BSSR, Ser Biol Nauk 3:29-33, 1975.

2025 Soil nitrogen from soybeans (*Glycine max* (L.) Merr.).
Schroder, V.N. (U Florida, Gainesville, FL, USA) and K. Hinson.
Soil Crop Sci Soc Fla Proc 34:101-103, 1974.
Nodulating and non-nodulating soybeans were grown in rotation with winter rye and in mixtures with rye to study the contribution of the legumes to soil nitrogen. The results of these experiments support the thesis that the roots of nodulating soybeans leave significant amounts of N in the soil.

2026 Ammonia assimilation in lupin nodules.
Scott, D.B. (U Otago, Dunedin, New Zealand), K.J.F. Farnden and J.G. Robertson.
Nature 263(5579):703-705, 1976.
A pathway by which ammonia produced by bacteroids is assimilated by the plant fraction of lupin nodules is proposed. NADH and ATP required for the incorporation of ammonia into asparagine are provided by the plant enzyme systems. The regulation of plant asparaginase activity and the reason why bacteroids produce more ammonia than is required for bacterial growth are questions demanding further study.

2027 Nitrogen gains by legumes and residual nitrogen left behind in the soil through *Rhizobium* application.
Subba Rao, N.S. (IARI, New Delhi, India).
Ind J Genet Plant Breed 35(2):236-238, 1976.
The fate of biologically fixed N in a soil ecosystem needs much more study. In a comparison, inoculated cowpea excreted N at the highest rate, followed by urid and gram. Previous experiments had shown that maize after berseem

produced the highest yield over a two year period. However, field tests need to be conducted in a wide variety of locations and under many conditions to provide data applicable to specific situations.

2028 Atmospheric nitrogen fixation through *Rhizobium* inoculation of pulse crops.
Sundara Rao, W.V.B. (Agr Coll, Rajendranagar, India), A. Venkatachari and V. Madhava Reddy.
Ind J Genet Plant Breed 35(2):229-235, 1976.
Symbiotic N fixation can be enhanced two- or three-fold by introducing more effective strains of rhizobia. Through judicious selection of legume varieties matched with superior rhizobia and the following of good agronomic practices of fertilization, the 24 million hectares now devoted to pulse crops in India could contribute 2.4 million tonnes of N per year.

2029 Nitrogen-fixing ability of alfalfa, nitrogen balance and the productivity of the following crop on soddy-podzolic soil. (Rus)
Trepachev, E.P. and Z.K. Spivak.
Agrokhimiia 9:7-17, 1977.

2030 Net mineralization of nitrogen in leaves and leaf litter of *Desmodium intortum* and *Phaseolus atropurpureus* mixed with soil.
Vallis, I. and R.J. Jones.
Soil Biol Biochem 5:391-398, 1973.

2031 Aftereffect of post-harvest lupine crop on bog-podzolic soils. (Rus)
Zubenko, V.F., I.A. Geller, Zh.I. Nikolaenko, L.I.A. Berguleve and A.F. Odrekhovskii.
Vestin S-Kh Nauki (Mosc) 2:29-34, 1974.

Additional references with information on Nitrogen Cycle may be found in relevant listings under:

Inoculation effects	*Rhizobium* effectiveness
Nitrogen fixation	*Rhizobium* efficiency
Polycrop systems	Symbiosis.

21. NITROGEN EFFECTS.

2101 Effect of nitrogen on nodulation and yield of irrigated soybeans.
Beard, B.H. (ARS, USDA, Brawley, CA, USA) and R.M. Hoover.
Agron J 63(5):815-816, 1971.
Plants grown with zero N showed yellowing in early growth, but became dark green later in the season and showed no significant difference in yield. Nodule number was reduced with addition of N at planting, but not at flowering.

2102 Response of nodulating and non-nodulating soybean isolines to applied nitrogen.
Bhangoo, M.S. (U Arkansas, Pine Bluff, AR, USA) and D.J. Albritton.
Ark Farm Res Nov-Dec 1975, p. 14.

Soybean seed yield and vegetative dry matter may be significantly increased by N fertilizer on poorly drained soil low in OM and having a strongly acid subsoil. Yield was generally greater for the nodulating isoline, particularly at lower N application levels.

2103 Nodulating and non-nodulating Lee soybean isolines response to applied nitrogen.
Bhangoo, M.S. (U Arkansas, Pine Bluff, AR, USA) and D.J. Albritton.
Agron J 68(4):642-645, 1976.
Grain yields from nodulating soybeans with no N treatment equalled those of the non-nodulating isolines treated with N up to 224 kg/ha. Symbiotic N fixation decreased to near zero when N applications exceeded 224 kg/ha.

2104 Induction of root nodule senescence by combined nitrogen in *Pisum sativum* L.
Chen, P-C. (Indiana St U, Terre Haute, IN, USA) and D.A. Phillips.
Plant Physiol 59(3):440-442, 1977.
Addition of either NH_4Cl or KNO_3 to the rooting medium caused a decline in nitrogenase activity and leghemoglobin content. Nitrogenase activity was not affected by the presence of nitrate and nitrate reductase activity in the leaves as a result of leaf application of nitrate, indicating that sufficient photosynthate was still reaching the nodules.

2105 Effect of anhydrous ammonia and organic matter on components of nitrogen fixation and yield of soybeans.
Criswell, J.G.(U Guelph, Ontario, Canada), D.J. Hume and J.W. Tanner.
Crop Sci 16(3):400-404, 1976.
Anhydrous ammonia did not significantly affect seed yields, but reduced N fixation and nodule mass. Depression of the nodule mass was overcome by addition of organic matter.

2106 Nitrogen nutrition of cowpea (*Vigna unguiculata*). II. Effects of short-term applications of inorganic nitrogen on growth and yield of nodulated and non-nodulated plants.
Dart, P.J. (U Reading, England), P.A. Huxley, A.R.J. Eaglesham, F.R. Minchin, R.J. Summerfield and J.M. Day.
Exp Agr 13:241-252, 1977.
Combined nitrogen treatments ranging from 60 to 240 ppm applied during one of 3 growth periods did not compensate for the loss of symbiotic N fixation in non-nodulating plants. The average yield was 38% greater for effectively nodulated cowpea plants.

2107 Nutrient requirements of tropical pasture legumes. I. Influence of soil type and nitrogen levels on growth, nodulation and nitrogen-fixation of *Centrosema pubescens* Bent and *Stylosanthes gracilis* L.
Fayemi, A.A., C.T.I. Odu and A. Fagbami.
Nigerian J Sci 4(1):67-75, 1971.

2108 Effect of planting date, nitrogen fertilization and inoculation on the yield of soybean in Iran.

Ghorashy, S.R. (Pahlavi U, Shiraz, Iran), M. Niknejad and M. Kheradnam.
Ind J Agr Sci 42(2):127-129, 1972.
Optimum planting dates for Iran in this experiment were April 17-27. Planting after May 17 reduced the yield of all varieties. Application of N (85 kg/ha) either at the time of planting or at flowering gave the highest yield (2,107 kg/ha). Inoculation had no effect in 1968, but increased the yield in the second year.

2109 Nitrate effects on the nodulation of legumes inoculated with nitrate-reductase -deficient mutants of *Rhizobium*.
Gibson, A.H. (CSIRO, Canberra City, Australia) and J.D. Pagan.
Planta 134(1):17-22, 1977.
Nitrate retarded initial nodulation by the mutant strains to an extent similar to that found with parent strains. It is therefore unlikely that nitrate produced from nitrite by the rhizobia plays a significant role in the inhibition of nodulation by nitrate.

2110 Effects of mineral nitrogen and soil temperature on nitrogen fixation of field beans (*Phaseolus vulgaris* L.). (Por)
Guss, A. (U Federal Rural do Rio de Janeiro, Brasil) and J. Döbereiner.
Pesqui Agropec Bras Ser Agron 7:87-92, 1972.
Nodule numbers and weight increased when N at 23 ppm was applied at planting in Leonard jars, but not in soil, where 46 ppm N was required. Soil temperatures above 32° C daily maximum decreased nodule efficiency, but some strains were able to compensate by an increase in nodule number and size.

2111 Nodulation response of soybeans (*Glycine max* L. Merr.) to application rate and placement of combined nitrogen.
Harper, J.E. (ARS, USDA, Urbana, IL, USA) and R.L. Cooper.
Crop Sci 11(3):438-440, 1971.
Nitrate placed in the lower 10cm of a 30.5cm soil column allowed greater root uptake and did not impair nodulation as did the nitrate when dispersed throughout the column.

2112 Effect of applied nitrogen on the nodulation and early growth of soybeans (*Glycine max* (L.) Merr.).
Hatfield, J.L. (U Kentucky, Lexington, KY, USA), D.B. Egli, J.E. Leggett and D.E. Peaslee.
Agron J 66(1):112-114, 1974.
Dry weight of inoculated plants receiving N for 0 and 2 weeks was significantly lower than that of inoculated plants receiving N for 4 and 6 weeks. Dry weight of stems and leaves of uninoculated plants receiving N for 6 weeks was the same as for inoculated plants receiving N for 4-6 weeks. Results indicate the importance of soil N for initial growth, even with inoculation.

2113 Bimodal response by inoculated legumes to combined nitrogen.
Hoglund, J.H. (Dept Sci Indus Res, Palmerston N, New Zealand).
Plant Soil 39(3):533-545, 1973.

Nodulating lucerne exhibited a bimodal growth response to combined N at low levels and at high levels. The trough corresponds to the virtual suppression of N fixation by combined N. The duration and severity of the growth depression is dependent on the balance between potential growth and N fixing capacity development rates. Temperature is an important variable in this regard.

2114 Effects of nitrogen sources and organic matter on nitrogen fixation and yield of soybean.
Johnson, H.S. (U Guelph, Ontario, Canada) and D.J. Hume.
Can J Plant Sci 52(6):991-996, 1972.
Nitrogen fixation gained most from treatments with organic matter and liquid cow manure, but seed yield benefited most from inorganic nitrogen plus organic matter.

2115 Effect of ammonium and nitrate nitrogen upon photosynthate supply and nitrogen fixation by soybeans.
Latimore, M. (U Georgia, Athens, GA, USA), J. Giddens and D.A. Ashley.
Crop Sci 17(3):399-404, 1977.
In a determinate cultivar of soybean ('Bragg'), there is indication that more photosynthate was transferred to nodules during the vegetative and early reproductive stages than has been reported for indeterminate cultivars. Furthermore, 23% of the total N demand occurred during a 20-day period (Mid-pod and late pod fill stage) at a time when N fixation was declining. Inorganic N supplied throughout the season or 10 days prior to sampling reduced ^{14}C in nodules. While ammonium and nitrate sources of N appeared about equal in reducing the energy flow to nodules, the latter had a greater effect upon nitrogenase activity.

2116 Symbiotic nitrogen fixation in soybeans. III. Effect of supplemental nitrogen and intervarietal grafting.
Lawn, R.J. (U Minnesota, St. Paul, MN, USA) and W.A. Brun.
Crop Sci 14(1):22-25, 1974.
The application of N increased protein content of the seeds of the grafted varieties tested, but a decline in acetylene reduction activity.

2117 Effects of nitrogen level and fruit removal on growth, nodulation and water consumption of soybean *Glycine max* (L.) Merrill.
Loong, S.G. (U Malaya, Kuala Lumpur, Malaysia) and F. Lenz.
Z Acker Pflanz 139(1):35-43, 1974.
Growth and yield benefitted from N. Growth of vegetative organs decreased with increasing fruit load. Exfloration resulted in a continued production of new leaves and flowers even when fruit-bearing plants were becoming senescent.

2118 Mineral nitrogen effect on legume crops cultivated in soils differently infected with nodule bacteria. (Pol)
Mercik, S. and T. Mercik.
Rocz Nauk Roln Ser A Prod Rosl 100(2):73-85, 1974.

2119 The relative performance of white clover genotypes with rhizobial and mineral nitrogen in agar culture and soil.
Mytton, L.R.
Ann Appl Biol 82(3):577-587, 1976.

2120 Effect of nitrogen on nodulation and yield of soybean.
Olsen, F.J.(S Illinois U, Carbondale, IL, USA), G. Hamilton and D.M. Elkins.
Exp Agr 11:289-294, 1975.
The yield of 'Bragg' soybeans was not increased by N fertilizer applied to the surface of the soil at 112 and 224 kg/ha. The bean yield was reduced when N was applied at 448 kg/ha. Nodulation was reduced by N applications on a soil with relatively low organic matter content, but had less effect on a soil with higher OM.

2121 A comparative study of the effects of certain nitrogen sources and sugars on nodulation in lucerne (*Medicago sativa* L.).
Pahwa, M.R.(IARI, New Delhi, India) and N.S. Subba Rao.
Sci Cult 40(6):254-258, 1974.
Nitrates of sodium, potassium and ammonium, and urea and ammonium sulphate were tested for their relative potencies to inhibit nodulation. Ammonium nitrate was consistently inhibitory, while the other N compounds were stimulatory at low concentrations. Galactose was inhibitory, but fructose and sucrose increased nodulation.

2122 Effect of nitrates in nitrogen fixation by kidney bean (*Phaseolus vulgaris* L.) nodules. (Fre)
Rigaud, J.
Physiol Veg 14(2):297-308, 1976.

2123 Effect of nitrogen-ammonia on atmospheric nitrogen fixation in *Casuarina* nodules. (Spa)
Rodriguez-Barrueco, C.
An Edafol Agrobiol 31:905-916, 1972.

2124 Influence of mineral nitrogen on the process of infecting bean plants with *Rhizobium* bacteria. (Rus)
Shil'nikova, V.K., O.D. Dovenko and N. Ergasheva.
Nauch Dokl Vysshei Shkoly Biol Nauk 9:83-87, 1971.

2125 Yield and nitrogen content of non-nodulating soybean grown in association with nodulating lines.
Singh, J.N.(G.B. Pant U of Agr Tech, Pantnagar, India), S. K. Tripathi and P.S. Negi.
Proc Ind Natl Sci Acad Pt B Biol Sci 40(5):507-511, 1974.
Isogenic nodulating and non-nodulating soybeans were grown in several combinations to determine the benefit derived from association. Even application of 200 kg N/ha to the non-nod soybeans did not produce yields equal to the nodulated isolines, suggesting that biologically supplied N might be more suitable than applied N. The total N supplied to non-nod plants through association was equal to 100 kg N/ha.

2126 Nodulation studies in soybeans. The influence of concentration, form and time of application of combined nitrogen on symbiotic response.
Sintachs, E.
Cuban J Agr Sci 8(2):203-209, 1974.

2127 The influence of urea on the capability of free nitrogen fixation by *Rhizobium* strains. II. The effect on the symbiosis of *Rhizobium meliloti* with lucerne. (Pol)
Strzelec, A.
Inst Uprawy Nawozenia Glebozn Pamiet Pulawski 52:103-144, 1972.

2128 Effects of combined nitrogen on legume root nodulation.
Subba Rao, N.S., M.R. Pahwa and M.L. Kumari.
Acta Bot Indica 2(1):54-60, 1974.

2129 Regulation of nitrogen fixation in *Rhizobium* sp.
Tubb, R.S. (Plant Gr Lab, U California, Davis, CA, USA).
Appl Environ Microbiol 32(4):483-488, 1976.
Excess NH^{4+} fully suppressed nitrogenase activity of *Klebsiella pneumoniae*, but only inhibited that of *Rhizobium* cultures by 64 to 86% compared to glutamate grown cultures. Glutamate inhibited exogenous NH^{4+} utilization. In cultures initiated on glutamate, NH^{4+} was excreted into the medium, but not when NH^{4+} was the sole source of fixed N for growth. The possibility of the use of glutamate in the promotion of ammonium excretion for the benefit of the host plant is raised.

2130 Foliar application of urea on nodulation, ATP & thiol content of root nodules of *Phaseolus aureus* at different soil moisture levels.
Varma, A.K.(IARI, New Delhi, India) and N.S. Subba Rao.
Ind J Exp Biol 11(6):589-590, 1973.
Urea spray decreased nodulation and yield at all soil moisture levels, and decreased ATP and -SH content in nodules. A soil moisture of 50% was optimal for root growth, nodulation and yield.

2131 Effect of nitrogen fertiliser on nitrogen yield from lucerne under cutting and grazing managements.
Vartha, E.W. and R.M. Allison.
N Z J Exp Agr 1(4):365-368, 1973.

2132 Nodulation of soybeans grown hydroponically on urea.
Vigue, J.T.(ARS, USDA, Urbana, IL, USA), J.E. Harper and D.B. Peters.
Crop Sci 17(1):169-172, 1977.
Urea providing up to 18 µM N allowed effective nodule development and function. Growth on urea proved a convenient hydroponic method of producing vigorous nodulated soybeans that are capable of fixing 27 to 71% of the total plant N.

2133 Effects of supplementary nitrogen fertilizer on nodulation, yield and seed characteristics of soybean *(Glycine max)* on the Darling Downs.
Williamson, A.J.P.(Dept Primary Ind, Brisbane, Qld., Australia) and A. Diatloff.
Aust J Exp Agr Anim Husb 15:694-699, 1975.

Nitrogen fertilizer had little effect on seed size or nitrogen content in soils carrying *Rhizobium japonicum*, but it had a depressive effect on nodulation.

2134 Effect of nitrogen fertilizing on the growth of root nodules of leguminous crops. (Jpn)
Yoshida, S.
Anim Husb (Tokyo) 26(11):77-78, 1972.

2135 The influence of various forms of nitrogen and bacterization on the growth and development of soybean under sterile pot experiment conditions. (Geo)
Zhgenti, M.P., L.Sh. Chachua and N.M. Ramishvili.
Soobshch Akad Nauk Gruz SSR 82(1):197-200, 1976.

Additional information on Nitrogen Effects may be found in relevant listings under:
Macronutrients (other than N alone)
Rhizobium inhibition and stimulation.

22. NITROGEN FIXATION.

2201 Fixation and excretion of nitrogen by tropical legumes.
Agboola, A.A. and A.A.A. Fayemi.
Agron J 64:409-412, 1972.

2202 Biological nitrogen fixation, a natural resource for better utilization. (Fre)
Amarger, N. and B. Lagacherie.
Acad Agr Fr C R Seances 60(13):1072-1083, 1974.

2203 Nitrogen fixation in honey mesquite.
Bailey, A.W. (U Alberta, Edmonton, Ata., Canada).
J Range Mgt 29(6):479-481, 1976.
Mesquite (*Prosopis glandulosa*) nodulates naturally in West Texas soils, the best nodulation occurring in moist, sandy soils. Nodules were readily produced in the growth chamber in both control (unsterilized soil) and sterilized, inoculated pots.

2204 Experimental demonstration of biological nitrogen fixation. (Ger)
Becker, D.P.
Mikrokosmos 66(1):21-23, 1977.

2205 Biological nitrogen fixation. (Ger)
Bothe, H.
Naturwiss Rundsch 29(9):316-324, 1976.

2206 Biological nitrogen fixation.
Brill, W.J. (U Wisconsin, Madison, WI, USA).
Sci Amer 236(3):68-74, 79-81, 1977.

NITROGEN FIXATION *continued*

The ability to fix nitrogen is reserved in nature to only a few genera of bacteria [and algae, now usually classified with the bacteria]. The various processes for fixing nitrogen, including the legume/*Rhizobium* symbiosis, are briefly described. Current research efforts to enhance BNF, including advances in the understanding of the chemistry, the regulation of nitrogenase, improved efficiency and genetic manipulation are discussed in this overview.

2207 Nitrogen fixation: some implications of recent research.
Cherry, M.
S P A N 18(3):100-102, 1975.

2208 Newdevelopments in nitrogen fixation research.
Child, J.J. (Prairie Reg Lab, Saskatoon, Sask., Canada).
Bio Sci 26(10):614-617, 1976.
Recent developments have given hope that the potential of symbiotic N fixation can be more fully realized. These include nitrogen fixation by free-living rhizobia; greater understanding of host-specificity; the relation of photosynthesis to N fixation; simplified methods for genetic screening; and the possibility of associations with non-leguminous plants.

2209 Worldwide nitrogen fixation estimated.
Council for Agricultural Science & Technology (Summary of rept).
Chem Egr News 54(7):34, 1976.
Estimates for terrestrial N fixation, 1974, total 237 metric tons from the folowing sources: agricultural land, 38%; forested and unused land, 25%; industrial fixation for fertilizers and other uses, 24%; combustion, 9% and lightning, 4%. In addition, it is estimated that the ocean may contribute 1 million metric tons per year.

2210 Biological nitrogen fixation.
Dazzo, F.B.(U Florida, Gainesville, FL, USA) and D.H. Hubbell.
Proc Soil Crop Sci Soc Fla 34:71-79, 1975.
A review of the nature, measurement and occurrence of biological N-fixing systems, with a view toward greater exploitation in forest, grove and field agriculture.

2211 Confirmation of nitrogen fixation in two tropical grasses by $^{15}N_2$ incorporation.
De-Polli, H.(Centro de Energ Nuc na Agr, Piracicaba, Brasil), E. Matsui, J. Döbereiner and E. Salati.
N fixation in tropical grass - bacteria associations was confirmed by nitrogen isotope incorporation studies. Sucrose addition in the soil doubled N_2-fixation. Only 8% of root enrichment was observed in the leaves.

2212 Associations of nitrogen fixing bacteria with roots of forage grass and grain species.
Döbereiner, J., J.M. Day, J.F.W. Von Bulow.
M P Nebr Agr Exp Stn 32:221-237, 1975.

2213 Symbiotic nitrogen fixation in a sequence of pastures of increasing age as measured by N-15 technique.
Edmeades, D.C. and K.M. Goh.
N Z Soil News, 24(4):113-114, 1976.

2214 Role of legumes and *Rhizobium* in solving the protein problems in India.
Gaur, Y.D. and A.N. Sen.
Qual Plant Mater Veg 22:285-305, 1973.

2215 The world protein shortage can be alleviated by better use of nitrogen fixation. (Swe)
Granhall, U.
Forsk & Framsteg 1:3-7, 1974.

2216 The extent of biological nitrogen fixation in the Republic of South Africa.
Grobbelaar, N. and B.W. Strijdom.
In Proteins and food supply in the Republic of South Africa, p. 291-305, 1971.

2217 Nitrogen fixation by nodulated species of *Pavetta* and *Psychotria*.
Grobbelaar, N. (U Pretoria, Repub S Africa) and E.G. Groenewald.
Z Pflanzenphysiol 73(2):103-108, 1974.
Previous reports of N fixation by bacteria filled nodules on the leaves of these non-legumes are not entirely convincing. Plants grown in N-free culture for 75 days developed severe symptoms of nitrogen deficiency and no increase in their N content could be detected.Tests for nitrogenase activity by the acetylene reduction method were negative.

2218 Use of leguminosae for building up soil fertility in dry tropical soils. (Ger)
Gutschow, A.
Leben Erde 6:221-223, 1975.

2219 The nitrogen barrier: can the root nodules of a soybean plant be coaxed into fixing more nitrogen?
Hardy, R.W.F. (E.I. du Pont de Nemours & Co, Wilmington, DE, USA) and U.D. Havelka.
Crops Soils 26(5):10-13, 1974.
A yield of 50 bushels per acre of soybeans produces 200 pounds of N in the beans and another 100 pounds in the unharvested root, stem and leaves. This requires a large N input, but excess fertilizer causes less N fixation. Using CO_2 enrichment to increase available photosynthate, the output of biologically fixed nitrogen was quadrupled.

2220 Nitrogen fixation research: a key to world food?
Hardy, R.W.F. (Dupont ..., Wilmington, DE, USA) and U.D. Havelka.
Science 188(4188):633-643, 1975.
An assessment of the need for fixed nitrogen for crop production, and a summary of advances in chemical and biological research that may lead to alternative technologies.

2221 Seed protein of peas in relation to nitrogen fixation.
Johnston, A.W.B.(John Innes Inst, Norwich, England), V. Brewster and D.R. Davies.
Ann Bot 41(172):381-385, 1977.
The seed protein of plants receiving their nitrogen as ammonium nitrate was compared with those in which nitrogen was biologically fixed in nodules. The N source did not affect the amounts of extractable seed protein or the fractional proportions of their composition.

2222 Changes in the rate of symbiotic nitrogen fixation in the process of lupine vegetation.
Kretovich, V.L.(A.N. Bakh Inst Biochem, Moscow, USSR), K.B. Evstigneeva, G.L. Shaposhnikov, N.A. Radyukina, V.I.Romanov and E.M.Martynova..
Sov Plant Physiol 20(6):1028-1030, 1973.
The greatest N-fixing activity in the nodules occurred at the budding phase, age 38 days, while partially-purified nitrogenase had greatest activity at the flowering phase.

2223 Biological nitrogen fixation. (Jpn)
Maruyama, Y.
J Agr Chem Soc Japan 50(5):R121-R132, 1976.

2224 Recent developments in clover nitrogen fixation.
Masterson, C.L.
Farm Food Res 4(4):94-96, 1973.

2225 Nitrogen fixation by forage legumes. (Fre)
Muller, J.
Fourrages Actual 11:19-22, 1975.

2226 Perspectives in biological nitrogen fixation.
Nutman, P.S. (Rothamsted Exp Stn, Harpenden, Herts., England).
Sci Prog (Oxford) 59(233):55-74, 1971.
An overview of the biological contributions to the nitrogen cycle, tracing the history of research up to ca. 1970. A "census of nitrogen fixers" lists the genera of free-living organisms in one table, and outlines N-fixing associations of plants and microorganisms in a second table. Table 3 gives quantitative data for temperate and tropical legumes.

2227 Regulation of nitrogen fixation by rhizobia export of fixed N2 as NH_4^+.
O'Gara, F.(Plant Gr Lab, U Calif., Davis, CA, USA) and K.T.Shanmugam.
Biochim Biophys Acta 437(2):313-321, 1976.
Most of the fixed $^{15}N_2$ was exported to the cell supernatant. The mechanism of regulation of ammonium production and assimilation is discussed.

2228 Nitrogen fixation in nitrate reductase-deficient mutants of cultured rhizobia.
Pagan, J.D.(CSIRO, Canberra, Australia), W.R. Scowcroft, W.F. Dudman and A.H. Gibson.
J Bac 129(2):718-723, 1977.

Mutant "cowpea" rhizobia unable to reduce nitrate were isolated and examined for impairment of nitrogenase activity. Only 2 of 48 isolates showed such impairment, indicating that nitrogenase activity is markedly less sensitive to nitrate than nitrite.

2229 Some recent advances on nitrogen fixation. (Ita)
Picci, G.
Agr Ital (new ser 28) 73(4):230-260, 1973.

2230 Relevant aspects of the physiological chemistry of nitrogen fixation.
Postgate, J.
In Soc for Gen Microbiol 21st symp Microbes & Biol Prod, p. 287-307, 1971.

2231 Biological nitrogen fixation.
Postgate, J.
Merrow (publisher), Watford, England, 61 p., 1972.
The bibliography includes 5 pages of references.

2232 Evolution within nitrogen fixing systems.
Postgate, J.
In Soc Gen Microbiol 24th symp, p. 263-292, 1974.

2233 Nitrogen fixation by *Pueraria phaseoloides* in Malaysia.
Rajaratnam, J.A. and P.G. Ang.
Malays Agr Res 1(2):92-97, 1972.

2234 Mineral nitrogen and nitrogen fixation in soybeans in relation to nodule growth and their phosphorus metabolism. (Rus)
Ratner, E.I. and S.A. Samoilova.
Agrokhimiia 9:3-10, 1971.

2235 N-15 isotopic effects in partial step models of nitrogen fixation by complex catalysis.
Rummel, S., B. Bayerl, H. Johnsen, B. Lorenz and M. Wahren.
Zeit Chem 16(5):193- , 1976.

2236 Nitrogenase activity, nitrogen content, *in vitro* digestibility and yield of 30 tropical forage grasses in Brazil.
Schank, S.C. (U Florida, Gainesville, FL, USA), J.M. Day and E.F. de Lucas.
Trop Agric (Trinidad)54(2):119-125, 1977.
Biological N fixation by free-living bacteria, as determined by nitrogenase activity, can reach rates over 500g N/ha/day under favorable conditions. The possibility of breeding grasses for increased N fixation is raised.

2237 Seasonal changes in symbiotic nitrogen fixation and haemoglobin content in nodules of peanuts.
Schiffmann, J. (Volcani Ctr, Bet Dagan, Israel) and R. Lübel.
Plant Soil 39(2):329-340, 1973.

The role of symbiotic N fixation in maintaining a certain level of N in the leaflets increases as the season advances, as indicated by fluctuations in the concentration of leghaemoglobin in the nodules.

2238 The chemistry of biological nitrogen fixation.
Schneider, P.W. (Kettering Res Lab, Yellow Springs, OH, USA).
Metal Ions Biol Syst 6:197-249, 1976.
A comprehensive, but not historical, review of the purely chemical aspects of the process of biological nitrogen fixation (BNF), with an emphasis on those steps leading from N_2 to ammonia. Main sections deal with nitrogenase and its properties, the present state of knowledge of the reactions and mechanisms involved in BNF, and a summary with some conclusions on the value of an inderdisciplinary approach to greater understanding of BNF. The bibliography includes 286 references.

2239 Daily changes in the rate of molecular nitrogen fixation, free amino acid content, and ammonia content in lupine nodules.
Shaposhnikov, G.L.(All Union Sci Res Inst Agr Microbiol, Leningrad, USSR), Z.G. Evstigneeva, K.B. Aseeva and V.L. Kretovich.
Sov Plant Physiol 22(4):681-688, 1975.
N fixation was shown to follow a rhythmic pattern coinciding with photosynthetic activity of the host. A correlation between the dynamics of content of reserve N in the amino acids of bacteroids and plants and the dynamics of the rate of N fixation was also shown. In plant cells, the reserve form of N was GABA; in the bacteroids it was phenylalanine.

2240 Biochemistry of N_2 fixation.
Sloger, C.(Plant Physiol Inst, USDA, Beltsville, MD, USA).
In Proc World Soybean Res Conf p. 125-134, 1976.
The properties of nitrogenase, a tentative scheme of its electron transport system, and the role of ATP are discussed. A working model for ammonia regulation of nitrogenase synthesis in the bacteroid is presented.

2241 Nitrogen fixation in field beans *(Vicia faba)* as affected by population density, shading and its relationhip with soil moisture.
Sprent, J.I. (U Dundee, Scotland) and A.M. Bradford.
J Agr Sci (Cambridge) 88(2):303-310, 1977.
Environmental factors exerted increasing effects on N fixing activity as densities increased. As plants aged, the acetylene reduction assay progressively underestimated total plant N accumulation. The N fixation potential of field beans proved sufficient to sustain high yields.

2242 Growth of two soybean shoots on a single root: effect on nitrogen and dry matter accumulation by shoots and on the rate of nitrogen fixation by nodulated roots.
Streeter, J.G. (Ohio Agr R & D Ctr, Wooster, OH, USA).
J Exp Bot 25(84):189-198, 1974.
The shoot:root ratio was doubled by grafting stems of 2 plants and then removing one root system. Acetylene reduction per gram of nodule was 75% greater in the grafted plants, indicating that soybeans are capable of fixing N at greater rates than those which normally prevail.

2243 Models of nitrogen fixation.
Thomson, A.J.
Nature 253(5486):7-8, 1975.
A reaction devised by Bell *et al* at the University of Sussex, and a later reaction prepared by Soviet and American workers should provide useful models for exploration of the mechanisms and the intermediaries by which multi-step reductions can occur.

2244 Nodulation and nitrogen fixation.
Vest, G., D.F. Weber and C. Sloger.
Agronomy 16:353-390, 1973.
A general review, with emphasis on recent advances.

2245 Symbiotic and semisymbiotic nitrogen fixation. (Ger)
Werner, K.
Naturwiss Rundsch 27(5):177-182, 1974.

2246 Nitrogen-fixing activity of lupine nodules in connection with the content of fixation products in them.
Yagodin, B.A. (K.A.Timiryazev Inst Plant Physiol, Moscow, USSR), M.S. Savich, V.B. Ilyasova and L.G. Grishina.
Sov Plant Physiol 22(6):1050-1053, 1975.
The relation between nitrogenase activity and the endogenous concentrations of ammonium and aminoamide nitrogen was investigated. The greatest content of both occurred at the peak of N fixing activity. The content of ammonium decreased with decreased nitrogenase activity, but the aminoamide level remained at its peak.

2247 Nitrogen fixation.
Yates, M.G. (U Sussex, England).
Trends Biochem Sci 1:17-20. 1976.
Some 15 biological systems that fix N were reviewed, both symbiotic and free-living, and including aerobic, facultative, and anaerobic systems. The recent decline in the acreage of most grain legumes is reported, and further research to improve legume yields through enhanced BNF is encouraged.

2248 Experiment on nitrogen-fixation of several species of leguminous pasture [plants]. (Jpn)
Yoshida, J.
Chikusan Kenkyu 26(6):835-836, 1972.

23. NITROGEN FIXATION - DETECTION AND MEASUREMENT.

NOTE: For purposes of subject arrangement, the acetylene reduction assay is assumed to be a test for nitrogen fixation. No equation of the terms is intended beyond that expressed by the authors in the articles listed.

2301 Diurnal changes in acetylene reduction in field-grown cowpeas and soybeans.
Ayanaba, A. (IITA, Ibadan, Nigeria) and T.L. Lawson.

Soil Biol Biochem 9(2):125-129, 1977.
Changes in acetylene reduction over a 30 hour period were compared with temperature changes of soil, canopy and ambient air, radiation levels, and vapor pressure deficit. Cowpea showed 2 peaks and 2 minima, but soybean failed to show a definite pattern. Vapor pressure deficit appeared to be the most influential factor in a decline between 1200-1600 hours.

2302 The experiment: colorimetric determination of nitrogenase activity.(Ger)
Becker, D.P.
Biol Unser Zeit 6(4):121-123, 1976.

2303 Acetylene reduction by legume root nodule protoplasts.
Broughton, W.J.(U Malaya, Kuala Lumpur, Malaysia), K.C. Wooi and C.H. Hoh.
Nature 262(5565):208-209, 1976.
A procedure for isolating protoplasts from nodules while retaining their acetylene reducing capability is described. The naked protoplasts showed activity after a lag period of about 2 days and continued to reduce acetylene for at least 11 days.

2304 Bacterial degradation of ethylene and the acetylene reduction test.
De Bont, J.A.M.(Agr U, Wageningen, The Netherlands).
Can J Microbiol 22(7):1060-1062, 1976.
The results indicate that it is unlikely that ethylene degradation occurs during application of the acetylene reduction assay.

2305 Nitrogen fixation in soybeans: measurement techniques and examples of applications.
Criswell, J.G.(E.I. du Pont de Nemours & Co., Wilmington, DE, USA), R.W.F. Hardy and U.D. Havelka.
In Proc World Soybean Res Conf p. 108-124, 1976.
Three quantitative approaches are discussed: nodule number, mass and leghaemoglobin concentration; N-analysis of the plant, including $^{15}N_2$ enrichment; and the acetylene reduction assay. Methodology, limitations and applicability of each approach is discussed. The preferred standard is $^{15}N_2$ enrichment.

2306 Soybean (*Glycine max* L. Merr.) nitrogen nutrition. Estimate of symbiotic nitrogen fixation and unsymbiotic nitrogen uptake from nitrate content. (Fre)
Decau, J., A. Buoniols, M. Mondies, A. Pace and B. Pujol.
Compt Rend Ser D Sci Nat 283(7):773- , 1976.

2307 The degree of symbiotic nitrogen fixation by leguminous plants and the methods of its determination. (Rus)
Dorosinskii, L.M.(All-Union Res Inst Agr Microbiol, Leningrad, USSR) and L.M. Afanasgeva.
Akad Nauk SSSR Izv Ser Biol 3:355-360, 1972.
The spectral-isotope method has shown that in peas and lupin the biologically bound N reaches 80-85%, and for clover and lucerne 90-95%. Data concerning the distribution of fixed N in the plant organs are included.

2308 A modified sand culture method for *Rhizobium* assay.
Elliott, L.F.(Agr Res Stn, U Nebraska, Lincoln, NB, USA) and J.W. Blaylock.
Soil Sci Soc Amer Proc 35(1):158-159, 1971.
A modification of the Leonard assembly for the prevention of air-borne *Rhizobium* contamination.

2309 Acetylene reduction assays for nitrogen fixation in freshwaters: a note of caution.
Flett, R.J.(U Manitoba, Winnipeg, Canada), J.W.M. Rudd and R.D.Hamilton.
Appl Microbiol 29(5):580-583, 1975.
It is suggested that acetylene reduction assays may not be accurately applied to samples containing methane oxidizing bacteria, which are widely distributed in soils.

2310 Acetylene reduction by effective and ineffective clover and soybean root nodules.
Francis, A.J.(Cornell U, Ithaca, NY, USA) and M. Alexander.
Arch Mikrobiol 85(4):294-303, 1972.
Effective soybean bacteroids were markedly stimulated by succinate and by several amino acids, but partially effective bacteroids were stimulated only slightly. The effective bacteroids were also stimulated by excretions of *in vitro* grown *Rhizobium japonicum*, excretions from bacteria derived from effective and ineffective nodules, and by the soluble fraction from these nodules. N fixation was not promoted in bacterial cells from ineffective nodules by any of the additives. Inhibitors of N fixation were not found in the ineffective nodules.

2311 An independent measurement of the amount of nitrogen fixed by a legume crop.
Fried, M. (IAEA, Vienna, Austria) and H Broeshart.
Plant Soil 43:707-711, 1975.
^{15}N fertilizer was used to calculate comparative values of fixed N for field grown test and control legume crops.

2312 Measurement of amount of nitrogen fixed by a legume crop.
Fried, M. (IAEA, Vienna, Austria) and V. Middelboe,
Plant Soil 47(3):713-715, 1977.
A follow-up of the 1975 article by Fried and Broeshart, with a mathematical formula to simplify application of the method.

2313 Application of the acetylene-ethylene assay for measurement of nitrogen fixation.
Hardy, R.W.F.(du Pont & Co., Wilmington, DE, USA), R.C. Burns and R.D. Holsten.
Soil Biol Biochem 5(1):47-81, 1973.
A report based on more than 200 accounts of the use and limitations of this technique for measurement of N_2 fixation. Includes 7 pages of references.

2314 Comparisons of nitrogen fixation estimates in soybeans by nodule weight, leghemoglobin content, and acetylene reduction.
Johnson, H.S.(U Guelph, Ontario, Canada) and D.J. Hume.
Can J Microbiol 19(9):1165-1168, 1973.
High correlations were found between nodule leghemoglobin content, acetylene reduction rates, and nodule weight for most sampling dates. Acetylene reduction/mg leghemoglobin constantly decreased during the growing season, while leghemoglobin content/g nodule remained relatively constant. The results indicate that leghemoglobin content of nodules can be used to compare rates of N fixation by plants at similar stages of development, but not at different stages in ontogeny.

2315 A tracer method for determining symbiotic nitrogen fixation in field studies.
Legg, J.O.(ARS, USDA, Beltsville, MD, USA) and C. Sloger.
In Proc Int'l Conf Stable Isotopes 2d:661-666, 1975.
A measure of mineralized soil N uptake was obtained by labeling the soil organic N with ^{15}N. Dilution of isotopic N in the plant was used to calculate biological nitrogen fixation, and this value was compared to estimates of fixation by an acetylene reduction method. Differential fixation was also obtained by comparing nodulating to non-nodulating isolines. Estimates by acetylene reduction were much lower than values obtained by the isotopic method and by the differential comparison method. The isotopic tracer method was concluded to offer a precise measure of N fixation which is adaptable to field-scale plots.

2316 Utilization of the Van't Hoff temperature coefficient to estimate nitrogen-fixation intensity in soil. (Ukr)
Mal'tseva,N.N., N.F. Kigel and A.A. Diul'din.
Mikrobiol Zh 38(5):551-561, 1976.

2317 Assessment of $C_2H_2:N_2$ molar ratios of detached *Phaseolus vulgaris* nodules using emission spectrometry for $^{14}N:^{15}N$ determinations.
MacRae, I.C. (U Queensland St. Lucia, Brisbane, Qld., Australia).
Soil Biol Biochem 7(3):239-240, 1975.
Optical emission spectrometry can give satisfactory results with debris-free nodule homogenates, provided certain precautions are observed.

2318 Continuous, automated acetylene reduction assays using intact plants.
Mederski, H.J.(Ohio Agr R & D Ctr, Wooster, OH, USA) and J.G. Streeter.
Plant Physiol 59(6):1076-1081, 1977.
An *in situ* method which provides assays at intervals as short as 3.5 minutes over a period up to several days, without attention except for plant watering. Diurnal decline rates in acetylene reduction indicated dependence on concurrent photosynthesis and on stored carbohydrates.

2319 Acetylene-reducing activity of detached root nodules of *Myrica faya* Ait.
Miguel, C. and C. Rodriguez-Barrueco.
Plant Soil 41(3):521-526, 1974.

2320 Non-uniformity of ^{15}N labelling in plant material.
Moore, A.W.(CSIRO, St. Lucia, Qld., Australia) and E.T.Craswell.
Commun in Soil Sci & Plant Anal 7(4):335-344, 1976.
Either as a result of non-symbiotic N fixation, absorption of ammonia from the atmosphere, or plant discrimination between ^{14}N and ^{15}N in uptake and/or translocation, uniformly labelled material was not produced in these experiments with wheat and Rhodegrass.

2321 Anomalous results encountered when measuring acetylene reduction by soil bacteria.
Murphy, P.M. (Agr Inst, Johnstown Castle, Wexford, Ireland).
Soil Biol Biochem 7(6):403-404, 1975.
The presence of transition metals and H_2 gave highly erroneous estimates of nitrogenase activity.

2322 Acetylene reduction (N_2-fixation) by nodules of *Acacia cyanophylla*.
Nakos, G. (Forest Res Inst, Athens, Greece).
Soil Biol Biochem 9(2):131-133, 1977.
Subjection of the plants to drought, waterlogging and defoliation led to drastic reduction or cessation of nodule activity. Return to regular regimes led to partial or total restoration of acetylene reduction.

2323 Rapid method of determining symbiotic nitrogen fixation during plant growth under sterile and natural conditions.
Pariiskaya, A.M. (Inst Microbiol, USSR) and O.P. Gorelova.
Microbiol 44(5):860-861, 1975.
Plants grown in tubes in a nitrogen free, inoculated medium were tested for acetylene reduction. If only qualitative data on N fixation is sought, it was found not to be necessary to replace the air in the tube with a gas mixture. Under natural conditions, nodules placed in small phials may be used to determine the presence or absence of nitrogenase activity. Storage up to 2 months did not affect the assay results.

2324 Detection of nitrogenase activity in collection strains of *Rhizobium*. (Rus)
Pariiskaia, A.N. and T.A. Kalininskaia.
Mikrobiologiia 46(1):181-184, 1977.

2325 Factors affecting the reduction of acetylene by *Rhizobium*-soybean cell associations *in vitro*.
Phillips, D.A. (Indiana St U, Terre Haute, IN, USA).
Plant Physiol 53(1):67-72, 1974.
Because endogenous ethylene production has been reported in cultured soybean tissue (LaRue, *et al*, 1971, Plant Physiol 48:394-398), this study was undertaken to determine whether reports of ethylene produced by an association between *Rhizobium* and soybean cells *in vitro* had actually resulted from acetylene reduction or from other metabolic pathways. Acetylene dependent production of ethylene was observed.

2326 Promotion of acetylene reduction by *Rhizobium*-soybean cell associations *in vitro*.
Phillips, D.A. (Indiana St U, Terre Haute, IN, USA).
Plant Physiol 54(4):654-655, 1974.
The addition of succinic acid or glutamine stimulated nitrogenase activity.

2327 Seasonal variations of nitrogenase activity in root nodules of *Alnus glutinosa* (L.) Gaertn., *Alnus incana* (L.) Moench and *Alnus cordata* (Louis.) Desf.
Pizelle, G.M. (U de Nancy, France).
C R Acad Sci Paris 281(Ser D):1829-1832, 1975.
Monthly measurement of nitrogenase activity of root nodules by acetylene reduction assay indicated that in all species checked the nitrogenase activity begins in spring when the leaves unfold, attained the highest rate in June-July, and disappeared several days after the leaves fell in autumn.

2328 Nitrogen-fixing ability of nodules of *Casuarina torulosa* L.
Rodriguez-Barrueco, C. (Centro de Edafologia y Biol Appl, Salamanca, Spain).
Agrochimica 18:119-127, 1974.
Nodules detached from the host at any time of day were able to continue fixing N on a scale readily detectable isotopically. The potential was significantly higher in nodules detached in the evening.

2329 Evaluation of symbiotic nitrogen fixation in kidney beans. (Por)
Ruschel, A.P. and R. Ruschel.
Pesqui Agropecu Bras, Ser Agron 10(11):11-17, 1975.

2330 Use of acetylene reduction assay for measurement of nitrogen fixation activity. (Pol)
Sawicka, A. and M. Trzoinska.
Kosmos, Ser A Biol 25(5):441-450, 1976.

2331 Non-destructive acetylene reduction assay of nitrogen fixation applied to white clover plants growing in soil.
Sinclair, A.G. (Invermay Agr Res Ctr, Mosgiel, N.Z.).
N Z J Agr Res 16(2):263-270, 1973.
Intact, undisturbed *Trifolium repens* plants in gas-tight polyethylene containers were exposed to an acetylene/air atmosphere, and the production of ethylene measured. The soil was confirmed as the route of transport of the acetylene to the roots. The test is accurate and offers several advantages over the method of direct exposure of nodules removed from their environment.

2332 Measurement of atmospheric nitrogen fixation in legume-based pasture turfs using the acetylene reduction assay.
Sinclair, A.G. (Invermay Agr Res Ctr, Mosgiel, N.Z.).
N Z J Agr Res 18(3):189-195, 1975.
Eighty clover-ryegrass pasture turfs in a glasshouse were assayed over a

period of 23 weeks. A close linear relationship between ethylene production and legume N uptake was found. The acetylene reduction assay provided at least a moderately accurate measure of N_2 fixation.

2333 Evaluation of the acetylene-reduction assay of nitrogen fixation in pastures using small soil-core samples.
Sinclair, A.G.(Invermay Agr Res Ctr, Mosgiel, NZ), R.B. Hannagan and W.H. Risk.
N Z J Agr Res 19(4):451-458, 1976.
A 25% coefficient of variation in acetylene reduction assays of clover-ryegrass pasture core samples made quantitative interpretation useful as an index for comparisons, but of limited value for absolute determinations.

2334 Acetylene reduction assay for nitrogen fixation under field conditions in remote areas.
Stutz, R.C.(U Alberta, Edmonton, Ata., Canada) and L.C. Bliss.
Plant Soil 38(1):209-213, 1973.
Acetylene generated from calcium carbide may be used with soil cores in specially adapted Mason jars to produce statistically reproducible data.

2335 Studies with detached lupine root nodules in culture. I. Maintenance and induction of acetylene reduction activity.
Sutton, W.D.(DSIR, Palmerston N, NZ) and N.M. Jepsen.
Plant Physiol 56(5):665-670, 1975.
The acetylene reduction activity of mature detached nodules was maintained at 10-25 n moles of ethylene hr^{-1} mg^{-1} fresh weight for 3 days. Immature nodules under the same culture conditions increased their activity from 0.01 n mole or less to about 1 n mole hr^{-1} mg^{-1} fresh weight.

2336 Experimental check of the principles of studying the amounts of nitrogen fixed by leguminous plants. (Rus)
Trepachev, E.P., N.A. Atrashkova and A.I. Khabarova.
In Novoe v Izuchenii Biologicheskoi Fiksatii Azota p 145-153, 1971.

2337 Factors affecting the reduction of acetylene by root nodules of *Lupinus* species.
Trinick, M.J.(CSIRO, Wembley, W.A., Australia), M.J.Dilworth and M. Grounds.
New Phytol 77:359-370, 1976.
Maximum reduction occurred at 23° C, after the onset of flowering, and at 0.2 - 0.5 atm. pO_2. Removal of nodules reduced that activity by 70-85%. Brief rinsing and rapid blotting had little effect, but prolonged wetting markedly decreased the acetylene reducing activity. No diurnal rhythm was detected.

2338 Acetylene method for studying nitrogen fixation in soil microbiological investigations. (Rus)
Umarov, M.M.
Pochvovedenie 11:119-123, 1976.

2339 Elimination of acetylene reduction during assay of detached soybean nodules.
[illegible] (U Minnesota, St Paul, MN, USA) and E.L. Schmidt.
Appl Microbiol 27(6):251-256, 1974.
[illegible] was identified as a product of acetylene reduction that may be [illegible] reduction under certain circumstances.

2340 Volatile compounds produced during acetylene reduction by detached soybean nodules.
Van Berkum, J. (U Minnesota, St Paul, MN, USA) and E.L. Schmidt.
Appl Microbiol 27(6):347-351, 1974.
[illegible] (acetaldehyde, acetone and ethanol) were studied. Neither of the first two appeared to be implicated in inhibition of C_2H_2 reduction. Evidence indicated that ethanol was the most likely cause of cessation of acetylene reduction during prolonged assay of detached nodules.

2341 Nitrogen fixation by intact annual rangeland species in soil.
Vaughn, C.E. (U California [Davis] CA, USA) and M.B. [illegible].
Agron J 68(4):561-564, 1976.
N fixation in a large, intact system was successfully assayed using the acetylene reduction technique. Quantitative estimates of N2 fixation may be made during an entire growing season. Both symbiotic and nonsymbiotic fixation were evaluated.

2342 Field use of the acetylene reduction assay for nitrogen fixation.
Vaughan, G.J. (U Dundee, Scotland).
Oikos 22(1):111-113, 1971.
Inexpensive portable apparatus for field use is described. The argon-oxygen-mixture and the acetylene are carried in football bladders. One set of bladders was usually sufficient for about 50 tests using 20 ml chambers.

2343 Acetylene reduction assay for nitrogen fixation in sand dunes.
Vaughan, G.J. (U Durham, England).
Oikos 23(2):206-212, 1972.
It was concluded that *Lotus corniculatus* was the main contributor of biologically fixed nitrogen to the dune ecosystem. Limitations and potentials of the investigation method are discussed.

24. NITROGENASE.

2401 Diurnal variation in nitrogenase activity in nodulated cowpea and soybean.
Ayanaba, A. (IITA, Ibadan, Nigeria).
Trop Grain Legume Bul 1(1):7, 1975.
Nitrogenase activity was greatest in mid-morning, reducing considerably after 1000 hours. Acetylene reduction by cowpea, but not soybean, increased again between 1400 and 1600 hours. No measurements were made after 1600.

2402 Nitrogenase, its regulation and genetic bases of nitrogen fixation. (Fre)
Blanchard, R.
Annee Biol (Ser 4) 15:129-153, 1976.

2403 Regulation of nitrogenase activity in soybean nodules by ATP and energy charge.
Ching, T.M. (Oregon St U, Corvallis, OR, USA).
Life Sci 18(10):1071-1076, 1976.
Nitrogenase consumes up to 15 moles of ATP to reduce 1 mole N, and appears to be one of the most energy demanding enzymes known in nature. A stop-and-go treatment may be applied by induced anaerobiosis followed by aeration, which causes a concomitant low-and-high ATP and energy charge.

2404 Dinitrogen fixation.
Dilworth, M.J. (U Western Australia, Nedlands, Australia).
Ann Rev Plant Physiol 25:81-114, 1974.
A systematic review, with emphasis on the role of the nitrogenase enzyme. "Literature cited" includes 300 references.

2405 Nitrogenase.
Eady, R.R.(U Sussex, England) and J.R. Postgate.
Nature 249(5460):805-810, 1974.
An examination of nitrogenase by physiochemical and kinetic methods revealing an elaborate reaction mechanism involving electron transport between component proteins.

2406 Nitrogenase activity in rhizobia in absence of plant host.
Kurz, W.G.W.(Natl Res Council Canada, Saskatoon) and T.A. LaRue.
Nature 256(5516):407-409, 1975.
The ability of cowpea *Rhizobium* to fix dinitrogen when grown close to, but not in contact with, callus cultures of legumes and non-legumes, supported other evidence that the rhizobia contained the genetic information for nitrogenase. Expression of the enzyme was promoted by diffusable factors from plant cells, or by either xylose, arabinose or galactose plus sucrose.

2407 Estimation of nitrogenase using a colorimetric determination for ethylene.
LaRue, T.A.(Prairie Reg Lab, Saskatoon, Sask., Canada) and W.G.W. Kurz.
Plant Physiol 51(6):1074-1075, 1973.
Nitrogenase is the only known biological agent which converts acetylene to ethylene. As an alternative to gas chromatography, a measurement of ethylene to determine nitrogenase is achieved by oxidizing it to formaldehyde and determining the formaldehyde colorimetrically. Low levels of ethylene cannot be detected by the procedure, but it is sufficiently sensitive to detect nitrogenase activity over most of a legume's growth.

2408 Separation into components and the recombination of nitrogenase from bacteroids of lupine nodule bacteria. (Rus)
Martynova, E.M., K.B.Aseeva, Z.G.Evstigneeva and V.L.Kretovich.
Dokl Akad Nauk SSSR 228(5):1230-1232, 1976.

2409 Compatibility of the components of nitrogenase from soybean bacteroids and free-living nitrogen-fixing bacteria.
Murphy, P.M. (U Wisconsin, Madison, WI, USA) and B.L. Koch.
Biochim Biophys Acta 253(1):295-297, 1971.

NITROGENASE continued

The nitrogenase complexes from symbiotic and free-living nitrogen-fixing bacteria were found to be very similar. Active enzyme complexes were formed from heterologous crosses of nitrogenase components.

2410 Reactivation of inactive nitrogenase by acid-treated component I.
Magnani, H.N. (U Wisconsin, Madison, WI, USA), V.K. Shah and W.J.Brill.
J Bac 119(2):487-488, 1974.

An activating factor which probably contains molybdenum was obtained from Mo-fixing bacteria by acid treatment of their component I. This factor activated Mo-deprived component I which did not activate *in vitro* when molybdate was added, although activation did occur *in vivo*.

2411 Nitrogenase V. The effect of Mo, W & V on the synthesis of nitrogenase components of *Azotobacter vinelandii*.
Magnani, H.N. (U Wisconsin, Madison, WI, USA) and W.J. Brill.
Biochim Biophys Acta 362:160-166, 1974.

Azotobacter vinelandii synthesized nitrogenase component II, but not component I, in the absence of Mo. An inactive component I was produced when W was added to the medium, but addition of V to the Mo-free medium did not increase the synthesis of component I.

2412 Location of nitrogenase and ammonia-assimilatory enzymes in bacteroids of *Rhizobium leguminosarum* and *Rhizobium lupini*.
Plamque, K. (St U of Leiden, The Netherlands), I.R. Kennedy, G.E. deVries, A. Quispel and A.A.N. Van Brussel.
J Gen Microbiol 102(1):95-104, 1977.

Nitrogenase was localized in the cytoplasm as distinct from the membrane fractions, while glutamate dehydrogenase was only superficially localized. About 95% of the glutamine synthetase activity was in the nodule cytosol.

2413 Interactions among substrates and inhibitors of nitrogenase.
Rivera-Ortiz, J.M. (U Wisconsin, Madison, WI, USA) and R.H. Burris.
J Bac 123(2):537-545, 1975.

Results obtained by interactions among various substrates and inhibitors reacting with nitrogenase are understandable if the enzyme serves as an electron sink and substrates and inhibitors bind at multiple modified sites on reduced nitrogenase. In this model, it is possible that acetylene reduction may require the electron sink of the MoFe protein to contain only 2 electrons, while the reduction of N_2 would require 6 electrons.

2414 Changes of protein and free amino acid content in bacteroids of *Rhizobium lupini* in the vegetative cycle.
Shumnik-Tsov, S.I. (A N Bakh Inst Biochem, Moscow, USSR), K.S. Aseeva and Z.G. Bystigneva.
Sov Plant Physiol 23(3):524-526, 1976.

The activity of nitrogenase, which increases from nodulation to early flowering, then shifts, is regulated in several ways. The changes of protein and free amino acid content as related to changes in the rate of N fixation were studied. Phenylalanine content was shown to repeat the vegetative rhythm of N fixation.

2415 Localization of nitrogenase components and other nonhemin ferroproteins of lupin bacteroids in polyacrylamide gel. (Ukr)
Zheliuk, V.M. and I.U.P. Starchenkov.
Mikrobiol Zh 37(5):640-641, 1975.

For additional references dealing with the induction of nitrogenase activity, see relevant listings under *Rhizobium* Cultures and Culture Media.

25. NODULATION.

2501 The nodulation profile of the genus *Cassia*.
Allen, E.K. and O.N. Allen.
Int'l Biol Prog 7:113-121, 1976.

2502 Nodulation of soybean under Indian conditions.
Balasundaram, V.R. (IARI, New Delhi, India).
Proc Ind Natl Sci Acad Pt B Biol Sci 40(5):512-515, 1974.
Effective nodulation is a basic requirement for successful cultivation of soybeans. Due to high temperature, inoculation has proven difficult in some parts of India. Pelleting, mulching and deep sowing offer little help. At the present, dependence on naturalized rhizobia is required. A greater understanding of intervarietal specificity would be helpful.

2503 Nodulation studies on *Phaseolus vulgaris* L. and *Phaseolus coccineus* L.
Beckham, L.S. and J.N. Rutger.
Bean Improv Coop Ann Rep 16:9-10, 1973.

2504 Nodulation and serological studies of rhizobia from six species of *Arachis*.
Dadarwal, K.R. (IARI, New Delhi, India), C.S. Singh and N.S. Subba Rao.
Plant Soil 40(3):535-544, 1974.
Isolates from one cultivated and six wild species were tested for nodulation and serological relationships. Rhizobia from all wild species nodulated, but the morphology and pattern of nodulation differed. Some isolates from *Arachis duranensis* were the most effective.

2505 Legume root nodule initiation and development.
Dart, P.J.
In The development and function of roots, Cabot Symp 3d:468-506, 1975.

2506 Investigation of a non-nodulating cultivar of *Pisum sativum*.
Degenhardt, T.L. (Prairie Reg Lab, Saskatoon, Sask., Canada), T.A. LaRue and E.A. Paul.
Can J Bot 54(14):1633-1636, 1976.
The non-nodulating cultivar formed infection threads in the root hairs, but swellings on the areas of the root where nodulation would normally occur were formed instead of nodules. After ruling out other factors, it was indicated through grafting experiments that the factor preventing nodulation was in the root and was not translocated from the cotyledon or plant top.

NODULATION MONITORING

[illegible] Factors of [illegible] nodulation.
[illegible] S.R., [illegible] and E.L. [illegible].
[illegible] 100(1):[illegible], 1972.

[illegible] elements in the nodulation and growth of legumes. (Spa)
[illegible]
[illegible] 43(501):23-24, 1974.

2509 Influence of the ecology on the nodulation of *Trifolium subterraneum* L. and *Medicago tribuloides* Desf., in the semi-arid zone of southeast Spain. (Spa)
Fuentes Sanchez, C.
Rev Ecol Biol Sol 13(3):419-436, 1976.

2510 Factors in the physical and biological environment affecting nodulation and nitrogen fixation by legumes.
Gibson, A.H. (CSIRO, Canberra, Australia).
Plant Soil (Special volume) p. 139-152, 1971.
Choice of biological material most suited to a particular environment, and utilization of management practices designed to minimize environmental stress, are the measures most likely to have a positive effect on the legume/Rhizobium symbiosis. A table of environmental variables and host plants is keyed to reference sources dealing with the particular circumstances. The reference list includes authors and sources, but not titles.

2511 Nodulation of soybean under field conditions.
Hamdi, Y.A. (Inst Soil & Water Res, Orman, Giza, Egypt), M.E. Abd-El-Samee and M. Lotfi.
Zentr Bak Par Infek .../ 2 Nat Abt 129(6):574-578, 1974.
Greatest nodulation of 'Clark' variety seeds in pots occurred when the inoculum had been applied at $28X10^6$ rhizobia. In the field, nodulation after 57 days was about 90% from inoculation at $28X10^6$/seed, but dropped to 47% at $28X10^6$. After 102 days, advantages of the heavier inoculation were still apparent.

2512 Nodulation and nitrogen fixation by *Lablab purpureus* under field conditions.
Norrigge, D.F. (Hort Res Stn, Marara, NSW, Australia) and R.J. Roughley.
Aust J Exp Agr Anim Husb 15(73):264-269, 1975.
Strain CB1024 established well at sites with low, medium and high competition by naturalized rhizobia. Yield responses to inoculation were not significant. Serotypic markers for typing nodules were used and shown to be as effective as serotyping.

2513 [illegible] of subclover in relation to nodulation, time of seeding, [illegible] conditions.
[illegible] Exp Sta, U Calif, [illegible], CA, USA), P.H. [illegible]
[illegible] 20(2):147-150, 1971.
The most rapid initial nodulation (2-5 days after inoculation) was observed at 68° F. Below 72° there was a marked increase in time to first visible nodule. At 48° F many plants took as long as 20 days to nodulate, or failed

to nodulate at all. Rhizobia survived on pelleted seed for a month on dry soil until rains came to promote germination, and this seed produced more vigorous clover than did seed drilled soon after rain.

2514 Studies in the nodulation of Kenya white clover (*Trifolium semipilosum*) under field conditions in south-east Queensland.
Jones, R.M. (CSIRO Div Trop Agron, St. Lucia, Qld., Australia) and R.A. Date.
Austral J Exp Agr Anim Husb 15:519-526, 1975.
The studies showed than an apparent establishment failure, which had been attributed to poor nodulation, was probably due to infection by Rugose Leaf Curl Virus. The inoculum strain CB 782 was found to be competetive, effective and persistent.

2515 The root nodulation of tall and dwarf peas and beans.
Masefield, G.B. (U Oxford, England).
Exp Agr 7(2):123-127, 1971.
The degree of root nodulation relative to tall and short cultivars of *Pisum sativum* and *Phaseolus vulgaris* was observed for 3 successive years. The dwarf pea cultivars produced more nodules with greater weight, but with beans the differences were not consistent. Short cultivars of peas may be more productive in N poor tropical and subtropical soils.

2516 Histology of the root nodules of *Melilotus albus* and *Trifolium alexandrinum*.
Naz, S.(U Karachi, Pakistan) and A. Mahmood.
Pak J Bot 8(1):95-101, 1976.
In these plants, the origin of nodules was exogenous. An intact endodermis between the vasicular strands is shown in one photomicrograph, and root cortex extending around the nodules is shown in two others. Degeneration, characterized by disintegration of host cell nuclei, proceeded from the nodule base upward.

2517 A correlated light and electron microscope study of symbiotic growth and differentiation in *Pisum sativum* root nodules.
Newcomb, W.
Can J Bot 54(17):2163- , 1976.

2518 Variation in growth and nodulation of *Glycine wightii* under controlled environment.
Nicholas, D.B.(CSIRO Cunningham Lab, St Lucia, Qld., Australia) and K.P. Haydock.
Austr J Agr Res 22:223-230, 1971.
Total nodule weight per plant was found to be a suitable character for selection in a breeding program to improve nodulation.

2519 Nodulation studies of a Caesalpenoid legume, *Cassia mimosoides*, Linn. occurring in Nandi hills.
Oblisami, G. (Tamil Nadu Agr U, Coimbatore, India).
Madras Agr J 60(5):343-344, 1973.
Nodulation of this species was first reported in 1970, occuring in the Nandi hills. Rhizobia isolated from those nodules were found to nodulate

a number of hosts in a manner to establish a close relationship to the cowpea group.

2520 Nodulation pattern in groundnut (*Arachis hypogaea* Linn.) as influenced by varying levels of plant density, nitrogen and phosphorus.
Pawar, K.R. (Marathwada Agr U, Parbhani, India) and V.S. Khuspe.
Curr Sci 45(3)
A density of 2 x 10^6 plants/ha produced significantly fewer and smaller nodules than 1.5 or 1 x 10^6 densities. N applications retarded nodulation during the plant growth phase, but this was not significant in earlier or later stages. P_2O_5 at 60 kg/ha increased the volume of nodules, particulatly under low population. Smaller doses of P were not effective.

2521 Negative correlation of nodulation and grain production of beans *(Phaseolus vulgaris)* in soils where nitrogen is not the limiting factor of plant growth. (Por)
Pessanha, G.G.(U Federal Rural do Rio de Janeiro, Brasil), A.A. Franco, J. Döbereiner, A. Groszmann, and D.P.P. de Souza Britto.
Pesqui Agropec Bras Ser Agron 7:49-56, 1972.
Inconclusive studies elucidating the complexity of the negative correlation between yield and nodulation in soil where N did not limit plant growth. Limited bean production was attributed to physiological disorders resulting from the *Rhizobium*-host association or from pathogens.

2522 Nodulation of kidney beans under natural conditions. (Por)
Pons, A.L., C.F.Goepfert, E.Kornelius and M.B.Altmayer.
Agron Sulriograndense 12(2):129-132, 1976.

2523 Effect of chlorflurenol, a morphactin, on root nodulation in *Pisum sativum*.
Ranga Rao, V. (U of Delhi, Delhi-7, India), K. Mukerji and N.S. Subba Rao.
Z Pflanzenphysiol 69(1):84-86, 1973.
Foliar spraying of this morphactin caused stunting and fragility of the plant at 100 and 1000 ppm. The numbers of lateral roots and nodules also decreased. A concentration of 10 ppm caused a slight increase in fresh weight of plants, but apparently inhibited nodulation by interfering with downward translocation of carbohydrates or IAA.

2524 The effect of soybean *(Glycine max)* variety and inoculants on the physiology of nodulation under field conditions. (Por)
Rios, C.P.(Inst de Pesquisas Agropec ... Uberaba, Minas Gerais, Brasil), and J. Döbereiner.
Pesqui Agropec Bras Ser Agron 7:123-127, 1972.
Significant differences between inoculant strains and soybean varieties as to total nodule weight and nodule number were found. The best inoculants continued to form nodules until 64 days after planting.

2525 Development of membrane systems in legume root nodules.
Robertson, J.G., M.P. Taylor, A.S. Craig and D.H. Hopcroft.
Bul R Soc N Z 12:31-36, 1974.

2526 Development of nodulation and symbiotic nitrogen fixation in soybean varieties *(Glycine max)* in different stages of development. (Por)
Ruschel, A.P. and H.W. Reuszer.
Pesqui Agropec Bras Ser Agron 8(8):251-256, 1973.

2527 Notes on the nodulation of some edible legumes of Indonesia.
Saono, S. (Natl Biol Inst, Bogor, Indonesia), H. Karsono and S. Abdulkadir.
Ann Bogor 6(1):27-37, 1975.
Of 13 species, all nodulated, but only a few of the nodules were pinkish white or pink. Isolation of the microsymbionts from the pinkish white and pink nodules of 10 species was carried out. About 56% of the isolates, or 87 strains, were "slow-growing" and the remainder were "fast growing".

2528 Nodulation of lucerne (*Medicago sativa* L.) under the influence of chlorides of magnesium and potassium.
Singh, C.S.(IARI, New Delhi, India), M. Lakshmi-Kumari, A. Biswas and N.S. Subba Rao.
Ind Acad Sci Proc Sec B Biol Sci 76(3):90-96, 1972.
The degree of salinity conducive to optimum nodulation was found to be definitely different from the limits of salt tolerance either of *Rhizobium* or the host. It was further noted that the host is more sensitive to KCl and $MgCl_2$ than the microsymbiont. It was hypothesized that the sensitivity of the infection thread to salt may be the cause of nodulation failure.

2529 Changes in the number, viability, and amino-acid-incorporating activity of *Rhizobium* bacteroids during lupin nodule development.
Sutton, W.D.(DSIR, Palmerston N., N.Z.), N.M. Jepsen and B.D. Shaw.
Plant Physiol 59(4):741-744, 1977.
Nodule weight increased 3-fold and the number of bacteroids per nodule more than 10-fold between days 10 and 21 after inoculation of seedlings. Bacteroid viability was highly sensitive to osmolarity. Two processes are suggested as contributing to bacteroid nonviability: a *reversible* change in the cell wall structure between days 10 and 14 after inoculation, and a subsequent *irreversible* change.

2530 Soybean nodulation as affected by wheel traffic.
Voorhees, W.B. (USDA, Morris, MN, USA), V.A. Carlson and C.G. Senst.
Agron J 68(6):976-979, 1976.
Rows with wheel traffic compaction on both sides had from 20 to 30% less total nodule mass than did rows with wheel traffic on only one side. Nontracted interrows had a greater percentage of nodule mass in the upper 30 cm. Control of wheel traffic offers a means of altering N fixation.

2531 Comparative nodulation, nitrogen fixation, and growth of *Glycine wightii* cv. Cooper and *Phaseolus atropurpureus* cv. Siratro seedlings.
Wilson, J.R. (Div Trop Pastures, Cunningham Lab, St. Lucia, Qld., Aust.)
Austral J Agr Res 23(1):1-8, 1972.
In early growth, *Glycine wightii* lagged behind siratro in both nodulation and N fixation. This slow initial nodule development in *Glycine wightii* is probably one of the factors hindering the field establishment of seedlings, although in subsequent growth the symbiosis appears fully effective.

NODULATION continued

[illegible] of nodule formation on growth and chemical composition of [illegible]
[illegible]
[illegible] 25(2):[illegible]-115, 1976.

[illegible] with information on Nodulation may be found under the [illegible] (Nodulation Problems and Nodules) and in relevant articles under:

[illegible] effects	Specificity and Promiscuity
[illegible] effectiveness, infectiveness	Soil Factors
[illegible]	Water factors

2. NODULATION PROBLEMS.

2668 Lucerne nodulation failures.
Blair, I.B.
Illinois Coll Farmers' Conf Proc 21st:58-66, 1971.

2669 Chamaecrista - a non-nodulating papilionaceous legume.
Dietloff, A. (DPI, Indooroopilly, Qld., Australia) and G. Dietloff.
Trop Agr (Trinidad) 54(2):143-147, 1977.
All attempts to nodulate *Chamaecrista longiflora* with diverse rhizobia and through complementary root treatments and top grafting were unsuccessful. A closely related species did nodulate in potted soil taken from the base of the non-nodulating species. *C. Lomiliqua* growing in nematode infested soil was not affected by root knot, indicating a possible value as trap hosts in nematode infested soils.

2670 Effect of rjirj$_1$ (non-nodulating) soybeans on near isogenic rjirj1 plants in nutrient culture.
Lukas, D.L. (U Wisconsin, Madison, WI, USA) and L.E. Schrader.
Can J Microbiol 23(8):888-893, 1977.
Results suggested that a nodulation inhibitor is not associated with the rj$_1$ gene. Nodulation was not stimulated in non-nod isolines by the presence of nodulating isolines, indicating that resistence to nodulation is not due to the absence of excreted nodulation promoters.

2671 Lucerne establishment studies on uncultivated country. II. A nodulation problem.
Jones, C.C. (Lincoln Coll, Canterbury, N. Z.) and J.G.H. White.
N Z J Agr Res 14(3):387-396, 1971.
A nematode antagonistic to *Rhizobium meliloti* in the soil beneath resident vegetation has apparently prevented good nodulation of overseum lucerne. There is a strong possibility that a toxin produced by *Dactylella* has been responsible for the difficulty in establishing overseum legumes.

2672 Studies on the causes of poor nodulation in groundnut in soils of [illegible]
[illegible] (Agr Col & Res Inst, Coimbatore, India), P.P. Ramamani and [illegible]
[illegible]

Madrus Agr J 58(1):5-8, 1971.
Counts of bacteria with better crop growth were significantly higher compared to less productive soils, though no such difference was observed in their capacity to evolve carbon dioxide. The good crops produced about 400% more nodules. One of the major soil factors determined was the inadequacy of available phosphate.

2606 Inhibition of nodulation of inoculated legumes by leaf leachates from pioneer plant species from abandoned fields.
Rice, E.L. (U Oklahoma, Norman, OK, USA).
Amer J Bot 58(4):368-371, 1971.
Nodule numbers of beans and clover were not significantly affected by leaf leachates of the 6 pioneer plants, but *Lespedeza stipulacea* was affected by 4 of the leachates from inhibitor species. Root exudates as well as very small amounts of decaying material of 3 forbs have been found to reduce nodulation. It appears likely that the inhibition of N fixation would retard succession by the legumes.

Additional references with information on Nodulation Problems may be found in relevant listings under:

Microorganisms (other than *Rhizobium*)	Roots & root exudates
Pesticides	Temperature and climate
Rhizobium inhibition	Soil factors

27. NODULES.

2701 Ultrastructure of soybean nodules. I. Release of rhizobia from the infection thread.
Bassett, B. (U Missouri, Columbia, MO, USA), R.N. Goodman and A. Novacky.
Can J Microbiol 23(5):573-582, 1977.
The infection process appeared identical in both effective and ineffective soybean nodules. Electron micrographs suggest that endocytosis of both the bacteria and the material composing the infection thread wall occurs during release of rhizobia into the host cell. In later stages of development, however, the ineffective nodules showed marked abnormalities in their ultrastructure.

2702 Ultrastructure of soybean nodules. II. Deterioration of the symbiosis in ineffective nodules.
Bassett, B. (U Mo., Columbia, MO, USA), R.N. Goodman and A. Novacky.
Can J Microbiol 23(7):873-883, 1977.
Infection by an ineffective strain of *Rhizobium japonicum* was followed closely by a deterioration of the symbiosis involving selective autolysis of host cell contents and degeneration of the intracellular bacteria. Only traces of the bacteria remained after 21 days, but most plant cells were still alive 55 days after inoculation. It is proposed that either changes in bacteroid cell walls cause incompatability with the host, or a nitrogen deficiency resulting from inability to fix N in the host environment lead to breakdown in the symbiosis.

2703 Root nodules and nitrogen fixation by legumes.
Bergersen, F.J.
Ann Rep Div Plant Ind CSIRO p. 30-43, 1973.

2704 Nodule formation and haemoglobin content in some species of Papilionaceae.
Iyer, N.R. (U de Oriente, Cumana, Venezuela).
Plant Soil 44:451-454, 1976.
Nodules and nodulation of 11 genera from the sub-family Papilionaceae were studied. The leghaemoglobin content of nodules of *Dolichos lablab* was highest, indicating the possibility of a greater potential for symbiotic activity.

2705 On the relationship among weight of nodules, their leghaemoglobin and bacteroid content, dry weight, and nitrogen content of soybean.
Jain, M.K. (IARI, New Delhi, India) and R.B. Rewari.
Zentralb Bak Paras ... 2 Nat Abt 130(8):732-737, 1975.
The relationships were studied at 6 and 8 weeks of growth. All factors showed positive and significant correlations in most varieties. The fresh weight of nodules did not bear a significant correlation to plant dry weight, indicating the probability that at that stage (6 weeks) the growth had been more dependent on soil nitrogen. After 6 weeks, the role of symbiotically fixed N becomes progressively more important.

2706 The fine structure of pea root nodules. 2. Senescence and disintegration of the bacteroid tissue.
Kijne, J.W. (Botanisch Laboratorium, Leiden, The Netherlands).
Physiol Plant Pathol 7(1):17-21, 1975.
At senescence, host cells and bacteroids simultaneously undergo ultrastructural changes. Incomplete knowledge about plant senescence limits the establishment of generally applicable criteria. Autolytic and heterophagic processes may be involved. More information on metabolic changes at senescence is needed.

2707 Studies on soybean nodule senescence.
Klucas, R.V. (U Nebraska, Lincoln, NB, USA).
Plant Physiol 54(4):612-616, 1974.
Loss of acetylene reduction was used as an indicator of nodule senescence. Nitrogenase activity decreased 60% between 58 and 65 days after planting 'Beeson' variety, and 68 to 75 days after planting 'Calland' soybeans. Enzyme activities of the bacteroids were studied, and changes described.

2708 Physiological and biochemical studies on senescing tap root nodules of soybeans.
Klucas, R.V. (U Nebraska, Lincoln, NB, USA) and D. Arp.
Can J Microbiol 23(10):1426-1432, 1977.
Changes in various physiological and biochemical activities were compared with changes in nitrogen- fixing capacity. Nodule number remained constant, but fresh weight, dry weight and mass of tap root nodules increased between 56 and 86 days. Nitrogenase activity was maximal at about 56 days, but metabolic activity as measured by carbon dioxide evolution did not appear to vary among nodules at different ages. A significant and consistent decline in pH values was correlated with N-fixation decline.

2709 Sterols of roots and nitrogen fixing root nodules of *Vicia faba*.
Knights, B.A. (U Glascow, Scotland), W.M. McKinley and C.T. Wheeler.
Phytochem 16(6):727-728, 1977.
Sterols of roots and nodules were mainly of the same 3 types, but in different proportions. Only insignificant amounts of sterol were detected in nodule bacteroid fractions or free living *Rhizobium leguminosarum*.

2710 Ultrastructure of root nodules formed by ineffective strains of *Rhizobium meliloti*.
MacKenzie, C.R. (U Sussex, England) and D.C. Jordan.
Can J Microbiol 20(5):755-758, 1974.
Infection of host cells by ineffective rhizobia was observed, with normal nodule development followed by a rapid disintegration of the invading bacteria. In a naturally occurring association, dissolution occurred at a slightly later stage.

2711 Surface features of soybean root nodules.
Pankhurst, C.E. (U Dundee, Scotland) and J.I. Sprent.
Protoplasma 85:85-98, 1975.
Ridges on the surface of functioning soybean root nodules were identified as lenticels that permit the free movement of gasses into and out of the nodule. In water stressed nodules the lenticel tissue collapses. In waterlogged conditions, the lenticel tissues produce large masses of loosely packed cells. Some highly detailed scanning electron micrographs are included with this article.

2712 The structure and development of *Trifolium subterraneum* L. root nodules. I. In subterranean clover plants grown at optimal root temperatures.
Roughley, R.J. (Rothamsted Exp Stn, Harpenden, Herts., England), P.J. Dart and J.M. Day.
J Exp Bot 27(98):431-440, 1976.
An examination by light microscopy of rhizobia during release into host cells, enlargement into bacteroid form, and later degeneration. The structure of effective nodules is described under a favorable temperature of 19° C. Includes numerous photomicrographs.

2713 The structure and development of *Trifolium subterraneum* L. root nodules. II. In subterranean clover plants grown at sub-optimal root temperatures.
Roughley, R.J. (Rothamsted Exp Stn, Harpenden, Herts., England), P.J. Dart and J.M. Day.
J Exp Bot 27(98):441-450, 1976.
The events of infection, nodulation, nitrogen fixation and degeneration were all slowed by sub-optimal root temperatures The deposition of starch throughout the nodule was favored by the low temperature.

2714 Relationship between number and specific volume of nodules in different species of *Phaseolus* and in *Glycine max*.
Sen, R. and P.N. Bhaduri.
Ind Agr 15:175-183, 1971.

2715 Contents of cobalamine and pantothenic acid in nodules of legumes as criteria of the activity of nodule bacteria. (Rus)
Shemakhanova, K.M. and O.D. Sidorenko.
In Novoe V Izuchenii Biologicheskoi Fiksatii Azota p. 86-90, 1971.

2716 Some observations on the bacteroids in nodules of *Arachis* spp. and the isolation of rhizobia from these nodules.
Staphorst, J.L. and B.W. Strijdom.
Phytophylactica (S Africa) 4(3):87-91, 1972.

2717 Content, composition, and the role of corrynoids in nodules of leguminous plants.
Troitskaya, G.N.
Sov Plant Physiol 23(6):1086-1093, 1976.

2718 Rhizobial root nodules of soybean as revealed by scanning and transmission electron microscopy.
Tu, J.C. (Electron Microscope Lab, U Alberta, Edmonton, Ata., Canada).
Phytopathol 65(4):447-454, 1975.
In the early stage, each bacteroid was enclosed in a membrane envelope; in the intermediate stage of nodulation, several bacteroids were enclosed in a single envelope; in the advanced stage, the membrane envelope was lacking, and the host cellular membrane had deteriorated. All stages were present simultaneously in all nodules observed. It was suggested that the efficiency of a root nodule in N fixation is related to the total surface area of envelope membranes, and that bacteroids in the advanced stage might lack N-fixing ability. Infection threads were repeatedly observed in the bacteroidal cells in the intermediate stage.

2719 Structural organization of the rhizobial root nodule of alfalfa.
Tu, J.C.
Can J Bot 55(1):35-43, 1977.

2720 Distribution and weight of nodules in tropical pasture legumes in the field.
Whiteman, P.C. (CSIRO Cunningham Lab, St. Lucia, Qld., Australia).
Exp Agr 7(1):75-85, 1971.
Two core sampling methods were compared with total root excavation to assess how truly core samples reveal changes taking place of the whole root system. In the second growing season, estimation of total nodule weight per plant in the field is not predictable, and root excavation is required.

28. OXYGEN.

2801 Effect of oxygen on the assay of nitrogenase activity of bacteroid suspension of *Rhizobium*. (Chi)
Anonymous.
Acta Microbiol Sinica 16(2):131-135, 1976.

2802 Nitrogenase activity and respiration of cultures of *Rhizobium* spp. with special reference to concentration of dissolved oxygen.
Bergersen, F.J. (CSIRO, Canberra, Australia), G.L. Turner, A.H. Gibson and W.F. Dudman.
Biochim Biophys Acta 444:164-174, 1976.
Nitrogenase activity appeared in cultures only when the dissolved O_2 concentration approached 1 μM. The absence of succinate from the medium caused a rise in O_2 concentration, with loss of nitrogenase activity. Upon restoration of succinate, the O_2 concentration fell immediately and nitrogenase activity was restored. NH_4^+ was also repressive.

2803 The role of O_2-limitation in control of nitrogenase in continuous cultures of *Rhizobium* sp.
Bergersen, F.J. (CSIRO, Canberra, Australia) and G.L. Turner.
Biochem Biophys Res Commun 73(2):524-531, 1976.
In cultures supplied with excess ammonium or glutamine, relative adenylylation of glutamine synthetase increased and nitrogenase activity was repressed when O_2 limitation was relieved. With higher ammonium concentration, more stringent O_2 limitation was required for high nitrogenase activity.

2804 Relevance of oxygen ligands to reduction of ligating dinitrogen.
Chatt, J., A.J. Pearman and R.L. Richards.
Nature 259:204, 1976.

2805 Adaptation of nitrogen fixation by intact soybean nodules to altered rhizosphere pO_2.
Criswell, J.G. (du Pont & Co, Wilmington, DE, USA), U.D. Havelka, B. Quebedeaux and R.W.F. Hardy.
Plant Physiol 58(85):622-625, 1976.
Continuous exposure to a pO_2 of 0.06 atmospheres initially reduced nitrogenase activity by 37 to 45%, with restoration to original activity in 4 to 24 hours and no further changes up to 95 hours. Continuous exposure to 0.02 atmosphere of O_2 initially reduced activity 72%, with only partial recovery by 95 hours. Exposure to a pO_2 of 0.32 atmospheres had little effect. At 0.89, activity was initially reduced by 98%, with restoration to only 14 to 24% of ambient controls after 95 hours. A time period was required for readaptation to ambient. The internal adaptive mechanism is undefined.

2806 Effect of rhizosphere pO_2 on nitrogen fixation by excised and intact nodulated soybean roots.
Criswell, J.G. (du Pont & Co., Wilmington, DE, USA), U.D. Havelka, B. Quebedeaux and R.W.F. Hardy.
Crop Sci 17(1):39-44, 1977.
Because of the oxygen sensitivity of nitrogenase, the internal pO_2 in the nodule must be maintained at a low level. Thirty minute exposures to pO_2's of 0.26 to 0.41 atm stimulated activity in excised roots but not in intact plants. Short exposures to 0.05 atm reduced fixation more in excised roots than by intact plants. It was concluded that measurement of stress effects should be made in intact plants.

2807 Oxygen requirement for acetylene reduction by pure cultures of rhizobia.
Bishop, P.E. and R.H. Evans.
J Bac 127(1):149-153, 1976.
The optimal oxygen concentration for rhizobia in liquid culture was found to be about 0.1% in the gas phase, lower than that of any other aerobic nitrogen-fixing microorganism. Succinate was the most effective metabolizable carbon source with some strains, but gluconate was better with some others. NH_4Cl was a satisfactory N source, and had no inhibitory effect even at concentrations of 30 mM.

2808 Oxygen inhibition of acetylene reduction (nitrogen fixation) in soil: effect of glucose and oxygen concentration.
O'Toole, P. and R. Knowles.
Soil Biol Biochem 5(6):783-788, 1973.

2809 Effect of altered pO_2 in the aerial part of soybean on symbiotic N_2 fixation.
Quebedeaux, B. (du Pont & Co, Wilmington, DE, USA), U.D. Havelka, K.L. Livak and R.W.F. Hardy.
Plant Physiol 56:76[illegible]-754, 1975.
Nitrogen fixation was increased by CO_2/O_2 ratios greater than ambient. Effects of altered pO_2 were consistent with the hypothesis that the amount of photosynthate available to the nodule may be the most significant primary limiting factor in N_2 fixation, while sink activity of the reproductive structures may be a secondary factor.

2810 Effect of the oxygen regime on the cultivation of *Rhizobium leguminosarum* on synthetic medium. (Rus)
Kuznov, V.I., A.V. Korolev and N.N. Gogolev.
Prikl Biokhim Mikrobiol 9(5):680-685, 1973.

2811 Nitrogen fixation in cultured cowpea rhizobia: inhibition and regulation of nitrogenase activity.
Bancroft, M.R. (CSIRO, Canberra, Australia), A.H. Gibson and J.D. Dugan.
Biochem Biophys Res Commun 73(2):516-523, 1976.
Ammonium inhibition was relieved by increased O_2 tension. Evidence indicated that the inhibition did not occur through repression of nitrogenase synthesis. In the absence of ammonium, nitrogenase activity was inhibited by oxygen.

2812 Effects of ozone on soybean nodules.
Thomas, D.T. (Natl Ecol Res Lab, Corvallis, OR, USA) and U. Blum.
J Environ Qual 2(3):341-342, 1973.
Three week old soybean plants exposed to 75 ppbm ozone had consistently reduced nodule number, nodule weight, leghemoglobin content, and root growth.

2813 Nitrogenase activity by *Klebsiella* and *Rhizobium* on solid substrata exposed to air.
Hilscheman, J. (Universität Hamburg, Germany) and D. Werner.

OXYGEN *continued*

A similarity of oxygen sensitivity between liquid cultures of *Rhizobium* and *Klebsiella* prompted investigations regarding similar resemblances on agar surfaces exposed to the air. The role of repressing sources of combined nitrogen and inhibition from acid production, and of the protective role of cell mass and slime production are discussed.

29. PELLETING.

2901 Effects of lime and lime pelleted seed on legume establishment and growth in South Brazil.
Elkins, D.M. (So Illinois U, Carbondale, IL, USA), F. J. Olsen and E. Gower.
Exp Agr 12:201-206, 1976.
Lime pelleting often improved establishment and yield of soy and desmodium at low pH (4.8-4.9). Application of 6 t/ha lime improved establishment and herbage yields.

2902 Effect of time and rate of application of lime, inoculation, and lime pelleting on clover establishment.
Lowther, W.L.
N Z J Exp Agr 2(2):145-149, 1974.

2903 Inoculation and pelleting of legume seed.
Bartholomew, P.E.
Farming S Afr 47(4):28-31, 1971.

2904 Seed pelleting in relation to nodulation and nitrogen fixation by *Phaseolus aureus* L. in a saline alkali soil.
Chhonkar, P.K. (IARI, New Delhi, India), V. Iswaran and K.S. Jauhri.
Plant Soil 35(2):449-452, 1971.
Growth, nodulation and nitrogen fixation were significantly increased by pelleting with lime and gypsum together with *Rhizobium* inoculation.

2905 Pelleting tropical legume seed.
Diatloff, A. (CSIRO, Queensland, Australia).
Qld Agr J, July, 1971, reprinted as Advis Leaflet 1121, 5 p.
General information on the need for pelleting, materials, methods, and a guide to inoculum and pelleting requirements for particular tropical pasture legumes.

2906 The effects of the interactions between seed inoculation, pelleting and fertilizer on growth and nodulation of *Desmodium* and *Glycine* on two soils in S. E. Queensland.
Diatloff, A. (Qld Dept Primary Indus, Indooroopilly, Australia) and P. E. Luck.
Trop Grassl 6(1):33-38, 1972.
Both genera required inoculation for satisfactory nodulation. Major growth and nodulation responses were to P. Lime application generally benefited *Glycine* more than *Desmodium*, but lime pelleting had little effect on either. Under Mn toxicity conditions, pelleting failed to lessen uptake or symptoms, although lime broadcast was efficaceous. The results indicate a higher lime requirement for nodulation and growth than is provided by pelleting.

PELLETING *continued*

2907 Seed pelleting of a legume to supply molybdenum.
Graham, P.H. (CIAT, Cali, Colombia), V.M. Morales and O. Zambrano.
Turrialba 24(3):335-336, 1974.
The soils of the Colombian Llanos are extremely acid, and probably limiting in Mo, but fertilizers supplying the element are not available. Treating seeds with Mo can result in toxicity to rhizobia. When seeds were pelleted with finely ground rock phosphate to which molybdic oxide or ammonium molybdate was added, little evidence of toxicity was noted.

2908 Produce more pulses by pelleting.
Iswaran, V. (IARI, New Delhi, India), K.S. Jauhri, P.K. Chhonkar and N.S. Subba Rao.
Ind Farming 22(1):12, 28, 1972.
Explanation of pelleting with data on the benefits to encourage its wider use.

2909 Calcium humate effect on nodulation and dry matter by soybean in a saline alkali soil.
Iswaran, V. (IARI, New Delhi, India) and P.K. Chhonkar.
Agrochimica 17:249-251, 1973.
Pelleting with calcium humate significantly increased nodulation and dry matter accumulation. Uninoculated plants produced an average of 3.13 nodules; plain inoculated, 38.45 and inoculated plus Ca-humate pelleted, 60.22 nodules per plant.

2910 New developments in seed pelleting and seed coating, with special reference to rangeland improvement.
Johnson, I.J. (Cal/West Seeds, Woodland, CA. USA).
Outlook on Agr 8(5):281-283, 1975.
Pelleting (without inoculation) and seed coating (with inoculation) were found to be of limited value in successful stand establishment.

2911 Clover response to inoculation and pelleting on Te Anau soils.
Lowther, W.L. and I.R. McDonald.
N Z Grassl Assoc Proc 34th:122-128, 1973.

2912 Inoculation and pelleting of clover for oversowing.
Lowther, W.L. and I.R. McDonald.
N Z J Exp Agr 1(2):175-179, 1973.

2913 Interaction of lime and seed pelleting on the nodulation and growth of white clover. I. Glasshouse trials.
Lowther, W.L. (Invermay Agr Res Ctr, Mosgiel, NZ).
N Z J Agr Res 17(3):317-323, 1974.
On low pH soils (4.7-5.0) the addition of lime markedly increased the growth of clover. The same effect was produced by pelleting the seed. On one soil where nodulation was investigated, this also was increased by lime or pelleting. Lime or Gafsa-phosphate + dolomite worked equally well for pelleting.

2914 Interaction of lime and seed pelleting on the nodulation and growth of white clover. II. Oversown trials.
Lowther, W.L.
N Z J Agr Res 18(4):357-360, 1975.

2915 Pelleting and fertilizer effects on nodulation of *Glycine wightii*.
Luck, P.E., P.T. Mears and J.S. Pulsford.
Trop Grassl 5(2):81-87, 1971.

2916 Seed pelleting to improve nodulation of tropical and sub-tropical legumes. 1. An examination of the validity of "grow-out" nodulation tests in tubes.
Norris, D.O. (Cunningham Lab, St. Lucia, Qld., Australia).
Austr J Exp Agr Anim Husb 11(49):194-201, 1971.
The assumption that lime pelleting is good for all legumes is unjustified in the case of hosts posessing the slow-growing cowpea type rhizobia. In some cases, lime may be harmful. "Grow-out" tests provide a preliminary guide to toxic material, but actual survival of rhizobia on stored seed combined with pot or field studies of nodulation are essential for a full evaluation of effects on bacgeria and host.

2917 Seed pelleting to improve nodulation of tropical and sub-tropical legumes. 2. The variable response to lime and rock phosphate pelleting of eight legumes in the field.
Norris, D.O. (Cunningham Lab, St. Lucia, Qld., Australia).
Aust J Exp Agr Anim Husb 11(50):282-289, 1971.
Lime pelleting improved nodulation over simple inoculation in only 8 of 16 legume-*Rhizobium* combinations, had no effect on 6 combinations, and depressed nodulation in 2. Phosphate pelleting gave a specific stimulation of nodulation in 4 combinations, with no harmful effects on any combinations. Storage of inoculated seeds was not a factor, as all plantings were made within 24 hours after treatment.

2918 Seed pelleting to improve nodulation of tropical and sub-tropical legumes. 3. A field evaluation of inoculant survival under lime and rock phosphate pellet on *Dolichos lablab*.
Norris, D.O. (Cunningham Lab, St. Lucia, Qld., Australia).
Aust J Exp Agr Anim Husb 11(53):677-683, 1971.
Use of rock phosphate resulted in more plants, a higher rate of nodulation, and better survival of the inoculant. In some cases, lime depressed nodulation. Pelleting offered no advantage over simple peat and adhesive.

2919 Seed pelleting to improve nodulation of tropical and sub-tropical legumes. 4. The effects of various mineral dusts on nodulation of *Desmodium uncinatum*.
Norris, D.O. (Cunningham Lab, St. Lucia, Qld., Australia).
Aust J Exp Agr Anim Husb 12(55):152-158, 1972.
The materials used for pelleting included some 20 types of rock phosphate, talc, kieselghur, kaolin, bentonite, mica, barytes, bauxite, alumina and aluminum dust. Nine materials had a nodulation index near or better than that of sticker inoculation. Rock phosphate, a kieselghur and bauxite were most promising. Where methyl cellulose is available as a sticker, it has advantages over gum arabic.

2920 Seed pelleting to improve nodulation of tropical and sub-tropical legumes. 5. The contrasting response to lime pelleting of two *Rhizobium* strains on *Leucaena leucocephala*.
Norris, D.O. (Cunningham Lab, St. Lucia, Qld., Australia).
Aust J Exp Agr Anim Husb 13(60):98-101, 1973.
[illegible] established on acid soils, the study shows that CB181, a wide-host pelleter (or a similar strain) should be used and that lime pelleting is important for stylosanthes. The faster growing, acid producing NGB4 formed nodules only when the seed was pelleted with lime.

2921 Seed pelleting to improve nodulation of tropical and sub-tropical legumes. 6. The effects of dilute sticker and of bauxite pelleting on nodulation of six legumes.
Norris, D.O. (Cunningham Lab, St. Lucia, Qld., Australia).
Aust J Exp Agr Anim Husb 13(65):700-704, 1973.
Bauxite was confirmed as a satisfactory pelleting material for tropical legumes. In field tests on a soil of pH 5.3, equally good nodulation was obtained using rock phosphate, bauxite, and only 1% methyl cellulose to apply the peat inoculum. The bauxite is softer and much more easily prepared than Florida rock phosphate, the standard pelleting material. Where pelleting is not required, dilute sticker is satisfactory.

2922 Use of pelleted seed in crop and pasture establishment.
Plucknett, D.L. (Kauai Res Ctr, Hawaii, USA).
U Hawaii Coop Extn Serv Cir 446, 1971.
An illustrated booklet explaining advantages and methods of pelleting. Tables give information on probable lime response of rhizobia specific to various legume species, longevity of rhizobia in pelleted seed, and recommended pelleting materials.

2923 Effect of lime, inoculant, and molybdenum pelleting of seed on growth and nitrogen content of crownvetch.
Sims, J.L. (U Kentucky, Lexington, KY, USA), R.E. Sigafus and K. Tiaranan.
Agron J 66(3):446-449, 1974.
Inoculated crownvetch benefited from Mo treatment, but a protective coating of lime must be applied first when pelleting seeds with sodium molybdate.

2924 Effect of pelleting as seed treatment on the nodulation and growth of *Pueraria phaseoloides*.
Tan, K.H.
In Seed technology in the tropics; Natl Seed Symp 1st:85-90, 1977.

2925 Inoculum rate and pelleting of arrowleaf clover seed.
Mode, R.H. (Auburn U, Auburn, AL, USA), C.S. Hoveland and A.E. Hiltbold.
Agron J 64(4):481-483, 1972.
Pelleting with gum, doubling the normal rate of inoculum, or soil fumigation increased yields and improved both nodulation and seedling growth. Seed pelleting added no benefit in fumigated soil.

30. PESTICIDES.

3001 Effect of soil application of Chloroxuron, Metobromuron and Fluometuron on nodulation, growth and nitrogen fixation by *Centrosema pubescens* and *Vigna sinensis*.
Amakiri, M.A. and C.T.I. Odu.
Pesticide Sci 9(1):51- , 1978.

3002 Compatability of certain seed dressing chemicals with *Rhizobium*.
Balaraman, K. and N.N. Prasad.
Cur Sci 41(9):344, 1972.

3003 Lindane increases nodulation and yield in soyabean plants.
Balasubramanian, A. (U Agr Sci, Bangalore, India), M.V. Shantaram, V.S. Emmimath and R. Siddaramappa.
Pesticides 8(1):35, 1974.
Lindane active ingredient was applied at 1, 5 and 10 X recommended level, and seeds were inoculated with *Rhizobium*. Increased levels of lindane application enhanced the number and size of nodules, dry matter, seed yield and nitrogen uptake.

3004 Effects of the herbicides Trifluralin and Carbetamide on nodulation and growth of legume seedlings.
Brock, J.L. (DSIR, Palmerston N., N. Z.).
Weed Res 12(2):150-154, 1972.
Nodulation and growth of all legumes was reduced when pre-sowing incorporated applications of trifluralin (1.0 and 2.0 kg/ha) and carbetamide (o.5 and 2.0 kg/ha). This is attributed to plant growth rather than effects on rhizobial populations because root dry weight/plant and nodules/plant were positively correlated. No bacteriological studies as such were performed in these experiments.

3005 Effects of Thiuram, Lindane, Aldrin, Phosphamidon, Parathion, and Heptachlor on *Rhizobium meliloti*. (Spa)
Camugli, E.N., O.E. Etchart Gomez and L. Tirao Canaviri.
Rev Fac Agron Univ Nac Plata 49(2):155-163, 1973.

3006 Compatibility of *Rhizobium japonicum* with chemical seed protectants.
Curley, R.L. and J.C. Burton.
Agron J 67(6):807-808, 1975.
Thiram had no adverse effect; Carboxin had little effect, when seeds were planted within 4 hours of inoculation. PCNB reduced *Rhizobium* survival on seed and decreased taproot nodulation. Captan was less toxic to rhizobia than PCNB, but also reduced taproot nodulation.

3007 Effect of seed dressing fungicides on nodulation and yield of groundnut crop inoculated with *Rhizobium* strain.
Dalela G.G. and P.C. Lodha.
Phytopathol Mediterr 15:127-128, 1976.

3008 The effect of Ethrel on nodulation in *Pisum sativum*.
Drennan, D.S.H. (Reading U, England) and C. Norton.
Plant Soil 36(1):53-57, 1972.

Ethanol at 2 ppm and above severely inhibited nodulation when applied to the roots. Foliar application of 10 ppm also depressed nodulation.

3009 Herbicidal pollution--nodule development in the herbicide treated soils.
Dubey, P.S.
Geobios (Jodhpur) 1(6):178-179, 1974.

3010 Herbicidal effects on the nodulation of *Glycine max* (L.) Merrill.
Dunigan, E.P. (Louisiana St U, Baton Rouge, LA, USA), J.P. Frey, L.D. Allen and A. McMahon.
Agron J 64(6):806-808, 1972.
Different rates of several of the herbicides had detrimental effects on the nodulation process in 4 of the 5 soils used in greenhouse studies. Dry weight of nodules was more readily affected than was total number of nodules. A 3 year field study did not reveal any detrimental effects from any of the herbicides used.

3011 Effects of some fungicides on *Rhizobium trifolii* and its symbiotic relationship with white clover.
Fisher, D.J. (U Bristol, England).
Pesticide Sci 7:10-18, 1976.
Symbiotic nitrogen fixation was affected by thiram. oxycarboxin and "Ethylan CP" but was unchanged by benomyl, captan, carbendazim, carboxin, dodine, dimethrimol, ethimirol, tridemorph, trifone or thiophenate-methyl.

3012 The effect of 2, 4, 5-trichlorophenoxyacetic acid on two nitrogen fixing bacteria.
Foldesy, R.G., L. Mineo and S.K. Majumdar.
Penn Acad Sci Proc 46:23-24, 1972.

3013 Effect of some soil insecticides on germination, dry weight and nodulation in *Trifolium alexandrinum* Jeslen.
Gawaad, A.A.A. (High Inst Cotton, Alexandria, Egypt), F.H. El-Gayar and A.A. Khadr.
Ind J Agr Sci 42(11):969-974, 1972.
Kepone, endrin, gusalthion, PP 211 and dyfonate at normal rates had no harmful effect on berseem. Some of the tested insecticides enhanced growth and nodulation.

3014 Effect of some soil insecticides on broad beans and Egyptian clover nodule forming bacteria.
Gawaad, A.A.A., A.M. El-Minshawy and M. Zeid.
Entomol Soc Egypt Bul Econ Ser 5:55-59, 1971.

3015 Studies on soil insecticides. VIII. Effect of some soil insecticides on broadbeans and Egyptian clover nodule forming bacteria.
Gawaad, A.A.A. (Alexandria U, Egypt), A.M. El-Minshawy and M. Zeid.
Zentralb Bak Parasit ... 2 Nat 127(2):172-177, 1972.
When used at normal rates, chlorinated hydrocarbon insecticides did not influence the nodulation by *Rhizobium phaseoli* or *R. trifolii*. The phosphorous insecticides had a positive effect on the size and number of nodules.

3016 On the effects of some pesticides on *Rhizobium* and isolation of pesticide-resistant mutants.
Gillberg, B.O. (Royal Agr Col Sweden, Ultuna, Uppsala, Sweden).
Arch Mikrobiol 75(3):203-208, 1971.
Strains of *Rhizobium meliloti* generally tolerated higher doses of the 2 herbicides and 2 fungicides studied than did strains of *R. trifolii* or *R. leguminosarum*. Mutants were isolated that tolerated much higher doses of the pesticides than the wild type strains.

3017 Influence of herbicides on symbiotic nitrogen fixation in leguminous plants. (Pol)
Hauke-Pacewiczowa, T.
Inst Uprawy Nawozenia Glebozn Pamiet Pulawski 46:191-200, 1971.

3018 Interaction of selected pesticides and *Rhizobium japonicum* in pure culture and under field conditions.
Kapusta, G. (Plant Ind Res Stn, S Illinois U, Carbondale, IL, USA) and D.L. Rouwenhorst.
Agron J 65(1):112-115, 1973.
Of 24 pesticides screened for bacteriostatic activity, only chlorpropham and disulfoton inhibited growth. Naturalized soil populations of *Rhizobium japonicum* remained unaltered 4 weeks after pesticide application.

3019 Effect of fungicides on the survival percentage of rhizobia.
Khatri, A.A. (Amar Hill Fld Res Stn, Bombay, India) and M. Choksey.
Sci Cult 39(6):282-284, 1973.
Ceresan, a water soluble fungicide, is very toxic and is capable of killing all 6 species of rhizobia tested when concentrations reach 50 ppm. Diathane, which forms water suspension, is less toxic, tolerated even up to 3000 ppm by some species, and stimulating Bengal gram *Rhizobium* at 1000 ppm.

3020 Symbiotic interrelationships of legumes with nodule bacteria in relation to pesticide application. (Rus)
Kruglov, I.V.V. and L.N. Paromenskaia.
Vses Akad Sel'skohoz Nauk V I Lenina Dokl 11:8-10, 1972.

3021 Effect of four soil-applied insecticides on symbiosis of *Rhizobium* sp. with *Arachis hypodaea* Linn.
Kulkarni, J.H. (U Agr Sci, Bangalore, India), J.S. Sardeshpande and D.J. Bagyaraj.
Plant Soil 40(1):169-172, 1974.
Carbofuran, thimet, dasanite and heptachlor had no harmful effect on nodulation or yield when applied at recommended rate.

3022 Effects of weed control and N fertilization at establishment on the growth and nodulation of alfalfa.
Kunelius, H.T. (Res Stn, Charlottetown, Prince Edward Island, Canada).
Agron J 66(6):806-809, 1974.
Interactions between N rate and method of weed control were not significant. Treatments of 2,4-DB + dalapon injured alfalfa and significantly lowered the dry matter yield at the first cutting.

PESTICIDES *continued*

3023 Effects of simazine and molybdenum on the yield, protein content and nodulation of soybeand (*Glycine max* (L.) Merril) and of simazine on the yield and protein content of kidney beans (*Phaseolus vulgaris* L.). (Por)
Lam-Sanchez, A. and M. Amad.
Cientifica 4(1):56-58, 1976.

3024 *In vitro* inhibitory effect of some fungicides on *Rhizobium* spp. and *Azotobacter chroococcum*.
Lahri, L.K. (U P Inst Agr Sci, Kanpur, UP, India) and S.N. Prasad.
J Ind Soc Soil Sci 24(2):214-216, 1976.
Dithane -M45 and -Z78, Flit 406, Ceresan (wet) and Aratan all inhibited the growth of rhizobia at normal dosage levels. The inhibition was significant in all except Dithane -M45, and was greatest with Aratan. Adequate care is required to protect rhizobia from direct contact with seed dressant chemicals. Pelleting of treated seeds may be useful.

3025 Influence of herbicides on the development of nodule bacteria on the roots of soybeans.
Lesniac, O.
Proc Eur Weed Control Conf 3:1101-1108, 1974.

3026 Effect of tryptophane on symbiosis between cluster clover and *Rhizobium trifolii*.
Magu, S.P. (IARI, New Delhi, India) and N.S. Subba Rao.
Cur Sci 40(15):416-417, 1971.
Incorporation of tryptophane in different amounts in the culture medium of inoculated seeds could hasten or delay nodulation, depending on the concentration. Large doses (1 - 2 mg/tube) were inhibitory to both nodulation and plant growth.

3027 The influence of some insecticides on *Rhizobium meliloti*. (Spa)
Mendoza, C.
Soc Ital Biol Sperim Bol 70:163-172, 1972.

3028 Effect of three granular insecticides on the growth of *Rhizobium* of redgram.
Oblisami, G. (Tamil Nadu U, Coimbatore, India), K. Balaraman, C.V. Venkataraman and G. Rangaswami.
Madras Agr J 60(7):462-464, 1973.
Endrin, disulfoton and carbofuran at 1 x, 5 x, 10 x, 50 x and 100 x normal dose were added to known quantities of yeast extract manitol culture medium. Endrin inhibited rhizobial growth most severely, followed by carbofuran and disulfoton. The results indicated that pelleting should be done with a greater number of bacterial cells to compensate the effect of insecticides.

3029 Resistance of *Rhizobium* strains to Phygon, Spergon and Thiram.
Odeyemi, O. (Cornell U, Ithaca, NY, USA) and M. Alexander.
Appl & Environ Microbiol 33:784-790, 1977.
Acclimated or mutant strains of rhizobia normally sensitive to the cides

fungicides without destroying the toxicity of the agents to fungi are being sought.

3030 Effect of seed dressing fungicides and antibiotic aureofungin on soybean inoculated with *Rhizobium japonicum*.
Ostwal, K.P. (IARI, New Delhi, India) and A.C. Gaur.
Hindustan Antibiot Bul 13:73-74, 1971.
Bean yield was increased by all tested fungicides and antibiotic aureofungins. No adverse effects on nodulation were noted.

3031 Effect of agricultural chemicals and non-edible cake on symbiotic nitrogen fixation in gram and pea.
Patil, P.L. (Col Agr, Poona, India), A.R. Kalekar, M.V. Ekhote.
M.V.M. Patrika. 9:35-40, 1974.
Higher doses of lindane and *karanjkake* applied to the soil reduced the number of nodules, dry weight and yield of gram in pot experiments. Ceresan did not have harmful effects except at 100 X normal dose, and improved pea yields when used as a seed dressing.

3032 Effect of paraquat on the nitrogen-fixing activity of white clover.
Polston, M.P. (Massey U, Palmerston N., N. Z.), A.C.P. Chu and I.R.P. Fillery.
N Z J Agr Res 19:47-49, 1975.
Nitrogen-fixing activity was markedly decreased within 24 hours after spraying of plants with paraquat. No recovery occurred after 16 days. The decrease in nodule activity probably results from decreased supply of photosynthetic assimilates.

3033 Insecticides and soil microorganisms. I. Effect of dipterex on the growth of *Rhizobium leguminosarum* and *Rhizobium trifolii* as influenced by temperature, pH and type of nitrogen.
Salama, A.M., I.Y. Mostafa and Y.A. El-Zawahry.
Acta Biol Acad Sci Hungaricae 24:25-30, 1973.

3034 Insecticides and soil microorganisms. II. Effect of dipterex on nodule formation in broad bean and clover plants under different manurial treatments.
Salama, A.M. (Cairo U, Egypt), I.Y. Mostafa and Y.A. El-Zawahry.
Acta Biol Acad Sci Hungaricae 25(4):239-246, 1974.
Dipterex at 10^{-3} mol/ml significantly depressed nodulation of broadbeans, but was stimulatory at 5 X 10^{-4}, and moreso at 10^{-4}. Nodulation of clover clover was depressed by dipterex at all concentrations.

3035 Insecticides and soil microorganisms. III. Fate of ^{14}C labelled dipterex as affected by two nodule forming *Rhizobium* spp. and roots of their respective leguminous host plants.
Salama, A.M. (Cairo U, Egypt), I.Y. Mostafa and Y.A. El-Zawahry.
Acta Biol Acad Sci Hungaricae 26:1-7, 1975.
Enzymatic degradation of dipterex produced metabolites identified as monoethyl- and dimethyl-phosphates in root tissues of broad bean as well as cultures of rhizobia. Some of the liberated methanol groups may also be oxidatively degraded by the rhizobia.

PESTICIDES *continued*

3036 Effect of insecticides on the physiological activity of effective and ineffective strains of *Rhizobium trifolii*. (Hun)
Salem, S.H.
Agrokem Talajtan 20(3):368-376, 1971.

3037 Influence of some insecticides on the symbiosis of rhizobia and legume plants. (Hun)
Salem, S.H., J. Szegi and F. Gulyas.
Agrokem Talajtan 20(4):581-589, 1971.

3038 Effect of antifungal agents on *in vitro* growth of rhizobia & on the formation of root nodules in excised root cultures of *Phaseolus mungo*.
Siddiqui, K.A.I.(Burdwan U, India), A.K. Banerjee and S. Ganguli.
Ind J Exp Biol 13(6):588-590, 1975.
Of seven antifungal agents tested, aureofungin, brassicol, dithane Z-78, captan and hexaferb were not inhibitory except at very high concentrations. Fytolan and argosan proved highly toxic to cultures and also caused complete inhibition of nodulation in excised root cultures.

3039 Effects of bentazon and dinoseb on soil microorganisms and on the *Rhizobium*-Leguminosae symbiosis.
Tortensson, L. (Uppsala U, Sweden).
Swed J Agr Res 5:177-183, 1975.
Dinoseb was toxic to rhizobia at doses higher than normal field applications, and had an unfavorable effect on *Rhizobium trifolii* at 10 ppm. Bentazon had no effect except at very high doses. MCPA had an effect at much lower doses than either dinoseb or bentazon.

3040 Effects of herbicides, a nematacide and *Rhizobium* inoculant on yield, chemical composition and nodulation of 'Starr' peanuts.
Walker, M.E. (Coastal Plain Exp Stn, Tifton, GA, USA), N.A. Minton and C.C. Dowler.
Peanut Sci 3(1):49-51, 1976.
The application of vernolate, benefin, or DBCP had no significant effect on yield or nodulation. Inoculation was also without effect.

3041 Compatibility of different fungicides with *Rhizobium japonicum*.
Wankhede, V.K. (Ahmednagar Col, Maharashtra, India) and V.P. Bhide.
Hindustan Antibiot Bul 14(3):131-136, 1972.
Dithane Z-78, Aureofungin and Ceresan allowed the rhizobia to produce a good number of nodules, although fewer than when the fungicides were absent. Nodulation was greatly reduced by Monosan. while Thiram completely checked nodulation. The combination of *R. japonicum* inoculation with Dithane Z-78 produced the best results.

3042 Effect of chemical seed dressings on quantitative development of nodule bacteria in soybean. (Pol)
Woynarowska, S.
Warsaw Inst Rodowli Aklim Nasl Biul 5:45-49, 1971.

3043 Effects of protective and systematic fungicides and molybdenum on emergence, grain yield and symbiotic nitrogen fixation in soybeans (*Glycine max* (L.) Merrill). (Por)
Zambolim, L., C.S. Sediyama, A.C. Ribeiro and G.M. Chaves.
Rev Ceres 22(124):440-448, 1975.

31. PHAGES AND PLANT VIRUSES.

3101 Reversible inhibition of a *Rhizobium* bacteriophage by host debris.
Barnet, Y.M. (U New South Wales, Kensington, NSW, Australia) and J.M. Vincent.
J Gen Virol 12(3):313-315, 1971.
Fragments of cell wall carrying phage receptor sites are probably responsible for inhibition which caused random fluctuations of plaque counts. Before unusual features in phage preparations are regarded as a feature of the phage itself, the inhibition status of the suspension should be known.

3102 Bacteriophages of *Rhizobium trifolii*. I. Morphology and host range.
Barnet, Y.M. (U New South Wales, Kensington, NSW, Australia).
J Gen Virol 15(1):1-15, 1972.
Eleven distinct morphological groups distinguished by head size and tail characteristics showed correspondingly similar plaque characteristics and host ranges.

3103 Isolation of bacteriophages of nodule bacteria in the lucerne and cotton rhizosphere and their characteristics. (Rus)
Boiko, L.A.
Izv Akad Nauk Mold SSR Ser Biol Khim Nauk 6:60-65, 1976.

3104 Rhizobiophage in Indian soil.
Foo, E.L. (IARI, New Delhi, India), A.K. Varma, N. Prakash and N.S. Subba Rao.
Cur Sci 42(22):797-798, 1973.
Rhizobiophage from *Cicer* plants in black cotton soils of Coimbatore were detected and characterized, using electron microscopy. Red loamy soils collected from the same area did not reveal the presence of phages.

3105 Relationship between strains of *Rhizobium japonicum* and their bacteriophages from soil and nodules of field-grown soybeans.
Kowalski, M. (Iowa Agr & Home Ec Stn, Ames, IA, USA), G.E. Ham, L.R. Frederick and I.C. Anderson.
Soil Sci 118(3):221-228, 1974.
Among 51 phages isolated from nodules and rhizosphere soil of 7 serogroups of *R. japonicum*, 45 lysed only rhizobial strains from the same group as that from which the phage was isolated. However, up to 50% of the rhizobial strains and serogroups were not sensitive to the phage isolated, indicating that more exact identification of strains may be possible by the use of phage types.

3106 Virulent bacteriophage infection of *Rhizobium leguminosarum*.
Ley, A.N. (U Minnesota, St. Paul, MN, USA), H.R. Warner and P.L. Kahn.
Can J Microbiol 18(4):375-384, 1972.
Incorporation studies indicate that phage infection markedly inhibits net RNA synthesis, suggesting that ribosomal and transfer RNA synthesis either ceases or is reduced to very low levels. This may result from a general turn-off of host functions. Phage infection has a slight stimulatory effect on DNA synthesis.

3107 Some biological properties of phages of *Rhizobium meliloti* (of alfalfa).
Marants, L.A. (Inst Microbiol, USSR), L.N. Moskalenko and Ya. I. Rautenshtein.
Microbiol 42(6):967-973, 1973.
Six phages isolated from soil and 11 from lysogenic cultures of *R. meliloti* were distributed into 4 groups according to morphology of plaques. Double stranded DNA of the GC type was detected in 3 phages which differed sharply in morphology of particles. Data on environmental sensitivity are given. The phages investigated were concluded to be a heterogeneous group.

3108 Morphology and host range of virulent phages of lotus rhizobia.
Patel, J.J. (DSIR, Palmerston N., N.Z.).
Can J Microbiol 22(2):204-212, 1976.
Most of the phage isolates were of 2 morphological types showing specificity for either the fast- or slow-growing rhizobia. The phages were characterized by host range, morphology and ecological distribution.

3109 A phage-like bacteriocin of *Rhizobium trifolii*.
Schwinghamer, E.A. (CSIRO, Canberra, Australia), C.E. Pankhurst and P.R. Whitfeld.
Can J Microbiol 19(3):359-368, 1973.
Certain characteristics plus the inability to reproduce in sensitive bacteria identified the bactericidal agent as a large bacteriocin of the defective phage type.

3110 Studies on the nodulation and nitrogen fixation by infected leguminous plants. I. Effect of arhar mosaic virus infection on nitrogen value, nodulation and nitrogen fixation by some pulse crops.
Singh, R. (Gorakhpur U, Gorakhpur UP, India) and T.P. Mall.
Plant Soil 41:279-286, 1974.
The two virus strains tested had negative effects on most values for urd, mung and cowpea, but some plant nitrogen values were increased, particularly in urd. Total N added to the soil was decreased by viral infection in all cases.

3111 Typing of *Rhizobium trifolii* mutants by means of phages.
Staniewski, R., I. Jurzyk and Z. Lorkiewicz.
Acta Microbiol Pol, Ser A Microbiol Gen 5(1):21-25, 1973.

3112 Typing of *Rhizobium meliloti* mutants by means of phages.
Staniewski, R. and W. Kowalska.
Acta Microbiol Pol, Ser A Microbiol Gen 6(2):183-186, 1974.

3113 Frequency of infection and efficiency of transfection of *Rhizobium meliloti* cells and spheroblasts.
Staniewski, R. (Maria Curie-Sklodowska U, Lublin, Poland) and A. Rugala.
Acta Microbiol Pol, Ser A Microbiol Gen 8(24):151-160, 1975.
Transfection, as determined by the uptake of phage DNA, was found to occur in *Rhizobium*, but at a low efficiency.

3114 Virus infectivity of alfalfa mosaic virus in soybean as influenced by nodulation.
Tu, J.C. (U Alberta, Edmonton, Alta., Canada) and S.Y. Tse.
Phytopath Z 85:170-175, 1976.
Healthy plants were more responsive to rhizobial inoculation than AMV-infected plants. A positive correlation between root nodule production and AMV infectivity was also established. It was suggested that increased nitrogen fixation may contribute to increased virus infectivity.

3115 Lipopolysaccharides as receptor for *Rhizobium* phage ^{1} P.
Zajac, E. (Maria Curie-Sklodowska U, Lublin, Poland), R. Russa and Z. Lorkiewicz.
J Gen Microbiol 90:305-307, 1975.
Cell walls and their LPS preparations were studied to elucidate the phage attachment site. It was suggested that heptoses might form part of the phage receptor.

3116 Studies of phage ^{1} P receptors in *Rhizobium trifolii* and *Rhizobium leguminosarum*.
Zajac, E. (Maria Curie-Sklodowska U, Lublin, Poland), R. Russa and Z. Lorkiewicz.
Acta Microbiol Pol, Ser A Microbiol Gen 7(4):181-188, 1975.
Ability of a bacteriophage to attach to a bacterial phage receptor determines the susceptibility to infection. This study investigated phage inactivating cosntituencies of the bacterial cell wall and conditions conducive to phage adsorption.

32. PHOTOSYNTHESIS AND PHOTOSYNTHATES.

3201 Ontogenetic interactions between photosynthesis and symbiotic nitrogen fixation in legumes.
Bethlenfalvay, G.J.(U California, Davis, CA, USA) and D.A. Phillips.
Plant Physiol 60(3):419-421, 1977.
Data from *Pisum sativum* and *Phaseolus vulgaris* collected at different stages of development were related to symbiotic N fixation in the nodules. A decrease in H_2 evolution preceded the peak in acetylene reduction, and was accompanied by an increase in relative efficiency of N_2 fixation from a value of 0.4 to a value of 0.7.

3202 Interactions between symbiotic nitrogen fixation, combined-N application, and photosynthesis in *Pisum sativum*.
Bethlenfalvay, G.J. (U California, Davis, CA, USA) and D.A. Phillips.
Physiol Plant 42:119-123, 1978.

Plants were grown under controlled conditions at three photosynthetic photon flux density (PPFD) values ranging from severly limiting to near saturation. Carboxylation efficiencies and CO_2 exchange rates were highest in N_2 fixing plants and lowest in plants supplied with NH_4^+, generally increasing with increasing PPFD. Percentage N in the plants decreased with increasing PPFD in plants treated with combined N, but increased in plants dependent on symbiotic N fixation. The data reveal that photosynthetic efficiency and the capacity to fix N_2 in peas are functions of PPFD and the availability of combined N, and that these two factors are interrelated.

3203 Indoleacetic acid effect on the distribution of photosynthetically fixed carbon on the bean plant.
Bidwell, R.G.S. (U Guelph, Ontario, Canada) and E.C.K. Quong.
Biochem Physiol Pflanz 168:361-370, 1975.

Using $^{14}CO_2$ and radioassay, the distribution of photoassimilated ^{14}C throughout the plant as affected by IAA applications was studied. Translocation of photosynthates and the rate of photosynthesis were affected.

3204 Photosynthesis of lupine leaves according to the effectiveness of plant symbiosis with nitrogen-fixing bacteria. (Rus)
Chernida'ev, I.I. and N.G. Doman.
Izv Akad Nauk SSSR, Ser Biol 1:134-138, 1974.

3205 Dependence of symbiotic nitrogen fixation in forage broadbeans on the provision of roots with carbohydrates. (Rus)
Gukova, M.M. and E.K. Lavrova.
Dokl Timiriazevsk S-Kh Akad 213:31-35, 1975.

3206 Symbiotic nitrogen fixation in soybeans. I. Effect of photosynthetic source-sink manipulations.
Lawn, R.J. (CSIRO, Brisbane, Australia) and W.A. Brun.
Crop Sci 14(1):11-16, 1974.

Supplemental light and depodding, designed to enhance the source/sink ratio, maintained nodule activity well above that of the control, in which symbiotic N fixation declined during the podfilling stage. The results were interpreted as evidence that the N fixation declined as the result of inadequate assimilate supply to the nodules.

3207 Symbiotic nitrogen fixation in soybeans. II. Interrelationship between carbon and nitrogen assimilation.
Lawn, R.J. (CSIRO, Brisbane, Australia), K.S. Fischer and W.A. Brun.
Crop Sci 14(1):17-22, 1974.

Using seedlings of 8 soybean genotypes in pots, reciprocal intervarietal grafts were made in all root-shoot combinations possible. The plants were then inoculated and watered with a low-N nutrient solution. At 28, 38, 50 and 58 days after grafting, combinations were sampled for leaf area, shoot and root dry weight, and number, fresh weight and activity of nodules. Root genotype effects independent of the shoot genotype occurred for all root traits measured except nodule fresh weight. No overall root effects occurred for any of the shoot traits.

3208 The supply of photosynthetic assimilates to nodules of *Pisum sativum* L. in relation to the fixation of nitrogen.
Lawrie, A.C. (U Glasgow, Scotland) and C.T. Wheeler.
New Phytol 72(6):1341-1348, 1973.
Both the rate of acetylene reduction and the accumulation of labeled photosynthates were reduced when plants were darkened, but when plants were fed $^{14}CO_2$ prior to darkening, photosynthates continued to accumulate in the nodules as nitrogenase activity declined. The main sites of accumulated photosynthates in active nodules apparently do not correspond with the sites of most active reduction.

3209 Nitrogen fixation in the root nodules of *Vicia faba* L. in relation to the assimilation of carbon. I. Plant growth and metabolism of photosynthetic assimilates.
Lawrie, A.C. (U of Glasgow, Scotland) and C.T.Wheeler.
New Phytol 74(3):429-436, 1975.
Isotopic studies revealed that photosynthates are rapidly metabolized after arrival in the nodules (within 30 minutes of feeding the shoot $^{14}CO_2$). The importance of glutamate, glutamine and aspartate as early products of the metabolism of fixed N was confirmed by the distribution of radioactivity.

3210 Nitrogen fixation in the root nodules of *Vicia faba* L. in relation to the assimilation of carbon. II. The dark fixation of carbon dioxide.
Lawrie, A.C. (U of Glasgow, Scotland) and C.T. Wheeler.
New Phytol 74(3):437-445, 1975.
Tracer studies showed that the amino acid fraction sequestered most of the radioactive carbon, and that none was associated with glucose or fructose, the main free sugars in ethanolic extracts of the nodules. Important roles for glutamate, aspartate and asparagine in the metabolism of the fixed carbon were supported by the labelling pattern. Relatively little radioactivity was associated with glutamine. Most of the ^{14}C in the acidic fraction was in malic and itaconic acids, the latter not detected until 30 minutes after detachment of the nodules.

3211 Photosynthate and nitrogen requirements for seed production by various crops.
Sinclair, T.R. (Agr U, Wagningen, The Netherlands) and C.T. DeWit.
Science 189:565-567, 1975.
Pulses and soybeans were classified as "potentially self destructive" because sustained seed growth demands continued N translocation from vegetative tissues. If the available N is insufficient, rapid translocation may lead to senescence of the plant and a shortened period for seed development.

3212 The relationships between nitrogen fixation and photosynthesis.
Stanier, R.Y. (Inst Pasteur, Paris, France).
Aust J Exp Biol Med Sci 52(1):3-20, 1974.
A technical review based on the third Rubbo oration delivered at the annual meeting of the Australian Society for Microbiology, Sydney, 1972.

See also relevant listings under Carbon and Carbon Compounds for additional information on this subject.

33. POLYCROP SYSTEMS.

3301 Preliminary investigations of the influence of some leguminous crops used as green manure on the field of hop. (Pol)
Derbec, S.
Ann U Maria Curie Sklodowska, Sec E Agr 30:39-44, 1976.

3302 Soybean in multiple and inter-cropping.
Chatterjee, B.N. (U Kalyani, W Bengal, India) and M.A. Roquib.
Ind J Genet & Plant Br 35(2):264-268, 1975.
In a comparison of pure and mixed cultures of maize, rice, soybeans and pigeon peas grown in various combinations, the advantages of soybean/maize intercropping were most apparent.

3303 Effects of intercropping maize with pigeon peas on grain yield and nutrient uptake.
Dalal, R.C. (U West Indies, St. Augustine, Trinidad).
Exp Agr 10:219-224, 1974.
The grain yield of maize was significantly reduced by intercropping either in a mixed stand or alternate rows, but the total protein production per hectare and total nutrient uptake were increased.

3304 Forage legume inoculation and grass-legume association studies.
Gopala Gowda, H.S. (Reg Res Stn, UAS, Mudigere, India) and R.B. Patil.
Mysore J Agr Sci 10(2):225-233, 1976.
Dharwar hybrid-2 grass in association with inoculated and uninoculated *Oxiopogonium mucunoides*, *Centrosema pubescens*, *Glycine javanica* and *Lablab purpureus* was studied over a 2 year period. Grass production was significantly higher in the mixtures, yielding best with inoculated legumes. Associations with *C. mucunoides* and *L. purpureus* were superior.

3306 Plant and nodule development and nitrogen fixation in climbing cultivars of *Phaseolus vulgaris* L. grown in monoculture or associated with *Zea mays* L.
Graham, P.H. and J.C. Rosas.
J Agr Sci 90(2):311- , 1978.

3307 Selection for mixed cropping.
Hamblin, J. (U Cambridge, England), J.G. Rowell and R. Redden.
Euphytica 25:97-106, 1976.
Experimental designs permitting two species to be selected simultaneously for mixed cropping are proposed. Apparently optimal combinations can then be tested to determine whether real advantages over monocrop culture in terms of total yield per land unit and input actually exist.

3308 Effects of previous crop on yield and nitrogen response of maize at Samaru, Nigeria.
Jones, M.J. (Inst for Agr Res, Samaru, Nigeria).
Exp Agr 10:273-279, 1974.
Soil analysis showed that groundnuts, but not cowpeas, increased nitrogen availability in the topsoil.

3309 Grass/legume pastures in Western Kenya. II. Legume performance at Kitale, Kisii, and Kakamega.
Keya, N.C.O.
E Afr Agr Fores J 39:247-257, 1974.

3310 Studies on mixed cultivation of tropical legumes and grasses. I. Legume effects in terms of the increased dry matter and nitrogen yield in mixed stands of *Desmodium intortum* and *Setaria* [*sphacelata*].(Jpn)
Kitamura, Y. (Kyushu U, Japan), S. Nishimura and S. Tanaka.
Nippon Sochi Gakkai Shi 21(3):199-206, 1975.
The mixed stands outyielded either pure legume or grass stands in dry matter, offering an advantage of 86 to 130 kg/10a. Nitrogen yield was enhanced by clipping at 50 cm as compared to 70 cm.

3311 Studies on mixed cultivation of tropical legumes and grasses. II. Effects of light intensity, inoculation and nitrogen application on early growth of dysmodium *(Desmodium intortum)*. (Jpn)
Kitamura, Y. (Kyushu U, Japan) and S. Nishimura.
J Japn Soc Grassl Sci 22(2):116-120, 1976.
Nitrogen applications increased dry matter under both full and 30% light. Inoculation had a similar, though delayed, effect. Combined inoculation and N application increased nodulation more than inoculation alone under full light, but not under shaded conditions.

3312 Studies on mixed cultivation of tropical legume[s] and grass[es]. III. Effects of temperature, inoculation and nitrogen application on the early growth of desmodium (*Desmodium intortum* cv. Greenleaf). (Jpn)
Kitamura, Y. (Kyushu U, Japan), S. Nishimura and S. Tanaka.
J Japn Soc Grassl Sci 22(2):121-124, 1976.
Under temperature conditions of 15, 20, 25 and 30° C, inoculation had an effect at only 25°, but nitrogen application effects were found at all temperatures. The highest dry matter yield was found at 25° in all combinations of inoculation and N application.

3313 Production of six tropical legumes each in combination with three tropical grasses in Florida.
Kretschmer, A.E., Jr. (ARS, Ft. Pierce, FL, USA), J.B. Brolmann, G.H. Snyder and G.J. Gascho.
Agron J 65:890-892, 1973.
The best forage crude protein yield came from a mixture of *Desmodium intortum* and Pangola grass.

3314 Effect of legumes on associated and subsequent crops.
Misra, A. (Orissa U Agr Tech, Bhubaneswar, Orissa, India) and H.C.Misra.
Ind J Genet & Plant Br 35(2):329-341, 1975.
Mung grown in rotation with cereal crops benefitted the latter, but not when grown as a companion crop.

3315 The relative performance of forage legumes as rotational crops in the Gezira [Sudan].
Musa, M.M. and H.O. Burhan.
Exp Agr 10:131-140, 1974.

3316 Leguminous plants in tropical pastures.
Morris, D.O. (CSIRO Div Trop Past, St. Lucia, Qld., Australia).
Trop Grassl 6(3):159-170, 1972.
Factors outlined as important for success with tropical pasture legumes are: a) an effective symbiosis; b) satisfactory plant nutrition, important to both symbionts, and c) satisfactory grazing management to produce nitrogen turnover. Particular emphasis was placed on P nutrition. The importance of rhizobial research was discussed.

3317 Legumes for forage.
Palmertree, M.D. (Mississippi St U, MS, USA).
Miss St Univ Ext, 15 lvs., 1974.
An outline of the advantages gained by mixing clovers with grass for forage plantings. Includes 10 tables on yields and management procedures for clover establishment.

3318 Nodulation in soybean (*Glycine max* (L.) Merr.) grown as a pure and mixed crop.
Reddy, M.N. (U Kalyani, W. Bengal, India) and B.N. Chatterjee.
Ind J Agron 18(4):410-415, 1973.
Nodulation was better at low levels of N, but was reduced by shading effects of tall companion plants.

3319 Possibility of growing soybean (*Glycine max* (L.) Merr.) in association with other crops.
Roquib, A. (U Kalyani, W. Bengal, India), A.L. Kundu and B.N. Chatterjee.
Ind J Agr Sci 43(8):792-794, 1973.
Better monetary return per unit area and more total yield of calories and grains were obtained when soybean was grown mixed with maize or rice or pigeon pea.

3320 Multiple cropping with short duration pulses.
Saxena, M.C. (G.B. Pant U Agr & Tech, Pantnagar, India) and D.S. Yadav.
Ind J Genet & Plant Br 35(2):194-208, 1975.
Advances in the development of short-duration varieties of pulses have made it possible to practice multiple cropping both in series and in parallel. Several plant combinations in verious multiple cropping methods (double and triple) are evaluated.

3321 Undersowing rice *(Oryza sativa)* with *Stylosanthes guyanensis*. I. Plant density.
Shelton, H.M. and L.R. Humphreys.
Exp Agr 11:89-95, 1975.

3322 Undersowing rice *(Oryza sativa)* with *Stylosanthes guyanensis*. II. Delayed sowing time and crop variety.
Shelton, H.M. and L.R. Humphreys.
Exp Agr 11:97-101, 1975.

3323 Undersowing rice *(Oryza sativa)* with *Stylosanthes guyanensis*. III. Nitrogen supply.
Exp Agr 11:103-111, 1975.

3324 Utilizing legumes in the nitrogen economy of the soil.
Singh, A. (Ind Council Agr Res, New Delhi, India).
Ind Farming 23(11):5-7, 9, 1974.
Sequential planting and intercropping with legumes can overcome some of the effects of fertilizer shortages or high costs. The chemical composition of the leaves of 29 wild leguminous plants and trees was determined, and their greater utilization urged.

3325 Inter-cropping of short duration grain legumes in sown pastures and field crops.
Singh, R.P. (Central Arid Zone Res Inst, Jodhpur, India) and M.V.R. Prasad.
Ind J Genet & Plant Br 35(2):271-275, 1975.
The introduction of short duration pulse crops in rotation and as intercrops has been encouraged by the short supply of high cost nitrogenous fertilizers. The breeding of superior legumes and the evolution of suitable polycrop systems was encouraged.

3326 The contribution of legumes to continuously productive agricultural systems for the tropics and sub-tropics.
Sprague, H.B. (AID Consultant, Washington, DC, USA).
USAID Tech Ser Bul 12, 42 p., 1975.
A concise, general guide to the utilization of legumes in tropical and sub-tropical agricultural systems. Includes sections on advantages of, and general practices in, growing legumes, including food grain legumes, green manure crops, legume-grass forage mixtures in rotation with other crops, and brief descriptions of the various legumes and grasses with information on their utilization.

3327 Performance of corn, peanut, mungbean and soybean in monoculture and intercrop combinations of corn and legumes in dry season 1973.
Syarifuddin, A. (Natl Biol Inst, Bogor, Indonesia), S. Effendy, I.G. Ismail and J. McIntosh.
Contrib Ctr Res Inst Agr Bogor (Indonesia) no. 12, 13 p., 1974.
Yields of legumes decreased when intercropped with corn and with increasing populations of corn. Yields of different corn varieties increased from 3 to 6 times. Peanuts gave the highest net return/ha due to high yield and market price, but the highest overall return was for Harapan corn intercropped with peanuts.

3328 Competition and population dynamics in legume-grass swards with *Stylosanthes hamata* (L.) Taub (sens. lat.) and *Stylosanthes humilis* (H.B.K.)
Torssell, W.R. (CSIRO, Canberra City, Australia), J.R. Ive and R.B. Cunningham.
Aust J Agr Res 27:71-83, 1976.
S. hamata competed much better with *Digitaria ciliaris* and yielded significantly more than *S. humilis* in pure stands. A simulation suggested that stability of legume pastures can be maintained against *Digitaria* by using *S. hamata*, whereas Townsville stylo would be less dominant.

Additional references with information on Polycrop Systems may be found in relevant listings under Nitrogen Cycle.

34. Rhizobium CHARACTERISTICS & PHYSIOLOGY.

Note: Articles dealing specifically with Rhizobium japonicum or Rhizobium trifolii are listed under the respective species heading.

3401 Characterization of soluble and structural proteins of *Rhizobium* [illegible] and bacteroids from soybean nodules.
Agarwal, A.K. (PGI, Van Nagar, India) and S.L. Mehta.
Can J Microbiol 22(2):170-173, 1976.
The soluble proteins of the bacteroids were found to differ markedly from those of Rhizobium cells. There were also differences between species of rhizobia and their respective bacteroids, suggesting a role in specificity.

3402 Characterization of ribosomal RNA proteins from *Rhizobium* cells, bacteroids & *Phaseolus aureus* roots.
Agarwal, A.K. and S.L. Mehta.
Can J Microbiol 22(3):287-288, 1976.

3403 Extracellular polysaccharides of *Rhizobium* strains associated with lotus species.
Bailey, R.W. (DSIR, Palmerston N., N.Z.) R.M. Greenwood and A. Craig.
J Gen Microbiol 65(3):315-324, 1971.
In an examination of monosaccharide composition of extracellular polysaccharides isolated from 101 strains of rhizobia principally associated with the lotus group of legumes, differences appeared to be correlated with the division into acid- and non-acid-producing classes of rhizobia.

3404 Vitamins A in strains of active and less active nodule bacteria of pisum. (Russ)
Bagishvili, T.S.K.
Akad Nauk Gruz SSR Soobshch 66(1):193-195, 1972.

3405 Cytofluorometrical determination of the DNA contents of bacteroids and corresponding broth-cultured *Rhizobium* bacteria.
Bisseling, T. (Agr U, Wageningen, The Netherlands), R.C. Van Den Bos, H. Van Der Ploeg, P. Van Kalje and A. Huisers.
J. Gen Microbiol 101(1):79-84, 1977.
In almost all species, the bacteroids appeared to contain more DNA than the corresponding bacteria. Bacteroid size is influenced by the host plant, and this was correlated to DNA content. It was suggested that the DNA/protein ratio may remain relatively constant in bacteria and bacteroids of *Rhizobium leguminosarum*.

3406 Rhizobia in tropical legumes. I. Some characteristics of Malaysian rhizobia.
Bonghan, W.J. (U Malaya, Kuala Lumpur, Malaysia), P.Y. Chan, S. Subramaniam and K.P. Tan.
Malays Agr Res 4(2):141-153, 1975.
Number of rhizobial isolates from 19 species of legumes were repeatedly [illegible] in sterile water and placed on sterile filter paper in petri dishes. [illegible] an uninoculated plug of pink [illegible] cultures were prepared. The isolates were characterized as to antibiotic resistance, temperature and pH tolerance. [illegible] range of characteristics was disclosed within the "cowpea miscellany" rhizobia.

3407 The wall of *Rhizobium leguminosarum* in bacteroid and free-living forms.
Brussel, A.A.N. Van (Botanical Labs, Leiden, The Netherlands), K. Planque and A. Quispel.
J Gen Microbiol 101(1):51-56, 1977.
Bacteroid walls had less lipopolysaccharide, a difference which may be relevant to the greater permeability of the outer membrane of bacteroids. This may have some importance in symbiotic interactions.

3408 Nodulation and symbiotic nitrogen fixation.
Burton, J.C. (The Nitragin C., Milwaukee, WI, USA).
Amer Soc Agron, no. 15 Ser Agron:229-246, 1972.
Rhizobia synthesize biotin, pantothenic acid and vitamin B_{12}. *Rhizobium meliloti* produces far greater amounts of this cobalt-containing vitamin B_{12} than do other species of *Rhizobium*. Strains of the alfalfa rhizobia are also the most sensitive to acidity, growing very poorly at a pH of 5.0 or below. The need for developing and using proper strains adapted to the specific environment is pointed out. Reference list includes 102 citations.

3409 Isolation of bacteria, transforming bacteria, and bacteroids from soybean nodules.
Ching, T.M. (Oregon St U, Corvallis, OR, USA), S. Hedtke and W. Newcomb.
Plant Physiol 60(5):771-774, 1977.
Mature bacteroids, transforming bacteria and bacteria were separated using a stepwise sucrose gradient centrifugation. These fractions could be used for studies involving development, regulation and senescence of bacteroids in the nodule.

3410 Inhibition of protein synthesis by D-threo-chloramphenicol in the laboratory and nodule forms of *Rhizobium lupini*.
Coventry, D.R. (U Western Australia, Nedlands, WA, Australia) and M.J Dilworth.
J Gen Microbiol 90(1):69-75, 1975.
A difference in membrane permeability between the bacteria and bacteroid forms was proposed, based on comparative intracellular concentrations of chloramphenicol.

3411 A study of physiological and biochemical characteristics of 63 strains isolated from root nodules of legumes. (Fre)
Delattre, J.M. (Inst Pasteur de Lille, France) and A. Deleplanque.
Inst Pasteur Lille Ann 22:215-230, 1971.
The study resulted in classification into 2 groups: 30 strains with very variable features which do not produce bacteroids in artificial conditions, and 35 strains which are aerobic, motile, do not absorb Congo red and exhibit other common characteristics. All but 1 of the latter group produced bacteroids under artificial conditions.

3412 Ecological studies of root-nodule bacteria introduced into field environments. 6. Antigenic and symbiotic stability in *Lotonomis* rhizobia over a 12 year period.

Bottiger, A. (DPI, Indooroopilly, Qld., Australia)
Soil Biol Biochem 9(2):85-88, 1977.
Stability of colony colour, effectiveness, cell antigens and antibiotic sensitivity for 2 introduced strains of rhizobia suited to *Lotonis bainesii* was studied after 5 - 12 years of occupancy in a pasture. 8.5% of the isolates had a lower N-fixing capacity than stock cultures, but all were effective. All characters except antibiotic sensitivity were sufficiently stable to be of use in long-term ecological studies.

3413 Response of *Rhizobium* spp. and pea seedlings to glycine.
Egeraat, A.W.S.M. Van (Agr U, Wageningen, The Netherlands)
Plant Soil 45(1):191-199, 1976.
Rhizobium trifolii strain Coryn, was completely inhibited by a glycine concentration of 10 µg/ml, whereas *R. leguminosarum* at the same concentration was found only in "bacteroid like" forms. Introducing amino acids into the cotyledons of pea and maize altered the amino acid composition of the seedlings.

3414 Protoplasts from legume root nodules.
Hoong, H.C. (U Malaya, Malaysia) and W.J. Broughton.
In Proc Nat'l Plant Tissue Culture Symp, p. 42-50, 1975.
A loss of 75% of original nodular acetylene reducing activity occurred on slicing and immersing *Vigna sinensis* nodule material in the maceration medium. The loss for *Centrosema pubescens* nodule material was 95%. Nitrogenase activity was similarly affected when whole nodules were immersed in the maceration medium. The nature of nodule protoplasts may present particular problems in obtaining metabolically active protoplasts.

3415 Absence of mannose in the extracellular polysaccharide of fast-growing rhizobia.
Humphrey, B. (U New South Wales, Australia), M. Edgley and J.M. Vincent.
J Gen Microbiol 81:267-270, 1974.
The possibility that mannose reported in earlier studies originated in the medium rather than the rhizobia was investigated. Highly sensitive methods of analysis revealed yeast mannan in the culture medium to be the possible source.

3416 Metabolism of certain aromatic compounds by rhizobia.
Hussein, Y.A. (Agr Res Ctr, Giza, Egypt), M.S. Tewfik and Y.A. Hamdi.
Egypt J Bot 18:91-99, 1976.
Strains of different species of rhizobia were tested for their ability to degrade certain phenolic compounds. The 4 compounds were all degraded to varying degrees from the initial concentrations in the presence of sodium glutamate. The metabolic pathways were investigated and discussed.

3417 Root-nodule bacteria of tropical legumes.
Ishizuka, S.
J Agr Res Qrtly 6(4):199-211, 1972.

3418 Demonstration of an octasaccharide repeating unit in the extracellular polysaccharide of *Rhizobium meliloti* by sequential degradation.

Jansson, P-E. (U Stockholm, Sweden), L. Kenne, B. Lindberg, H. Junggren, J. Lonngren, U. Ruden and S. Svensson.
J Amer Chem Soc 99(11):3812-3815, 1977.
After removal of a substituent, 4 sugar residues were removed sequentially. It was concluded that the polysaccharide is composed of octasaccharide repeating units with the structure 25. This is the largest repeating unit that has been demonstrated from a bacterial polysaccharide.

3419 Monomethyl sugars in extracellular polysaccharides from slow-growing rhizobia.
Kennedy, L.D. (DSIR, Palmerston N., N. Z.) and R.W. Bailey.
Carbohyd Res 49:451-454, 1976.
The levels of mannose present in slow-growing cultures are much higher than for fast-growing rhizobia. It appears very unlikely that yeast contamination was the source of the mannose, as has been suggested in the case of fast-growing cultures.

3420 The possibility of the effect of symbiosis on the DNA of nodule bacteria. (Ukr)
Krikunets, V.M. and M.M. Nichik.
Mikrobiol Zh 37(6):760-761, 1975.

3421 Study of exopolysaccharide of nitrogen-fixing tubercular bacteria. (Rus)
Linevich, L.L., S. Kh. Lobzhanidze and B.N. Stepanenko.
Dokl Akad Nauk SSSR 226(5):1214-1216, 1976.

3422 Study of lipopolysaccharide of nitrogen-fixing nodule bacteria of *Rhizobium lupini* in the symbiotic form with lupine. (Rus)
Linevich, L.L., A.V. Bolobova and B.N. Stepanenko.
Dokl Akad Nauk SSSR 231(6):1482-1485, 1976.

3423 6-Phospho-D-Gluconate:NAD+2-oxidoreductase (decarboxylating) from slow-growing rhizobia.
Martinez-Drets, G. (Inst de Investig Biol Clemente Estable, Montivideo, Uruguay), A. Gardiol and A. Arias.
J Bac 130(3):1139-1143, 1977.
NAD + -6PGD activity was detected in cell-free extracts from 8 strains of slow-growing rhizobia, and no activity of NADP+-6PGD was found in the same extracts. NADP+-6PGD was found in all fast-growing strains, while NAD+-6PGD was absent in 2 of 10 fast-growing strains.

3424 Tryptophan and indole-3-acetic acid metabolism by *Rhizobium meliloti*.
Mino, Y., N. Riuda and T. Harada.
Nippon Sochi Gakkai Shi 21(2):86-90, 1975.

3425 Occurrence of streptomycin resistant and dependent mutations of *Rhizobium lupini* under the influence of nitrous acid.
Mishra, A.K. (Bose Inst, Calcutta, India), P. Roy and S.K. Das.
Cur Sci 44(8):267-269, 1975.
The highest rate of mutation to streptomycin resistance occurred at 60 seconds of nitrous acid treatment (0.017 M at pH 4.5). Only one strep dependent strain was obtained.

3426 Ultrastructure of rhizobia in pure culture and symbiosis.
Mishustin, E.N. and V.K. Shil'nikova.
In Proc Intersect Congr Int Assoc Microbiol Soc, 1st 2:208-221, 1975.

3427 Large plasmids in different *Rhizobium* species.
Nuti, M.P. (St U Leiden, The Netherlands), A.M. Ledeboer, A.A. Lepidi and R.A. Schilperoort.
J Gen Microbiol 100(2):241-248, 1977.
Conditions suitable for the reproducible recovery of large plasmids not detected when using "cleared" lysates are reported. Further investigation of the possible role of large plasmids in establishment of the association between plant and bacterium is suggested as being worthwhile.

3428 Rhizobium in the soil.
Nutman, P.S.
In Walker, N., ed., Soil Microbiology, Wiley, NY, p. 111-131, 1975.
A review restricted to *Rhizobium* as a normal soil inhabitant and excluding the symbiotic portion of its life cycle. Some problems in the present host-based taxonomy are discussed. The major portion deals with rhizobial ecology. 91 of the "more important or recent" references are cited.

3429 Preliminary physiological studies on cowpea rhizobia.
Okafor, N. (Cornell U, Ithaca, NY, USA) and M. Alexander.
Soil Biol Biochem 7(6):405-406, 1975.
A short communication reporting on the laboratory determination of tolerance to temperature, pH and salinity of 2 strains of "cowpea" rhizobia. High sensitivity to the fungicide PMA was also noted.

3430 Cultural and symbiotic properties of *Rhizobium* strains isolated from nodules of *Cicer arietinum* L.
Okon, Y. (Hebrew U of Jerusalem, Rehovot, Israel) Y. Eshel and Y. Henis.
Soil Biol Biochem 4(2):165-170, 1972.
Inoculation of chickpea with rhizobia from the United States and Israel in a soil free of its specific rhizobia doubled the yield. Fertilization with inorganic N was much less effective. Captan increased production and had no adverse effect on rhizobia in peat based inoculum. Local strains reverted to the original form after 5 transfers on agar medium.

3431 Comparison of DNA polymerase of *Rhizobium meliloti* and alfalfa bacteroids.
Paau, A. (U Houston, Texas, USA) and J.R. Cowles.
Plant Physiol 56(4):526-528, 1975.
Polymerase activity in partially purified fractions of extracts from *R. meliloti* bacteria and bacteroid cultures showed characteristic dependence on Mg^{2+}, DNA, and a full complement deoxyribonucleoside triphosphates. Polymerase activity in crude extracts from the bacteria and bacteroids was compared, and certain differences were observed. *R. japonicum* bacteria and bacteroids also exhibited differences in DNA polymerase activity, but much less than for *R. meliloti*. The differences may be related to growth rates and to changes essential for nodulation.

3432 Factors of multiple resistance to antibiotics in nodule bacteria.(Rus)
Pariiskaia, A.N. and O.P. Gorelova.
Mikrobiologiia 45(5):869-872, 1976.

3433 Binding of pea lectins to a glycan type polysaccharide in the cell walls of *Rhizobium leguminosarum*.
Planque, K. (State U Leiden, The Netherlands) and J.W. Kijne.
Fed Eur Biochem Soc (FEBS) Lett 73(1):64-66, 1977.
A new type of polysaccharide in rhizobial lipopolysaccharides was isolated from the bacterial cell wall by phenol extraction. The chemical characteristics and interaction with pea seed were described.

3434 Synthesis and decomposition of poly-beta-hydroxybutyric acid in *Rhizobium lupini*.
Romanov, V.I. (A.N. Bakh Inst Biochem, Moscow, USSR), L.A. Yushkova and V.L. Kretovich.
Microbiology 44(5):740-744, 1975.
In the presence of glucose and ß-hydroxybutyrate substrates, the content of PHB in the cell suspensions of *R. lupini* and its bacteroids increased 2.0- to 2.5-fold. In the absence of exogenous substrates, PHB decomposition was observed. This was intensified in the presence of ammonium ions. The introduction of glucose and ammonium together at the stage of active N fixation caused rapid decomposition of PHB.

3435 Effect of nitrate and nitrite on respiration and the cytochrome system of *Rhizobium lupini*.
Romanov, V.I. (A.N. Bakh Inst Biochem, Moscow, USSR), N.G. Fedulova, A.V. Korolev and V.L. Kretovich.
Microbiology 45(1):72-78, 1976.
Under anaerobic conditions, nitrate or nitrite at 10^{-3}M accepted electrons from the cytochrome system in a suspension of bacteroids and bacterial cells, but cytochromes of bacteria grown under aerobic conditions did not oxidize. Bacteroid and bacteria cultures grown in an O_2 deficiency showed similarities with respect to various properties of the cytochrome system.

3436 Nitrogen fixation and content of poly-beta-hydroxybutyric acid in bacteroids of *Rhizobium leguminosarum* and *Rhizobium lupini*.
Romanov, V.I., V.I. Shramko, N.G. Fedulova and V.L. Kretovich.
Sov Plant Physiol 23(6):967-971, 1976.

3437 Some physiological characteristics of *Rhizobium meliloti* and *R. trifolii* in relation to efficiency of symbiosis with lucerne and Egyptian clover.
Sarma, K.S.B. (IARI, New Delhi, India), M. Lakshmi-kumari, R. Apte and N.S. Subba Rao.
Plant Soil 38(2):299-305, 1973.
The abilities of bacteria to produce total Salkowski positive compounds (SPC) in terms of IAA equivalents on a tryptophane-containing substrate, to catabolize IAA, to reduce nitrate, and to reduce TTC were studied in an effort to correlate these physiological properties with symbiotic efficiency. No positive and significant correlations were established. However, certain significant inverse relationships were apparent.

3438 Synthesis of thiamin and riboflavin by nodule bacteria of clover and lupine. (Ukr)
Skochyns'ka, N.M., R.M. Kantseliaruk and T.T. Dolgopolova.
Mikrobiol Zh 37(3):314-319, 1975.

3439 Synthesis of pyridoxin and cobalamine by nodule bacteria of clover and lupine. (Ukr)
Skochinskaia, N.M., R M. Kantseliaruk and V.M. Rangelova.
Mikrobiol Zh 37(4):433-438, 1975.

3440 Group B vitamins in nodules of lupine inoculated with active and low active strains of nodule bacteria. (Ukr)
Skochyns'ka, N.M. and R.M. Kantseliaruk.
Mikrobiol Zh 37(5):580-583, 1975.

3441 Soil bacteria: principal component analysis of physiological descriptions of some named cultures of *Agrobacterium*, *Arthrobacter*, and *Rhizobium*.
Skyring, G.W. (Cell Biol Res Inst, Ottawa, Canada), C. Quadling and J.W. Rouatt.
Can J Microbiol 17(10):1299-1311, 1971.
A prinicpal component analysis in which 38 cultures of *Arthrobacter*, 16 of *Agrobacterium*, and 27 of *Rhizobium* were subjected to 65 physiological tests. The results indicated important differentiating characteristics between the three groups. The rhizobia and agrobacteria were most alike.

3442 Homospermidine in *Rhizobium* and legume root nodules.
Smith, T.A. (U Bristol, England).
Phytochem 16(2):278-279, 1977.
Homospermidine, an amine previously known in the free state only in sandalwood leaves, is reported to have been identified in root nodules of lupine, broad bean, runner bean and pea. It was not found in nodule-free roots of pea or broad bean. The amine was also detected in *R. leguminosarum* and *R. phaseoli*, while putrescine, spermidine and spermine were absent in agar plate cultures of the bacteria.

3443 Growth and respiration of glycine resistant and sensitive strains of *Rhizobium meliloti*.
Staphorst, J.L. and B.W. Strijdom.
Phytophylactica 4(1):19-24, 1972.

3444 Morpholigical development of *Rhizobium* bacteroids in nodules of *Arachis hypogaea* L.
Van Rensberg, H.J., J.S. Hahn and B.W. Strijdom.
Phytophylactica 5(3):119-122, 1973.

3445 Adsorption and selection of rhizobia with ion-exchange papers.
Werner, D. (Philipps-U, Marburg, Germany), J. Wilcockson and E. Zimmerman.
Arch Microbiol 105:27-32, 1975.
The method of adsorption and subsequent desorption using increasing ion

concentration showed great promise for the characterization of different strains of *Rhizobium*. Additional information about the cationic-anionic charge pattern of rhizobia strains may make it possible to select and enrich the strains from soil samples within minutes instead of the days or weeks now required.

3446 Discrimination of *Rhizobium japonicum*, *Rhizobium lupini*, *Rhizobium trifolii*, *Rhizobium leguminosarum* and of bacteroids by uptake of 2-kenoglutaric acid, glutamic acid and phosphate.
Werner, D.(Phillips-U, Marburg, Germany) and K. Berghauser.
Arch Microbiol 107(3):257-262, 1976.
"Slow-growing" rhizobia are characterized by a rapid uptake of glutamic acid and 2-ketoglutaric acid. "Fast growing" rhizobia may be characterized by a much slower uptake, with more than ten times higher concentrations of both metabolites remaining in the medium after the same culture time.

3447 Species characteristics and culture condition as affecting rhizobial production of IAA. (Jpn)
Yoshida, S. and M. Yatazawa.
J Sci Soil Manure Japan 44(2):63-66, 1973.

Articles dealing with symbiotic characteristics of rhizobia are listed under numerous subjects throughout this bibliography.

35. *Rhizobium* COUNTS & POPULATIONS.

3501 Note on the distribution and effectiveness of *Rhizobium* of *Sesbania aculeata* Poir. in saline-alkali soils.
Bhardwaj, K.K.R. (Centr Soil Sal Res Inst, Karnal, Haryana, India).
Ind J Agr Sci 44(10):683-684, 1976.
Fair nodulation was obtained from rhizobia inhabiting all 9 soils tested. Dry matter yield was almost directly correlated with nodule weight, but not with nodule number. Most strains were either ineffective or only moderately effective in N fixation.

3502 Use of wild soybean (*Glycine ussuriensis* Regel Maack) as a test plant in dilution-nodulation frequency tests for counting *Rhizobium japonicum*.
Brockwell, J. (DPI, Indooroopilly, Qld., Australia), A. Diatloff, A. Grassia and A.C. Robinson.
Soil Biol Biochem 7:305-311, 1975.
In a pure culture comparison with agar plate counting, the dilution-nodulation frequency test gave an accurate estimate of numbers. Simplified tables for calculating most probable numbers of nodule bacteria from the distribution of nodulated test plants are appended.

3503 The colonization of host-root and soil by rhizobia. I. Species and strain differences in the field.
Chatel, D.L. (U Western Australia, Nedlands, W.A.) and C.A. Parker.
Soil Biol Biochem 5(4):425-432, 1973.

Rhizobium SPECIES & POPULATIONS, continued

[illegible] shows the ability of *Rhizobium lupini* and *R. trifolii* [illegible] and to survive the summer. A [illegible] of *R. trifolii* in the second year was followed [illegible]

[illegible] the colonisation of host-root and soil by rhizobia. II. Strain differences in the species *Rhizobium trifolii*.
[illegible] (U Western Australia, Nedlands, W.A.) and R.H. Greenwood.
[illegible] 1973.
The ability of 4 strains of clover rhizobia to colonise host-root and soil was compared at 7-day intervals for 78 days from field sowing. One strain (WU-0) was consistently inferior to another introduced strain (WU29) and to locally isolated strains.

3505 The location and distribution in soil of rhizobia under senesced annual legume pastures.
Chenal, B.L. (U Western Australia, Nedlands, W.A.) and R.H. Greenwood.
Soil Biol Biochem 5(6):799-808, 1973.
Soil cores taken below senesced legume swards were partitioned into soils, legume roots, nodules, and debris. The viable *Rhizobium trifolii* population under subterranean clover was found to be predominantly in the nodule fraction, but with *R. lupini* under serradella the distribution was more evenly distributed among the 4 fractions. In commercially sown stands the rhizobia often failed to migrate from the original sown rows into the soil between the rows.

3506 Effective natural nodulation of peanuts in Queensland.
Bistoff, A. and S. Langford.
Queensl J Agr Anim Sci 32(1):95-100, 1975.
Yield response to inoculation could be achieved on new land, but not on land previously cropped to peanuts. The majority of field isolates of peanut rhizobia were found to be effective. Some natural transfer of rhizobia on seed was recorded.

3507 Effect of cropping history on soybean growth and nodulation and soil rhizobia.
Elkins, D.M. (So Illinois U, Carbondale, IL, USA), G. Hamilton, C.K.Y. Chen, M.A. Briskovich and J.W. Vandeventer.
Agron J 64(5):513-517, 1976.
To clarify the effect of previous soybean cropping history, sterile soybean seeds were inoculated with the supernatant from soil suspensions representing variations of soil exposure to rhizobia. Good nodulation and growth occurred from populations of rhizobia which had persisted for 10 or 11 years since soybean cropping had occurred.

3508 Studies of field populations of *Rhizobium*: effectiveness of strains of *Rhizobium trifolii* associated with *Trifolium subterraneum* L. pastures in Southeastern Australia.
Gibson, A.H. (CSIRO, Canberra City, Australia), B.C. Curnow, F. J. Bergersen, J. Brockwell and A.C. Robinson.
Soil Biol Biochem 7(2):95-102, 1975.

Using a known effective strain as a standard for comparison, populations from 8 regions of S.E. Australia were sampled over a period of 5 years. Mean comparative effectiveness of nitrogen fixation ranged between 62 and 93%. Effectiveness values were not related to other variables such as soil, weather, previous inoculation, etc.

3509 Evaluation of *Rhizobium japonicum* inoculants in soils containing naturalized populations of rhizobia.
Ham, G.E. (U Minnesota, St. Paul, MN, USA), V.B. Cardwell and H. W. Johnson.
Agron J 63(2):301-303, 1971.
Yields and protein percentages were not significantly increased by use of inoculants.

3510 Nodulation and frequencies of wild leguminous species in the northern Negev region of Israel.
Hely, F.W. (CSIRO, Canberra City, Australia) and I. Ofer.
Aust J Agr Res 23(2):267-284, 1972.
Natural root nodulation in the field was normally plentiful and effective. The fact that these range plants have survived heavy grazing pressures for 6000 years or more should make them interesting subjects for further studies.

3511 Survey and isolation of root nodule bacteria in Indian soils - final report.
Indian Agricultural Research Institute [New Delhi]
IARI Proj A7-SNC-46, 62 lvs., 1973.
Covers period 1967-1972.

3512 Distribution of nodule bacteria in soils. (Rus)
Karaguishieva, D., Kh.K. Adil'bekova and L.B. Aksenova.
Vestn Akad Nauk Kaz SSR 3:43-48, 1976.

3513 On the development of nodular bacteria in the soil.
Koleshko, O.I.
Microbiol 44(2):291-293, 1976.

3514 Collection of strains of *Rhizobium* spp. of the Instituto Agronomico.(Por)
Lopes, E.S.
Inst Agron, Campinas, Cir 11, 12 p., 1972.

3515 Observation of natural nodulation in peanut cultivars. (Por)
Lopes, E.S., F.A. Savy, M.L. Oliveira, A.R. Giardini and A.S. Pompeo.
Bragantia 35(1):xi-xiii, 1976.

3516 Interrelationship between soybean varieties and indigenous *Rhizobium* strains in Northeast Thailand.
Na Lampang, A.
Int Soybean Prog (INTSOY) 10:198-199, 1976.

[illegible] isolated from legumes native to Argentina.
[illegible] Arg Cien Nat R, Rivadavia C Cuen Cien Nat 2(5):21-27, 1972.

3518 Variability associated with sampling of *Rhizobium japonicum* populations in soybeans.
[illegible] (Beltsville, MD, USA), B.E. Caldwell and H.D. Peterson.
Crop Sci 11(6):780-782, 1971.
R. japonicum samples from 500 soybean nodules were serotyped and classified annually for three years. The standard errors obtained by extensive sampling proved to be less than one half the standard errors obtained by usual sampling methods. Therefore, if definitive information is needed, the sample size and number should be increased beyond the usual sampling.

3540 A new technique for most-probable-number counts of rhizobia.
Weaver, R.W. (Texas A & M U, College Stn., TX, USA) and L.R. Frederick.
Plant Soil 36(1):219-222, 1972.
Because a selective medium suitable for making plate counts of rhizobia in contaminated material has not been developed, the MPN method has been used for counting soil rhizobia. Plastic pouches for growing plants for MPN counts proved practical and gave accurate results.

Additional references with information related to this topic may be found under:

Competition (microbial)
Legumes: evaluation, physiology, taxonomy.
Nodulation problems
Survival (rhizobial)

36. *Rhizobium* CULTURES & CULTURE MEDIA.

3601 Effect of protein additives on acetylene reduction (nitrogen fixation) by *Rhizobium* in the presence and absence of soybean cells.
Anderson, S.J. (Indiana St. U, Terre Haute, IN, USA) and D.A. Phillips.
Plant Physiol 57(6):890-893, 1976.
Aqueous extracts of hexane-extracted soybean, kidney bean and garden pea, as well as casein or bovine serum albumin, promoted acetylene reduction when added to the basal medium. Egg albumin completely suppressed nitrogenase activity. It was suggested that free-living rhizobia may reduce some N in certain field situations.

3602 Involvement of oxylegheamoglobin and cytochrome *P*-450 in an efficient oxidative phosphorylation pathway which supports nitrogen fixation in *Rhizobium*.
Appleby, C.A. (CSIRO, Canberra, Australia), G.L. Turner and P.K. MacNicol.
Biochim Biophys Acta 387:461-474, 1975.
Addition of oxylegheamoglobin to respiring suspensions of *Rhizobium japonicum* bacteroids increased the cellular ATP level, the ATP/ADP ratio, and nitrogenase activity. Cytochrome *P*-450 was suggested to be a component of the leghemoglobin-facilitated respiration pathway which may act as intracellular O_2 carrier rather than terminal oxidase.

3603 Obtaining of callus culture and suspension of isolated kidney bean root cells and their effect on the growth of nodule bacteria in joint cultivation. (Rus)
Arutiunian, R.Sh., N.L. Kuladzhian, M.D. Stepanian, H.A. Karapetian and M. Kh. Chailakhian.
Dokl Akad Nauk SSSR 229(5):1270-1273, 1976.

3604 Nitrogen fixation by a *Rhizobium* sp. in association with non-leguminous plant cell cultures.
Child, J.J. (Prairie Reg Lab, Saskatoon, Sask., Canada).
Nature 253(5490):350-351, 1975.
A "cowpea" *Rhizobium* strain formed nitrogenase in association with plant cells of rapeseed, wheat and brome grass as well as with plant cells of several legumes.

3605 Reduction of acetylene by stationary cultures of free-living *Rhizobium* sp. under atmospheric oxygen levels.
Evans, W.R.(C.F. Kettering Res Lab, Yellow Springs, OH, USA) and D.L. Keister.
Can J Microbiol 22(7):949-952, 1976.
Non-shaking cultures of free-living rhizobia under atmospheric oxygen levels reduced acetylene in the absence of plant constituents. The formation of ethylene was inhibited by NH_4^+ and by shaking at high oxygen levels.

3606 A method of culturing *Rhizobium meliloti* on porous granules to form a pre-inoculant for lucerne seed.
Fraser, M.E. (Allen & Humbrys Ltd., Ware, England).
J Appl Bac 39(3):345-351, 1975.
Granules made from builders' plaster were arranged in columnar beds through which medium and inoculant could be percolated. A 10-fold increase in rhizobia count over pumice granules, and a higher survivor count on storage, were attained.

3607 Nitrogenase activity in cultured *Rhizobium* sp. strain 32H1. Nutritional and physical considerations.
Gibson, A.H. (CSIRO, Canberra City, Australia), W.R. Scowcroft, J.J. Child and J.D. Pagan.
Arch Microbiol 108(1):45-54, 1976.
The various constituents of a basic CS7 medium were tested for their ability to support nitrogenase activity in a strain of "cowpea" *Rhizobium*. Sources of carbon, nitrogen and other nutrients were evaluated, as were vitamins and certain environmental factors.

3608 The induction of nitrogenase activity in *Rhizobium* by non-legume plant cells.
Gibson, A.H. (CSIRO, Canberra ACT, Australia), J.J. Child, J.D. Pagan and W.R. Scowcroft.
Planta 128(3):233-239, 1976.
"Cowpea" rhizobia grown in association with cell cultures of tobacco had maximum nitrogenase activity at an O_2 concentration of 20% and at an assay temperature of 30° C. Nitrogenase activity induced in rhizobia when cultured adjacent to, but not in contact with, plant cells could be stimulated by providing succinate in the medium.

3608 Effect of additional shots on growth of *Rhizobium trifolii* in relation to mass cultivation of rhizobia.
Gulati, S.L. (IARI, New Delhi, India) and N.S. Subba Rao.
Microbiom Antibiot Bul 16:84-88, 1974.
Additional shots of several chemicals to the YEM medium were tried in an effort to overcome growth decreases in culture transfers. Starch, calcium carbonate, phosphoric acid and citric acid (with pH of the medium corrected) depressed growth. Addition of casein hydrolysate, berseem seed extract and yeast extract enhanced growth, particularly when added just after a lag phase.

3610 Root hair cell enhancement in tissue cultures from soybean roots: a useful model system.
Hasuina, N. (C.F. Kettering Res Lab, Yellow Springs, OH, USA) and M. Reporter.
Plant Physiol 59(1):97-102, 1977.
Cultures enriched by cells with root hairs offer advantages for studies of *in vitro* symbiosis. Root cell and root hair cell proliferation were obtained when the cells were cultured in a medium lacking 2,4-D and kinetin. Root hair cells can also be used for studying the iniciation of bacterial attachment.

3611 Establishment of symbiosis between *Rhizobium* and plant cells *in vitro*.
Holsten, R.D. (E.I. du Pont de Nemours & Co., Wilmington, DE, USA), R.C. Burns, R.W.F. Hardy and R.R. Hebert.
Nature 232(5307):173-176, 1971.
Cultured soybean callus was infected with *Rhizobium japonicum*. The *in vitro* acetylene reduction activity was on the order of 1% of that found in soybean nodules.

3612 Utilization of soybean seed extract for growth of *Rhizobium* spp.
Iswaran, V. (IARI, New Delhi, India) and P.K. Chhonkar.
Zentr Bak Parasit Infek ... 2 Nat 127(4):346-347, 1972.
Soybean meal extract was investigated as a source of growth factors for production of commercial inoculants. The numbers of cells in the non-defatted meal extract/mannitol medium were higher than with defatted soybean meal or yeast extract media.

3613 Use of sodium lactate for culture of *Rhizobium* spp.
Iswaran, V. (IARI, New Delhi, India), R. Apte and A. Sen.
Zentr Bak Parasit Infek ... 2 Nat 128:240-242, 1973.
In addition to being as good a carbon source as mannitol, sodium lactate was found to help the survival of rhizobia even at a temperature of 45°C by keeping the moisture content in the peat.

3614 A simple medium for quick growth of *Rhizobium japonicum*.
Iswaran, V. (IARI, New Delhi, India), A. Sen and R. Apte.
Zentr Bak Parasit Infek ... 2 Nat 128(1):23-24, 1973.
A medium of mannitol or sucrose, 10g; K_2HPO_4, o.5g; $FeCl_3$ 0.01g; yeast extract, 2.0g; H_2O, 1 litre, at pH 6.8, enables *R. japonicum*, slow-growing in commonly used media, to grow quickly. 250×10^6 viable rhizobia were obtained in 96 hr instead of the usual 7 days.

3615 Acetylene reduction by pure cultures of rhizobia.
Keister, D.L. (Kettering Res Lab, Yellow Springs, OH, USA).
J Bac 123(3):1265-1268, 1975.
The most important factors required for acetylene reduction in pure cultures of rhizobia are a low density and a very low oxygen concentration. No plant materials are required in the culture medium.

3616 Effect of a foam suppressor on the growth and development of nodule bacteria in nutrient media. (Rus)
Klintsare, A.I.A., M.Zh. Kristapson and A.M. Yaknena.
In Mikrobiologicheskie Preparaty, p. 81-85, 1976.

3617 Antagonisms between *Rhizobium* strains in culture. (Fre)
LaJudie, J.
Ann Phytopathol 6(1):109-111, 1974.

3618 Methods for growing nitrogen-fixing bacteria separated from plant cells.
LaRue, T.A. (Prairie Reg Lab, Saskatoon, Sask., Canada), W.G.W. Kurz and J.J. Child.
Can J Microbiol 21(1):1884-1886, 1975.
A procedure for studying the nature of the diffusible factor from plant cells which induces nitrogenase activity in "cowpea" *Rhizobium* outside the nodule is described.

3619 Asymbiotic nitrogen fixation by *Rhizobium* spp.
LaRue, T.A. (Prairie Reg Lab, Saskatoon, Sask., Canada), W.G.W. Kurz and J.J. Child.
In Proc World Soybean Res Conf p. 164-169, 1976.
This paper outlines the experiments leading to the discovery that some rhizobial strains are capable of dinitrogen fixation during axenic growth on simple defined media. The significance of asymbiotic N fixation by rhizobia lies in the hope that associations with non-legumes may prove possible. A great deal of work on host-symbiont relationships and rhizobial physiology remains to be done, however.

3620 The effect of culture medium composition on the generation time of a *Rhizobium japonicum* strain. (Spa)
Lopreto, C.R., L.A. Mazza and A.P. Balatti.
Soc Cient Argent 193:35-47, 1972.

3621 Acetylene reduction by *Rhizobium* in pure culture.
McComb, J.A. (U Western Australia, Nedlands, W.A.), J. Elliott and M.J. Dilworth.
Nature 256(5516):409-410, 1975.
A strain of "cowpea" *Rhizobium* in a callus culture medium supplemented with glutamine and succinate produced acetylene-dependent ethylene which can be attributed to nitrogenase activity.

3622 The effect of aeration on certain biochemical indices of cultures of *Rhizobium leguminosarum*.
Maiorova, I.P. (All-Union Sci Res Inst, USSR), E.A. Krongauz, N.I. Porter and N.I. Monakova.

Appl Biochem Microbiol 9(2):143-146, 1973.
Utilization of nutrients in the medium increased with aeration, which also promoted resistance to hydrolysis and to the production of glucose.

3623 Nitrogen fixation by *Rhizobium* cultured on a defined medium.
Pagan, J.D.(CSIRO, Canberra, Australia), J.J. Child, W.R. Scowcroft and A.H. Gibson.
Nature 256(5516):406-407, 1975.
Medium CS7 contents are listed. Arabinose, succinate and glutamine or a suitable substitute were required constituents for the induction of nitrogenase activity. The optimal pO_2 was found to be 0.15-0.20 atm.

3624 New nitrogen-fixing symbiosis *in vitro*.
Postgate, J.
Nature 253(5490):305, 1975.
The apparent success of Scowcroft and Gibson in obtaining *in vitro* nitrogen fixation with rhizobia (very carefully checked for contamination) and callus from non-legumes such as wheat and tobacco seems to establish the possibility of new nitrogen-fixing associations. [This "News and Views" article relates to #3632 in this bibliography.]

3625 Nitrogenase activity in *Rhizobium* associated with leguminous and non-leguminous tissue cultures.
Ranga Rao, V. (Rothamsted Exp Stn, Harpenden, Herts., England).
Plant Sci Lttr 6(2):77-83, 1976.
Experiments on the infection of root-, leaf-, and stem-tissue cultures of *Trifolium* spp. and *Stylosanthes gracilis* with *Rhizobium* spp. Infected *Trifolium* callus differentiated to produce roots, a probable response to kinetin and IAA released by the bacterium. Uninfected callus remained undifferentiated.

3626 Nitrogenase activity of *Rhizobium* sp. strain 1552 on defined medium.
Ranga Rao, V. (Rothamsted Exp Stn, Harpenden, Herts., England).
Plant Sci Lttr 8(4):363-366, 1977.
In defined medium solid cultures, the level of nitrogenase activity depended upon the glutamine concentration of the medium. The effects of cysteine, asparagine and succinate on nitrogenase activity were also studied.

3627 Acetylene reduction by transfilter suspension cultures of *Rhizobium japonicum*.
Reporter, M. (C.F. Kettering Res Lab, Yellow Springs, OH, USA) and M. Hermina.
Biochem Biophys Res Comm 64(4):1126-1133, 1975.
Evidence that plant diffusates can activate nitrogenase production and acetylene reduction by soybean rhizobia in a transfilter suspension apparatus. Activity continued for 10 days. Advantages offered by the transfilter apparatus are pointed out.

3628 Synergetic cultures of *Glycine max* root cells and rhizobia separated by membrane filters.
Reporter, M. (C.F. Kettering Res Lab, Yellow Springs, OH, USA).
Plant Physiol 57:651-655, 1976.

A double chambered apparatus in which root cells, separated from the rhizobia by two or three membranes, activated nitrogenase activity as indicated by acetylene reduction and hydrogen evolution, is described. The activity persisted for several days after removal of the rhizobia to a separate culture with a carbon source and controlled environment. Some possible applications of the transfilter method are discussed.

3629 Nitrogenase activity in *in vitro* associations between callus tissue of non-leguminous horticultural plants and *Rhizobium*.
Schetter, C. (U Hohenheim, Stuttgart, W. Germany) and D. Hess.
Plant Sci Lttr 9:1-5, 1977.
Calli of several varieties of agriculturally important non-legumes formed associations with rhizobia, producing detectable nitrogenase activity. Removal of the plant tissue caused rapid decline in the nitrogenase activity.

3630 On the resistence of effectiveness of *Rhizobium trifolii* to a low pH.
Schreven, D.A.Van (Kampen, The Netherlands).
Plant Soil 37(1):49-55, 1972.
On agar medium, growth was retarded at pH 4.5 and was very poor at 4.0. The cells were not killed at 3.5. Effectiveness seemed to be affected after 12 subcultures over 300 days on the low pH media, but all test plants produced nodules with red pigment.

3631 Antagonism between strains of *Rhizobium trifolii* in culture.
Schwinghamer, E.A. (CSIRO, Canberra, Australia).
Soil Biol Biochem 3(4):355-363, 1971.
Interstrain antagonism in culture between 41 strains of diverse origin and 270 isolates of Australian clover nodule bacteria was examined. Potent antibiotics are apparently very infrequently produced by this species, but there was ample evidence of interstrain antagonism involving mildly antibiotic substances, bacterocins and phage. The incidence of antagonism is sufficiently high to warrent study of a possible ecological role for these phenomena - i.e., whether they provide a competetive advantage in nature.

3632 Nitrogen fixation by *Rhizobium* associated with tobacco and cowpea cell cultures.
Scowcroft, W.R (CSIRO, Canberra, Australia) and A.H. Gibson.
Nature 253(5490):351-352, 1975.
A diffusable factor secreted by plant cells is apparently responsible for expression of the nitrogenase gene by *Rhizobium* as verified by these experiments. Nitrogenase mediated acetylene reduction and ^{15}N incorporation occurred when the rhizobia were cultured adjacent to, but not in contact with, tobacco callus.

3633 On the possibility of using a jointly cultu system of isolated tissues from legumes and nodular bacteria for investigating their interrelations.
Shamtsyan, M.G., E.N. Avvakumova and M.Kh. Chailakhyan.
Dokl Bot Sci 220/222:41-44, 1975.

3634 Nitrogen content in joint cultures of *Amoeba albida* and *Rhizobium meliloti*. (Rus)
Shetalova, M.V.
Uz Biol Zhur 4:71, 1971.

3635 Carbohydrate components in the nutrient medium for slowly growing nodule bacteria. (Rus)
Shmyreva, T.V. and T.B. Plaksina.
Priklad Biokhim Mikrobiol 8(1):34-37, 1972.

3636 The effect of yeast extract concentration in media on strains of *Rhizobium meliloti*.
Staphorst, J.L. and B.N. Strijdom.
Phytophylactica 4(2):29-32, 1972.

3637 Toxicity of sodium and chloride ions to *Rhizobium* spp. in broth and peat culture.
Steinborn, J. (Hort Res Stn, Gosford, NSW, Australia) and R. J. Roughley.
J Appl Bac 39:133-138, 1975.
The following salts were added to broth and peat cultures of *Rhizobium trifolii* and *R. meliloti*: Na_2HPO , $CaCl_2 2H_2O$, and NaCl. Calcium chloride was more toxic than sodium chloride. *R. meliloti* strains grew on 3.5% NaCl after a long adaptation period. Rhizobia for soya and cowpea grew at 0.5%, and for clover at 1.0% NaCl.

3638 The effect of the ratio of Mg:Ca on numbers of *Rhizobium* in liquid medium.
Steinborn, J. (Hort Res Stn, Gosford, NSW, Australia) and R.J. Roughley.
J Appl Bac 39:213-216, 1975.
Ca^{2+} and Mg^{2+} are both necessary for growth of rhizobia in broth culture. Three strains of rhizobia differed in their response to changes in the ratio of these ions in solutions of different ionic concentrations.

3639 Rhizobial culture.
Subba Rao, N.S. (IARI, New Delhi, India).
Ind Farming 23(11):19, 21-23, 1974.
The needs for, and means of, manufacturing large quantities of inoculant to meet the agricultural needs of India are discussed.

3640 Nitrogen fixation by free living *Rhizobium* in a defined liquid medium.
Tjepkema, J. (Oregon St U, Corvallis, OR, USA) and H.J. Evans.
Biochem Biophys Res Comm 65(2):625-628, 1975.
Confirmation of findings reported by Dilworth and Scowcroft, 1975. The acetylene reduction rates obtained from "cowpea" strains of rhizobia were comparable to those of bacteroids from soybean nodules.

3641 A laboratory culture medium for *Rhizobium* from *Lotus pedunculatus*.
Walsh, M.B. and P.L. Curran.
Sci Proc R Dublin Soc, Ser B 3(19):267-271, 1974.

3642 Nitrogenase activity in the *in vitro* symbiosis of *Rhizobium japonicum* and tissue cultures of *Glycine max* and in *Rhizobium* in pure culture on defined media.
Werner, D. (U Marburg, Germany).
Ber Dtsch Bot Ges 89:563-574, 1976.
Tissue cultures of 3 soybean varieties were used to study plant cell influence on the differentiation of *Rhizobium* cells and the induction of nitrogenase activity. Var. 'Chippewa' was 4-10 times more effective than 'Caloria' in promoting bacterial growth on agar surfaces. The excreted plant factors responsible for induction of nitrogenase activity were heat stable at 90°C.

3643 Fixation of molecular nitrogen by nodule bacteria of lupine in association with tobacco and wheat cells. (Rus)
Yurkova, G.N., M.M. Nichik, B.A. Lavenko and E.P. Starchenkov.
Dokl Akad Nauk SSSR 230(4):1006-1008, 1976.

3644 Influence of the conditions of culturing on the accumulation of poly-beta-hydroxybutyric acid in *Rhizobium lupini*.
Yushkova, L.A. (A.N. Bakh Inst Biochem, USSR), N.G. Fedulova, V.I. Romanov and V.L. Kretovich.
Appl Biochem Microbiol 11(2):181-184, 1976.
Maximum polymer accumulation occurs between the end of the logarithmic phase and the beginning of the stationary phase of bacterial development. The most polymer was formed on a medium with glutamate as the nitrogen source, followed in order with ammonium phosphate, then nitrate.

3645 Determination of cytokinins in the culture medium of the nodule bacteria *Rhizobium meliloti* D-208. (Rus)
Zikmani, P.
Vestis Latv PSR Zinat Akad 7:69-74, 1975.

Additional references with information on *Rhizobium* cultures and culture media may be found in relevant listings under:

Carbon and carbon compounds.	Oxygen
Inoculant production	*Rhizobium* inhibition & stimulation
Micronutrients and toxic elements	Temperature & climate.

37. *Rhizobium* DETECTION & IDENTIFICATION.

3701 Ecological studies of root-nodule bacteria introduced into field environments. V. A critical examination of the stability of antigenic and streptomycin-resistance markers for identification of strains of *Rhizobium trifolii*.
Brockwell, J. (CSIRO, Canberra, Australia), E.A. Schwinghamer and R.R. Gault.
Soil Biol Biochem 9(1):19-24, 1977.
Evidence led to the conclusion that both gel immune diffusion serology and the use of streptomycin resistant mutants were reliable methods for identifying strains of rhizobia reisolated from field environments.

3702 A new method for identification of *Rhizobium trifolii* in nodules.
Cloesen, M.J. and B. Humphrey.
J Appl Bac 40(1):101-107, 1976.

3703 A comparison of antigenic properties of rhizobia cultured *in vitro* and their bacteroid forms from root nodules.
Dudeja, K.R. (IARI, New Delhi, India), A.N. Sen and M.S. Subba Rao.
Cur Sci 42(19):686-687, 1973.
Bacterial and bacteroid cells from identical strains were used for the preparation of antisera and for making immuno-diffusion plates. Variations in the development of internal antigen bands are suggestive of changes in the antigenic compounds during conversion to bacteroids.

3704 Antigenic analysis of *Rhizobium japonicum* by immunodiffusion.
Dudman, W.F. (CSIRO, Canberra, A.C.T., Australia).
Appl Microbiol 21(6):973-985, 1971.
Seven strains of *R. japonicum* and three of the cowpea miscellany were studied by using antisera against 8 of the strains. Results indicated that with appropriate standards and controls the immunodiffusion technique can provide quick, reliable identification of strains from cultures and from nodules.

3705 The utility of manganese in lactose medium to differentiate rhizobia from agrobacteria.
Gaur, Y.D. (IARI, New Delhi, India) and A.N. Sen.
Cur Sci 45(24):855, 1976.
Verification of the Clark (1969) finding that a modified Bergersen's medium containing lactose and 20 m.e. Mn^{2+}/l could preferentially support the growth of all the species of *Agrobacterium* while excluding certain rhizobia. Additional *Rhizobium* spp. were also verified in this work.

3706 Absence of 3-ketalactose production by *Rhizobium phaseoli*.
Gaur, Y.D. (Inst Plant Nutr, Prague, Poland) and H. Mareckova.
Folia Microbiol 22(4):311-312, 1977.
Fifty-four strains listed in the IBP World Catalogue were tested for 3-ketalactose production. None of the *R. phaseoli* could produce 3-ketalactose on a lactose medium, confirming the validity of the 3-ketalactose test in the identification of this species.

3707 Variation within serogroup 123 of *Rhizobium japonicum*.
Gibson, A.H. (Iowa St U, Ames, IA, USA), W.F. Dudman, R.W. Weaver, J.C. Horton and I.C. Anderson.
Plant Soil Spec Vol:33-37, 1971.
Three subgroups of isolates were identified from 20 isolates of *R. japonicum*. A heterogeneous population, having in common at least one antigen, was found rather than the previously supposed more uniform population. The difference could result from mutations rather than a wide range of introductions.

3708 Differential antibody response to the somatic antigenic determinants of *Rhizobium trifolii*.

Humphrey, B. (U New South Wales, Kensington, NSW, Australia) and J.M. Vincent.
Microbios 7:87-93, 1973.
Some antisera in which a significant proportion of high-titre cross agglutinating strains failed to produce any somatic gel diffusion line were investigated. The inefficiency of IgM as a precipitin may cause failure of a precipitin line in some cases.

3709 Specific and shared antigens in strains of *Rhizobium meliloti*.
Humphrey, B.A. (U New South Wales, Kensington, NSW, Australia) and J.M. Vincent.
Microbios 13:71-76, 1975.
Eight strains revealed common flagellar, LPS and internal antigens, indicating a severe limitation on the usefulness of serological techniques (agglutination, gel diffusion) when applied to *R. meliloti*.

3710 Identification of the *Rhizobium* strains in pea root nodules using genetic markers.
Johnston, A.W.B. (John Innes Inst, Norwich, England) and J.E. Beringer.
J Gen Microbiol 87(2):343-350, 1975.
Of 297 nodules examined, 56 contained both of the applied inoculant strains as identified by genetic markers (auxotrophy and antibiotic resistance). Inoculum ratios did not correlate with strains forming nodules. Certain strains were identified as superior competitors. The advantages of genetic markers over serological techniques were discussed.

3711 Serological grouping of nodule bacteria of the species *Rhizobium trifolii* and *Rhizobium leguminosarum*. (Rus)
Kalnin'sh, A.D.
In Novoe V Izuchenii Biologicheskoi Fiksatsii Azota p. 72-79, 1971.

3712 Serological properties of mutants of *Rhizobium*.
Kaushik, B.D. (IARI, New Delhi, India), K.R. Dadarwal and G.S. Venkataraman.
Cur Sci 42(14):508-509, 1973.
Immune diffusion studies of mutants and a recombinant and transformant indicated that the donor DNA, in addition to transferring markers for resistance to radiation and drugs, also transferred antigenic properties to the recipient.

3713 Comparative study of fluorescent spectra of active and slightly active strains of nodule bacteria of alfalfa. (Rus)
Petrenko, L.D.
In Mikroorganizmy, Produtsenty Biologicheski Aktivnykh Veshchestv p. 165-168, 1973.

3714 Applying the serological method for study of symbiosis of leguminous plants and nodule bacteria. (Rus)
Ryzhova, A.S., V.P. Izrail'zskii, T.E. Kucherova, T.N. Aranson and E.K. Kosheleva.
In Novoe v Izuchenii Biologicheskoi Fiksatii Azota p. 65-71, 1971.

3715 An evaluation of the Nile Blue test for differentiating rhizobia from agrobacteria.
Skinner, F.A. (Rothamsted Exp Stn, Harpenden, Herts., England).
J Appl Bac 43(1):91-98, 1977.
With 35ppm Nile Blue in the medium, 89 of 90 rhizobia failed to reduce the dye, while all 24 strains of agrobacteria reduced it to the colorless state. The test detected rapid-growing, but not slow-growing strains of agrobacteria as contaminants of rhizobia cultures even when their initial numbers were small.

3716 Serotyping of fresh and/or dried soybean root-nodules.
Skrdleta, V. (Res Inst Crop Prod, Prague, Czechoslovakia) and H. Mareckova.
Zentr Bak Parasit Infek ... 2 Nat 126(7):656-658, 1971.
Efforts to serotype 462 fresh and 472 dried root nodules demonstrated that drying had a time-related effect on immune diffusion results.

3717 Nodule samples in the identification of *Rhizobium* strains by serological tests. (Por)
Stammer, E.E. (Inst de Biol e Pesq Tecn do Parana Curitiba, Sao Paulo, Brasil).
Arq Biol Tecnol 16(1):29-33, 1973.
Strains of *Rhizobium* from the nodules of 5 varieties of soybean were identified by serological tests. All except those from var 'Hardee' were representatives of the population analysed.

3718 Serological groups of nodule bacteria of alfalfa. (Lav)
Stikute, I.
Latv Sel'skokhoz Akad Tr 29:142-153, 1971.

3719 Serological specificity of rhizobia from nodules of groundnuts cultivated in South African soils.
Van Der Merwe, S.P. and B.W. Strijdom.
Phytophylactica 5(4):163-166, 1973.

3720 Group antigens in slow-growing rhizobia.
Vincent, J.M. (U New South Wales, Kensington, NSW, Australia), B Humphrey and V. Skrdleta.
Arch Mikrobiol 89:79-82, 1973.
Fast-growing rhizobia were clearly distinguished from slow-growing strains in gel-diffusion tests with antisera to 3 strains of *Rhizobium japonicum*. The slow-growing strains of several species had at least one, and generally two, common antigens. Five strains of agrobacteria grouped with the fast-growing rhizobia.

3721 Loss of agglutinating specificity in stock cultures of *Rhizobium meliloti*.
Wilson, M.H.M.(U New South Wales, Kensington, NSW, Australia), B.A. Humphrey and J.M. Vincent.
Arch Mikrobiol 103(2):151-154, 1975.
Several strains of alfalfa rhizobia which had been markedly specific in their somatic agglutination reactions became wildly cross-reactive after 23-33 years of subculturing. A note of warning concerning the use of serological strain typing for *R. meliloti* was expressed.

3722 Differentiation of the nodule bacteria symbiotic with lucerne with the aid of infrared spectroscopy. (Rus)
Zagreba, D., A.J. Klincare, J. Eiduss and J. Jakobsons.
Vestis Latv PSR Zinat Akad 9:78-81, 1975.

Several of the references listed under *Rhizobium* Characteristics & Physiology include information relevant to detection and identification.

38. *Rhizobium* EFFECTIVENESS, INFECTIVENESS & EFFICIENCY.

3801 Research work concerning the efficiency of bacterization in lucerne. (Rum)
Balan, N., W. Galbenu, R. Zahan, F. Patrascoiu, D. Halalau and R.Lacatusu.
Probl Agr 26(3):5-16, 1974.

3802 Effects of strains of *Rhizobium meliloti* and successive cuttings of alfalfa *(Medicago sativa)* on symbiotic nitrogen fixation. (Fre)
Bordeleau, L.M. (Stn de Res, Sainte-Foy, Que., Canada), H. Antoun and R.A. LaChance.
Can J Plant Sci 57(2):433-439, 1977.
Statistical studies indicate that plant yield in dry weight can be used as an indirect measurement of N fixation in alfalfa, and as a criterion for rhizobia strain selection.

3803 Selection of *Rhizbium meliloti* strains for inoculation of *Medicago rugosa* Desr. cv. Paragosa.
Brockwell, J.
Field Stn Rec CSIRO 10(2):51-58, 1971.

3804 Symbiotic characteristics of *Rhizobium trifolii* from Israel in association with 10 species of *Trifolium*.
Brockwell, J. (CSIRO, Canberra City, Australia) and J. Katznelson.
Aust J Agr Res 27(6):799-810. 1976.
All of 25 isolates of rhizobia from 10 clover species formed nodules, but the symbiotic effectiveness varied greatly. All species except *T. repens* showed some degree of strain specificity in effectiveness. Three species were highly specific in bacterial associations. Over all isolates, *T. alexandrinum* was most effective in symbiosis, and *T. repens* poorest. Host groupings were less defined than the 10 distinct groups of rhizobial isolates that emerged, based on symbiotic behaviour. There was some evidence of a tendency for nodulation by the more effective strains in a competitive situation.

3805 Evaluation of *Rhizobium meliloti* strains for inoculation of annual medics, with special reference to new cultivars of *Medicago tornata* (L.) Mill.
Brockwell, J. (CSIRO, Canberra, Australia), R.R. Gault, A. Haile and V.E. Rogers.
Fld Stn Rec, CSIRO 15(2):51-61, 1976.
Cultivars 'Tornafield' and 'Murrayland' were effectively inoculated with commercial strains U45 and SU47. The latter competed well against the naturalized population.

3806 Rhizobia selection for forage legumes.
Burton, J.C.
Proc So Pasture Forage Crop Improv Conf 33rd:42-46, 1976.

3807 Nodulation studies on chickpea (*Cicer arietinum*).
Crubin, E.J. (Dept Agr, Wagga Wagga, NSW, Australia), J. Brockwell and R.R. Gault.
Aust J Exp Agr Anim Husb 17(84):126-134, 1977.
Although chickpea is highly *Rhizobium*-specific, no host-strain specificity within the species was noted in these studies. A distinct advantage in using solid inoculant applied in the row with the seed instead of seed preinoculation was found when fungicide-treated chickpea was being sown. Strains CB1189 and 1192 were considered most suitable of the 5 tried.

3808 Principles of *Rhizobium* strain selection.
Date, R.A.
In Nutman, P.S. ed., Symbiotic nitrogen fixation in plants, IBP 7:137-150, 1975.
The need for inoculation should be determined first, then selection criteria based on requirements of the locality established. Detailed information on collecting, evaluating and field testing strains is provided in this chapter. The author advocates that the responsibility for strain recommendation should lie with a central laboratory which is separate from the inoculant manufacturing groups.

3809 Antigenic differences between infective and noninfective strains of *Rhizobium trifolii*.
Dazzo, F.B. (U Florida, Gainesville, FL, USA) and D.H. Hubbell.
Appl Microbiol 30(2):172-177, 1975.
Soluble antigens detected in 4 infective strains by immunodiffusion and immunoelectrophoresis were absent in similar sonicated preparations of related noninfective mutants derived from the infective strains. The soluble antigens unique to infective strains were cross-reactive with one another. Experiments to isolate and characterize the antigens are in progress.

3810 Influence of amino acids on the competence of *Rhizobium trifolii*.
Drozanska, D. and Z. Lorkiewicz.
Acta Microbiol Pol, Ser A Microbiol Gen 5(1):27-30, 1973.

3811 Physiological comparison of effective and ineffective strains of two *Rhizobium* species.
Francis, A.J. (Cornell U, Ithaca, NY, USA) and M. Alexander.
Soil Sci 118(1):31-37, 1974.
No consistent physiological patterns were found as a correlation of effectiveness and ineffectiveness in strains of *R. trifolii* and *R. Meliloti*, nor were specific activating substances found which could promote nitrogen fixation by ineffective strains.

3812 Efficiency of *Rhizobium meliloti* strains and their effects on alfalfa cultivars.

Gasser, H. (Res Stn, Sainte-Foy, Quebec, Canada), M. Obaton and I. Sikora.
Can J Plant Sci 52(4):441-448, 1972.
An evaluation of the *Rhizobium* strain/host cultivar relation prevailing beyond first growth and under different environmental conditions.

3813 The *Rhizobium* component of the nitrogen-fixing symbiosis.
Greenwood, R.M. (DSIR, Palmerston N., N.Z.) and C.E. Pankhurst.
Proc N Z Grassl Assoc Conf 38(1):167-174, 1977.
In a pasture, legume seedlings in competition with grasses require effective nodulation for survival. Of several important hosts, only sainfoin will nodulate with rhizobia from legumes indigenous to New Zealand, but introduced clover and slow-growing lotus rhizobia are now widespread in New Zealand soils. The various cross-inoculation groups of rhizobia important to pasture legumes are described.

3814 Improved inoculation of white clover.
Hastings, A. (DSIR, Aukland, New Zealand) and D. Drake.
N Z J Agr 123(2):44-45, 1971.
New Zealand-wide field collections of rhizobia associated with clover were assembled and evaluated in an effort to locate more persistent and effective strains. Test soils ranged in pH from 5.8 to 4.6. Eleven strains were selected from 271 tested.

3815 Further tests to improve inoculation of clovers. 3. *Rhizobium*.
Hastings, A. and D. Drake.
N Z J Agr 125(3):53, 55, 1972.

3816 Variation in colony characteristics and symbiotic effectiveness of *Rhizobium*.
Herridge, D.F. (Hort Res Stn, Narara, NSW, Australia) and R.J. Roughley.
J Appl Bac 38(1):19-27, 1975.
Colony characteristics of most isolates were found to be unstable and not true-breeding. The most ineffective sub-strains were isolated from large, gummy colonies, the most effective were from pinpoint, dry colonies.

3817 Nutrient levels and rhizobial efficiency.
Iswaran, V.
Mod Agr 3(2):15-16, 1972.

3818 Mixed inoculations with effective and ineffective strains of *Rhizobium leguminosarum*.
Johnston, A.W.B. and J.E. Beringer.
J Appl Bac 40(3):375-380, 1976.
An ineffective strain was found to be more competetive than an effective strain. When mixed infections occurred, the ineffective strain influenced the pattern of nodulation.

3819 Pea root nodules containing more than one *Rhizobium* species.
Johnston, A.W.B. (John Innes Inst, Norwich, UK) and J.E. Beringer.
Nature 263(5577):502-504, 1976.

It was shown that the presence of *R. leguminosarum* in pea root nodules can allow *R. trifolii* and *R. phaseoli* to also enter the nodules. Both strains of *R. trifolii* were ineffective, but *R. phaseoli* strain 1233 was effective in reducing nitrogen. This suggests the existence of more than one barrier to effective nodulation by rhizobia of some cross-inoculation groups with legumes from another.

3820 Tolerance to crystal violet and relative effectiveness of *Rhizobium* sp. (cowpea group) and *Rhizobium meliloti* Dangeard.
Konde, B.K. (Mahatma Phule Krishi Vidyapeeth, Rahuri, India).
Ind J Microbiol 15(1):46-48, 1975.
The relative effectiveness in N fixation with *Dolichos lablab* and *Trigonella foenum graecum* of crystal violet tolerant strains was tested. Less effective strains could tolerate 1:5000 concentrations, while highly effective strains could not tolerate concentrations greater than 1:10,000.

3821 Infection ability of *Rhizobium japonicum* strains and contamination of soils. (Fre)
Lagacherie, B., R. Hugot and K. Amarger.
Inf Tech Cent Tech Int Prof Ol Metro 49:13-19, 1976.

3822 Effectiveness of cross inoculation of clover with various strains of nodular bacteria.
Lapinskas, E. B. (Lithuanian Agr Res Inst).
Microbiol 44(4):626-630, 1975.
Of five strains studied, one was more effective for 4 of 7 clover varieties; a second strain was more effective for only one variety, and two strains were more effective for 2 varieties. The fifth strain was least effective for all varieties and species tested.

3823 Response of unselected South African clovers (*Trifolium africanum* and *Trifolium burchellianum*) to inoculation with selected *Rhizobium* strains.
Law, I.J. (Plant Protec Res Inst, Pretoria, S. Africa) and B.W. Strijdom.
Phytophylactica 8(1):7-11, 1976.
The most effective strains of 19 tested were among the 15 that incited nodulation in 90% or more of the plants. The results indicate that wide spectrum strains could be used successfully for inoculation of S. African clovers.

3824 Symbiotic effectiveness of antibiotic-resistant mutants of *Rhizobium japonicum*.
Levin, R.A. (Oberlin Coll, Oberlin, OH, USA) and M.P. Montgomery.
Plant Soil 41(3):669-676, 1974.
Response to 55 antibiotics was determined. No dramatic differences in infectivity or effectiveness were found between antibiotic-sensitive strains and their resistant mutants.

3825 Isolation of effective strains of *Rhizobium phaseoli*.
Mahmoud, S.A.Z.(Ain Sham U, Cairo, Egypt), S.M. Taha and S.H. Salem.

Zentr Bak Parasit Infek ... 2 Nat 126(1):33-42, 1971.
Tests indicated that the failure of inoculated *Phaseolus vulgaris* to form effective nodules when cultivated in different localities in Egypt was due to the absence of effective strains of rhizobia. Four strains were isolated which were able to form numerous effective nodules in pot experiments and under field conditions. The best results were obtained from R_{39} which was isolated from lobed nodules on the main root.

3826 Effective and ineffective root nodules in *Myrica faya*.
Mian, S.(U Glasgow, Scotland), G. Bond and C. Rogriguez-Barrueco.
Proc R Soc London B Biol Sci 194(1116):285-293, 1976.
Nodule endophytes from the non-legume host plants *Myrica gale*, *M. cerifera*, *M. cordifolia* and *M. pilulifera* were applied separately to the roots of *Myrica faya*. All induced nodulation, and all except the inoculum from *M. gale* were effective in supplying nitrogen to the host plant. The nodules were studied by light and electron microscopy. No vesicles were found in the ineffective nodules.

3827 Factors influencing the ineffectiveness and effectiveness of *Rhizobium japonicum* on soybeans.
Miller, R.H.
Ohio Agr Res Dev Ctr Res Sum 49:31-32, 1971.

3828 Glucose catabolism in two derivatives of a *Rhizobium japonicum* strain differing in nitrogen fixing efficiency.
Mulongoy, K. (N Carolina St U, Raleigh NC, USA) and G.H. Elkan.
J Bac 131(1):179-187, 1977.
A strain characterized by greater nitrogen-fixing efficiency oxidized glucose to a greater extent than did a less efficient strain. It also utilized the Embden-Meyerhof-Parnas pathway, known as a more efficient source of energy than the Entner-Dudoroff pathway. The latter pathway apparently dominates in the less efficient strain.

3829 Symbiotic effectiveness of antibiotic-resistant mutants of fast- and slow-growing strains of *Rhizobium* nodulating *Lotus* species.
Pankhurst, C.E. (DSIR, Palmerston N, New Zealand).
Can J Microbiol 23(8):1026-1033, 1977.
Resistance to 4 inhibitors of protein synthesis was associated with little or no loss of effectiveness in either fast- or slow-growing strains, but resistance to inhibitors of nucleic acid synthesis and to inhibitors to cell-wall membrane synthesis was associated with significant loss of effectiveness in 20 to 100% of the mutants. The effectiveness of antibiotic-resistant mutants is apparently influenced by both bacterium and host plant characteristics.

3830 Differential response of gram varieties to an efficient isolate of rhizobia from gram (*Cicer arietinum* L.).
Patil, R.D. and L. Moniz.
Res J Mahatma Phule Agr U 5(1):42-46, 1974.

3831 Selection of strains of *Rhizobium japonicum* with exceptional nodule efficiency grown in culture medium with asparagine. (Por)
Pedrosa, F. de O. (Inst Bioquim da U Federal do Parana, Brasil), A.A. Franco and J. Döbereiner.
Pesqui Agropec Bras Ser Agron 7:153-163, 1972.
Exceptional strains grown for 7 to 8 days at 30°C in a liquid medium containing 400 ppm DL-asparagine were inhibited 60% more than strains grown in a medium containing 100 ppm DL-asparagine. Normal strains were inhibited much less or not at all in the higher concentration. Eleven of the 34 strains were classified as exceptional by the asparagine test. Serological tests identified 2 of the exceptional strains as having originated in Australia and 9 were related to inoculants from the U.S.A.

3832 Application of the electrochemical illumination method to study effectiveness of lupine nodule bacteria. (Rus)
Prikhod'ko, O.I., I.A.E. Doskoch, B.N. Tarusov and A.V. Manorik.
Fiziol Biokhim Kul't Rast 5(2):136-140, 1973.

3833 Nodulation of *Stylosanthes guyanensis*: prediction of *Rhizobium* effec-effectiveness response with seed isozyme patterns.
Robinson, P.J. (CSIRO Davies Lab, Townsville, Qld., Australia), R.A. Date and R.G. Megarrity.
Aust J Agr Res 27(3):381-389, 1976.
Determination of seed isozyme patterns on 49 introductions revealed 2 major groups of 28 and 21 accessions corresponding on a broad basis with accessions differentiated by effectiveness response with 22 strains of *Rhizobium*.

3834 Studies on the effect of different rhizobial strains on *Phaseolus lunatus* in sand culture.
Saono, S. (Indonesian Inst Sci, Bogor, Indonesia), H. Karsono and D. Suseno.
Ann Bogor 6(2):83-95, 1976.
P. lunatus plants were nodulated by 88 of 90 strains of rhizobia in sand under glasshouse conditions. A very significant correlation between the effectiveness of strains and symbiotic capacity (Sc) values larger than 0.33 was shown. Since no correlation was found between effectiveness and Sc values less than 0.33, it is possible to use values larger than 0.33 as a criterion for the selection of effective strains.

3835 Hydrogen evolution: a major factor affecting the efficiency of nitrogen fixation in nodulated symbionts.
Schubert, K.R. (Oregon St U, Corvallis, OR, USA) and H.J. Evans.
Proc Natl Acad Sci USA (Bot) 73(4):1207-1211, 1976.
Results indicate that the extent of hydrogen evolution during nitrogen reduction is a major factor affecting the efficiency of nitrogen fixation by many legumes. A few legumes, e.g. *Vigna sinensis*, apparently evolved mechanisms for minimizing net H production. Selection of rhizobial strains and legume cultivars which minimize H evolution may lead to improved efficiency.

3836 Comparative efficiency of different commercial inoculants of *Rhizobium japonicum* on field-grown soybeans.
Sharma, D.S. and K.V.B.R. Tilak.
Ind J Agr Res 8(4):223-226, 1974.

3837 On the activity and virulence of the nodule bacteria of beans. (Rus)
Shemakhanova, N.M. and R.R. Oleinikov.
In Novoe v Izucheni Biologicheskoi Fiksatii Azota p. 79-86, 1971.

3838 Importance of using the correct test host in assessing the effectiveness of indigenous populations of *Rhizobium trifolii*.
Sherwood, M.T. and C.L. Masterson.
Irish J Agr Res 13(1):101-108, 1974.

3839 Comparative performance of different strains of *Rhizobium* species on pigeonpea (*Cajanus cajan* (L.) Milsp.).
Simhadri, P. and K.V.B.R. Tilak.
Pantnagar J Res 1(1):26-29, 1976.

3840 Effectiveness of rhizobia from wild species of *Arachis* on the cultivated species, *Arachis hypogaea*, and their physiological characteristics.
Singh, C.S. (IARI, New Delhi, India), K.R. Dadarwal and N.S. Subba Rao.
Zentr Bak Par Infek ... 2 Nat 131(1):72-78, 1976.
The 40 strains tested showed a wide variation in their efficiency. The several efficient strains identified revealed no significant correlation between physiological properties and symbiotic efficiency.

3841 Infectivity and effectiveness of colony isolates of ineffective glycine resistant *Rhizobium meliloti* strains.
Staphorst, J.L. and B.W. Strijdom.
Phytophylactica 3(4):131-135, 1971.

3842 Criteria and methods for comparing the effectiveness of *Rhizobium* strains for pasture legumes under field conditions.
Thompson, J.A. (Agr Res Ctr, Tamworth, NSW, Australia), R.J. Roughley and D.F. Herridge.
Plant Soil 40(3):511-524, 1974.
Swards, rows and spaced plantings of 6 clover hosts with 5 rhizobial strains were evaluated by several criteria. Harvested dry matter yield per unit area was accepted as the most reliable criterion.

3843 Stability of infectivity in strains of *Rhizobium japonicum*.
Van Rensburg, H.J. and B.W. Strijdom.
Phytophylactica 3(4):125-130, 1971.

3844 Relationship between virulence and auxin production by *Rhizobium* isolates from groundnut.
Vidhyasekaran, P., K. Balaraman, M. Deiveedasundaram and G. Rangaswami.
Cur Sci 42(2):66-67, 1973.

3900 Symbiotic characteristics of *Trifolium ambiguum* seedlings grown in tube culture as affecting subsequent symbiotic vigour.
Zorin, M. (CSIRO, Canberra, Australia), J. Brockwell and W.J. Muller.
Aust J Exp Agr Anim Husb 16(83):854-862, 1976.
Data from potted plants transplanted from tube cultures led to the conclusion that the use of "within tube" symbiotic characteristics will be successful as a means of selecting symbionts only when a substantial component of the plant-to-plant variability is due to the symbiosis. A method which could be useful in selecting rhizobia for plants suited to particular environmental situations is described.

For additional information relating to these qualities of *Rhizobium*, see relevant listings under:

Inoculation effects	Nodulation
Methods & techniques	*Rhizobium* characteristics
Nitrogen fixation	Specificity & promiscuity

39. *Rhizobium* INHIBITION.

3901 Anti-rhizobial substances in soyabean seeds.
Paizah, A.W., C.K. John and W.J. Broughton.
In Seed Technol in Tropics, Natl Seed Symp 1st:91-96, 1977.

3902 Allelopathic effects of *Aristida adscensionis* on *Rhizobium*.
Murthy, M.S, (Saurashtra U, Rajkot, India) and T. Nagodra.
J Appl Ecol 14(1):279-282, 1977.
The effects of shoot, root and litter extracts were studied under laboratory conditions to assess their allelotropic activity by bioassay techniques. Root extracts were more toxic thanthose of shoots or litter, but root exudates were no more toxic. Possible buffering effects of the soil system were not determined, but inhibition of nodulation in the field is known to occur. Circumstantial evidence indicated that toxic substances produced by the grass may inhibit development of *Rhizobium*.

3903 Reversal of inhibitory effects of combined nitrogen on nodulation of lucerne (*Medicago sativa* L.) by sugars.
Pahwa, M.R. (IARI, New Delhi, India), M. Lakshmi-Kumari and N.S. Subba Rao.
Ind J Exp Biol 12(2):212-213, 1974.
Sucrose at 5-25 mg/plant and fructose at 20-25 mg/plant reversed inhibitory effects of ammonium nitrate, but not of ammonium sulphate.

3904 Effect of soil phenolics on the growth of *Rhizobium*.
Prushotheman, D. (Tamil Nadu U, Coimbature, India) and K. Balaraman.
Curr Sci 42(14):507-508, 1973.
All the extracted phenols tested *in vitro* inhibited the growth of *Rhizobium* sp. (groundnut). p-Amino benzoic acid and hydroquinone were more inhibitory than others. As lignite contains more quantities of phenolics than other soils do, it may prove toxic if used as a carrier. Peat, on the other hand, is very low in phenolics.

3905 Inhibitory analysis of the respiration of bacteroids from yellow lupine nodules.
Raikhinshtein, M.V. (A.N. Bakh Inst Biochem, USSR), S.S. Melik-Sarkisyan, G.G. Zaigraeva and V.L. Kretovich.
Microbiology 45(2):190-195, 1976.
Low concentrations of cyanide and azide strongly suppressed O_2 uptake and acetylene reduction by bacteroids. By comparing supressant and non-supressant effects of several inhibitors on the processes mentioned, the authors were able to conclude that an electron transport chain built into bacteroid membranes is coupled with phosphorylation. Under low pO_2, peroxidase and cytochrome peroxidase were detected.

3906 Soak seeds in water to avoid seed coat toxins and produce more pulses.
Sen, A.N. (IARI, New Delhi, India), K.R. Dadarwal and N.S. Subba Rao.
Ind Farming 22(3):25-26, 1972.
A procedure for washing, then soaking pulse seeds to remove toxic materials before inoculating is described.

3907 Inhibition of *Rhizobium trifolii* by yeast extracts or glycine is prevented by calcium.
Sherwood, M.T. (Agr Inst, Johnstown Castle, Wexford, Ireland).
J Gen Microbiol 71(2):351-358, 1972.
An interaction between glycine and monovalent cations was found to be the main cause of yeast extract toxicity to strains of *Rhizobium trifolii*, *R. japonicum* and *R. leguminosarum*. Addition of Ca^{2+} to inhibitory media prevented the toxicity and enhanced growth when coupled with increased concentrations of yeast extract.

See also relevant listings under:
Microorganisms (other than *Rhizobium*)
Nematodes
Nitrogen effects
Pesticides
Roots and root exudates
Temperature and climate
Water factors

40. *Rhizobium japonicum*.

4001 Isolation and characterization of streptomycin-resistant mutants in *Rhizobium japonicum*. (Por)
Alves, M.F. and Azevedo, J.L.
Summa Phytopathol 1(3):205-213, 1975.

4002 Immunofluorescent polar tips of *Rhizobium japonicum*: possible site of attachment or lectin binding.
Bohlool, B.B. (Cawthorn Inst., Nelson, New Zealand) and E.L. Schmidt.
J Bac 125(3):1188-1194, 1976.
Fluorescent antibody prepared against strains 110 and 138, and against *R. trifolii* strain TA1, cross reacted with *R. japonicum* USDA 31 only in the polar tip region at one end of the cell, but such polarity was not seen in certain other cases. A possible involvement of polar tips in specificity is discussed.

4003 Effect of various races of *Rhizobium japonicum* on the amsoy variety of soybeans. (Spa)

Chamber Perez, M.A. and M. Diaz De La Guardia.
An Inst Nac Invest Agrar, Ser Prod Veg 3:133-144, 1973.

4004 Ecological studies of root nodule bacteria introduced into field environments. 4. Symbiotic properties of *Rhizobium japonicum* and competitive success in nodulation of two *Glycine max* cultivars by effective and ineffective strains.
Diatloff, A. (DPI, Indooroopilly, Qld., Australia) and J. Brockwell.
Austr J Exp Agr Anim Husb 16:514-521, 1976.
CB1809 was ineffective with the related cultivars Hardee and Geduld, but was highly effective with cv. Hampton. CB1809 suppressed nodule formation by effective strains with Hardee, but there was no evidence that such suppression occurs in natural populations of rhizobia.

4005 P-450 hemeproteins of *Rhizobium japonicum* purification by affinity chromatography and relationship to P-450 CAM and P-450 LM-2.
Dus, K. (St. Louis U, St. Louis, MO, USA), R. Goewert, C.C. Weaver, D. Carey and C.A. Appleby.
Biochem Biophys Res Comm 69(2):437-445, 1976.
A family of soluble P-450 hemeproteins was unexpectedly found in both symbiotic and free-living *R. japonicum* cells. Immunochemical experiments tabulated cross-reactivity with antibodies, producing data supporting a closer correlation of P-450c and P-450-CAM.

4006 Symbiotic behaviour of some cultures of *Rhizobium japonicum* with soybean.
Ghai, B.S. (Punjab Agr U, Ludhaina, India), A. Sarihyan, T.P. Singh and P.S. Charaia.
Ind J Ecol 2(2):151-154, 1975.
Nodule weight and effectiveness showed high heritability values in 6 cultures tested. Infectivity and effectivity characters were positively correlated with total nitrogen per plant, a character which showed 87.7% heritability. Lower heritability rates for nodule number and dry plant weight indicate that selection might be most effectively based on nodule weight

4007 Streptomycin resistance in *Rhizobium japonicum*.
Gollobin, G.S. (Oberlin Col, Oberlin, OH, USA) and R.A. Levin.
Arch Mikrobiol 101(1):83-90. 1974.
The upper limit of resistable antibiotic concentration was determined to be between 25-50,000 micrograms/ml streptomycin. All mutants tested retained the symbiotic properties of the parental strains, which differs from reported findings in certain other rhizobial species. The relationship between the strep-resistance mechanism and possible alterations in the cell envelope is still not understood.

4008 Carbohydrate, nucleic acid, and protein composition of extracellular material from *Rhizobium japonicum*.
Kelle, B.B. (N Carolina St U, Raleigh, NC, USA), R.W. Wheat and G.H. Elkan.
J Gen Appl Microbiol 20(4):187-196, 1974.

Fractions of the extracellular material from 4 strains of *Rhizobium japonicum* with differing nodulating abilities did not differ in this analysis and could not be associated with a specific role in the nodulating process.

4009 Receptivity of different soybean varieties to *Rhizobium japonicum* nodule bacteria. (Bul)
Konova, L., L. Raicheva and L. Rainova.
Rastenievud Nauk 13(2):24-31, 1976.

4010 *Rhizobium japonicum* derivatives differing in nitorgen-fixing efficiency and carbohydrate utilization.
Kuykendall, L.D. (N Carolina St U, Raleigh, NC, USA) and G.H. Elkan.
Appl Envir Microbiol 32(4):511-519, 1976.
Four clones were isolated from morphologically different colonies grown on yeast extract-mannitol-HM salts. The two clones found to utilize D-mannitol were 5- to 10-fold less efficient in acetylene reduction. The more efficient clones were able to utilize D-arabitol.

4011 Some features of mannitol metabolism in *Rhizobium japonicum*.
Kuykendall, L.D. (N Carolina St U, Raleigh, NC, USA) and G.H. Elkan.
J Gen Microbiol 98(1):291-295, 1977.
Although the basic metabolic differences between slow-growing and fast-growing species are not clearly understood, what little is known suggests that both physiological and genetic data obtained with either *R. meliloti* or *R. trifolii* might not be applicable to *R. japonicum*. Clones derived from *R. japonicum* differed in N-fixing efficiency and exhibited a clear difference in ability to utilize D-mannitol.

4012 Studies of different strains of *Rhizobium japonicum*. (Spa)
Lopreto, C.R., L.A. Mazza and A.P. Balatti.
Rev Fac Agron U Nac Plata 51(1):49-57, 1975.

4013 Ineffective and non-nodulating mutant strains of *Rhizobium japonicum*.
Maier, R.J. (U Wisconsin, Madison, WI, USA) and W.J. Brill.
J Bac 127(2):763-769, 1976.
Five mutant strains which grew as well as wild rhizobia in a variety of media were isolated. SM1 and SM2 did not form nodules, but did reduce acetylene in the nonsymbiotic assay. Strains SM3 and SM4 produced small nodules lacking pink pigment. Mutant strain SM5 produced large pink nodules, but failed to reduce acetylene. Complementation studies showed an inactive component II in the nitrogenase.

4014 The utilization of hardly soluble phosphates by the cultures of *Rhizobium japonicum*. (Cze)
Reichlova, E.
Rostlinna Vyroba 18(2):205-208, 1972.

4015 Varietal response of soybean (*Glycine max* (L.) Merr.) to different strains of *Rhizobium japonicum*.
Rewari, R.B. (IARI, New Delhi, India), M.K. Jain and R.S. Bhatnagar.
Ind J Agr Sci 43(8):801-804, 1973.

The study showed that both strain variation and varietal specificity control the efficiency of *Rhizobium*. Maximum increase in yield by inoculation was achieved with 'Improved Pelican' with rhizobial strain USDA-b-136.

4016 Inoculation of soybeans. (Fre)
Rollier, M. and M. Obaton.
Inform Tech Cetiom (Cent Tech Interprof Oleagineux Metro) 28:1-35, 1972.

4017 Interactions between *Rhizobium japonicum* and soybean rhizosphere bacteria.
Smith, R.S. (Ohio St U, Columbus, OH, USA) and R.H. Miller.
Agron J 66(4):564-567, 1974.
Eight of nine rhizosphere bacteria isolates inhibited *R. japonicum* on agar. Nodulation was not affected, but one isolate caused severe soybean tap root injury.

4018 *Rhizobium japonicum* strains effective on nitrogen fixation with soybean S.J. 2 in Korat soil series. (Tha)
Tansiri, B., Y. Vasumat and S. Vangnai.
Kasetsart J 8(1):19-22, 1974.

4019 Comparison of colony morphology, salt tolerance, and effectiveness in *Rhizobium japonicum*.
Upchurch, R.G. (N Carolina St U, Raleigh, NC, USA) and G.H. Elkan.
Can J Microbiol 23(9):1118-1122, 1977.
Strains with 4 colony characteristics (slimy, non-slimy, large, small) were cloned and characterized as to sinsitivity to Na^+ and K^+ ions, and relative levels of symbiotic and free living nitrogen fixation. From the data, four factors appear to be correlated: increased salt sensitivity, high non-associative nitrogenase activity, high symbiotic nitrogen fixing potential, and small non-slimy colony morphology.

41. *Rhizobium trifolii*.

4101 Resistance to antibiotics in *Rhizobium trifolii* and its relation to nitrogen fixation.
Abdel-Wahab, S.M. (Cairo U, Egypt), O.M. Rifaat, K.A. Ahmed and Y.A. Hamdi.
Zentral Bak Parasit Infek ... 2 Nat 131(2):170-178, 1976.
In general, no appreciable change in efficiency is attendant with resistance to penicillin. A positive correlation between resistance to streptomycin and efficiency was found. Resistance to chloramphenicol showed no direct effect on nitrogen fixation, but some mutants became non-effective. Certain nutritional requirements were also related to antibiotic resistance.

4102 Ecological studies of root-nodule bacteria introduced into field environments. 3. Persistence of *Rhizobium trifolii* in association with white clover at high elevations.
Bunchwell, J., W.G. Bryant and R.R. Gault.
Austr J Exp Agr Anim Husb 12(57):407-413, 1972.

4103 Differences between strains of *Rhizobium trifolii* in ability to colonize soil and plant roots in the absence of their specific host plants.
Chatel, D.L. (U Western Australia, Nedlands, WA) and R.M. Greenwood.
Soil Biol Biochem 5(6):809-813, 1973.
Evidence of strain differences within *Rhizobium trifolii* in ability to colonize soil surrounding common pasture species, both legume and non-legume, in problem sandy soils in Western Australia is presented. Among species, *R. lupini* and *R. Trifolii* both spread better than *R. meliloti* in these soils.

4104 Establishment and persistence of *Rhizobium trifolii* in Western Australian soils.
Chatel, D.L. (U Western Australia, Nedlands) and W.A. Shipton.
Soil Biol Biochem 5(6):815-824, 1973.
Recent isolates of *Rhizobium trifolii* from healthy plants in problem pastures were superior to the commercial inoculants in field experiments.

4105 Comparison of nodulating and non-nodulating strains of *Rhizobium trifolii.*
MacGregor, A.N. (Cornell U, Ithaca, NY, USA) and M. Alexander.
Plant Soil 36(1):129-139, 1972.
A major distinction between a non-nodulating mutant and its nodulating parent was the inability of the mutant to grow on the roots of *Trifolium pratense*. A small quantitative difference in the antigen composition was also noted.

4106 Selection of *Rhizobium trifolii* strains by white and subterranean clovers.
Masterson, C.L. and M.T. Sherwood.
Irish J Agric Res 13(1):91-99, 1974.

4107 Plant genotypeX*Rhizobium* strain interactions in white clover.
Mytton, L.R. (Welsh Plant Br Stn, Aberystwyth, Wales).
Ann Appl Biol 80(1):103-107, 1975.
Variations in the yield of vegetative propagates from plants nodulated by rhizobia from related and unrelated plants suggested that productivity may be improved through inoculant selection.

4108 The effect of ultra violet light on the symbiotic effectiveness and some physiological characteristics of four strains of *Rhizobium trifolii.*
Russell, P.E. (U College of Wales, Aberystwyth) and D.G. Jones.
J Appl Bac 36(4):567-573, 1973.
UV induced mutants with modified acid production, generation time, polysaccharide production and symbiotic effectiveness were examined. The only significant relationship found was between effectiveness and acid production.

4109 Immunofluorescence studies of selection of strains of *Rhizobium trifolii* by S 184 white clover (*Trifolium repens* L.).
Russell, P.E. (U College of Wales, Aberystwyth) and D.G. Jones.
Plant Soil 42(1):119-129, 1975.
Acid conditions favored the effective strain. Only when the ineffective strain was present in the population 100:1 or 1000:1 were approximately equal numbers of nodules formed by both strains. These experiments provided good evidence for host plant influence in strain selection.

4110 Properties of some bacteriocins produced by *Rhizobium trifolii*.
Schwinghamer, E.A. (CSIRO, Canberra ACT, Australia).
J Gen Microbiol 91(pt 2):403-413, 1975.

Spontaneously produced bacteriocins of relatively low molecular weight, non-phage type, were categorized by various physical and physiological criteria. The possibility that such antibacterial substances may confer a competetive advantage on the producing rhizobia was discussed.

4111 Plasmid deoxyribonucleic acid in *Rhizobium trifolii*.
Zurkowski, W. (U Marie Curie-Sklodowska, Lublin, Poland) and Z. Lorkiewicz.
J Bac 128(1):481-484, 1976.

Cesium chloride-ethidium bromide centrifugation confirmed the presence of plasmid DNA which had previously been shown in *Rhizobium trifolii* by genetic methods or sedimentation analysis.

42. ROOT INFECTION [by *Rhizobium*].

4201 Scanning electron microscopy of plant roots.
Dart, P.J. (Rothamsted Exp Stn, Harpenden, Herts., England).
J Exp Bot 22(70):163-168, 1971.

Inoculated clover roots were examined and described in detail, with numerous photomicrographs of infected root hairs.

4202 Adsorption of bacteria to roots as related to host specificity in the *Rhizobium*-clover symbiosis.
Dazzo, F.B. (U Wisconsin, Madison, WI, USA), C.A. Napoli and D.H. Hubbell.
Appl & Envir Microbiol 32(1):166-171, 1976.

Adsorption of rhizobial cells was examined, using quantitative microscope techniques. Infective *Rhizobium trifolii* strains were adsorbed at a rate four to five times that of noninfective strains of the same species or of infective strains of a different species (*R. meliloti*). Attachment of the rod-shaped bacteria to root cells occurred in a polar, end-on fashion. Rhizobia pre-coated with a clover lectin had increased adsorption, but not when the lectin was inactivated by heat. Preferential adsorption through a 2-deoxyglucose-sensitive receptor site was suggested as a means of specificity expression.

4203 Receptor site on clover and alfalfa roots for *Rhizobium*.
Dazzo, F.B. (U Wisconsin, Madison, WI, USA) and W.J. Brill.
Appl Envir Microbiol 33(1):132-136, 1977.

The results of studies of the binding of fluorescein isothiocyanate-labeled capsular material from *Rhizobium trifolii* and *R. meliloti* with clover and alfalfa root hairs suggest that clover roots contain proteins which cross-link complementary polysaccharides on the surface of the root hairs and infective clover rhizobia through 2-dG-sensitive binding sites. Such binding was not prevented by 2-dG in alfalfa, in which a host-specific surface polysaccharide from *R. meliloti* was shown to bind to root hairs.

4204 Role of pectic and cellulolytic enzymes in the invasion of the soybean by *Rhizobium japonicum*.
Hunter, W.J. (North Carolina St U, Raleigh, NC, USA) and G.H. Elkan.
Can J Microbiol 21(8):1254-1258, 1975.
Exposure of soybeans to infective rhizobia did not produce increases in pectic or cellulolytic enzyme activity, suggesting that these enzymes are not involved in invasion. It is difficult to rule out such involvement until efforts to detect it at the point of infection have been made.

4205 *Rhizobium*-stimulated callose formation in clover root hairs and its relation to infection.
Kumarasinghe, R.M.K (Rothamsted Exp Stn, Harpenden, Herts., England) and P.S. Nutman.
J Exp Bot 28(105):961-976, 1977.
Inclusion or addition of IAA increased root tip callose formation in clover. The callose formation was optimal at 12°C, decreasing progressively to only slight formation at 36°. New features of callose deposits, bacterial attachment, root hair wall pegs, and modifications in the shape of the bacterial cells and its organelles were revealed in this study.

4206 Preliminary studies on the development and structure of root nodules in *Casuarina equisetifolia* L.
Kant, S. (U Rajasthan, Jaipur, India) and H.S. Narayana.
Proc Ind Acad Sci Sec B 85(1):34-41, 1977.
Infection of this non-legume occurs in the coiled region of the root hair, usually at more than one locus. A microscopic examination of the infection process and nodule development is described, with figures and plates.

4207 Root hair infection and nodulation in lucerne (*Medicago sativa* L.) as influenced by salinity and alkalinity.
Lakshmi-Kumari, M. (IARI, New Delhi, India), C.S. Singh and N.S. Subba Rao.
Plant Soil 40(2):261-268, 1974.
Increasing levels of alkalinity/ salinity resulted in a root system devoid of root hairs, mucilaginous layer or infection thread formation despite optimal growth of *Rhizobium*.

4208 Evidence for double infection within soybean nodules.
Lindemann, W.C. (U Minnesota, St. Paul, MN, USA), E.L. Schmidt and G.E. Ham.
Soil Sci 118(4):274-279, 1974.
At an inoculation density of 10^8 rhizobia /plant, using 2 strains in equal proportions, 32% of the nodules were infected by both strains. The percent double infection decreased as inoculum density decreased.

4209 Production of cellulose microfibrils by *Rhizobium*.
Napoli, C. (U Florida, Gainesville, FL, USA), F. Dazzo and D. Hubbell.
Appl Microbiol 30(1):123-131, 1975.
Cellulose microfibrils were produced by flocculating strains of *Rhizobium*, but not by nonflocculating strains. More infection threads were observed in clover root hairs in the presence of flocs than where single bacterial cells predominated.

4210 Ultrastructure of *Rhizobium*-induced infection threads in clover root hairs.
Napoli, C.A. (U Florida, Gainesville, FL, USA) and D.H. Hubbell.
Appl Microbiol 30(6):1003-1009, 1975.
Studies utilizing electron microscopy showed that the infection thread is initiated by an invagination process. An open pore is formed by the redirection of root hair wall growth at a localized point. The bacteria remain extracellular within the root hair, with no direct penetration through the wall. Includes 17 photographs and diagramatic illustrations.

4211 A correlated light and electron microscopic study of symbiotic growth and differentiation in *Pisum sativum* root nodules.
Newcomb, W. (Cabot Fndn, Harvard U, Petersham, MA, USA).
Can J Bot 54(18):2163-2186, 1976.
Invasion of cortical cells by the infection thread, structure of the thread, and release of bacteria from it into the host cytoplasm with subsequent symbiotic growth and differentiation are described in detail. Light microscopic observations of morphogenesis are correlated with fine structure electron microscopic observations. Ambiguity of the term "vesicle" is discussed, and restrictions in its use are proposed. The morphogenetic significance of the loss of the nodule meristem is discussed. Numerous micrographs accompany this paper.

4212 Invasion of soybean root cells in culture by *Rhizobium japonicum*.
Raveed, D. (C.F. Kettering Res Lab, Yellow Springs, OH, USA), M. Reporter and G. Norris.
Proc Electron Micro Soc Amer 33:582-583, 1975.
The effect of rhizobial invasion on the morphology of the root cells was studied. Three types of deformation were observed: elongated thin walled cells, which appeared to act as passageways for the rhizobia; a wall folding of the elongated cells which resembled stoma-like structures; and degeneration of soy cell walls for bacterial invasion. Four micrographs record the process.

4213 Binding of *Rhizobium japonicum* to cultured soybean root cells: morphological evidence.
Reporter, M. (C.F. Kettering Res Lab, Yellow Springs, OH, USA), D. Raveed and G. Norris.
Plant Sci 5:73-76, 1975.
A filamentous material was secreted by compatable root cells exposed to rhizobia. The binding of the bacteria by this material may involve a pectic material containing some form of polygalacturonic acid.

4214 Characterization of the substances causing deformation of root hairs of *Trifolium repens* when inoculated with *Rhizobium trifolii*.
Solheim, B. (U Bergen, Norway) and J. Raa.
J Gen Microbiol 77(2):241-247, 1973.
Two factors able to cause deformation of root hairs were identified. One had properties of a nucleic acid and the other of either a protein or polysaccharide. The factors were stabilized by attachment to a component formed by clover roots. Distinct points of deformity indicated the possibility of specific receptor sites containing the stabilizing host component.

4215 Method of detecting infectious filaments in root hairs of legumes inoculated by nodule bacteria. (Rus)
Shil'nikova, V.K.
Dokl Timiriazevsk S-Kh Akad 208:161-162, 1975.

4216 The establishment of nodule bacteria in the rhizosphere of clover during the initial stages of infection. (Rus)
Shil'nikova, V.K.
Izv Timiriazevsk S-Kh Akad 6:19-29, 1975.

4217 Rhizobia in plant tissue cultures. I. Investigation of the infection of plant cells by rhizobia *in vitro*. (Ger)
Stenz, E.
Zentr Bak Parasit Infek ... 2 Nat 126(2):142-150, 1971.

4218 Cytoplasmic changes during and after infection of soybean root nodule cells with rhizobia.
Tu, J.C. (U Alberta, Edmonton, Ata., Canada).
Phytopathol 66(9):1065-1071, 1976.
Root cortical cells showed an increase in ribosomes and extension of the endoplasmic reticulum. An increase in dictyosome activity during early infection may be attributed to stimulated production of cell wall materials. The dictyosomes were arranged in a long chain between the bacteroids and the interior nucleus of the root cortical cells. Electron micrographs show infection thread invasion through bacteroid deposition.

4219 Factors responsible for the curling and branching of clover root hairs by *Rhizobium*.
Yao, P.Y. (U New South Wales, Kensington, NSW, Australia) and J.M. Vincent.
Plant Soil 45(1):1-16, 1976.
A factor (or factors) readily extracted from *Rhizobium trifolii* cells caused branching of clover root hairs. The branching response could not be attributed to polysaccharides or indole acetic acid from the dried residue of active filtrate. Reducing the inoculum to less than one microcolony per root hair significantly reduced the curling response, but had a much slighter effect on branching. It was concluded that root hair branching can be caused by an extremely diffusible product of rhizobial growth which is apparently absent in non-invasive mutants.

Additional references with information on the infection process may be found in relevant listings under Nodulation.

43. ROOTS & ROOT EXUDATES.

4301 Chemotaxis of *Rhizobium* spp. to plant root exudates.
Currier, W.W. (Montana St U, Bozeman, MT, USA) and G.A. Strobel.
Plant Physiol 57(5):820-823, 1976.
Both legume and non-legume root exudates attracted the 6 rhizobial strains studied, but to differing degrees. Peas, beans and 2 vetches were not nodulated by the *R. meliloti*, *R. japonicum* or cowpea strains used in the

study. Alfalfa was the least specific of the 6 legumes that did nodulate, while birdsfoot trefoil showed the greatest specificity. The nodules formed on sainfoin and 3 clovers failed to reduce acetylene.

4302 Chemotaxis of *Rhizobium* spp. to a glycoprotein produced by birdsfoot trefoil roots.
Currier, W.W. (Montana St U, Bozeman, MT, USA) and G.A. Strobel.
Science 196(4288):434-436, 1977.
A glycoprotein containing twice as much protein as carbohydrate attracted strains of rhizobia at micromolar concentrations. The substance represents a new class of bacterial chemoattractants.

4303 The growth of *Rhizobium leguminosarum* on the root surface and in the rhizosphere of pea seedlings in relation to root exudates.
Egeraat, A.W.S.M. Van (Agr U, Wageningen, The Netherlands).
Plant Soil 42(2):367-379, 1975.
A distinct zone of bacterial growth near the roots of a number of legumes was not observed in the case of pea seedlings. A zone of bacterial growth at some distance from the lateral roots of pea seedlings was observed.

4304 Interaction between plant roots and soil microorganisms. (Dut)
Egeraat, A.W.S.M. Van
Landbouwkd Tijdschr 88(9):286-293, 1976.

4305 Swelling forms on roots of berseem clover *(Trifolium alexandrinum)* caused by a strain of *Rhizobium trifolii*.
Hamdi, Y.A. (Inst Soils & Water, Orman, Giza, U.A.R.).
Zentralb Bak Parasit Infek ... 2 Nat 128:532-537, 1973.
Strain NA 30 developed irregular swelling forms on berseem roots, but nodulated only a few plants. The exact cause was not determined, but avenues for further inquiry were suggested.

4306 Plant roots and biological nitrogen fixation.
Hubbell, D.H. (U Florida, Gainesville, FL, USA).
Proc Soil Crop Soc Fla 36:37-40, 1977.
The benefits to plants from symbiotic and asymbiotic biological nitrogen fixation (BNF) are briefly reviewed in this paper. The necessity for greater exploitation of BNF under present world energy conditions is discussed.

4307 Formation of tumor-like structure on legume roots by *Rhizobium*.
MacGregor, A.N. (Cornell U, Ithaca, NY, USA) and M. Alexander.
J Bac 105(3):728-732, 1971.
Tumorogenic strains of rhizobia were isolated and studied. Rhizobia which could nodulate legumes of one cross-inoculation group were tumorogenic on some other groups. A non-nodulating strain of *Rhizobium trifolii* was able to form the aberrant structures on its homologous host as well as on species from other genera. Large numbers of the tumor-like structures were regularly found on *Alyiscarpus vaginalis*, a member of the promiscuous cowpea cross-inoculation group.

4308 The effect of cycloheximide on absorption of ions by bean (*Phaseolus vulgaris* L.) roots.
Nassery, H. (Pahlavi U, Shiraz, Iran) and F. Didehvar.
Ann Bot 40:43-48, 1976.
Cycloheximide, an inhibitor of protein synthesis, inhibited root elongation by about 22% and inhibited salt uptake to a much greater extent. Evidence suggested that the inhibitor is unlikely to have exerted its effect through uncoupling action.

4309 Studies on the infection of legume root callus with *Rhizobium*.
Ranga Rao, V. (Sri Venkateswara Coll, New Delhi U, India) and N.S. Subba Rao.
Z Pflanzenphysiol 80(1):14-20, 1976.
Measurable nitrogenase activity was detected when inoculated root calli of *Arachis*, *Cajanus* and *Cicer* species were tested. Observed infection of the root cells indicated the possibility of symbiosis in inoculated legume root calli. Intense bacterial growth around the callus mass raised the possibility that the calli produce stimulatory exudates such as those known to be produced by legume roots.

4310 Root exudation in relation to inoculation with rhizobia.
Rao, A.V. (Coll of Agr, Solan, H.P., India).
Zentr Bak Parasit Infek ... 2 Nat 131(1):79-82, 1976.
Inoculation caused an increase in exudation of non-reducing sugars, ortho-dihydroxy phenols, amino-nitrogen, polygalacturonase, and pectin methyl esterase. There was a decrease in reducing sugars and total phenols. Homologous rhizobia caused a higher increase in amino-nitrogen exudation than did heterologous rhizobia.

4311 Biochemical changes in the roots of legumes upon inoculation with *Rhizobium*.
Rao, A.V. (IARI, New Delhi, India) and V. Iswaran.
Zentr Bak Parasit Infek ... 2 Nat 131(1):83-90. 1976.
Biochemical changes parallel to those observed in plant-parasite interactions were produced by inoculation with homologous and heterologous rhizobia. The possible role in specificity was recognized.

4312 Inhibition of *Rhizobium in vitro* by non-nodulating legume roots and root extracts.
Rao, V.R. (U Delhi, Delhi, India), N.S. Subba Rao and K.G. Mukerji.
Plant Soil 39(2):449-452, 1973.
The inhibition of rhizobia by non-nodulating legume roots was confirmed *in vitro* with root extracts. Clear inhibition zones were seen around the roots of *Cassia fistula*. The degree of inhibition differed with plant and bacterial species.

See also relevant listings under Specificity for additional references with information on Roots & Root Exudates.

44. SOIL FACTORS.

4401 Influence of soil organic matter on cowpea's response to N fertilizer.
Agboola, A.A. (U Ibadan, Nigeria).
Agron J 70(1):25-28, 1978.
The treatment that produced the highest yield fixed the lowest nitrogen. In soils having less than 2% O.M., it was concluded that starter N should be applied no later than 2 weeks after planting to enhance nodulation.

4402 Effects of some soil amendments on plant growth, survuval and yield of dry beans (*Phaseolus vulgaris* L.) in relation to sodium toxicity.
Ayoub, A.T. (Hudieba Res Stn, Ed-Damer, Sudan).
J Agr Sci(Cambridge) 85:471-475, 1975.
Gypsum and straw mulch increased nodulation and bean tolerance to salininty. Seed yield was increased about 30% with gypsum, 50% with straw mulch, and 100% with the two in combination. The increased number of plants surviving under saline conditions was the principal factor affecting seed yield/ha. Animal manure depressed nodulation.

4403 A note on the effect of salinity on symbiosis between *Rhizobium trifolii* and Berseem *(Trifolium alexandrinum)* crops.
Bajpai, B.D., B.R. Gupta and C. Singh.
J Ind Soc Soil Sci 22(4):375-376, 1974.

4404 Studies on the exploitation of rhizobial potentiality for berseem (*Trifolium alexandrinum* L.) under saline-alkali soils.
Bajpai. P.D. (C.S. Azad U Agr & Technol, Kanpur, U.P., India) and B.R. Gupta.
J Ind Soc Soil Sci 25(1):62-68, 1977.
The greatest inoculation effect was achieved by pelleting with gypsum. Either pelleting or soil amendment was required for any response to inoculation in high salani-alkali soil, but in medium saline-alkali soil (pH 8.9 and ESP 25.4) inoculation alone was effective.

4405 Nodulation and nitrogen fixation in chickpea (*Cicer arietinum* L.) under salt stress.
Balasubramanian, V. (Water Technol Ctr, IARI, New Delhi, India) and S.K. Sinha.
J Agr Sci (Cambridge) 87(pt. 3):465-466, 1976.
Growth, N accumulation and N fixing efficiency were adversely affected by salt stress during the vegetative stage. Existing nodules on larger plants became enlarged when the plants were stressed. It was concluded that the reduced plant vigour, which was the primary effect of salt stress, was mediated through processes other than symbiotic nitrogen fixation.

4406 Effects of salt stress on growth, nodulation and nitrogen fixation in cowpea nad mung beans.
Balasubramanian, V. (IARI, New Delhi, India) and S.K. Sinha.
Physiol Plant 36:197-200, 1976.
NaCl treatments to produce electrical conductivity of 3.0, 6.0 and 15.0 mmhos/cm were commenced on the third day of emergence of inoculated mung and cowpea sown in sand. Apparently, nodule initiation, but not further development, was affected by salt stress. N fixation by cowpea was less sensitive to salt stress than was that of mung bean.

4407 The effect of clay minerals in the soil on nitrogen fixation. (Bul)
Bekhar, A. and T. Mineva.
Pochvozn Agrokhim 9(2):25-35, 1974.

4408 The effect of clay minerals on nitrogen fixation. II. The effect of concentrations and hydrogen-ion solutions and temperatures on additional nitrogen fixation. (Bul)
Bekhar, A. and T. Mineva.
Pochvozn Agrokhim 9(4):13-22, 1974.

4409 Effect of soil factors on the distribution of *Rhizobium japonicum* serogroups.
Bezdicek, D.F. (U Maryland, College Park, MD, USA).
Soil Sci Soc Amer Proc 36(2):305-307, 1972.
Nodule samples from soybean plants at 19 sites on the Maryland peninsula were used to establish serological relationships of rhizobia. These were then correlated with soil types and conditions.

4410 Note on the growth of *Rhizobium* strains of dhaincha (*Sesbania cannibina* (Retz.) Pers.) in a saline-alkali soil.
Bhardwaj, K.K.R. (Centr Soil Salinity Res Inst, Karnal, India).
Ind J Agr Sci 42(5):432-433, 1972.
When dhaincha is grown to reclaim saline and alkali soils, the rhizobial strains of normal soils cannot be used effectively. Amendments of gypsum and farmyard manure offer some help, but more tolerant strains of rhizobia should be sought. In these preliminary studies, one strain selected from saline-sodic soil did significantly better than those from normal soils.

4411 Note on the occurrence of pigmented strains of *Rhizobium* in saline-alkali soils.
Bhardwaj, K.K.R. (Centr Soil Salinity Res Inst, Karnal, India).
Ind J Agr Sci 42(10):963-964, 1972.
Red, orange and yellow strains of rhizobia were found associated with 4 leguminous crops grown in saline-alkali soils. A possible relationship between pigmentation and salt tolerance was suggested.

4412 Growth and symbiotic effectiveness of indigenous *Rhizobium* species of a saline-alkali soil.
Bhardwaj, K.K.R. (Centr Soil Salinity Res Inst, Karnal, India).
Proc Ind Natl Sci Acad Pt B Biol Sci 40(5):540-543, 1974.
Indigenous rhizobia produced good nodulation in Indian clover and *Sesbania aculeata*, poor in berseem, very poor in guar and cowpea, and extremely poor in lentil. No nodulation was observed in pea. Application of gypsum and farmyard manure to the highly saline-alkaline soil had a marked stimulatory effect upon the numbers of rhizobia.

4413 The effect of long term straw and green manuring fertilizing on the factors of soil fertility. I. Dehydrogenase activity of soils. (Ger)
Bogulawski, E. Von, F. Zadrazil and J. Debruck.
Z Acker Pflanzenbau 143(4):249-258, 1976.

4414 The effect of long term straw treatment and green manuring fertilizing on factors of soil fertility. II. Physical soil properties.
Bogulawski, E. Von, F. Zadrazil and J. Debruck.
Z Acker Pflanzenbau 143(4):259-269, 1976.

4415 The effect of lime and two strains of *Rhizobium* on ten genetically distinct lines of lucerne.
Bray, R.A. (CSIRO Cunningham Lab, St. Lucia, Qld., Australia).
Austr J Exp Agr Anim Husb 11(50):290-294, 1971.
Problems associated with Al and Mn toxicity, Ca deficiency, low pH and lack of effective nodulation have made the establishment of lucerne difficult in acid soils. The variation between lines of lucerne in response to low levels of added lime, being under genetic control, should make it possible to develop selections with good response to the lower applications. There was no apparent superiority of an alkali producing strain of rhizobia over a commonly used strain.

4416 Studies on the nodulation of *Stylosanthes guyanensis* Aubl. I. Effect of added organic matter in four types of Malaysian soil.
Chandapillai, M.M.
Trop Agr (Trinidad) 49(3):205-213, 1972.

4417 Inhibition of rhizobia by toxic soil-water extracts.
Chatel, D.L. (U Western Australia, Nedlands, WA) and C.A. Parker.
Soil Biol Biochem 4(3):289-294, 1972.
Because some toxins inhibiting nodulation are transitory, an effort was made to identify their probable biological origin. Filtered broths from pure cultures of 59 soil micro-organisms isolated from problem soils and roots were tested for their effect on *Rhizobium lupini* and *R. Trifolii*. Nine inhibited both species, 19 inhibited *R. trifolii* only, and 31 had no inhibitory effect on either species. It was not determined whether these toxins were identifiable with the potent soil-water extracts which also inhibited *R. trifolii* in seeded agar plates.

4418 Effect of lime and *Rhizobium* strains on the growth and yield of soybean (*Glycine Max* (L.) Merr.).
Chatterjee, B.N. (U Kalyani, India), B. Roy, S. Maiti and M.A. Roquib.
Ind J Agr Sci 42(2):130-134, 1972,
Field experiments in leached sandyloam, alluvial and slightly acid soils revealed differences in grain yield due to *Rhizobium* strains, and that liming helped in increasing grain yield, dry matter accumulation, nodulation and N, P and Ca contents in plants. High doses of N reduced nodulation but increased the yield, as did liming. The effects of lime and rhizobial strain persisted in soils for 3 years.

4419 Problems of the ecology of nodule bacteria in relation to soil characteristics and symbiotic legume host. (Rus)
Dorosinskii, L.M.
USP Mikrobiol 10:201-213, 1975.

4420 Influence of the type of soil as well as its characteristic features on the occurrence of *Rhizobium meliloti*. (Slo)
Haban, L.
Vysk Ustav Rast Vyroby Ved Pr 9:119-130, 1971.

4421 Influence of soil type on the fixing activity and virulence of *Rhizobium meliloti*. (Slo)
Haban, L.
Vysk Ustav Rast Vyroby Ved Pr 10:137-144, 1972.

4422 Effect of improving certain salt affected soils of the Nile delta on the nodule formation and growth of broad bean and cowpea plants. (Hun)
Ibrahim, A.N. and M.S. Khadr.
Agrokem Talajtar 23:111-120, 1974.

4423 Acclimation of *Rhizobium* to salts, increasing temperature and acidity.
Mendez-Castro, F.A.(Cornell U, Ithaca, NY, USA) and M. Alexander.
Rev Latinoamerica Microbiol 18(3):155-158, 1976.
Both *Rhizobium japonicum* and *R. meliloti* populations proved able to adapt to increasing levels of NaCl and K_2SO_4 but showed only slight adaptation to high temperature and low pH.

4424 Investigations on dhaincha *(Sesbania aculeata)* cultivation for seed on saline-alkali soils.
Misra, P.N. and B. Singh.
Ind J Agr Res 10(4):238-240, 1976.

4425 Comparative lime requirements of tropical and temperate legumes.
Munns, D.N. (U California, Davis, CA, USA) and R.L. Fox.
Plant Soil 46:533-548, 1977.
Inoculated legumes representing 18 species and varieties were grown in N deficient soil in pH gradients from 4.7 to 7.1. Lime reaponse curves showed no distinct general difference between tropical and temperate legumes. Lime requirements in Hawaiian Oxisol for 90% of maximum attained yield ranged from 16 tons/ha for *Coronilla varia* down to 0.1 ton/ha lime for *Stylosanthes guyanensis*. Magnitudes of yield increase due to lime ranged from 20 fold down to less than 50%.

4426 Effect of nitrogen fixationby legumes on soil acidity.
Nyatsanga, T. and W.H. Pierre.
Agron J 65(6):936-940, 1973.
Under intensive cropping in the greenhouse, the amount of N fixed by alfalfa and soybeans was sufficient to lower the pH by more than 1.0 unit. The acidity produced by N fixation may have been important in soil genesis and development.

4427 Effect of pH on the growth, nodulation and nitrogen fixation of *Centrosema pubescens* and *Stylosanthes gracilis*.
Odu, C.T.I., A.A. Fayemi and J.A. Ogunwale.
J Sci Food Agr 22(2):57-59, 1971.

4428 Soil acidity and liming in the humid tropics.
Pearson, R.W. (Cornell U, Ithaca, NY, USA).
Cornell Internat'l Agr Bull 30:66 p., 1975.
A review of the available results of liming trials to determine information useful in soil management systems for tropical areas. Under crop response to lime, there are subsections on soybeans, beans, peanuts and forage legumes with information on N fixation effects. Soil properties affecting rhizobia are also discussed.

4429 The effect of lime and *Rhizobium* strain on the nodulation of *Glycine wightii* and *Macroptilium atropurpureum* on acid soils.
Philpotts, H.(Agr Res Ctr, Wollongbar, N.S.W., Australia).
Trop Grassl 9(1):37-43, 1975.
Glycine benefited from lime and superphosphate, but Siratro was not influenced. The *Glycine* showed signs of Mn toxification, but Siratro was more resistant. A better inoculant strain than QA922 is needed for unfavorable soils.

4430 Salt tolerance of *Rhizobium* from *Dolichos lablab*.
Pillai, R.N. (IARI, New Delhi) and A. Sen.
Zentralb Bak Parasit Infek ... 2 Nat 128:538-542, 1973.
Optimum and lethal levels of NaCl were determined for 6 strains of *Rhizobium* of *Dolichos lablab*. Unlike *Rhizobium trifolii* from berseem, the strains from *Dolichos* were salt tolerant to a remarkable extent (3.19 to 3.58%) and required a fair amount of salt (0.71-1.20%) for good growth.

4431 Effects of soil acidity on rhizobia numbers, nodulation and nitrogen fixation by alfalfa and red clover.
Rice, W.A. (Res Stn, Beaverlodge, Ata., Canada), D.C. Penney and N. Nyborg.
Can J Soil Sci 57:197-203, 1977.
Rhizobium meliloti numbers and nodulation scores decreased sharply as the soil pH decreased below 6.0, but *R. trifolii* showed little effect down to pH 5.0. Predicting crop response to lime requires consideration of soil pH as well as plant-available Al and Mn.

4432 Biological activity of soil and symbiosis of nodule bacteria with legumes under different agrotechnical methods. (Ukr).
Nko, V.I. and L.M. Chechel'nyts'ka.
Mikrobiol Zhur 33(6):724-726, 1971.

4433 Comparative salt tolerance of some tropical and temperate legumes and tropical grasses.
Russell, J.S. (CSIRO Cunningham Lab, St. Lucia, Qld., Australia).
Austr J Exp Agr Anim Husb 16:103-109, 1976.
Alfalfa was the most tolerant legume in both tropical and temperate groups. *Macroptilium atropurpureum* was almost equivalent to *Medicago sativa*, while the least tolerant tropical legume was *Desmodium uncinatum*.

4434 Stabilization of newly formed amino acid metabolites in soil by clay minerals.

Sorenson, L.H.
Soil Sci 114:5-11, 1972.

4435 Nodulation of lucerne (*Medico sativa* L.) under the influence of sodium chloride.
Subba Rao, N.S. (IARI, New Delhi, India), M. Lakshmi-Kumari, C.S. Singh and S.P. Magu.
Ind J Agr Sci 42(5):384-386, 1972.
Although strains of *Rhizobium meliloti* nodulating *Medicago sativa* could tolerate NaCl up to 3.0%, seeds of the host plant did not germinate even at 1.5%. At 0.4% NaCl, initial nodulation was delayed, and the numbers of nodules and roots reduced. At 0.7% the plants failed to nodulate, indicating that the symbiosis inhibiting levels of sodium chloride are different from those of the individual symbionts.

4436 Salinity and alkalinity in relation to legume-*Rhizobium* symbiosis.
Subba Rao, N.S. (IARI, New Delhi, India), M. Lakshmi-kumari, C.S. Singh and A. Biswas.
Proc Ind Natl Sci Acad Pt B Biol Sci 40(5):544-547, 1974.
Seeds of lucerne could not germinate beyond 1.5% NaCl levels, but the microsymbiont could tolerate levels up to 3%. Nodulation was inhibited beyond 0.7%. Tolerance thresholds for carbonate and bicarbonate were much lower, with inhibition of nodulation at 0.1 to 0.2%, although the individual symbionts had higher tolerance levels.

4437 The effect of soil type on the establishment, early growth and nodulation of *Glycine wightii*.
Thomas, D. (U of Queensland, St. Lucia, Qld., Australia) and P.C. Whitman.
Austr J Exp Agr Anim Husb 11(52):513-520. 1971.
Seedling emergence and establishment, growth rates and nodulation were compared in glasshouse experiments on a range of soil types. Black earth and alluvium provided more rapid establishment than did red soils of volcanic origin.

4438 Response of root-nodule rhizobia to saline, alkaline and acid conditions.
Yadav, N.K. (Haryana Agr U, Hissar, India) and S.R. Vyas.
Ind J Agr Sci 41(10):875-881, 1971.
Medicago sativa, Phaseolus mungo, P. Aureus, P. aconitifolius and *Pisum sativum* were tested for sensitivity to various salts and pH levels. Both salt sensitive (0.2%) and salt resistant (3%) strains of lucerne and pea were present. Black-gram and moth-bean strains were proportionately sensitive to Cl and SO_4 of Na^+ and K^+, but green-gram *(P. aureus)* was stable. Mg^{++} salts were stimulatory at concentrations lower than 1%. For all rhizobia. 0.4-0.6% $NaHCO_3$ was critical. All the plant strains survived at pH 10.0, but were inhibited at 3.5. Rhizobial strains of lucerne were more acid-sensitive (pH 4.5-5.0) than microsymbionts of the other legumes.

4439 Note on the response of root-nodule rhizobia to saline, alkaline and acid conditions.
Yadav, N.K. (Haryana Agr U, Hissar, India) and S.R. Vyas.
Ind J Agr Sci 41(12):1123-1125, 1971.
Optimum pH for rhizobia is neutral or slightly alkaline, but species and

strains are differently sensitive to acidity. Data on optimal, tolerant, sensitive and inhibited categories for rhizobial strains associated with *Sesbania*, *Crotolaria* and *Glycine* spp. were tabulated.

4440 Salt and pH tolerance of rhizobia.
Yadav, N.K. (Haryana Agr U, Hissar, India) and S.R. Vyas.
Folia Microbiol 18(3):242-247, 1973.
Rhizobium strains specific for *Sesbania cannabina*, *Crotolaria juncea* and *Glycine max* were studied for tolerance to pH and to various salts. No strains were inhibited by pH 10.0, but all were sensitive to acidity (pH 3.5-4.0). Of the salts, chlorides were more toxic than sulphates of Na, K and Mg. $NaHCO_3$ was lethal at 0.2-0.8%.

45. SPECIFICITY & PROMISCUITY.

4501 Specificity of *Rhizobium* spp. in nodulation and fixation of nitrogen in beans *(Phaseolus vulgaris)*. (Spa)
Avila Lozano, R.
Zulia Venez Univ Fac Agron Rev 1(4):51-66, 1971.

4502 Studies of tree legumes. I. Nodulation pattern and characterization of the symbiont.
Basak, M.K. (IARI, New Delhi, India) and S.K. Goyal.
Ann Arid Zone Res Assoc India 14(4):367-370, 1975.
Rhizobia isolated from 5 representatives of the genera *Acacia*, *Albizzia* and *Prosopis* were characterized and their nodulation patterns described. All were akin to the cowpea group in their properties. Cross-inoculation patterns showed *Acacia trotilis* bacteria as having the greatest specificity. The trees studied are increasingly important as "shelter belts" to check desert erosion. Their responsiveness to inoculation was noted.

4503 Lectins: a possible basis for specificity in the *Rhizobium*- legume root nodule symbiosis.
Bohlool, B.B. (U Minnesota, Minneapolis, MN, USA) and E.L. Schmidt.
Science 185:269-271, 1974.
The specificity may be accounted for by an interaction between legume lectins and *Rhizobium* cells. Labeled lectin combined with 22 of 25 strains of soybean-nodulating rhizobia, but did not bind with 23 strains that do not nodulate soybean.

4504 Advances in *Rhizobium* specificity and its significance to forage legume breeding.
Burton, J.C. (Nitragin Co., Milwaukee, WI, USA).
Proc So Pasture Forage Crop Improv Conf 32d:57-67, 1976.
The postulate that the plant is the major controlling factor in symbiotic N_2 fixation may be true in the case of grain legumes, but is less convincing with forage legumes due to their longer growing season and comparatively lower seed yield. The matching of rhizobia to cultivars requires correlation of the efforts of *Rhizobium* workers with that of plant breeders and agronomists.

4505 Attachment of *Rhizobium* to legume roots as the basis for specific interactions.
Chen, A-P. T. (Indiana St U, Terre Haute, IN, USA) and D.A. Phillips.
Physiol Plant 38(2):83-88, 1976.
When rhizobia specific for a variety of legumes were exposed to pea roots, *Rhizobium leguminosarum* did not attach to the roots in greater numbers than did those strains incapable of infecting the plant. A quantitative study of interactions between lectins and rhizobia revealed no relationship between lectin-*Rhizobium* interactions, suggesting that simple attachment to root hair tips is not the basis of host-symbiont specificity.

4506 Varietal specificity for rhizobial serotypes in relation to nodulation and crop yield.
Dadarwal, K.R. (IARI, New Delhi, India) and A.N. Sen.
Proc Ind Natl Sci Acad Pt B Biol Sci 40(5):548-553, 1974.
Nodule number and efficiency varied with the genotype of the host species. Nodule bacteroids showed homology for somatic antigens with cultured rhizobia but differed in internal antigen bands, indicating that the internal antigens might undergo modifications during the transformation to the bacteroid form.

4507 Serology and host range infectivity of 'cowpea group' rhizobia.
Dadarwal, K.R., S. Prabha, P. Tauro and N.S. Subba Rao.
Ind J Exp Biol 15(6):462-465, 1977.

4508 Cross-reactive antigens and lectin as determinants of symbiotic specificity in the *Rhizobium*-clover association.
Dazzo, F.B. (U Florida, Gainesville, FL, USA) and D.H. Hubbell.
Appl Microbiol 30(6):1017-1033, 1975.
Clover lectin capable of binding to the cross-reactive antigen and agglutinating only infective cells of *Rhizobium trifolii* was extracted from white clover seeds. The most probable haptenic determinant of the cross-reactive capsular antigen capable of binding to the root antiserum and the clover lectin was found to be 2-deoxyglucose. The mechanism for preferential adsorption of infective *R. trifolii* cells is suggested in a proposed model.

4509 Concanavalin A: lack of correlation between binding to *Rhizobium* and specificity in the *Rhizobium*-legume symbiosis.
Dazzo, F.B. (U Florida, Gainesville, FL, USA) and D.H. Hubbell.
Plant Soil 43(3):713-717, 1975.
A lectin from jackbean combined strongly with various nodulating and non-nodulating strains of *Rhizobium* regardless of their respective hosts. The interactions between host lectins and rhizobial cells may not always account for host/bacteria specificity.

4510 The possible role of homoserine in the development of *Rhizobium leguminosarum* in the rhizosphere of pea seedlings.
Egeraat, A.W.S.M. Van (Agr U, Wageningen, The Netherlands).
With homoserine as the only source of N and C, *Rhizobium leguminosarum* grew well while other species of rhizobia showed little or no growth. The possible role of homoserine in selective stimulation is described.

4511 Cross-inoculation relationships of *Psophocarpus tetragonolobus* and its *Rhizobium* with other legumes and rhizobia.
Elmes, R.P.T. (Dept Primary Indus, Papua New Guinea).

Papua New Guinea Agr J 27(3):53-57, 1976.
Results of inoculation of winged bean with 6 cross-inoculation groups of rhizobia, and of legumes from 5 cross-inoculation groups by a rhizobial isolate from winged bean show that this legume belongs to the cowpea cross-inoculation miscellany and is relatively promiscuous. CB756 is the suggested inoculant.

4512 Promiscuity in groundnut *Rhizobium* association.
Gaur, Y.D. (IARI, New Delhi, India), A.N. Sen and N.S. Subba Rao.
Zentr Bak Paras Infek ... 2 Nat 129:369-372, 1974.
The existence of "double promiscuity" in the groundnut-*Rhizobium* symbiosis is reflected by the nodulation of groundnuts by rhizobia isolated from other legumes, and likewise by the nodulation of several species of indigenous legumes by rhizobia from groundnut root nodules.

4513 The application of immunofluorescence techniques to host plant/nodule bacteria selectivity experiments using *Trifolium repens*.
Jones, D.G. (U Coll of Wales, Aberystwyth, Wales) and P.E. Russell.
Soil Biol Biochem 4(3):277-282, 1972.
The fact that individual plants exerted selection from specific bacterial strains, but not always for the same strain, was clearly demonstrated. The potential of immunofluorescent techniques for ecological, strain competition and host selectivity experiments is discussed.

4514 Some observations on plant lectins and *Rhizobium* specificity.
Law, I.J. (Plant Prod Res Inst, Pretoria, S. Africa) and B.W. Strijdom.
Soil Biol Biochem 9(2):79-84, 1977.
Lectins from legume species of 5 genera were studied for their ability to bind with strains of various rhizobia species. Six out of ten strains of *R. phaseoli* and two of ten strains of *R. japonicum* were able to bind lectin from their normal host plants, but all others were not. The results do not support suggestions of a role for lectins in specificity.

4515 On the host specificity of nodule bacteria. (Rus)
Nariiskaia, A.N.
USP Mikrobiol 10:189-200, 1975.

4516 Effect of some specific and nonspecific strains of nodule bacteria on growth of clover, alfalfa and soybeans. (Rus)
Parsim, E. and R. Kooli.
Akad Nauk Est SSR Izv Ser Biol 21(1):20-27, 1972.

4517 Variation in the selection of *Rhizobium trifolii* by varieties of red and white clover.
Russell, P.E. (U Coll of Wales, Aberystwyth, Wales) and D.G. Jones.
Soil Biol Biochem 7(1):15-18, 1975.
The specificity shown between rhizobial strains and varieties of clover points up the need to determine that all varieties are covered by a compatible strain when clover mixtures are inoculated.

4518 Note on the specificity of the rhizobia of crownvetch and sainfoin.
Schreven, D.A. Van.
Plant Soil 36(2):325-330, 1972.

4519 Evidence countering the theory of specific induction of pectin-degrading enzymes as basis for specificity in *Rhizobium*-Leguminosae associations.
Solheim, B. (U Bergen, Norway) and J. Raa.
Plant Soil 35(2):275-280, 1971.
Significant levels of pectinase were not produced by *Trifolium repens* or *Medicago sativa* whether inoculated with infective or non-infective strains of *Rhizobium*. The possibility of contamination by saprophytic fungi which produce high levels of pectin degrading enzymes is raised.

4520 Host-symbiont interactions. I. The lectins of legumes intaract with O-antigen-containing lipopolysaccharides of their symbiont rhizobia.
Wolpert, J.S. (U Colorado, Boulder, CO, USA) and P. Albersheim.
Biochem Biophys Res Comm 70(3):729-737, 1976.
Four lipopolysaccharides isolated from symbionts showed specific interaction with lectins purified from the seeds of four host legumes. This strongly supports the hypothesis that specificity is accounted for, at least in part, by the interaction of the rhizobial somatic surface antigen with the plant's lectin. It is still uncertain, however, whether this interaction is required for the formation of a successful symbiosis.

Additional references with information on Specificity may be found in relevant listings under:
Nodulation — *Rhizobium* Characteristics
Root infection

46. SURVIVAL [of *Rhizobium*].

4601 Influence of the age of the culture on the survival of *Rhizobium meliloti* after freeze drying and storage. (Fre)
Amarger, N. (Lab de Microbiol des Sols, INRA, Dijon, France), M. Jacquemetton and G. Blond.
Arch Mikrobiol 81(4):361-366, 1972.
Survival was higher in young cultures when cells were in the log phase than in the old cultures in the stationary phase. Conversely, freeze-dried organisms from old cultures survived better during storage at 30°C than did freeze-dried bacteria from young cultures.

4602 Methods of inoculating seeds and their effect on survival of rhizobia.
Burton, J.C. (Nitragin Co., Milwaukee, WI, USA).
Int Biol Programme 7:175-189, 1976.
The wide range in sizes of legume seeds (from 4000 seeds/gram for hop clover to 1 per gram for broadbean), differences in seed coat characteristics, and other variables mandate a variety of inoculation materials and methods to ensure survival of sufficient numbers of rhizobia to nodulate the crop. Qualitative and quantitative data for various materials and methods are provided in this chapter.

4603 Survival of field grown rhizobia over the dry summer period in Western Austraila.
Chatel, D.L.(U Western Australia, Nedlands, W.A.) and C.A. Parker.
Soil Biol Biochem 5(4):415-423, 1973.

Dry field soils with populations of *Rhizobium trifolii* and *R. lupini* were subjected to a range of temperatures in the laboratory. The rhizobia survived exposures to temperatures as high as 80°C for 6 hours. In the field, high populations of *R. lupini* were maintained at all depths throughout the summer, but clover rhizobia populations were initially much smaller and declined with both depth and time. The problem of "second year clover mortality" was attributed to the low numbers of rhizobia.

4604 Survival of *Rhizobium japonicum* on soybean seeds.
Dadarwal, K.R. (IARI, New Delhi, India) and A.N. Sen.
Ind J Agr Sci 41(6):564-568, 1971.
Many leguminous seeds contain certain water-soluble toxic compounds which adversely affect the viability of rhizobia. The *Rhizobium* population on the surface of unsoaked seeds of 'Bragg' and 'Clark' varieties rapidly declined, with only 2% survival after 2 days. The population increased greatly with the use of peat-based culture or when the seeds were soaked in water overnight before inoculation. Seeds from which toxic diffusates had been washed had rhizobia population increases of 200 to 600%. After 7 days the count declined, but 30 to 70% of the population survived on soaked seeds inoculated with peat-based culture.

4605 Survival of two strains of *Rhizobium* in soil.
Danso, S.K.A. and M. Alexander (Cornell U. Ithaca, NY, USA).
Soil Sci Soc Amer Proc 38(1):86-89, 1974.
Streptomycin-resistant mutants of *Rhizobium trifolii* and *R. meliloti* were added to soil, counted, and their survival studied. Survival was better in sterile soil and at lower temperatures, and the bacteria were able to withstand soil desiccation.

4606 A comparison of competitiveness and persistence amongst five strains of *Rhizobium trifolii* used to inoculate subterranean clover.
Gibson, A.H. (CSIRO, Canberra, Australia), R.A. Date, J.A. Ireland and J. Brockwell.
Soil Biol Biochem 8(5):395-401, 1976.
Sub clover inoculated with 5 strains of rhizobia (singly and in combinations) was sown into 2 soils with naturally occurring populations of rhizobia. All inoculant strains used singly were present at high frequency in the nodules in the first year. When all 5 strains were mixed in the inoculant, one strain predominated at both sites. After 3 years, three of the strains were still present in 75% of the nodules sampled, but the other 2 strains showed poor persistence.

4607 Some factors affecting the survival of *Rhizobium trifolii* on white clover.
Hale, C.N. (DSIR, Auckland, N.Z.).
Proc N Z Grassl Assoc Conf 38(1):182-186, 1977.
Washing clover seed, or treating with phenolic absorbents, reduced the inhibitory effects of a water-soluble toxin which diffuses from the seed coat during the inoculation process. Survival and competitive ability are important criteria in selecting strains of rhizobia.

4608 Survival of some slow-growing *Rhizobium* on inoculated legume seed.
Herridge, D.F. (Hort Res Stn, Narara, N.S.W., Australia) and R.J. Roughley.
Plant Soil 40(2):441-444, 1974.
The survival of non acid-producing rhizobia was not improved when inoculated seeds of *Vigna sinensis*, *Glycine wightii*, *Lupinus albus*, *Desmodium uncinatum* and *Glycine max* were pelleted with neutral rock phosphate rather than lime. The rhizobia survived equally well when applied in a 15% w/v gum arabic slurry without pelleting. Survival was better at 25°C than at 35°. Pelleting is still required when seed is sown in contact with superphosphate.

4609 Survival of *Rhizobium meliloti* in soil studied by genetic labeling. (Rus)
Imshenetskii, A.A., A.N. Pariiskaia and O.P. Gorelova.
Mikrobiologiia 45(6):1107-1110, 1976.

4610 Effect of aeration on survival of *Rhizobium japonicum* in peat contained in polythene bag.
Iswaran, V.
Mysore J Agr Sci 5(2):230-232, 1971.

4611 Survival of *Rhizobium japonicum* on soybean seeds.
Iswaran, V. (IARI, New Delhi, India).
Israel J Agr Res 21(2):79-80, 1971.
Surface sterilized soybeans were slurry inoculated in 10% sucrose solution. Within 12 hours the total count of viable rhizobia fell below the accepted number of 300/seed, indicating the clear advantage of sowing as quickly as possible after inoculation.

4612 Growth and survival of *Rhizobium trifolii* in coir dust and soybean meal compost.
Iswaran, V. (IARI, New Delhi, India).
Madras Agr J 59(1):52-53, 1972.
Coir dust, a waste product of the coconut fiber industry, was found to be a suitable carrier material when mixed with an equal quantity of soil, and is superior to soybean meal. The bacterial counts were generally higher than those considered satisfactory for peat cultures.

4613 Influence of sterilization and duration of autoclaving on the growth and survival of rhizobia in Indian peat.
Iswaran, V. and R. Apte.
Mysore J Agr Sci 6(3):363-366, 1972.

4614 Survival of rhizobia in Nilgiris peat.
Lund, D.B. (Tamil Nadu Agr U, Coimbatore, India), G. Viswanathan and K.K. Krishnamoorthy.
Cur Sci 42(12):412-415, 1973.
The Nilgris peat, with 10g/100g $CaCO_3$ added, sterilized, proved a satisfactory carrier for groundnut rhizobia. The trend of survival indicated a limited life of about 3 weeks on this carrier. Higher populations proved less successful than an initial level of 6×10^7 microorganisms.

A number of other topics in this bibliography relate to the survival of *Rhizobium* in cultures and inoculum as well as under various conditions.

47. SYMBIOSIS.

4701 Symbiosis: *Rhizobium* and leguminous plants.
Allen, O.N.
Forages Sci Grassl Agr p. 98-104, 1973.

4702 Homeostatic control in nodulation.
Banerjee, S.K. (Burdwan U, West Bengal, India).
Proc Ind Natl Sci Acad Pt B Biol Sci 40(5):499-506, 1974.
The existence of an autonomous control conserving the normal limit of nodular activity was postulated, as supported by data from X-ray induced variants of soybean. Such a homeostasis would be unique because it involves intaracting organisms of absolutely different natures.

4703 *Rhizobium*-legume symbiosis: prospects of improved effectiveness in Mauritius.
Beeraj, D.R.
Rev Agr Sucr Ile Maurice 52(2):84-87, 1973.

4704 Symbiotic nitrogen fixation by legumes.
Bergersen, F.J.
In Chemistry and biochemistry of herbage 2:189-226, 1973.

4705 Legumes and nitrogen fixation. (Spa)
Delorenzini, C.G.
Bolsa Cereal 102(2884):30-31, 1975.

4706 Symbiosis of *Centrosema pubescens* with homologous *Rhizobium* strains. (Por)
Franco, A.A., A. Serpa and S.M. Souto.
Pesqui Agropecu Bras, Ser Agron 8(2):13-17, 1973.

4707 Soil-plant-*Rhizobium* interactions in tropical agriculture.
Graham, P.H. and D.H. Hubbell.
In Soil management in tropical America; proceedings of a seminar, p. 211-227, 1975
The legume-*Rhizobium* symbiosis is probably the major source of fixed N on a global basis. It is contended that because legumes must play a major role in overcoming protein shortages in the tropics, achieving maximum benefit from the symbiosis is important. Large land holders will probably improve agricultural practices, but pre-inoculated seeds may be the best means for helping poorly educated farmers with holdings too small to justify the purchase of inoculants.

4708 Symbiosis between legumes and bacteria of the genus *Rhizobium*. (Ger)
Holl, W.
Naturwiss Rundsch 28(8):281-288, 1975.

4709 Some studies on the groundnut *Rhizobium* symbiosis.
Iswaran, V. (IARI, New Delhi, India) and A. Sen.
Zentr Bak Paras Infek ... 2 Nat 129(5):477-480, 1974.
A high rate of inoculation containing Mo and B was required to overcome ineffective indigenous strains of rhizobia.

4710 Physiology of the *Rhizobium*-legume association. I. The presence of bacterial DNA within the plant root.
Lepidi, A.A. (U di Pisa, Italy), M.P. Nuti, G. Bernacchi and R. Neglia.
Plant Soil 45(3):555-564, 1976.
Through *in situ* hybridization and autoradiography, *Rhizobium* DNA was detected in *Vicia faba* root cells following exposure of root apexes to viable rhizobia cells. Exposure to non-nodulating strains or to bacteria other than rhizobia did not result in DNA detection. The results are consistent with a hypothesis that a physiological integration occurs at the first stages of nodule formation. This could affect specificity, nodule genesis and certain biochemical mechanisms of the nitrogen fixation process.

4711 Legume bacteriology.
Norris, D.O. (CSIRO Cunningham Lab, St. Lucia, Qld., Australia) and R.A. Date.
In Shaw, N.H. and W.W. Bryan, eds., Tropical pasture research, CAB 51:134-174, 1976.
This chapter is intended to supplement information available in various manuals and reviews concerning the many factors affecting the legume-*Rhizobium* symbiosis, the requirments for maintaining and selecting inoculants, and the requirements for preparing and supplying effective inoculant materials. Isolation, culturing and strain testing techniques are spelled out in considerable detail.

4712 Problems relating to nitrogen fixing symbiosis and seed inoculation in tropical legumes. (Fre)
Obaton, M.
Agron Trop (Paris) 29(11):1128-1139, 1974.

4713 Factors affecting the symbiosis of *Rhizobium phaseoli* and *Phaseolus vulgaris*. (Por)
Ruschel, A.P. and H.W. Reuszer.
Pesqui Agropecu Bras Ser Agron 8(8):287-292, 1973.

4714 The *Rhizobium* requirements of legumes in Papua New Guinea.
Shaw, D.E.
Sci New Guinea Univ Papua 2(1):97-101, 1974.

4715 The role of leguminous plants in effective symbiosis with nodule bacteria. (Rus)
Shemakhanova, N.M., G.A. Volartseva and B.V. Il'asova.
Mikorbiologiia 45(6):1071-1074, 1976.

4716 Rhizobia and nodulation.
Subba Rao, N.S. (IARI, New Delhi, India).
Cur Sci 41(1):1-9, 1972.
A brief review of the history and research of the legume-*Rhizobium* symbiosis, with emphasis on Indian applications.

4717 Symbiosis between *Rhizobium* and the non-legume *Trema aspera*.
Trinick, M.J. (CSIRO, Wembley, W.A., Australia).
Nature 344:459-460, 1973.
The endophytes from the abundant root nodules of these non-leguminous plants showed marked affinities with the actinomycetes. Strain NGR231 were straight or curved rods apparently producing no spores. *Trema* formed nodules in Leonard jars when inoculated with the strain, grew well in a nitrogen free medium, and gave positive acetylene reduction assays. Effective nodulation by this strain was also obtained with 4 legumes.

4718 Host-strain relationships in symbiosis between hexaploid *Trifolium ambiguum* Bieb. (Caucasian clover) and strains of *Rhizobium trifolii*.
Zorin, M. (CSIRO, Canberra, Australia), F.W. Hely and B.S. Dear.
CSIRO Fld Stn Rec 15(2):63-71, 1976.
A high degree of variability made it difficult to assign a single strain as suitable for all hexaploid populations of Caucasian clover, but strain CC286a was generally more effective for all lines examined.

48. TEMPERATURE AND CLIMATE.

4801 Irrigation cum high dose of inoculum for better nodulation and establishment of soybean.
Balasundaram, V.R. (IARI, New Delhi, India).
Sci Cult 41(7):350-351, 1975.
Early Kharif soil temperatures usually exceed 40°C, affecting the survival of rhizobia applied on seeds. Deep sowing, mulching, irrigation, increased inoculum dose and genetic selection of inoculants may mitigate this. When the monsoon showers are delayed, early irrigation is suggested to lower the soil temperature and enhance survival.

4802 Effects of irrigation water temperature on growth of some legume species in glasshouses.
Brockwell, J. (CSIRO, Canberra, ACT, Australia) and R.R Gault.
Austr J Exp Agr Anim Husb 16:500-505, 1976.
The form and growth of soybean, lablab and cowpea showed significant response to daily irrigation with water adjusted to temperatures between 5° and 30°C, but lupin and bean *(Phaseolus vulgaris)* were not affected. No nodulation differences occurred with any species.

4803 Symbiosis in tropical grain legumes: some effects of temperature and the composition of the rooting medium.
Dart, P., J. Day, R. Islam and J. Döbereiner.
In Nutman, P.S., ed., Symbiotic nitrogen fixation in plants, IBP 7:361-386, 1976.
At 21°C there was little difference in N fixation by soybean plants inoculated with *Rhizobium* strains CB1809, Smlb or CC705. At 27°, and moreso at 33°, Smlb was the most effective. In *Cicer*, no nodules were formed above 32°, but nodules functioned over a range of 6-40° with greatest nitrogenase activity between 24 and 33°. *Vigna mungo* and *V. radiata* plants grew poorly in quartz sand grit, but grew well if this was amended with 10% clay loam.

4804 Investigation of ecological adaptation to climatic temperature conditions in *Rhizobium phaseoli* cultures of a different soil-climatic origin. (Rus)
Gassel'blat, T.O.
Akad Nauk SSSR Izv Ser Biol 2:306-309, 1971.

4805 Influence of temperature and *Rhizobium* strain on nodulation and growth of two tropical legumes.
Herridge, D.F. (Hort Res Stn, Gosford, NSW, Australia) and R.J. Roughley.
Trop Grassl 10(1):21-23, 1976.
Siratro grew best at 31/26°C (day/night), while axillaris grew best at 26/21° but did poorly at higher temperatures. At optimal temperatures, the plants inoculated with effective strains of rhizobia had greater dry weight than the nitrate controls.

4806 Effects of daylength and day/night temperatures on growth and seed yield of cowpea cv. K2809 grown in controlled environments.
Huxley, P.A. (U Dar-es-Salaam, Morogoro, Tanzania) and R.J. Summerfield.
Ann Appl Biol 83:259-274, 1976.
In all combinations of two daylengths (11 hr 40 min and 13 hr 20 min) and two day (27 and 33°C), two night (19 and 24°C) temperatures, the warmer night temperature hastened flowering as much as 6 days, a period when the later-flowering plants were more than doubling their dry weight. The warmer days shortened the growing period by 20%.

4807 Influence of storage temperature of peat on nodulation and growth of pea *(Pisum sativum)*.
Iswaran, V. (IARI, New Delhi, India).
Mysore J Agr Sci 5(4):493-494, 1971.
Cultures stored at 26°C, or at 40° for two weeks, and cultures removed from storage at 4° and then kept at 26° for one week were tested for ability to nodulate. Inoculation immediately after removal from 4° storage severely affected nodulation. Keeping the inoculant at 26° for one week after removal from the low temperature overcame this.

4808 Temperature-dependent root-nodule formation in pea cv. Iran.
Lie, T.A. (Agr U, Wageningen, The Netherlands).
Plant Soil 34(3):751-752, 1971.
An exceptional *Rhizobium* strain which forms nodules on pea both at 20°C and at 26° was found. Many rhizobia have been found to be "resistant" at 20°. Temperatures above 26°C were not investigated.

4809 Germination response of legume seeds subjected to moist and dry heat.
Martin, R.E. (Virginia Polytech Inst, Blacksburg, VA, USA), R.L. Miller and C.T. Cushwa.
Ecol 56(6):1441-1445, 1975.
Leguminous plants are common understory species in forested land subjected to annual burning. In this study, moist heat increased germination in 8 legume species, while dry heat increased germination in 7 species. The periods of exposure and temperatures simulated a prescribed forest floor fire.

4810 Diurnal functioning of the legume root nodule.
Minchin, F.R. (Queen's U, Belfast, N. Ireland) and J.S. Pate.
J Exp Bot 25(85):295-308, 1974.
Fluctuating temperature and humidity vs. constant temperature and humidity during day/night cycles produced different patterns of transpiration, N fixation, carbohydrate translocation, and other physiological activities in *Pisum sativum* plants.

4811 Effect of root temperature on growth and yield in cowpea *(Vigna unguiculata)*.
Minchin, F.R. (U Dar-es-Salaam, Tanzania), P.A. Huxley and R.J. Summerfield.
Exp Agr 12(3):279-288, 1976.
In plastic house experiments, mean maximum soil temperatures above 32°C significantly reduced vegetative growth. Nodule activity was adversely affected only in the extremely warm regime (35.4°C), with a sharp increase in efficiency at about 33° for nodules which persisted.

4812 Alfalfa root nodule distribution and inhibition of nitrogen fixation by heat.
Munns, D.N. (U California, Davis, CA, USA), V.W. Fogle and B.G. Hallock.
Agron J 69(3):377-380, 1977.
Nitrogen fixation was impaired by daily heating of greenhouse solution cultures to 32°C, and eliminated by repeated exposures to 36° or a single exposure to 40°. In field trials, most nodules were at depths below 10cm where near optimal temperatures prevailed.

4813 *Rhizobium* strain influence on disruption of clover nodule development at high root temperature.
Pankhurst, C.E. (Australian Natl U, Canberra) and A.H. Gibson.
J Gen Microbiol 74(2):219-231, 1973.
Rhizobium trifolii strains which were sensitive to root temperatures of 30°C were examined by light and electron microscopy, and their abnormalities described. Effects of higher temperature on bacterial development were found to be highly strain specific.

4814 Effects of temperature and oxygen tension on the nitrogenase and respiratory activities of turgid and water-stressed soybean and French bean root nodules.
Pankhurst, C.E. (U Dundee, Scotland) and J.I. Sprent.
J Exp Bot 27(96):1-9, 1976.
Maximum nitrogenase activity was exhibited by turgid nodules at between 15 and 30°C, but by moderately water-stressed nodules at between 10 and 15°. Variable effects of pO_2 were also studied.

4815 *Rhizobium* inoculation of soybeans for sub-tropical and tropical soils. I. Initial field trials.
Scudder, W.T. (Hort Res & Educ Ctr, U Florida, Sanford, FL, USA).
Proc Soil Crop Sci Soc Fla 34:79-82, 1975.
Efficient nodulation of soybeans has been difficult to obtain under high temperature conditions. In field trials, soil placement of the inoculum

significantly increased nodulation and yields and improved plant color. Inoculum applied with the seed, either by coating or stirring it into the hopper-box, gave unsatisfactory results.

4816 Vegetative growth of nineteen tropical and subtropical grasses and legumes in relation to temperature.
Sweeney, F.C. (Queensland Dept. Primary Indus, Australia) and J.M. Hopkinson.
Trop Grassl 9(3):209-217, 1975.
Legumes in which growth was depressed above 30/25°C (day/night) included *Desmodium uncinatum*, *D. intortum* and all cultivars of *Glycine wightii*. Legumes with no demonstrable depression at 36/31° were *Stylosanthes guyanensis*, *S. humilis*, *Calopogonium mucunoides*, *Pueraria phaseoloides*, *Macroptilium atropurpureum* and *Centrosema pubescens*. Several grasses showed even higher temperature tolerance. All taxa were depressed with falling temperature below 30/25 ±3°C, and at 15/10° relative growth rates never exceeded about one third of the recorded maximum.

4817 Investigations of nitrogenase activity in rheotrophic peat.
Waughman, G.J. (U Durham, England).
Can J Microbiol 22(10):1561-1566, 1976.
Nitrogenase was inactivated at temperatures above 35°C. Optimal acetylene reduction was at 30°, and was unaffected by light. Initial inhibition from exposure to oxygen was followed by stimulation to rates of acetylene reduction much higher than in an anaerobic condition. The existence of nitrogen-fixing associations of aerobic and anaerobic bacteria in the peat may explain these results.

4818 The effect of temperature on nitrogenase activity.
Waughman, G.J. (U Durham, England).
J Exp Bot 28(105):949-960, 1977.
Temperature effects on the nitrogenase activity of five legumes, four non-legumes and two blue-green algae were tested. In all cases the activity in detached nodules was temperature sensitive. Approximate optimum temperatures were fairly well defined in *Lupinus* (25°C) and *Medicago* (22°), but were less defined with pea, soybean and broadbean.

4819 Effect of soil temperature on *Rhizobium japonicum* serogroup distribution in soybean nodules.
Weber, D.F. (ARS, USDA, Beltsville, MD, USA) and V.L. Miller.
Agron J 64(6):796-798, 1972.
Within a temperature range of 10-30°C in greenhouse experiments, plant development and nodulation were generally favored by the highest temperature. Serogroups from an established soil population of rhizobia which were infrequently recovered at the lower temperatures became dominant at 30°, and those that predominated at 10 or 15° formed fewer nodules at higher temperatures.

4820 Effect of sowing date on lucerne emergence, survival, nodulation and early growth.
Wynn-Williams, R.B. (DSIR, Christchurch, New Zealand).

N Z J Exp Agr 4(4):439-445, 1976.
Germination rate increased with increasing soil temperature, but emergence and survival were greatest in earlier months (October and November, southern hemisphere). Nodulation was best in spring sowing (September) and worst in June. Spring sowings resulted in the earliest forage, greatest daily growth and best overall yields.

Certain references listed under Water factors (below) also relate to temperature and climate. See also relevant listings under:

Inoculant materials	Soil factors
Inoculation methods	Survival [of *Rhizobium*]

49. WATER FACTORS.

4901 Effect of alfalfa irrigation on soil microflora and on the process of nitrogen-fixing nodule formation. (Mac)
Ancev, T., M. Mickovski and K. Ivanova-Bandzo.
God Zb Zemjod Skopje U Zemjod-Sumar Fak 26:61-77, 1975.

4902 Effects of flooding on nitrogen fixation in root nodules of *Sesbania cannabina* Pers. in paddy field. (Chi)
Anonymous.
Chih-wu Hsueh-pao 17(4):320-322, 1975.

4903 Water status of rhizobia in relation to their susceptibility to desiccation and to their protection by montmorillonite.
Bushby, H.V.A. (U Tasmania, Hobart, Tas., Australia) and K.C. Marshall.
J Gen Microbiol 99(1):19-27, 1977.
A greater affinity for water by the *Rhizobium leguminosarum* group compared with slow-growing rhizobia makes them also more susceptible to desiccation. Montmorillonite clay protects the fast-growing , but not the slow-growing, rhizobia from the effects of desiccation. It was postulated that the protection results from a decrease in internal water content to levels below the equilibrium value attained in the absence of the clay. In the slow-growing bacteria, that level may be below the survival level.

4904 Effect of moisture content on denitrification in a clay soil.
Craswell, E.T. and A.E. Martin.
Soil Biol Biochem 6:127-129, 1974.

4905 Effects of flooding on nodulation and growth of tropical forage legumes. (Por)
De-Polli, H., M.A.T. Vargas, A.A. Franco and J Döbereiner.
Pesqui Agropecu Bras Ser Agron 8(2):27-34, 1973.

4906 Effects of water stress on growth and nitrogen-fixing activity of *Trifolium repens*.
Engin, M. (U Dundee, Scotland) and J.I. Sprent.
New Phytol 72(1):117-126, 1973.

Growth and nitrogen fixation were depressed by water stress. Meristematic nodules such as found with clover respond more effectively to re-watering than do spherical nodules. A quantitative difference between acetylene reduction and Kjeldahl analyses under water stress was reported but not explained.

4907 Effect of drought on three species of *Rhizobium*.
Foulds, W. (Dudley Coll Educ, Dudley, Wores, England).
Plant Soil 35(3):665-667, 1971.
Rhizobium trifolii proved to be more drought tolerant than either *R. meliloti* or a *Rhizobium* of the "Lotus" group.

4908 Effect of soil moisture on nodulation of cowpea and hyacinth bean.
Habish, H.A. (U Khartoum, Sudan) and A.A. Mahdi.
J Agr Sci (Camb) 86(3):553-560, 1976.
Nodulation, N-fixation and plant growth were poor at 15% soil moisture. Cowpea was more tolerant of dry conditions. Application of 75 mm of water every 7 days gave the best combination of nodulation and plant growth.

4909 Soil water tension and the movement of rhizobia.
Hamdi, Y.A. (Ministry of Soils, Orman, Giza, UAR).
Soil Biol Biochem 3(2):121-126, 1971.
Movement of *Rhizobium* through soil was slowed with increasing water tension and ceased when water-filled pores became discontinuous. Migration of rhizobia could be restricted at water tensions permitting the germination of legume seeds.

4910 Vertical movement of rhizobia in soil.
Hamdi, Y.A. (Inst Soil & Water, Giza, A.R.E.).
Zentralb Bak Parasit Infek ... 2 Nat 129:373-377, 1974.
Vertical movements in columns of fine sand, coarse sand, and silt loam soils were examined. In general, precipitated water removed rhizobia from the surface layers of the soil. Although retention of rhizobia is greater in fine sand and silt loam, only a small fraction of the original cells remained after the equivalent of a 3 inch precipitation.

4911 Recovery of nodulated cowpea plants (*Vigna unguiculata* (L.) Walp.) from waterlogging during vegetative growth.
Hong, T.D. (U Reading, U.K.), F.R. Minchin and R.J. Summerfield.
Plant Soil 48:661-672, 1977.
Waterlogging during the period when symbiotic N fixation was increasing at maximum rate (24-32 days from sowing) caused reduced nodule production and increased nodule cortication. Adventitious root formation at or near the water table was stimulated, but submerged roots and nodules were killed. Screening for symbionts producing "lenticel-type" nodules might reduce the effects of waterlogging.

4912 Acetylene reduction (nitrogen fixation) and metabolic activities of soybean having various leaf and nodule potentials.
Huang, C.Y.(U Illinois, Urbana, IL, USA), J.S. Boyer and L.N.Vanderhoef.
Plant Physiol 56:222-227, 1975.

No acetylene reduction was detected in flooded soil or in soil desiccated to a water potential of -19.5 bars. A sharp optimum of acetylene reduction was displayed between these extremes. The apparatus used permitted measurement of metabolic activities of the shoot without exposure of the leaves to acetylene.

4913 Limitation of acetylene reduction (nitrogen fixation) by photosynthesis in soybean having low water potentials.
Huang, C.Y. (U Illinois, Urbana, IL, USA), J.S. Boyer and L.N. Vanderhoef.
Plant Physiol 56:228-232, 1975.

The apparatus used permitted simultaneous measurements of acetylene reduction, net photosynthesis, and transpiration. The inhibition of acetylene reduction caused by low water potentials and their aftereffects could be reproduced by depriving shoots of atmospheric CO_2 even though the soil remained at water potentials which should have favored rapid acetylene reduction. The inhibitory effect of low water potentials coyld be partially reversed by high CO_2 concentrations. It was concluded that the inhibition of photosynthesis accounts for nodule acetylene reduction inhibition at low water potentials.

4914 Effects of soil moisture around nodules on nitrogen fixation by well watered soybeans.
Hume, D.J. (U Guelph, Ontario, Canada), J.G. Criswell and K.R. Stevenson.
Can J Plant Sci 56(4):811-815, 1976.

Very dry soil, or soil near field capacity around the nodules, decreased fixation slightly but did not affect nodule moisture content as long as adequate moisture was available from below the nodule zone. In plants with leaf water potentials greater than -6 bars there was no relationship between soil moisture around the nodules and nitrogen fixation.

4915 Soil water suction and root temperature effects on nitrogen fixation in soybeans.
Kuo, T. (Oregon St U, Corvallis, OR, USA) and L. Boersma.
Agron J 63(6):901-904, 1971.

Within a range of 15.6 to 37.8°C and 0.30 to 2.50 bars, effects on N fixation, transpiration and net photosynthesis were studied. Optimum temperatures were 27 to 30° for N fixation. Rates of activity decreased with increasing soil water suction. Effects were indicated but all were not clearly elucidated.

4916 Effects of water, aeration, and salt regime on nitrogen fixation in a nodulated legume -- definition of an optimum root environment.
Minchin, F.R. (Queen's U, Belfast, N. Ireland) and J.S. Pate.
J Exp Bot 26(99):60-69, 1975.

Even a slight departure from a supposedly perfect regime can result in a measurable fall in N fixation performance. Waterlogging showed the most severe adverse effect.

4917 Symbiotic nitrogen fixation and vegetative growth of cowpea (*Vigna unguiculata* (L.) Walp.) in waterlogged conditions.
Minchin, F.R. (U Reading, U.K.) and R.J. Summerfield.
Plant Soil 45(1):113-127, 1976.

Waterlogging treatments increased nodule cortication, and nodules formed under waterlogged conditions had conspicuous lenticel-type protuberances. Both conditions are regarded as adaptive anatomical responses which facilitate continued symbiotic N fixation. Total dry weight of nodules per plant was reduced by 60% after only 8 days of waterlogging, but the N fixing efficiency which persisted was only 18% less than control.

4918 Effect of water stress on growth, nodulation and rhizosphere micropopulation of *Pisum sativum* L. in Durgapura soils.
Mohan Rao, V. (U Rajasthan, Jaipur, India), B.V. Ratnam and H.S. Narayana.
Proc Ind Acad Sci Sec B 85(3):160-166, 1977.
Nodules were reduced in number and size, with an increase in the number of ineffective nodules, under water stress.

4919 Effects of water stress on the respiratory and nitrogen-fixing activity of soybean root nodules.
Pankhurst, C.E. (U Dundee, Scotland) and J.I. Sprent.
J Exp Bot 26(91):287-304, 1975.
Moderately stressed nodules lost 75% of the nitrogenase activity and 50% of their respiratory activity. Severe stress caused almost total loss of N_2 fixing activity and up to 80% loss of respiratory activity. Data indicating that water stress decreases the apparent diffusion of O_2 into nodules are presented, and the possible role of a diffusion barrier discussed,

4920 Effect of water stress on carbon assimilation and distribution in soybean plants at different stages of development.
Silvius, J.E. (USDA-ARS, Beltsville, MD, USA), R.R. Johnson and D.B. Peters.
Crop Sci 17(5):713-716, 1977.
Reduction of ^{14}C in nodules was associated with water stress at all growth stages. Relatively more assimilate was present in the root fraction at the expense of the nodules, suggesting decreased sink strength, lowered storage capacity, or increased turnover in nodules at low soil moisture levels.

4921 Interactive effect of fluorine and salt contents of irrigation water on germination, growth and nodulation of berseem (*Trifolium alexandrinum*).
Somani, L.L. (U Udaipur, India).
Trop Agr (Trinidad) 54(3):219-222, 1977.
Fluorine (to 100 ppm) and salt (to 50 mequiv/litre) in irrigation water acted additively to adversely affect germination, growth and nodulation. Increasing the fluorine content progressively lowered the critical salt tolerance limit. The inhibitory level of salinity and fluorine content was much lower for affecting nodulation than for crop growth.

4922 The effects of water stress on nitrogen-fixing root nodules. III. Effects of osmotically applied stress.
Sprent, J.I. (U Dundee, Scotland).
New Phytol 71(3):451-460, 1972.
Hypotinic concentrations of mannitol had a depressing effect on N fixation. Equivalent concentrations of electrolytes had a much more rapid effect on whole root systems and on detached nodules.

4923 The effects of water stress on nitrogen-fixing root nodules. IV. Effects on whole plants of *Vicia faba* and *Glycine max*.
Sprent, J.I. (U Dundee, Scotland).
New Phytol 71(4):603-611, 1972.
Experiments confirmed that water en route from the root to the shoot system could be withdrawn by stressed nodules. A high degree of correlation between soil-water content and nitrogen-fixing activity was shown. Maximum fixation occurred at about field capacity. Above this, activity was reduced due to waterlogging.

4924 Anaerobiosis in soybean root nodules under water stress.
Sprent, J.I. (U Dundee, Scotland) and A. Gallacher.
Soil Biol Biochem 8(4):317-320, 1976.
Evidence led to the conclusion that both water deficiency and excess may depress nitrogenase activity by restricting supplies of intermediates from aerobic pathways, while fermentative pathways are stimulated leading to production of inhibitory concentrations of ethanol. Both bacteroids and plant tissues produced ethanol when rendered anoxic.

4925 Some effects of environmental stress on seed yield of cowpea (*Vigna unguiculata* (L.) Walp) cv. Prima.
Summerfield, R.J. (U Reading, England), P.A. Huxley, P.J. Dart and A.P. Hughes.
Plant Soil 44:527-546, 1976.
Effects of shading, wilting and rehydration, and combined nitrogen supply were studied in simulated tropical conditions. Repeated wilting prior to flowering markedly reduced seed yields, nodule weight and nitrogenase activity. At first flowering stage, plants grown without combined N had nitrogenase activities less than 10% of those supplied with 25 ppm N, but 60 ppm N at any stage more than halved nitrogenase activity. Shading to 50% reduced seed yield by about 25%.

4926 Effect of moisture on acetylene reduction (symbiotic nitrogen fixation) by *Rhizobium japonicum* and soybean root nodules in silica sand.
Tu, C.M. (Res Inst Agr Canada, London, Ontario, Canada) and G. Hietkamp.
Commun Soil Sci Plant Anal 8(1):81-86, 1977.
Optimum water contents were 60 to 80% of capacity. Recovery by plants from moderate stress was considerable one hour after remoistening. Resumption of acetylene reducing activity was only slight at first, but full recovery was effected in time.

4927 Action of water in depressing acetylene reduction by detached nodules.
Van Straten, J. (U Minnesota, St. Paul, MN, USA) and E.L. Schmidt.
Appl Microbiol 29(3):432-434, 1975.
A water layer had no effect on intact soybean nodules so long as the nodule surface was undamaged. It was proposed that acetylene reduction assays should be carried out with nodulated roots to avoid adverse effects from washing detached nodules.

WATER FACTORS, *continued*

4928 Effect of different levels of soil moisture on growth, yield and some physiological aspects of nodulation in green-gram.
Varma, A.K. (IARI, New Delhi, India) and N.S. Subba Rao.
Ind J Agr Sci 45(1):11-16, 1975.

Plant N content, ATP content of nodules, and the pattern of amino acids, organic acids and sugars in the rhizosphere and nodules were all appreciably affected by different levels of soil moisture. A 50% moisture level appeared optimal for encouraging exudation of rhizosphere nutrients and for *Rhizobium* multiplication.

4929 The effect of moisture stress on infection of *Trifolium subterraneum* L. by *Rhizobium trifolii* Dang.
Worrall, V.S. (Hort Res Stn, Gosford, N.S.W., Australia) and R.J. Roughley.
J Exp Bot 27(101):1233-1241, 1976.

Reduction of soil moisture from 5.5 to 3.5% significantly decreased the number of infection threads and completely inhibited nodulation, although the number of rhizobia was unaffected. Between 5.5 and 9.5%, there was little effect on infection.

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